APPENDIX 1 – PURPOSE AND NEED

PURPOSE AND NEED FOR ACTION

Project Background and Need:

Dyke Bridge (Br#2246) carries Route 1 over the Middle River in the Town of Machias, Maine. The Middle River joins the tidal portion of the Machias River at/immediately downstream of the bridge. The bridge consists of four box culverts within an embankment structure (causeway). The culverts are constructed of timber and stone masonry and are approximately 130 feet long, 6 feet wide and 5 feet high. Each culvert has top-hinged flap gate installed on its seaward side. The causeway is constructed of timber cribbing with rubble and earthen fill and is over 1,000 feet long.

Photo 1. Route 1 Causeway with parking and Downeast Sunrise Trail.

Photo 2. Dyke Bridge culverts with flap gates.

The culverts and the flap gates are deteriorated. MaineDOT completed a dive inspection of the Dyke Bridge on 9/21/2016 and routine inspections on 12/27/2016 and 4/28/20. The inspections indicated large spalls, heavy scaling, wide cracks, loss of and rotten timber members, and roadway settlement. MaineDOT Bridge Maintenance has replaced broken flapper gates in 2012 and repaired pavement (Light Capital Paving) in 2017.

MaineDOT uses Federal Highway's *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridge* (NBIS). Based on these inspections the bridge has a current structure rating of four (4) on a scale of zero to nine (0-9). The structure item evaluates the alignment, settlement, joints, structural condition, scour, and other items associated with the structure. The rating code is intended to be an overall condition evaluation of the structure.

Route 1 is classified as a minor arterial, is a highway corridor Priority 2, and carries approximately 8,600 vehicles per day. Route 1 over the causeway consists of two 12-foot travel lanes, two 8-foot shoulders and a 20-foot wide public parking area that is regularly used for local markets and trade events. In addition, the causeway carries the Calais Branch Rail Corridor and a section of the 87-mile off-road Downeast Sunrise Trail[1]. A municipal boat launch is located at the southeast corner of the causeway.

The Dyke Bridge does not currently allow landward flow of tides into the Middle River except by leakage through the flap gates and the causeway during flood tides. Residents have indicated anecdotally that some fish passage occurs at the bridge, however it is generally considered a barrier to fish passage. NOAA Fisheries, the Coordinator of the Downeast Salmon Habitat Recovery Unit (SHRU), and state fisheries agencies have expressed interest in fisheries habitat restoration above the Dyke Bridge.

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[1] https://www.sunrisetrail.org/about-the-downeast-sunrise-trail/

Project Purpose:

The primary purposes of the project are:

1. To achieve an overall structure rating of Good (a rating of 7 or better on a scale 0-9). The desired structure rating of at least 7 indicates there are no noticeable or noteworthy deficiencies which affect the condition of the structure. This is in accordance with Federal Highway's *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridge* (NBIS); and
2. To preserve the Calais Branch Rail Corridor in the area in accordance with the State Railroad Preservation Act.

Secondary Goals of the action and other desirable outcomes include:

- To improve fish passage through the transportation asset.
- Consistent with surrounding infrastructure, to account for Sea Level Rise (SLR) in accordance with Maine's Climate Council guidance to manage for 1.5 feet of relative sea level rise by 2050 and to assess 3.9 feet of sea level rise by the year 2100;
- Consistent with other goals, to minimize inundation of land upstream from Dyke Bridge that may result from increased tidal exchange from the Project;
- To accommodate existing transportation uses of the causeway (trail/railroad);
- To accommodate existing community uses of the causeway (parking/local markets and trade); and
- To coordinate with the ongoing Town of Machias flood protection project[2].

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[2] http://wccog.net/machias-resilience.htm

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Notes
1. Coordinate System: NAD 1983 UTM Zone 19N
2. Data Sources include:USGS Imagery/Topo provided by The National Map Mapping Service (http://basemap.nationalmap.gov/arcgis/services/USGSImageryTopo).

Stantec

30 Park Drive
Topsham, ME USA 04086
Phone (207) 729-1199

Prepared by ABC on 2014-00-00
Reviewed by ABC on 2015-00-00

00963_DykeBridge_LOC.mxd

Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
1

Title
Project Location Map
7/1/2015

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195600963

Stantec

30 Park Drive
Topsham, ME USA 04086
Phone (207) 729-1199

Prepared by EPL on 2015-02-23
Reviewed by MRC on 2015-02-23

00963_DykeBridge_Aerial.mxd

Notes

1. Coordinate System: NAD 1983 UTM Zone 19N
2. Aerial imagery provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).

Legend

⇄ Dominant Upland Flow

Client/Project

Maine DOT
Dyke Bridge
Machias, Maine

Figure No.

2

Title

Dyke Bridge Aerial

7/1/2015

APPENDIX 2 – ALTERNATIVES MATRIX

Machias Dyke Bridge (#2246)
WIN 016714.00
December 9, 2023

DRAFT - RESULTS BASED ON PHASE 1 HYDRAULICS ANALYSES FOR NORMAL RIVERINE FLOWS AND TIDES. PHASE 2 ANALYSES EVALULATED RIVERINE FLOODS, SPRING TIDES, STORM SURGES, AND SEA LEVEL RISE FOR ALTERNATIVES 4m & 10.

Legend:
Alternatives Included in Phase 1 Hydraulics Analysis
Alternatives Included in Phase 1 & 2 Hydraulics Analysis

	ALTERNATIVE		**CONFIGURATION**	**ALTERNATIVE EVALUATION**								**LANDWARD IMPACTS**					**CONSTRUCTION COST (Includes 5% contingency and inflation for projected 2026 construction start)**
				PURPOSE AND NEED		**SECONDARY GOALS**			**OTHER**								
				Overall Structure Rating	**Railroad Corridor**	**Fish passage**	**Sea Level Rise (SLR) Accomodation**	**Transportation & Community Uses**	**Impacts to Tidal Regime**	**Constructability and Maintenance**	**Stride Bridge (#3973)**	**Water Surface Elevation (WSEL) (NAVD88)**	**Increased Acreage Impact**	**Number of Properties**	**Hazardous Waste Sites**	**Wells/Septic**	
												*NOTE: Impacts noted are from differences in normal water levels for normal tides and normal riverine flow (impacts do **NOT** include riverine floods, spring tides, storm surges or SLR)*					
	See "Technical Report: Middle River Hydrologic and Alternatives Analyses (June 30, 2015)", Memo "Updated Hydraulic Analysis for Culvert Replacement Alternatives (August 29, 2019)" and Memo "1st Phase Hydraulic Analysis for Machias Dyke Bridge Planning Phase Support Services (June 2, 2021)" for additional information		Culvert or Bridge-- Number, Span and Size	Good (a rating of 7 or better on a scale 0-9)	Preserves railroad corridor in accordance with Rail Preservation Act	Improvement (Yes/No) 95% exceedance flow speed; Min water depth	Consistency with Town planning & Maine State Climate Council guidance	Causeway Parking Multi-Use Trail	Ranges from No change to full restoration (ie no tidal restriction); Increase in intertidal habitat	Water management during construction, timber cribbing causeway, dredging, and future maintenance	1948 ~ 12.5 ft span corrugated steel plate pipe arch located upstream.	MHW Water Surface Elevation LOW (<2') MEDIUM (2' to 4') HIGH (>4')	Additional acreage impacts due to change in WSEL	Parcels impacted by change in WSEL	Number of potential hazmat sites impacted by change in WSEL	Number of parcels with water supply wells & septic impacted by alternative	Low:$2 to $10 mil. Mid:$10 to $25 mil. High: > $25 mil.
2015 Study	**Alternative 1**	Existing Condition/ No Action *(Not carried into 2019/2020)*	Four - box culverts with Flap Gates	Not Considered in 2015, see 2019-2021 study			Not Considered in 2015, see 2019-2021 study			Not Considered in 2015, see 2019-2021 study	2015 Study suggests a new small span bridge when Stridge Bridge needs replacement due to condition and age.	Existing (EL -0.7')	Not considered in 2015, see 2019-2021 study				-
	Alternative 2	Replacement In-Kind *(Refined in 2019 as Alt 1)*	Four - (5 ft x 5 ft) Box Culverts with Flap Gates, No leakage			No			None			LOW					MID
		Variation A ***(Carried in 2019 as Alt 2,3&4)***	Five - (5 ft x 5 ft) Box Culverts Flap Gates on four culverts			Yes (advection)			Improvement			LOW					MID
		Variation B	Four - (5 ft x 5 ft) Box Culverts Flap Gates on three culverts			Yes (advection)			Improvement			LOW					MID
		Variation C	Four - (5 ft x 5 ft) Box Culverts Flap Gates on two culverts			Yes (advection)			Improvement			MED IUM					MID
	Alternative 3	Replacement Culverts *(Not carried into 2019/2020)*	Self-Regulating Tide Gates (SRTs)			Marginal (high flow speeds impact normal gate operation)			Evaluate Gate Alternatives								MID

NOTE: RAISING FINISHED GRADE ELEVATION OF THE CAUSEWAY FOR ALL ALTERNATIVES WILL HAVE ENVIRONMENTAL IMPACTS ALONG THE CAUSEWAY WITH SIDESLOPES WHICH MAY REQUIRE EARTH RETAINING STRUCTURES OR CHANGES TO THE EXISTING LANE/SHOULDER/PARKING WIDTHS.

Machias Dyke Bridge (#2246)
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December 9, 2023

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Legend:
Alternatives Included in Phase 1 Hydraulics Analysis
Alternatives Included in Phase 1 & 2 Hydraulics Analysis

	ALTERNATIVE		CONFIGURATION	ALTERNATIVE EVALUATION								LANDWARD IMPACTS					CONSTRUCTION COST (Includes 5% contingency and inflation for projected 2026 construction start)
				PURPOSE AND NEED		SECONDARY GOALS			OTHER								
				Overall Structure Rating	Railroad Corridor	Fish passage	Sea Level Rise (SLR) Accomodation	Transportation & Community Uses	Impacts to Tidal Regime	Constructability and Maintenance	Stride Bridge (#3973)	Water Surface Elevation (WSEL) (NAVD88)	Increased Acreage Impact	Number of Properties	Hazardous Waste Sites	Wells/Septic	
												*NOTE: Impacts noted are from differences in normal water levels for normal tides and normal riverine flow (impacts do **NOT** include riverine floods, spring tides, storm surges or SLR)*					
	See "Technical Report: Middle River Hydrologic and Alternatives Analyses (June 30, 2015)", Memo "Updated Hydraulic Analysis for Culvert Replacement Alternatives (August 29, 2019)" and Memo "1st Phase Hydraulic Analysis for Machias Dyke Bridge Planning Phase Support Services (June 2, 2021)" for additional information		Culvert or Bridge-- Number, Span and Size	Good (a rating of 7 or better on a scale 0-9)	Preserves railroad corridor in accordance with Rail Preservation Act	Improvement (Yes/No) 95% exceedance flow speed; Min water depth	Consistency with Town planning & Maine State Climate Council guidance	Causeway Parking Multi-Use Trail	Ranges from No change to full restoration (ie no tidal restriction); Increase in intertidal habitat	Water management during construction, timber cribbing causeway, dredging, and future maintenance	1948 ~ 12.5 ft span corrugated steel plate pipe arch located upstream.	MHW Water Surface Elevation LOW (<2') MEDIUM (2' to 4') HIGH (>4')	Additional acreage impacts due to change in WSEL	Parcels impacted by change in WSEL	Number of potential hazmat sites impacted by change in WSEL	Number of parcels with water supply wells & septic impacted by alternative	Low:$2 to $10 mil. Mid:$10 to $25 mil. High: > $25 mil.
2015 Study Continued	**Alternative 4**	Replacement Culverts *(Not carried into 2019/2020)*	"Fish-Friendly" SRTs	Not Considered in 2015, see 2019-2021 study		Marginal (high flow speeds impact normal gate operation)	Not Considered in 2015, see 2019-2021 study		Evaluate Gate Alternatives	Not Considered in 2015, see 2019-2021 study	2015 Study suggests a new small span bridge when Stridge Bridge needs replacement due to condition and age.		Not considered in 2015, see 2019-2021 study				MID
	Alternative 5	Replacement Culverts *(Refined in 2020 as Alt 9)*	Four - (12 ft span x 15 ft rise) Box Culverts Without flap gates			Yes (advection)			Restoration			HIGH					MID
	Alternative 6	Replacement Bridge *(Refined in 2020 as Alt 10)*	One - 60 ft single span bridge			Yes (volitional)			Restoration			HIGH					HIGH
	Alternative 7	Replacement Bridge & Culverts	One - 60 ft single span & Relief culverts in the causeway			Yes (volitional)			Restoration			HIGH					MID

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Machias Dyke Bridge (#2246)
WIN 016714.00
December 9, 2023

DRAFT - RESULTS BASED ON PHASE 1 HYDRAULICS ANALYSES FOR NORMAL RIVERINE FLOWS AND TIDES. PHASE 2 ANALYSES EVALULATED RIVERINE FLOODS, SPRING TIDES, STORM SURGES, AND SEA LEVEL RISE FOR ALTERNATIVES 4m & 10.

Legend:
Alternatives Included in Phase 1 Hydraulics Analysis
Alternatives Included in Phase 1 & 2 Hydraulics Analysis

	ALTERNATIVE		CONFIGURATION	ALTERNATIVE EVALUATION								LANDWARD IMPACTS					CONSTRUCTION COST (Includes 5% contingency and inflation for projected 2026 construction start)
				PURPOSE AND NEED		SECONDARY GOALS			OTHER								
				Overall Structure Rating	Railroad Corridor	Fish passage	Sea Level Rise (SLR) Accomodation	Transportation & Community Uses	Impacts to Tidal Regime	Constructability and Maintenance	Stride Bridge (#3973)	Water Surface Elevation (WSEL) (NAVD88)	Increased Acreage Impact	Number of Properties	Hazardous Waste Sites	Wells/Septic	
												*NOTE: Impacts noted are from differences in normal water levels for normal tides and normal riverine flow (impacts do **NOT** include riverine floods, spring tides, storm surges or SLR)*					
	See "Technical Report: Middle River Hydrologic and Alternatives Analyses (June 30, 2015)", Memo "Updated Hydraulic Analysis for Culvert Replacement Alternatives (August 29, 2019)" and Memo "1st Phase Hydraulic Analysis for Machias Dyke Bridge Planning Phase Support Services (June 2, 2021)" for additional information		Culvert or Bridge-- Number, Span and Size	Good (a rating of 7 or better on a scale 0-9)	Preserves railroad corridor in accordance with Rail Preservation Act	Improvement (Yes/No) 95% exceedance flow speed; Min water depth	Consistency with Town planning & Maine State Climate Council guidance	Causeway Parking Multi-Use Trail	Ranges from No change to full restoration (ie no tidal restriction); Increase in intertidal habitat	Water management during construction, timber cribbing causeway, dredging, and future maintenance	1948 ~ 12.5 ft span corrugated steel plate pipe arch located upstream.	MHW Water Surface Elevation LOW (<2') MEDIUM (2' to 4') HIGH (>4')	Additional acreage impacts due to change in WSEL	Parcels impacted by change in WSEL	Number of potential hazmat sites impacted by change in WSEL	Number of parcels with water supply wells & septic impacted by alternative	Low:$2 to $10 mil. Mid:$10 to $25 mil. High: > $25 mil.
2019 Study (Include in 2020-2023 Planning)	**Alternative 1**	Fully Gated Culverts *(2015 Alt 2)*	Four - (5 ft x 5 ft) Box Culverts With Flap Gates, No leakage	Yes	Yes	No	Yes	• Maintains parking on causeway	None			LOW (EL. -2.5' Change = -1.7')	N/A	N/A	N/A	N/A	MID ($20-23 million)
	Alternative 2	Modified Alternative 1 *(2015 Alt 2A)*	Five - (5 ft x 5 ft) Box Culverts With Flap Gates on 4 culverts Culverts at invert elevation -4.05 ft	Yes	Yes	Yes (advection)	Yes	• Maintains parking on causeway • Structure does not restrict amenities	Improvement	• Locate new culverts to the East to facilitate water management during construction		LOW (EL. 0.2' Change = +0.9') needs refinement	40 +/-	10 +/-	0	0	MID
	Alternative 3	Modified Alternative 2 *(2015 Alt 2A)*	Five - (5 ft x 5 ft) Box Culverts With Flap Gates on 4 culverts Open 5th culvert at lower invert elevation -6.05 ft	Yes	Yes	Yes (advection)	Yes	• Maintains parking on causeway • Structure does not restrict amenities	Improvement	• Locate new culverts to the East to facilitate water management during construction • Constuctability more difficult for varied invert elevation		LOW (EL. 0.5' Change = +1.2') needs refinement	40 +/-	10 +/-	0	0	MID
	Altenative 4	Modified Alternative 2 *(2015 Alt 2A)*	Five - (5 ft x 5 ft) Box Culverts With Flap Gates on 4 culverts All culverts at invert elev. -6.05 ft	Yes	Yes	Yes (advection 59% of time)	Yes	• Maintains parking on causeway • Structure does not restrict amenities	Improvement; 40 intertidal habitat acres	• ~1,100 CY of near-field dredging • Difficult dewatering		LOW (EL. 0.8' Change = +1.5') needs refinement	40	10	0	0	MID

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Legend:
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Alternatives Included in Phase 1 & 2 Hydraulics Analysis

	ALTERNATIVE		**CONFIGURATION**	**ALTERNATIVE EVALUATION**									**LANDWARD IMPACTS**					**CONSTRUCTION COST (Includes 5% contingency and inflation for projected 2026 construction start)**
				PURPOSE AND NEED		**SECONDARY GOALS**			**OTHER**									
				Overall Structure Rating	**Railroad Corridor**	**Fish passage**	**Sea Level Rise (SLR) Accomodation**	**Transportation & Community Uses**	**Impacts to Tidal Regime**	**Constructability and Maintenance**	**Stride Bridge (#3973)**	**Water Surface Elevation (WSEL) (NAVD88)**	**Increased Acreage Impact**	**Number of Properties**	**Hazardous Waste Sites**	**Wells/Septic**	
												*NOTE: Impacts noted are from differences in normal water levels for normal tides and normal riverine flow (impacts do **NOT** include riverine floods, spring tides, storm surges or SLR)*					
	See "Technical Report: Middle River Hydrologic and Alternatives Analyses (June 30, 2015)", Memo "Updated Hydraulic Analysis for Culvert Replacement Alternatives (August 29, 2019)" and Memo "1st Phase Hydraulic Analysis for Machias Dyke Bridge Planning Phase Support Services (June 2, 2021)" for additional information		Culvert or Bridge-- Number, Span and Size	Good (a rating of 7 or better on a scale 0-9)	Preserves railroad corridor in accordance with Rail Preservation Act	Improvement (Yes/No) 95% exceedance flow speed; Min water depth	Consistency with Town planning & Maine State Climate Council guidance	Causeway Parking Multi-Use Trail	Ranges from No change to full restoration (ie no tidal restriction); Increase in intertidal habitat	Water management during construction, timber cribbing causeway, dredging, and future maintenance	1948 ~ 12.5 ft span corrugated steel plate pipe arch located upstream.	MHW Water Surface Elevation LOW (<2') MEDIUM (2' to 4') HIGH (>4')	Additional acreage impacts due to change in WSEL	Parcels impacted by change in WSEL	Number of potential hazmat sites impacted by change in WSEL	Number of parcels with water supply wells & septic impacted by alternative	Low:$2 to $10 mil. Mid:$10 to $25 mil. High: > $25 mil.
2020-2023 Planning	**Alternative 4 Modified**	Alternative 4 with larger culvert widths	Three - (10 ft span x 5 ft rise) Box Culverts With Flap Gates on 2 culverts Gated culverts at invert elev. -4.05 ft, open at -6.05	Yes	Yes	Yes (advection 52% of time)	Yes	• Maintains parking on causeway •Structure does not restrict amenities	Improvement; 86 intertidal habitat acres	• ~1,100 CY of near-field dredging • Constuctability more difficult for varied invert elevation • Difficult dewatering		MEDIUM (EL. 2.1' Change = +2.8')	86	28	1 municipal landfill (needs further study)	0	MID ($20-23 million)
	Alternative 5	Rehabilitation (15-year)	Additional buried roadway slab over top of existing culverts	No	Yes	No	No	• Maintains parking on causeway	None	• Continued deterioration of Timber culverts • Stabilize roadway settlement		no change	N/A	0	0	0	LOW
	Alternative 6	Rehabilitation (30-year)	Slipline existing <u>with</u> new flap gates & 2 new culverts <u>with</u> flap gates No leakage	No	Yes	No	No	• Maintains parking on causeway	None	• Risk damage to existing deteriorating structure • Stabilize existing timber culverts		LOW (estimated)	N/A	0	0	0	LOW
	Alternative 7	Rehabilitation (30-year)	Slipline existing culverts <u>without</u> flap gates & 2 new culverts <u>without</u> flap gates	No	Yes	Yes (advection)	No	• Maintains parking on causeway	Improvement	• Risk damage to existing deteriorating structure • Stabilize existing timber culverts • No flap gates to maintain		MEDIUM/HIGH (estimated)	100 to 200 +/-	38 +/-	0	1 (parcel P well near NE corner of causeway)	LOW
	Alternative 8	Phased Alternative - Replacement Culverts (Alt 4) & Future Replacement Bridge (Alt 10)	Five new culverts located to the East (intermediate SLR accomodation) Future Bridge to the west (high SLR accomodation) Flap gates on four culverts	Yes	Yes	Yes (advection now)	Yes	• Maintains parking on causeway (Now)	Improvement (Now)	• Can locate culverts to the East to facilitate water management during construction	• Requires replacement due to increased hydraulic opening, salinit,y and ice floes (in future)	LOW (now, estimated)	40 +/-	10 +/-	0	0	HIGH
				Yes	Yes (dependent on final highway bridge roadway profile)	Yes (volitional later)	Yes	• May not maintain full parking (future)	Restoration (future)			HIGH (future, estimated)	415 +/-	54 +/-	1 municipal landfill (needs further study)	5 (parcels F & G well/sewer near Stride Bridge; P, O, N wells near NE corner of causeway)	
	Alternative 9	Replacement Culverts	Four - (5 ft x 5 ft) Box Culverts without Flap Gates	Yes	Yes	Yes (advection 41% of time)	Yes	• Maintains full parking • Structure does not restrict amenities	Improvement; 168 intertidal habitat acres	• No flap gates to maintain • Difficult dewatering	• Requires replacement sooner due to increased hydraulic opening, salinity, and ice floes	MEDIUM/HIGH (EL. 4.1' Change = +4.8')	168	38	1 municipal landfill (needs further study)	1 (parcel P well near NE corner of causeway)	MID

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				PURPOSE AND NEED		SECONDARY GOALS			OTHER			Water Surface Elevation (WSEL) (NAVD88)	Increased Acreage Impact	Number of Properties	Hazardous Waste Sites	Wells/Septic	
				Overall Structure Rating	Railroad Corridor	Fish passage	Sea Level Rise (SLR) Accomodation	Transportation & Community Uses	Impacts to Tidal Regime	Constructability and Maintenance	Stride Bridge (#3973)	*NOTE: Impacts noted are from differences in normal water levels for normal tides and normal riverine flow (impacts do **NOT** include riverine floods, spring tides, storm surges or SLR)*					
	See "Technical Report: Middle River Hydrologic and Alternatives Analyses (June 30, 2015)", Memo "Updated Hydraulic Analysis for Culvert Replacement Alternatives (August 29, 2019)" and Memo "1st Phase Hydraulic Analysis for Machias Dyke Bridge Planning Phase Support Services (June 2, 2021)" for additional information		Culvert or Bridge--Number, Span and Size	Good (a rating of 7 or better on a scale 0-9)	Preserves railroad corridor in accordance with Rail Preservation Act	Improvement (Yes/No) 95% exceedance flow speed; Min water depth	Consistency with Town planning & Maine State Climate Council guidance	Causeway Parking Multi-Use Trail	Ranges from No change to full restoration (ie no tidal restriction); Increase in intertidal habitat	Water management during construction, timber cribbing causeway, dredging, and future maintenance	1948 ~ 12.5 ft span corrugated steel plate pipe arch located upstream.	MHW Water Surface Elevation LOW (<2') MEDIUM (2' to 4') HIGH (>4')	Additional acreage impacts due to change in WSEL	Parcels impacted by change in WSEL	Number of potential hazmat sites impacted by change in WSEL	Number of parcels with water supply wells & septic impacted by alternative	Low:$2 to $10 mil. Mid:$10 to $25 mil. High: > $25 mil.
2020-2023 Planning Continued	**Alternative 10**	Replacement of Dyke and Stride Bridge No parking on bridge (parking in approaches) *(Refined 2015 Alt 6)*	Dyke Bridge: Single span bridge 120' to 150' long (120' analyzed) 2 lane highway bridge Separate bridge for trail Stride Bridge: 75'+/- single span	Yes	Yes	Yes (volitional); 8.8 feet/sec; 1.3 +/- feet min.; low flow channel needed	No (potential for nuisance flooding beyond year 2070)	• May not maintain full parking, less amenities	Restoration; 398 intertidal habitat acres	• ~6,000 CY of near-field dredging • Large volume (>20,000 CY) of natural landward far-field sediment scour & seaward shoaling • Difficult to connect low flow channel landward of dredge and scour areas	• Requires replacement now due to increased hydraulic opening, salinity and ice floes	HIGH (EL. 7.9' Change = +8.6')	398	54	1 municipal landfill (needs further study)	5 (parcels F & G well/sewer near Stride Bridge; P, O, N wells near NE corner of causeway)	HIGH ($37-41 million)
	Alternative 10A	Replacement of Dyke and Stride Bridge Parking on bridge and in the approaches *(Refined 2015 Alt 6)*	Dyke Bridge: Single span bridge 120' to 150' long (120' analyzed) Full width bridge for highway & parking Separate bridge for trail Stride Bridge: 75'+/- single span	Yes	Yes	Yes (volitional); 8.8 feet/sec; 1.3 +/- feet min.; low flow channel needed	No (potential for nuisance flooding beyond year 2070)	• Maintains parking on causeway, less amenities	Restoration; 398 intertidal habitat acres	• ~6,000 CY of near-field dredging • Large volume (>20,000 CY) of natural landward far-field sediment scour & seaward shoaling • Difficult to connect low flow channel landward of dredge and scour areas	• Requires replacement now due to increased hydraulic opening, salinity and ice floes	HIGH (EL. 7.9' Change = +8.6')	398	54	1 municipal landfill (needs further study)	5 (parcels F & G well/sewer near Stride Bridge; P, O, N wells near NE corner of causeway)	HIGH ($39-43 million)
	Alternative 11	Replacement of Dyke and Stride Bridge No parking on bridge (parking in approaches)	Dyke Bridge: 2 span bridge 150' to 250' long 2 lane highway bridge Separate bridge for trail Stride Bridge: 75'+/- single span	Yes	Maybe (dependent on final bridge roadway profile)	Yes (volitional); 4.2 to 6.2 feet/sec; 1 +/- foot min.; low flow channel needed	No (potential for nuisance flooding beyond year 2050)	• May not maintain full parking, less amenities	Restoration; 405 intertidal habitat acres; not significant increase over Alternative 10	• 8,000 CY of near-field dredging •Volume of natural landward far-field sediment scour & seaward shoaling not evaluated • Difficult to connect low flow channel landward of dredge and scour areas	• Requires replacement now due to increased hydraulic opening, salinity and ice floes	HIGH (EL. 8.2' Change = +8.9')	405	56 +/-	1 municipal landfill (needs further study)	5 (parcels F & G well/sewer near Stride Bridge; P, O, N wells near NE corner of causeway)	HIGH (>$45 million)
	Alternative 11A	Replacement of Dyke and Stride Bridge Parking on bridge and in the approaches	Dyke Bridge: 2 span bridge 150' to 250' long Full width bridge for highway & parking Separate bridge for trail Stride Bridge: 75'+/- single span	Yes	Maybe (dependent on final bridge roadway profile)	Yes (volitional); 4.2 to 6.2 feet/sec; 1 +/- foot min.; low flow channel needed	No (potential for nuisance flooding beyond year 2050)	Maintains parking on causeway, less amenities	Restoration; 405 intertidal habitat acres; not significant increase over Alternative 10	• >8,000 CY of near-field dredging •Volume of natural landward far-field sediment scour & seaward shoaling not evaluated • Difficult to connect low flow channel landward of dredge and scour areas	• Requires replacement now due to increased hydraulic opening, salinity and ice floes.	HIGH (EL. 8.2' Change = +8.9')	405	56 +/-	1 municipal landfill (needs further study)	5 (parcels F & G well/sewer near Stride Bridge; P, O, N wells near NE corner of causeway)	HIGH (>$45 million)
	Alternative 12	Replacement of Dyke and Stride Bridge No parking on bridge (parking in approaches)	Dyke Bridge: Multi span bridge - 400' to 700'+/- long 2 lane highway bridge Separate bridge for trail Stride Bridge: 75'+/- single span	Yes	No	Yes (volitional); 2.5 feet/sec; 1 +\- foot min.; low flow channel needed	No (potential for nuisance flooding beyond year 2050)	May not maintain full parking, less amenities	Restoration; 405 intertidal habitat acres; not significant increase over Alternative 10	• >20,000 CY of near-field dredging •Volume of natural landward far-field sediment scour & seaward shoaling not evaluated • Difficult to connect low flow channel landward of dredge and scour areas	• Requires replacement now due to increased hydraulic opening, salinity and ice floes	HIGH (EL. 8.2' Change = +8.9')	405	56 +/-	1 municipal landfill (needs further study)	5 (parcels F & G well/sewer near Stride Bridge; P, O, N wells near NE corner of causeway)	HIGH (>$50 million)

NOTE: RAISING FINISHED GRADE ELEVATION OF THE CAUSEWAY FOR ALL ALTERNATIVES WILL HAVE ENVIRONMENTAL IMPACTS ALONG THE CAUSEWAY WITH SIDESLOPES WHICH MAY REQUIRE EARTH RETAINING STRUCTURES OR CHANGES TO THE EXISTING LANE/SHOULDER/PARKING WIDTHS.

APPENDIX 3 – ENDANGERED SPECIES ACT – BIOLOGICAL ASSESSMENT

1. 5/5/2024 Biological Opinion
2. 9/20/2023 Biological Assessment

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
GREATER ATLANTIC REGIONAL FISHERIES OFFICE
55 Great Republic Drive
Gloucester, MA 01930

May 5, 2024

Todd Jorgensen, Administrator
Federal Highways Administration, Maine Division
Edmund S. Muskie Federal Building
40 Western Avenue, Room 614
Augusta, ME 04330

Re: Endangered Species Act Section 7 Consultation for the Machias Dike Bridge Replacement

Dear Mr. Jorgensen:

Enclosed is our Biological Opinion, issued under section 7 of the Endangered Species Act (ESA), for the proposed Machias Dike Bridge replacement project. The Federal Highway Administration (FHWA) is the lead federal agency for purposes of section 7(a)(2) consultation. We understand that the project proponent, the Maine Department of Transportation, will require a permit from the U.S. Army Corps of Engineers, but no application has been filed to date. In the Opinion, we use the best available scientific and commercial data to analyze effects of the proposed action on ESA-listed species and designated critical habitat that occur in the action area. We conclude that the proposed action is likely to adversely affect but is not likely to jeopardize the continued existence of the Gulf of Maine distinct population segment (DPS) of Atlantic salmon and is not likely to adversely affect shortnose sturgeon or the Gulf of Maine DPS of Atlantic sturgeon. We have determined that the project is likely to adversely affect, but is not likely to destroy or adversely modify critical habitat designated for the Gulf of Maine DPS of Atlantic salmon.

As required by section 7(b)(4) of the ESA, an incidental take statement (ITS) is provided with the enclosed Opinion. The ITS exempts an identified amount of incidental take of ESA-listed Atlantic salmon from the ESA section 9 prohibitions on take. The ITS specifies Reasonable and Prudent Measures (RPMs) and implementing Terms and Conditions necessary and appropriate to minimize, monitor, and report the take of ESA-listed Atlantic salmon. In order to be exempt from the prohibitions on take, FHWA must comply (and must ensure that Maine DOT, as the applicant, complies) with the RPMs and their implementing Terms and Conditions. Failure to implement the Terms and Conditions through enforceable measures may result in a lapse of the protective coverage of section 7(o)(2). All mitigation measures listed and described in the *Description of the Proposed Action* section of the Opinion as part of the proposed action that were designed to avoid or minimize adverse effects to listed species were evaluated and relied on in our effects and our jeopardy analyses; failure to implement those measures could require reinitiation of consultation and/or invalidate this Opinion, including the take exemptions provided by the ITS.

Issuance of this Opinion concludes section 7 consultation for the proposed actions. As described in 50 CFR 402.15, an action agency has several responsibilities following issuance of a Biological Opinion. As such, the action agency identified in this Opinion is obligated to: (a)

Determine whether and in what manner to proceed with its action(s) in light of its section 7 obligations and our Biological Opinion; and (b) notify us of your final decision on the action. We look forward to hearing from you on these matters.

Reinitiation of consultation is required and shall be requested by FHWA where discretionary Federal involvement or control over the action has been retained or is authorized by law and: (1) The amount or extent of taking specified in the ITS is exceeded; (2) new information reveals effects of the action that may not have been previously considered; (3) the identified action is subsequently modified in a manner that causes an effect to listed species; or, (4) a new species is listed or critical habitat designated that may be affected by the identified action.

Additional Comments
As noted in our November 22, 2021, letter to you regarding this project, our preferred alternative at this site is one that will: minimize effects to diadromous fish, including endangered Atlantic salmon; minimize negative effects on designated critical habitat; maximize passage opportunities for diadromous fish; and, maximize opportunities for tidal habitat restoration. We also support development of climate resilient infrastructure. We continue to conclude that Alternative 10 (a pile supported single span bridge) provides a better opportunity to meet these goals than Alternative 4M (a solid-fill dike bridge with a series of culverts and tide gates). The proposed action that was subject to our ESA consultation is essentially Alternative 4M. While we have concluded that the proposed action is not likely to jeopardize the continued existence of Atlantic salmon and is not likely to destroy or adversely modify designated critical habitat, it will have significant negative consequences on Atlantic salmon and their critical habitat as well as other aquatic resources and habitats. The proposed action will perpetuate negative impacts on the local salt marsh, intertidal mudflats, and other important habitats that provide important ecosystem services and will reduce opportunities to restore functions in the Middle River watershed. We expect that many, if not all, of these negative outcomes could be avoided with selection of a different alternative that provides full tidal transparency which allows for fish passage and minimizes effects to sensitive habitats. We note that the consultation assessing effects to Essential Fish Habitat is ongoing; additional concerns regarding the subject project will be noted through that consultation.

Section 7(a)(1) of the ESA directs Federal agencies to utilize their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or designated critical habitat, to help implement recovery plans, or to develop information. In our Biological Opinion, we provide a number of conservation recommendations for your consideration. Additionally, in the spirit of ESA section 7(a)(1) and consistent with our comments above, we encourage FHWA to pursue an alternative that would improve habitat conditions in the Machias River watershed rather than perpetuate habitat degradation and impeded fish passage while also addressing regional transportation and infrastructure needs. The 2019 Recovery Plan for the Gulf of Maine DPS of Atlantic salmon[1] identifies a number of recovery criteria. One criterion for recovery is having 30,000 units of suitable rearing habitat fully accessible in the Downeast Coastal salmon habitat recovery unit. Modeling indicates that, if accessible, the Middle River would provide up

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[1] Available online at: https://www.fisheries.noaa.gov/s3//dam-migration/final_recovery_plan2.pdf

to 259 units of rearing habitat for Atlantic salmon. The suitability of this habitat to support rearing and spawning of Atlantic salmon has not been empirically evaluated; therefore, we lack specific information on the baseline condition that would be necessary to detect any changes resulting from the operation of the proposed tide gates. As such, we have included a conservation recommendation to evaluate the amount and condition of the physical and biological features of the habitat so that we can better understand the effects of the operation of the tide gates. Regardless, based on the results of the habitat model, we anticipate that an alternative design that allowed for fish passage would directly contribute to attaining the goal of 30,000 accessible and suitable habitat units in the Downeast SHRU.

We would like to continue to work collaboratively to achieve an ecologically sound and climate resilient approach to the replacement of the Machias Dike Bridge and encourage the state and federal agencies involved to pursue an alternative that improves the resilience of our coastal marine ecosystem, protects and conserves designated Essential Fish Habitat, and advances the recovery of endangered Atlantic salmon. If you have any questions or concerns about the consultation, please contact David Bean (David.Bean@noaa.gov, 207-866-4172). Questions regarding the ongoing EFH consultation should be directed to Mike Johnson in our Habitat and Ecosystem Services Division (mike.r.johnson@noaa.gov, 978-281-9130).

Sincerely,

Jennifer Anderson

Jennifer Anderson
Assistant Regional Administrator
for Protected Resources

Enclosure (Final Biological Opinion)

EC: Bean, Tierney, Crocker – F/GAR PRD

File Code: Sec 7 FHWA/formal/Machias Dike Bridge
ECO ID: GARFO-2023-02387

NATIONAL MARINE FISHERIES SERVICE
ENDANGERED SPECIES ACT SECTION 7 CONSULTATION
BIOLOGICAL OPINION

AGENCY: Federal Highway Administration, Maine Division (lead)

ACTIVITY CONSIDERED: In-kind Replacement of the Machias Dike Bridge (Rt. 1, Machias, Maine)
GARFO-2023-02387

CONDUCTED BY: NOAA's National Marine Fisheries Service
Greater Atlantic Regional Fisheries Office

Date Issued: May 5, 2024

Approved by: Jennifer Anderson

Jennifer Anderson
Assistant Regional Administrator
for Protected Resources

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1. INTRODUCTION AND BACKGROUND

This constitutes the biological opinion of NOAA's National Marine Fisheries Service (NMFS) issued to the Federal Highway Administration, as the lead Federal agency, in accordance with section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. §§ 1531-1543), on the effects of its proposed funding and/or approval of the Maine Department of Transportation's (MaineDOT) in kind replacement of the Machias Dike Bridge (MEDOT WIN 16714.00), which carries Route 1 over Middle River, a tributary to the Machias River in Machias, Maine. The proposed action will also require permits or authorizations from the U.S. Army Corps of Engineers (USACE), to be issued pursuant to the Rivers and Harbors Act and/or Clean Water Act; however, to date, MaineDOT has not applied for these permits or authorizations. As such, any action by the USACE is not addressed in this Opinion and will need to be addressed through a review of this consultation to determine if reinitiation of consultation is necessary.

A complete administrative record of this consultation will be maintained at our Maine Field Office in Orono, Maine.

1.1. Consultation History

The planning of the Machias Dike Bridge project has been ongoing for over a decade and the approaches to replacement have varied through the years. NMFS has been involved in a number of meetings and discussions regarding impacts of various alternatives, including expressing support in 2022 for a preferred alternative that would provide full tidal transparency (i.e., open bottom bridge spanning the entire Middle River).

Extensive technical assistance and other project discussions occurred between June 2015 and September 2023, as summarized below.

- June 30, 2015; Technical Report: Middle River Hydrologic and Alternatives Analyses (MaineDOT 20150630) conducted by Stantec compared the different alternatives for the Machias Dike Bridge.
- April 2, 2018; MaineDOT held a public meeting to discuss the need to replace the Machias Dike Bridge.
- December 13, 2019; MaineDOT reached out to NMFS to initiate dialogue for the in kind replacement of the Machias Dike Bridge.
- August 19, 2020; Discussion on in kind replacement and potential impacts to ESA species and habitat and EFH. In addition, the Downeast Coastal SHRU Coordination Committee (DCC) discussed a letter to MaineDOT dated June 30, 2020 identifying the potential for impacts to Atlantic salmon and its critical habitat located in the Middle River.
- September 25, 2020; Discussion of effects to ESA species and EFH from in kind replacement of the Machias Dike Bridge.
- September 30, 2020; Letter to MaineDOT from NMFS identifying the importance of this area to recovery of Atlantic salmon in the Downeast Coastal SHRU. We emphasized our continued commitment to working with MaineDOT to achieve an ecologically sound and

climate resilient approach to the replacement of the Machias Dike Bridge and strongly encouraged the state and federal agencies involved to pursue alternatives beyond an in kind replacement.

- December 9, 2020; Discussion of a recent correspondence from NMFS GARFO dated September 30, 2020. Also a recent correspondence to the town of Machias from MaineDOT informing them of a change in the process in order to address the potential effects to Atlantic salmon critical habitat from an in kind replacement. After reviewing a recent 2019 Waterfront Resiliency Study the MaineDOT identified the need for further coordination between projects planned in the town of Machias to adequately address sea level rise and flooding. MaineDOT presented a preliminary alternatives analysis.
- June 24, 2021; Discussion with MaineDOT to develop a list of reasonable alternatives to in kind replacement; MaineDOT requested technical assistance for determining the best alternatives for the replacement of the Machias Dike Bridge.
- July 20, 2021; Discussed a memo from Stantec (12-10-2020) describing the tidal response to the different alternatives for replacement of the Machias Dike Bridge.
- August 17, 2021; Discussed alternative designs in light of fish passage and climate change (SLR considerations were presented by Stantec. MaineDOT presented fish passage potential at various tide stages comparing different options with existing conditions. MaineDOT announced the first public meeting scheduled for September 2021.
- September 21, 2021; discussed different design alternatives with open span and culvert configurations and how these can affect the tide height above the Machias Dike Bridge in the Middle River.
- October 19, 2021; further discussed various culvert configurations and tidal marsh habitat area above the Machias Dike Bridge within the Middle River.
- November 22, 2021; Letter to FHWA and MaineDOT providing technical assistance during the early planning stages. The letter described our preferred alternative of an open span bridge based on fish passage and restoration of tidal habitat in the Middle River.
- March 31, 2022; Discussed letter from MaineDOT and FHWA in regards to safe, timely, and effective fish passage for the different alternative designs, specifically the fish passage standards of 95% passage within 48hrs and subsequent monitoring to determine if this was being met.
- April 15, 2022; Letter to MaineDOT and FHWA providing clarity for safe, timely, and effective fish passage standards as it relates to effects of the project and determination of jeopardy of the species and adverse modification of critical habitat for Atlantic salmon.
- June 14, 2022; Discussed information needs for the draft BA.
- July 14, 2022; Response to information submitted by the FHWA.
- August 22, 2022; Received first draft Biological Assessment (BA) from MaineDOT on August 3, 2023 and discussed general comments through informal email exchange.
- October 12, 2022; Discussed draft BA and information needed to complete the BA.
- April 14, 2023; Email to MaineDOT and FHWA in regards to recent draft BA and need for additional information.
- May 2, 2023; Call with MaineDOT, FHWA and NMFS to discuss comments on draft BA.
- May 19, 2023; Call with MaineDOT, FHWA and NMFS to discuss monitoring for potential effects from the proposed project.

- May 26, 2023; Sent MaineDOT and FHWA recent paper (Befus et al., 2023) on Sea Level Rise and associated impacts to coastal lowlands with flow regulating structures such as tide gates.
- August 7, 2023; NMFS sent email in regards to recent BA and need for additional information.
- August 10, 2023; MaineDOT sent revised map of action area showing modeled critical habitat in the Middle River drainage that would be effected from the long term operation of the tide gates.
- August 11, 2023; MaineDOT sent revised BA to NMFS GARFO
- August 14, 2023; NMFS sent email to MaineDOT in regards to revised BA and need for additional information.
- August 28, 2023; Call with MaineDOT, FHWA and NMFS to discuss draft BA.
- September 14, 2023; NMFS provided MaineDOT and FHWA additional information to include in the analysis of effects from the project.

On September 20, 2023, we received a revised BA from MaineDOT and FHWA. On October 12, 2023, we sent a letter to MaineDOT and FHWA confirming that the September 20, 2023 BA and accompanying request for consultation contained the information necessary to initiate the section 7 consultation. In response to requests for information during the consultation period, MaineDOT and FHWA provided additional information:

- February 6, 2024; MaineDOT provided a revised estimate for fill needed to construct the temporary roadway and approaches along with a conceptual drawing of the site during construction.
- February 14, 2024; FHWA provided estimates of the amount of time required for the different pile driving activities proposed for cofferdam and pipe pile installation and removal.

Consideration of the ESA Regulations

On July 5, 2022, the U.S. District Court for the Northern District of California issued an order vacating the 2019 regulations that were revised or added to 50 CFR part 402 in 2019 ("2019 Regulations," see 84 FR 44976, August 27, 2019) without making a finding on the merits. On September 21, 2022, the U.S. Court of Appeals for the Ninth Circuit granted a temporary stay of the district court's July 5 order. On November 14, 2022, the Northern District of California issued an order granting the government's request for voluntary remand without vacating the 2019 regulations. The District Court issued a slightly amended order two days later on November 16, 2022. As a result, the 2019 regulations remain in effect, and we are applying the 2019 regulations here. For purposes of this consultation and in an abundance of caution, we considered whether the substantive analysis and conclusions articulated in this biological opinion and its incidental take statement would be any different under the pre-2019 regulations. We have determined that our analysis and conclusions would not be any different.

On April 5, 2024, NMFS and USFWS published a final rule revising portions of the section 7 implementing regulations (89 FR 24268). These revised regulations are effective on May 6, 2024; therefore, they were not relied on in this Biological Opinion. We note that the preamble of the final rule states, "These revisions will further improve and clarify interagency consultation.

With the exception of the revisions at 50 CFR 402.02 and 402.14 regarding the RPMs in an incidental take statement (ITS), the revisions do not make any changes to existing practice of the Services in implementing section 7(a)(2) of the Act." As such, we do not consider that the substantive analysis and conclusions articulated in this Opinion would be any different under the April 2024 regulations.

Application of ESA Section 7(a)(2) Standards – Analytical Approach

This section reviews the approach used in this Opinion in order to apply the standards for determining jeopardy and destruction or adverse modification of critical habitat as set forth in section 7(a)(2) of the ESA and as defined by 50 CFR §402.02 (the consultation regulations). Additional guidance for this analysis is provided by the Endangered Species Consultation Handbook, March 1998, issued jointly by NMFS and the U.S. FWS. In conducting analyses of actions under section 7 of the ESA, we take the following steps, as directed by the consultation regulations:

- Identifies the action area based on the action agency's description of the proposed action (section 2);
- Evaluates the current status of the species with respect to biological requirements indicative of survival and recovery and the essential features of any designated critical habitat (sections 3 and 4);
- Evaluates the relevance of the environmental baseline in the action area to biological requirements and the species' current status, as well as the status of any designated critical habitat (section 5);
- Evaluates the relevance of climate change on environmental baseline and status of the species (section 6);
- Determines whether the proposed action affects the abundance, reproduction, or distribution of the species, or alters any physical or biological features of designated critical habitat (section 7);
- Determines and evaluates any cumulative effects within the action area (section 8); and,
- Evaluates whether the effects of the proposed action, taken together with any cumulative effects and the environmental baseline, can be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of the affected species, or is likely to destroy or adversely modify their designated critical habitat (section 9).

In completing the last step, we determine whether the action under consultation is likely to jeopardize the ESA-listed species or result in the destruction or adverse modification of designated critical habitat. If so, we must identify a reasonable and prudent alternative(s) (RPA) to the action as proposed that avoids jeopardy or adverse modification of critical habitat and meets the other regulatory requirements for an RPA (see 50 CFR §402.02). In making these determinations, we rely on the best available scientific and commercial data.

The critical habitat analysis determines whether the proposed action will destroy or adversely modify designated critical habitat for ESA-listed species by examining any change in the conservation value of the physical and biological features of that critical habitat. As defined by NMFS and U.S. FWS, destruction or adverse modification "means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species.

Such alterations may include, but are not limited to, those that alter the physical and biological features essential to the conservation of a species or that preclude or significantly delay development of such features" (81 FR 7214; February 11, 2016).

2. DESCRIPTION OF THE PROPOSED ACTION

The proposed action is FHWA's authorization of MaineDOT's plan to replace the existing Machias Dike Bridge. The existing bridge consists of four box culverts within an embankment structure over the top of the culverts (causeway). The culverts are constructed of timber and stone masonry and are approximately 130 feet long, 6 feet wide, and 5 feet high. Each culvert has a top-hinged flap gate installed on its seaward side. The causeway is constructed of timber cribbing with rubble and earthen fill and is over 1,000 feet long. The entire bridge structure, consisting of the road surface (causeway) and the culverts will be replaced.

The description of the proposed action provided here is based on the information provided in FHWA's BA. We note that MaineDOT has not yet entered into any contracts for final design or construction of the new structure, thus the BA is based on DOT and FHWA's best professional judgment and experience to predict the likely construction scenario and impacts. FHWA is proposing to fund MaineDOT's planned replacement of the Machias Dike Bridge carrying U.S. Route 1 over Middle River in the Town of Machias, Maine (Figure 1). In addition, MaineDOT will seek appropriate permit authorizations from the USACE, pursuant to section 404 of the Clean Water Act and/or section 10 of the Rivers and Harbors Act. The Machias Dike Bridge replacement project will require fill below the ordinary high water mark of Middle River and Machias River estuary. During construction, in-water structures will occupy 45,000 square feet of aquatic habitat. Bridge replacement will occur in stages, and the existing culvert structures will continue to pass flow while the new bridge is constructed. Once the new structure is operating, the old culverts will be removed. As described in the BA, the invert elevation (height is measured at the inside bottom of the culvert) of the new structure will be set at the same elevation as the old structures. Based on this, we expect this will mean the operation of the tide gates will be similar to what is in place now and will open and close at a similar tide height providing flow through the culvert during daily tidal cycles.

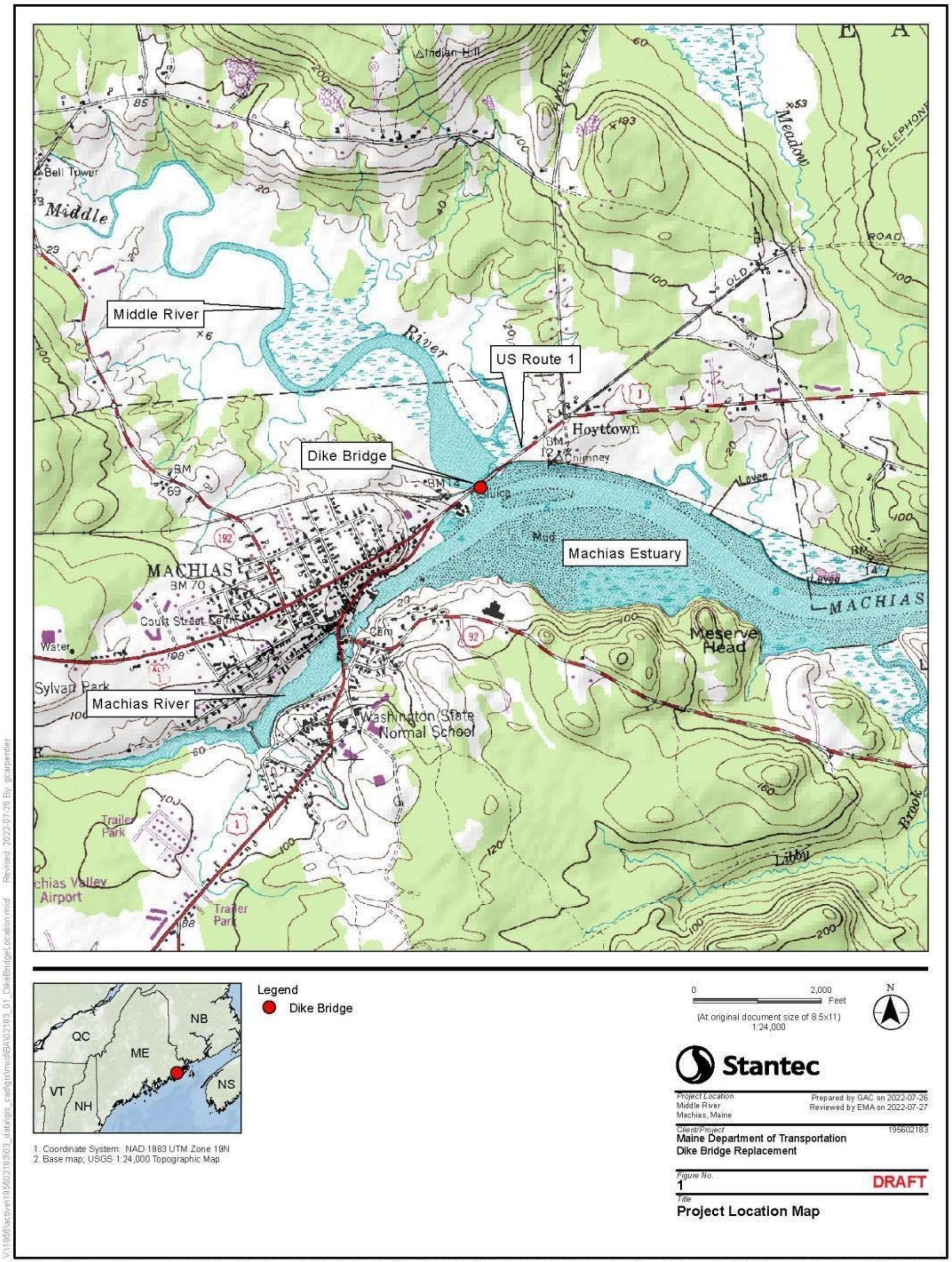


Figure 1. The location of the Machias Dike Bridge that MaineDOT is proposing to replace.

2.1. Description of the Existing Structure

As described in the BA, the causeway itself is 150 years old, and the culvert structure is 88 years old. The interior of the causeway is composed of timber cribbing and fill. The slopes of the causeway are lined with riprap. On the Middle River side (upriver), riprap is interspersed with shrubs and herbs and borders an intertidal zone. On the Machias River side (seaward), vegetation is sparse, and the intertidal zone is dominated by mudflat (Photo 1). The existing Machias Dike Bridge is composed of four box culverts that are each approximately 5.5 feet tall, 6 feet wide, and contained within a 130-foot-long timber box. The causeway is constructed of timber cribbing with rubble and earthen fill and is over 1,000 feet long. On the downstream side, each culvert is fitted with a top hinging flap gate (tide gate) made of a reinforced concrete panel surrounded by a metal frame (Photo 1). Traditional tide gates are designed to reduce or prevent the upstream flow of tidal water and to reduce fluctuations of water levels upstream. These gates are designed to prevent intrusion of salt water in the Machias estuary into the lower Middle River. The orientation of the culverts (e.g., invert height) and top hinging gates prevent water from flowing freely into the culvert during the incoming tide when the height of the water in the Machias estuary is greater than the Middle River outflow. Although the structure is intended to block tidal flow at high tide, the existing conditions of the culverts and tide gates allow leakage of tidal waters to pass through the structure and into the Middle River.

Photo 1. View of the existing Machias Dike Bridge as seen from the downstream Machias estuary side during low tide conditions.

2.2. Description of the Proposed Replacement

MaineDOT is proposing to replace the Machias Dike Bridge with a similar structure (i.e., in kind replacement). It is expected that work will commence in 2025 and may take up to four years to complete. The replacement of the existing bridge (which is comprised of a roadway/causeway on top of four box culverts) will occur in stages. The first phase of the project is to install a temporary bridge and roadway to maintain the flow of traffic along Route 1. Then, new culverts will be installed along the alignment of the new permanent causeway bridge. The existing structure will then be removed, and water will be diverted from the old culverts to the new culverts. Finally, the new roadway will be constructed around the new culverts and the temporary bridge will be removed. Details on these steps are provided below.

2.2.1 Description of the Construction related activities

The following list describes the anticipated project activities that will occur and the presumed sequence of these activities. As noted in the BA, although it is unknown how a contractor may stage and schedule for this project, MaineDOT staff experienced in construction and similar projects worked together to create the following construction sequence which forms the basis for the description of the proposed action. In water activities are in bold:

- Mobilization
- **Install temporary bridge (fill placement and pile driving)**
- **Install cofferdams around location of new box culverts**
- Excavate and install new box culverts with tide gates
- Backfill around new box culverts
- **Remove cofferdams**
- **Install cofferdam around existing series of four box culverts**
- Remove old timber box culvert structures
- **Remove cofferdams**
- **Remove temporary bridge**
- Addition of fill to raise the causeway
-

Table 1. Approximate timing of in water activities specific to the Machias Dike Bridge Construction

Activity	Duration	Timing
Installation of temporary bridge pile with a vibratory hammer	1-2 weeks	Anytime
Installation of temporary bridge pile with an impact hammer	1 week	In the dry or December 1–March 31
Sheet pile installation of two cofferdams for the new culvert	3-4 weeks in total (1-2 weeks each)	Anytime
Sheet pile installation of two cofferdams for removal of old culvert	3-4 weeks in total (1-2 weeks each)	Anytime

structure		
Removal of two cofferdams needed for placement of new culverts	2-3 weeks in total (10 days each)	Anytime
Removal of two cofferdams needed for removal of old culvert structure	2-3 weeks in total (10 days each)	Anytime
Removal of temporary bridge piles with a vibratory extractor	1 week	Anytime

Prior to any soil disturbance or site work, contractors will implement Best Management Practices (BMP) in accordance with the MaineDOT manual on *Best Management Practices for Erosion and Sedimentation Control* (2008), which outlines means and methods to prevent sedimentation in streams during construction or heavy precipitation. As a component of the Soil Erosion and Water Pollution Control Plan (SEWPCP) required for each project, MaineDOT or their contractor will develop and implement a Spill Prevention Control and Countermeasure Plan designed to avoid stream impacts from inadvertent spills of chemicals, such as diesel fuel, oil, lubricants, and other hazardous materials (see below).

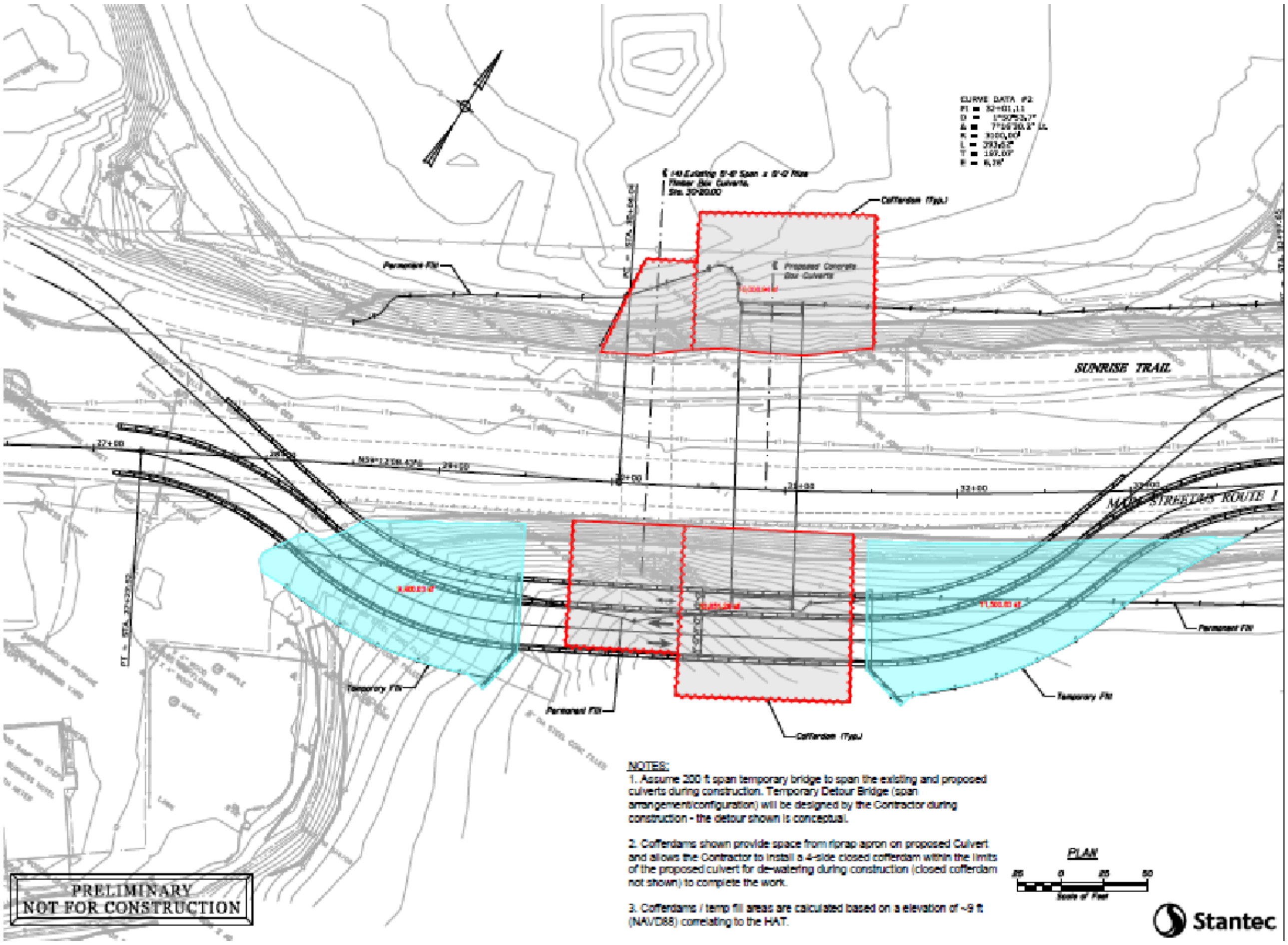
Cofferdam Installation

A total of four cofferdams will be installed, two separate areas on each side of the causeway (upstream and downstream) need to be isolated to allow for most of the proposed construction activities to occur in the dry (Figure 2). The first cofferdam installation will be to install two cofferdams to contain the site and enable working in the dry (upstream and downstream) to receive the new culvert structures. The cofferdam will have structure walls (sheet piles) supported by a frame. Once the cofferdam is installed, the interior will be dewatered using typical pumping procedures. MaineDOT anticipates it will take approximately 1-2 weeks to install each of the cofferdams (one upstream and one downstream) to isolate each site. DOT anticipates that the temporary cofferdams will be constructed with up to 50 24-inch AZ steel sheet piles each. The sheet piles will be installed using a vibratory hammer either when the tide is out and the area is dewatered or in water, depending on location and construction schedule; approximately 30 minutes of pile driving will be required for each pile.

The temporary bridge crossing will be placed downstream of the existing causeway. After the temporary roadway is complete, the existing roadway will be replaced, including placing the new culvert configuration under the new roadway. Following the completion of the new roadway and culvert structure the cofferdams will be removed to allow water to flow into and out of the Middle River. After the removal of the existing culvert structure and replacement of the road infrastructure, all sheet piles will be removed. MaineDOT anticipates removal of the sheet piles with a vibratory hammer will take approximately 10 days for each cofferdam (see additional information below).

Construction of Temporary Bridge

A temporary bridge will be built downstream of the existing dike to allow for the maintenance of two-way traffic throughout project construction (Figure 2). As described in the BA, the temporary bridge will be a combination of temporary fill and a pile-supported bridge. FHWA provided additional information on the planned pile driving on February 14, 2024. Based on the information provided, the temporary bridge will be supported by a series of 5 bents that would each contain up to 7 30”-diameter steel pipe piles, for a total of 35 total pipe piles. Pipe piles will be installed with a vibratory hammer, with final seating with an impact hammer. The vibratory hammer will be used for 15-45 minutes on each pile, followed by 5-15 minutes with an impact hammer (200-500 strikes). Approximately 5 piles per day are expected to be installed. FHWA will require compliance with measures to reduce potential effects of pile driving (see below); accordingly, impact pile driving will occur at low tide in the dry or, in the water only during the December 1 to March 31 work window (AMM 1). Following installation of the temporary bents, the superstructure, which will consist of a series of steel supports, will be attached above the water. It is expected that the temporary bridge could take 2-3 months to install.



NOTES:

1. Assume 200 ft span temporary bridge to span the existing and proposed culverts during construction. Temporary Detour Bridge (span arrangement/configuration) will be designed by the Contractor during construction - the detour shown is conceptual.

2. Cofferdams shown provide space from riprap apron on proposed Culvert and allows the Contractor to install a 4-side closed cofferdam within the limits of the proposed culvert for de-watering during construction (closed cofferdam not shown) to complete the work.

3. Cofferdams / temp fill areas are calculated based on a elevation of ~9 ft (NAVD88) correlating to the HAT.

Figure 2. Conceptual design drawing of proposed cofferdam configurations (red outline) on each side of Route 1 which are needed to isolate the work area for the proposed in kind replacement. The shaded blue area is proposed temporary fill needed for the temporary detour bridge, which is shown as curved black lines downstream of the existing Route 1 roadway.

New Structure Installation

Prior to placing the new culvert structures, portions of the old dike will be removed. This material will consist of larger stones and old cribwork pieces. The contractor will install granular material to set the new box culverts. The box culverts will then be installed section by section using a crane sitting on the dike. Each section of box culvert is fastened together and the joint between the sections is sealed. The contractor will install new tide gates on the downstream side of the new box culverts. These gates will be fastened to the culverts and hinged to allow flow from the Middle River downstream, and close when water from the Machias River Estuary comes up and attempts to flow back into the Middle River. When the new culverts are installed, the contractor will backfill the new bridge and install riprap where necessary.

Cofferdam Relocation/Removal and Temporary Bridge Removal

Once the new box culverts are installed, the sheet pile cofferdam that surrounded them will be moved to provide water control for the removal of the old box culverts. Sheet piles will be removed with an excavator-mounted vibratory hammer. Water pumps will be shut off and the cofferdam will slowly be breached by using the vibratory hammer to remove a section of sheet pile. Breaching of cofferdams will occur at high slack tide to minimize water velocities upon release (AMM3). Once the cofferdam is breached, contractors will remove the remainder of the sheet piles and pump system. If sandbags are used to seal the base of the cofferdams, they will also be removed. Any disturbed areas will be stabilized, and all permanent erosion control BMPs will be installed. The temporary bridge will also be removed. The superstructure will be disassembled, and the piles will be extracted with a vibratory hammer similar to the removal of the sheet piles. Any fill that was placed will be removed.

Raising the Dike
As described in the BA, adaptations for sea-level rise include various ranges of raising the roadway. Replacing the bridge with box culverts allows MaineDOT to match the new roadway profile into the concurrent sea wall project that the town of Machias has been planning. The top of the roadway will be raised to allow for Route 1 to be passable during future predicted sea level rise. The top height of Route 1 is expected to target 13.1 NAVD88 as a part of this project. To raise the roadway, it will be necessary to increase the amount of fill placed adjacent to the existing causeway. The amount of fill will depend on the extent to which the roadway is raised. The placement of this fill will occur at low tide as much as possible. If fill is placed when water is present, a BMP such as a turbidity curtain will be used.

2.2.2 Avoidance and Minimization Measures (AMM) that are part of the proposed action

There are a number of measures that MaineDOT is proposing to take and FHWA is proposing to incorporate into any authorizations for the project. We expect that USACE will also require compliance with measures consistent with their authorities; however, at this time any such mitigation measures are unknown and therefore are not considered part of the proposed action we are consulting on. For the purpose of this consultation, the avoidance and monitoring measures proposed by DOT and identified in the BA as part of the action that FHWA is requesting consultation on are considered as part of the proposed action. The measures included in the BA are listed below:

- AMM 1. Pile driving with an impact hammer will be completed at low tide or within the December 1- March 31 window.
- AMM 2. The Contractor will use a vibratory hammer to drive all piles to the fullest extent practicable. Impact-hammer pile driving will be necessary to seat 30-inch steel bent piles for temporary bridge structure. Steel bent pipe pile size will be limited to 30 inches to minimize the potential for fish injury (> 187dB).
- AMM 3. Breaching of cofferdams will occur at high slack tide to minimize water velocities upon release.
- AMM 4. Before project construction begins, each Contractor must submit a Soil Erosion and Water Pollution Control Plan (SEWPCP) for review and approval of MaineDOT staff prior to the start of work. The plan includes the review of the implementation of any AMMs proposed. Prior to soil disturbance, the erosion control portion of the SEWPCP

will be reviewed and in place.

- AMM 5. Contractors will implement BMPs in accordance with the MaineDOT manual Best Management Practices for Erosion and Sedimentation Control (MaineDOT 2008; available at https://www.maine.gov/mdot/env/documents/bmp/BMP2008full.pdf.), which outlines means and methods to prevent sedimentation in streams during construction or heavy precipitation. The Contractor will maintain sediment and erosion controls throughout construction and until the site is deemed completely stable.
- AMM 6. As a component of the SEWPCP required for the bridge replacement project, MaineDOT or their Contractor will develop and implement a Spill Prevention Control and Countermeasure Plan (SPCCP) designed to avoid stream impacts from hazardous chemicals, such as diesel fuel, oil, lubricants, and other hazardous materials.
- AMM 7. During construction, any disturbed soils will be temporarily stabilized with BMPs, such as straw mulch, plastic sheeting, erosion control mix, or other appropriate BMPs. Disturbed areas with erodible soil can include, but are not limited to, temporary storage piles, access ways, partially constructed slopes, etc.
- AMM 8. No equipment, materials, or machinery shall be stored, cleaned, fueled, or repaired within any wetland or watercourse; dumping of oil or other deleterious materials on the ground will be forbidden; the Contractor shall provide a means of catching, retaining, and properly disposing of drained oil, removed oil filters, or other deleterious material; and all oil spills shall be reported immediately to the appropriate regulatory body. Response to any contaminant release will follow protocols contained in the SPCCP.
- AMM 9. Temporary roads (wet roads) in the project area will be constructed of clean, non-erodible material (i.e., plain riprap or large riprap per MaineDOT standard specifications) over geotextile fabric. No fill for temporary access (riprap) will be placed in the primary or bypass channel. Culverts will be installed where wet roads cross secondary channels to provide connectivity of flow and downstream fish passage.
- AMM 10. All areas of temporary waterway or wetland fill will be restored to their original contour and character upon completion of the project. Temporary fill includes fill that received authorization and fill that mistakenly enters a resource (i.e., from slope failures, accidental broken sandbag cofferdams).
- AMM 11. No heavy construction equipment will travel into or through any flowing streams with erodible substrate (e.g., sand, silt, and clay). Travel of heavy construction equipment into or through flowing streams and onto stream substrate will only occur when the stream substrate is non-erodible (e.g., ledge, cobble) and the Contractor has received approval from the MaineDOT or the MTA environmental field office staff.
- AMM 12. Turbid water within a cofferdam during dewatering will be pumped to a sediment basin for filtration. The “Dirty Water” Treatment System will be installed according to MaineDOT’s BMPs.
- AMM 13. In those portions of the project area where fish are likely to occur, all intake pumps will have a fish screen installed, operated, and maintained. To prevent fish entrainment during water diversions, the Contractor will use a screen on each pump intake large enough so that the approach velocity does not exceed 0.06 meters per second (0.20 feet per second). Square or round screen face openings are not to exceed 2.38 millimeters (3/32 inch) on a diagonal. Criteria for slotted face openings will not exceed 1.75 millimeters (approximately 1/16 inch) in the narrow direction. These screen criteria

follow those indicated by NMFS. Intake hoses will be regularly monitored while pumping to minimize adverse effects to sturgeon and salmon.

- AMM 14. Fresh concrete will be poured inside of a cofferdam (concrete seal) and will not contact flowing water (outside cofferdam).
- AMM 15. Water pumped out of the cofferdam will be within one pH unit of background pH level of the resource (Middle River/Machias River) (MaineDOT standard specifications). A representative of the MaineDOT Surface Water Quality Unit will periodically evaluate pH to determine whether the water is within the allowable tolerance to be pumped directly back into the river or whether it needs to be treated prior to discharge.
- AMM 16. Demolition and debris removal and disposal will comply with Section 202.03 of MaineDOT's Standard Specifications. The Contractor will contain all demolition debris, including debris from wearing surface removal, saw cut slurry, dust, etc., and will prevent debris from entering any resource to the extent feasible. The Contractor will dispose of debris in accordance with the Maine Solid Waste Law (Title 38 M.R.S.A., Section 1301 et. seq.) and in compliance with applicable regulatory approvals. The demolition plan, containment, and disposal of demolition debris will be addressed in the Contractor's SEWPCP.
- AMM 17. If pile driving is occurring during a time of year when ESA-listed species may be present, and the anticipated noise is above the behavioral noise threshold (i.e., 150 dB re 1uPa RMS), a "soft start" is required to allow animals an opportunity to leave the project vicinity before sound pressure levels increase. In addition to using a soft start at the beginning of the work day for pile driving, one must also be used at any time following cessation of pile driving for a period of 30 minutes or longer. For impact pile driving: pile driving will commence with an initial set of three strikes by the hammer at 40% energy, followed by a one minute wait period, then two subsequent three- strike sets at 40% energy, with one-minute waiting periods, before initiating continuous impact driving. For vibratory pile installation: pile driving will be initiated for 15 seconds at reduced energy followed by a one-minute waiting period. This sequence of 15 seconds of reduced energy driving, one-minute waiting period will be repeated two additional times.

2.3 Operations and Maintenance of the New Structure

As noted in the BA, the new tide gates that will be placed on the structure will operate similar to the current gates. They will be hinged at the top and placed on the downstream side of the new culvert structures. When the water elevation in the Machias River Estuary is greater than the Middle River impoundment, the gates will be shut, and water will not be allowed to flow upstream (north) of the dike. When the water elevation in the Machias River Estuary is lower than the Middle River impoundment, the gates will open and allow water to flow into the estuary. This type of gate is referred to as a flap gate. There is no motorized operation. The gates are expected to be made of a durable material (e.g., metal). MaineDOT will create an asset management plan for the Machias Dike Bridge once final design is complete. This plan will ensure that funding is available for maintenance of the structure throughout its life cycle. The intended life of the crossing structure is 80-100 years. The intention is for the flap gate to function properly for the entire lifespan of the Machias Dike Bridge. Debris inspection and removal will occur throughout the year. MaineDOT will inspect the new Machias Dike Bridge every two years. Inspection of the gate structures will occur every other year. This inspection will include the condition and function of the flap gates. Any identified damage or needed repairs to the flapper gate system will be repaired within the MaineDOT Work Plan cycle.

2.4 Description of the Action Area

The action area is defined as "all areas to be affected directly or indirectly by the Federal action and not merely the immediate area (project area) involved in the proposed action" (50 CFR 402.02). The action area for this consultation includes the area affected by both construction of the Machias Dike Bridge replacement project and long term operation of the tide gates. The action area includes the area affected by underwater noise, sedimentation and turbidity, and temporary and permanent habitat modification.

Construction for the replacement of the bridge (comprised of a roadway on top of four box culverts) will occur behind the drained cofferdams within an approximate footprint of 24,000 $feet^2$, along with the temporary bridge occupying approximately 21,000 $feet^2$. During construction, temporary in-water structures will occupy a total of 45,000 square feet of aquatic habitat within the Middle and Machias Rivers (Figure 2).

As described in the BA, MaineDOT anticipates that turbidity impacts will not extend more than 300 feet above the upstream cofferdam, and no more than 300 feet downstream of the downstream cofferdam (Figure 4 -100 m yellow circle), however, we do not anticipate any listed salmon and sturgeon in the Middle River upstream of the project area during construction. Noise during impact pile driving would extend up to 2.1 km from the pile being installed (Figure 4-thick red line) (73.6 m behavioral threshold for vibratory hammer; Figure 4 -thin red outline); however, as listed salmon and sturgeon are only present downstream of the bridge, exposure to increased noise only has the potential to occur in an area extending up to approximately 2.1 km downstream from the pile being installed (see explanation in section 6 below; Figure 4 red outlines).

The long term operation of the tide gates has impacted the habitat within the Middle River upstream of the causeway (Figure 4 blue outline). This area is also listed critical habitat for Atlantic salmon (see section 3 below). The construction activities proposed by the MaineDOT have the potential to temporarily impact Atlantic salmon critical habitat through sedimentation and turbidity and will also will permanently (i.e., for the life of the project) impede migration into and out of the Middle River.

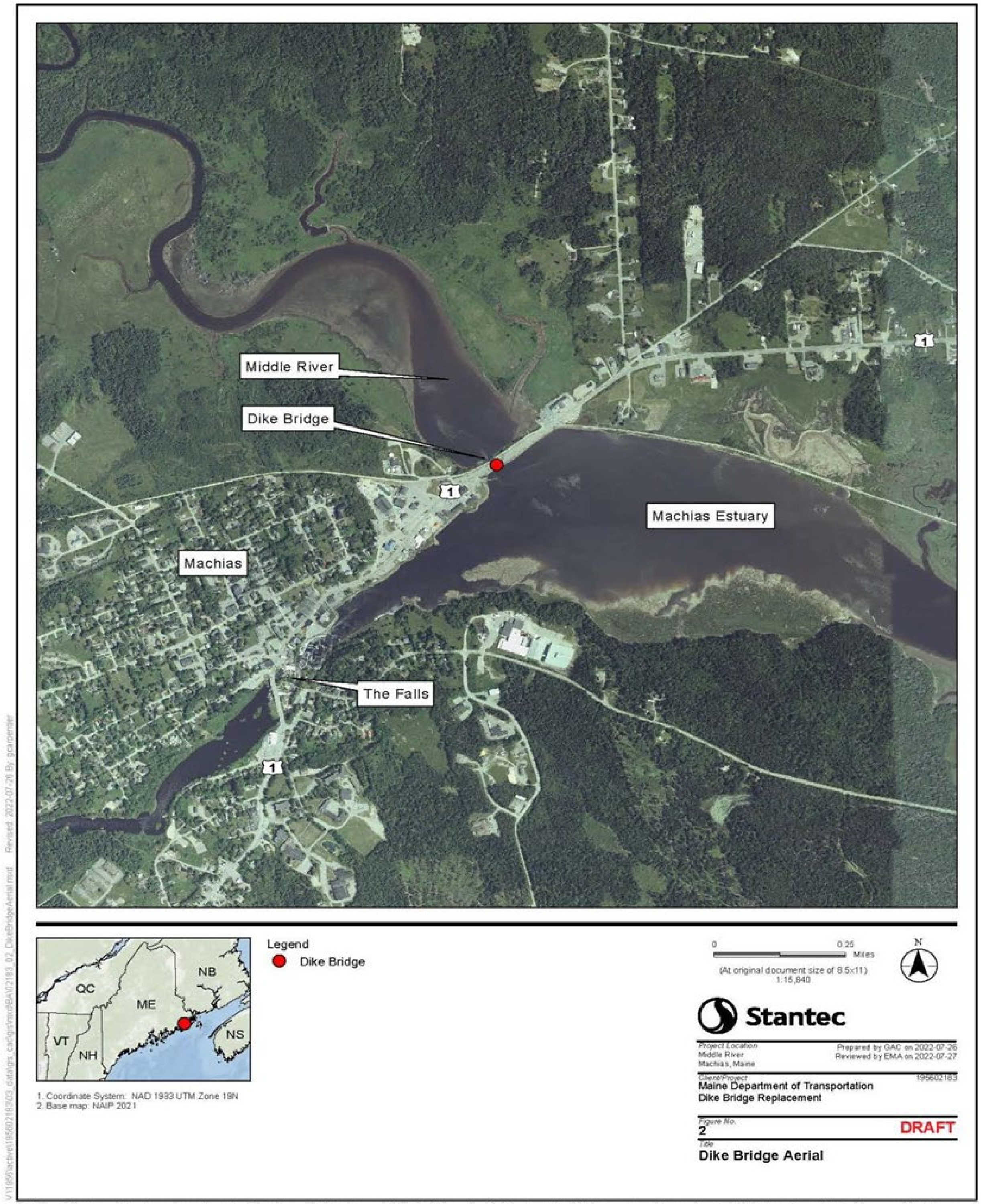


Figure 3. Aerial view of Machias Dike Bridge project

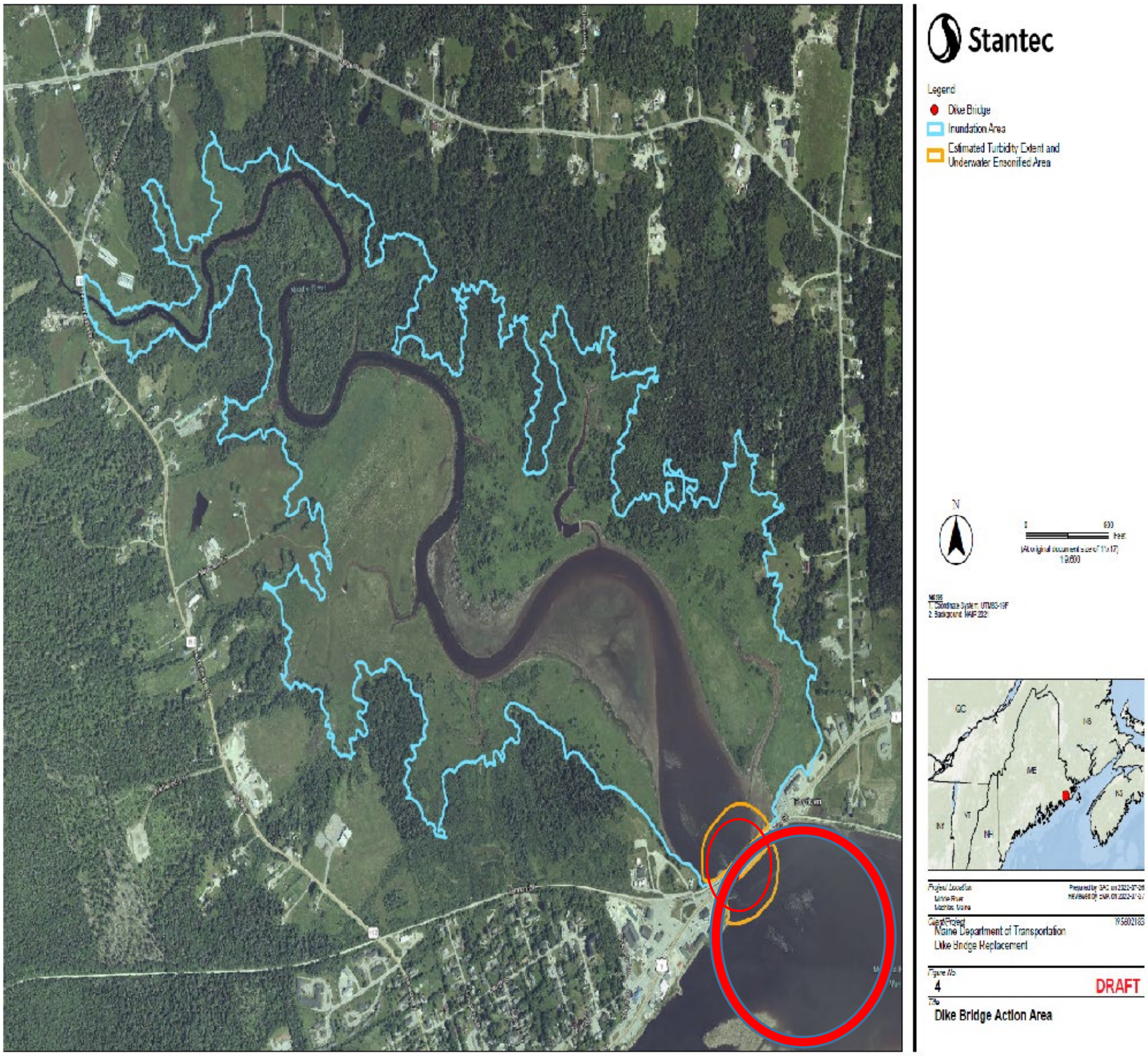


Figure 4. Action area in Machias and Middle Rivers including upstream habitat affected by the Machias Dike Bridge (blue outline) and effects from replacement including turbidity (yellow outline) and sound (red outlines) (Stantec 2015).

In summary, the upstream extent of the action area includes the habitat anticipated to be affected by the long term operation of the proposed tide gates due to changes in flow, temperature, and salinity (blue outline). The downstream extent of the action area includes the habitat that will be affected by increased turbidity/suspended sediment (100 m -yellow outline), as well as underwater noise from pile driving with a vibratory hammer for cofferdam installation and removal (73.6 m -thin red circle) and impact hammer for construction of a temporary bridge/roadway supported by pipe piles (2.1 km -thick red circle).

3. STATUS OF LISTED SPECIES AND CRITICAL HABITAT

We have determined that the actions being considered in this Opinion may affect the endangered or threatened species and critical habitat under our jurisdiction included in Table 2. Critical habitat has been designated for the Gulf of Maine distinct population segment (GOM DPS) of Atlantic sturgeon, but the designation does not extend into the Machias or Middle rivers (i.e., it does not overlap with the action area).

Table 2. ESA-listed species and critical habitat in the action area

ESA-Listed Species	**Latin Name**	**Distinct Population Segment (DPS)**	**Federal Register (FR) Citation**	**Recovery Plan**
Atlantic Salmon	*Salmo salar*	Gulf of Maine	74 FR 29344	Final Recovery plan: NMFS & U.S. FWS 2019
Atlantic Sturgeon	*Acipenser oxyrinchus oxyrinchus*	Gulf of Maine	77 FR 5880	N/A[11]
Shortnose Sturgeon	*Acipenser brevirostrum*	Range-wide	32 FR 4001	NMFS 1998
Designated Critical Habitat (species)	**Latin Name**	**Distinct Population Segment (DPS)**	**Federal Register (FR) Citation**	**Recovery or River Unit**
Atlantic Salmon	*Salmo salar*	Gulf of Maine	74 FR 29300	Downeast Coastal Salmon Habitat Recovery Unit

3.1. Species Not Likely to be Adversely Affected by the Proposed Action

3.1.1 Shortnose Sturgeon

Shortnose sturgeon occur in rivers and estuaries along the east coast of the United States and Canada. Shortnose sturgeon were listed as endangered in 1967 (32 FR 4001), and the species remained on the endangered species list with the enactment of the ESA in 1973. Shortnose sturgeon spawn in freshwater, but feed and overwinter in both fresh and saline habitats. Shortnose sturgeon spawn at discrete sites within their natal river (Kieffer and Kynard 1996). As

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[1] A Recovery Outline for the 5 distinct populations of Atlantic sturgeon was published by NMFS in 2018. It is available at: https://media.fisheries.noaa.gov/dam-migration/ats_recovery_outline.pdf (last accessed March 25, 2024).

explained above, the action area is limited to the lower Middle River and a portion of Machias River downstream of the Bad Little Falls, extending out from the mouth of the Middle River approximately 2,154 meters into the Machias River estuary (Figure 4).

This project is located within the range of listed shortnose sturgeon (i.e., St. John River, Canada to St. Johns River, Florida, USA). There have been no shortnose sturgeon documented in the Machias River. In order to complete their life cycle, shortnose sturgeon require access to freshwater. Because the salt wedge intrudes all the way to the first impassable barrier at river km 10, the Machias River (Bad Little Falls, which is considered impassable for sturgeon) could not support a population of spawning shortnose sturgeon. We have considered the possibility that coastal migrant shortnose sturgeon (as described in Dionne et al. 2013 and Zydlewski et al. 2011) could be present in the action area.

Tagging and telemetry studies indicate that shortnose sturgeon are present in the Penobscot, Kennebec, Androscoggin, Sheepscot, and Saco Rivers in Maine. Shortnose sturgeon are known to move between the Kennebec and Penobscot Rivers as well as between the Kennebec, Saco, and Merrimack Rivers. Tagged individuals have also been detected at telemetry receivers in smaller coastal rivers (Damariscotta, Medomak, St. George) located between the Kennebec and Penobscot Rivers (Zydlewski et al. 2011; Dionne et al. 2013). Movement east of the Penobscot is thought to be rare, with only one tagged sturgeon detected in the Narraguagus River; however, the limited number of tagged fish and telemetry receivers make determinations regarding presence of shortnose sturgeon in waters east of the Penobscot difficult to predict (Dionne et al. 2013). Nearly all visits to these smaller coastal rivers were short in duration (1-48 hours and typically less than 24 hours, with the exception of one shortnose that spent three months in the Damariscotta River) (Zydlewski et al. 2011). Once in the rivers, shortnose sturgeon were most often detected at least 10km from the coast. The significance of these coastal rivers is unknown. Researchers speculate that these detections may be an inadvertent consequence of a near-coast navigational strategy or may serve as stopover sites, for refuge (from ocean salinities) or foraging (Zydlewski et al. 2011).

At this time there is no information to indicate that shortnose sturgeon are present in the Machias River. In all coastal rivers where shortnose sturgeon have been documented, there is access to low salinity waters. The only accessible habitats for shortnose sturgeon in the Machias River are completely saline. Based on the available information, it is extremely unlikely any shortnose sturgeon would be present in the Machias River generally or the action area specifically at any time of year. As such, it is extremely unlikely that any shortnose sturgeon will be exposed to any effects of the proposed action and all effects are discountable.

3.1.2 Atlantic Sturgeon

There are five DPSs of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*) listed as threatened or endangered. Atlantic sturgeon originating from the New York Bight, Chesapeake Bay, South Atlantic, and Carolina DPSs are listed as endangered; the Gulf of Maine DPS is listed as threatened. The marine range of all five DPSs extends along the Atlantic coast from Canada to Cape Canaveral, Florida. Because the salt wedge intrudes all the way to the first impassable barrier at river km 10, (Bad Little Falls, which is considered impassable for sturgeon), the Machias River could not support a population of spawning Atlantic sturgeon. The presence of

Atlantic sturgeon in the action area is expected to be limited to occasional, transient Atlantic sturgeon that may enter the watershed while making coastal migrations. Based on a recent genetic mixed stock analysis (Kazyak et al. 2021), we expect Atlantic sturgeon in the action area (which falls within the "NORTH" region addressed in the paper) to consist of nearly 88% Gulf of Maine DPS with the remainder originating from Canada, which are not included in the ESA listing. Critical habitat has been designated for the Gulf of Maine DPS of Atlantic sturgeon but it does not overlap with the action area.

While generally unexpected, subadult Atlantic sturgeon would be most likely to occur in the Machias River portion of the action area in the summer and fall. We do not anticipate any Atlantic sturgeon in the Middle River due to existing passage conditions at the Machias Dike Bridge. Here, we consider the potential effects to any Atlantic sturgeon that occur in the action area during the bridge replacement activities. As we do not expect Atlantic sturgeon to be present in the Middle River regardless of passage opportunities, there will be no effects to Atlantic sturgeon from the presence and operation of the new structure.

Any Atlantic sturgeon present in the Machias River portion of the action area when work is occurring may be exposed to underwater noise (sound pressure) and minor increases in suspended sediments/turbidity. Underwater noise (from the impact and vibratory hammer) and minor turbidity will result in short-term environmental stressors (Table 6). During the construction phase of the project, increased underwater noise will result from the use of a vibratory hammer to install and remove temporary sheetpile cofferdams and the use of an impact hammer to install pipe piles to support the temporary bridge. As such, during pipe pile installation using an impact hammer will produce underwater sound pressure levels that exceed the injury threshold for sturgeon (206 dB re: 1uPa Peak; 187 dB re: 1uPa SELcum) in the Machias River portion of the action area; additionally, noise during pile installation will be louder than 150 dB re 1: uPa (which is the level above which we expect behavioral disturbance to occur) within a portion of the Machias River (Figure 4).

Increased noise from vibratory hammer

Noise resulting from pile driving with a vibratory hammer for the installation and removal of sheet piles is expected to exceed the behavioral disturbance threshold only within 73.6 m of the sheet pile being installed or removed and only during the 30 minutes at a time that the vibratory hammer is operating (Figure 4 – thin red circle). There are no seasonal restrictions included in the proposed action for vibratory pile driving; as such, this work may occur when sturgeon are present in the action area. A sturgeon moving through the area during any of the 30 minute periods when the vibratory hammer is being operated that was within 73.6 m of the sheet pile would be expected to detect the increase in noise (AMM 17 - soft start) and move away from the noise source (which would only require swimming less than 75 m, which would take a few minutes at most). Sturgeon in the action area during any of these 30-minute periods are also expected to avoid the area with noise above the behavioral disturbance threshold. Avoidance or displacement of an area with a radius of up to 73.6 m will have effects on Atlantic and shortnose sturgeon that are so small that they cannot be meaningfully measured, evaluated, or detected; this is because of the small size of the area, the temporary nature of any displacement, and because avoidance of this area would have minimal, if any, effects on the energy budget of the animal and would not affect its ability to move through the area. Effects are therefore insignificant. No take of any Atlantic or shortnose sturgeon is expected to result from exposure to noise resulting from pile driving for the installation or removal of the sheet piles.

Increased noise from impact hammer
The information outlined in section 6.1.2 indicates that in order to be exposed to pile driving noise that could result in injury, a fish would need to be within 2.2 m of a pile for a single pile strike of the impact hammer (based on the 206 dB peak threshold). For pipe pile installation using an impact hammer, an area extending approximately the width of the Middle River out 2,154 meters into the mainstem Machias River from the mouth of Middle River may be louder than 150 dB re: 1uPa rms (see explanation in section 6.1.2, below). To minimize potential hydroacoustic effects to ESA listed sturgeon the pile size will be limited to 30 inches (AMM 2) and have a soft start (AMM 17). MaineDOT proposes to conduct these activities in the dry (outside of the water) or within the December 1- March 31 winter work window (AMM 1). We do not anticipate sturgeon to be occupying the upper portions of Machias estuary during the winter work window and therefore would not be exposed.

Given the rarity of Atlantic and shortnose sturgeon in the action area during the December 1 to March 31 period when in-water impact pile driving can occur and the small area where exposure to peak noise could occur (extending less than 3 m from the pile), the potential for co-occurrence in time and space that would be necessary for a sturgeon to be exposed to noise above the peak threshold is extremely unlikely. The soft-start, which we expect would result in a behavioral reaction and movement outside the area with the potential for exposure to the peak injury threshold, reduces this risk even further. Given these considerations, we do not anticipate any Atlantic or shortnose sturgeon to be exposed to noise above the peak injury threshold during pile installation with an impact hammer.

Increased turbidity and sedimentation during construction
Increased suspended sediment may extend up to 300 feet into the mainstem Machias River (approximately 25% of the river width in that area). These minor increases in total suspended sediments (TSS) of 5-10 mg/L over baseline conditions (maximum of 20 mg/L) are well below the levels we expect to result in adverse effects (580 mg/L for the most sensitive species, with 1,000 mg/L more typical) (Burton 1993, EPA 1986), and will only last for a period of a few minutes before sediment resettles and returns to baseline conditions. Given this minor and temporary increase in TSS and the small area that will experience an increase in turbidity, any effects to Atlantic sturgeon in the action area are extremely unlikely to occur and are, therefore, discountable. Similarly, any exposure to contaminants is extremely unlikely to occur and effects are discountable.

Because all effects to Atlantic sturgeon will be insignificant or discountable, the proposed action is not likely to adversely affect the Gulf of Maine DPS of Atlantic sturgeon. This concludes consultation on the effects of the action on shortnose sturgeon and the Gulf of Maine DPS of Atlantic sturgeon.

3.2. Species and Critical Habitat Likely to be Adversely Affected by the Proposed Action – Gulf of Maine DPS of Atlantic Salmon

3.2.1 GOM DPS of Atlantic salmon

The GOM DPS of Atlantic salmon was initially listed by the U.S. FWS and NMFS (collectively, the Services) as an endangered species on November 17, 2000 (65 FR 69459). A subsequent rule issued by the Services (74 FR 29344, June 19, 2009) expanded the geographic range for the GOM DPS of Atlantic salmon. The GOM DPS of Atlantic salmon is defined as all anadromous Atlantic salmon whose freshwater range occurs in the watersheds from the Androscoggin River northward along the Maine coast to the Dennys River, and wherever these fish occur in the estuarine and marine environment. The marine range of the GOM DPS extends from the Gulf of Maine, throughout the Northwest Atlantic Ocean, to the coast of Greenland.

Included in the GOM DPS are all associated conservation hatchery populations used to supplement these natural populations; currently, such conservation hatchery populations are maintained at Green Lake National Fish Hatchery (GLNFH) and Craig Brook National Fish Hatcheries (CBNFH), both operated by the U.S. FWS, as well as private watershed-based facilities (Downeast Salmon Federation's East Machias and Pleasant River facilities). Excluded from the GOM DPS are landlocked Atlantic salmon and those salmon raised in commercial hatcheries for the aquaculture industry (74 FR 29344, June 19, 2009).

Coincident with the June 19, 2009 endangered listing, we designated critical habitat for the GOM DPS of Atlantic salmon (74 FR 29300). The final rule was revised on August 10, 2009. In this revision, designated critical habitat for the expanded GOM DPS of Atlantic salmon was reduced to exclude trust and fee holdings of the Penobscot Indian Nation and a table was corrected (74 FR 39003; August 10, 2009).

Atlantic salmon life history

Atlantic salmon spend most of their adult life in the ocean and return to freshwater to reproduce. Atlantic salmon have a complex life history that includes territorial rearing in rivers to extensive feeding migrations on the high seas (Figure 6). During their life cycle, Atlantic salmon go through several distinct phases that are identified by specific changes in behavior, physiology, morphology, and habitat requirements.

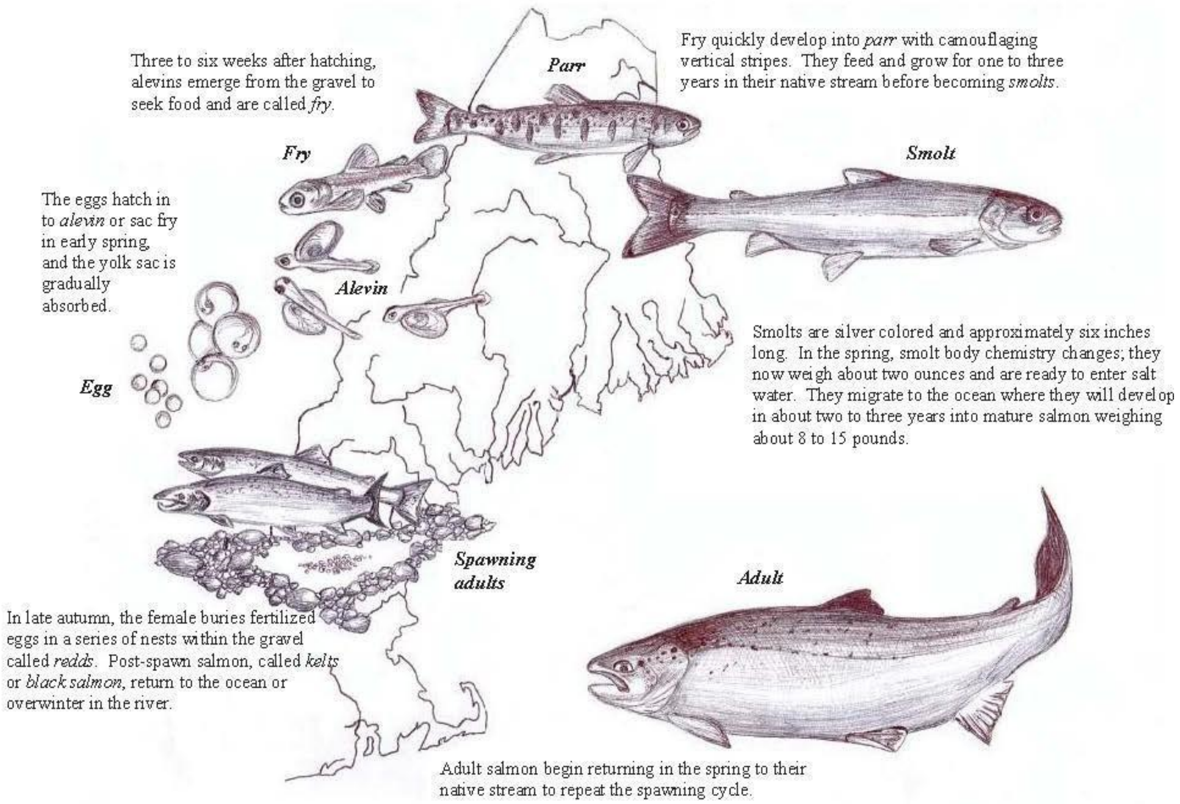

Figure 6. Life Cycle of the Atlantic salmon (diagrams courtesy of Katrina Mueller)

Spawning

Adult Atlantic salmon return to rivers in Maine from the Atlantic Ocean and migrate to their natal streams to spawn. Although spawning does not occur until late fall, the majority of Atlantic salmon in Maine enter freshwater between May and mid-July (Meister 1958, Baum 1997), but may enter at any time between early spring and late summer. Early migration is an adaptive trait that ensures adults have sufficient time to reach spawning areas (Bjornn and Reiser 1991). Salmon that return in early spring spend nearly five months in the river before spawning, often seeking cool water refuge (e.g., deep pools, springs, and mouths of smaller tributaries) during the summer months.

From mid-October to mid-November, adult females select sites in rivers and streams for spawning. Spawning sites are positioned within flowing water, particularly where upwelling of groundwater occurs, allowing for percolation of water through the gravel (Danie *et al.*1984). These sites are most often positioned at the head of a riffle (Beland et al. 1982), the tail of a pool, or the upstream edge of a gravel bar where water depth is decreasing and water velocity is increasing (McLaughlin and Knight 1987, White 1942). The female salmon creates an egg pit (redd) by digging into the substrate with her tail and then deposits eggs while male salmon release sperm to fertilize the eggs. After spawning, the female continues digging upstream of the last deposition site, burying the fertilized eggs with clean gravel. Females produce a total of 1,500 to 1,800 eggs per kilogram of body weight, yielding an average of 7,500 eggs per two sea-winter (SW) female (an adult female that has spent two winters at sea before returning to spawn) (Baum and Meister 1971). After spawning, male, and female Atlantic salmon either return to sea immediately or remain in fresh water until the following spring before returning to the sea (Fay et al. 2006).

Postspawn Adult Salmon (Kelts)

Atlantic salmon are iteroparous, meaning they are able to spawn more than once. Repeat spawners may comprise a significant proportion of a self-sustaining Atlantic salmon population, with estimates reaching upwards of 60% for some populations (Lawrence et al., 2016). Repeat spawners provide considerable benefits to Atlantic salmon populations as repeat spawning females are considerably larger than first time spawners. Larger fish have greater fecundity and larger egg size, resulting in increased fitness of their progeny (Beacham & Murray, 1993; Fleming, 1996). Repeat spawners also increase genetic diversity because they add additional year classes to the spawning population (Niemelä et al., 2006; Saunders & Schom, 1985). Consequently, a salmon population with a higher proportion of repeat spawners is widely considered to be more resilient and better able to compensate for the many threats posed through their life-cycle (Babin et al., 2021; Baktoft et al., 2020; Lawrence et al., 2016; Maynard et al., 2018; Schindler et al., 2010). In years when marine survival is particularly low, a higher proportion of repeat-spawners can partially offset the overall reduction in returns given their higher fecundity. As such, it has been estimated that a high proportion of repeat spawners may reduce the probability of population decline by 27% or greater (Lawrence et al., 2016). Lawrence et al. (2016) has estimated that a salmon population in a river with four dams is 16% less likely to face decline if it has kelt stage as part of its life history[2].

It is thought that only a small proportion of adult salmon that survive spawning will migrate back to the ocean in the fall, whereas the majority (>80%) overwinter in the river and then out-migrate in the subsequent spring (Maynard et al., 2018; Babin et al., 2021). Though initial survival after spawning may be upwards of 80 percent for first time spawners (Maynard et al., 2018), in-river mortality among overwintering postspawn adults can be quite high (~50% or greater), particularly in males (up to 100%) (Babin et al., 2021; Maynard et al., 2018). This mortality is a result of depleted energy reserves after a lengthy migration when salmon are not feeding. Although this is a natural part of salmon life-history, the presence of dams can significantly increase postspawn mortality due to the additional depletion of reserves associated with substantial migratory delay at multiple dams during their spawning run (Baktoft et al., 2020; Rubenstein et al., 2022).

Since 1970, repeat spawners have represented just over 1% (on average) of the US adult returns (Maynard et al., 2018). The low proportion is likely due to a number of factors such as poor marine survival, and the presence of dams on all major river systems. Dams lead to energy depletion in prespawn adults, which can lead to increased prespawn and postspawn mortality (Rubenstein, 2021). The Kennebec River, which hosts four mainstem dams downstream of the

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[2] Assuming a 90% per dam passage survival probability.

Sandy River, only had a single repeat spawning adult documented between 2011 and 2020 (USASAC, 2021), which constitutes less than 0.5% of the run over that time period.
Out-migrating postspawn salmon are subjected to similar challenges as out-migrating smolts when it comes to passing dams. Postspawn adults may experience both direct mortality (e.g., turbine strikes) and indirect mortality as a result of injury or delay (Baktoft et al., 2020). As with prespawn adults, postspawn adults are exposed to delay at dams as they migrate back out to the ocean. Delay of kelts at hydro-dams has been shown to reduce their remaining energy reserves by as much as 4 to 5 percent, which may lead to reduced postspawn survival (Baktoft et al., 2020). Babin et al. (2021) found that kelt movement slowed in dam reservoirs as kelts either entered searching mode or underwent multiple reversals, resulting in lower migration success. Jonnson et al. (1997) found that even minor additional energy expenditures by kelts resulted in considerable reduction in postspawn survival (Jonsson et al., 1997).

Early Life Stages

The fertilized eggs develop in the redd for a period of 175 to 195 days, hatching in late March or April (Danie et al. 1984). Newly hatched salmon, also referred to as sac fry, remain in the redd for approximately six weeks after hatching and are nourished by their yolk sacs (Gustafson-Greenwood and Moring 1991). In three to six weeks, they consume most of their yolk sac, travel to the surface to gulp air to fill their swim bladders, and begin to swim freely; at this point, they are called "fry." Survival from the egg to fry stage in Maine is estimated to range from 15 to 35% (Jordan and Beland 1981).

Parr

When fry reach approximately 4 cm in length, the young salmon are termed "parr" (Danie et al. 1984). Most parr remain in the river for two to three years before undergoing smoltification, the process in which parr go through physiological changes in order to transition from a freshwater environment to a saltwater marine environment. Some male parr may not go through smoltification and will become sexually mature and participate in spawning with sea-run adult females. These males are referred to as "precocious parr."

Smolts

During the smoltification process, parr markings fade and the body becomes streamlined and silvery with a pronounced fork in the tail. Naturally reared smolts in Maine range in size from 13 to 17 cm, and most smolts enter the sea during May to begin their first ocean migration (USASAC 2004). The spring migration of smolts to the marine environment takes 25 to 45 days. Most smolts migrate rapidly, exiting the estuary within several tidal cycles (Hyvarinen et al. 2006, Lacroix and McCurdy 1996, Lacroix et al. 2004, 2005). Researchers have identified a "smolt window" or period of time in which smolts must reach estuarine waters or suffer irreversible negative effects (McCormick et al., 1998). Late migrants lose physiological smolt characteristics due to high water temperatures during spring migration. Most smolts migrate rapidly if unimpeded (Hyvärinen et al., 2006; Lacroix & McCurdy, 1996; Lacroix & Knox, 2005; Lacroix et al., 2004)

Smallmouth bass and chain pickerel are each significant predators of juvenile Atlantic salmon within the range of the GOM DPS (Fay et al., 2006). Smallmouth bass are a warm-water species whose range now extends through north-central Maine and well into New Brunswick (Jackson, 2002). Smallmouth bass are important predators of smolts in mainstem habitats, although bioenergetics modeling indicates that bass predation is insignificant at 5°C and increases with increasing water temperature during the smolt migration (van den Ende, 1993).

Chain pickerel are known to feed upon smolts within the range of the GOM DPS and also feed upon fry and parr (van den Ende, 1993). Chain pickerel feed actively in temperatures below 10°C (van den Ende, 1993). Smolts were, by far, the most common item in the diet of chain pickerel observed by Barr (Barr, 1962) and van den Ende (1993). However, van den Ende (1993) concluded that "daily consumption was consistently lower for chain pickerel than that of smallmouth bass" apparently due to the much lower abundance of chain pickerel.

Many species of birds prey upon Atlantic salmon throughout their life cycle (Fay et al., 2006). Blackwell et al. (1997) reported that salmon smolts were the most frequently occurring food item in cormorant sampled at mainstem dam foraging sites (Blackwell et al., 1997). Given their piscivorous diets, common mergansers, belted kingfishers, cormorants, and loons likely prey upon Atlantic salmon in the Sebasticook River.

Post-smolts

Smolts are termed post-smolts after ocean entry to the end of the first winter at sea (Allen and Ritter 1977). Post-smolts generally travel out of coastal systems on the ebb tide and may be delayed by flood tides (Hyvarinen et al. 2006, Lacroix and McCurdy 1996, Lacroix et al. 2004, 2005). Lacroix and McCurdy (1996), however, found that post-smolts exhibit active, directed swimming in areas with strong tidal currents. Studies in the Bay of Fundy and Passamaquoddy Bay suggest some aggregation and common migration corridors related to surface currents (Hyvarinen et al. 2006, Lacroix and McCurdy 1996, Lacroix et al. 2004). Post-smolt distribution may reflect water temperatures (Reddin and Shearer 1987) and/or the major surface-current vectors (Lacroix and Knox 2005). Post-smolts travel mainly at the surface of the water column (Renkawitz et al. 2012) and may form shoals, possibly of fish from the same river (Shelton et al. 1997). Post-smolts grow quickly, achieving lengths of 30-35 cm by October (Baum 1997). Smolts can experience high mortality during the transition to saline environments for reasons that are not well understood (Kocik et al. 2009, Thorstad et al. 2012).

During the late summer and autumn of the first year, North American post-smolts are concentrated in the Labrador Sea and off the west coast of Greenland, with the highest concentrations between 56° N. and 58°N. (Reddin 1985, Reddin and Short 1991, Reddin and Friedland 1993, Sheehan et al. 2012). Atlantic salmon located off Greenland are primarily composed of non-maturing first sea winter (1SW) fish, which are likely to spawn after their second sea winter (2SW), from both North America and Europe, plus a smaller component of previous spawners who have returned to the sea prior to their next spawning event (Reddin 1988, Reddin et al. 1988). The following spring, 1SW and older fish are generally located in the Gulf of St. Lawrence, off the coast of Newfoundland, and on the east coast of the Grand Banks (Reddin 1985, Dutil and Coutu 1988, Ritter 1989, Reddin and Friedland 1993, and Friedland et al. 1999).

Adults

Some salmon may remain at sea for one or two years before they are ready to return to the rivers to spawn. After their second winter at sea, the salmon likely over-winter in the area of the Grand Banks before returning to their natal rivers to spawn (Reddin and Shearer 1987).

The average size of Atlantic salmon is 71-76 cm (28-30 inches) long and 3.6-5.4 kg (8-15 pounds) after two to three years at sea. Although uncommon, adults can grow to be as large as 30 pounds (13.6 kg). The natural life span of Atlantic salmon ranges from two to eight years (ASBRT 2006).

Status and Trends of the GOM DPS of Atlantic salmon

We have divided the GOM DPS into three Salmon Habitat Recovery Units (SHRUs) (74 FR 29300, June 19, 2009). The three SHRUs are the Downeast Coastal SHRU, Penobscot Bay SHRU, and Merrymeeting Bay SHRU. The SHRU delineations were designed to: 1) ensure that a recovered Atlantic salmon population has widespread geographic distribution to help maintain genetic variability; and 2) provide protection from demographic and environmental variation. A widespread distribution of salmon across the three SHRUs will provide a greater probability of population sustainability in the future, which will be needed to achieve recovery of the GOM DPS.

The historic distribution and abundance of Atlantic salmon in Maine has been described extensively (Baum, E. T., 1997; Beland, 1984). In short, substantial populations of Atlantic salmon existed in nearly every river in Maine that was large enough to maintain a spawning population. The upstream extent of the species' distribution extended far into the headwaters of even the largest rivers (Saunders et al., 2006).

Today, the spatial distribution of the GOM DPS of Atlantic salmon is limited directly by dams that obstruct passage and indirectly by low abundance levels. Within the range of the GOM DPS, the Kennebec, Androscoggin, Union, Narraguagus, and Penobscot rivers contain dams that severely limit passage of salmon to significant amounts of spawning and rearing habitat. Atlantic salmon presently have unobstructed access to only about 8% of their historic spawning and rearing habitat in Maine (NMFS 2016a). Indirectly, the spatial distribution of the GOM DPS of Atlantic salmon is also limited by low abundance (i.e., lack of potential donor or source populations) as well as the species' strong and inherent homing tendencies (Pess et al., 2014).

The reproduction, distribution, and abundance of Atlantic salmon within the range of the GOM DPS have been generally declining since the 1800s (Fay et al. 2006). A comprehensive time series of adult returns to the GOM DPS dating back to 1967 exists (Figure 7 - USASAC 2023). Contemporary abundance levels of Atlantic salmon within the GOM DPS are several orders of magnitude lower than historical abundance estimates. For example, Foster and Atkins (1869) estimated that roughly 100,000 adult salmon returned to the Penobscot River alone before the river was dammed, whereas estimates of abundance for the entire GOM DPS have rarely exceeded 5,000 individuals in any given year since 1967 (Fay et al. 2006, USASAC 2023).

The abundance of Atlantic salmon in the GOM DPS has been low, and the trend has been either stable or declining over the past several decades. The proportion of fish that are of natural origin is very small, but appears stable (USASAC 2023). The conservation hatchery program has assisted in slowing the decline and helping to stabilize populations at low levels. However, stocking of hatchery fry and smolts has not contributed to an increase in the overall abundance of salmon and, has not yet been able to increase the naturally reared component of the GOM DPS. Continued reliance on the conservation hatchery program is expected to prevent extinction in the short term, but recovery of the GOM DPS will not be accomplished without significant increases in naturally reared salmon.

After a period of population growth between the 1970s and the early 1980s, adult returns of salmon in the GOM DPS peaked between approximately 1984 and 1991 before declining during the 2000s. Adult returns have fluctuated over the past decade. Presently, the majority of all adults in the GOM DPS return to a single river, the Penobscot, which accounted for over 90% of all adult returns to the GOM DPS over the last decade (USASAC 2023). The population growth observed in the 1970s is likely attributable to favorable marine survival and increases in hatchery capacity, particularly from GLNFH (constructed in 1974). Marine survival remained relatively high throughout the 1980s, and salmon populations in the GOM DPS remained relatively stable until the early 1990s. In the early 1990s, marine survival rates decreased, leading to the declining trend in adult abundance that persists today.

The pattern of low marine survival is not unique to the GOM DPS of Atlantic salmon. Chaput et al. (2005) first raised the potential for a “regime shift” in marine survival for Atlantic salmon throughout North America resulting in decreased productivity and abundance. The effects of this regime shift appear to be particularly acute at the southern edge of the range with many researchers implicating the effects of climate change as a key driver in the ongoing reductions in marine survival of Atlantic salmon (Mills et al., 2013). Marine survival, growth, and maturation are affected in complex ways by warming conditions in the ocean (Friedland, 1998; Friedland & Todd, 2012) and a warming ocean is generally problematic for Atlantic salmon (Friedland & Todd, 2012) except in the northernmost portions of the range (Jonsson & Jonsson, 2009). Reductions in energy content of prey resources in the marine environment may also be linked to recent changes in climate and reduced marine survival (Renkawitz et al., 2015), but considerable uncertainty remains. While the reasons for the decline in marine survival of Atlantic salmon are not well understood at this time, a growing consensus has emerged: abundant healthy wild smolts should be free to emigrate from rivers to the ocean if populations are to sustain the contemporary challenges imposed by the marine environment (Thorstad et al., 2021).

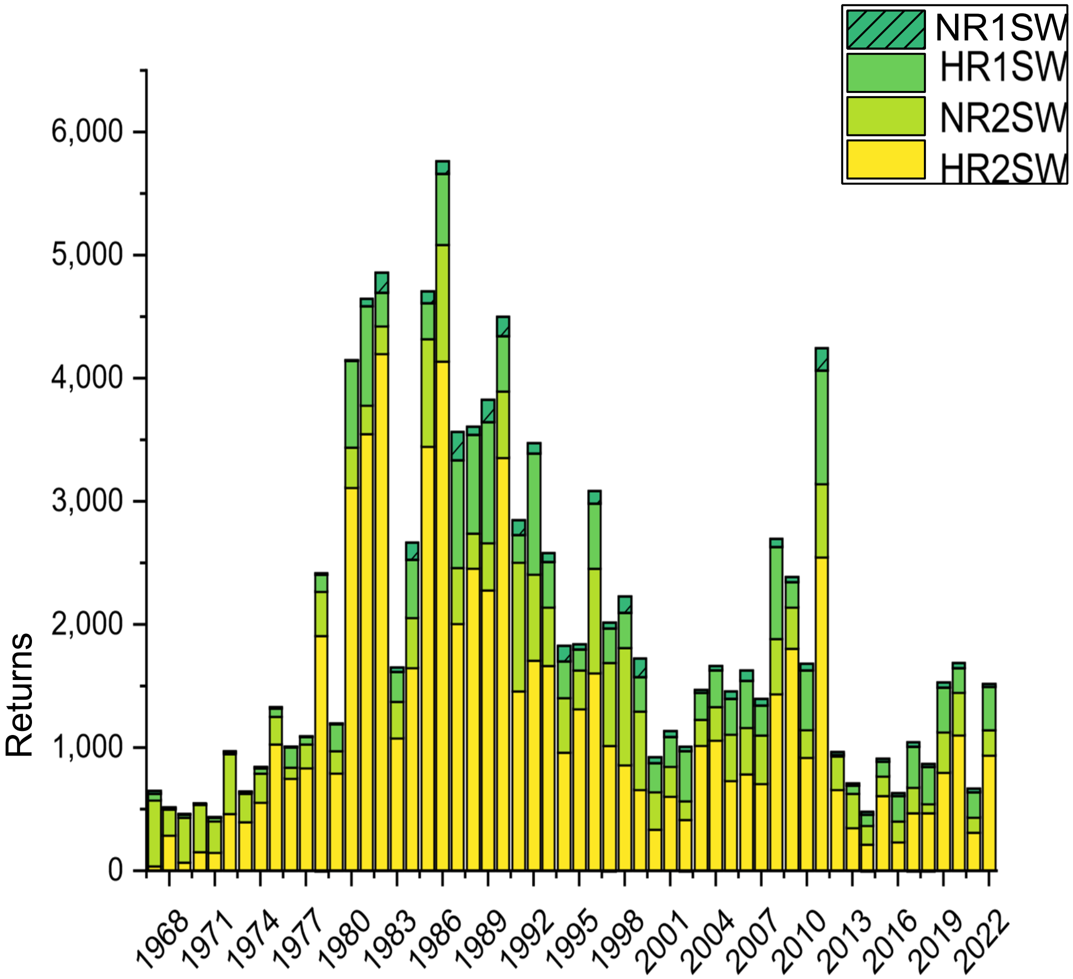

Figure 7. Summary of natural vs. hatchery adult salmon returns to the GOM DPS Rivers between 1967 and 2022 (USASAC 2023).

Since 1967 when numbers of adult returns were first recorded, the vast majority of adult returns have been the result of smolt stocking; only a small portion of returning adults were naturally reared (Figure 7). Natural reproduction of the species contributes approximately 20% of Atlantic salmon returns to the GOM DPS (CMS, 2022). The term "naturally reared" includes fish originating from both natural spawning and from stocked hatchery eggs and fry (USASAC, 2012). Adults that result from the stocking of eggs and fry are included as naturally reared because hatchery eggs and fry are not marked, and therefore cannot be visually distinguished from fish produced through natural spawning. While the Penobscot hosts the largest run in the GOM DPS by far (10-year average of 83% of the total returns), only 22% of that run consists of naturally reared fish (CMS, 2022). This compares to 53% and 78% of the run in the Downeast Coastal and Merrymeeting Bay SHRUs, respectively. The run in the Kennebec River, which occurs in the Merrymeeting Bay SHRU, consists of 94% naturally reared returns (as a result of egg planting in the Sandy River). The distinction between hatchery and naturally reared adult salmon is critical in understanding the potential for the achievement of the recovery criteria as laid out in the Final Recovery Plan (USFWS & NMFS 2019). Only naturally reared and wild salmon are considered when determining achievement of the downlisting and delisting criteria. Hatchery returns do not count towards the criteria themselves; however, if they return and successfully spawn in the wild their progeny would be counted toward the criteria. Therefore, in the context of reaching downlisting and delisting goals, a more meaningful metric than the total adult returns to the GOM DPS is the abundance of naturally reared or wild returns (Figure 8).

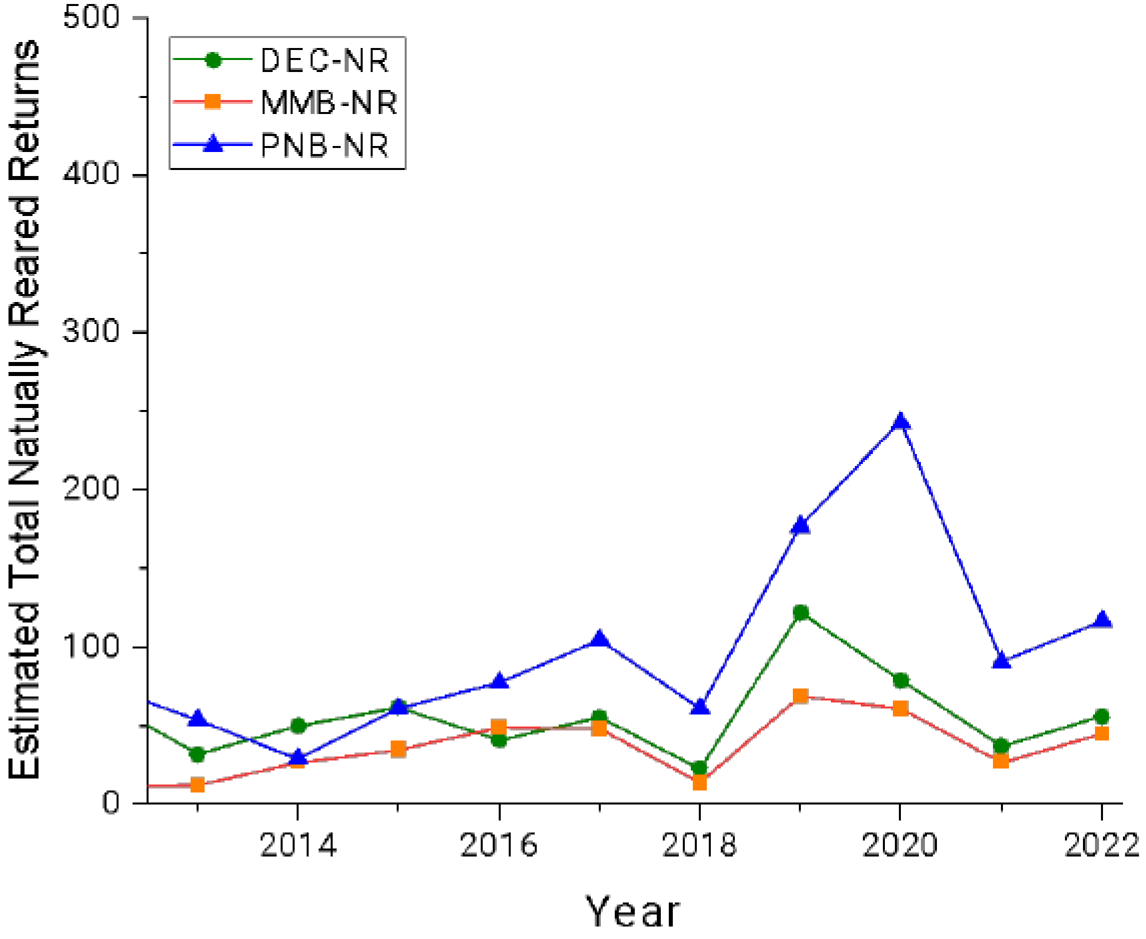

Figure 8. Time series of the last decade of naturally reared adult returns to the Merrymeeting Bay (Orange), Penobscot Bay (Blue), and Downeast (Green) SHRUs. The downlisting target of 500 natural spawners is maximum axis value (USASAC, 2023).

Although the *proportion* of naturally reared salmon is significantly higher in the Downeast and Merrymeeting Bay SHRUs, the more extensive stocking effort in the Penobscot SHRU leads to a higher number of naturally reared adults compared to the other SHRUs. Of the naturally reared or wild adults returning to the GOM DPS, on average 51%, 30%, and 19% return to the Penobscot Bay, Downeast, and Merrymeeting Bay SHRUs, respectively. It should be emphasized that this distribution is dependent on current stocking effort (lifestage and abundance), and by itself should not be construed to mean that any one SHRU is inherently more important or suitable in regards to its contribution to recovery.

Salmon Habitat Recovery Units

As part of the 2009 GOM DPS listing and designation of critical habitat, we defined three Salmon Habitat Recovery Units (SHRU): the Merrymeeting Bay SHRU, the Penobscot Bay SHRU, and the Downeast Coastal SHRU (Figure 9). As defined in the Endangered Species Consultation Handbook, a Recovery Unit is a "management subset of the listed species that is created to establish recovery goals or carry out management actions." The NMFS Interim Recovery Plan Guidance[3] goes on to state that recovery units are frequently managed as management units, though makes the distinction that recovery units are deemed necessary to both the survival and recovery of the species, whereas management units are defined as not always being "necessary" to both the survival and recovery.

Figure 9: Location of Atlantic salmon SHRU in the GOM DPS

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[2] http://www.nmfs.noaa.gov/pr/pdfs/laws/esa_section7_handbook.pdf

[3] http://www.nmfs.noaa.gov/pr/pdfs/recovery/guidance.pdf

Merrymeeting Bay SHRU

Outside of marine survival, dams are the greatest impediment to the recovery of salmon in the Penobscot, Kennebec, and Androscoggin river basins (Fay et al. 2006). Hydropower dams in the Merrymeeting Bay SHRU significantly impede the migration of Atlantic salmon and other diadromous fish and either reduce or eliminate access to roughly 352,000 units of historically accessible spawning and rearing habitat. In addition to hydropower dams, agriculture and urban development largely affect the lower third of the Merrymeeting Bay SHRU by reducing substrate and cover, reducing water quality, and elevating water temperatures. Additionally, smallmouth bass and brown trout introductions, along with other non-indigenous species, significantly degrade habitat quality throughout the Merrymeeting Bay SHRU by altering natural predator/prey relationships.

Downeast Coastal SHRU

Impacts to substrate and cover, water quality, water temperature, biological communities, and migratory corridors, among a host of other factors, have impacted the quality and quantity of habitat available to Atlantic salmon populations within the Downeast Coastal SHRU. Two hydropower dams on the Union river, and, to a lesser extent, the small ice dam on the lower Narraguagus River, limit access to roughly 18,500 units of spawning and rearing habitat within these two watersheds. In the Union River, which contains over 12,000 units of spawning and rearing habitat, physical and biological features have been most notably limited by high water temperatures and abundant smallmouth bass populations associated with impoundments. In the Pleasant River and Tunk Stream, which collectively contain over 4,300 units of spawning and rearing habitat, pH has been identified as possibly being the predominate limiting factor. The Machias, Narraguagus, and East Machias rivers contain the highest quality habitat relative to other HUC 10s in the Downeast Coastal SHRU and collectively account for approximately 40 percent of the spawning and rearing habitat in the Downeast Coastal SHRU.

Penobscot Bay SHRU

The mainstem Penobscot has the highest biological value to the Penobscot SHRU because it provides a central migratory corridor crucial for the entire Penobscot SHRU. Dams, along with degraded substrate and cover, water quality, water temperature, and biological communities, have reduced the quality and quantity of habitat available to Atlantic salmon populations within the Penobscot SHRU. Twenty FERC-licensed hydropower dams in the Penobscot SHRU significantly impede the migration of Atlantic salmon and other diadromous fish to nearly 300,000 units of historically accessible spawning and rearing habitat. Agriculture and urban development largely affect the lower third of the Penobscot SHRU below the Piscataquis River sub-basin by reducing substrate and cover, reducing water quality, and elevating water temperatures. Introductions of smallmouth bass and other non-indigenous species significantly degrade habitat quality throughout the mainstem Penobscot and portions of the Mattawamkeag, Piscataquis, and lower Penobscot sub-basins by altering predator/prey relationships. Similar to smallmouth bass, recent Northern pike introductions threaten habitat in the lower Penobscot River. Of the 323,700 units of spawning and rearing habitat (within 46 HUC 10 watersheds), approximately 211,000 units of habitat are within the 28 HUC 10 watersheds designated as critical habitat. Of the 211,000 habitat units within critical habitat in the Penobscot SHRU, we calculated these units to be the equivalent of nearly 66,300 functional units or approximately 20 percent of the historical functional potential.

Summary of Rangewide Status of Atlantic salmon

The GOM DPS of Atlantic salmon currently exhibits critically low spawner abundance, poor marine survival, and is confronted with a variety of additional threats. The abundance of GOM DPS Atlantic salmon has been low and either stable or declining over the past several decades. The proportion of fish that are of natural origin is small and displays little sign of growth. The most recent five year review for the species concluded that:

> The demographic risks to Atlantic salmon remain high. The three SHRUs have 10-year average abundance of less than 100 natural spawners per SHRU. Of the eight locally adapted populations that remain in the GOM DPS, seven are supported by conservation hatcheries that act to buffer extinction risk. The eighth, the Ducktrap River, is at very high risk of extirpation. With naturally reared populations being very low, the geometric mean population growth rates have been, as can be expected, highly variable. Given the high degree of variability in the population growth rates and the very low population abundances of naturally reared fish, we will need to continue to monitor population trajectories very carefully (NMFS and USFWS, 2020).

The spatial distribution of the GOM DPS has been severely reduced relative to historical distribution patterns due to the construction of dams. The conservation hatchery program assists in slowing the decline and helps stabilize populations at low levels, but has not contributed to an increase in the overall abundance of salmon and has not been able to halt the decline of the naturally reared component of the GOM DPS. Although the hatchery program is critical, it alone cannot recover the species. Recovery of the GOM DPS must be accomplished through increases in naturally reared salmon, which will only occur if the ongoing threats to the species (as defined in the 2019 Recovery Plan) are abated. This can be accomplished by improving connectivity at dams and road stream crossings, and through projects that improve freshwater habitat productivity.

The USFWS and NMFS issued a recovery plan ("Recovery Plan") for Atlantic salmon on February 12, 2019 (USFWS & NMFS, 2019). The Recovery Plan presents a recovery strategy based on the biological and ecological needs of the species as well as current threats and conservation accomplishments that affect its long-term viability. The Recovery Plan is based on two premises: first, that recovery must focus on rivers and estuaries located in the GOM DPS until the Services have a better understanding of the threats in the marine environment, and second, that survival of Atlantic salmon in the GOM DPS will be dependent on conservation hatcheries through much of the recovery process. In addition, the scientific foundation for the plan includes conservation biology principles regarding population viability, an understanding of freshwater habitat viability, and threats abatement needs.

As described in the Recovery Plan, reclassification of the GOM DPS from endangered to threatened will be considered when all of the following criteria are met:

- Abundance: The DPS has total annual returns of at least 1,500 naturally reared adults (i.e., originating from spawning in the wild, or from hatchery stocked eggs, fry or parr), with at least two of the three SHRUs having a minimum annual escapement of 500 naturally reared adults;

- Productivity: Among the SHRUs that have met or exceeded the abundance criterion, the population has a positive mean growth rate greater than 1.0 in the 10-year (two-generation) period preceding reclassification; and,
- Habitat: In each of the SHRUs where the abundance and productivity criterion have been met, there is a minimum of 7,500 units[3] of accessible and suitable spawning and rearing habitats capable of supporting the offspring of 1,500 naturally reared adults.

As described in the Recovery Plan, the delisting criteria are:

- Abundance: The DPS has a self-sustaining annual escapement of at least 2,000 wild origin adults in each SHRU, for a DPS-wide total of at least 6,000 wild adults;
- Productivity: Each SHRU has a positive mean population growth rate of greater than 1.0 in the 10-year (two-generation) period preceding delisting. In addition, at the time of delisting, the DPS demonstrates self-sustaining persistence, whereby the total wild population in each SHRU has less than a 50-percent probability of falling below 500 adult wild spawners in the next 15 years based on population viability analysis (PVA) projections; and
- Habitat: Sufficient suitable spawning and rearing habitat for the offspring of the 6,000 wild adults is accessible and distributed throughout the designated Atlantic salmon critical habitat, with at least 30,000 accessible and suitable habitat units in each SHRU, located according to the known migratory patterns of returning wild adult salmon. This will require both habitat protection and restoration at significant levels.

In 2020, NMFS and USFWS completed a 5-year review that evaluated whether any of these reclassification criteria had been achieved. The review concluded that the demographic risks to Atlantic salmon are still high, that the number of naturally reared or wild adults is still less than 100 per SHRU, and that the primary threats have not been sufficiently abated. As such, the review indicated that none of the above criteria had been achieved; and therefore did not recommend any change to the classification of the GOM DPS of Atlantic salmon (NMFS & USFWS, 2020).

3.2.2 Critical Habitat Designated for the GOM DPS of Atlantic Salmon

Coincident with the June 19, 2009 endangered species listing, we designated critical habitat for the GOM DPS of Atlantic salmon (74 FR 29300; June 19, 2009) (Figure 10). The final rule was revised on August 10, 2009. In this revision, designated critical habitat for the expanded GOM DPS of Atlantic salmon was reduced to exclude trust and fee holdings of the Penobscot Indian Nation and a table was corrected (74 FR 39003; August 10, 2009). That designation defines critical habitat as “specific areas within the geographical area occupied by the species at the time of listing, on which are found those physical or biological features that are essential to the conservation of the listed species and that may require special management considerations or protection.”

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[3] One habitat unit equals 100 square meters.

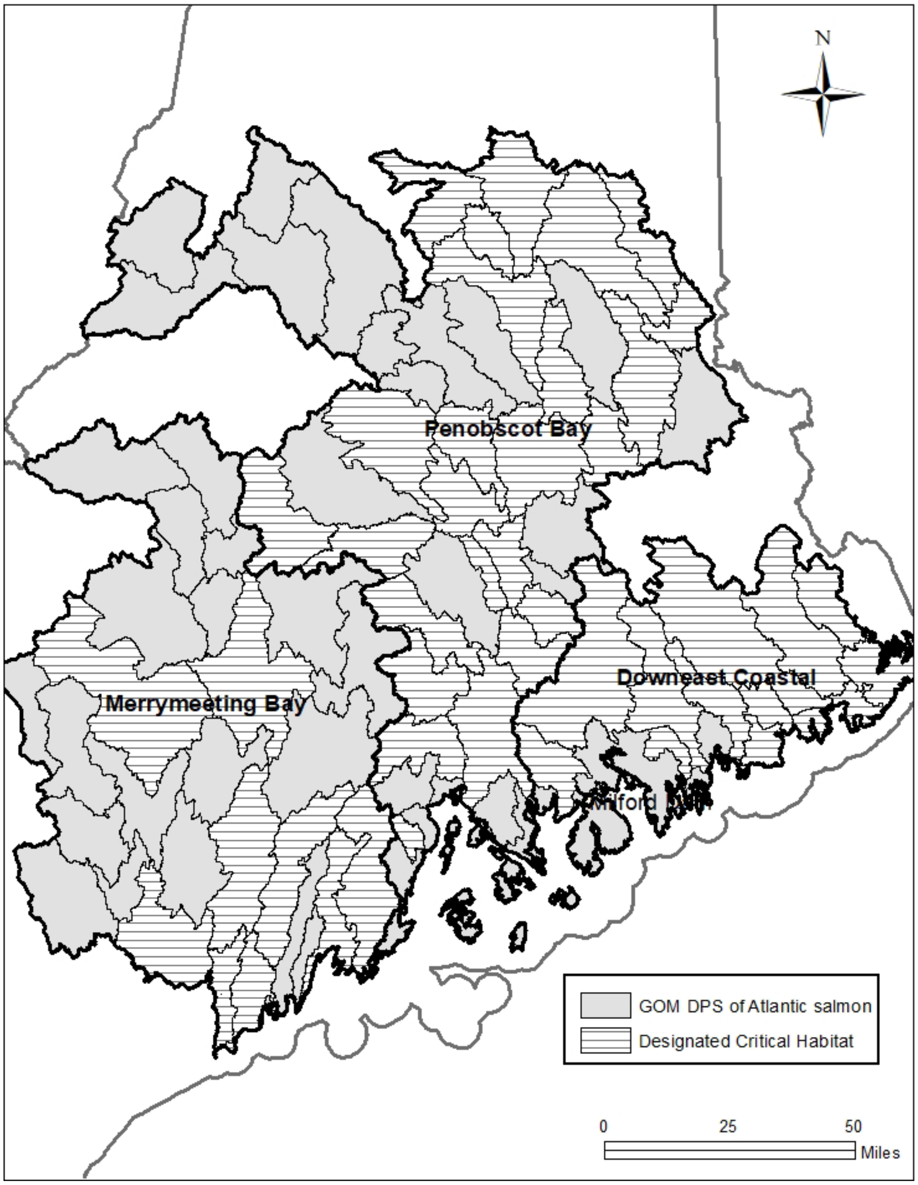

Figure 10. HUC-10 Watersheds Designated as Atlantic Salmon Critical Habitat and Salmon Habitat Recovery Units within the GOM DPS.

Physical and Biological Features of Atlantic Salmon Critical Habitat
Designation of critical habitat is based on the known physical and biological features within the occupied areas of a listed species that are deemed essential to the conservation of the species. For the GOM DPS, the physical and biological features (PBFs[4]) essential for the conservation of Atlantic salmon are: 1) sites for spawning and rearing, and, 2) sites for migration (excluding

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[4] The 2009 critical habitat designation identifies "primary constituent elements," a term that is not used in more recent critical habitat designations. We use the term "physical and biological features" or PBFs interchangeably with the PCE term used in the critical habitat designation.

marine migration[5]). Although each habitat does have distinct features, spawning, and rearing habitats were not separated into distinct PBFs in the critical habitat designation. The reason for this is that the GIS-based habitat prediction model approach that was used to designate critical habitat (74 FR 29300; June 19, 2009) cannot consistently distinguish between spawning and rearing habitat across the entire range of the GOM DPS.

The physical and biological features for Atlantic salmon critical habitat are as follows:

PBFs for Spawning and Rearing (SR) Habitat	
SR1	Deep, oxygenated pools and cover (*e.g.*, boulders, woody debris, vegetation, etc.), near freshwater spawning sites, necessary to support adult migrants during the summer while they await spawning in the fall.
SR2	Freshwater spawning sites that contain clean, permeable gravel and cobble substrate with oxygenated water and cool water temperatures to support spawning activity, egg incubation, and larval development.
SR3	Freshwater spawning and rearing sites with clean, permeable gravel and cobble substrate with oxygenated water and cool water temperatures to support emergence, territorial development, and feeding activities of Atlantic salmon fry.
SR4	Freshwater rearing sites with space to accommodate growth and survival of Atlantic salmon parr.
SR5	Freshwater rearing sites with a combination of river, stream, and lake habitats that accommodate a parr's ability to occupy many niches and maximize parr production.
SR6	Freshwater rearing sites with cool, oxygenated water to support growth and survival of Atlantic salmon parr.
SR7	Freshwater rearing sites with diverse food resources to support growth and survival of Atlantic salmon parr.
PBFs for Migration (M) Habitat	
M1	Freshwater and estuary migratory sites free from physical and biological barriers that delay or prevent access of adult salmon seeking spawning grounds needed to support recovered populations.
M2	Freshwater and estuary migration sites with pool, lake, and instream habitat that provide cool, oxygenated water and cover items (*e.g.*, boulders, woody debris, and vegetation) to serve as temporary holding and resting areas during upstream migration of adult salmon.
M3	Freshwater and estuary migration sites with abundant, diverse native fish communities to serve as a protective buffer against predation.

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[5] Although successful marine migration is essential to Atlantic salmon, we were not able to identify the essential features of marine migration and feeding habitat or their specific locations at the time critical habitat was designated.

M4	Freshwater and estuary migration sites free from physical and biological barriers that delay or prevent emigration of smolts to the marine environment.
M5	Freshwater and estuary migration sites with sufficiently cool water temperatures and water flows that coincide with diurnal cues to stimulate smolt migration.
M6	Freshwater migration sites with water chemistry needed to support seawater adaptation of smolts.

Habitat areas designated as critical habitat must contain one or more physical and biological features within the acceptable range of values required to support the biological processes for which the species uses that habitat (see above). Critical habitat includes all perennial rivers, streams, and estuaries and lakes connected to the marine environment within the range of the GOM DPS, except for those areas that have been specifically excluded as critical habitat. Critical habitat includes the stream channels within the designated stream reach and includes a lateral extent as defined by the ordinary high-water line or the bankfull elevation in the absence of a defined high-water line. In estuaries, critical habitat is defined by the perimeter of the water body as displayed on standard 1:24,000 scale topographic maps or the elevation of extreme high water, whichever is greater. Critical habitat was designated in areas (HUC-10 watersheds) occupied by the species at the time of listing. As described in the designation, for each SHRU, we determined that there were sufficient habitat units within the currently occupied habitat to achieve recovery objectives in the future; therefore, no unoccupied habitat (at the HUC-10 watershed scale) was designated as critical habitat.

We have determined that the action area contains spawning and rearing PBFs 1-7 (SR 1-7) and the migratory PBFs 1-6 (M 1-6). We discuss the features and their current status in the action area in the Environmental Baseline (Section 4).

Table 3. Matrix of essential features for assessing the functioning of critical habitat in the action area (below).

	Conservation Status Baseline		
Essential Features	Fully Functioning	Limited Function	Not Properly Functioning
A) Adult Spawning (October 1st - December 14th)			
Substrate	highly permeable course gravel and cobble between 1.2 to 10 cm in diameter	40- 60% cobble (22.5-256 mm dia.) 40-50% gravel (2.2 – 22.2 mm dia.); 10-15% course sand (0.5 -2.2 mm dia.), and <3% fine sand (0.06-0.05mm dia.)	more than 20% sand (particle size 0.06 to 2.2 mm), no gravel or cobble
Depth	17-30 cm	30 - 76 cm	< 17 cm or > 76 cm
Velocity	31 to 46 cm/sec.	8 to 31cm/sec. or 46 to 83 cm/sec.	< 5-8 cm/sec. or > 83cm/sec.
Temperature	7° to 10°C	often between 7° to 10°C	always < 7° or > 10°C
pH	> 5.5	between 5.0 and 5.5	< 5.0
Cover	Abundance of pools 1.8-3.6 meters deep (McLaughlin and Knight 1987). Large boulders or rocks, over hanging trees, logs, woody debris, submerged vegetation or undercut banks	Limited availability of pools 1.8-3.6 meters deep (McLaughlin and Knight 1987). Large boulders or rocks, over hanging trees, logs, woody debris, submerged vegetation or undercut banks	Absence of pools 1.8-3.6 meters deep (McLaughlin and Knight 1987). Large boulders or rocks, over hanging trees, logs, woody debris, submerged vegetation or undercut banks
Fisheries Interactions	Abundant diverse populations of indigenous fish species	Abundant diverse populations of indigenous fish species, low quantities of non-native species present	Limited abundance and diversity of indigenous fish species, abundant populations of non-native species
B) Embryo and Fry Development: (October 1st - April 14th)			
Temperature	0.5°C and 7.2°C, averages nearly 6°C from fertilization to eye pigmentation	averages < 4°C, or 8 to 10°C from fertilization to eye pigmentation	>10°C from fertilization to eye pigmentation
D.O.	at saturation	7-8 mg/L	< 7 mg/L
pH	> 6.0	6 - 4.5	< 4.5
Depth	5.3-15cm	NA	<5.3 or >15cm
Velocity	4 – 15cm/sec.	NA	<4 or > 15cm/sec.
Fisheries Interactions	Abundant diverse populations of indigenous fish species	Abundant diverse populations of indigenous fish species, low quantities of non-native species present	Limited abundance and diversity of indigenous fish species, abundant populations of non-native species

Table 3 continued…

	Conservation Status Baseline		
Essential Features	Fully Functioning	Limited Function	Not Properly Functioning
C) Parr Development: (All year)			
Substrate	gravel between 1.6 and 6.4 cm in diameter and boulders between 30 and 51.2 cm in diameter. May contain rooted aquatic macrophytes	gravel < 1.2cm and/or boulders > 51.2cm. May contain rooted aquatic macrophytes	no gravel, boulders, or rooted aquatic macrophytes present
Depth	10cm to 30cm	NA	<10cm or >30cm
Velocity	7 to 20 cm/sec.	< 7cm/sec. or > 20 cm/sec.	velocity exceeds 120 cm/sec.
Temperature	15° to 19°C	generally between 7-22.5°C, but does not exceed 29°C at any time	stream temperatures are continuously <7°C or known to exceed 29°C
D.O.	> 6 mg/l	2.9 - 6 mg/l	< 2.9 mg/l
Food	Abundance of larvae of mayflies, stoneflies, chironomids, caddisflies, blackflies, aquatic annelids, and mollusks as well as numerous terrestrial invertebrates and small fish such as alewives, dace or minnows	Presence of larvae of mayflies, stoneflies, chironomids, caddisflies, blackflies, aquatic annelids, and mollusks as well as numerous terrestrial invertebrates and small fish such as alewives, dace or minnows	Absence of larvae of mayflies, stoneflies, chironomids, caddisflies, blackflies, aquatic annelids, and mollusks as well as numerous terrestrial invertebrates and small fish such as alewives, dace or minnows
Passage	No anthropogenic causes that inhibit or delay movement	Presence of anthropogenic causes that result in limited inhibition of movement	barriers to migration known to cause direct inhibition of movement
Fisheries Interactions	Abundant diverse populations of indigenous fish species	Abundant diverse populations of indigenous fish species, low quantities of non-native species present	Limited abundance and diversity of indigenous fish species, abundant populations of non-native species

Table 3 continued…

Essential Features	Conservation Status Baseline Fully Functioning	Limited Function	Not Properly Functioning
D) Adult migration (April 15th- December 14th)			
Velocity	30 cm/sec to 125 cm/sec	In areas where water velocity exceeds 125 cm/sec adult salmon require resting areas with a velocity of < 61 cm/s	sustained speeds > 61 cm/sec and maximum speed > 667 cm/sec
D.O.	> 5mg/L	4.5-5.0 mg/l	< 4.5mg/L
Temperature	14 – 20ºC	temperatures sometimes exceed 20ºC but remain below 23ºC.	> 23ºC
Passage	No anthropogenic causes that delay migration	Presence of anthropogenic causes that result in limited delays in migration	Presence of anthropogenic barriers to migration known to cause significant delay, injury, or mortality of adults
Fisheries Interactions	Abundant diverse populations of indigenous fish species	Abundant diverse populations of indigenous fish species, low quantities of non-native species present	Limited abundance and diversity of indigenous fish species, abundant populations of non-native species
E) Juvenile Migration: (April 15th - June 14th)			
Temperature	8 - 11ºC	5 - 11ºC.	< 5ºC or > 11ºC
pH	> 6	5.5 - 6.0	< 5.5
Passage	No anthropogenic causes that delay migration	Presence of anthropogenic causes that result in limited delays in migration	barriers to migration known to cause direct or indirect mortality of smolts

3.2.3 Factors Affecting Atlantic salmon and Critical Habitat

Atlantic salmon face a number of threats to their survival, which are fully described in the Recovery Plan (USFWS & NMFS, 2019) with additional information provided in the 2020 5-Year Review. As described in the listing rule and the Recovery Plan, we consider the following to be the most significant threats to the GOM DPS of Atlantic salmon:

- Lack of access to spawning and rearing habitat due to dams and road-stream crossings
- Reduced habitat complexity

- Continued low marine survival rates for U.S. stocks of Atlantic salmon
- Degraded water quality
- Water withdrawal
- Incidental capture of adults and parr by recreational anglers
- Poaching of adults
- Intercept fishery
- Introduced fish species that compete or prey on Atlantic salmon
- Diseases
- Predation
- Inadequate regulatory mechanisms related to dams
- Aquaculture practices, which pose ecological and genetic risks
- Climate change
- Depleted diadromous fish communities
- Recovery hatchery program (potential for artificial selection/domestication)
- Sedimentation of spawning and rearing habitat.

These conclusions were reaffirmed in the 2020 5-Year Review (NMFS and USFWS, 2020).

Many actions have been implemented to protect and restore the GOM DPS of Atlantic salmon. These activities include hatchery supplementation, dam removal, fishway construction, upgrading road crossings, protecting riparian corridors along rivers, reducing the impact of irrigation water withdrawals, limiting effects of recreational and commercial fishing, reducing the effects of finfish aquaculture, outreach and education activities, and research focused on better understanding the threats to Atlantic salmon and developing effective restoration strategies. As noted in the 2020 5-Year Review, while progress has been made to reduce or better understand many of those threats, each of these threats continues to contribute to the endangerment of the species (NMFS & USFWS, 2020).

The final rule designating critical habitat for the GOM DPS identifies a number of activities that have and will likely continue to affect the biological and physical features of spawning, rearing, and migration habitat for Atlantic salmon. These include agriculture, forestry, changing land-use and development, hatcheries and stocking, roads and road-crossings and other instream activities (such as alternative energy development), mining, dams, dredging, and aquaculture. Most of these activities have or still do occur, at least to some extent, throughout the Gulf of Maine.

4. ENVIRONMENTAL BASELINE

Environmental baselines for biological opinions include the past and present impacts of all state, federal or private actions and other human activities in the action area, the anticipated impacts of all proposed federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions that are contemporaneous with the consultation in process (50 CFR 402.02). The environmental baseline for this Opinion includes the effects of several activities that may affect the survival and recovery of the listed species in the action area. The activities that shape the environmental baseline in the action area of this consultation generally include: actions that impact water quality, scientific research, fisheries, and recovery activities associated with reducing those impacts. The past and present effects of the existence of the Machias Dike Bridge and operation of the tide gates, including the effects to riverine processes (e.g., flow fluctuations, impounded habitat) and fish passage in the Middle River (i.e., passage efficiency, passage survival and injury, and migratory delay) are consistent with the types of activities addressed in the Environmental Baseline and therefore are addressed in this section. Future effects to ESA listed species and designated critical habitat from the new structure and its operation are considered in the Effects of the Action section. As such, given that this is an in kind replacement, there may be effects that are addressed in both sections, with the difference being the timeframe being addressed.

As described in section 2.0, the action area includes the area that will experience increased turbidity during construction (approximately 300 feet in diameter within the Middle River upstream and downstream of the bridge replacement project (Figure 4 - yellow outline), the area where increased underwater noise will be experienced during pile driving (extending into the mainstem Machias River, approximately 73.6 m for vibratory hammer and extending out to 2.1 km for impact hammer, from the outlet of the Middle River protruding into the entrance to the Machias River (Figure 4 – red circles) and spanning the width of the bay). It also includes the area above the Machias Dike Bridge where the structure and its operation will affect in-stream habitat conditions such as flow, temperature and salinity (Figure 4 - blue outline).

Description of Habitat in the Action Area

The existing Machias Dike Bridge structure consists of four box culverts, with tide gates, which are placed slightly above the stream grade in an earthen crib works constructed causeway supporting the existing road, converted railroad bed and footpath. Invert elevations that are set at the natural grades of riverbeds allow full exchange of salt water even during low flow and low tide conditions; however, those conditions are not experienced with the current structure. The presence of tide gates has changed the local hydrology by restricting tidal flushing. The result has likely been reduced water quality, reduced pH, and changes to the salt marsh upstream of the causeway. The Machias Dike Bridge has significantly altered the local ecosystem.

Although the structure is intended to block tidal flow at high tide, the existing conditions of the culverts and tide gates allow leakage of tidal waters to pass through the structure and into the Middle River (Photo 4). Although the volume of tidal exchange through the tide gates and structure is modest, there is a persistent tidal community, including salt marsh vegetation, in the Middle River (Photo 6). The substrate upstream of the existing bridge is sand/silt, with interspersed cobbles, moderately embedded and coated with fine sediment and forms a large wetland system north of Route 1 (Photo 7). The area downstream from the culvert is tidal with silty sediment coating on rocky substrate with a large mud flat adjacent to the dike structure (Photo 8).

Photo 2. Existing Structure Inlet during falling tide - Middle River

Photo 3. Existing Structure Outlet at falling tide - Machias Bay

Photo 4. Existing structure inlet at incoming tide - Middle River

Photo 5. Existing Structure outlet at incoming tide - Machias Bay

Photo 6. Coastal marsh grass habitat upstream of the existing structure - Middle River

Photo 7. Tidal mudflat upstream of the existing structure – Middle River

Photo 8. Tidal mud flat at low tide adjacent to existing structure - Machias Bay

4.1. Atlantic salmon and their Designated Critical Habitat in the Action Area

A summary of the status of the species range wide and designated critical habitat in its entirety was provided above. This section will focus on the status of Atlantic salmon and designated critical habitat in the action area; to provide context and given the small size of the action area, we also provide information on the Machias River population of Atlantic salmon.

The Machias River is one of eleven rivers in Maine designated as a Habitat Area of Particular Concern (HAPC) for Atlantic salmon because it supports one of the only remaining U.S. populations of naturally spawning Atlantic salmon that have historic river-specific characteristics. These river populations harbor an important genetic legacy that is vital to the persistence of these populations and to the continued existence of the GOM DPS. The Middle River contains historic spawning habitat for a number of other diadromous fish species, including rainbow smelt, blueback herring, alewife, and American eel.

Adults

Based on historic reports, Atlantic salmon were once abundant in the Machias River (Foster and Atkins 1867). Adult returns have dwindled and native stocks of Atlantic salmon are being sustained through stocking juveniles throughout the watershed. Dams, pollution, and over-fishing have contributed to the decline of Atlantic salmon in the GOM DPS. The number of Atlantic salmon returning to the Machias River annually is very low; ranging between 5 and 64 between 2013 and 2023, with an average of approximately 16 salmon per year (USASAC 2023). There were an estimated 6 returning adults in 2023, this is based on redd counts conducted on over 59% of the available spawning habitat in the Machias river watershed (Table 4). The fluctuating population is mostly related to fry stocking efforts and more recently the stocking levels have been decreased.

Table 4. Redd counts and percentage of habitat surveyed in the Machias River in 2023 (USASAC 2023)

Management Unit/watershed	River	Number of redds	Coverage (%)	Total Kilometers Surveyed
DEC/Machias River	Crooked River	0	59.87	5.14
DEC/Machias River	Machias River	0	51.57	8.72
DEC/Machias River	Mopang Stream	0	47.84	11.32
DEC/Machias River	Old Stream	6	79.95	20.43
DEC/Machias River	West Branch Machias River	0	93.29	11
Machias River Drainage Total	**All Surveyed**	**6**	**59.26**	**56.61**

MaineDOT proposes to conduct in-water work throughout the year (Table 1). There is no information on the presence of adult salmon in the Middle River. Because of the in-water work and instream structures, we consider it extremely unlikely that adults would be present in the Middle River above the Machias Dike Bridge at any time during construction. This is due to the extremely poor passage conditions that currently exist which are expected to prevent any adult Atlantic salmon from moving upstream through the tide gates into the Middle River. Any Atlantic salmon returning to the Machias River would move through the Machias River portion of the action area; individuals are most likely to occur between the spring and fall and would be rare in the winter.

Early migration is an adaptive trait that ensures adult Atlantic salmon have sufficient time to effectively reach spawning areas despite the occurrence of temporarily unfavorable conditions that naturally occur within rivers (Bjornn and Reiser 1991). Gorsky (2005) found that migration of Atlantic salmon was significantly affected by flow and temperature conditions in the Penobscot River. He found that high flow led to a decrease in the rate of migration and that rates increased with temperature up to a point (around 23° C) where they declined rapidly. To avoid high flows and warmer temperatures in the river, Atlantic salmon have adapted to migrating in the late spring and early summer, even though spawning does not occur until October and November. Between 2007 and 2010, 78% of migrating Atlantic salmon migrated past the first dam on the Penobscot River in May and June. Similarly, we anticipate adult salmon would typically be migrating through the mainstem of the Machias River between April and October, with the majority moving past the outlet of Middle River by July prior to increasing water temperatures during the summer. During the spring migration period river temperatures are well within the thermal tolerance of adult salmon, and we would not anticipate that salmon would be seeking thermal refuge in cooler water during this time. However, salmon that occur in the mainstem during warmer periods may seek out cool water refuge in tributaries to hold until thermal conditions improve. As such, a small portion of returning adult Atlantic salmon may be attracted to the flow of water coming from the Middle River while seeking to find passage into the Machias River, or to locate cool water, during the migration period. As noted above, however, the current conditions of the tide gates are expected to prevent any such passage attempts if they were made.

After spawning, adult salmon move downstream toward the ocean as kelts. Movement may be triggered by increased water temperatures or flows. The best available information suggests that 20% of kelts outmigrate to the ocean in the fall after spawning, with the remaining 80% migrating to the ocean in the spring (Baum 1997). Based on life history needs and behavior of kelts, we expect these fish would use the habitat in the lower Machias River, and habitat in the estuary as they are resting and foraging during their downstream migration. Therefore, it is likely that kelts would be migrating through the action area in the mainstem of the Machias River in the months of late November through April.

Juveniles

The population of Atlantic salmon in the Machias River is comprised of individuals that were naturally reared from eggs and stocked fry (spawned in the hatchery and reared until first feeding and then stocked out into natal habitat). Recently, there have been low numbers of adult Atlantic salmon spawning in the Machias River which had resulted in fewer naturally reared offspring. Stocking within the Machias River drainage is predominantly comprised of fry stocking in the headwater areas approximately 20 miles upstream of the action area. No stocking currently occurs in Middle River. In 2022, approximately 16,000 parr, 938 smolts, and 220,000 fry were stocked into the Machias River watershed (USASAC 2023). Typically, an estimated 300,000 fry have been stocked in the Machias River annually, more recently fry stocking has decreased (USASAC 2023).

Maine Department of Marine Resources (MDMR) has conducted parr assessments at several designated sites in the mainstem Machias and tributaries to estimate freshwater production in the watershed. Electrofishing data collected throughout the GOM DPS looking at young of the year and parr survival (i.e., habitat suitability index), generally show fish stay within a few kilometers of the reach where they were stocked if the habitat is suitable (MDMR-NOAA report 2019).

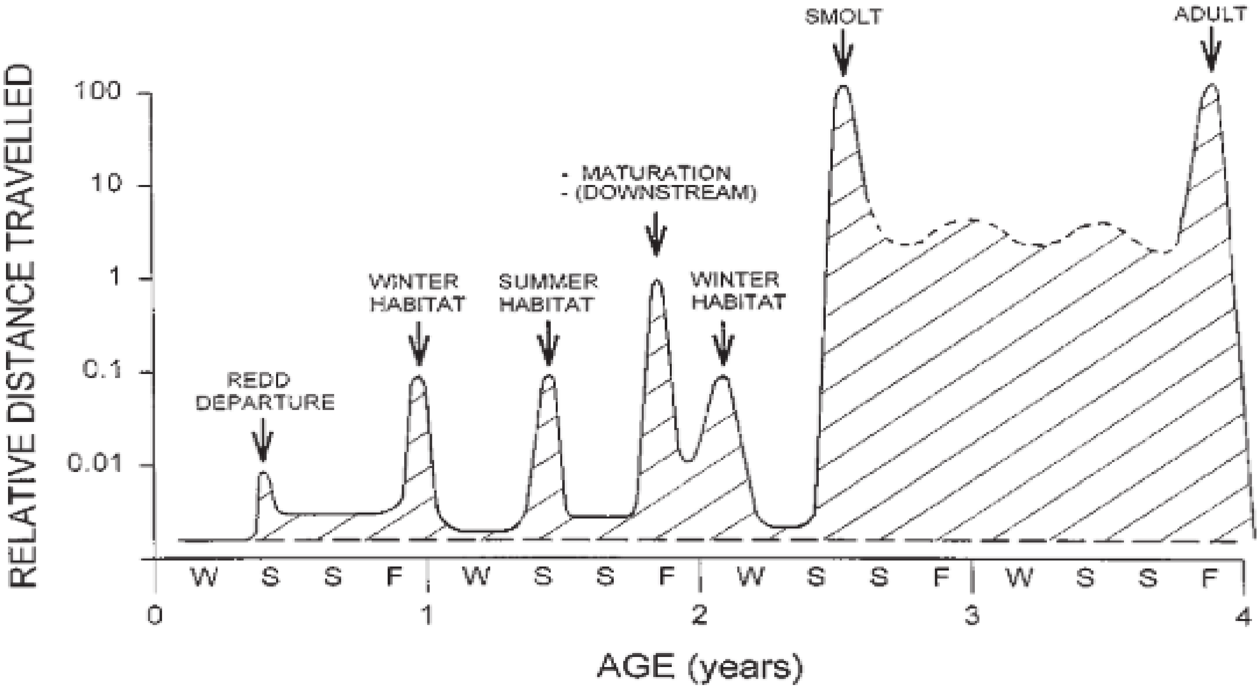

Figure 11. Relative distances that juvenile Atlantic salmon disperse from their redds (excerpted from McCormick et al. (1998)).

Some studies indicate that parr can move relatively large distances to seek cold water refuge (Cunjak et al. 1989, McCormick et al. 1998) and suggested that parr can move substantial distances when moving to overwintering habitat and summer feeding areas, as well as when they begin to mature into smolts. The distances are still relatively short when compared to distances traveled by smolts (Figure 11). Parr have been observed leaving their natal streams to move to other nearby streams that may be too small for spawning but that provide food resources or ideal temperatures for development. McCormick et al. (1998) observed that these fish may move to these small streams in the summer, and leave as smolts the following year. Similarly, another study documented Atlantic salmon parr moving out of their natal river to the estuary in the spring, where they spent the summer (Cunjak et al. 1989). However, given that the majority of the parr produced in the Machias originate from fry stocking (>20 miles upstream of the action area), it is extremely unlikely that Atlantic salmon parr are currently migrating out of the Machias River watershed. Additionally, the distance between the upper Machias River and the location of the Machias Dike Bridge (confluence of the Middle River) being in the Machias River estuary with saltwater influences (tidal) any parr in the Machias would not be physiologically able to make the transition from freshwater into saltwater to enter the Middle River to occupy available habitat and feed or overwinter. Therefore, given the current stocking practices and population numbers, as well as the freshwater-saltwater transition, it is extremely unlikely that juvenile salmon would occur in the action area.

We do not anticipate that salmon parr occur in the Middle River at this time, and therefore, since there are no parr in the river undergoing smoltification, we would not anticipate any smolts migrating out of the river. However, smolts are outmigrating through the Machias River estuary portion of the action area between the months of April and June, with the majority passing in the month of May. Timing of smolt migrations appears to differ slightly amongst rivers within the GOM DPS (Figure 11). In previous smolt trapping studies on the East Machias River located in the Downeast Coastal SHRU indicated most smolts are leaving in May with a migration duration of over 30 days (USASAC 2016). As some of the in-water work will continue throughout the year, we would anticipate that there could be smolts migrating through the Machias estuary portion of the action area at the time of construction.

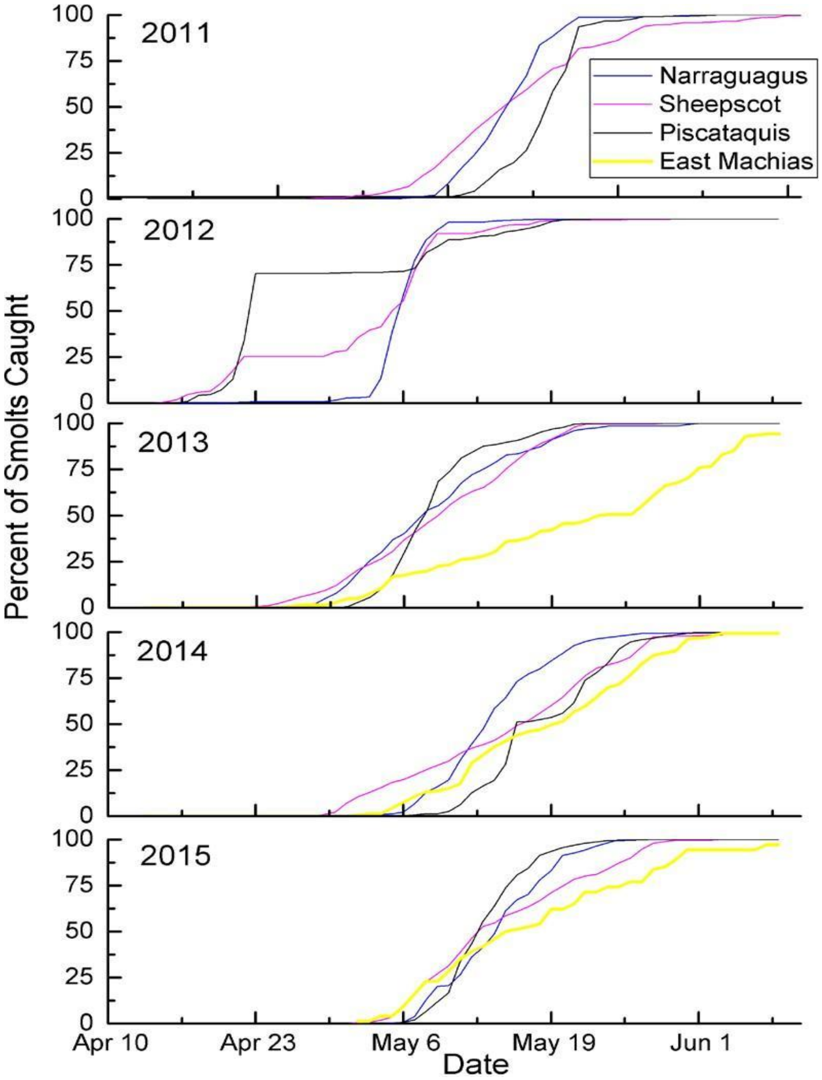

Figure 12: Cumulative percent smolt capture of all origins by date (run timing) on the Narraguagus (blue line), Sheepscot (pink line), Piscataquis (black line), and East Machias (yellow line) rivers, Maine (2011-2015) (USASAC 2016).

In summary, based on the information presented here, we do not anticipate any adult or juvenile Atlantic salmon in the Middle River portion of the action area. In the Machias estuary portion of the action area, we would anticipate some outmigrating smolts during the spring; in addition, returning pre spawn adult salmon may be present during the annual spring/summer/fall migration period and post spawn kelts would be anticipated in late November through April.

4.2 Critical Habitat in the Action Area

As detailed in Section 3.3.2, we designated critical habitat for the GOM DPS of Atlantic salmon including the Machias River and Middle River. The action area includes a small amount of modeled spawning and rearing critical habitat (10 units) upstream of the Machias Dike Bridge and migration habitat within the Middle River; in addition to migration habitat below the bridge in the Machias River estuary (Figure 4); the entirety of the action area is a migratory corridor and designated CH. Accordingly, the action area includes the PBFs for Atlantic salmon critical habitat considered essential to the conservation of the species that support: spawning and rearing (SR 1-7), and migration habitat (M1-6).

Spawning and rearing critical habitat in the action area

MaineDOT determined in the BA that spawning and rearing (SR) PBFs 4 through 7 are present in the action area, but that SR 1, 2, and 3 are not (Table 3). We concur that PBFs SR 4-7 occur in the Middle River watershed portion of the action area. Additionally, based on the location of modeled spawning and rearing habitat (Figure 13), SR 1, 2, 3 (i.e., clean permeable gravel and cobble to support egg and fry development) could also occur within the action area (Figure 4).

We do not have information regarding the presence or abundance of spawning habitat in the Middle River; the rearing habitat model (Wright et al., 2008) does not directly predict features that are suitable for spawning, and the Maine Department of Marine Resources has not conducted field assessments in the area. However, as described in NMFS (2009) spawning and rearing habitat are correlated with each other (i.e., spawning habitat is generally located within rearing habitat), it is reasonable to expect that the amount of rearing habitat identified by the habitat model represents the maximum amount of spawning habitat that would be expected to occur in the Middle River (Figure 13). This is a reasonable assumption as juveniles are reared near the redds where eggs are deposited (Figure 11). NMFS (2009) indicated that the model helps to "reveal stream segments with gradients that would likely represent areas of riffles or fast moving water, habitat most frequently used for spawning and rearing of Atlantic salmon." Further, they indicate that:

> Although we have found the model to be nearly 75 percent accurate in predicting the presence of sites for spawning and rearing within specific areas, and we have an abundance of institutional knowledge on the physical and biological features that distinguish sites for spawning and sites for rearing, the model cannot be used to distinguish between sites for spawning and sites for rearing across the entire geographic range. This is because: (1) sites used for spawning are also used for rearing; and (2) the model is unable to identify substrate features most frequently used for spawning activity, but rather uses landscape features to identify where stream gradient conducive to both spawning and rearing activity exists. (NMFS, 2009)

Based on these conclusions and that spawning and rearing habitat are correlated, we conclude that while the model shouldn't be used to estimate abundance of spawning habitat, it can be used to identify the upper limit of spawning habitat that could be expected. That is, we expect that some subset of rearing habitat could also be used for spawning. Accordingly, based on the rearing model (Wright et al. 2008), the action area upstream of the Machias Dike Bridge contains approximately 10 units of rearing habitat, some of which may also be used for spawning. Likewise, the model indicates that the habitat upstream of the action area contains 249 units that could be used for rearing. We expect that some proportion of this habitat could also be used for spawning (Figure 13).

Migration critical habitat in the action area

MaineDOT determined in the BA that the migration essential features (M2-M6) are present within the action area, with the exception of M1. We concur that features M2-M6 occur in the action area, but disagree that M1 is not (Table 4):

- M1 references the need for sites "free from physical and biological barriers that delay or prevent access of adult Atlantic salmon seeking spawning grounds." The justification presented for concluding that M1 is not present is "due to the existing Machias Dike Bridge being a complete barrier and the one that is proposed for replacement is a complete barrier."

However, the existence of a barrier that is partially accessible does not preclude the presence of the PBF. Rather, the PBF is present, but is not fully functioning because of the presence of an artificial barrier (the tide gate/culverts) that does not provide safe, timely, or effective passage and does not meet the fully accessible criteria.

In summary, based on the information provided within the BA and analysis above, we have determined the following PBFs to be present within the action area; SR 1-7 and M 1-6. Furthermore, using the Matrix of Essential Features presented in Table 3, we have determined that the PBFs for SR 1-7 and M 1-4 in the action area are reduced to the point they are not fully functioning due to the presence of the dike and tide gates installed on the culvert openings that significantly alters the natural stream processes. Although present in the action area, we have determined that PBFs M5 and M6 (temperature and water chemistry (pH), respectively, needed to initiate smolt emigration and support salt water adaptation) are functioning and are not affected by the existing tide gate structure. We have also determined, all of the Atlantic salmon critical habitat PBFs present in the Middle River watershed above the Machias Dike Bridge (Figure 13) have reduced conservation value as a result of not being fully accessible from the long term operation of the tide gates which affects passage efficiency and results in delays of movement.

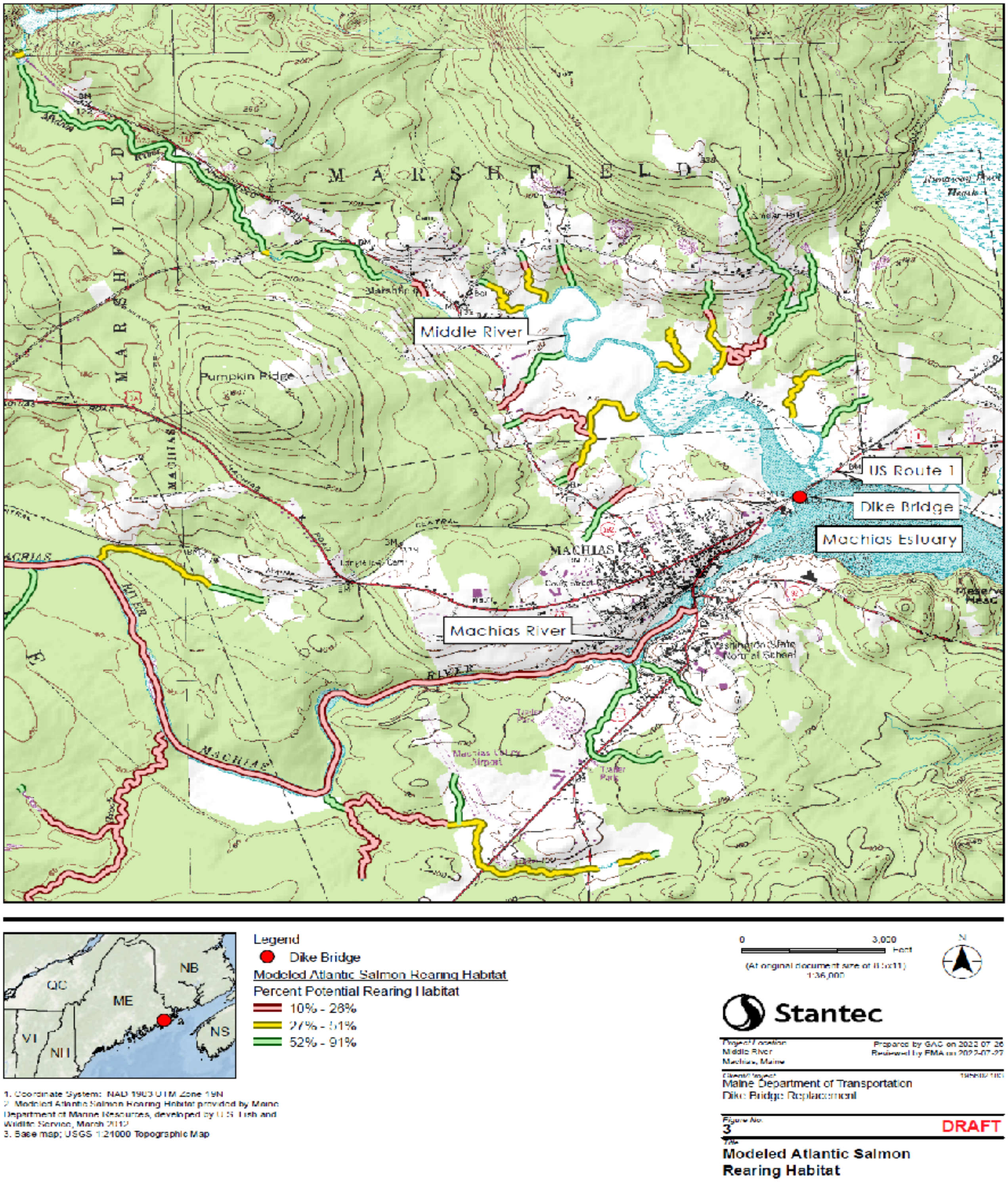

Figure 13. Modeled rearing habitat in the designated critical habitat in the Middle River watershed.

4.3 Consideration of Federal, State and Private Activities in the Action Area

In the Environmental Baseline section of an Opinion, we discuss the impacts of all proposed Federal actions in the action area that have already undergone formal or early section 7 consultation. No formal section 7 consultations have taken place for projects in the action area. Below, we discuss the effects of the current Machias Dike Bridge structure.

The action area contains the Machias Dike Bridge, which as discussed above, contains tide gates that open during low tide (when flow from the Middle River can freely pass into the Machias River) and close during high tide (which blocks flow from the Middle River into the Machias and leads to impounding of water upstream of the bridge). The operation of the tide gates limits passage of Atlantic salmon and other diadromous fish into the action area (as discussed in section 6), and affects upstream habitat by raising water levels at high tide (i.e., closed tide gates restrict movement of water out of the Middle River), and by restricting salt water from moving upstream of the bridge. The habitat within the action area has been impacted by the existing dike and culverts with tide gates that create an impoundment by restricting the flow of water into and out of the Middle River, significantly altering the natural tidal exchange in the action area. Dikes and their associated operational impacts from tide gates have been shown to alter streamflow through flow diversion structures, and can significantly affect water temperatures due to changes in thermal capacity, with water temperature being inversely related to discharge (Webb et al., 2003). This combination of culverts and tide gates can directly affect natural stream processes such as flow, temperature, and water depth that would affect the function of critical habitat in the action area such that it is not fully functioning. Additionally, the existing structure diminishes the conservation value of this critical habitat by restricting access to it.

Other Activities in the Action Area
Routine in-water construction activities such as dock, pier, and boat ramp maintenance and construction may occasionally occur in the action area; there are no documented adverse effects of these activities on Atlantic salmon or their critical habitat in the action area. Recreational and commercial fishing and shellfishing occurs in the Machias River watershed and may occur in the action area; Atlantic salmon may occasionally be caught but these instances are considered rare.

5. CLIMATE CHANGE

The discussion below presents background information on global climate change and information on past and predicted future effects of global climate change throughout the range of the listed species considered here. Additionally, we present the available information on predicted effects of climate change on listed species and critical habitat in the action area over the lifespan of the proposed project. Climate change is relevant to the *Status of the Species*, *Environmental Baseline,* and *Cumulative Effects* sections of this Opinion; rather than include partial discussion in several sections of this Opinion, we are synthesizing this information into one discussion, below.

5.1 Background Information on Global climate change

In its Sixth Assessment Report (AR6) from 2021, the Intergovernmental Panel on Climate Change (IPCC) stated that the "global surface temperature in the first two decades of the 21st century (2001–2020) was 0.99 [0.84 to 1.10] °C higher than 1850–1900" (IPCC 2021). Similarly, the total increase between the average of the 1850-1900 period and the 2010-2019 period is 1.07°C (likely range: 0.8° to 1.3°C). On a global scale, ocean warming has on average increased by 0.88 [0.68–1.01] °C from 1850-1900 to 2011-2020, with 0.60 [0.44–0.74] °C of this warming having occurred since 1980 (Fox-Kemper et al., 2021). In regards to resultant sea level rise, the global mean sea level increased by 0.20 (0.15 to 0.25) meters between 1901 and 2018. The average rate of sea level rise between 2006 and 2018 increased to 3.7 mm/yr (likely range of 3.2 to 4.2), up from 1.3 mm/yr between 1901 and 1971.

The IPCC (2021) climate model projections exhibit five scenarios, or shared socioeconomic pathways (SSP's) that cover a range of plausible future development of anthropogenic drivers of climate change, for both temperature and precipitation over the next several decades. SSP3-7.0 and SSP5-8.5 represent very high emission scenarios with CO_2 levels continuing to increase; SP2-4.5 represents a moderate emission scenario; and SP1-1.9 and SP1-2.6 represent low emission scenarios. Under all scenarios global surface temperature will continue to increase by 1.5°C to 2.0°C until at least mid-century unless there are deep reductions in CO_2 and other greenhouse gas emissions. A warmer climate is expected to result in increased climate extremes including intensified periods of very wet and very dry conditions resulting in increased periods of flooding and drought (IPCC, 2021). Climate warming has also resulted in increased river discharge and glacial and sea-ice melting (Greene et al. 2008). Over the remainder of the 21st century, upper ocean stratification, ocean acidification, and ocean deoxygenation will continue to increase at rates dependent on future scenarios (IPCC, 2021).

The most recent estimate of likely global mean sea level rise by 2100 ranges from 0.28-0.55 m under the lowest emissions scenarios, to 0.63 - 1.01 m under the highest emission scenarios (IPCC 2021). Over the long term, sea levels are expected to rise for centuries to millennia due to continuing deep-ocean warming and ice sheet melting.

The past three decades have witnessed major changes in ocean circulation patterns in the Arctic, and these were accompanied by climate associated changes as well (Greene et al., 2008). Shifts in atmospheric conditions have altered Arctic Ocean circulation patterns and the export of freshwater to the North Atlantic (Greene et al., 2008; IPCC, 2007). With respect specifically to the North Atlantic Oscillation (NAO), changes in salinity and temperature are thought to be the result of changes in the Earth's atmosphere caused by anthropogenic forces (IPCC, 2007). The NAO impacts climate variability throughout the Northern Hemisphere (IPCC, 2007). Data from the 1960s through the 2000s showed that the NAO index increased from minimum values in the 1960s to strongly positive index values in the 1990s and somewhat declined since (IPCC, 2007). On a global scale, large discharges of freshwater into the North Atlantic subarctic seas can lead to intense stratification of the upper water column and a disruption of North Atlantic Deepwater (NADW) formation (IPCC, 2007; Greene et al., 2008). There is evidence that the NADW has already freshened significantly (IPCC, 2007). This in turn can lead to a slowing down of the global ocean thermohaline (large-scale circulation in the ocean that transforms low-density upper ocean waters to higher density intermediate and deep waters and returns those waters back to the upper ocean), which can have climatic ramifications for the entire world (Greene et al., 2008).

There is a high confidence, based on substantial new evidence, that observed changes in marine systems are associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels, and circulation. Ocean acidification resulting from massive amounts of carbon dioxide and pollutants released into the air can have major adverse impacts on the calcium balance in the oceans. Changes to the marine ecosystem due to climate change include shifts in ranges and changes in algal, plankton, and fish abundance (IPCC, 2007). These trends have been most apparent over the past few decades, although this may also be due to increased research. Information on future impacts of climate change in the action area is discussed below.

Regional Impacts

In the Northeast U.S. (West Virginia to Maine), between 1895 and 2011, temperatures increased by nearly 2°C; precipitation increased by approximately 13 cm, and sea levels rose by approximately 30 cm (Melillo et al., 2014). Relative to other regions, the Northeast has experienced greater increases in extreme precipitation, and the rate of sea level rise exceeds the global average (Melillo et al., 2014). Looking forward, it is expected that temperatures in the Northeast could warm between 4.5°C to 10°C by the 2080s if carbon emissions continue to increase (Melillo et al., 2014).

In Maine, the average annual temperature has increased nearly 1.8°C in the last 124 years with northern and western Maine (1.7°C) warming at slower rates than coastal Maine (1.8°C) (Fernandez et al., 2020). Most of the warming that has occurred in Maine has happened since 1960 with an average annual increase of 0.026°C per year (Fernandez et al., 2020). The average annual precipitation in Maine has also increased. Maine's average annual precipitation has increased 15% (~15 cm) since 1895, with most of that increase in the form of rain and less snow. Much of the increased precipitation is associated with increases in storm intensity predominantly during the fall time (*summarized in* Fernandez et al., 2020). As for snowfall, the average annual snow depth has decreased by 20% (5.8 cm) since 1895 (Fernandez et al., 2020). Although Maine has seen a considerable increase in the average annual precipitation, Maine has also experienced increases in the severity and duration of drought events (Fernandez et al., 2020).

While predictions are available regarding potential effects of climate change globally, it is more difficult to assess the potential effects of climate change over the time period considered in this consultation on coastal and marine resources on smaller geographic scales, such as the action area, especially as climate variability is a dominant factor in shaping coastal and marine systems. The duration of the action considered in this consultation (i.e., life of the project) is the proposed operation of the Machias Dike Bridge tide gates; when replaced, the life of the structure with maintenance and replacement of gates, is expected to last for the foreseeable future. The effects of future change will vary greatly in diverse coastal regions for the U.S. Additional information on potential effects of climate change specific to the action area is discussed below.

The longest duration action considered in this consultation is the proposed operation of the tide gates and culvert structure; once replaced, it is expected to continue operations for 75 to 100 years. Warming is very likely to continue in the U.S. over the time period considered in this consultation regardless of reduction in greenhouse gasses, due to emissions that have already occurred (Pörtner et al., 2022). It is very likely that the magnitude and frequency of ecosystem changes will continue to increase over this period, and it is possible that they will accelerate (Portner et al., 2022). Climate change can cause or exacerbate direct stress on ecosystems through high temperatures, a reduction in water availability, and altered frequency of extreme events and severe storms. Water temperatures in streams and rivers are likely to increase as the climate warms and are very likely to have both direct and indirect effects on aquatic ecosystems. Changes in temperature will be most evident during low flow periods when they are of greatest concern (NAST, 2000). In some marine and freshwater systems, shifts in geographic ranges and changes in algal, plankton, and fish abundance are associated with high confidence with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels, and circulation (IPCC, 2007).

Expected consequences of climate change for river systems include a decrease in the amount of dissolved oxygen in surface waters and an increase in the concentration of nutrients and toxic chemicals due to reduced flushing rate (Murdoch et al. 2000). Increased warming may also invoke mutualistic and antagonistic interactions among species (Hulme, 2005) (i.e., give warmer water species an advantage over cool or cold water species). A warmer-wetter climate could ameliorate poor water quality conditions in places where human-caused concentrations of nutrients and pollutants currently degrade water quality (Murdoch et al., 2000). Increases in water temperature and changes in seasonal patterns of runoff will very likely disturb fish habitat. Surface water resources along the U.S. Atlantic coast are intensively managed with dams and channels and almost all are affected by human activities; in some systems water quality is either below recommended levels or nearly so. A global analysis of the potential effects of climate change on river basins indicates that due to changes in discharge and demands for water resources, the area of large river basins in need of reactive or proactive management interventions in response to climate change will be much higher for basins impacted by dams than for basins with free-flowing rivers (Palmer et al., 2008). Human-induced disturbances also influence coastal and marine systems, often reducing the ability of the systems to adapt so that systems that might ordinarily be capable of responding to variability and change are less able to do so. Because stresses on water quality are associated with many activities, the impacts of the existing stresses are likely to be exacerbated by climate change. Within 50 years, river basins that are impacted by dams or by extensive development will experience greater changes in discharge and water stress than unimpacted, free-flowing rivers (Palmer et al., 2008).

5.2 Anticipated Effects to Atlantic salmon and Critical Habitat

Atlantic salmon are one of the most vulnerable managed fish species in the Northeast U.S. Shelf to climate change as a function of their sensitivity and exposure to climate stressors (Hare et al., 2016). Factors such as fecundity, anadromy, and finite range of suitable habitats and prey resources contribute to salmon's vulnerability. Water temperature is one of the most important environmental factors affecting all forms of aquatic life in rivers and streams (Annear et al., 2004). Temperature is especially important for Atlantic salmon given that they are poikilothermic (i.e., their body temperatures and metabolic processes are determined by temperature). Although temperature can be a stimulant for salmon migration, spawning, and feeding (Elson, 1969), they are cold water fish and, therefore, have a thermal tolerance zone where activity and growth is optimal (DeCola, 1970). Elliot (1991) identified the upper incipient lethal maximum temperature (i.e., the temperature at which 50% of the test fish survive) for juvenile Atlantic salmon as 27.8°C (survival over 7 days). Adult Atlantic salmon in rivers may experience thermal stress when temperatures exceed 20°C, and some fish will experience mortality when temperatures exceed 26°C (Shepard, 1995; Wilkie et al., 1996). Temperature can also significantly influence egg incubation success or failure, food requirements and digestive rates, growth and development rates, vulnerability to disease and predation, and may be responsible for direct mortality (Peterson et al., 1977; Spence et al., 1996; Whalen et al., 1999).

Atlantic salmon may be especially vulnerable to the effects of climate change in New England, since the areas surrounding many watersheds where salmon are found are heavily populated and have already been affected by a range of stresses associated with agriculture, industrialization, and urbanization (Elliott et al., 1998). Climate effects related to temperature regimes and flow conditions determine juvenile salmon growth and habitat (Friedland, 1998). One study conducted in the Connecticut and Penobscot rivers, where temperatures and average discharge rates have been increasing over the last 25 years, found that dates of first capture and median capture dates for Atlantic salmon have shifted earlier by about 0.5 days/year, and these consistent shifts are correlated with long-term changes in temperature and flow (Juanes et al., 2004). Temperature increases are also expected to reduce the abundance of salmon returning to home waters, particularly at the southern limits of Atlantic salmon spatial distribution (Beaugrand & Reid, 2003).

A study conducted in the United Kingdom that used data collected over a 20-year period in the Wye River found Atlantic salmon populations have declined substantially and this decline was best explained by climatic factors like increasing summer temperatures and reduced discharge more than any other factor (Clews et al., 2010). Changes in temperature and flow serve as cues for salmon to migrate, and smolts entering the ocean either too late or too early would then begin their post-smolt year in such a way that could be less optimal for opportunities to feed, predator risks, and/or thermal stress (Friedland, 1998). Since the highest rate of mortality affecting Atlantic salmon occurs in the marine phase, both the temperature and the productivity of the coastal environment may be critical to survival (Drinkwater et al., 2003). Temperature influences the length of egg incubation periods for salmonids (Elliott et al., 1998) and higher water temperatures could accelerate embryo development of salmon and cause premature emergence of fry.

Since fish maintain a body temperature almost identical to their surroundings, thermal changes of a few degrees Celsius can critically affect biological functions in salmonids (NMFS and USFWS, 2005). While some fish populations may benefit from an increase in river temperature for greater growth opportunity, there is an optimal temperature range and a limit for growth after which salmonids will stop feeding due to thermal stress (NMFS and USFWS, 2005). Thermally stressed salmon also may become more susceptible to mortality from disease (Clews et al., 2010). A study performed in New Brunswick found there is much individual variability between Atlantic salmon and their behaviors and noted that the body condition of fish may influence the temperature at which optimal growth and performance occur (Breau et al., 2007).

The productivity and feeding conditions in Atlantic salmon's overwintering regions in the ocean are critical in determining the final weight of individual salmon and whether they have sufficient energy to migrate upriver to spawn (Lehodey et al., 2006). Survival is inversely related to body size in pelagic fishes, and temperature has a direct effect on growth that will affect growth-related sources of mortality in post-smolts (Friedland, 1998). Post-smolt growth increases in a linear trend with temperature, but eventually reaches a maximum rate and decreases at high temperatures (Brett 1979 in Friedland, 1998). When at sea, Atlantic salmon eat crustaceans and small fishes, such as herring, sprat, sand-eels, capelin, and small gadids, and when in freshwater, adults do not feed but juveniles eat aquatic insect larvae (FAO, 2012). Species with calcium carbonate skeletons, such as the crustaceans that salmon sometimes eat, are particularly susceptible to ocean acidification, since ocean acidification will reduce the carbonate availability necessary for shell formation (Wood et al., 2008). Climate change is likely to affect the abundance, diversity, and composition of plankton, and these changes may have important consequences for higher trophic levels like Atlantic salmon (Beaugrand and Reid, 2003).

In addition to temperature, stream flow is also likely to be impacted by climate change and is vital to Atlantic salmon survival. In-stream flow defines spatial relationships and habitat suitability for Atlantic salmon and since climate is likely to affect in-stream flow, the physiological, behavioral, and feeding-related mechanisms of Atlantic salmon are also likely to be impacted (Friedland, 1998). With changes in in-stream flow, salmon found in smaller river systems may experience upstream migrations that are confined to a narrower time frame, as small river systems tend to have lower discharges and more variable flow (Elliot et al., 1998). The changes in rainfall patterns expected from climate change and the impact of those rainfall patterns on flows in streams and rivers may severely impact productivity of salmon populations (Friedland, 1998). More winter precipitation falling as rain instead of snow can lead to elevated winter peak flows which can scour the streambed and destroy salmon eggs (Battin et al., 2007).

Increased sea levels in combination with higher winter river flows could cause degradation of estuarine habitats through increased wave damage during storms (NSTC, 2008). Since juvenile Atlantic salmon are known to select stream habitats with particular characteristics, changes in river flow may affect the availability and distribution of preferred habitats (Riley et al., 2009). The critical point at which reductions in flow begin to have a damaging impact on juvenile salmonids is difficult to define, but generally flow levels that promote upstream migration of adults are likely adequate to encourage downstream movement of smolts (Hendry et al., 2003).

Humans may also seek to adapt to climate change by manipulating water sources, for example in response to increased irrigation needs, which may further reduce stream flow and biodiversity (Bates et al., 2008). Water extraction is a high level threat to Atlantic salmon, as adequate water quantity and quality are critical for all life stages of Atlantic salmon (NMFS and USFWS, 2005). Climate change will also affect precipitation, with northern areas predicted to become wetter and southern areas predicted to become drier in the future (Karl et al., 2009). Droughts may further exacerbate poor water quality and impede or prevent migration of Atlantic salmon (Riley et al., 2009).

We anticipate that these climate change effects could significantly affect the functioning of Atlantic salmon critical habitat. Increased temperatures will affect the timing of upstream and downstream migration and make some areas unsuitable as temporary holding and resting areas.

Higher temperatures could also reduce the amount of time that conditions are appropriate for migration (<23° C), which could affect an individual's ability to access suitable spawning habitat. In addition, elevated temperatures will make some areas unsuitable for spawning and rearing due to effects to egg and embryo development.

5.3 Anticipated Effects to Atlantic salmon and Critical Habitat in the Action Area

Information on how climate change will impact the action area is extremely limited. As reported by the University of Maine's Climate Change Institute (Fernandez et al. 2020), models predict that Maine's annual temperature is projected to increase between 1.7–2.8°C by 2050, with continued increases in precipitation frequency and intensity. Under moderate to high emissions scenarios, ocean temperatures in the Gulf of Maine are also expected to rise as much as 1.2°C (2.2°F) by 2050 and 2.2°C (3.9°F) by 2100, and sea levels are expected to rise as much as 30 to 90 cm by 2050 and 1.10 to 3.3 m by 2100. These rising sea levels would likely shift the salt wedge (i.e., layer of salt water in an estuary that underlies a layer of less dense freshwater) in the Machias River and other rivers in the GOM DPS. Because there remains uncertainty in the rate and timing of change as well as the effect of any changes that may be experienced in the action area due to climate change, it is difficult to predict the impact of these changes on Atlantic salmon. However, we use the best available information to anticipate how Atlantic salmon and designated critical habitat in the action area may be affected by climate change over the life of the actions considered in this consultation. In the action area, it is possible that changing seasonal temperature regimes could result in changes in the timing of seasonal migrations for the GOM DPS of Atlantic salmon.

The timing of spawning could shift later into the fall as water temperatures warm and spawning migrations could occur earlier in the year as salmon attempt to avoid peak summer water temperatures. However, because salmon spawning is not triggered solely by water temperature, but also by day length (which would not be affected by climate change) and river flow (which could be affected by climate change), it is not possible to predict how any change in water temperature or river flow alone will affect the seasonal movements of salmon throughout the action area. Increasing water temperatures will also likely increase energy consumption of upstream migrating Atlantic salmon, depleting energy reserves that may lead to lower spawning success and postspawn recovery (Rubenstein, 2021).

Dikes and their associated operational impacts from tide gates have been shown to exacerbate the effects of climate change as changes in streamflow, including impoundments and flow management through flow diversion structures, can significantly affect water temperatures due to changes in thermal capacity, with water temperature being inversely related to discharge (Webb et al., 2003). Furthermore, any increases in stream temperatures associated with project operations, or delays in the migration of Atlantic salmon that increase their exposure time to warmer temperatures can negatively affect their reproductive success (Mantua et al., 2010; Rubenstein, 2021). It is important to note that this impoundment is relatively riverine, and that some of the increase in water temperature in the action area likely would occur regardless of the presence of the dike and culvert, due to the natural warming of the water as it flows downstream exposed to warm summer air temperatures. Both surface (e.g., runoff, tributary flow) and groundwater sources could also affect the temperature of the Middle River. Despite some background factors, it is likely that the warming rate in the impounded reach could be higher than what would be expected in an unimpounded reach. However, as the flow through the impoundment is potentially low during the summer months, and the tide gates prevent flow out of the impoundment during high tides, it is likely that the effect of the impoundment on temperature in the action area has more than an insignificant effect on habitat suitability and the function of that habitat for Atlantic salmon.

As described above, over the long term, global climate change may affect Atlantic salmon and critical habitat by affecting the location of the salt wedge, distribution of prey, water flows, temperature. However, there is significant uncertainty, due to a lack of scientific data, on the degree to which these effects may be experienced over the life of the project (e.g., 75-100 years). While we can make some predictions on the likely effects of climate change on this species, without modeling and additional scientific data, these predictions remain speculative. Additionally, these predictions do not take into account the adaptive capacity of this species, which may allow them to deal with change better than predicted. We would recommend gaining a better understanding of the effects from operation of the tide gates on critical habitat in the Middle River in addition to the potential effects to migration critical habitat in the Machias and Middle Rivers through long term monitoring efforts following construction.

Despite the lack of certainty, we can make some predictions regarding potential outcomes of the warming climate. With an expected air temperature increase of 1.7–2.8°C by 2050, there is potential for significant effects to Atlantic salmon and designated critical habitat in the action area during the term of the proposed action. First, it is possible that portions of the already thermally challenged mainstem of the Machias will become uninhabitable by juvenile Atlantic salmon during the summer months. The thresholds for mortality in juvenile and adult salmon discussed previously would be exceeded regularly, and it will likely be less productive and would produce less outmigrating smolts. There may also be times in the summer months when the mainstem becomes a thermal barrier to migrating adults. Under these conditions, adults would need to access cold water refuge, where they may need to hold for days at a time. Warmer water will also take an energetic toll on adult salmon (prespawn and postspawn) as they will deplete their energy reserves more quickly during their upstream and downstream migration. Potential delays to find suitable summer holding areas or cold water refuge could result in a larger proportion of adults with lower energy reserves that could impact spawning success, and that reduced spawning could lead to a reduction in the number of salmon smolts leaving the Machias River, which will have a corresponding reduction in the number of returning adults coming back to the river. The further warming of the rivers will make them more suitable for warm water nonnative species, such as smallmouth and largemouth bass, which prey on juvenile Atlantic salmon (Baum, 1997).

The projected sea level rise (SLR) for the project area (using the nearest tide gauge at Eastport, Maine) for three global SLR scenarios and three time projections are shown in Table 5 below. Given the proposed structure will have a lifespan of approximately 75 to 100 years, the implications of higher sea levels should be considered and further evaluated as it may exacerbate the adverse effects related to the long term operation of the project on NOAA trust resources.

Table 5. Projected SLR for Eastport, ME based on three mean global SLR scenarios (Sweet et

al. 2022).

Year	Projected SLR for Eastport, ME		
	1.0 m mean global SLR scenario	1.5 m mean global SLR scenario	2.0 m mean global SLR scenario
2050	0.34 m (1.1 ft.)	0.39 m (1.3 ft.)	0.42 m (1.4 ft.)
2070	0.56 m (1.8 ft.)	0.71 m (2.3 ft.)	0.86 m (2.8 ft.)
2100	1.06 m (3.0 ft.)	1.37 m (4.5 ft.)	1.77 m (5.8 ft.)

In addition to the effects of SLR on the proposed project, New England has experienced more extreme precipitation events in the past few decades, and this trend is projected to increase in the 21st century with corresponding higher air temperature (Easterling et al. 2017), and will result in higher maximum peak river flows in Maine (Hodgkins and Dudley 2013). Climate studies that incorporate hydrological models have projected increased variability in streamflow, with greater frequencies of both high-flow and low-flow events predicted for much of the Northeast region (Demaria et al. 2016; Hayhoe et al. 2007). Increases in high flow events can cause stream channel erosion and increased sediment, nutrient, and microbial pathogen delivery to streams, while droughts and decreases in low flow volume can expose aquatic organisms to high temperatures and low dissolved oxygen (U.S. Global Change Research Program 2017).

Furthermore, temperatures of northern New England streams and rivers are projected to increase disproportionately higher than the national average over the 21st century (Letcher et al. 2016), which would have implications to habitats in the Middle River. New England riverine habitats have been historically altered by a host of non-climate perturbations (Daley et al. 2009; Hall et al. 2012; US EPA 2016; Mattocks et al. 2017), which can exacerbate climate-related changes in temperature and streamflow.

6. EFFECTS OF THE ACTION ON ATLANTIC SALMON AND THEIR CRITICAL HABITAT

This section of a biological opinion assesses the effects of the proposed action on threatened or endangered species or critical habitat in the action area. Effects of the action "are all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur but for the proposed action and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action." (50 CFR § 402.02) Here, we assess the effects of the proposed action on the GOM DPS of Atlantic salmon and its designated critical habitat in the action area. In the *Integration and Synthesis of Effects* section below, we consider these effects on the species and their habitat within the context of the *Status of the Species*, *Environmental Baseline*, and *Cumulative Effects*, as described in those sections of this Opinion.

As explained in the "Description of the Proposed Action" section (2.0), the action under consideration in this Opinion is the replacement of the Machias Dike Bridge, which carries Route 1 over Middle River in Machias, Maine. As described in the BA, all in-water work will be required to follow the Soil Erosion and Water Pollution Control Plan and a number of mitigation measures (AMM) and BMPs, described in section 2, will be required. Work is expected to take several years and begin in 2024 or 2025 depending on the timing of permitting, design, and contracting.

6.1. Effects to Atlantic salmon

As described in section 4.1, small numbers of Atlantic salmon adults and smolts are expected to be present annually in the mainstem Machias River below the Machias Dike Bridge and causeway. We anticipate prespawn adults would be present during the months of April - October, and post spawn kelts from late November – April. We also anticipate Atlantic salmon smolts to be migrating through the Machias River portion of the action area from April through June. We do not anticipate the presence of any Atlantic salmon in the Middle River portion of the action area during the construction phase as there is no means of passage into the Middle River currently. This analysis considers the potential for exposure of adults and smolts to the activities associated with the replacement of the bridge and the consequences of that exposure as well as the effects of the presence and operation of the new structure.

Table 6. List of proposed activities and associated stressor

Activity	duration	Timing	Species life stage	Stressor
Sheet pile installation with vibratory hammer (2 - upstream)	3-4 weeks	Anytime	Adult Atlantic salmon, smolts	Sound and sedimentation
Sheet pile installation with vibratory hammer (2 - downstream)	3-4 weeks	Anytime	Adult Atlantic salmon, smolts	Sound and sedimentation
Vibratory hammer for pipe pile installation (temporary bridge)	1-2 weeks	Anytime	Adult Atlantic salmon, smolts	Sound and sedimentation
Impact hammer for pipe pile installation (temporary bridge)	1 week	In the dry or December 1-March 31	Adult Atlantic salmon kelts	Sound and sedimentation
Removal cofferdam with vibratory hammer (2 - upstream)	1-2 weeks	Anytime	Adult Atlantic salmon, smolts	Sound and sedimentation
Removal cofferdam with vibratory hammer (2 - downstream)	1-2 weeks	Anytime	Adult Atlantic salmon, smolts	Sound and sedimentation
Removal of temporary Bridge with vibratory	1 week	Anytime	Adult Atlantic salmon,	Sound and sedimentation

hammer (downstream)			smolts	
Long term operations	Life of the structure estimated (75-100 years)	Anytime	Adult Atlantic salmon	Passage barrier, migratory delay

6.1.1 Sedimentation and Turbidity

The installation and removal of cofferdams and pipe piles will result in disturbance of the substrate and, when done in the water, result in a temporary increase in turbidity from that suspended sediment. The placement of riprap may also disturb bottom sediments, but this will mostly occur at low tide or within the dewatered cofferdam which limits the potential for increased turbidity in the water column. Removal of sheet piles with a vibratory hammer would occur at slack tide (AMM 3), thereby limiting the extent of the sediment plume, and minimizing the potential for exposure of salmon to increased turbidity that would be temporarily present in the mainstem Machias portion of the action area. These activities will occur throughout the year. Based on information on the type of substrate in the area included in the BA, the disturbed substrate could be exposed bedrock, boulders, smaller cobbles, gravel, sand, and coarse substrate fill.

Using available information collected from a project in the Hudson River, we expect pile driving in soft substrates (clays, silt, fine sand) to produce total suspended sediment (TSS) concentrations of approximately 5.0 to 10.0 mg/L above background levels within approximately 300 feet (91 meters) of the pile being driven (FHWA 2012). This is a reasonable estimate of the TSS that would result from the proposed pile driving given the similar substrate types and sediment disturbing activity. A number of measures are included in the proposed action to control turbidity levels and duration (AMM 3, 4, 5); as such, we anticipate that any sedimentation or turbidity would not exceed the estimates outlined above and would dissipate quickly in stream flows and settle back on the riverbed or tidal portion in a matter of several minutes.

Effects of Turbidity and Suspended Sediments on Atlantic salmon

In order to be exposed to increased turbidity, an Atlantic salmon would need to be present in the portion of the Machias River where increased turbidity will be experienced; during pile installation and removal, this area will extend approximately 300 feet from the mouth of the Middle River, which is equivalent to approximately 25% of the width of the Machias estuary (Figure 4). Effects of exposure to turbidity and TSS to Atlantic salmon worsen with increased levels of turbidity and duration of exposure (Newcomb 1994). Juvenile and adult salmonids show minor physiological stress and sublethal effects at suspended sediment concentrations of 7 mg/l for a six-day exposure and at 55 mg/l for a seven-hour exposure (Newcomb and Jensen 1996). MaineDOT's Programmatic Biological Assessment (ATS PBA 2016) summarizes the best available information on effects of exposure to turbidity and suspended sediments on Atlantic salmon; from this information MaineDOT outlined biological responses for Atlantic salmon and classified them into three major categories; 1) behavioral responses, 2) sub-lethal effects, and 3) potential mortality, as defined below.

Behavioral response - The range of turbidity releases expected to result in behavioral reactions ranging from a startle response to avoidance. These responses are anticipated after exposure to turbidity/suspended sediment levels of:

- 1-20 mg/l for one hour; or,
- 1 mg/l for 24 hours

Sub-lethal effects – The ranges of turbidity releases expected to result in sub-lethal effects including stress, reduction in feeding rates, and increased respiration rates. These responses are anticipated after exposure to turbidity/suspended sediment levels of:

- 20-22,026 mg/l for one hour; or,
- 1 mg/l for six days

Potential mortality - A higher range of releases has the potential to result in fish mortality. These responses are anticipated after exposure to turbidity/suspended sediment levels of:

- >22,026 mg/l for one hour; or,
- 7 mg/l for 30 months.

Consistent with the information summarized above, we expect that the effects of exposure to the anticipated TSS levels (5-10 mg/l above baseline conditions or a maximum temporary exposure of 20 mg/l) would be limited to a behavioral response that would result in the individual swimming away from the turbidity plume. This response is expected to result in avoidance of the portion of the area affected (<25% of the width of the estuary) for a very short period of time (minutes). This would not affect the ability of the individual to complete their migration up or down stream (pre-spawn adults and smolts, post-spawn kelts, respectively) due to the very short duration of the disturbance. Any increase in energy or stress related to avoidance would be short lived (minutes) and resolve quickly with no lingering effects. We do not expect any individual to be exposed to TSS of 20 mg/l for one hour or longer, and therefore, no sub-lethal physiological effects are expected to occur.

Therefore, given the short duration of in-water work that would lead to a sediment release, the tidal portion of the action area, the ephemeral nature of the stressor, the low level of TSS, and the limited area affected (Figure 4), and considering the minor and temporary effects to behavior for any individuals exposed, we expect any effects to Atlantic salmon resulting from minor and temporary changes in behavior to be so small that they cannot be meaningfully measured, detected or evaluated, and therefore, effects are insignificant.

6.1.2 Underwater Noise

During construction, a portion of the action area will experience temporary increases in sound pressure from pile driving (Figure 4 –red circles). The installation or removal of a sheetpile cofferdam or pile supports for a temporary roadway will produce elevated sound levels during the time that the vibratory or impact hammer is used. The MaineDOT proposes to conduct cofferdam installation and removal activities with a vibratory hammer year around, but only conduct pile driving with an impact hammer during the winter work window (December 1-March 31) or in the dry (Table 1). The greatest increase in sound pressure will occur in association with the construction of the temporary bridge downstream of the existing Machias

Dike Bridge. MaineDOT anticipates having to use an impact hammer to seat the 30- inch steel pipe piles to support the temporary bridge below the existing structure and have proposed to conduct this work in the dry or during the winter work window (December 1 through March 31). Therefore, Atlantic salmon adults and smolts could be migrating through the action area in the mainstem Machias River during in-water work and be exposed to elevated noise.

Available Information on Effects of Sound Pressure on Fish

We consider the effects of sound pressure on adult and juvenile Atlantic salmon that could be present in the action area during their annual migration period (spring/summer/fall) and kelts later during their post spawning migration period (late fall/winter/spring). The only potential for exposure of Atlantic salmon to increased sound pressure levels from pile installation and removal will be if the fish are present in the portion of the Machias River where increased sound will be experienced.

Background on Noise

This section contains a brief technical background on sound, the characteristics of certain sound types, and metrics used in this consultation inasmuch as the information is relevant to the specified activity and to consideration of the potential effects of the specified activity on listed species found later in this document.

Sound travels in waves, the basic components of which are frequency, wavelength, velocity, and amplitude. Frequency is the number of pressure waves that pass by a reference point per unit of time and is measured in hertz (Hz) or cycles per second. Wavelength is the distance between two peaks or corresponding points of a sound wave (length of one cycle). Higher frequency sounds have shorter wavelengths than lower frequency sounds, and typically attenuate (decrease) more rapidly, except in certain cases in shallower water. Amplitude is the height of the sound pressure wave or the "loudness" of a sound and is typically described using the relative unit of the decibel (dB). A sound pressure level (SPL) in dB is described as the ratio between a measured pressure and a reference pressure (for underwater sound, this is 1 microPascal (μPa)), and is a logarithmic unit that accounts for large variations in amplitude; therefore, a relatively small change in dB corresponds to large changes in sound pressure. The source level (SL) typically represents the SPL referenced at a distance of 1 m from the source, while the received level is the SPL at the listener's position (referenced to 1 μPa).

Root mean square (rms) is the quadratic mean sound pressure over the duration of an impulse. Root mean square is calculated by squaring all of the sound amplitudes, averaging the squares, and then taking the square root of the average (Urick, 1983). Root mean square accounts for both positive and negative values; squaring the pressures makes all values positive so that they may be accounted for in the summation of pressure levels (Hastings and Popper, 2005). This measurement is often used in the context of discussing behavioral effects, in part because behavioral effects, which often result from auditory cues, may be better expressed through averaged units than by peak pressures.

Sound exposure level (SEL; represented as dB re 1 μPa^2-s) represents the total energy in a stated frequency band over a stated time interval or event, and considers both intensity and duration of exposure. The per-pulse SEL is calculated over the time window containing the entire pulse (*i.e.*, 100 percent of the acoustic energy). SEL is a cumulative metric; it can be accumulated over a single pulse, or calculated over periods containing multiple pulses. Cumulative SEL represents the total energy accumulated by a receiver over a defined time window or during an event. Peak sound pressure (also referred to as zero-to-peak sound pressure or 0-pk) is the maximum instantaneous sound pressure measurable in the water at a specified distance from the source, and is represented in the same units as the rms sound pressure.

When underwater objects vibrate or activity occurs, sound-pressure waves are created. These waves alternately compress and decompress the water as the sound wave travels. Underwater sound waves radiate in a manner similar to ripples on the surface of a pond and may be either directed in a beam or beams or may radiate in all directions (omnidirectional sources), as is the case for sound produced by the pile driving activity considered here. The compressions and decompressions associated with sound waves are detected as changes in pressure by aquatic life and man-made sound receptors such as hydrophones.

Even in the absence of sound from the specified activity, the underwater environment is typically loud due to ambient sound, which is defined as environmental background sound levels lacking a single source or point (Richardson *et al*., 1995). The sound level of a region is defined by the total acoustical energy being generated by known and unknown sources. These sources may include physical (*e.g.*, wind and waves, earthquakes, ice, atmospheric sound), biological (*e.g.*, sounds produced by marine mammals, fish, and invertebrates), and anthropogenic (*e.g.*, vessels, dredging, construction) sound. A number of sources contribute to ambient sound, including wind and waves, which are a main source of naturally occurring ambient sound for frequencies between 200 hertz (Hz) and 50 kilohertz (kHz) (Mitson, 1995). In general, ambient sound levels tend to increase with increasing wind speed and wave height. Precipitation can become an important component of total sound at frequencies above 500 Hz, and possibly down to 100 Hz during quiet times. Marine mammals can contribute significantly to ambient sound levels, as can some fish and snapping shrimp. The frequency band for biological contributions is from approximately 12 Hz to over 100 kHz. Sources of ambient sound related to human activity include transportation (surface vessels), dredging and construction, oil and gas drilling and production, geophysical surveys, sonar, and explosions. Vessel noise typically dominates the total ambient sound for frequencies between 20 and 300 Hz. In general, the frequencies of anthropogenic sounds are below 1 kHz and, if higher frequency sound levels are created, they attenuate rapidly.

The sum of the various natural and anthropogenic sound sources that comprise ambient sound at any given location and time depends not only on the source levels (as determined by current weather conditions and levels of biological and human activity) but also on the ability of sound to propagate through the environment. In turn, sound propagation is dependent on the spatially and temporally varying properties of the water column and sea floor, and is frequency-dependent. As a result of the dependence on a large number of varying factors, ambient sound levels can be expected to vary widely over both coarse and fine spatial and temporal scales. Sound levels at a given frequency and location can vary by 10-20 dB from day to day (Richardson *et al*., 1995). The result is that, depending on the source type and its intensity, sound from the specified activity may be a negligible addition to the local environment or could form a distinctive signal that may affect a particular species.

Sounds are often considered to fall into one of two general types: pulsed and non-pulsed. The distinction between these two sound types is important because they have differing potential to cause physical effects, particularly with regard to hearing (*e.g.*, Ward, 1997 in Southall *et al*., 2007). Non-impulsive sounds can be tonal, narrowband, or broadband, brief or prolonged, and may be either continuous or intermittent (ANSI, 1995; NIOSH, 1998).

Pulsed sound sources (*e.g.*, impact pile driving) produce signals that are brief (typically considered to be less than one second), broadband, atonal transients (ANSI, 1986, 2005; Harris, 1998; NIOSH, 1998; ISO, 2003) and occur either as isolated events or repeated in some succession. Pulsed sounds are all characterized by a relatively rapid rise from ambient pressure to a maximal pressure value followed by a rapid decay period that may include a period of diminishing, oscillating maximal and minimal pressures, and generally have an increased capacity to induce physical injury as compared with sounds that lack these features.

Non-pulsed sounds can be tonal, narrowband, or broadband, brief or prolonged, and may be either continuous or intermittent (ANSI, 1995; NIOSH, 1998). Some of these non-pulsed sounds can be transient signals of short duration but without the essential properties of pulses (*e.g.*, rapid rise time). Examples of non-pulsed sounds include those produced by vessels and vibratory pile driving.

Specific to pile driving, the impulsive sound generated by impact hammers is characterized by rapid rise times and high peak levels. Vibratory hammers produce non-impulsive, continuous noise at levels significantly lower than those produced by impact hammers. Rise time is slower, reducing the probability and severity of injury, and sound energy is distributed over a greater amount of time (e.g., Nedwell and Edwards, 2002; Carlson et al., 2005).

Summary of Available Information on Sources of Increased Underwater Noise

During the construction phase of the project, increased underwater noise will result from the use of a vibratory hammer to install and remove temporary sheetpile cofferdams and the use of an impact hammer to install pipe piles to support the temporary bridge. Here, we present a summary of available information on these noise sources based on information provided to us in FHWA's BA and supplemental information provided by MaineDOT in February 2024.

Vibratory Pile Driving – Cofferdam Installation and Removal

Vibratory pile installation is a technique where piles are driven into soil using a longitudinal vibration motion. The vibratory hammer installation method continues until the pile is inserted to a depth that is sufficient to fully support the structure. In the BA, FHWA indicates that vibratory pile driving will be used to install, and then remove, cofferdams consisting of up to 50 interlocking 24-inch AZ steel sheet piles each. A total of 4 cofferdams will be installed and removed (in some cases reusing the same sheet piles). Each cofferdam is expected to take 3-4 weeks to install, with pile driving occurring for only a portion of that period. Each of the 50 sheet piles is expected to require approximately 30 minutes of vibratory driving over a 15 day period. Removal will occur over approximately 10 days. Assuming an 8-10 hour work day, up to 16 sheet piles could be installed per day. Vibratory pile driving will occur throughout the year (i.e., no time of year restriction) and may occur in the dry (i.e., sheet pile driven into the sediment when the tide is out and the area is dewatered) or in water.

In the BA, FHWA presents acoustics data from installation of similar piles (24-inch AZ steel sheet) with a vibratory hammer as reported in Caltrans 2009. The Caltrans report was updated in 2020 (Caltrans 2020). We reviewed Caltrans 2020 and noted three sets of acoustic data for installation of 24-inch AZ steel sheet piles with a vibratory hammer (all at water depths of 15 m, Table 1.2-1d in Caltrans 2020); acoustic measurements for all three projects were very similar, with maximum noise differing by only 1 dB. To avoid underestimating noise during the installation of sheet piles with the vibratory hammer, and considering that the differences between the available data sets were very small (only 1 dB difference), we, selected the loudest of the three measurements (which was only 1 dB higher than the other two projects) as a reasonable proxy for estimating maximum underwater noise from the proposed cofferdam installation and removal. The relevant information is presented in Table 7 below.

Table 7. Estimate of Underwater Noise – Vibratory Pile Driving for Sheet Pile Installation and Removal

Type of Pile	Hammer Type	Water Depth (m)	Measurement distance from pile (m)	Peak Noise (dBpeak)	RMS (dB)
AZ steel sheet	Vibratory	15	10	177	163

In the BA, FHWA reports using the NMFS pile driving calculator to determine distances to the acoustic thresholds for fish (described above). However, it is not clear if they used the most current version of the calculator. As such, we input the data into the NMFS Multi-Species Pile Driving Calculator[6]; predicted distances to thresholds of concern are noted in the table below.

Table 8. Estimated distances to Onset of Injury and Behavioral Disturbance Thresholds anticipated during vibratory pile driving for sheet pile installation and removal

Thresholds	Distance From Pile to Threshold (m)
peak injury (206 dB re 1uPa peak)	N/A
cumulative injury (187 dB re 1uPa cSEL)	N/A
behavior (150 dB RMS)	73.6

The injury thresholds for fish outlined above (FHWG 2008) are only for impulsive sound sources. Non-impulsive sources, such as vibratory pile driving, do not have the high peak sound pressure with rapid rise time typical of impulsive sounds. At this time, there is no information to indicate that vibratory pile driving has the potential to result in the injury of fish. As such,

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[6] https://www.fisheries.noaa.gov/resource/data/multi-species-pile-driving-calculator-tool

NMFS only considers the 150 dB re: 1uPa rms "behavioral response" threshold when considering effects of exposure to vibratory pile driving noise.

Noise resulting from pile driving for the sheet piles is expected to exceed the behavioral disturbance threshold only within 73.6 m of the sheet pile being installed or removed and only during the 30 minutes at a time that the vibratory hammer is operating. There are no seasonal restrictions included in the proposed action for vibratory pile driving; as such, this work may occur when smolts, adults, and/or kelts are migrating through the action area. A salmon moving through the area during any of the 30 minute periods when the vibratory hammer is being operated that was within 73.6 m of the sheet pile would be expected to detect the increase in noise and move away from the noise source (which would only require swimming less than 75 m, which would take a few minutes at most). Salmon in the action area during any of these 30-minute periods are also expected to avoid the area with noise above the behavioral disturbance threshold. Avoidance or displacement of an area with a radius of up to 73.6 m will have effects on Atlantic salmon that are so small that they cannot be meaningfully measured, evaluated, or detected; this is because of the small size of the area, the temporary nature of any displacement, and because avoidance of this area would have minimal, if any, effects on the energy budget of the animal and would not affect its ability to move through the area. Effects are therefore insignificant. No take of any Atlantic salmon is expected to result from exposure to noise resulting from pile driving for the installation or removal of the sheet piles.

Vibratory and Impact Pile Driving – Temporary Bridge Bents

As part of the construction of the temporary bridge, up to 35 30-inch steel bent piles will be first driven with a vibratory hammer and then seated using an impact hammer. Impact pile driving will be restricted to occurring between December 1 and March 31 or, if occurring between April 1 and November 30 will only occur in the dry (i.e., when the tide is out and piles can be installed in a dewatered area). During the consultation period, FHWA and MaineDOT provided additional information on this pile driving; vibratory pile driving will occur for 15-45 minutes for each pile, followed by 5-15 minutes of impact driving for a total of 200-500 strikes (which may occur on the same day or the next day). FHWA and MaineDOT estimate approximately 5 piles will be installed per day.

In the BA, FHWA presents acoustics data from installation of similar piles (30-inch steel pipe with vibratory and impact hammers) as reported in Caltrans 2009. As with the sheet piles, we evaluated the information in Caltrans 2020 as it is a more recent and more complete compendium of acoustics data for pile driving. Caltrans 2020 (Table 1.2-1a) presents information from a number of projects with installation of 30"-diameter steel pipe piles with an impact hammer; however, only two of the datasets are for piles installed without a bubble curtain (which acts as a noise attenuation system, reducing in-water noise levels) and only one had a complete dataset (SR 520 Test Pile Project). A bubble curtain is not proposed for use during the impact pile driving for the temporary bridge bents, as such we have used the data from the SR 520 Test Pile Project as a reasonable proxy for estimating maximum underwater noise from the proposed in-water steel pipe pile installation that may occur from December 1 – March 31 with an impact hammer. The SR 520 Test Pile Project pile parameters are the most similar to the pile driving proposed for the temporary bridge bents (30"-diameter steel pipe piles installed with an impact hammer without a bubble curtain). We note that this is a different dataset than what

FHWA used in the BA. We did not use the dataset cited in the BA (Siuslaw River, Florence OR) as it was not clear from Caltrans 2020 whether the measurements were made when the bubble curtain was operational or not.

For 30”-diameter steel pipe piles installed with a vibratory hammer, Caltrans 2020 presents three data sets (Prichard Lake pumping station, Redwood City Fender Replacement Project, and WETA Downtown Ferry); we compared the project descriptions for each data set to the information available for the Machias project and determined that the Prichard Lake pumping station dataset was the best proxy for the proposed in-water steel pipe pile installation that may occur with a vibratory hammer. This determination was based on the pile driving installation methods and water depth. We note that this is not the same dataset FHWA used in the BA; the BA references data from the Siuslaw River (Florence, OR) but Caltrans 2020 only reports on noise measurements for use of an impact hammer for that project. The relevant information on the representative/proxy projects is presented in Table 9 below.

Table 9. Estimate of Underwater Noise – Vibratory and Impact Pile Driving for Steel Pipe Pile Installation and Removal

Type of Pile	Hammer Type	Water Depth (m)	Measurement distance from pile (m)	Peak Noise (dBpeak)	SEL (single strike) dB	RMS (dB)
30-inch steel pipe	Vibratory*	3	10	196	N/A	159
	Impact**	3	10	196	172	185

*data from Prichard Lake Pumping Station (Caltrans 2020, Table 1.2-1a)
**data from SR520 Test Pile Project (Caltrans 2020, Table 1.2-1a)

In the BA, FHWA reports using the NMFS pile driving calculator to determine distances to the acoustic thresholds for fish (described above). However, it is not clear if they used the most current version of the calculator. We input the data from the cited proxy projects into the NMFS Multi-Species Pile Driving Calculator[7]; predicted distances to thresholds of concern are noted in the table below.

Table 10. Distance to thresholds of concern as predicted from the NMFS acoustic tool.

Threshold	Distance From Pile to Threshold (m)	
	Vibratory Hammer	Impact Hammer
peak injury (206 dB re 1uPa)	N/A	2.2 m
cumulative injury (187 dB re 1uPa cSEL)	N/A	184.2 m (all 5 piles in a day); 63 m for a single pile
behavior (150 dB re 1uPa RMS)	39.8	2,154.4 m

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[7] https://www.fisheries.noaa.gov/resource/data/multi-species-pile-driving-calculator-tool

As explained above, NMFS only considers the 150 dB re: 1uPa rms "behavioral response" threshold when considering effects of exposure to vibratory pile driving noise. Noise resulting from vibratory pile driving for the pipe piles is expected to exceed the behavioral disturbance threshold only within 39.8 m of the sheet pile being installed or removed and only during the 15-45 minutes at a time that the vibratory hammer is operating. There are no seasonal restrictions included in the proposed action for vibratory pile driving; as such, this work may occur when smolts, adults, and/or kelts are migrating through the action area. A salmon moving through the area during any of the 15-45 minute periods when the vibratory hammer is being operated that was within 39.8 m of the sheet pile would be expected to detect the increase in noise and move away from the noise source (which would only require swimming less than 40 m, which would take a few minutes at most). Salmon in the action area during any of these 15 to 45-minute periods are also expected to avoid the area with noise above the behavioral disturbance threshold. Avoidance or displacement of an area with a radius of up to 39.8 m will have effects on Atlantic salmon that are so small that they cannot be meaningfully measured, evaluated, or detected; this is because of the small size of the area, the temporary nature of any displacement, and because avoidance of this area would have minimal, if any, effects on the energy budget of the animal and would not affect its ability to move through the area. Effects are therefore insignificant. No take of any Atlantic salmon is expected to result from exposure to noise resulting from vibratory pile driving for the installation of the pipe piles.

The information outlined above indicates that in order to be exposed to pile driving noise that could result in injury, an Atlantic salmon would need to be within 2.2 m of a pipe pile for a single pile strike of the impact hammer (based on the 206 dB peak threshold). Given the rarity of Atlantic salmon in the action area during the December 1 to March 31 period when in-water impact pile driving can occur and the small area where exposure to peak noise could occur (extending less than 3 m from the pile), the potential for co-occurrence in time and space that would be necessary for a salmon to be exposed to noise above the peak threshold is extremely unlikely. The soft-start, which we expect would result in a behavioral reaction and movement outside the area with the potential for exposure to the peak injury threshold, reduces this risk even further. Given these considerations, we do not anticipate any Atlantic salmon to be exposed to noise above the peak injury threshold during pile installation with an impact hammer.

Considering the 187 dB SELcum threshold, an Atlantic salmon would need to remain within approximately 63 m of a pipe pile for the duration of the operation of the impact hammer (i.e., 5-15 minutes) or stay within approximately 184 m of all pipe piles installed in a 24 hour period (5 to 15 minutes per pile, 5 piles per day). Considering the anticipated behavioral reaction of salmon to avoid pile driving noise above 150 dB re 1 uPa RMS and the small area a salmon would need to swim out of to avoid accumulating enough noise exposure to experience injury, this is extremely unlikely to occur. This risk is further reduced by the rarity of salmon in the action area during the December 1 to March 31 period which results in a very low likelihood of any exposure. Given these considerations, we expect that even in the unlikely event that a salmon is exposed to impact pile driving noise they will be able to avoid exposure to noise above the levels that could result in exposure to the cumulative injury threshold. Based on this analysis and consideration of the peak and cumulative noise thresholds for injury, it is extremely unlikely that any salmon will be exposed to noise that will result in injury. Therefore, no take by harm (i.e., injury) of any Atlantic salmon is expected to occur.

During the 5 to 15 minute periods where impact pile driving occurs, the area that will have underwater noise above the 150 dB re 1uPa RMS threshold will extend approximately 2.1 km from the pile being installed. We expect that Atlantic salmon exposed to noise above 150 dB re 1uPa RMS would exhibit a behavioral response and may temporarily avoid the entire area where noise is louder than 150 dB re 1uPa RMS. We anticipate the percentage of adult kelts overwintering in the estuary following spawning is likely very low, and the action will occur during the time of year when we would anticipate only kelts to be in the action area (e.g., late November - April), the number of individuals exposed would be very limited, especially given the low number of adult salmon returning to the Machias River is very low. Therefore, exposure may occur but effects are insignificant given the displacement/avoidance would last no more than 15 minutes and it isn't persistent enough to prevent the salmon from using the greater Machias River Bay for rehabilitation following spawning.

Further, we do not anticipate an increase in noise from any work being conducted in the dry, since this AMM would significantly reduce any effects from sound due to the attenuation effects from the ground limiting the SPLs transferred into the wetted areas where salmon would occur.

Exposure to Contaminants

Use of heavy equipment in or near a water body increases the risk of introducing contaminants (e.g., fuel, oil, etc.). Chemical contaminants can enter into waterbodies through direct contact with contaminated surfaces or by the introduction of storm or washwater runoff and can remain in solution in the water column or deposit on the existing substrate. Research has shown that exposure to contaminants can reduce reproductive capacity, growth rates, and resistance to disease, and may lead to lower survival rates for salmon (Arkoosh et al. 1998). We have considered the risk for contaminants entering the Middle River to increase during construction.

Consistent with AMM 4, MaineDOT will be required to follow several BMPs to reduce the potential for introducing contaminants into the river during construction activities including:

- All vehicle refueling shall occur more than 100 feet from any watercourse.
- All vehicles carrying fuel shall have specific equipment and materials needed to contain or clean up any incidental spills at the project site. Equipment and materials would include spill kits appropriately sized for specific quantities of fuel, shovels, absorbent pads, straw bales, containment structures and liners, and/or booms.
- During use, all pumps and generators shall have appropriate spill containment structures and/or absorbent pads in place.
- All equipment used for instream work shall be cleaned of external oil, grease, dirt, and mud. Any leaks or accumulations of these materials would be corrected before entering streams or areas that drain directly to streams or wetlands.

Considering the proposed action and the required AMMs, any exposure of listed species to harmful contaminants will be extremely unlikely to occur; therefore, effects are discountable.

6.1.3 Habitat Modification in Middle and Machias Rivers during Construction

As described in section 2, the project will require the placement of structures and materials (temporary and permanent) into aquatic habitat within the Middle River and Machias River estuary. Current plans include installation of approximately 8,000 ft^2 of plain riprap at the culvert inlets and outlets to stabilize the slope. Temporary in-stream habitat modifications include the placement of the cofferdams encompassing 24,000 ft^2 and an approach for the temporary bridge approximately 21,000 ft^2. During construction, temporary in-water structures will occupy 45,000 ft^2 of aquatic habitat (Figure 2). As explained above, use of the action area by adults and smolts is expected to be limited to temporary use as they migrate through the area; the temporary loss of access to instream habitat in the Middle and Machias Rivers as a result of construction activities is extremely unlikely to result in any effects to any individual Atlantic salmon as there will be no impediment to movements and no other impacts on use of the area.

6.1.4 Post-Construction Effects to Atlantic salmon

Here, we consider the potential effects to Atlantic salmon from the presence and operation of the new structure through the following mechanisms: 1) Migratory delay caused by attraction to flow from the Middle River; 2) low upstream passage efficiency for adult Atlantic salmon attempting to enter the Middle River; 3) injury incurred by adults migrating through the culvert structure given very high velocities at some flows; and 4) potential for increased predation on adult Atlantic salmon by seals resulting from delays during upstream migration associated with attraction to the Middle River. We note that our analysis is based on the information provided in FHWA's BA and consideration that the new structure will be substantially similar to the existing structure with the exception of having properly operating tide gates that will be well maintained over the life of the structure. If there are significant changes in the design or planned operations of the new structure, reinitiation of this consultation may be necessary to evaluate any different effects to Atlantic salmon that would result from those changes.

As explained in the *Environmental Baseline* section of this Opinion, the existing structure with top hinging tide gates obstructs fish passage during differing tide heights and water levels present at the outlet of the structure; we expect the same obstructions with the new structure. Accordingly, the orientation of the outlet (invert height) in relation to the stage of the tide (ebb and flood) will limit the time the outlet is accessible to fish. During low tide, the outlet is exposed above the water line (Photo 1 in section 2) and would be inaccessible to migrating fish. During an incoming tide, the water level increases enough to eventually submerge the culvert structure and completely close the hinged tide gate, prohibiting passage of water and fish into the Middle River (Photo 5). However, depending on environmental factors such as base river flows coming out of the Middle River (Table 13) and the various tide stages that occur daily during the migration period, there are expected to be limited conditions that result in opportunities for an adult salmon to pass through the tide gates and into the Middle River (Figure 14).

There are several factors to consider when predicting the potential for an adult Atlantic salmon to pass the proposed structure and enter the Middle River. First, in order for fish to be successful at passing through the structure, the fish must be able to access the entrance to one of the culverts, then the fish needs to be able to swim through the structure and enter the Middle River. This involves several aspects of a fish's ability to migrate up rivers, including to leap, jump or enter the culvert at different tide stages, then maintain enough swim speed to exceed the flow of water (sprint speed), and finally have enough capacity to make its way upstream past the obstruction (prolonged). We expect that, based on the known swimming abilities of adult Atlantic salmon and their ability to move upstream past obstacles such as falls and rapids, that adult Atlantic salmon would have the physiological ability and swimming capability to move through the culverts in some conditions. For upstream passage, there must also be an innate urge or motivation to ascend the river to find suitable spawning habitat. This behavior is enhanced by imprinting on instream cues (i.e., water chemistry) during its juvenile life stage that would stimulate the fish to investigate the potential of this river discharge. While adult returns to the Machias River are expected to be motivated to move upstream to seek out spawning habitat, as there is no juvenile production in the Middle River, we do not expect any of those adults to be imprinted on the Middle River. As such, we expect that any salmon that attempt to pass into the Middle River are straying from the Machias River. Straying (i.e., fish moving up and spawning in rivers where they weren't reared) of Atlantic salmon is a natural process that helps maintain population diversity through exchange of genes between populations and allows for population expansion and recolonization of extirpated populations. Atlantic salmon have a high degree of river of origin homing, however, with straying rates of only 1-3% (Baum, 1997). This means that as many as three out of every 100 adult salmon may attempt to stray to a river other than the one where they were stocked or naturally reared.

Effects to Adults

As explained above, there is currently no natural Atlantic salmon spawning or stocking that occurs in the Middle River. As such, there is no juvenile production in the Middle River, no smolts leaving the Middle River, and no adults imprinted on the Middle River that are attempting to return to the Middle River to spawn. However, some adult Atlantic salmon returning to the Machias River may be attracted to the discharge from the Middle River that will occur during the daily tidal cycle. During the spring freshets and high flow periods that coincide with their annual migration window, there could be some mixing of discharges from the Machias and Middle Rivers that could confuse the salmon and make it difficult to find the Machias River; note that this would occur regardless of the presence and operation of the Machias Dike Bridge. During these high flow events, water levels upstream of the dike could make the Middle River more accessible than in lower flow periods by causing the tide gates to stay open for a longer period during the tide cycle; these conditions would also provide more flow for attraction of adults. However, an increase over the baseline flow in the Middle river (Table 13) could make it more difficult for an adult Atlantic salmon to pass through the culvert structure itself (Figure 14).

We generally anticipate a small percentage of fish (1-3%) to stray into adjacent riverine habitat based on previous studies and data from Maine (USASAC, Baum 1997); it is possible that absent barriers to passage, “straying” of adults to nearby tributaries to seek out suitable spawning habitat would be higher (e.g., the number of salmon reared in the Machias River that spawned in the nearby Middle River, which shares an estuary, would likely be more than the number that strayed to the more distant Union River), however, we have no information from which to generate an anticipated percentage other than to consider it may be closer to 3% than 1%. If the Middle River was accessible to returning adult salmon, we would expect that a small portion of the annual migration into the Machias River would stray into the Middle River (up to 3%). In this situation, it would be conceivable that the number of individuals produced in the river would increase, which would lead to more salmon being produced in, and homing back to, the Middle River. Given the nearly full blockage of passage caused by the existing and proposed bridge structures, however, we do not expect any adults to be homing to the Middle River over the life of the project. Individuals that stray may seek out spawning habitat and if there are multiple strays in the same area, spawning could occur. Alternatively, strays may return back downstream and migrate to their natal stream or an alternate, nearby spawning location. Given the generally low rate of straying by adult Atlantic salmon and the small number of adults returning to the Machias River, averaging 16 fish in recent years, we would not expect more than one individual would stray into the Middle River in a given year.

As there are variable hydrologic conditions within the impounded area of the Middle River as a result of the operation of the tide gates, in addition to having limited spawning and rearing habitat upstream of the bridge, we would anticipate any adult passing upstream of the bridge would not be motivated to stay or holdover/rest in the Middle River for any prolonged period of time and would ultimately leave the Middle River. When migrating into rivers to spawn, adult Atlantic salmon have been documented to have three phases of movement: 1) direct, step-wise migration to spawning habitat, 2) searching behavior, which includes both upstream and downstream movements, and 3) holding in an area near the spawning area prior to spawning (Okland et al. 2001). The most common movement identified by Okland et al. (2021), is "a search phase of erratic movements with more than one down river movement." As such, we expect that salmon that manage to enter the Middle River will, after a period of searching, fall back out of the Middle River to continue their migration into the Machias River. As such, we anticipate that any delay within the river would be minimal, but would likely exceed 48 hours due to the full and partial closure of the tide gates for two-thirds of the tidal cycle, as well as some amount of time needed to perform searching behaviors.

Here, we consider the potential for adult Atlantic salmon that may attempt to move upstream into the Middle River to be able to do so through the new tide gates. As explained below, there is limited, intermittent, opportunities for an adult to gain passage through the tide gates, and we expect any individual attempting to pass, will incur some type of minor injury (abrasion, scale loss) from colliding with the gate valve structure or culvert. An Atlantic salmon adult that does pass upstream into the Middle River would have access to habitat that would provide cover, temperature, and flow for an adult to temporarily rest. However, given the very small amount of spawning habitat and that we do not expect more than one adult to move upstream into the Middle River in a given year, we do not expect spawning to occur. As described above, we expect that fish that pass the bridge will exhibit search behavior with multiple upstream and downstream movements (Okland et al. 2021) prior to falling back to the Machias River. As such, we expect that any adult that moves up into the Middle River would not find suitable habitat and will return back to the Machias River but the result may delay their migration to spawning grounds in the Machias River for more than 48 hours.

NMFS Interim Guidance on the ESA Term "Harass" (PD 02-110-19; December 21, 2016)[8] provides for a four-step process to determine if a response meets the definition of harassment.

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[8] Available at: https://www.fisheries.noaa.gov/national/laws-and-policies/protected-resources-policy-directives

The Interim Guidance defines harassment as to "[c]reate the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering." The guidance states that NMFS will consider the following steps in an assessment of whether proposed activities are likely to harass: 1) Whether an animal is likely to be exposed to a stressor or disturbance (i.e., an annoyance); 2) The nature of that exposure in terms of magnitude, frequency, duration, etc. Included in this may be type and scale as well as considerations of the geographic area of exposure (e.g., is the annoyance within a biologically important location for the species, such as a foraging area, spawning/breeding area, or nursery area); 3) The expected response of the exposed animal to a stressor or disturbance (e.g., startle, flight, alteration [including abandonment] of important behaviors); and; 4) Whether the nature and duration or intensity of that response is a significant disruption of those behavior patterns which include, but are not limited to, breeding, feeding, or sheltering, resting or migrating.

Here, we carry out that four-step assessment. We have established that pre-spawn adult salmon will encounter the Machias Dike Bridge and that the operation of the tide gates will result in a disruption of their upstream migrations (step 1). We have determined that up to one salmon a year would experience minor injury, as well as migratory delay in excess of 48 hours (step 2). We have established the expected response of the exposed adults (step 3). Individual adults delayed more than 48 hours at the bridge and in the Middle River during their upstream migration will need to expend additional energy possibly under potentially adverse river conditions (e.g., warm water), which will reduce the energy reserves available for successful spawning in the Machias River. Finally, we establish that the nature and duration of the response is a significant disruption of migration (step 4). Based on this four-step analysis, we find that individual prespawn adults delayed for more than 48 hours at the Machias Dike Bridge project during their upstream migration are likely to be adversely affected and that effect meets the definition of harassment. Therefore, we anticipate that up to one adult salmon that passes into the Middle River through the tide gates will be harassed.

NMFS considers "harm" in the definition of "take" as "an act which actually kills or injures fish or wildlife. Such an act may include significant habitat modification or degradation where it actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding or sheltering" (50 CFR §222.102). As defined above, we consider "harm" in the definition of "take" as "an act which actually kills or injures fish or wildlife." We have determined that delay of greater than 48 hours would significantly disrupt the behaviors of individual adults; at some time period, migratory delay could rise to the level of "harm," that is, it could result in the injury or mortality of salmon (e.g., an adult could die either before or after spawning because of the energy loss associated with migratory delay). Such injury or death could, for example, be a result of loss of energy reserves or to exposure to high water temperatures without access to thermal refugia. At this time, we are not able to quantify the extent of delay that would equate to harm, and note that we expect it to be specific to the circumstances of an individual river as well as the circumstances of individual fish (e.g., a fish may be more tolerant to long delay if it enters the river early in the year when there are months before the spawning period and if that fish has suitable habitat for resting and escaping predators). However, we do not anticipate that to occur at this project. Adult salmon that are delayed by more than 48 hours in the Middle River will only have a short distance to migrate to access spawning habitat in the Machias River. According to field surveys conducted by MDMR biologists, there are approximately 450 habitat units of spawning habitat in the Machias River upstream of the Middle River confluence (MDMR 2017). The closest habitat is only 25-km upstream of the Machias Dike Bridge. As such, we expect that even a salmon that experiences delay greater than 48 hours is unlikely to fully deplete their energy reserves. Given the relatively short distance to habitat, and the fact that salmon will encounter few, if any, additional barriers in the Machias, we do not consider delay of adults during their upstream migration at this project to meet the definition of "harm."

Considering Opportunities for Atlantic salmon Passage at the Machias Dike Bridge

The swimming capability of fish can be difficult to ascertain and has been the focus of many lab studies to evaluate the different aspects of swimming mechanics (Webb 2006, Castro-Santos and Haro 2006). As defined in the interagency design guidelines for nature-like fishways (Turek et al. 2016) "There are three operationally-defined swimming modes that exist in fish: sustained, prolonged, and sprint speeds. Sustained swimming occurs at low or sustained speeds that are maintained for greater than 200 minutes (Beamish 1978). Prolonged swimming occurs at speeds that fish can maintain for 20 seconds to 200 minutes, and sprint swimming can only be maintained for periods of less than 20 seconds." For many species, quantitative measures of these swimming modes are unknown, and only a few fish species have been comprehensively evaluated for all three modes. Fortunately, there are federal guidelines published for fish passage facility designs which have considered these different methods and estimated the swimming ability for many diadromous fish found along the east coast (Turek et al. 2016) and west coast (NOAA WCR Anadromous Salmonid Passage Design Manual 2022). We referenced these guidelines in Table 11 and for making our determinations for passage opportunities at the Machias Dike Bridge (Figure 14).

Swimming abilities vary among diadromous species (Table 11 and Figure 14), and are very dependent on body shape and size to increase swimming performance; which is largely a function of fish biomechanics and hydrodynamics of its environment (Castro-Santos and Haro 2010). As described in the NOAA/USFWS guidelines, "larger fish have proportionally more propulsive area and a larger muscle mass, and are thus able to move at greater absolute speeds (i.e., the absolute distance through water covered over time)"(Turek et al. 2016). For example, a 30-cm long Atlantic salmon swimming at 5 body lengths per second will move through the water at 150 cm per second, while a 57 cm Atlantic salmon swimming at 5 body lengths per second will move through the water at 285 cm per second. Fish age, physiological state, and environmental conditions such as water temperature, photoperiod are additional factors influencing fish movement, behavior (e.g., homing, exploratory), which ultimately determines if a fish passes successfully through the structure. Due to their size and shape, Atlantic salmon are one of the strongest swimmers in the suite of diadromous fish in Maine and are capable of ascending falls by leaping and having sprint swim speeds up to 13 ft/sec (Turek et al. 2016).

As documented by Rillahan (2021) and Alcotte et al. (2021), tide gates at the Herring River in Massachusetts have had a deleterious effect on fish behavior including unsuccessful passage and delay, injury and mortality and increased exposure to predators like striped bass. Any tide gate, when fully open or partially open, allow for water flow that fish may try to use for passage.

Furthermore, partially open or fully open tide gates can create high velocities that sweep fish through narrow openings. When velocities exceed the burst speeds of fish, they cannot make evasive maneuvers away from predators and obstacles in the water, like debris, increasing the risk of injury. In particular, high velocity flow through the narrow openings of flap gates promotes collisions with the gate structure itself, including the gate and frame. Larger fish like adult salmon may also have a greater likelihood of injury from coming in contact with structures within and supporting the culverts (Turek et al. 2016).

In this Opinion we have considered the opportunities for Atlantic salmon to successfully pass through the box culverts, with tide gates, planned for the in kind replacement of the Machias Dike Bridge. The tide gates will be closed for a significant portion of each day; during these periods, there is no opportunity for fish passage. (Potential passage conditions for adult Atlantic salmon would exist when the tide gates are open and the culvert opening is accessible. Given the best available information, we expect salmon would require velocities less than 12 fps and depths greater than 6 inches for upstream passage. Therefore, passage opportunities are limited to the period when the gates are open, the culvert is accessible, and flow and depth would allow for passage. As such, we expect extremely limited opportunities for passage that are unlikely to exist for more than a few minutes at a time. We are not able to predict the frequency and duration of these conditions and expect that they may not exist every day. MaineDOT Adults present in the action area may also enter the area of the Machias River estuary directly adjacent to the project to rest or hold during their upstream migration into upper portions of the river that contain suitable habitat that is used for spawning. Adults that hold below the Machias Dike Bridge will still have access to cool salt water, but we expect that they could still be exposed to migratory delay by the operation of the tide gates. However, as tidal flow into the Middle River is blocked during high tide (due to the closure of the tide gates), we expect that any salmon downstream of the gates during this period would detect the flow coming out of the Machias River and continue their migration upstream. As such, we do not anticipate adults to hold downstream of the bridge for more than a tidal cycle (i.e., any delay in migration would be significantly less than 48 hours).

Effects to Juvenile Atlantic salmon

As explained above, there is no known production of Atlantic salmon juveniles in the Middle River and no stocking occurs in this area. With the limited, intermittent opportunities for upstream passage of adult Atlantic salmon through the new tide gates, we do not expect any future spawning. Therefore, we do not expect production of juvenile Atlantic salmon in the Middle River over the life of the new structure. As such, we do not expect any smolts to be migrating downstream and attempting to move out of the Middle River through the culverts. Any indication that there is spawning occurring upstream of the new structure would represent new information on the effects of the action that we expect would require reinitiation of this consultation.

6.2. Effects to Critical Habitat for the Gulf of Maine DPS of Atlantic salmon

In this analysis, we consider the effects of the action on the PBFs of critical habitat we determined to be in the action area, these are M 1-6 and SR 1-7 (see Section 4.2). For each PBF, we identify those activities that may affect the habitat components identified in the Matrix of Essential Features (Table 3). For each feature that may be affected by the action, we then determine whether any effects to the feature are adverse, insignificant, discountable, or entirely beneficial and we consider the consequences of those effects on the conservation value of the habitat. In making this determination, we consider the action's potential to affect how each PBF supports Atlantic salmon's conservation needs in the action area. Part of this analysis is consideration of the conservation value of the habitat and whether the action will have effects on the ability of Atlantic salmon to use the feature, temporarily or permanently, and consideration of the effect of the action on the action area's ability to develop the feature over time.

As noted above, the proposed action will continue to affect the ability of fish to move into the Middle River and will result in adverse effects to migration and to spawning and rearing habitat in the Middle River. All of the PBFs in the action area will be affected by the proposed action, except for PBFs M5 and M6. M5 refers to the need for cool water and sufficient flows to stimulate smolt migration in the spring. Given the small amount of rearing habitat and the lack of pre-spawn adults in the Middle River, we do not expect that any smolts are initiating movement in the action area. The majority of smolts in the system will be produced in the Machias River or other tributaries. Additionally, as we do not expect the temporary impoundment in the Middle River to significantly affect water temperatures in the spring months, and as there will no effects to temperature in the Machias River downstream of the bridge, the proposed actions will have no effect on PBF M5, and it will not be considered further. PBF M6 refers to the need for water chemistry that will support seawater adaptation of smolts. Specifically, this PBF addresses the need for low acidity water as smolts that are exposed to water that is too acidic (low pH) can lose their tolerance for salt water (USOFR, 2009), which would affect their ability to successfully transition to the ocean. We do not anticipate that the proposed action will affect the pH of water in the action area (in either the Middle or Machias Rivers); therefore, the project will have no effect on this feature and we will not consider PBF M6 further.

The replacement of the existing tide gates with fully operational tide gates is anticipated to limit the incoming flow of salt water during the incoming portion of the tide cycle. This would also limit the opportunities for an adult salmon to be able to enter the culverts considering the proposed invert elevation (Figure 14). Additionally, the configuration and size of the box culverts will affect the velocities through the structure during peak in-stream flows above the Machias Dike Bridge (Table 13), which could make it more difficult for salmon to successfully swim through once they have entered (Figure 14).

Table 13. Predicted baseline flows in the Middle River watershed occurring with peak flow events

Location	Drainage Area (sq. mi.)	Return-Interval Event (Years)/Peak Flow (cfs)							
		1.1	2	5	10	25	50	100	500
Stride Bridge	9.41	130	265	213	522	670	787	912	1,221

Dike Bridge	13.22	152	297	452	565	715	832	958	1,264

Effects of the Action on Critical Habitat in the action area

In this analysis, we consider how the proposed action may affect the functioning of the PBFs in the action area as well as access to those PBFs; we consider if effects will be wholly beneficial, insignificant, or discountable, and if not, explain that the anticipated effects will be adverse. It is important to note that an action may adversely affect critical habitat, without adversely affecting individuals of the species for which it was designated.

PBF SR1-3 - Deep, oxygenated pools and cover (e.g., boulders, woody debris, vegetation, etc.), near freshwater spawning sites, necessary to support adult migrants during the summer while they await spawning in the fall (SR 1). Freshwater sites that contain clean, permeable gravel and cobble substrate with oxygenated water and cool water temperatures to support spawning activity, egg incubation, and larval development (SR2), as well as to support emergence, territorial development, and feeding activities of Atlantic salmon fry (SR3).

The habitat downstream of the bridge is tidal and the substrate is dominated by riprap and exposed boulders during low tide; therefore, it is not suitable for spawning and does not contain the SR 1-3 PBFs.

In Section 4.2, we established that, based on the Wright et al. (2008) model, the action area contains a small amount (10 units) of rearing habitat upstream of the project in the Middle River. The Wright et al. (2008) model does not specifically identify spawning habitat, nor has spawning habitat been identified in the Middle River through field assessments. However, as described above, we use the rearing habitat model to approximate the amount of available habitat within the action area that could be used for spawning. As there are only 10 units of modeled rearing habitat, we would expect that no more than 10 units would be available for spawning. Although we do not have sufficient data to determine the suitability of PBFs SR1-3 in the Middle River, we anticipate that the small amount of potential spawning habitat (no more than 10 habitat units) functions at a limited capacity due to the impounding effects (e.g., inundation, warming) associated with the operation of the existing tide gates. The matrix of essential features (Table 3) suggests that increasing depths and temperatures can limit the functionality of spawning sites for egg and embryo/fry development habitat. In addition, holding pools may become less functional if depths and temperatures are increased due to the closing of the tide gates. As the reinstallation of new tide gates will result in the continuation of these effects for an additional 75-100 years, the proposed action will continue to limit the function of PBF SR 1-3 in the action area and is expected to prevent the habitat from becoming fully functional during the life of the project.

The new structure will largely block passage of adult Atlantic salmon into the Middle River; while blocking passage does not modify the physical and biological features of the habitat that make it otherwise suitable for spawning and rearing, the limited accessibility resulting from the new structure will significantly limit the conservation value of the habitat by preventing prespawn Atlantic salmon from accessing the habitat for the purpose of spawning. As there will be no spawning, the habitat then will not support any rearing. This, combined with the way that the tide gates will limit the ability of the habitat in the Middle River to support spawning and development of early life stages (through the impoundment effects noted above) will adversely affect PBFs SR 1-3.

PBF SR4-SR7 - Freshwater rearing sites with the space (SR4), habitat diversity (SR5), cool water (SR6), and diverse food resources (SR7) necessary to support growth and survival of Atlantic salmon parr.

In Section 4.2, we established that the action area contains a small amount (10 units) of parr rearing habitat upstream of the project in the Middle River. The habitat downstream of the Machias Dike Bridge is tidal and is therefore not suitable for the freshwater rearing of salmon parr. As such, the habitat downstream of the bridge does not contain PBFs for rearing (SR 4-7). As explained above, we do not expect any parr to be present in the Middle River during construction; therefore, any temporary effects to the PBFs for growth and survival of Atlantic salmon parr will have no effect on the value of that habitat for conservation of the species.

Although we do not have sufficient data to determine the suitability of the 10 units of rearing habitat available in the Middle River (due to lack of survey data), it is reasonable to expect that it functions at a limited capacity due to the impounding effects associated with the operation of the existing tide gates (see above) which affect space, habitat diversity, water temperature, and food resources in the existing rearing habitat and that these effects will be perpetuated over the life of the new structure. The proposed action will also reduce the conservation value of this habitat by limiting access which will prevent spawning which means there will be no parr to use the habitat.

The bridge and tide gates will reduce the conservation value of the rearing habitat by preventing access to this habitat and will reduce the function of this habitat by altering water flows which will result in negative impacts on space, habitat diversity, water temperature, and food resources. Therefore, over the life of the new structure there will be a reduction in the ability of the action area to support growth and survival of Atlantic salmon parr; these effects are not wholly beneficial, insignificant, or discountable.

PBF M1 - Migratory sites free from physical and biological barriers that delay or prevent access of adult salmon seeking spawning grounds needed to support recovered populations

The anticipated turbidity during construction is not expected to impact the suitability of habitat in the action area for movement of adults through the action area. For intermittent periods over the construction, pile driving is expected to result in underwater noise levels that would be avoided by migrating adults. However, the area affected is small and effects are temporary and of short duration, there would never be a time when upstream passage was blocked due to noise. As such, effects of construction on PBF M1 will be insignificant; that is, they will be so small that they cannot be meaningfully measured, evaluated, or detected. This is because while there may be small areas where the habitat conditions are temporarily affected in a way that affect movement, there will be no barriers that delay or prevent access of adults moving to spawning grounds. As all effects are temporary, we do not expect these effects will affect the long-term functionality of the Machias River as a migratory corridor for adult salmon.

As described above, adult Atlantic salmon may be delayed downstream of the new Machias Dike Bridge structure as they migrate upstream through the Machias River estuary during various flows and tides. Since these flow conditions are not consistent throughout the migration period, as the tide and flows will fluctuate daily, we anticipate the attraction to flows from the Middle River and associated delays to migration should be temporary (no more than one or two tide cycles). As such, we expect that minor delay experienced by salmon in the Machias River will have an insignificant effect on the functionality of PBF M1; that is, any effect of the new structure on habitat conditions that would impeded or delay adult salmon moving upstream in the Machias River will be so small that it cannot be meaningfully measured, detected, or evaluated.

The portion of the action area located in the Middle River contains PBF M1, and but for the presence of the tide gates we would expect it to function fully. However, the presence of the existing tide gate structure greatly limits function of PBF M1 in the action area in the Middle River. The habitat upstream of the tide gate in the Middle River will not be fully accessible during construction nor during the long term operation of the new structure with tide gates. The long term operation of the tide gates will continue to adversely affect PBF M1 in the Middle River. As described above, there is a small chance that an adult salmon could successfully migrate through the tide gates at the new Machias Bridge. However, daily tidal fluctuations create impassable conditions during portions of low and high tides each day. It is anticipated the proposed action will exacerbate this condition by improving the operation of the tide gates (the existing gates malfunction regularly) such that they fully close during portions of the incoming and outgoing tides, thereby increasing the amount of time each day that the bridge is impassable (see section 6 Climate Change for further discussion). The matrix of essential features (Table 3, Section D) indicates that anthropogenic barriers that result in obstructed passage of adults may limit the function of migratory habitat. When there is adequate water depth in the culverts and incoming tide in the outlet pool (i.e., the pool below the culvert opening), we anticipate the operation of the tide gates will obstruct passage into the Middle River. We expect that the bridge culvert would only be passable for adult salmon for a short period and only at tide levels when the depth of the downstream pool may be sufficient for them to enter one of the partially closed box culverts. As the proposed action significantly affects the ability of Atlantic salmon to migrate into the Middle River, it will reducing the function and conservation value of PBF M1 in the action area; these effects are not wholly beneficial, insignificant, or discountable.

PBF M2 - Freshwater and estuary migration sites with pool, lake, and in-stream habitat that provide cool, oxygenated water and cover items (e.g., boulders, woody debris, and vegetation) to serve as temporary holding and resting areas during upstream migration of adult salmon.

In section 4.2, we established that there may be a small amount of spawning habitat within the Middle River (Figure 12), and it is probable that there are areas within the action area in the mainstem Middle River that could be used by adults for holding and resting as they make their way to that habitat. As turbidity and noise producing construction activities are largely occurring downstream of the bridge in the Machias River, we do not expect that the migratory PBFs in the Middle River will be affected during the construction period. However, over the long-term operation of the new tide gates, we expect the function of PBF M2 in the Middle River to be reduced by the impounding of the upstream habitat during high tide periods when the gates are closed. Impounding of the habitat is expected to lead to warmer water temperatures, which would reduce the value of the holding pools for Atlantic salmon. As such, the installation of tide gates on the new bridge structure will adversely affect PBF M2 by reducing the suitability of the habitat for salmon holding during high tide periods.

The new structure will largely block passage of adult Atlantic salmon into the Middle River; while blocking passage does not modify the physical and biological features of the habitat that make it otherwise suitable for holding and resting, the limited accessibility resulting from the new structure will significantly limit the conservation value of the habitat by preventing prespawn Atlantic salmon from accessing suitable holding habitat. Therefore, the proposed action will both reduce the conservation value and function of PBF M2 in the Middle River over the life of the new structure.

Holding areas used by prespawn adult salmon may also occur downstream of the bridge in the Machias River estuary. As described above, the portion of the action area downstream of the bridge is likely to be affected by activities associated with construction, including the placement of fill, the driving of piles, and the construction and removal of a temporary bridge and sheetpile cofferdams. In our analysis we have determined that the areas would be affected by turbidity and noise associated with construction activities. To the extent that these effects overlap with areas that would provide habitat for resting and holding during the time of year that adults would be using the area, the function of these habitats would be affected; this is because increased turbidity and noise would result in avoidance of these areas so they would not serve their habitat function during this period. However, as the construction effects will be intermittent and temporary, we do not anticipate that there will be any long-term effect to the functioning of PBF M2 downstream of the bridge over the life of the project.

PBF M3 - Migration sites with abundant, diverse native fish communities to serve as a protective buffer against predation

The habitat upstream of the Machias Dike Bridge is potential habitat for a number of anadromous species. Adult alewives, blueback herring, and American shad all may be present in the action area during their seasonal upstream migration period. Despite having a high sprint speed (Table 11), these smaller species are not as capable as Atlantic salmon at negotiating strong currents over a great distance (Turek et al. 2016). As these fish are not strong swimmers, it is unlikely that many individuals, if any, would successfully pass through the bridge structure given the expected high velocities and the length of the culvert, in addition, the limited period of time each day when the gates would be open and accessible. Although there is some anecdotal information suggesting a small number of individual shad or river herring might pass into the Middle River under current conditions, we expect this is rare and intermittent and that the new bridge structure will continue to significantly limit the potential for passage of these species into the Middle River over the life of the new structure.

There is no accessible alewife spawning habitat within Middle River. There are two dams upstream of the Machias Dike Bridge on the Middle River without fish passage facilities. These dams currently block the migration corridor into Marks Lake (240 acres) and Second Marks Lake (51 acres). If access was to become available, this habitat could serve as spawning habitat for alewives. Habitat above the Machias Dike Bridge is lower gradient and there is potential for blueback herring and American shad to spawn. Alewives generally move upstream in May. American shad and blueback herring tend to run during the latter part of the spring (i.e., late May and June). Based on species-specific habitat requirements and upstream impediments to passage, we expect the Middle River currently has viable habitat for sea run rainbow smelt, blueback herring and American shad to use for spawning. However, under current operational conditions, we do not anticipate that a significant number of any sea-run fish species can enter the Middle River under existing obstructed passage conditions. As such, PBF M3 is present but not functioning in the Middle River portion of the action area. There is no barrier to passage downstream of the bridge on the Machias River; therefore, we expect that the PBF is fully functional in the Machias River portion of the action area.

In-water construction will occur during the spawning migration of the native fish that are considered to serve as a protective buffer against Atlantic salmon predation. BMPs will minimize any potential impacts to these species in the Machias River downstream of the bridge, where they may gather due to the water flow coming out of the Middle River. We anticipate that construction effects (i.e., noise and turbidity) may have minor effects on the distribution of these species in the action area as they avoid areas of increased turbidity and underwater noise; we expect the measures built into the proposed action will minimize the potential for any serious injury or mortality of any river herring or shad. As construction effects will be minor and temporary, we do not expect that they will affect the abundance or distribution of these species in a way that would reduce their ability to function as a predation buffer to migrating salmon. As such, we anticipate the construction-related effects on PBF M3 to be discountable.

We expect that the proposed permanent structure will continue to impede passage of all sea-run fish into the Middle River over the long term operation of the project. The passage conditions anticipated with the new structure are expected to significantly limit the ability for any anadromous fish to move upstream into Middle River. As noted above, we expect that habitat in the Middle River could support spawning of sea run rainbow smelt, blueback herring and American shad. Because the new structure will largely be a barrier to passage for those species, it is unlikely that any spawning populations could be established in the Middle River over the life of the new structure. Thus, compared to a future with accessible passage into the Middle River to use for spawning, we would expect less production of these species in the watershed as a result of the new structure. However, given that we do not expect any production of Atlantic salmon in the Middle River over the life of the new structure (also due to a lack of adequate access), the lack of abundant and diverse native fish communities in the Middle River will not affect any Atlantic salmon in the Middle River because we do not expect there to be any.

As noted above, PBF M3 is functional in the Machias River; there is abundant accessible habitat in the Machias River upstream of the confluence with the Middle River that will not be affected by the long-term operation of the tide gates thus there will be no effect from the proposed action on the production of anadromous species such as alewife, shad, and blueback herring in the Machias River. As such, PBF M3 is expected to remain fully functioning within the portion of the action area located within the Machias River. While there would be a reduction in the abundance of native fish to serve as a predation buffer in the Machias River estuary due to the continued impacts of the new structure and its tide gates on the ability of the Middle River to support populations of these species, this will not be a change from current conditions. At the scale of the action area as a whole, the effects of reduced abundance of native fish due to the effects of the new bridge structure on PBF M3 will be so small that they cannot be meaningfully measured, evaluated, or detected. Therefore, the effects are insignificant.

PBF M4 - Migration sites free from physical and biological barriers that delay or prevent emigration of smolts to the marine environment.

Construction related activities occurring during the smolt outmigration period will result in noise and turbidity; while this may result in minor and temporary effects on the suitability of habitat for migration, there will not be any physical or biological barriers that delay or prevent movement of smolts through the action area. As such, effects of construction on PBF M4 will be extremely unlikely to occur and discountable. We do not anticipate any impacts to the functioning of PBF M4 in the Machias River portion of the action area during the 75-100 year life of the project.

As described above, the new bridge structure will block access to the majority of upstream migrating adults in the Middle River, with upstream passage expected to be limited to no more than one adult per year (who is then expected to return back to the Machias River after a short period of time). As such, we do not expect that any spawning, and therefore juvenile production, will occur in the Middle River during the 75-100 year life of the new structure. As such, the poor passage conditions expected at the new bridge will prevent the Middle River from functioning as a migration corridor for juvenile salmon. Therefore, the proposed action will negatively affect the function and conservation value of PBF M4 in the Middle River over the life of the project.

Summary of Effects of Proposed Activities on Atlantic salmon Critical Habitat

We have determined that during the construction period all effects to critical habitat will be insignificant or discountable. However, the presence and operation of the new structure and its tide gates will have long-term (i.e. the structural life of the structure) adverse effects on PBFs SR 1-7, M1, M2, and M4. Therefore, as not all effects of the proposed action on critical habitat in the action area are wholly beneficial, insignificant, or discountable, the proposed action is likely to adversely affect critical habitat in the action area. In the Integration and Synthesis section (8.0), we consider whether the adverse effects to critical habitat in the action area will appreciably diminish the conservation value of the critical habitat designated within the Downeast Coastal SHRU. We then consider whether the action will destroy or adversely modify the critical habitat designated for the Gulf of Maine DPS.

6.3 Consideration of Effects of the Action in the Context of Anticipated Climate Change

More extreme precipitation, extremes in river flows, higher water temperatures, and higher sea levels and storm surges will impact the proposed Machias Dike Bridge structure, as well as the operation of tide gates (Bufas et al. 2023), in addition to altering the flow rates between the Machias River and Middle River. As described in the BA, the proposed tide gates will be placed on the downstream side of the new culvert structures and hinged at the top. Therefore, when the water elevation in the Machias River is greater than the Middle River impoundment, the gates will be shut, and tidal water will be prevented from flowing upstream of the dike. When the water elevation in the Machias River is lower than the Middle River impoundment, the gates will open and allow water to flow into the Machias River estuary. Predicted future sea levels will be greater than current tidal heights such that the proposed tide gates will remain in the closed position longer than the designed operation when they were constructed. This change in the operational design of the tide gates and dike structure will presumably affect the habitat conditions in the Middle River upstream of the dike structure. For example, less downstream flow through the tide gates will exacerbate the aquatic conditions in the Middle River as air and water temperatures increase due to climate change (Easterling et al. 2017). Furthermore, more extreme precipitation is projected for Maine with corresponding higher air temperature, which will result in higher maximum peak river flows and flooding (Hodgkins and Dudley 2013; Demaria et al. 2016; Hayhoe et al. 2007). This can have profound effects in the Middle River if the tide gates are closed more frequently due to higher sea levels in the future. The tide gates and dike structure will effectively act as a restriction to downstream flow during high flood elevations in the Middle River, and will exacerbate floods, erosion, and scour of habitats upstream and downstream of the structure and could result in increased effects to critical habitat.

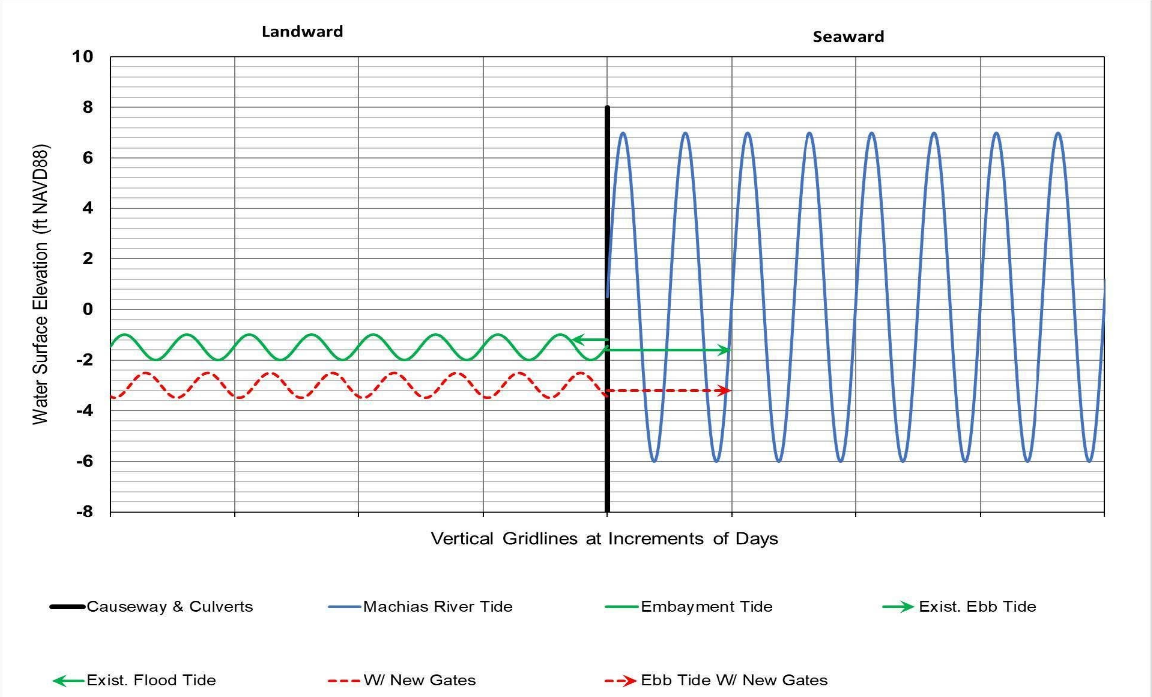

Figure 15. Comparison of tidal height elevations at Machias Dike Bridge between existing structure and proposed new replacement structure (Stantec memo 12-20-2020).

A study sponsored by MaineDOT (Douglas et al. 2013) evaluated the projected impacts of SLR and inland flooding on the Machias Dike Bridge alternatives (i.e., in kind replacement and span bridge design). The analysis assumed wave action in the project area is 1.0 foot and that all storm surges occurred at Mean Higher High Water (MHHW), which was 7.44 feet (North American Vertical Datum) NAVD at the time of the study. As shown in Table 13 below, this report found the simulated elevation for the 20-year and 100-year storm surge events at high tide for a low SLR scenario (+1.0 ft.) for 2050 is approximately 14.2 ft. and 16.48 ft. NAVD, respectively. Therefore, these analyses indicate a 20-year and 100-year storm surge, combined with a low SLR scenario for 2050, would exceed the proposed elevation of the Phase 1 roadway (13.1 ft. NAVD) at MHHW by approximately 1.1 ft. and 3.38 ft., respectively. Using a high SLR scenario for 2050 (+1.7 ft.), the projected 20-year and 100-year storm surge would exceed the proposed Phase 1 roadway elevation at MHHW by 1.8 ft. and 4.08 ft., respectively.

Table 14. Storm surge and projected SLR for 2050 (adapted from Douglas et al. 2013)

Storm surge return period (yrs.)	Surge height (ft.)	Existing MHHW (ft. NAVD)	Wave height (ft.)	Low (+1.0 ft.) SLR elevation (ft. NAVD)	Low SLR + storm surge bridge exceedance (ft.) relative to 13.1 ft. NAVD elevation	High (+1.7 ft.) SLR elevation (ft. NAVD)	High SLR + storm surge bridge exceedance (ft.) relative to 13.1 ft. NAVD elevation
20	4.76	7.44	1.0	14.2	+1.1	14.9	+1.8
100	7.04	7.44	1.0	16.48	+3.38	17.18	+4.08

However, as shown in Table 14, the projected SLR for all scenarios increases non-linearly over the latter half of the 21st century, which indicates far greater inundation of the proposed dike structure after 2050. Assuming a lifespan of 75-100 years, future SLR could exceed the elevation of the proposed dike structure exposed to storm surge far greater than the 2050 projections.

In summary, it is important to emphasize that these analyses suggest the proposed project could be subjected at least once to a 20-year storm surge between construction and the year 2050, and the Machias Dike and roadway would be inundated for both the low and high SLR scenario projections used in the Douglas et al. (2013) study. Over the expected life of the proposed project, the combined effects of higher sea levels and storm surge will repeatedly inundate the proposed dike structure and increase the wave energy environment reflected from the structure onto the banks and the intertidal and subtidal habitats of the Machias and Middle Rivers (Figure 15 & Table 14).

Increased tidal height could alter the operation of the tide gate over the life of the project such that opportunities for fish passage may change, these effects would be the most significant during certain tide stages during the ebb and flood tides (Figure 15). Furthermore, wave energy on the structure can scour and erode vegetated habitats and unvegetated habitats in the subtidal and intertidal zones, which would result in changing passage conditions due to access at the culvert structure at certain tide stages during ebb and flood tides (Figure 15). Currently, the outlet of the existing structure is a barrier to passage at different times during the incoming and outgoing tides (Photo 1).

Specifically, over the expected design life of the project (~75 - 100 years), sea level is projected to increase in this area (Eastport, Maine) under a 1.0 and 2.0 global SLR scenario by 2100 by about 4.0 and 8.9 feet, respectively (Sweet et al. 2017). According to information provided by

MaineDOT, the proposed finished grade of the causeway is between 11.1 feet and 11.9 feet NAVD88, and the existing MHHW line is 7.4 feet NAVD88. This provides an approximate 4-foot freeboard on the highest average high tides in 2020. However, if the 4.0-foot SLR scenario occurs, the freeboard will be eliminated altogether, and under an 8.9- foot SRL scenario, the proposed structure would be inundated by almost 5 feet of water on the highest average high tides. Neither of these SLR projections accounts for higher water levels from spring tides or storm surge that occur multiple times per year.

Based on the available information, it appears that the planned structure may not be resilient to anticipated changes in the action area due to climate change. However, it is difficult to predict how the potential for fish passage through the structure, which we expect to be extremely limited, will be affected by climate change. It is also difficult to predict whether there would be any different effects to critical habitat. At this time, the best available information does not allow us to predict any different effects to Atlantic salmon or their critical habitat that would be reasonably certain to occur, other than those addressed above.

7. CUMULATIVE EFFECTS

Cumulative effects are defined in 50 CFR §402.02 as those effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation. The effects of future state and private activities in the action area that are reasonably certain to occur are continuation of recreational fisheries and the discharge of pollutants. It is important to note that the definition of "cumulative effects" in the section 7 regulations is not the same as the National Environmental Policy Act definition of cumulative effects.

Impacts to Atlantic salmon from non-federal activities are largely unknown within the action area. Pollution from point and non-point sources has been a major problem in the Machias and Middle Rivers, which continues to receive discharges from landfills in the watershed (PFAS, metals, dioxin, dissolved solids, phenols, and hydrocarbons), in addition to landowners which are adjacent to the Middle River wetlands that will continue to discharge nutrients from septic systems. Atlantic salmon are vulnerable to impacts from pollution and are likely to continue to be impacted by water quality impairments in the Machias River and its tributaries.

Sources of contamination in the action area include atmospheric loading of pollutants, stormwater runoff from residential development and roads, landfill, groundwater discharges, and industrial development. Chemical contamination may have an effect on listed species reproduction and survival. As noted above, impacts to listed species from all of these activities are largely unknown. However, we have no information to suggest that the effects of future activities in the action area will be any different from effects of activities that have occurred in the past.

8. INTEGRATION AND SYNTHESIS OF EFFECTS

The *Integration and Synthesis* section is the final step in our assessment of the effects and corresponding risk posed to ESA-listed species and designated critical habitat affected as a result of implementing the proposed action. In Section 3, we determined that the project may affect, but is not likely to adversely affect the Gulf of Maine or New York Bight DPS of Atlantic sturgeon. Those species for which we reached a "not likely to adversely affect" conclusion are addressed in Section 3.1of the federal Endangered Species Act and its implementing regulations.

In addition, we use the following guidance and regulatory definitions related to survival and recovery to guide our jeopardy analysis. In the NMFS/USFWS Section 7 Consultation Handbook (1998), for the purposes of determining whether jeopardy is likely, survival is defined as, "the species' persistence as listed or as a recovery unit, beyond the conditions leading to its endangerment, with sufficient resilience to allow for the potential recovery from endangerment. Said in another way, survival is the condition in which a species continues to exist into the future while retaining the potential for recovery. This condition is characterized by a species with a sufficient population, represented by all necessary age classes, genetic heterogeneity, and number of sexually mature individuals producing viable offspring, which exists in an environment providing all requirements for completion of the species' entire life cycle, including reproduction, sustenance, and shelter." Recovery is defined in regulation as, "Improvement in the status of listed species to the point at which listing is no longer appropriate under the criteria set out in Section 4(a)(1) of the Act" (50 C.F.R. §402.02).

The 2019 Recovery Plan projects four phases of recovery over a 75-year timeframe to achieve delisting of the GOM DPS of Atlantic salmon. The four phases of recovery are:

- Phase 1: The first recovery phase focuses on identifying the threats to the species and characterizing the habitat needs of the species necessary for their recovery.
- Phase 2: The second recovery phase focuses on ensuring the persistence (survival) of the GOM DPS through the use of the conservation hatcheries while abating imminent threats to the continued existence of the DPS. Phase 2 focuses on freshwater habitat used by Atlantic salmon for spawning, rearing, and upstream and downstream migration; it also emphasizes research on threats within the marine environment.
- Phase 3: The third phase of recovery will focus on increasing the abundance, distribution, and productivity of naturally reared Atlantic salmon. It will involve transitioning from dependence on the conservation hatcheries to wild smolt production.
- Phase 4: In Phase 4, the GOM DPS of Atlantic salmon is recovered and delisting occurs. The GOM DPS will be considered recovered once: a) 2,000 wild adults return to each SHRU, for a DPS-wide total of at least 6,000 wild adults; b) each SHRU has a population growth rate of greater than 1.0 in the 10-year period preceding delisting, and, at the time of delisting, the DPS demonstrates self-sustaining persistence; and c) sufficient suitable spawning and rearing habitat for the offspring of the 6,000 wild adults is accessible and distributed throughout the designated Atlantic salmon critical habitat, with at least 30,000 accessible and suitable habitat units in each SHRU, located according to the known migratory patterns of returning wild adult salmon.

We are presently in Phase 2 of our recovery program (ensuring the survival of the GOM DPS through the use of the conservation hatcheries while abating imminent threats to the continued existence of the DPS). As indicated in the 2019 Recovery Plan for Atlantic salmon, the Services do not have plans to transition from dependence on conservation hatcheries to wild fish production in the foreseeable future. Therefore, for purposes of this analysis, we assume hatchery supplementation will continue in the Downeast Coastal SHRU over the life of the proposed action.

GOM DPS Atlantic salmon currently exhibit critically low spawner abundance, poor marine survival, and are confronted with a variety of additional threats. The abundance of GOM DPS Atlantic salmon has been low and either stable or declining over the past several decades. The proportion of fish that are of natural origin is extremely low. The very low population sizes constitutes a significant risk to the resiliency of the species through increasing losses in genetic fitness, loss of adaptive traits, and reduced ability to withstand catastrophic events. The conservation hatchery program assists in slowing the decline and helps stabilize populations at low levels, but has not contributed to an increase in the overall abundance of salmon and has not been able to halt the decline of the naturally reared component of the GOM DPS. As described in the 5-Year Review for the Gulf of Maine DPS (NMFS and UFWS 2020), the demographic risk for the DPS is "high."[9] There is also new information indicating genetic bottlenecks as well as low levels of inbreeding. However, the recovery potential is considered high.

8.1 Gulf of Maine DPS of Atlantic Salmon

We determined that all effects of construction would be insignificant or discountable. However, the new structure will impede passage of Atlantic salmon into the Middle River and will largely be a barrier to passage. Over the long-term existence of the new structure (75-100 years), we expect that no more than one adult Atlantic salmon will pass through the new tide gates annually. As explained in section 6.1, adults that move upstream through the culvert are expected to experience minor injury. Passage into the Middle River will also result in delays to migration to upstream spawning habitat in the Machias River. As explained in section 6.1.4, we determined that the effect of this delay meets the definition of harassment but not harm, in the context of take as defined under the ESA.

When considering whether the proposed action is likely to reduce appreciably the likelihood of both the survival and recovery of a species, we consider how the proposed action will affect its numbers, reproduction, or distribution. The jeopardy analysis makes a conclusion regarding the survival and recovery of the GOM DPS of Atlantic salmon as a whole, and not just survival and recovery of the species in the action area. Therefore, we consider how the effects to individual salmon that were identified in the *Effects of the Action* section of this Opinion will affect the Machias River watershed population of Atlantic salmon, how the effects to the Machias River population will affect the Downeast Coastal SHRU, and then finally, how the effects to the Downeast Coastal SHRU are likely to affect the survival and recovery of the GOM DPS as a whole. As highlighted in the 2019 Recovery Plan, the survival and recovery of the Downeast

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[9] 84 FR 18243; April 30, 2019 - Listing and Recovery Priority Guidelines.

Coastal SHRU is necessary for attainment of the delisting criteria and recovery of the GOM DPS.

The number of returning adult Atlantic salmon to the Downeast Coastal SHRU is a measure of both the reproduction and numbers of the species. We consider the ability of prespawn Atlantic salmon to access high quality spawning and rearing habitat in all the rivers of the Downeast Coastal SHRUs as a measure of distribution. Below, we analyze whether the proposed action (FHWA's funding of a new in kind bridge structure on the Middle River) will reduce the reproduction, numbers, or distribution of the Atlantic salmon in the action area and the Downeast Coastal SHRU to a point that appreciably reduces the species likelihood of survival in the wild.

The proposed action will not result in the mortality of any Atlantic salmon. Effects to the numbers, reproduction, and distribution of Atlantic salmon will occur as a result of the loss of the potential for the habitat in the Middle River to support spawning and rearing which could result in a reduction in numbers, reproduction, and distribution compared to a hypothetical future in which there was no barrier to passage in the Middle River. The Machias River watershed contains 15,927 modeled rearing habitat units, of which only 259 (1.6%) occur within the Middle River (Wright et al. 2008). As such, the Middle River represents a very small portion of the available habitat in the Machias River watershed, and could produce a limited number of juveniles, which would contribute a very small number of outmigrating smolts, and an even smaller number of returning adults. Field assessments conducted in the Machias have confirmed that the watershed contains approximately 450 habitat units of spawning habitat (MDMR 2017). That suggests that approximately 3% (i.e., 450/15,927) of the modeled rearing habitat is useable for spawning. Lacking any specific available information on the spawning habitat in the Middle River, we can reasonably assume that the proportion of habitat used for spawning is similar to what occurs in other parts of the Machias watershed. As such, we estimate that there are approximately 8 units (i.e., 3% of 259 rearing units) of spawning habitat upstream of the bridge in the Middle River. Given this small amount of habitat (roughly 1.8% of what occurs in the Machias as a whole), we expect that the number of adults that could be produced as a result of spawning and rearing in this habitat would be very small (likely no more than a few individuals a year). As such, we expect that the long term blockage of the Middle River to Atlantic salmon will result in a very small decrease in numbers, reproduction, and distribution of Atlantic salmon in the Machias River watershed compared to a future without a barrier to passage. It is also important to note that these theoretical reductions would likely occur only if spawning and rearing habitat in the Machias River was fully saturated and optimized, which it is not. Given the small scale of the Middle River compared to abundant habitat in the Machias River and the other Downeast rivers (which contain 54,933 habitat units), we do not anticipate the action leading to a reduction in the numbers, reproduction, or distribution of salmon in the Middle River watershed that would be significant to the Downeast Coastal SHRU, or the Gulf of Maine DPS as a whole. That is, we expect the reduction in numbers, reproduction, and distribution resulting from a continued lack of reproduction in the Middle River compared to a future without a barrier to passage, would not result in a meaningful or detectable effect on the resilience or status of the Downeast Coastal SHRU or the Gulf of Maine DPS as a whole.

Based on the information provided above, including the consideration of the non-lethal effects to Atlantic salmon, the proposed project will not appreciably reduce the likelihood of survival of the Gulf of Maine DPS (i.e., it will not decrease the likelihood that the species will continue to persist into the future with sufficient resilience to allow for the potential recovery from endangerment). The action will not affect GOM DPS Atlantic salmon in a way that prevents the species from having a sufficient population, represented by all necessary age classes, genetic heterogeneity, and number of sexually mature individuals producing viable offspring, and it will not result in effects to the environment which would prevent Atlantic salmon from completing their entire life cycle, including reproduction, sustenance, and shelter.

In certain instances, an action may not appreciably reduce the likelihood of a species survival (persistence) but may affect its likelihood of recovery or the rate at which recovery is expected to occur. As explained above, we have determined that the proposed action will not appreciably reduce the likelihood that Atlantic salmon will survive in the wild. Here, we consider the potential for the action to reduce the likelihood of recovery. As noted above, recovery is defined as the improvement in status such that listing is no longer appropriate. Thus, we have considered whether the proposed actions will affect the likelihood that the GOM DPS of Atlantic salmon can rebuild to a point where listing is no longer appropriate. As noted above, in 2019, NMFS and the USFWS issued a recovery plan for the GOM DPS (NMFS and USFWS 2019). The plan includes recovery criteria for the DPS as well as recovery actions to reduce threats.

As described above, the condition of the GOM DPS of Atlantic salmon is dire. Adult return rates continue to be extremely low, and it is unlikely that the species can recover unless there is a significant improvement in both marine and freshwater survival. At existing freshwater and marine survival rates (the medians have been estimated by NMFS as 1.1% and 0.5%, respectively), it is unlikely that Atlantic salmon will be able to achieve recovery. A significant increase in either one of these parameters (or a lesser increase in both) will be necessary to overcome the significant obstacles to recovery. We have created a conceptual model to indicate how marine and freshwater survival rates would need to change in order to recover Atlantic salmon (NMFS 2010). In Figure 16, the dot represents current marine and freshwater survival rates, whereas the curved line represents all possible combinations of marine and freshwater survival rates that would result in a stable population with a growth rate of zero. If survival conditions are above the curved line, the population is growing, and, thus, trending towards recovery (lambda greater than one). The straight lines indicate the rates of freshwater survival that have been historically observed (Legault 2004). This model indicates that there are many potential routes to recovery; for example, recovery could be achieved by significantly increasing the existing marine survival rate while holding freshwater survival at existing levels, or, conversely, by significantly increasing freshwater survival while holding marine survival at today’s levels. Conceptually, however, the figure makes clear that an increase in both freshwater and marine survival will lead to the shortest path to achieving a self-sustaining population that is trending towards recovery.

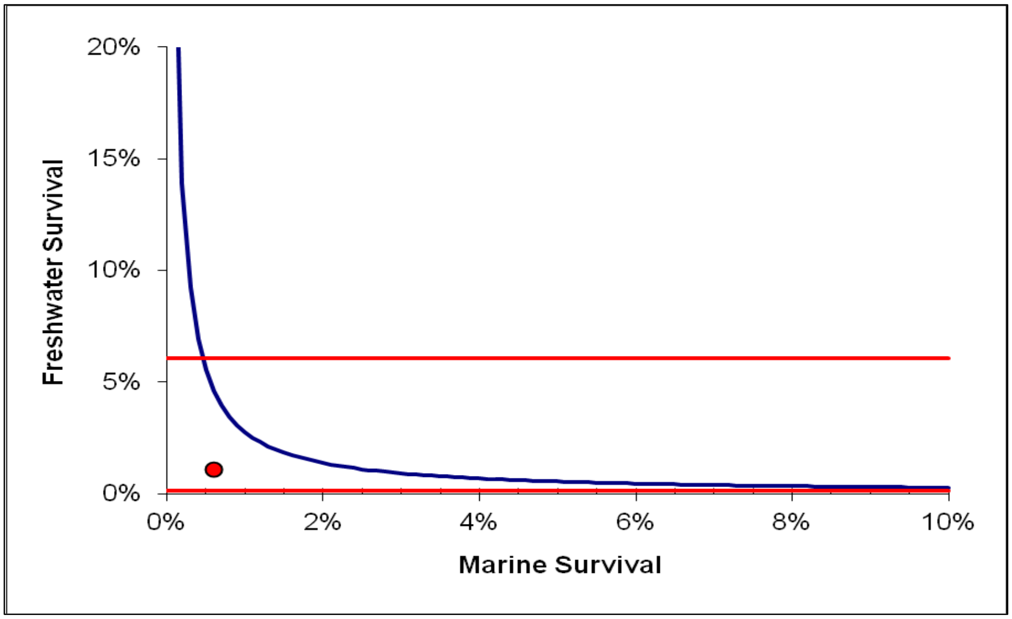

Figure 16. NMFS (2010) conceptual model depicting marine and freshwater survival relative to recovery of the GOM DPS of Atlantic salmon (Note: The dot represents current conditions, the curved line represents recovery, and the straight lines are the historic maximum and minimum freshwater survival).

As explained above, the proposed action will result in a temporary behavioral disturbance of up to one adult annually and a long term effect by creating a barrier to upstream migration which will prevent future spawning in the Middle River. The replacement of the Machias Dike Bridge including tide gates will impede passage for Atlantic salmon to modeled spawning and rearing critical habitat in the Middle River, thus decreasing the productivity of vacant habitat. Furthermore, maintaining this barrier would decrease the amount of accessible habitat that could lead to a greater distribution of Atlantic salmon juveniles. However, the amount of modeled spawning and rearing habitat within the action area is very small (10 units). The modeled spawning and rearing habitat in the Middle River outside of the action area is approximately 249 units and would produce a limited number of juveniles, which would contribute a very small number of smolts. Thus, the potential contribution of salmon from the Middle River on the Downeast Coastal SHRU and the DPS as a whole is very small and unlikely to affect the rate or ability at which the downlisting or delisting goals outlined in the 2019 Recovery Plan could be met.

This action will not change the status or trend of the Gulf of Maine DPS. The effects on distribution will be limited to the action area and will not be significant to the SHRU or DPS and will not affect the distribution of the Gulf of Maine DPS across the historical range. The proposed action will not result in mortality and will not impair the species' resiliency, genetic diversity, recruitment, or year class strength. For these reasons, the action will not reduce the likelihood that the Gulf of Maine DPS can recover. Therefore, the proposed action will not appreciably reduce the likelihood that the Gulf of Maine DPS of Atlantic salmon can be brought to the point at which they are no longer listed as threatened; that is, the proposed action will not appreciably reduce the likelihood of recovery of the Gulf of Maine DPS.

Based on the analysis presented herein, the effects of the proposed action are not likely to appreciably reduce the likelihood of both the survival and recovery of the Gulf of Maine DPS of Atlantic salmon. These conclusions were made in consideration of the endangered status of the Gulf of Maine DPS of Atlantic salmon, the effects of the action, other stressors that individuals are exposed to within the action area as described in the *Environmental Baseline* and *Cumulative Effects*, and any anticipated effects of climate change.

8.2 Critical Habitat Designated for the Gulf of Maine DPS of Atlantic Salmon

As explained in Section 6, we have determined that the proposed action will adversely affect critical habitat designated for the GOM DPS of Atlantic salmon in the action area. Specifically, we expect adverse effects to: PBFs M1-2, and M4 (i.e., Freshwater and estuary migratory sites free from physical and biological barriers that delay or prevent access of adult salmon seeking spawning grounds needed to support recovered populations), and PBFs SR 1-7 (i.e., spawning and rearing sites to promote successful spawning and with space to accommodate growth and survival of Atlantic salmon eggs, fry and parr), that are present in the action area. The proposed new structure will limit the ability of salmon to move into the Middle River and will affect critical habitat upstream in the Middle River by creating an impounded area that will impact stream function. As described above, these effects reduce the function and conservation value of critical habitat in the action area.

Here, we consider whether the proposed action, in the context established by the status of the species, environmental baseline, and cumulative effects, is likely to result in destruction or adverse modification of critical habitat designated for the Gulf of Maine DPS of Atlantic salmon. For the critical habitat that may be affected by the proposed action, we summarize the status of the critical habitat and its essential physical and biological features (PBFs) and consider whether the proposed action will appreciably diminish the value of the critical habitat designated for the Downeast Coastal SHRU and then consider the impacts at the scale of the entirety of the critical habitat designated for the GOM DPS of Atlantic salmon.

On February 11, 2016, NMFS and U.S. FWS published a revised regulatory definition of "destruction or adverse modification" (81 FR 7214). Destruction or adverse modification "means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species or that preclude or significantly delay development of such features." As described in the preamble to the proposed rule for the revised definition (79 FR 27060, May 12, 2014), the ''destruction or adverse modification'' definition focuses on how federal actions affect the quantity and quality of the physical or biological features in the designated critical habitat for a listed species and, especially in the case of unoccupied habitat, on any impacts to the critical habitat itself. Specifically, the Services will generally conclude that a federal action is likely to ''destroy or adversely modify'' designated critical habitat if the action results in an alteration of the quantity or quality of the essential physical or biological features of designated critical habitat, or that precludes or significantly delays the capacity of that habitat to develop those features over time, and if the effect of the alteration is to appreciably diminish the value of critical habitat for the conservation of the species.

The action area overlaps critical habitat designated in the Middle River, a tributary to the Machias River, and a small portion of the Machias River estuary. The Middle River portion of the action area contains a small amount of modeled rearing habitat (10 units) that is not fully functioning and is not accessible due the operation of the tide gates. In addition, there are approximately 249 units of modeled rearing habitat in the tributary streams and main stem of the Middle River outside of the action area, which equates to approximately 0.5% (259 units in the Middle River/54,933 units in the Downeast SHRU = 0.5%) of the modeled rearing habitat in the Downeast Coastal SHRU.

The in kind replacement of the Machias Dike Bridge with tide gates would continue to degrade aquatic habitat in the impounded reach above the causeway and significantly impede fish passage into the Middle River for the foreseeable future. Our 2019 Recovery Plan for the GOM DPS identifies a number of recovery criteria that must be achieved before we can consider downlisting Atlantic salmon to threatened or removing the species from the endangered species list. One criterion for recovery is having 30,000 units of suitable rearing habitat fully accessible in the Downeast SHRU. If fully accessible, the Middle River would provide up to 259 units of rearing habitat for Atlantic salmon.

As explained in Section 6.4, we have determined that the action (e.g., in-kind replacement of Machias Dike Bridge and long term operation of the tide gates) is likely to adversely affect PBFs M1-2, M4, and SR1-7. Here, we summarize those adverse effects and consider whether the adverse effects to the PBFs in the action area result in a direct or indirect alteration of the critical habitat that appreciably diminishes the value of critical habitat for the conservation of the Gulf of Maine DPS of Atlantic salmon (i.e., we determine whether the proposed action is likely to result in the destruction or adverse modification of critical habitat). This analysis takes into account the geographic and permanent scope of the proposed action, recognizing that "functionality" of critical habitat necessarily means that it must now and must continue in the future to support the conservation of the species and progress toward recovery. The analysis takes into account any changes in amount, distribution, or characteristics of the critical habitat that will be required over time to support the successful recovery of the species. Destruction or adverse modification does not depend strictly on the size or proportion of the area adversely affected, but rather on the role the action area and the affected critical habitat serves with regard to the function of the overall critical habitat designation, and how that role is affected by the action.

Designated critical habitat within the Middle River contains the essential features of both spawning and rearing, as well as migratory PBFs. Some of these features in the action area have been impacted by the placement of the Machias Dike Bridge and associated water conveyance structures (culverts/tidegates) that limit the amount of tidal exchange occurring daily. Other areas of designated critical habitat outside of the action area that have not been impacted by the restricted flows have features that are fully functional and would support various life stages of Atlantic salmon. However, the amount of modeled CH upstream of the Machias Dike Bridge outside of the action area is very limited (249 units), and we would anticipate if it were accessible it could provide opportunities for spawning and rearing for only a few individuals. It would also provide a potential for increased production of coevolved diadromous species that would increase the conservation value of this habitat (assuming other barriers at Marks Pond are addressed). We would expect some beneficial effects to the Machias River as well through increased production of diadromous fish contributing to a robust fish community in the lower Machias River estuary.

The small amount of critical habitat (10 units) that is directly impacted by the Machias Dike Bridge has been diminished to the point that it is not fully functioning. As discussed throughout this Opinion, the PBFs within the action area would continue to be impacted over the life of the project (i.e.., 75-100 years) and any effects to the essential features would decrease the potential to support various life stages of Atlantic salmon.

Overall, the Middle River may have played a significant role in the production of diadromous fish since it is a tributary positioned in the lower Machias River, below Bad Little Falls, that has sufficient habitat to support a robust diadromous fish community. However, there is a very limited amount of critical habitat for Atlantic salmon as compared to what is available in the Machias River. This critical habitat could support a slight increase in juvenile fish if it was occupied. Further, since there is sufficient accessible critical habitat within the Machias River that is of good quality and fully functional, the habitat within the Middle River does not play a crucial role in supporting the Machias River population or the larger Downeast Coastal SHRU or recovery of the GOM DPS of Atlantic salmon.

Here, we consider the reduction in access to rearing habitats upstream of the Machias Dike Bridge in the context of the conservation value provided by the critical habitat in the Downeast Coastal SHRU to determine if this reduction in access (which we consider to equate to a reduction in quality of the critical habitat within the Middle River) appreciably diminishes the value of critical habitat for the conservation of the species. In our analysis of accessibility of the critical habitat in the Middle River for adult Atlantic salmon, we determined that adults could potentially pass upstream into the Middle River during a very limited time period when conditions align, which is expected to result in opportunities for passage being intermittent and opportunistic. This impeded access would directly affect migration and could cause delays to individuals seeking spawning habitat in the Middle River. Since the rearing habitat is not fully accessible, the full potential of this habitat to rear juveniles would be reduced. Additionally, the operation of the tide gates would directly affect the PBFs of a small portion (10 units) of this habitat because they would be physically altered. If access to critical habitat in the Middle River was restored, the conservation value of this habitat would be increased. While the action will adversely affect the critical habitat features in the action area, critical habitat features outside of the action area will not be affected. Therefore, we have determined that the reduction in the conservation value of the PBFs M1-2, M4, and SR 1-7 in the Middle River, through impeded access to rearing habitat will not appreciably diminish the value of critical habitat for the Downeast Coastal SHRU because: 1) the action will only reduce the quality of a very small amount of rearing habitat (<0.5% of the habitat in the SHRU) by limiting access; 2) the effects of the action are limited to the Middle River and a small portion of the Machias River estuary, and will have no effect on the value of critical habitat in the rest of the Downeast Coastal SHRU or in any other SHRUs; and, 3) the action will not significantly interfere with achieving the objectives outlined in the 2019 Recovery Plan.

Therefore, because the adverse effects to the PBFs of critical habitat in the action area will not appreciably diminish the value of critical habitat for the conservation of the Downeast Coastal SHRU, it is not likely to result in the destruction or adverse modification of critical habitat designated for the Gulf of Maine DPS of Atlantic salmon.

9. CONCLUSION

After reviewing the best available information on the status of endangered and threatened species and their designated critical habitat under our jurisdiction, the environmental baseline within the action area, the effects of the proposed action, and cumulative effects, it is our biological opinion that the proposed action is likely to adversely affect but is not likely to jeopardize the continued existence of the Gulf of Maine DPS of Atlantic salmon and may affect, but not likely to adversely affect shortnose sturgeon, or the Gulf of Maine DPS of Atlantic sturgeon. The proposed action may adversely affect, but is not likely to destroy or adversely modify or critical habitat designated for the Gulf of Maine DPS of Atlantic salmon.

10. INCIDENTAL TAKE STATEMENT

Section 9 of the ESA prohibits the take of endangered species of fish or wildlife, without a permit or exemption. “Take” is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm, as explained above, is further defined by regulation to include significant habitat modification or degradation that results in death or injury to ESA listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. NMFS has not defined “harass” under the ESA in regulation, but has issued interim guidance on the term “harass,” defining it as to “create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering” (NMFS PD 02-110-19). We considered NMFS’ interim definition of harassment in evaluating whether the proposed activities are likely to result in harassment of ESA listed species.

Incidental take statements serve a number of functions, including providing reinitiation triggers for all anticipated take, providing exemptions from the Section 9 prohibitions against take for endangered species and from any prohibition on take extended to threatened species by 4(d) regulations, and identifying reasonable and prudent measures with implementing terms and conditions that will minimize the impact of anticipated incidental take and monitor incidental take that occurs. The measures described below must be undertaken by FHWA so that they become binding conditions for the exemption in section 7(o)(2) to apply. FHWA has a continuing duty to regulate the activity covered by this Incidental Take Statement. If the FHWA: 1) fails to assume and implement the terms and conditions or; 2) fails to require the project sponsor or their contractors to adhere to the terms and conditions of the Incidental Take Statement through enforceable terms that are added to grants, permits and/or contracts as appropriate, the protective coverage of section 7(o)(2) may lapse. The protective coverage of section 7(o)(2) also may lapse if the project sponsor fails to comply with the terms and conditions and the minimization and mitigation measures included in the ITS as well as those described in the proposed action and set forth in Section 2 of this opinion as we consider those measures necessary and appropriate to minimize take but have not restated them here for efficiency. In order to monitor the impact of incidental take, FHWA or MaineDOT must report the progress of the action and its impact on the species to us as specified in the Incidental Take Statement [50 CFR §402.14(i)(3)] (See U.S. Fish and Wildlife Service and National Marine Fisheries Service's Joint Endangered Species Act Section 7 Consultation Handbook (1998) at 4-49).

10.1 Amount or Extent of Take

Section 7 regulations require NMFS to specify the impact of any incidental take of endangered or threatened species; that is, the amount or extent of such incidental taking on the species (50 C.F.R. §402.14(i)(1)(i)). As explained in the Effects of the Action section, we anticipate the presence and operation of the new Machias Dike Bridge to result in the minor injury and harassment of up to one adult Atlantic salmon per year over the life of the structure. No harm, serious injury, or mortality is anticipated or exempted. No incidental take of any Atlantic salmon is expected to result as a consequence of exposure to effects of construction; no such take is exempted by this ITS.

We have determined that due to the effects of the project (i.e., the almost complete blockage of passage due to the construction and operation of the tide gates) that Atlantic salmon passage into the Middle River will only occur incidentally (i.e., no more than one salmon a year), and that salmon that pass upstream will experience minor injury, including scale loss, as well as migratory delay (i.e., they need to wait for the tide gates to reopen and for passage conditions to be conducive prior to moving back downstream). Passage at this site is difficult to monitor due to the relatively small number of salmon in the drainage, as well as a lack of radio tagged fish. There is also no practicable means to monitor and document the number of salmon moving through the culverts. For example, given the in-water conditions, we do not expect that video or other in-water monitoring would be reliable. We also considered whether receivers or detectors could be placed to document tagged fish; however, there are so few adult salmon in the watershed and very few, if any, of those are tagged, making this also an unreliable monitoring method.

In circumstances where we cannot effectively monitor take, we use a surrogate to estimate its extent. As described in 80 FR 26832 (June 10, 2015) a surrogate may be used to express the amount or extent of anticipated take when the incidental take statement: 1) Describes the causal link between the surrogate and take of the listed species; 2) describes why it is not practical to express the amount of anticipated take or to monitor take-related impacts in terms of individuals of the listed species; and 3) sets a clear standard for determining when the amount or extent of the taking has been exceeded. The surrogate identified here are the conditions that allow for passage of adult Atlantic salmon, which is how we determined the take estimate (no more than 1 salmon per year that remains in the Middle River for more than 48 hours). For the purpose of this surrogate we define the necessary passage conditions for salmon to include the periods when the tide gates are open and: 1) velocity through the culvert of less than 12 feet per second; <u>and;</u> 2) water depths in the culvert greater than 6 inches. As explained above, we expect such conditions to be intermittent and unlikely to occur for more than an hour on any given day. We will consider take to have been exceeded if the conditions that we have determined would allow for passage occur for a cumulative period of more than an average of one hour in a 24-hour period. The hydraulic conditions through the box culverts with tide gates are directly linked to the likelihood of passage at the project. The defined depth and velocity is expected to be necessary for passage to occur and is the basis for our estimate of take; therefore, there is a causal relationship. Above, we described why it is not practical to monitor take in terms of individual Atlantic salmon. Term and Condition 4(b) (the requirement to monitor hydraulic conditions at the project) will provide the information necessary to monitor this surrogate and will provide the basis for determining when the amount or type of take has been exceeded.

10.2 Effects of the Take

In this opinion, we determined that the amount or extent of anticipated take, coupled with other effects of the proposed action, is not likely to jeopardize the continued existence of any ESA listed species under NMFS' jurisdiction.

10.3 Reasonable and Prudent Measures and Implementing Terms and Conditions

Section 7(b)(4) of the ESA requires that when a proposed agency action is found to be consistent with section 7(a)(2) of the ESA and the proposed action is likely to incidentally take individuals of ESA listed species, NMFS will issue a statement that specifies the impact of any incidental taking of endangered or threatened species. To minimize such impacts, reasonable and prudent measures, and terms and conditions to implement the measures, must be provided. Only incidental take specified in this ITS that would not occur but for the agency actions described in this Opinion, and any specified reasonable and prudent measures and terms and conditions identified in the ITS, are exempt from the taking prohibition of section 9(a), provided that, pursuant to section 7(o) of the ESA, such taking is in compliance with the terms of the ITS. NMFS has determined that the RPMs identified here are necessary and appropriate to minimize impacts of incidental take that might otherwise result from the proposed action, to monitor, document, and report incidental take that does occur, and to specify the procedures to be used to handle or dispose of any individual listed species taken. These reasonable and prudent measures and terms and conditions are in addition to the minimization and avoidance measures incorporated into the proposed action. We have determined that all of the RPMs and Terms and Conditions are reasonable and prudent and necessary and appropriate to minimize or document and report the level of incidental take associated with the proposed action. None of the RPMs or the terms and conditions that implement them alter the basic design, location, scope, duration, or timing of the action and all of them involve only minor changes (50 CFR§ 402.14(i)(2)).

Reasonable and Prudent Measures

We have determined the following RPMs are necessary and appropriate to minimize, monitor, document, and report the impacts of incidental take of Atlantic salmon that occurs during implementation of the proposed action:

1. Effects to ESA listed species must be minimized and monitored during all phases of the proposed action.
2. Effects to, or interactions with, ESA listed species must be properly documented during all phases of the proposed action, and all incidental take must be reported to NMFS GARFO.

3. FHWA must exercise their authorities to assess and ensure compliance with the implementation of measures to avoid, minimize, monitor, and report incidental take of ESA listed species during activities described in this Opinion.

Terms and Conditions

To be exempt from prohibitions of section 9 of the ESA, the federal action agencies and MaineDOT (the project proponent and applicant) must comply with the following terms and conditions, which implement the reasonable and prudent measures described above. These include the minimization, monitoring, and reporting measures required by the Section 7 regulations (50 C.F.R. §402.14(i)). These Terms and Conditions are non-discretionary; that is, if the Federal agencies and/or MaineDOT fail to ensure compliance with these terms and conditions and the RPMs they implement, the protective coverage of Section 7(o)(2) may lapse. As noted above, these Terms and Conditions are in addition to the BMPs and AMMs that are part of the proposed action; thus, those measures are not repeated here.

1. To implement the requirements of RPM #1 and 2, FHWA must require, and MaineDOT must carry out, acoustic monitoring during a representative sample of pile driving activities. This must include monitoring of at least five sheet piles installed with a vibratory hammer and at least three pipe piles installed with a vibratory hammer and set with an impact hammer. At least 180 days prior to the planned start of pile driving, MaineDOT must submit the acoustic monitoring plan to NMFS for review and approval. This plan must describe the equipment that will be used and how MaineDOT will determine distances to the acoustic thresholds considered in the Opinion (i.e., the distances to injury and behavioral disturbance for both pile types).

    a. Interim monitoring reports must be submitted within 3 days of data collection for each pile monitored with a final report submitted within 45 days of completion of acoustic monitoring.

2. To implement the requirements of RPM #2, FHWA must require MaineDOT to implement the following reporting requirements necessary to document the amount or extent of incidental take that occurs during all phases of the proposed action. Unless otherwise specified all reports must be submitted to NMFS GARFO via e-mail (nmfs.gar.incidental-take@Noaa.gov).

    a. Notify NMFS GARFO PRD within 24 hours of the start of in-water work and again within 24-hours of the completion of all in-water work.

    b. All observations or interactions with ESA listed species that occur must be reported within 24 hours to NMFS GARFO Protected Resources Division by email (nmfs.gar.incidental-take@noaa.gov). Take reports should reference the Machias Dike Project and include the Take Report Form available on NMFS webpage (https://media.fisheries.noaa.gov/2021-07/Take%20Report%20Form%2007162021.pdf?null).

3. To implement the requirements of RPM #2, FHWA must require, and MaineDOT must submit the following information:

   a. Final construction plans, including a description of project staging, pile installation and removal schedules (including number and type of piles and anticipated duration of pile driving) including any changes to the BMPs or AMMs incorporated into the description of the proposed action.
   b. Final designs for the new structure including information on the tide gates, hydraulic designs, and anticipated flow through the structure across a tidal cycle.

   NMFS GARFO will review this information and, to the maximum extent practicable, within 10 business days of receipt will request a meeting with FHWA and MaineDOT if there is any indication that there are changes to the proposed action that would cause an effect to listed species or critical habitat that was not considered in this Opinion, including the amount or extent of predicted take, such that any potential trigger for reinitiation of consultation can be discussed with the relevant action agencies.

4. To implement the requirements of RPM # 1 and 2, FHWA must require, and MaineDOT must prepare and implement the following plans:
   a. *Operations and Maintenance of the New Structure*. This plan must address: inspection schedule, debris management, and routine maintenance and operations of the tide gates to ensure operation as designed over the life of the structure.
   b. *Monitoring of Hydraulic Conditions*. This plan must include measures to monitor hydraulics and flow (e.g., velocity and depth) over a range of tidal and seasonal conditions to demonstrate the frequency at which Atlantic salmon may be able to incidentally pass through the tide gates. This plan must be submitted for NMFS approval at least 180 days before planned completion of the construction and must be implemented in the first year of project operations. A draft report must be submitted to NMFS within 60 days of completion of the first year monitoring. Following review and comment from NMFS the report must be finalized.

11. CONSERVATION RECOMMENDATIONS

In addition to Section 7(a)(2), which requires agencies to ensure that all projects will not jeopardize the continued existence of listed species, Section 7(a)(1) of the ESA places a responsibility on all federal agencies to “utilize their authorities in furtherance of the purposes of this Act by carrying out programs for the conservation of endangered species.” Conservation Recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information. As such, we recommend that FHWA, consistent with their authorities, consider implementing the following Conservation Recommendations:

1. FHWA should require that the MaineDOT provide compensatory mitigation/offsets for unavoidable impacts to designated critical habitat for Atlantic salmon.
2. The uncertain performance of culverts, including tide gates, in passing diadromous species in Maine, especially endangered Atlantic salmon, requires more baseline

information and long-term monitoring to better understand the potential effects from extensive operation using a type of flow conveyance that has largely been untested in regards to passage efficiency for diadromous fish within the GOM DPS. Accordingly, the FHWA should require the MaineDOT to conduct an assessment of the current conditions following the Machias Dike Bridge completion to validate the assumptions of this Biological Opinion in regards to the long term effects to designated Critical Habitat in the Middle River and the potential to affect (i.e., significance of any delays) individual adult Atlantic salmon returning to the Machias River to spawn (e.g., passage opportunities into the Middle River). A comparative climate change assessment, including sea level rise projections and changes in extreme precipitation and peak flows, should also be conducted for this in kind replacement as it applies to the effectiveness of fish passage. As such, the MaineDOT shall evaluate conditions at the culvert replacement structure soon after construction (<1 year), both when flows are low and later at near normal flow conditions (e.g., about average annual minimum and average annual) and during the spring migration period of Atlantic salmon. Following that evaluation period, a report should be prepared with a summary of findings that provides information regarding fish presence at the outlet of the Middle River to determine the extent in which the tide gates limits access and causes significant delays to migrating adult Atlantic salmon. The evaluation should include stream flow and depth measurements and photos of the culvert inlet and outlet. Photos should be taken during the inspection to document characteristics of the culvert inlet(s), outlet(s), bed details, and the stream characteristics upstream and downstream from the Machias Dike Bridge. Any channel condition changes, including scour and bedload deposition in the stream above the project area, should be noted. Additionally, the assessment should include the characteristics of the substrate deposited around the structure (including type, size, depth, and relative amounts) for mobility. Based on the summary of findings, additional long-term monitoring needs should be evaluated to determine the extent fish passage conditions exist and if any delays are significantly affecting adult Atlantic salmon migrating into the Machias River.

3. Carry out an assessment of Atlantic salmon Critical Habitat above the Machias Dike Bridge to document;
    a. The existing amount and condition of PBFs to be able to evaluate any changes to the PBFs and the conservation value of this habitat.
    b. Any use of the habitat by adult Atlantic salmon such as conducting annual redd counts and follow up with a juvenile assessment if redds were observed.

12. REINITIATION NOTICE

This concludes formal consultation for FHWA’s proposed action to replace the Machias Dike Bridge. As 50 C.F.R. §402.16 states, reinitiation of formal consultation is required and shall be requested by the Federal action agency or by the Service, where discretionary Federal involvement or control over the action has been retained or is authorized by law and:

(1) If the amount or extent of taking specified in the incidental take statement is exceeded;
(2) If new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered;
(3) If the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion or

written concurrence; or,

(4) If a new species is listed or critical habitat designated that may be affected by the identified action.

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U.S. Department
of Transportation
**Federal Highway
Administration**

Maine Division

40 Western Ave, Rm 614
Augusta, ME 04330
207-622-8350

September 20, 2023

Sent Electronically

In Reply Refer To:
HDA-ME

Jennifer Anderson
Assistant Regional Administrator for Protected Resources
55 Great Republic Drive
NOAA Fisheries Office
Gloucester, MA 01930

Dear Ms. Anderson:

The purpose of this letter is to initiate formal consultation pursuant to Section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.) for a bridge replacement project that proposes to remove and replace Dike Bridge (Br. No. 2246) in Machias, Maine. The bridge replacement project is within the geographic range of three species and one designated critical habitat, all afforded protection under the ESA and within NOAA Fisheries jurisdiction.

On March 16, 2023, The Federal Highway Administration (FHWA) previously submitted a letter with an enclosed Biological Assessment (BA) requesting formal consultation. As a result of that submission, on April 14, 2023, via email, the National Marine Fisheries Service (NMFS) submitted comments and requested additional items necessary to begin consultation. On May 2, 2023, NMFS, MaineDOT, and FHWA discussed the submitted comments and requested items needed to begin formal consultation. Accordingly, the BA has been revised to appropriately incorporate NMFS's comments and address the requested items, which include the proposed action and its potential to affect three ESA-listed species: endangered shortnose sturgeon (*Acipenser brevirostrum*), threatened Gulf of Maine (GOM) Distinct Population Segment (DPS) as well as the endangered New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs of Atlantic sturgeon of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), and the endangered GOM DPS of Atlantic salmon (*Salmo salar*).

On June 23, 2023, the FHWA re-submitted the BA requesting formal consultation. As a result of that submission, on August 7, via email, the NMFS submitted comments and requested additional items necessary to begin consultation. Thus, FHWA, with MaineDOT assistance, has revised the BA to properly incorporate and consider all effects of the action directly and indirectly affecting listed ESA species and their critical habitat during and following construction. All effects and/or stressors have been included in the description of the action area and fully described in the documentation.

On August 11, 2023, the FHWA re-submitted the BA requesting formal consultation. As a result of that submission, on August 14, 2023, via email, the NMFS submitted comments and requested additional items to begin consultation. These additional items have been addressed accordingly with Mr. Bean from your office. Thus, the essential features and effects analysis have been revised and fully described in the documentation.

The project area is also within designated critical habitat for the GOM DPS of Atlantic salmon. Northern Long Eared Bat, a federally endangered species, could also be present at the project site and will be consulted on with the U.S. Fish and Wildlife Service.

This revised BA meets the submittal requirements of 50 CFR402.14(c) and was prepared using the best scientific and commercial data available in accordance with 50 CFR 402.14(d). At this time, FHWA requests formal consultation and the regulatory timeframe be initiated and NMFS's concurrence with our determination that the proposed project is not likely to adversely affect shortnose sturgeon and GOM DPS of Atlantic sturgeon, but likely to adversely affect GOM DPS of Atlantic salmon and designated critical habitat for Atlantic salmon.

If you have any questions in the meantime, please contact me at (207) 512-4917 or gary.scholze@dot.gov.

Sincerely,

Digitally signed by GARY JON SCHOLZE
Date: 2023.09.20 14:28:48 -04'00'

Gary Scholze
Environmental Protection Specialist

Enclosure

ecc:
Rachel LeVee, FHWA
Todd Jorgensen, FHWA
David Bean, NOAA
Rory Saunders, NOAA
David Gardner, MaineDOT
Kristen Chamberlain, MaineDOT
Eric Ham, MaineDOT

BIOLOGICAL ASSESSMENT

Machias Dike Bridge
MaineDOT Project PIN 16714.00

September 20, 2023

Prepared by:

Maine Department of Transportation
Environmental Division
16 State House Station
Augusta, ME 04333-0016

and

Stantec Consulting Services Inc.
136 West Street Suite 203
Northampton MA US 01060-3711

On behalf of:

Federal Highway Administration
40 Western Avenue
Augusta, ME 04330

Table of Contents

Executive Summary

The Maine Department of Transportation (MaineDOT) is proposing to replace the Dike Bridge at the mouth of the Middle River (project), a tributary of the Machias River, in Machias, Maine. Dike Bridge carries U.S. Route 1 and a rail-trail over the Middle River at the confluence of the Middle River with the Machias River. The Federal Highway Administration (FHWA) is providing funding for this project and is required to review project impacts pursuant to Section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 USC 1531 *et seq*.), and its implementing regulations (50 CFR Part 402). The project will also require federal permits pursuant to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act as administered by the U.S. Army Corps of Engineers (USACE). The USACE may accept the findings of this consultation for their permitting process.

Section 7 of the ESA requires that agencies ensure their activities are not likely to jeopardize the continued existence of federally listed species or destroy or adversely modify designated critical habitat. Hence, the FHWA is required to consult with the U.S. Fish and Wildlife Service (USFWS) or National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (Fisheries) to determine whether any federally listed species or species proposed for listing as endangered or threatened, or their designated critical habitats, may be affected by a proposed project. If a federally listed or proposed endangered or threatened species or their designated critical habitat occurs in the vicinity of a major construction activity and the proposed action may affect the listed species or critical habitat, a Biological Assessment (BA) must be prepared to determine whether the proposed federal action would adversely affect that species.

The bridge replacement project is within the geographic range of three species and one designated critical habitat (Table ES-1), all afforded protection under the ESA and within NOAA Fisheries jurisdiction. This BA addresses the proposed action and its potential to affect three ESA-listed species under jurisdiction of NOAA: endangered shortnose sturgeon (*Acipenser brevirostrum*), threatened Gulf of Maine (GOM) Distinct Population Segment (DPS) of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), and endangered GOM DPS of Atlantic salmon (*Salmo salar*). The project area is also within designated critical habitat for the GOM DPS of Atlantic salmon. Listed species in which USFWS has jurisdiction over will be addressed in a separation process.

The FHWA and MaineDOT have determined that the proposed project is **not likely to adversely affect shortnose sturgeon and GOM DPS of Atlantic sturgeon, but likely to adversely affect GOM DPS of Atlantic salmon and designated critical habitat for Atlantic salmon.** The FHWA is requesting formal consultation with the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA Fisheries) under Section 7 of the ESA. MaineDOT certifies that the best scientific and commercial data available were used to complete this Biological Assessment.

Table ES-1. **Federally listed species and federally designated critical habitat within the jurisdiction of NOAA-Fisheries with potential to occur in the project area.**

Species	Distinct Population Segment	Federal Listing Status	Effect Determination
Shortnose sturgeon *Acipenser brevirostrum*	N/A	Endangered	Not likely to adversely affect
Atlantic sturgeon *Acipenser oxyrinchus oxyrinchus*	Gulf of Maine	Threatened	Not likely to adversely affect
Atlantic sturgeon	Gulf of Maine, Carolina, Chesapeake Bay, New York Bight, South Atlantic	Endangered	Not likely to adversely affect
Atlantic salmon *Salmo salar*	Gulf of Maine	Endangered	Likely to adversely affect
Critical habitat for Atlantic salmon	Gulf of Maine	N/A	Likely to adversely affect

1.0 PROJECT OVERVIEW

The Maine Department of Transportation (MaineDOT) is proposing to replace the Dike Bridge at the mouth of the Middle River, a tributary of the Machias River, in Machias, Maine (**Error! Reference source not found.**). Dike Bridge carries U.S. Route 1 and a rail line current being utilized as a multiuse trail over the Middle River at the confluence of the Middle River with the Machias River (**Error! Reference source not found.**). This Biological Assessment (BA) evaluates the potential effects of the proposed bridge project on the following fish species and critical habitats afforded protection under the federal Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. § 1531 et seq.):

- Shortnose sturgeon (Acipenser brevirostrum), endangered
- Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus), Gulf of Maine (GOM) Distinct Population Segment (DPS), threatened
- Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus), Gulf of Maine, Carolina, Chesapeake Bay, New York Bight, South Atlantic, endangered
- Atlantic salmon (*Salmo salar*), GOM DPS, endangered
- Atlantic salmon, GOM DPS critical habitat

All three species have potential to occur in the Machias and Middle rivers at the site of the project and action areas.

1.1 FEDERAL NEXUS

The Federal Highway Administration (FHWA) is providing partial funding for this project and is required to review the project’s potential effects to listed species pursuant to Section 7 of the ESA 1973 and its implementing regulations (50 CFR Part 402). The project will also require permits pursuant to Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act, both of which are administered by the U.S. Army Corps of Engineers (USACE) and are federal actions. The FHWA is acting as the lead federal agency on this consultation; the USACE acknowledges this and will accept the findings of this consultation for their own permitting processes.

This BA addresses the proposed federal action in compliance with Section 7(c)(1) of the ESA. Section 7(a)(2) of the ESA requires that, through consultation (or conferencing for proposed species) with the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA Fisheries), the federal action is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species. This BA identifies project-specific design elements, construction sequences and methods, and avoidance and minimization measures (AMMs) to reduce the likelihood for adverse effects on shortnose sturgeon, Atlantic sturgeon, Atlantic salmon, and Atlantic salmon critical habitat.

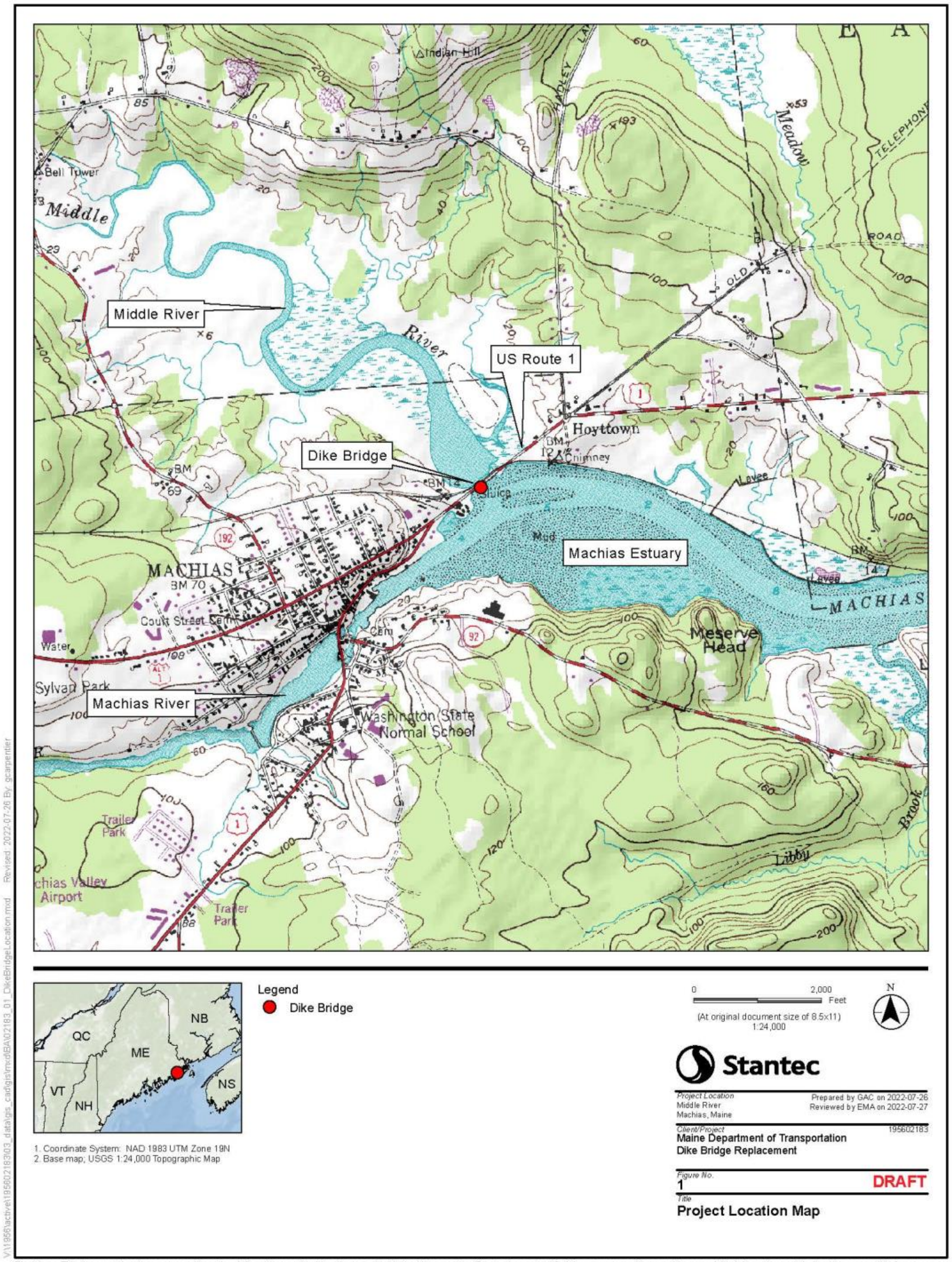
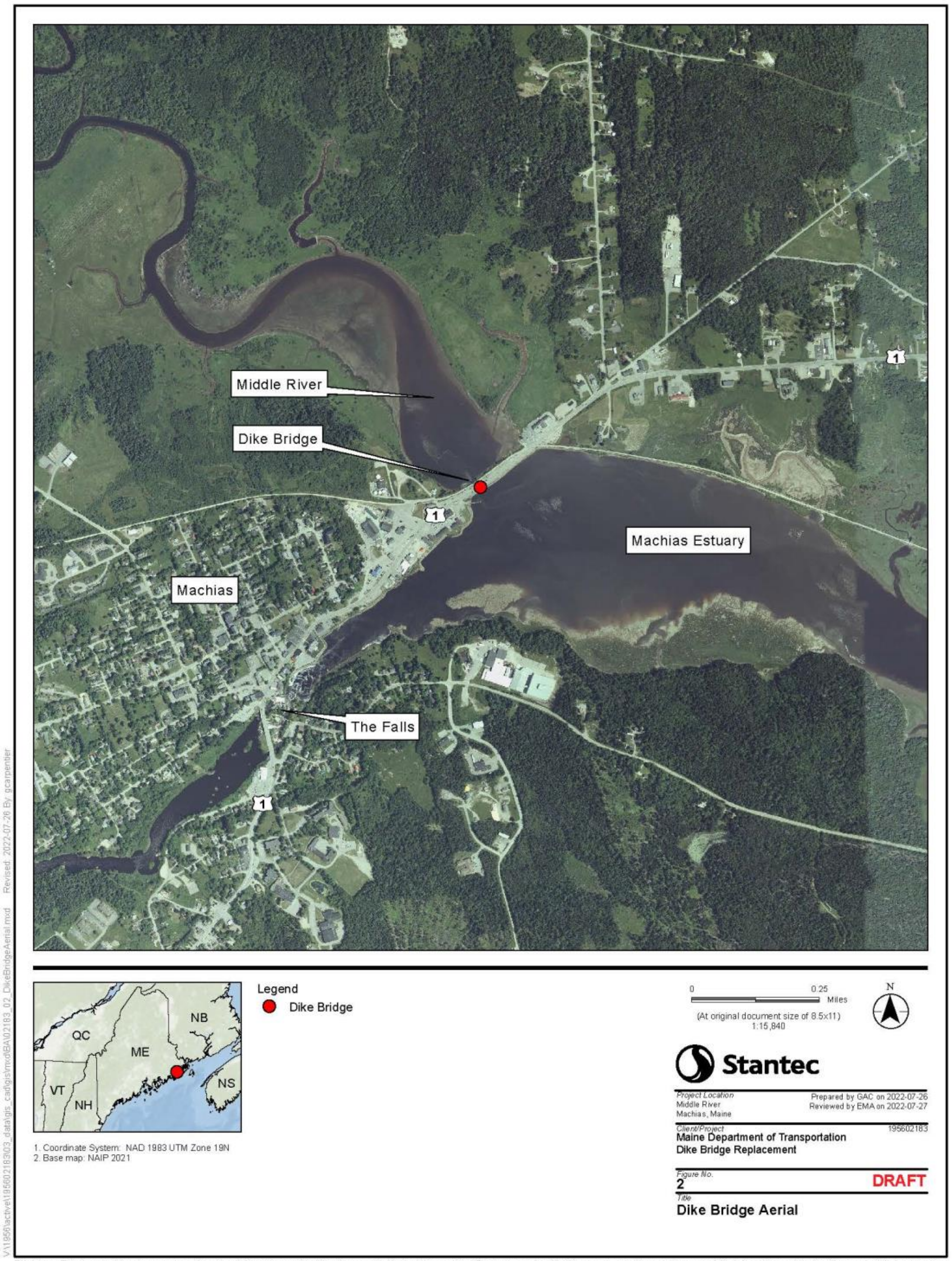


Figure 1. Location



1. Coordinate System: NAD 1983 UTM Zone 19N
2. Base map: NAIP 2021

Figure 2. Aerial view of Dike Bridge and environment

In accordance with 50 Code of Federal Regulations (CFR) Part 600, the FHWA has legal responsibility for complying with Sections 305(b)(2) and 305(b)(4)(B) of the Magnuson Stevens Fishery Conservation and Management Act. The MaineDOT will submit an Essential Fish Habitat (EFH) assessment for this project under a separate letter to the Habitat Conservation Division of NOAA Fisheries.

1.2 EXISTING DIKE BRIDGE

The causeway itself is 150 years old, and the culvert structure is 88 years old. The bridge sits amidst a 1,000-foot-long causeway and is roughly 200 feet from the southwest end and 800 feet from the northeast end. Along its entire length, the causeway supports U.S. Route 1, a paved roadway with two 12-foot-wide travel lanes each with 8-foot-wide shoulders (40 feet total width). The causeway also supports a parking lot, utilities, drainage, and the Down East Sunrise Trail. There is a public boat launch at the southwest end of the causeway.

Dike Bridge’s four box culverts are each approximately 5.5 feet tall, 6 feet wide, and contained within a 130-foot-long timber box. On the downstream side, each culvert is fitted with a flap gate made of a reinforced concrete panel surrounded by a metal frame.

The interior of the causeway is composed of timber cribbing and fill. The slopes of the causeway are lined with riprap. On the Middle River side (upriver), riprap is interspersed with shrubs and herbs and borders an intertidal zone. Salt marsh occupies the area to the east. On the Machias River side (seaward), vegetation is sparse, and the intertidal zone is dominated by mudflat.

The entire culvert structure has sustained considerable damage. MaineDOT made repairs to the culvert structure in 2008 and again in 2021.

1.3 CONSULTATION HISTORY

MaineDOT has been consulting with NOAA Fisheries, FHWA, and Maine Department of Marine Resources (Maine DMR) about the Machias Dike Bridge project for more than 10 years, and MaineDOT has conducted multiple public meetings to discuss the project since 2009.

In early 2021, MaineDOT, FHWA, and NOAA Fisheries discussed the variations of two likely alternatives and how to move the ESA consultation forward. It was decided all parties would share information in a collaborative approach to technical assistance.

MaineDOT, FHWA, and NOAA Fisheries staff conducted meetings on the following dates.

- August 19, 2020
- June 24, 2021
- July 20, 2021
- August 17, 2021
- September 21, 2021
- October 19, 2021
- March 31, 2022

- June 14, 2022
- October 12, 2022
- May 2, 2023
- May 19, 2023
- August 28, 2023

MaineDOT and FHWA received official correspondence from NOAA Fisheries on the following dates. There were also numerous emails and phone conversations among agency staff where project updates and technical assistance items were discussed. Notably, important correspondence occurred on the following dates:

- May 9, 2018
- September 30, 2020
- November 22, 2021
- April 15, 2022
- July 14, 2022
- August 22, 2022
- April 14, 2023
- May 26, 2023
- August 10, 2023
- August 14, 2023
- September 14, 2023

MaineDOT is looking NOAA Fisheries Biological Opinion on a replacement in-kind alternative to help inform their National Environmental Policy Act process.

2.0 ACTION DESCRIPTION

As identified in Section 1.3, MaineDOT has engaged agencies and the public on bridge design alternatives, and MaineDOT continues to review alternatives that involve open and closed culverts and span bridges. For this BA, MaineDOT is proposing to replace the current bridge with a similar but modern structure, i.e., replacement in-kind. The bridge will consist of an arrangement of four pre-cast concrete culverts. The box culverts will have similar dimensions as those that make up the existing structure. All of the culverts will be fitted with top-hinged, flap gates on the seaward-end opening. The embankment will continue to support a two-lane roadway, parking lot, and rail line (the Downeast Sunrise Trail).

2.1 PROJECT DESIGN

Final design on the bridge will be completed after the National Environmental Policy Act process is complete. MaineDOT and their consultants familiar with bridge construction have shared their expertise to estimate potential effects of project construction on endangered species in the action area. However, MaineDOT and their consultants familiar with bridge construction have shared their expertise to estimate potential effects of project construction on endangered species in the action area. Means and methods and contractor flexibility will be maintained to the greatest extent possible.

Bridge replacement will occur in stages, and the existing culvert structures will continue to operate during the time the new bridge is constructed. Once the new structure is operating, the old culverts will be removed. The inverts of the new structures will be set at the same elevation as the old structures intending to have de minimis effects of water levels above the dike.

Construction activities are described in the following sections, and corresponding AMMs are detailed in Appendix A. Additional AMMs that are standard for MaineDOT work are also contained in Appendix A.

2.2 CONSTRUCTION

All construction elements of the project will be conducted in compliance with MaineDOT's Standard Specifications (MaineDOT 2020).[1] The Standard Specifications are a compilation of provisions and requirements for the performance of any MaineDOT work and includes measures that avoid and minimize effects to endangered species. AMMs can be precautionary, avoidance, or protection procedures, such as timing restrictions or buffers around sensitive habitats and habitat features that are important to listed species. A list of all AMMs proposed for the project is located in Appendix A.

In addition to following MaineDOT AMMs, construction actions also include implementation of best management practices (BMPs). BMPs are methods, facilities, built elements, and techniques implemented or installed during project construction to prevent or reduce project impacts on natural resources, such as water quality, soil, and animal habitats. AMMs and BMPs are measures that are considered part of the proposed activity that will be implemented. They are not recommendations, guidelines, or suggestions. Each description below is followed by or references appropriate AMMs that address potential impacts from construction actions. AMMs are stated and numbered to ensure they can be clearly transferred in MaineDOT's contract process. The likely construction process is explained in the following text.

2.2.1 Project Overview

2.2.2 Project Schedule

Conceptual schedules are a part of planning and help in the assessment of timeframes for minimizing effects to resources, i.e., biological, physical, and economic, and some elements may change. Project construction has not been fully scheduled but will likely take approximately 3-4 years to complete. Hard to predict issues here come from utility relocations, maintaining access to the adjacent boat launch, and traffic maintenance.

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[1] Source: http://maine.gov/mdot/contractors/publications/standardspec/

The potential occurrence of listed species in the action area is explained in Section 5.0 Environmental Baseline. The period in which listed species are most likely to occur in the proposed action area would be April 1–November 30, but any of the species could occur year-round. Use of this window would minimize potential effects on sturgeon and Atlantic salmon, and other anadromous fish species, but keeping to this window would force the project to take a longer duration to complete. Review of project schedules by MaineDOT experienced at project construction have demonstrated that following the April 1- November 30 timeframe for construction would result in a construction project that could last 4 years or longer. Completing the in-water work in the December 1– March 30 window to avoid species' exposure to stressors is also a challenge as water flows in winter would not be advantageous to completing any of the necessary in-water work. The location of project and tidal fluctuation also do not make it possible to complete all the activities on the downstream side of the dike at low tide. The mean low tide line is approximately 30 feet away from the existing dike footprint. The temporary work is likely to extend further than that into the Machias River to allow for traffic maintenance. Because the listed species currently do not use the Middle River and the complexities of winter construction, MaineDOT is proposing to conduct most in-water at any time (see Table 2. Activities that could result in an adverse effect (pile driving with an impact hammer) will be completed outside of the water or within the December 1- March 31 window. (AMM 1)

In addition, the Dike Bridge is located on Route 1 a high priority corridor in eastern Maine, and a protracted construction schedule would seriously affect traffic and economic conditions in the region. MaineDOT plans to maintain two-way traffic as much as possible throughout construction.

Though it is unknown how a contractor may stage and schedule for this project, MaineDOT staff experienced in construction and similar projects worked together to create the following construction sequence. In water activities are in bold:

- Mobilization
- **Install temporary bridge (fill placement and pile driving)**
- **Install cofferdams around location of new box culverts**
- Excavate and install new box culverts with tide gates
- Backfill around box culverts
- **Remove cofferdams**
- **Install cofferdam around existing series of four box culverts**
- Remove old timber box culvert structures
- **Remove cofferdams**
- **Remove temporary bridge**
- **Addition of fill to raise the causeway**

2.2.3 Mobilization

2.2.3.1 Pre-Construction

MaineDOT will hold a pre-construction meeting with appropriate MaineDOT Environmental Office staff, other MaineDOT staff, and the MaineDOT construction crew or contractor(s) to review all procedures and requirements for avoiding and minimizing effects to listed species and to emphasize the importance of these protective measures. The FHWA, USACE, and NOAA Fisheries staff will be notified of the meeting and encouraged to attend.

2.2.4 Bridge Construction

2.2.4.1 Temporary Bridge Construction

A temporary bridge is likely to be built downstream of the existing dike to allow for the maintenance of two-way traffic throughout project construction. The downstream location of the temporary bridge will allow traffic to be maintained and provide adequate work area to complete the project. The temporary bridge will likely be a combination of temporary fill and a pile-supported bridge. The amount of and size of piles required to support the temporary bridge are currently unknown. However, it is reasonable to assume the temporary bridge will require a series of 5 bents that could each contain up to 7 piles. To minimize potential hydroacoustic effects to endangered species the pile size will be limited to 30 inches (AMM 2). Impact driving of these piles may be driven at low tide in the dry or during the December 1 to March 31 work window. (AMM 1).

The temporary bridge will be built in stages. Temporary bents will be installed followed by the superstructure. The superstructure will be a series of steel supports that are attached above the water. It is expected that the temporary bridge could take 2-3 months to install.

Photo 1- Photo of Temporary Bridge

2.2.4.2 Cofferdam Installation

Means and methods of how the contractor is going to control water during project construction is still unknown. The configuration of the box culverts within the bridge structure will create challenges for installing temporary water control structures. It is likely there will be water leaks through the cribwork. Sandbags or other barrier methods placed on a surface, are not likely to stop water flowing through the dike. Further, it is not possible to drive a traditional sheet pile through the cribwork structure.

MaineDOT and their consultants familiar with bridge construction have shared their expertise to estimate potential effects of project construction on endangered species in the action area. Portions of the temporary cofferdams will likely consist of 24-inch AZ steel sheet piles. The sheets will likely be installed in the areas that are outside of the existing dike footprint. Cofferdams will be installed on both sides (landward and seaward) of the embankment to permit construction activities to occur in the dry.

Within the dike, the cofferdam is likely to have structure walls (i.e., sheet piles) supported by a frame. Inside the frame, methods to seal the cofferdam may include a combination of smaller sandbags, sheet plastic, and concrete. The existing dike will have to be excavated to allow for the placement of any of these walls. Sheet piles will be installed with a vibratory hammer mounted on an excavator or a crane. Fill may be used to connect the portion of the sheet pile cofferdam to the portion being constructed on the dike. This fill will be material that can be removed after project completion. The fill material may include sheet plastic to seal off waterflow. Once the cofferdam is installed, the interior will be pumped using typical procedures. The dike site is unique in that there is no typical place for a vegetated buffer/BMP treatment. As discussed above, controlling water intrusion into the work area will be challenging. The placement of a BMP for dirty water being removed from the cofferdam will be located on the Dike.

The first cofferdam installation will contain the site to receive the new culvert structures. After the new culverts are installed, sheet piles will be removed and installed to isolate the site of the existing culvert structures. It is expected that cofferdams will be installed in water, but some may be installed during low tides, minimizing effects associated with in-water work. MaineDOT anticipates it will take approximately 3-4 weeks to install the upstream and downstream cofferdams to isolate each site. Each of the cofferdams could require ~ 50 sheetpiles. The cofferdam installation process requires careful fitting of the sheets together, but generally each it take ~ 30 mins of driving per sheet pile.

Water management during construction using any pump systems is not feasible due to the amount of water flow from the Middle River. The location of the new box culverts and cofferdam will allow water to continue to flow through the existing box culverts during construction. Water from the Middle River system will be allowed to flow out, and water from tidal fluctuations in the Machias River Estuary will be blocked from entering the Middle River. Though there has been some recent maintenance of the gate structures, the contractor may choose to further maintain the gates to help manage water during the bridge replacement project.

Table 1. Extent of temporary structures for the Dike Bridge Replacement Project

Project Element	Temporary Fill
Temporary Bridge	~40,000 sq ft
Cofferdammed area	~4000 sq ft

2.2.4.3 New Structure Installation

To begin placing the new culvert structures, the contractor must first remove portions of the old dike. This material will consist of larger stones and old cribwork pieces and will be challenging. The material underneath the location of the new boxes will potentially have to be excavated deeper than a typical box culvert installation to provide a stable location for installation.

The contractor will install granular material to set the new box culverts. The box culverts will then be installed section by section using a crane sitting on the dike. Each section of box culvert is fastened together and the joint between the sections is sealed. The contractor will install new tide gates on the downstream side of the new box culverts. These gates will be fastened to the culverts and hinged to allow flow from the Middle River downstream, and close when water from the Machias River Estuary comes up and attempts to flow back into the Middle River. When the new culverts are installed, the contractor will backfill the new bridge and install riprap where necessary.

2.2.4.4 Cofferdam Relocation

Once the new box culverts are installed, the sheet pile cofferdam that surrounded them will be moved to the provide water control for the removal of old box culverts. Sheet piles will be removed with an excavator-mounted vibratory hammer. Water pumps will be shut off and the cofferdam will slowly be breached by using the vibratory hammer to remove a section of sheet pile, which will possibly cause a limited sediment release that may last up to several minutes. Breaching of cofferdams will occur at high slack tide to minimize water velocities upon release (AMM3). At this time, water velocity and effects to listed species downstream of the dike will be minimized. Once the cofferdam is breached, contractors will remove the remainder of the sheet piles and pump system. There would also likely be short turbidity releases when removing each cofferdam sheet. If sandbags were used to seal the base of the cofferdams, they will also be removed. Any disturbed areas will be stabilized, and all permanent erosion control BMPs will be installed.

2.2.4.5 Cofferdam Removal and Temporary Bridge removal

Sheet piles will be removed with an excavator or crane-mounted vibratory hammer. Water pumps will be shut off and the cofferdam will slowly be breached by using the vibratory hammer to remove a section of sheet pile, which will possibly cause a limited sediment release that may last up to several minutes. Once the cofferdam is breached, contractors will remove the remainder of the sheet piles and pump system. There would also likely be short turbidity releases when removing each cofferdam sheet. If sandbags were used to seal the base of the cofferdams, they will also be removed. Any disturbed areas will be stabilized, and all permanent erosion control BMPs will be installed.

The temporary bridge will also be removed. The superstructure will be disassembled, and the piles will be extracted with a vibratory hammer similar to the removal of the sheet piles. Any fill that was placed to will be removed.

2.2.4.6 Raising the Dike

Adaptations for sea-level rise include various ranges of raising the roadway. Replacing the bridge with box culverts allows MaineDOT to match the new roadway profile into the concurrent sea wall project that the town Machias has been planning. The top of the roadway will be raised to allow for Route 1 to be passable during future predicted sea level rise. There are multiple phases being discussed, but Phase 1 of the town project and the top height of Route 1 is likely to target 13.1 NAVD88 as a part of this project. To raise the roadway, it will be necessary to increase the amount of fill placed adjacent to the existing causeway. The amount of fill will depend on the extent to which the roadway is raised. The placement of this fill will occur at low tide as much as possible. If fill is placed when water is present, a BMP such as a turbidity curtain will be used.

Table 2. **Timing of in water activities specific to the Dike Bridge Construction**

Activity	Duration	Timing
Sheet pile/ fill installation upstream of Dike for cofferdam	3-4 weeks	Anytime
Sheet pile/ fill installation downstream of the Dike for cofferdam	3-4 weeks	Anytime
Installation of temporary bridge pile with a vibratory hammer	1-2 weeks	Anytime
Installation of temporary bridge pile with an impact hammer	1 week	In the dry or December 1–March 31
Removal of cofferdam/ fill upstream of Dike	1-2 weeks	Anytime
Removal of cofferdam downstream of Dike	1-2 weeks	Anytime
Removal of temporary bridge pile with a vibratory extractor	1 week	Anytime

2.3 OPERATION AND MAINTENANCE

The new tide gates that will be placed on the structure will operate similar to the current gates. They will be hinged at the top and placed on the downstream side of the new culvert structures. When the water elevation in the Machias River Estuary is greater than the Middle River impoundment, the gates will be shut, and water will not be allowed to flow upstream (north) of the dike. When the water elevation in the Machias River Estuary is lower than the Middle River impoundment, the gates will open and allow water to flow into the estuary. This type of gate is referred to as a flap gate. There is no motorized operation. New gates are likely to seal better and have more longevity than the older gates (

Photo 2).

The gates are likely to made of a durable material (e.g., metal). MaineDOT will create an asset management plan for the Dike Bridge once final design is complete and lifespans are predicted for the materials. This plan will ensure that funding is available for maintenance of the structure throughout its life cycle. The intended life of the crossing structure is 80-100 years. The intention is for the flap gate to function properly for the entire lifespan of the Dike Bridge.

MaineDOT maintenance staff travel this stretch of road regularly. Emphasis will be made for crews to complete regular debris inspection and removal through the year.

MaineDOT will inspect Dike bridge every 2 years. Inspection of the gate structures every other year. This inspection will include the condition and function of the flap gates. Any identified damage or needed repairs to the flapper gate system will be repaired within the MaineDOT Work Plan cycle.

Photo 2. Existing tide gates during a low tide in the Machias River Estuary

3.0 PROJECT ACTION AREA

A project's action area is defined as "all areas to be affected directly or indirectly by the federal action and not merely the immediate area (project area) involved in the proposed action" (50 CFR 402.02). The action area for this consultation includes the area affected by both construction of the culvert replacement project, and the area affected temporarily and permanently by passage effects of the project, both during and after completion. Therefore, the action area includes the area affected by underwater noise, sedimentation and turbidity, and temporary and permanent modification of critical habitat.

3.1 SUSPENDED SEDIMENT AND TURBIDITY

The project area is likely to experience temporary increases in suspended sediment (i.e., turbid water discharges) from cofferdam and pile installation and removal and riprap placement. Cofferdams will be installed around the sites of the new and old structures, preventing turbidity increases from occurring during these two activities. Using available information collected from a project in the Hudson River, pile driving activities may produce total suspended sediment (TSS) concentrations of approximately 5.0 to 10.0 mg/L above background levels within approximately 300 feet (91 meters) of the activity (FHWA 2012, NOAA Fisheries (2021)[2]).

The effects of any increased turbidity from disturbed substrate associated with construction of the new bridge and removal of the old structure will be minimized by sediment and erosion control BMPs and use of cofferdams. Therefore, any increased turbidity from these activities will be contained within the area around construction activities. Stream turbidity may increase temporarily from sheet pile driving and removal at the site of the bridge, and, as a conservative estimate, extend from approximately 300 feet upstream into the Middle River on incoming tides and approximately 300 feet downstream of the bridge into the Machias River. These distances are based on MaineDOT observations of turbidity releases during similar projects.

3.2 UNDERWATER NOISE

During construction, the project area is likely to experience temporary increases in sound pressure from pile driving. The greatest increase will occur in association with the construction of the temporary bridge. MaineDOT anticipates having to use an impact hammer to seat the 30-inch steel bent piles to construct the temporary bridge.

Unattenuated impact hammer installation of 30-inch steel bent piles is capable of inducing injury (at 150 dBs SEL [surrogate for 187 dB cSEL]) to salmon and sturgeon up to 64 meters (210 feet) and behavior modification (at 150 dB RMS) to salmon and sturgeon up to 90 meters approximately (300 feet) from the pile driving activity. Depending on the location of the pile, the ensonified area could extend approximately 300 feet from the project footprint, upstream and downstream.

3.3 COFFERDAM AREA

The project area will be temporarily isolated within cofferdams during construction (during new bridge construction and old culvert structure removal). There will be the potential for fish to become entrapped within the enclosed areas at the site of actual bridge construction and culvert removal.

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[2] Section 7 Effect Analysis: Turbidity in the Greater Atlantic Region | NOAA Fisheries

3.4 TEMPORARY STRUCTURES

The project area will be occupied by temporary structures, including the footprint of the temporary bridge for traffic maintenance, piles supporting the temporary detour bridge, and cofferdams. These effects will occur at the immediate site of the bridge replacement project.

3.5 FALSE ATTRACTION

There was no literature or reference to understand at what distance migrating fish may be falsely attracted to the outlet of the Dike Bridge. Following discussions with NOAA staff, it seemed reasonable to assume that migrating salmon in the area from the Dike upstream to Bad Little Falls could potentially be falsely attracted to water flowing out of the Middle River into the estuary. Fish species such as river herring have been documented to be attracted to flow from a gated dike system and wait for advantageous passage conditions (Alcott et al. 2021). This behavior would be false attraction if there was no opportunity for passage.

3.6 MIGRATION BARRIER

Following the replacement of the bridge structure, the project will continue to affect the species ability to migrate into Middle River and use the critical habitat that is present. The operation of the tide gates will also continue to have effects on the habitat that would regularly be inundated with tidal flow. The action area includes all of the stream, lake, and pond areas upstream of the Dike.

3.7 SUMMARY

The limits of the action area are defined by the project activity that will affect the largest areal extent. Based on the above factors for potential turbidity and hydroacoustic effects, the overall action area during construction encompasses waters in the Middle and Machias rivers within 300 feet of the Dike Bridge (**Error! Reference source not found.**), reflecting the extent of the upstream and downstream turbidity effects. The action area defines the area that may be affected during the bridge construction activities and the project's potential effects on listed species, given the implementation of AMMs and best management practices implemented. We anticipate that all effects of the action will occur within the geographic area shown in **Error! Reference source not found.**.

Figure 3. Action area for the proposed replacement of the Dike Bridge over the Middle River

4.0 LISTED SPECIES AND DESIGNATED CRITICAL HABITAT

Below we briefly discuss the three listed species and designated critical habitats addressed in this BA. The following accounts largely focus on the species and critical habitats associated with the Gulf of Maine.

4.1 SHORTNOSE STURGEON

4.1.1 Status and Conservation

The Department of Interior listed shortnose sturgeon as an endangered species in 1967 (USDOI 1967) under the Endangered Species Preservation Act. Shortnose sturgeon remained on the endangered species list with the enactment of the ESA. The most significant threats to the species are dams that block access to spawning areas or lower parts of rivers; poor water quality, dredging, and water withdrawals from rivers; and unintended bycatch in some commercial fisheries.

4.1.1.1 Recovery Efforts

In 1998, NOAA Fisheries approved the shortnose sturgeon recovery plan (NOAA Fisheries 1998). The recovery plan defined objectives and criteria for measuring progress. Specifically, the plan seeks to recover shortnose sturgeon populations to levels of abundance at which they no longer require protection under the ESA; the minimum population size will be large enough to maintain genetic diversity and avoid extinction. Since publication of the recovery plan, researchers completed a number of studies (Walsh et al. 2001; Grunwald et al. 2002; Wirgin et al. 2005, 2009; and others) and revised population assessments. The findings are summarized in the Shortnose Sturgeon Status Review Team's (SSSRT) biological assessment of the species (SSSRT 2010).

NOAA Fisheries has worked with conservation organizations, energy companies, states, tribes, and citizens to evaluate manmade barriers to improve fish passage and migration. Bred in captivity and held in accordance with specific permits, there are shortnose sturgeon housed at research facilities to provide important information on the physical, chemical, and biological parameters necessary for optimal growth, survival, and reproduction in the wild. These captive-bred sturgeon are also used to promote public awareness of the species. NOAA Fisheries and other scientists are proactively involved in educating the public on the value of shortnose sturgeon to promote support for conservation efforts.

4.1.2 Distribution and General Habitat Use

Shortnose sturgeon occur on the east coast of North America in rivers, estuaries, and marine waters. Their current riverine distribution extends from the Saint John River, New Brunswick, Canada, to the St. Johns River, Florida (**Error! Reference source not found.**), and recent information indicates that their marine range extends into the Minas Basin, Nova Scotia

(Dadswell et al. 2014). Despite this relatively broad range for the species, currently there are no known reproducing populations in the river systems that occur between Chesapeake Bay and the southern boundary of North Carolina, roughly a gap of 250 miles. As a result of this distribution and apparent reproductive isolation, researchers group shortnose sturgeon into three metapopulations, Acadian Province (northern), Virginian Province (mid-Atlantic), and Carolinian Province (southern).

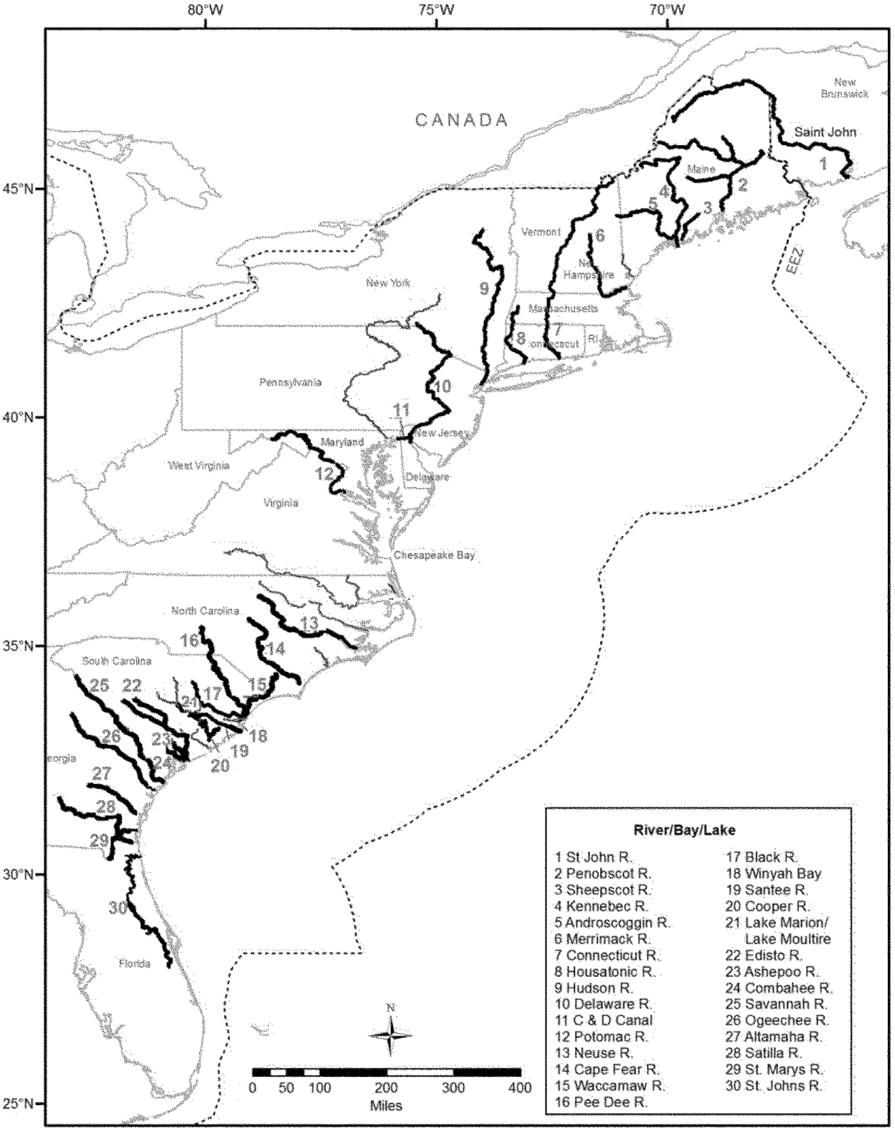


Figure 4. Major river systems within the currently or potentially occupied range of shortnose sturgeon

Source: NOAA Fisheries (2015)

Shortnose sturgeon are born in freshwater, and they live in the estuarine and freshwater habitats of their natal river for the most part. Adults may make short feeding or migratory trips into salt water, and then return to freshwater to feed and escape predation.

Adults prefer slow-moving riverine, estuarine, and nearshore marine habitats of large river systems, migrating occasionally into faster moving freshwater areas to spawn. In Maine, shortnose sturgeon are known to occur in the estuarine complex formed by the Sheepscot, Kennebec, and Androscoggin rivers (SSSRT 2010). Feeding and overwintering occur in either freshwater or saltwater areas (NOAA Fisheries 1998). In general, foraging habitat for shortnose sturgeon and Atlantic sturgeon overlap; however, shortnose sturgeon typically spawn farther upriver than Atlantic sturgeon (SSSRT 2010).

4.1.3 Life History

4.1.3.1 Spawning and Larval Development

Spawning typically occurs in the natal river in the farthest accessible upstream reach of an undammed river or near the base of the dam or in the tailrace of a dammed river in areas with gravel, rubble, timber, scoured clay, cobble, and large rocks (Dadswell 1979; Taubert 1980; Dadswell et al. 1984; Buckley and Kynard 1985a,b; Kynard 1997). Spawning occurs in mid- to late-spring when water temperatures reach 8–9°C (46-48°F; SSSRT 2010). Once they reach a length of 2 centimeters (0.8 inches), larvae migrate downstream where they typically reside in deep, freshwater channels for 1 year or more before migrating to the estuary (Dadswell et al. 1984; Richmond and Kynard 1995; Kynard 1997).

4.1.3.2 Juveniles

Juveniles, up to 10 years old depending on river latitude, live in the estuary of their natal rivers where they move back and forth within the low-salinity portion of the salt wedge in water generally 10-20 meters (33–66 feet) deep (NOAA Fisheries 1998). Salinity tolerance increases with age (Dadswell et al. 1984, Kynard 1997).

4.1.3.3 Adults

Adult shortnose sturgeon have been found at temperatures from 2–34°C (36-93°F), but temperatures above 28°C (82°F) are thought to adversely affect them. They occur at a wide range of depths from 0.6–30 meters (2–98 feet), but generally occur in <20 meters (66 feet) of water in the deepest parts of the river or estuary with suitable oxygen values (Dadswell 1979, Dadswell et al. 1984, Gilbert 1989, Fernandes et al. 2010). Shortnose sturgeon tolerate a wide range of salinities from freshwater (0 parts per thousand[ppt]) to seawater (32 ppt; Holland and Yeverton 1973, Dadswell 1979).

Adult migrations include spring movement from overwintering sites to upriver spawning sites, late-spring downstream movements to feeding areas lower in the river and directed movements in the fall to overwintering sites (Fernandes et al. 2010, SSSRT 2010). In the northern part of their range, shortnose sturgeon are seldom found in shallow water once temperature exceeds 22°C (72°F; Dadswell et al. 1984). Individuals seem to remain in their natal river or the river’s estuary (Dadswell 1979), though Wippelhauser et al. (2015) have documented that shortnose sturgeon migrate long distances in coastal waters to known spawning sites or historical spawning habitat in Maine’s Kennebec River system, and enter small coastal rivers, such as the Saco River in Maine and the Merrimack River in New Hampshire.

Typically, adult shortnose sturgeon in the northern part of their range will spawn and forage in shallower water in the upper reaches of a river in the spring/summer and over-winter in the deeper channels in the lower estuary (Kynard 1997). Overwintering occurs in deep river segments and deep depressions at depths of 10–30 meters (33–98 feet; Dadswell et al. 1984). In northern rivers, overwintering juvenile and adult shortnose sturgeon form tight aggregations in specific, relatively deep sandy segments of the freshwater or saline reaches of the river with little movement or foraging (Dadswell 1979, SSSRT 2010). Between spring and fall, shortnose sturgeon forage in shallow water (1–15 meters [3-50 feet] deep) on sand-mud bottoms covered with aquatic plants, feeding on a variety of benthic and epibenthic animals, including insects, mollusks, crustaceans, worms, and small fishes (Dadswell 1979, Dadswell et al. 1984, Kynard et al. 2000).

Shortnose sturgeon leave their natal estuaries, make coastal migrations, and use other river systems (Kynard 1997, Savoy 2004, Fernandes et al. 2010, Zydlewski et al. 2011, Dionne et al. 2013, Wipplehauser et al. 2015). Within the Gulf of Maine, adults have been observed migrating along the coast, traveling between the Penobscot, Kennebec, and Merrimack rivers and making stops in smaller coastal rivers along this route (Zydlewski et al. 2011). Outside the Gulf of Maine, marine migrations have only rarely been documented. Available tagging and tracking data are too limited to determine if Hudson River and Connecticut River shortnose sturgeon make regular movements outside their natal rivers and if movements as far as the Merrimack River are a normal behavior. At this time, researchers do not suspect shortnose sturgeon make coastal migrations south of the Hudson River. Shortnose sturgeon overwinter in the rivers, so the time of year for coastal migrations would be roughly from April 1–November 30. These coastal migrations are likely to occur within the 50-meter (164-foot) depth contour.

4.1.4 Shortnose Sturgeon in Maine

Table 3.3 summarizes known important habitats for shortnose sturgeon in the Gulf of Maine. Individuals have been observed or captured in other Maine rivers, but so far researchers have not indicated shortnose sturgeon use these other rivers specifically for important life strategies.

Table 3. Important habitat sites for shortnose sturgeon in the Gulf of Maine

River System	Location	Habitats
Merrimack	Estuary	Spawning Wintering| Foraging
Androscoggin	Androscoggin River below Brunswick Dam	Spawning
Kennebec	Kennebec River below site of former Edwards Dam	Spawning
Kennebec	Merrymeeting Bay	Wintering
Kennebec	Lower Kennebec estuary and Sagadahoc Bay	Foraging
Sheepscot	Back and Sasanoa rivers	Foraging
Penobscot	Upper estuary	Wintering
Penobscot	Middle and lower estuary	Foraging
Saint John	Estuary	Spawning Wintering

Source: summarized in Wippelhauser et al. (2015)

4.2 ATLANTIC STURGEON

4.2.1 Status and Conservation

As of February 6, 2012, NOAA Fisheries listed the New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs as endangered and the GOM DPS as threatened (NOAA Fisheries 2012a). NOAA Fisheries determined the GOM DPS is threatened throughout its range due to the following:

- significant declines in population sizes and the protracted period during which sturgeon populations have been depressed.
- limited amount of current spawning; and
- impacts and threats that have and will continue to prevent population recovery.

Numbers of Atlantic sturgeon in the GOM DPS are significantly lower than historical levels and have remained so for more than 100 years. Currently, there are two known spawning subpopulations within the GOM DPS, the Kennebec River and Androscoggin River spawning subpopulations. There are no abundance estimates for either subpopulation or for the GOM DPS as a whole (ASSRT 2007; Wippelhauser et al. 2015, 2017). The Atlantic States Marine Fisheries Commission (ASMFC) benchmark stock assessment concluded there was a 51% probability that abundance of the GOM DPS increased since implementation of the 1998 fishing moratorium here in the U.S., but there was a 74% probability that mortality exceeds the mortality threshold used for the assessment (ASMFC 2017).

Threats to Atlantic sturgeon include habitat changes, impeded access to historical habitat by dams and reservoirs, degraded water quality, reduced water quantity, vessel strikes, and bycatch in commercial fisheries (NOAA Fisheries 2012a; 77 Federal Register 5880–5912).

4.2.1.1 Recovery Efforts

NOAA Fisheries is in the recovery planning process and has prepared an interim guidance document (Recovery Outline; NOAA Fisheries 2018). Steps already taken to conserve and recover Atlantic sturgeon include the moratorium on harvest (1998 amendment to the Atlantic Sturgeon Fishery Management Plan). Several states within the species' range have received funding under Section 6 of the ESA (recovery grants to states) to conduct studies that eventually inform management and conservation measures to facilitate recovery of the DPSs.

4.2.1.2 Critical Habitat

In September 2017, NOAA Fisheries designated critical habitat for each of the DPSs, i.e., the GOM, New York Bight, Chesapeake Bay, Carolina, and South Atlantic DPSs (82 Federal Register 39160–39274; NOAA Fisheries 2017). Specific occupied areas designated as critical habitat for the GOM DPS include approximately 152 miles of aquatic habitat in the Penobscot, Kennebec, Androscoggin, Piscataqua, Cocheco, Salmon Falls, and Merrimack rivers.

NOAA Fisheries (2017) identified the following physical and biological features (PBFs) essential to the survival of Atlantic sturgeon in the GOM, New York Bight, and Chesapeake Bay DPSs:

- Hard bottom substrate (e.g., rock, cobble, gravel, limestone, boulder, etc.) in low salinity waters (i.e., 0.0–0.5 ppt range) for settlement of fertilized eggs, refuge, growth, and development of early life stages.

- Aquatic habitat with a gradual downstream salinity gradient of 0.5 ppt up to as high as 30 ppt and soft substrate (e.g., sand, mud) between the river mouth and spawning sites for juvenile foraging and physiological development.

- Water of appropriate depth and absent physical barriers to passage (e.g., locks, dams, thermal plumes, turbidity, sound, reservoirs, gear, etc.) between the river mouth and spawning sites necessary to support: Unimpeded movements of adults to and from spawning sites; seasonal and physiologically dependent movement of juvenile Atlantic sturgeon to appropriate salinity zones within the river estuary, and staging, resting, or holding of subadults or spawning condition adults. Water depths in main river channels must also be deep enough (e.g., at least 1.2 meters [4 feet]) to ensure continuous flow in the main channel at all times when any sturgeon life stage would be in the river, and

- Water, between the river mouth and spawning sites, especially in the bottom meter of the water column, with the temperature, salinity, and oxygen values that, combined, support: Spawning; annual and interannual adult, subadult, larval, and juvenile survival; and larval, juvenile, and subadult growth, development, and recruitment (e.g., 13-26°C [55.4-78.8°F] for spawning habitat and no more than 30°C [86°F] for juvenile rearing habitat, and 6 milligrams per liter or greater dissolved oxygen for juvenile rearing habitat).

4.2.2 Distribution and General Habitat Use

Atlantic sturgeon inhabit rivers and coastal waters from New Brunswick and Nova Scotia, Canada to Florida, spending most of their adult life in the marine environment (ASSRT 2007). The GOM DPS is defined as including all Atlantic sturgeon that are spawned in the watersheds from the Maine-Canadian border and extending southward to include all associated watersheds draining into the Gulf of Maine as far south as Chatham, MA, as well as wherever these fish occur in coastal bays and estuaries and the marine environment (NOAA Fisheries 2012a). They have been documented in the following GOM DPS rivers: Penobscot, Kennebec, Androscoggin, Sheepscot, Saco, Pemaquid, Piscataqua, and Merrimack. Atlantic sturgeon spawn in the Kennebec River, and they potentially spawn in other rivers (ASSRT 2007, Damon-Randall et al. 2013). Exact spawning locations in the Kennebec River are not known, but spawning is inferred based on substrates, salinity, and water depths, and on tracking of adults and capture of eggs, larvae, and young-of-year.

In Canada, Atlantic sturgeon are commonly caught in the upper Bay of Fundy and Minas Basin in western Nova Scotia (Dadswell 2006, Taylor et al. 2016).

4.2.2.1 Life History

Spawning and Larval Development

Evidence from genetic studies indicates that Atlantic sturgeon return to their natal river to spawn. In Maine, adults migrate upriver from coastal areas in the spring (March to May) and spawning usually occurs in early- to mid-summer (Wippelhauser and Squiers 2015, Wippelhauser et al. 2017). Atlantic sturgeon spawn in freshwater reaches of estuaries, in flowing water between the salt front and fall line of large rivers or estuarine tributaries (ASSRT 2007, Greene et al. 2009). Silt-free hard bottom substrates such as boulder, bedrock, cobble-gravel, hard clay, and coarse sand are required to spawn adhesive eggs (Collette and Klein-MacPhee 2002, Greene et al. 2009). Depth at which the fish spawn is highly variable. Eggs, larvae, and young-of-the-year do not tolerate high salinities, with mortality documented at salinities as low as 5 ppt to 10 ppt (Green et al. 2009).

Juveniles

The juvenile stage lasts months to years in brackish waters. Juvenile Atlantic sturgeon are found over sand, mud, cobble, rocks, and transitional substrates, and remain in their natal estuary for up to six years before migrating out to sea. Juveniles continue to move further downstream into brackish waters, and eventually become residents in estuarine waters for months or years. Upon reaching a size of approximately 76–92 cm, the large juveniles are then considered subadults and may move to coastal waters (Smith 1985), where populations may undertake long range seasonal migrations (Dovel and Berggren 1983, Bain 1997). Juveniles overwinter in brackish water near the mouth of estuaries.

4.2.2.2 Adults

Atlantic sturgeon adults spend most of their lives in offshore marine waters. During winter months (November – March), Atlantic sturgeon primarily occupy deeper water, generally deeper than 20 meters (66 feet). Shallower waters are inhabited in summer and early fall (May – September) (Erickson et al. 2011). Adult Atlantic sturgeon frequently aggregate in upper estuary habitats around the saltwater interface (Greene et al. 2009). Adults have been documented in moderately shallow (7-50 meters) sand and gravel nearshore habitats (Stein et al. 2004, Laney et al. 2007, Greene et al. 2009). Prey items include polychaetes, amphipods, isopods, decapods, mollusks, and sand lance (*Ammodytes* spp.) (Scott and Scott 1988, Johnson et al. 1997).

4.2.3 Atlantic Sturgeon in Maine

In Maine, researchers have discovered three GOM Atlantic sturgeon spawning areas in the Kennebec River system (Wippelhauser and Squiers 2015; Wippelhauser et al. 2017) and several potential foraging areas in the lower Kennebec River estuary (Wippelhauser and Squiers 2015), Saco River (Novak et al. 2017), and Penobscot River estuary (Altenritter et al. 2017).

4.2.4 Designated Atlantic Sturgeon Critical Habitat

In June 2016, NOAA Fisheries proposed to designate critical habitat for the GOM, New York Bight, and Chesapeake Bay DPSs of Atlantic sturgeon (NOAA Fisheries 2016a). On August 17, 2017, NOAA Fisheries published the Final Rule designating critical habitat for the GOM Atlantic sturgeon in the Penobscot, Kennebec, Androscoggin, Piscataqua, and Merrimack rivers (NOAA Fisheries 2017).

4.3 GULF OF MAINE DISTINCT POPULATION SEGMENT OF ATLANTIC SALMON

4.3.1 Status and Conservation

In 2000, NOAA Fisheries and USFWS (collectively, the Services) listed the DPS of anadromous Atlantic salmon in the Gulf of Maine as an endangered species under the ESA (USFWS and NOAA Fisheries 2000). The 2000 listing included all naturally reproducing wild populations and hatchery populations having historical river specific characteristics found north of the Kennebec River. On 19 June 2009, the USFWS and NOAA Fisheries published the Final Rule determination of endangered status for the GOM DPS of Atlantic salmon (NOAA Fisheries and USFWS 2009) and designated critical habitat for Atlantic salmon (NOAA Fisheries 2009). The Services' subsequent 2009 listing included an expanded range for the GOM DPS of Atlantic salmon to include populations from the Androscoggin River north along the Maine coast to the Dennys River and wherever these fish occur in the estuarine and marine environment.

In 2016, the USFWS and NOAA Fisheries provided the draft recovery plan for the species (USFWS and NOAA Fisheries 2016). It supersedes the 2005 recovery plan insofar as it addresses the 2009 expanded DPS.

4.3.1.1 Trends

Atlantic salmon populations have been declining in the GOM DPS since the early 1800s and the present population estimates are a great deal lower than the historic run numbers (Fay et al 2006). The returning adults records show that numbers have somewhat stabilized at very low numbers since the late 1990s (Fay et al 2006). Adult salmon returns in Maine rivers during 2012–2022 are shown in **Error! Reference source not found.**. Contemporary abundance levels of Atlantic salmon within the GOM DPS are significantly lower than historical abundance estimates. For example, Atkins and Foster (1867 as cited in Schmitt and Anderson 2012) estimated that roughly 100,000 adult salmon returned to the Penobscot River alone before the river was dammed. Since 1967, contemporary estimates of abundance for the entire GOM DPS exceeded 5,000 individuals in only 1 year, i.e., 1986.

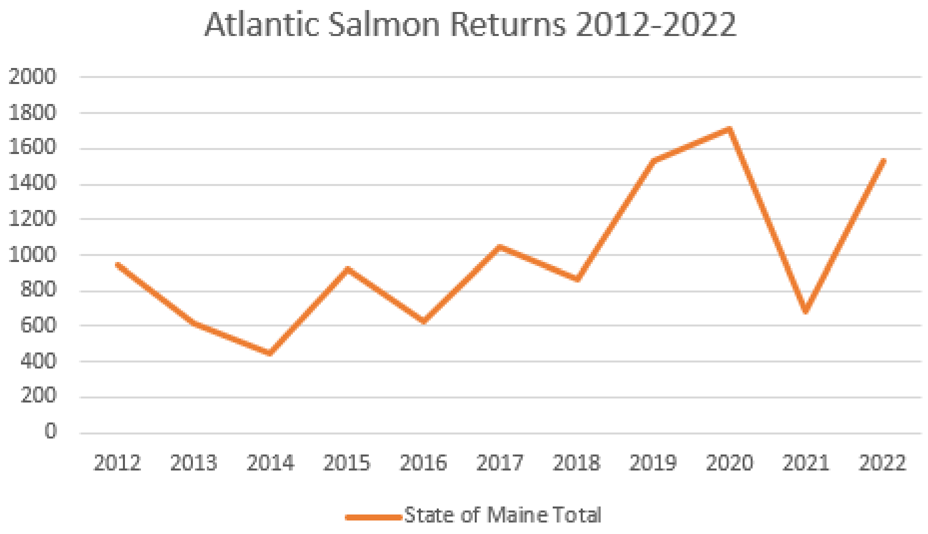


Figure 5. Adult Atlantic salmon returns to GOM DPS rivers 2012-2022

Data source: USASAC (2020)

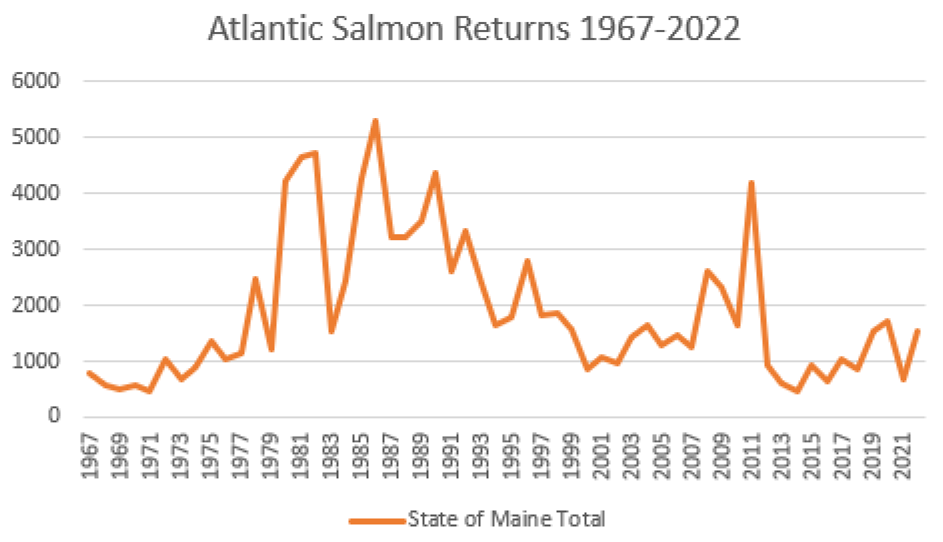


Figure 6. Adult Atlantic salmon returns to all GOM DPS Rivers 1967-2020

Data source: USASAC (2020)

After a period of population growth in the 1970s, adult returns of salmon in the GOM DPS have been steadily declining since the early 1980s and appear to have stabilized at very low levels since 2000 with a moderate increase in 2009–2011 (**Error! Reference source not found.**).

NOAA Fisheries has assigned a threshold of 2,000 wild spawners per SHRU totaling 6,000 wild spawners annually for the GOM DPS as the recovery target for delisting (USASAC 2020). The first management target for down-listing to threatened is 500 naturally reared adult spawners (i.e., returning adults originating from wild spawning, egg planting, fry stocking, or fall parr stocking) per SHRU (USASAC 2020). Table 4 shows documented adult returns for each SHRU in 2020.

Table 4. Documented adult returns for GOM DPS Atlantic salmon in 2022 relative to the target of 500 naturally reared adults in each SHRU

SHRU	Hatchery	Natural	Total	Percent of 500 target
Downeast Coastal	17	56	73	11.2
Penobscot Bay	1,228	106	1,334	21.2
Merrymeeting Bay	68	45	113	9.0
GOM DPS	1,313	202	1,520	--

Source: USASAC (2020)

4.3.1.2 Recovery Efforts

Conservationists have been implementing Atlantic salmon restoration efforts for more than a century. Once depletion of fish stocks was observed, efforts have included water quality improvements, closing the commercial fishery, fish culture programs, habitat restoration, targeted salmon and river restoration in occupied rivers, genetics research, international collaboration on restoration, and eventually listing the species as endangered under the ESA in 2000.

Conservation hatchery activities play a major role in fish distribution and recovery, and for the Downeast Coastal SHRU, the chief conservation hatchery strategy is broodstock collected primarily from wild-exposed or truly wild parr collections. These juveniles are raised to maturity in a freshwater hatchery.

Since the species listing, recovery efforts shifted to improving habitat connectivity by identifying and remedying passage barriers at culverts and dams. Endeavors included removing two hydroelectric projects and constructing a bypass at a third project on the Penobscot River. In addition, the Services and hydro developers in the GOM DPS are working together to improve fish passage at hydro facilities within designated critical habitat for Atlantic salmon (USFWS and NOAA Fisheries 2016).

Most of the dams in the Downeast Coastal SHRU have either been removed or breached and no longer impede salmon migration. Remaining dams include the Stillwater Dam on the Narraguagus River and the Ellsworth and Graham Lake dams on the Union River.

4.3.2 Description and General Habitat Use

Atlantic salmon are an anadromous fish that use freshwater rivers and streams for spawning and nursery, and saline ocean environments for periods of rapid growth. Atlantic salmon have a complex life history that includes territorial rearing in rivers to extensive feeding migrations on the high seas. During their life cycle, Atlantic salmon go through several distinct phases that are identified by specific changes in behavior, physiology, morphology, and habitat requirements.

4.3.2.1 Life History

Spawning and Larval Development

In the fall, the female Atlantic salmon select sites for spawning. Spawning sites are positioned in flowing water, particularly where upwelling of groundwater occurs, allowing for percolation of water through the gravel (Danie et al. 1984). These sites are most often positioned at the head of a riffle (Beland et al. 1982), the tail of a pool, or the upstream edge of a gravel bar where water depth is decreasing, water velocity is increasing (White 1942, McLaughlin and Knight 1987), and hydraulic head allows for permeation of water through the redd (a gravel depression where eggs are deposited). Female salmon dig redds and deposit eggs that are then fertilized by the males (Jordan and Beland 1981). A single female may create several redds before depositing all her eggs. Upstream of the last deposition site, the female continues digging which buries the fertilized eggs with clean gravel.

After spawning, Atlantic salmon may either return to sea immediately in late fall or remain in freshwater until the following spring before returning to the sea (Fay et al. 2006). Embryos develop in the redd for a period of 175 to 195 days then hatch in late-March or April (Danie et al. 1984). Newly hatched salmon referred to as larval fry, alevin, or sac fry, remain in the redd for approximately 6 weeks after hatching and are nourished by their own yolk sac (Gustafson-Greenwood and Moring 1991).

Juveniles

Once larval fry emerge from the gravel and begin active feeding they are referred to as fry. When fry reach approximately 4 centimeters (1.6 inches) in length, the young salmon are termed parr (Danie et al. 1984). Parr overwinter beneath stones and while movement is limited between December and April, it occurs primarily between dusk and dawn for feeding (Cunjak 1988, Heggenes 1990) and as ice formation reduces total habitat availability (Whalen et al. 1999). Parr remain in the river for 2 to 3 years before undergoing smoltification, a process where parr go through physiological changes when transitioning from a freshwater environment to a saltwater marine environment. For parr to undergo smoltification, they must reach a critical size of 10 centimeters (4 inches) in length at the end of the previous growing season (Hoar 1988). Most smolts enter the sea during May to begin their first ocean migration (Fay et al. 2006).

When smolts migrate from the river and into the ocean they are referred to as “post-smolts”. The post-smolt migration out of the coastal environment is generally rapid, within several tidal cycles, and follows a direct route to the summer feeding area south of Greenland (Lacroix et al. 2004). During the late-summer and autumn of the first year, North American post-smolts are concentrated in the Labrador Sea and off the west coast of Greenland (Reddin 1985, Reddin and Short 1991, Reddin and Friedland 1993). In the spring, North American post-smolts are generally located in the Gulf of St. Lawrence, off the coast of Newfoundland, and on the east coast of the Grand Banks (Reddin 1985; Friedland et al. 1999).

Adults

Some salmon may remain at sea for another year or more before maturing. After their second winter at sea, the salmon over-winter in the area of the Grand Banks before returning to their natal rivers to spawn (Reddin and Shearer 1987). Adult Atlantic salmon return to rivers from the ocean and migrate to their natal streams to spawn. Adults ascend their natal rivers beginning in the spring. The ascent of adult salmon continues into the fall. Although spawning does not occur until late-fall; the majority of Atlantic salmon in Maine enters freshwater between May and mid-July (Meister 1958, Baum 1997). Salmon that return in early spring spend nearly five months in the river before spawning, often seeking cool water refuge (e.g., deep pools, springs, and mouths of smaller tributaries) during the summer months.

4.3.3 Atlantic Salmon in Maine

Information on the occurrence of Atlantic salmon in Maine is summarized in Sections 4.3.1 and 4.3.2.

4.3.4 Designated Critical Habitat for GOM DPS of Atlantic Salmon

Coincident with the June 19, 2009 endangered listing, NOAA Fisheries designated critical habitat for the GOM DPS of Atlantic salmon, with the final rule revised on August 10, 2009 (NOAA Fisheries 2009). Within the GOM DPS, NOAA Fisheries designated 45 specific areas of Maine (in HUC 10 watersheds) occupied by Atlantic salmon at the time of listing. These areas comprise approximately 19,751 square kilometers (7,626 square miles) of perennial river, stream, and estuary habitat and 799 square kilometers (308 square miles) of lake habitat. **Error! Reference source not found.** illustrates the extent of designated critical habitat for the GOM DPS.

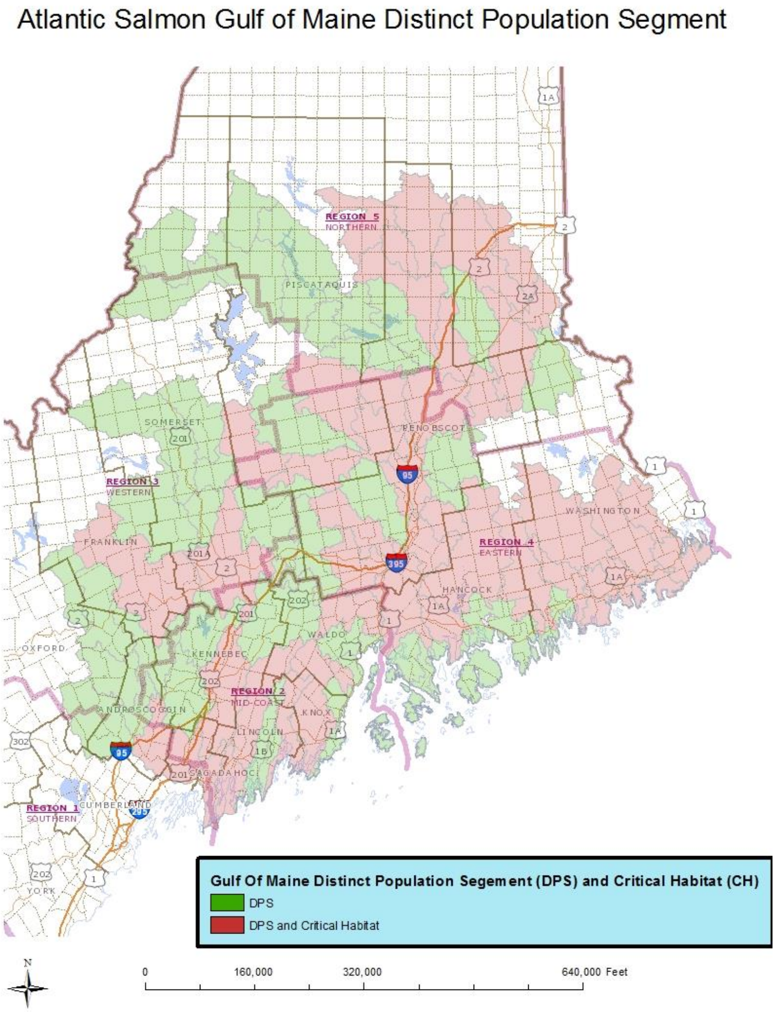


Figure 7. Atlantic salmon critical habitat within the GOM DPS.

The status of Atlantic salmon critical habitat in the GOM DPS is important for two reasons: a) because it affects the viability of the listed species within the action area at the time of the consultation; and b) because those habitat areas designated "critical" provide primary constituent elements (PCEs) essential for the conservation (i.e., recovery) of the species.

The GOM DPS is divided into three Salmon Habitat Recovery Units (SHRU): the Downeast Coastal SHRU, Penobscot Bay SHRU, and Merrymeeting Bay SHRU (NOAA Fisheries 2009; **Error! Reference source not found.**). Currently, the species occupies specific areas within the Downeast Coastal SHRU.

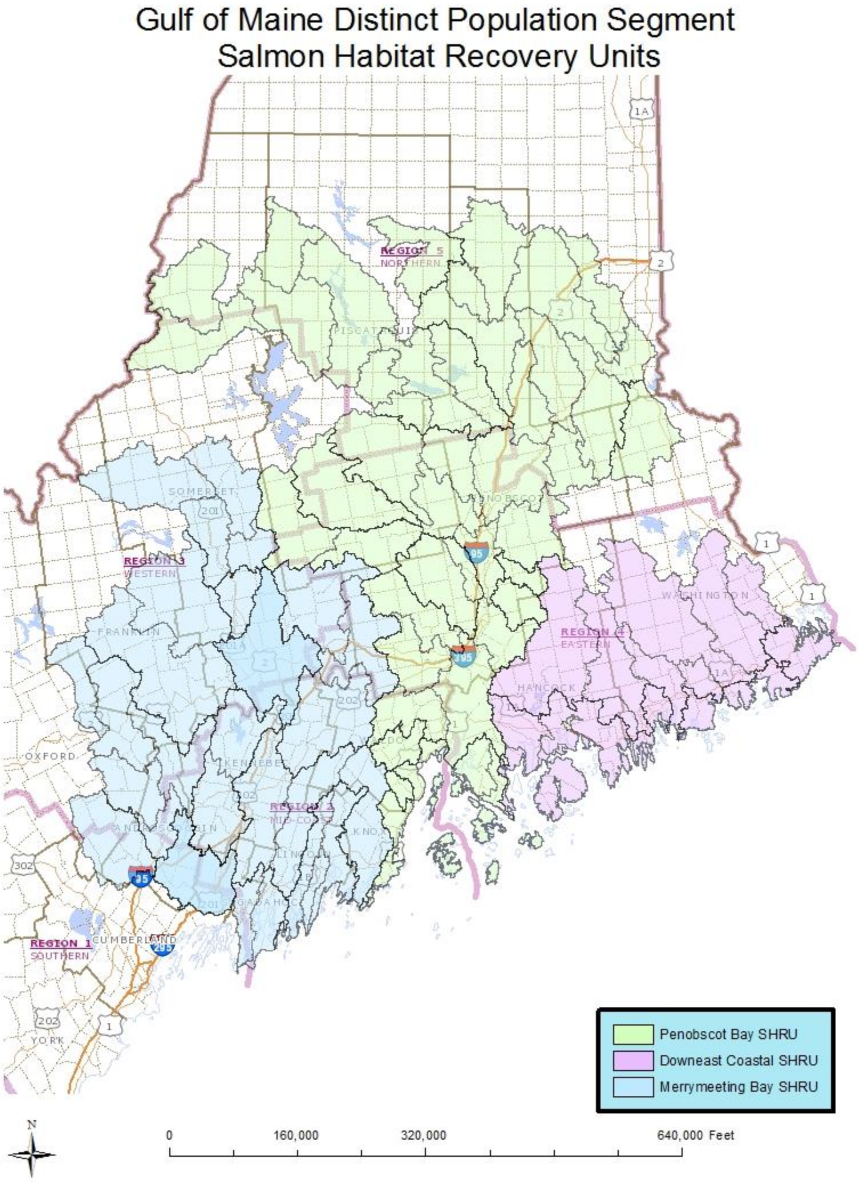


Figure 8. Salmon habitat recovery units (SHRUs) for GOM DPS of Atlantic salmon and limits of HUC 10 watersheds.

The PBFs of the two PCEs for Atlantic salmon critical habitat are as follows:

Physical and biological features of the spawning and rearing PCE

- SR 1. Deep, oxygenated pools and cover (e.g., boulders, woody debris, vegetation, etc.), near freshwater spawning sites, necessary to support adult migrants during the summer while they await spawning in the fall.

- SR 2. Freshwater spawning sites that contain clean, permeable gravel and cobble substrate with oxygenated water and cool water temperatures to support spawning activity, egg incubation, and larval development.
- SR 3. Freshwater spawning and rearing sites with clean, permeable gravel and cobble substrate with oxygenated water and cool water temperatures to support emergence, territorial development and feeding activities of Atlantic salmon fry.
- SR 4. Freshwater rearing sites with space to accommodate growth and survival of Atlantic salmon parr.
- SR 5. Freshwater rearing sites with a combination of river, stream, and lake habitats that accommodate parr's ability to occupy many niches and maximize parr production.
- SR 6. Freshwater rearing sites with cool, oxygenated water to support growth and survival of Atlantic salmon parr.
- SR 7. Freshwater rearing sites with diverse food resources to support growth and survival of Atlantic salmon parr.

Physical and biological features of the migration PCE

- M 1. Freshwater and estuary migratory sites free from physical and biological barriers that delay or prevent access of adult salmon seeking spawning grounds needed to support recovered populations.
- M 2. Freshwater and estuary migration sites with pool, lake, and in-stream habitat that provide cool, oxygenated water and cover items (e.g., boulders, woody debris, and vegetation) to serve as temporary holding and resting areas during upstream migration of adult salmon.
- M 3. Freshwater and estuary migration sites with abundant, diverse native fish communities to serve as a protective buffer against predation.
- M 4. Freshwater and estuary migration sites free from physical and biological barriers that delay or prevent emigration of smolts to the marine environment.
- M 5. Freshwater and estuary migration sites with sufficiently cool water temperatures and water flows that coincide with diurnal cues to stimulate smolt migration.
- M 6. Freshwater migration sites with water chemistry needed to support sea water adaptation of smolts.

The complex life cycle exhibited by Atlantic salmon gives rise to complex habitat needs, particularly during the freshwater phase (Fay et al. 2006). Spawning gravels must be a certain size and free of sediment to allow successful incubation of the eggs. Eggs also require cool, clean, and well oxygenated waters for proper development. Juveniles need abundant food sources, including insects, crustaceans, and other small fish, and need places to hide from predators (mostly birds and bigger fish), such as under logs, root wads, and boulders in the stream, as well as beneath overhanging vegetation. They also need places to seek refuge from periodic high flows (e.g., side channels and off-channel areas) and from warm summer water temperatures (e.g., coldwater springs and deep pools). Returning adults generally do not feed in fresh water but instead rely on limited energy stores to migrate, mature, and spawn. Like juveniles, they also require cool water and places to rest and hide from predators. During all life stages, Atlantic salmon require cool water that is free of contaminants. They also need migratory corridors with adequate passage conditions (e.g., timing, water quality, and water quantity) to allow access to the various habitats required to complete their life cycle.

Atlantic salmon restoration efforts within the Downeast Coastal SHRU watershed have primarily been enhanced fish passage and habitat improvement of anthropologically degraded features carried out by Project SHARE (NOAA Fisheries 2009), which stands for Salmon Habitat and River Enhancement. In 2008, in the Downeast SHRU, Project SHARE replaced seven culverts with open bottom arch culverts, removed six remnant log drive dams, and removed the culvert or bridge and stabilized the banks at twelve road crossings. Dam removal or improved fish passage has the potential to significantly increase the function of critical habitat in the Downeast Coastal SHRU (NOAA Fisheries 2009). Scientists with the Maine DMR monitor annual fish returns in the Narraguagus River. As of July 25, 2022, 11 multi-sea winter salmon and 7 one-sea-winter salmon were counted (Maine DMR 2022).

5.0 ENVIRONMENTAL BASELINE

Stantec Consulting Services Inc. conducted a hydrologic and alternatives analysis (Stantec 2015), two coastal wetland characterizations (in 2017 and 2021), and a coastal wetland delineation (Stantec 2021b). Stream, aquatic habitat, and wetland conditions are described based on the observations made during these efforts.

5.1 AQUATIC HABITAT

5.1.1 Middle River

The Middle River flows under the Dike Bridge at its confluence with the Machias River. The watershed area is approximately 13.2 square miles. The watershed includes Marks, Second Marks, Six Mile, and Seavey lakes. Heading upstream, the river flows through marsh, small agricultural fields, low-density development, and forests that experience some logging. The bridge’s gated culverts and causeway both affect hydrologic conditions in the Middle River. However, leakage through the culvert flap gates and the causeway contribute to landward flow during semi-diurnal flood tides.

The Middle River is tidal with flows affected by the US Route 1 causeway (embankment) and four tide gate structures (Photo 1 and Photo 2). Upstream of the crossing, the river is an intertidal impoundment (Photo 3). Shoreline substrates consist of boulders, cobble, gravel, sand, and silt (Photo 4), and wetland plants are present along the north side of the Dike Bridge embankment (Photo 5).

The embankment and tide gate structures are barriers to aquatic organism passage. However, the tide gates are in poor condition, and tidal flows enter the upstream impoundment. Mudflats are exposed at low tide (Photo 6), but the tidal range is <3 feet in the impoundment. The marsh bordering the impoundment is vegetated predominately by freshwater cordgrass (*Spartina pectinata*; Photo 7). Other species observed included saltmeadow cordgrass (*S. patens*), seaside plantain (*Plantago maritima*), seaside goldenrod (*Solidago sempervirens*), black-grass (*Juncus gerardii*), sea lavender (*Limonium carolinianum*), and silverweed (*Argentina anserina*).

Photo 3. Middle River box culvert and riprap shoreline during falling tide (Stantec 2017)

Photo 4. Middle River box culvert and riprap shoreline during rising tide

Photo 5. Shoreline of Middle River and embankment of Dike Bridge looking east

Photo 6. Riprap, mixed coarse, and fine substrate along north side of Dike Bridge

Photo 7. Looking northeast along embankment of Dike Bridge

Photo 8. Intertidal flat along eastern shore of impoundment north of Dike Bridge

Photo 9. Marsh dominated by freshwater cordgrass (*Spartina pectinata)* north of Dike Bridge along the Middle River

During the site visit on October 10, 2017, the out-going high tide delay in the impoundment was 3.5 hours. The biologist observed extensive algal mats on the shore of the embankment. Animals observed north of the Dike Bridge in the Middle River included acorn barnacle

(*Semibalanus balanoides*), an amphipod (*Gammarus* sp.), common periwinkle (*Littorina littorea*), green crab (*Carcinus maenas*), herring gull (*Larus argentatus*), double-crested cormorant (*Phalacrocorax auritus*), and willet (*Tringa semipalmata*).

Table 5 briefly describes the wetlands delineated on November 17, 2021 as described in Stantec (2021b).

Table 5. Summary of coastal wetland communities

Resource Identifier	**Resource Classification**[1]	**Comments**
VA_01A; VA_01E	E2US2/3	Large intertidal mudflat located to south of Dike bridge; beginning at base of roadway riprap embankment; dominated by sand and silt
VC_01B	E2EM1/2	Area of brackish emergent tidal marsh in southeast corner of Middle River impoundment north of Route 1; significant reduction of vegetation compared with October 2017 observations.
VR_01C	R1UB2/3	Middle River channel at bridge downstream of Route 1
VC_01D	E2EM1	Small saltmarsh dominated by salt-meadow cord grass and saltmarsh rush between roadway and boat launch
VB_01F, VB_01H	E2US1/2 / E1UB2/3	Middle River impoundment. Intertidal rocky shoreline beginning at the base of road embankment, transitions to permanently inundated impoundment
VR_01G	R1UB2/3	Middle River channel at bridge upstream of Route 1
VA_01I	E2US2/3	Small unvegetated mudflat in southwest corner of Middle River impoundment to north of Route 1

[1] E2US2/3 = Estuarine Intertidal Unconsolidated Shore with sand and mud substrates
E2EM1/2 = Estuarine Intertidal Emergent with persistent and non-persistent vegetation
E2EM1 = Estuarine Intertidal Emergent with persistent vegetation
E2US1/2 = Estuarine Intertidal Unconsolidated Shore with cobble, gravel, and sand
E1UB2/3 = Estuarine Subtidal Unconsolidated Bottom with sand and mud substrate
R1UB2/3 = Riverine Tidal with Unconsolidated Bottom with sand and mud substrate

5.1.2 Machias River/Bay Estuary

The Machias River flows for approximately 60 miles and drains approximately 460 square miles before emptying into Machias Bay in downtown Machias, where it becomes tidal at the foot of the falls. Several sawmills and dams were constructed along the river in Machias where lumber was the main industry. Since restoration efforts removed the sawmill dams, the river now flows naturally. Heading upstream, the river travels through the towns of Machias and Whitneyville before flowing through an extensively forested landscape to the Machias Lakes at its headwaters.

The Dike Bridge is roughly 4 miles up the estuary from Machias Bay (assuming the mouth of the estuary is located south of Machiasport in Sanborn Cove). The mouth and head-of-tide for the Machias River is located approximately 0.6 miles southwest of the bridge at the falls in the center of town in Machias (Figure 2).

The Dike Bridge embankment is flanked with riprap that slopes down to cobble, gravel, and mudflats, all of which are exposed at low tide (Photo 8, Photo 9, Photo 10). Along the embankment, high salt marsh vegetation is limited to a few scattered patches (Photo 11). At low intertidal period, one can observe approximately 6-12 inches of wood debris and sawdust in the flats adjacent to the western end of the embankment, likely related to the area's significant lumber industry in the 19th century. On an outgoing tide, high flows pass through the culverts and out the gates with a 3-4-foot drop to the estuary (Photo 12 and Photo 13). On an incoming tide, the gates are closed (Photo 14), but water still enters the impoundment through the leaky gates and culverts.

Photo 10. High intertidal riprap along Machias dike looking east.

Photo 11. Riprap and mixed coarse and fines in the mid-intertidal.

Photo 12. Mixed coarse and fines and mudflat in the lower intertidal.

Photo 13. A small patch of high salt marsh vegetation west of the bridge.

Photo 14. Looking west at tide gates on an outgoing tide.

Photo 15. Looking east at tide gates on an outgoing tide.

Photo 1. Looking east at tide gates on an incoming tide.

5.2 ESA-LISTED SPECIES IN THE ACTION AREA

MaineDOT reviewed the NOAA ESA Mapper and met with the Maine DMR regarding the timing of when listed species have the potential to occur in the action area (Table 66).

Table 6. Potential occurrence of listed species in the action area

Species	Life Stage	Behavior	Habitat	Likely Times Of Year [1]
Atlantic salmon	Adult	Migrating and foraging	Marine/Estuarine	4/1–9/1
Atlantic salmon	Smolt (juvenile)	Migrating and foraging	Marine/Estuarine	4/15–6/15
Atlantic sturgeon	Subadult	Migrating and foraging	N/A	1/1-12/31
Atlantic sturgeon	Adult	Migrating and foraging	N/A	1/1-12/31
Shortnose sturgeon	Adult	Migrating and foraging	N/A	4/1-11/30

1 Based on personal communication with E. Atkinson and C. Bruchs, Maine Department of Marine Resources, July 25, 2022

5.2.1 Shortnose Sturgeon

Shortnose sturgeon have not been documented in the Machias estuary or Machias River. The nearest known occupied habitats are in the Saint John River estuary in New Brunswick, which is more than 75 miles east of Machias Bay. Shortnose sturgeon use the Penobscot River (>80 miles west of Machias Bay) for foraging and wintering, but no spawning sites have been located. The Union River (>60 miles west of Machias Bay) is the most eastern river in Maine where shortnose sturgeon have been documented. It is possible, but reasonably unlikely that shortnose sturgeon from the Penobscot River, Union River, Saint John River or Bay of Fundy could occur in the Machias estuary. Therefore, based on the limited information on their behavior any occurrences of shortnose sturgeon would likely be during the summer when making migratory movements.

5.2.2 Atlantic Sturgeon

Atlantic sturgeon have not been documented in the Machias estuary or Machias River. The nearest population of Atlantic sturgeon occurs in the Saint John River in New Brunswick, which is more than 75 miles east of Machias Bay. Atlantic sturgeon use the Penobscot River and estuary (>80 miles west of Machias Bay) from spring into fall (Altenritter et al. 2017). Sturgeon tagged in the Penobscot estuary were later detected in the Saint John River, New Brunswick (1 individual), Minas Passage Bay of Fundy (4 individuals), and off the coast of Halifax, Nova Scotia (2 individuals) (Altenritter et al. 2017).

To our knowledge, Atlantic sturgeon have not been documented in the action area, but they are assumed to be present. It is possible that Atlantic sturgeon making long migratory movements could occur in the Machias estuary, but it is unknown. Therefore, based on the available information, we anticipate Atlantic sturgeon could occur in the action area when making migratory movements in early-spring or fall.

5.2.3 Atlantic Salmon

Adult Atlantic salmon are likely to occur in the action area during the times when they are migrating up the Machias River and then returning to the ocean after spawning. Data collected from four rivers in the GOM DPS between 2011 and 2015 show that migration could last between 1 and 5 weeks depending on river conditions (**Error! Reference source not found.**). This period runs from mid-April to mid-June. Any occurrences would be that of individuals on the move as opposed to resting or holding. However, adult salmon can occur in rivers from April through October. Adults migrating up the Machias River need to reach and climb Bad Little Falls when river conditions are ideal during spring flows. Otherwise individuals may rest or hold in the Machias River below the falls (E. Atkinson and C. Bruchs, Maine Department of Marine Resources, personal communication).

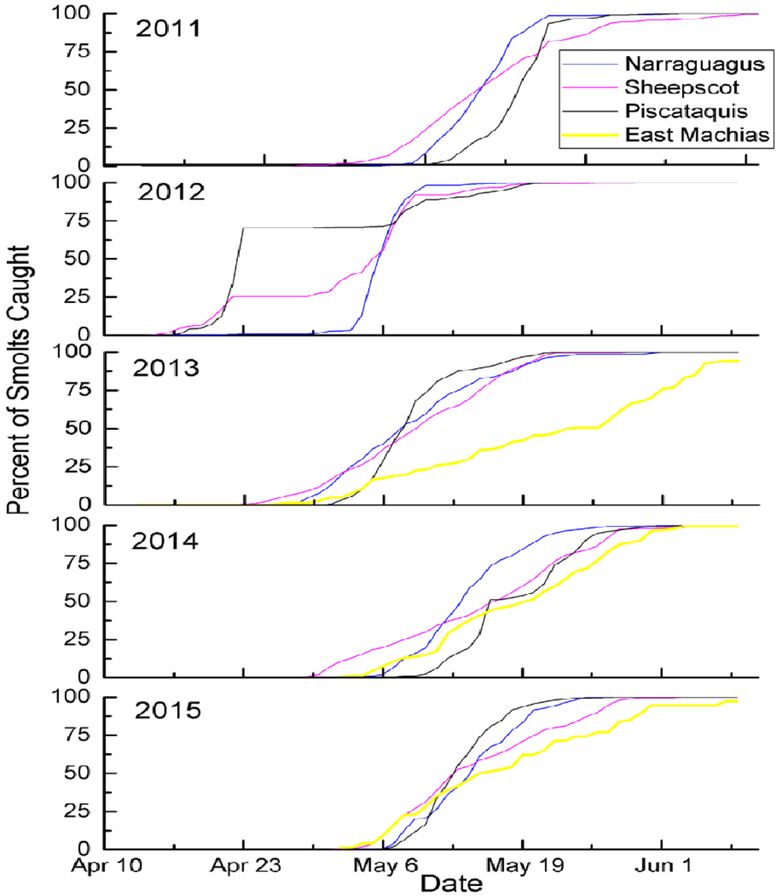
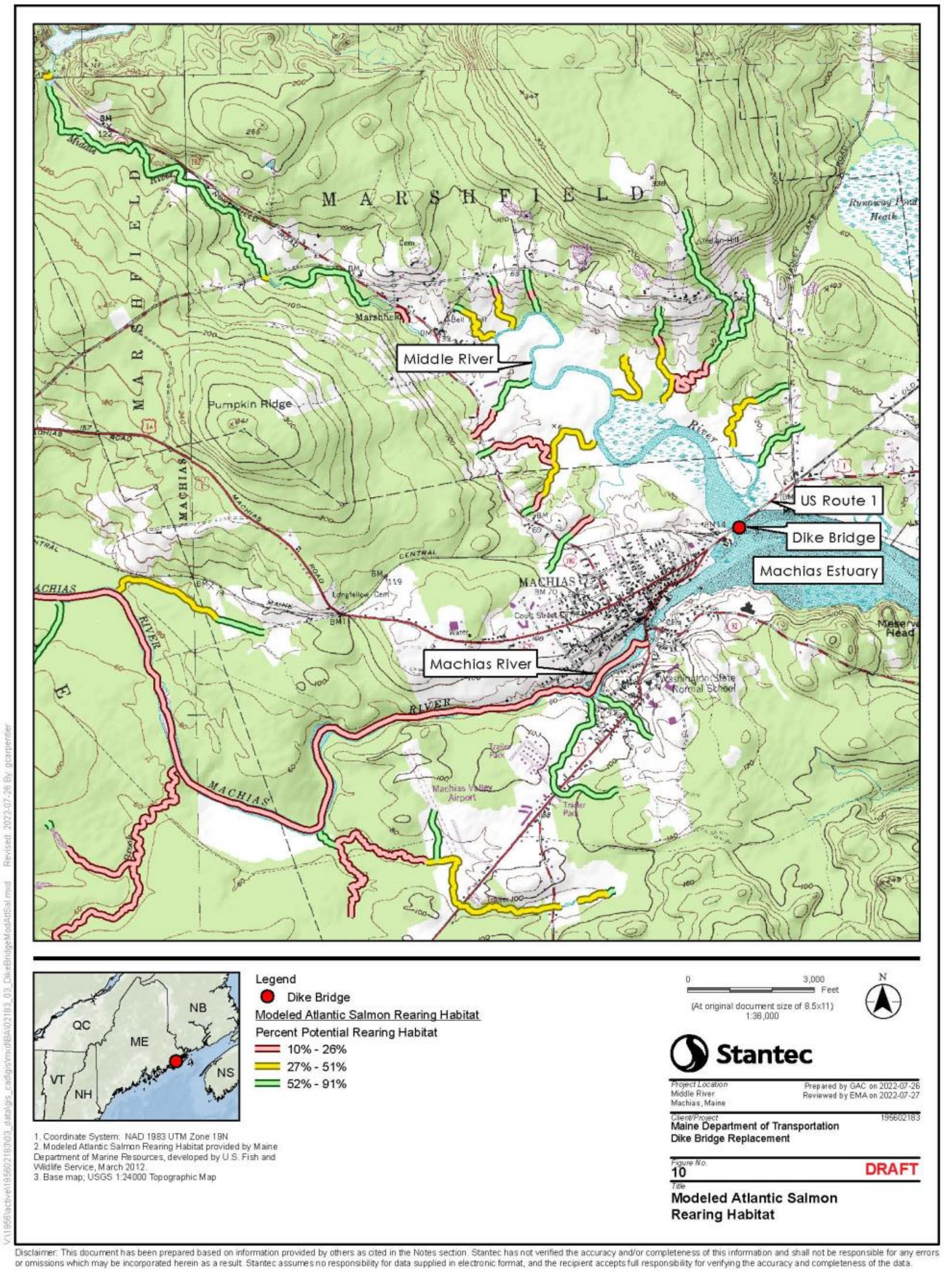


Figure 9. Cumulative percent smolt capture of all origins by date (run timing) on the Narraguagus (blue line), Sheepscot (pink line), Piscataquis (black line), and East Machias (yellow line) rivers, Maine (2011-2015)

Source: USASAC (2016)

Smolt Atlantic salmon may occur in the action area during their outward migration in mid-April to mid-June. Any occurrences would be that of individuals on the move as opposed to resting or holding.

Detailed habitat surveys were conducted in the Machias River, along with Sheepscot, Dennys, Sandy, Piscataquis, Mattawamkeag, and Souadabscook rivers (NOAA Fisheries 2009). Data from the habitat surveys were used to develop a habitat model. Maine DMR has modeled Atlantic salmon rearing in the Middle River and its tributaries (**Error! Reference source not found.**). The outputs of the habitat modeling include three percentile bins of potential rearing habitat: 1) 10–26%; 2) 27–51%; and 3) 52–91% (**Error! Reference source not found.**). The Atlantic salmon rearing habitat model indicates there are as many as 258.8 potential rearing habitat units upstream of the Dike. Field surveys have not been completed in the action area to determine the presence and abundance of rearing or spawning habitat.



1. Coordinate System: NAD 1983 UTM Zone 19N
2. Modeled Atlantic Salmon Rearing Habitat provided by Maine Department of Marine Resources, developed by U.S. Fish and Wildlife Service, March 2012.
3. Base map; USGS 1:24000 Topographic Map

Figure 10. Modeled Atlantic salmon rearing habitat relative to the Dike Bridge project area

Bad Little Falls under most conditions is a partial or complete barrier to some anadromous fish, including alewives and shad. The falls is not a barrier to Atlantic salmon, but salmon may be delayed under some conditions. The Bad Little Falls fishway (no longer functional) provided passage around a dam that has since been breached and Salmon can use the west channel to head upriver.

The habitat upstream of the Dike represents potential habitat for other anadromous species. The middle river would presumably be viable habitat for sea run rainbow smelt to use for spawning. There are two dams upstream of the Machias Dike on the Middle River without fish passage facilities. These dams currently block the migration corridor into Marks Lake and Second Marks Lake. If accessible, this habitat could serve as spawning habitat for alewives.

In summary, we estimate Atlantic salmon are most likely to occur in the action area when making migratory movements in the Machias River from mid-April to mid-June. Atlantic salmon smolts may occur in the action area during their outward migration in May and June. Any occurrences would most likely be that of individuals on the move as opposed to resting or holding. However, we do not discount the possibility that adult salmon could rest or hold proximal to the action area.

5.2.4 Summary

There are anecdotal accounts of fish occurring in the Middle River through the existing bridge. Most of the accounts are of anadromous sport fish (striped bass) being angled in the Middle River above the causeway. At this time, it is not expected that any listed species will be present upstream of the causeway in the Middle River. However, all of the species and life stages of those species listed above in Table 6 could potentially be present in the action area on the downstream side of the bridge in the Machias River Estuary.

5.3 DESIGNATED CRITICAL HABITAT IN THE ACTION AREA

The defined Action Area covers a diverse geographic extent that contains all of the PBFs within its range. Full surveys of the Middle River for Atlantic salmon spawning and rearing habitat have not been completed. However, anecdotal information indicates that it is likely to contain all the Spawning and rearing PBFs. There are two dams in the upper Middle River that also represent barriers to fish passage an alter the habitat in their vicinity. The critical habitat located downstream of the dike represents an estuarine environment. This environment is part of the migratory pathway for Atlantic salmon of different life stages moving in and out of the Machias River.

Table 7.- Critical habitat status in the Action Area

Primary biological feature	Location in Action Area	PBF Status	Current Function
SR 1	Present upstream of the dike in the Middle River	The current dike limits access to the PBF and the two dams on the	Limited

		Middle River also effect access and habitat in their vicinity.	
SR 2	Likely present though not confirmed upstream of the Dike in the Middle River	The current dike limits access to the PBF and the two dams on the Middle River also effect access and habitat in their vicinity.	Limited
SR 3	Present upstream of the dike in the Middle River	The current dike limits access to the PBF and the two dams on the Middle River also effect access and habitat in their vicinity.	Limited
SR 4	Present upstream of the dike in the Middle River	The current dike limits access to the PBF and the two dams on the Middle River also effect access and habitat in their vicinity.	Limited
SR 5	Present upstream of the dike in the Middle River	The current dike limits access to the PBF and the two dams on the Middle River also effect access and habitat in their vicinity.	Limited
SR 6	Present upstream of the dike in the Middle River	The current dike limits access to the PBF and the two dams on the Middle River also effect access and habitat in their vicinity.	Limited
SR 7	Present upstream of the dike in the Middle River	The current dike limits access to the PBF and the two dams on the Middle River also effect access and habitat in their vicinity.	Limited
M 1	Present upstream and downstream of the dike	The current Dike prevents access into the Middle River. The PBF is function for Adult Atlantic	Limited

		salmon migrating into the Machias River. That function may be limited by false attraction of the Middle River flow.	
M 2	Present upstream of the dike	The current dike limits access to the PBF and the two dams on the Middle River also effect access and habitat in their vicinity.	Limited
M 3	This PBF is present upstream and downstream of the dike	There are native fish communities located throughout the action area. The dike limits the abundance of some of the sea run fish.	Limited
M 4	This PBF is present upstream and downstream of the dike	The dike would delay any downstream migration.	Not properly functioning
M 5	This PBF is present upstream and downstream of the Dike	Though the amount is unknown, it is likely that the dike effects water temperatures in the impoundment	Limited
M 6	This PBF is present upstream and downstream of the Dike	Though the amount is unknown, it is likely that the dike effects water quality in the impoundment	Limited

6.0 EFFECTS ANALYSIS

The ESA Consultation Handbook (USFWS and NOAA Fisheries 1998) identifies six factors that should be examined (as appropriate for the proposed action under consideration) to assess the direct and indirect effects of a proposed action. These factors include the following:

1) proximity of the proposed action to the species, management units or designated critical habitat units;

2) geographic areas where the proposed action-induced disturbance occurs;
3) timing of the proposed action in relative to the sensitive period of a species' life cycle;
4) the nature of the effects of the proposed action on elements of a species life cycle, population size or variability, or distribution; or on the primary constituent elements of the critical habitat;
5) duration of the effects (i.e., pulse effect – short-term event whose effects are relaxed almost immediately; press effect - sustained, long-term, or chronic event whose effects are not relaxed; and threshold effect - permanent event that sets a new threshold for some feature of a species' environment); and
6) the disturbance frequency of the effects resulting from the proposed action (USFWS and NOAA Fisheries 1998).

The factors described above are to be evaluated, as appropriate, to determine if the proposed action is likely to adversely affect listed species or critical habitat.

Both the direct effects on a protected species at the individual level and to critical habitat should be thoroughly evaluated when determining the extent of the adverse effect. The potential effects of the action to the listed species and to each PBF of critical habitat needs to be evaluated and a determination made regarding whether the effects will be beneficial, extremely unlikely, insignificant, or may result in adverse effects. The six factors identified above were used to assess the consequences of the action on the listed species and whether the proposed activities would adversely affect listed species or critical habitat. In turn, this information is used to select the appropriate ESA determination for the proposed action.

The occurrence and timing of each species' life stage in the action area, in-water work window, and the approximate timing of each potential project-related effect were considered when reaching an ESA determination. The following sections present the potential project-related effects on shortnose sturgeon, Atlantic sturgeon, Atlantic salmon, and Atlantic salmon designated critical habitat and the subsequent determination for each.

Table 8.- Summary of in water construction activities and species exposure

Activity	Duration	Activity Timing	Potential species and life stage present[3]	Stressor
Sheet pile/ fill installation upstream of Dike for cofferdam	3-4 weeks	Anytime	Atlantic salmon- Adult and smolt, shortnose sturgeon adults	Limited turbidity release
Sheet pile/ fill installation downstream of the Dike for cofferdam	3-4 weeks	Anytime	Atlantic salmon- Adult and smolt, shortnose sturgeon adults	Turbidity release and hydroacoustic
Installation of temporary bridge pile with a vibratory hammer	1-2 weeks	Anytime	Atlantic salmon- Adult and smolt, shortnose sturgeon adults	Turbidity release and hydroacoustic
Installation of temporary bridge pile with an impact hammer	1 week	In the dry or December 1–March 31	Limited Atlantic salmon adults	Turbidity release and hydroacoustic
Removal of cofferdam/ fill upstream of Dike	1-2 weeks	Anytime	Atlantic salmon- Adult and smolt, shortnose sturgeon adults	Limited turbidity release
Removal of cofferdam downstream of Dike	1-2 weeks	Anytime	Atlantic salmon- Adult and smolt, shortnose	Turbidity release and hydroacoustic

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[3] Atlantic sturgeon adults could be present in the action area any time of year

			sturgeon adults	
Removal of temporary bridge pile with a vibratory extractor	1 week	Anytime	Atlantic salmon-Adult and smolt, shortnose sturgeon adults	Turbidity release and hydroacoustic

6.1 CONSTRUCTION EFFECTS

6.1.1 Turbidity and Sedimentation

Construction elements that occur in water may create turbidity increases. These include installing and removing cofferdams and piles and placing riprap. Land-based soils may also enter the water and create turbidity. Construction equipment and ineffectively stabilized soils may cause sedimentation. Cofferdams will be installed around the sites of the new and old structures, preventing turbidity increases from occurring during these two activities.

6.1.1.1 Species Turbidity Thresholds

Species turbidity thresholds were taken from NOAA Fisheries Section 7 effects analysis on turbidity (NOAA Fisheries 2021).

Atlantic Salmon

High total suspended sediment (TSS) levels can cause a reduction in dissolved oxygen (DO) levels. Earlier life stages of Atlantic salmon require DO levels at saturation, whereas adults can tolerate lower levels closer to approximately 5.0 mg/L (NOAA Fisheries 2009b). Newcombe and Jensen (1996) demonstrated that behavioral changes for both adult and juvenile salmonids began to occur at relatively low TSS levels, around 20 mg/L after 1 hour of exposure (avoidance response). If animals remain exposed to elevated TSS levels, sub-lethal effects began to occur, and major physiological stress can occur at approximately 1,100 mg/L after 24 hours of exposure. Lethal effects could begin to occur at TSS levels of 3,000 mg/L and higher after 24 hours of exposure. Servizi and Martens (1992) observed the cough frequency of juvenile coho salmon significantly increased at 240 mg/L after 24 hours of exposure. Additionally effects that last longer than 24 hours reduces tolerance to TSS levels to about only 50 mg/L (Johnson 2018). Mortality for eggs/larvae can occur anywhere between 10 mg/L and 120 mg/L depending on the duration of exposure (Wilber and Clarke 2001). The turbidity plumes caused by dredging are generally expected to last for less than 24 hours. While the increase in suspended sediments may cause Atlantic salmon to alter their normal movements, these minor movements will be too small to be meaningfully measured or detected. TSS is most likely to affect Atlantic salmon if a plume causes a barrier to normal behaviors. However, we expect adult and juvenile salmon to swim through the plume to avoid the area with no adverse effects.

Sturgeon

High TSS levels can cause a reduction in DO levels. Both Atlantic and shortnose sturgeon may become stressed when DO falls below certain levels. Jenkins et al. (1993) observed that younger shortnose sturgeon experienced high levels of mortality at low DO levels while older individuals tolerated those reduced levels for short periods of time. Tolerances may decline if chronic exposure to low DO levels occurs. Johnson (2018) recommends that sturgeon should not be exposed to TSS levels of 1,000 mg/L above ambient for longer than 14 days at a time to avoid behavioral and physiological effects. During times when early life stages could be present in an action area, it is recommended that they be exposed to less than 50 mg/L of TSS. While the increase in suspended sediments may cause Atlantic and shortnose sturgeon to alter their normal movements, these minor movements will be too small to be meaningfully measured or detected. TSS is most likely to affect sturgeon if a plume causes a barrier to normal behaviors. However, we expect sturgeon to swim through the plume to avoid the area with no adverse effects.

6.1.1.2 Potential for Turbidity and Sedimentation Effects

Several activities associated with proposed action have the potential to disturb sediments and increase turbidity. These activities are described below.

Cofferdam and Temporary Bridge Installation and Removal

The installation of piles will disturb bottom sediments and may cause a temporary increase in suspended sediment in the action area. Using available information collected from a project in the Hudson River, we expect pile driving activities to produce total suspended sediment (TSS) concentrations of approximately 5.0 to 10.0 mg/L above background levels within approximately 300 feet (91 meters) of the pile being driven (FHWA 2012). Using a clamshell to extract piles allows sediment attached to the pile to move vertically through the water column until gravitational forces cause it to slough off under its own weight. The small resulting sediment plume is expected to settle out of the water column within a few hours. Studies of the effects of turbid water on fish suggest that concentrations of suspended sediment can reach thousands of milligrams per liter before an acute toxic reaction is expected (Burton 1993). The TSS levels expected for pile driving or removal (5.0 to 10.0 mg/L) are below those shown to have adverse effect on fish (typically up to 1,000.0 mg/L; see summary of scientific literature in Burton [1993]; Wilber and Clarke [2001]) and benthic communities (390.0 mg/L [EPA 1986]).

MaineDOT assumes the downstream extent of turbidity releases will not exceed 300 feet. These turbidity releases from pile driving and removal will likely cause only short-duration, localized effects.

Riprap Placement

Cofferdams will be in place to allow riprap to be installed in the dry, thereby avoiding and minimizing the potential for sedimentation or increased turbidity. Although not anticipated for the Project, there may be instances where riprap is placed in the wet without a cofferdam. Based on experience from past projects, MaineDOT assumes that the intensity, duration, and extent of turbidity effects of riprap placement without a cofferdam will be similar to or less than for cofferdam installation/removal. If riprap is placed in the wet outside of a cofferdam, then placement will occur at low tide, and the contractor will use suitable best management practices as necessary to contain turbidity releases.

Land-based Erosion

Land-based soils may erode into the stream, but erosion control measures will be in place to avoid and minimize these instances. See Section 2.2.5.

6.1.1.3 Species Determinations

Implementation of the AMMs will reduce the likelihood and severity of sedimentation and temporary increases in turbidly in the Machias River. Although the potential exists for adults of both sturgeon species to occur in the action area during the in-water work window, the likelihood of presence is low. During any of the activities with potential to create turbidity, TSS level will be below those shown to have adverse effect on fish (typically up to 1,000 mg/L).

Avoidance behavior could negatively affect sturgeon if it reduces or hinders essential behaviors such as foraging. We expect sturgeon to swim through any turbidity plumes caused by project activities, but turbidity plumes could also cause Atlantic and shortnose sturgeon to alter their movements to avoid the plumes. Such avoidance behavior may temporarily block upstream or downstream movements.

Both sturgeon species are bottom feeders that stir up sediment while foraging, suggesting that these fish are at least as tolerant to suspended sediment as striped bass and other estuarine fish species. Dadswell et al. (1984) reported an increased capture rate of shortnose sturgeon during higher levels of turbidity that may indicate that sturgeon are more tolerant to increased turbidity. MaineDOT expects project-related increases in turbidity will be minor and temporary in nature (i.e., a matter of hours or minutes), and will not increase to a level that will affect adults or subadult sturgeon (of either species) that may be migrating and enter the action area during the construction period.

While an increase in suspended sediments may cause sturgeon to alter their normal movements, this behavior was deemed too small to be meaningfully measured or detected and, therefore, are insignificant.

Atlantic salmon eggs, alevin, fry, and parr are not expected to be present in the action area due to a lack of suitable spawning habitat. In-water work will may occur when smolts are expected to occur in the action area. However, the extent of the turbidity releases is not expected to go across the Machias Estuary and will always contain an unaffected migratory pathway.

Project construction elements have the potential to result in turbidity releases (i.e., cofferdam installation and removal and riprap placement) in the range (e.g., <10 mg/L for a matter of hours) that could potentially induce avoidance-type behavioral responses in salmon. Salmon moving in the river would be able to avoid this type of plume, if it occurs, by continuing upstream in the Machias River. Adverse effects to smolt and adult life stages are unlikely because: (1) instream work will avoid the timing of smolt migration; (2) measures to avoid and minimize increased turbidity will be implemented during construction; and (3) both smolt and adult life stages are highly mobile and, if present, can avoid any turbidity releases resulting from the proposed activities when moving through the action area in the Machias River.

6.1.1.4 Critical Habitat Determination

Effects to Atlantic salmon critical habitat would be minimal and may consist of temporary increased turbidity in the Middle and Machias rivers. This potential decrease in water quality would occur during in-water work and would affect the migratory pathway function of the habitat for adult Atlantic salmon moving up or down the Machias River. These temporary and minor adverse effects on water quality in the river would not create physical or biological barriers to migration, or measurably affect characteristics such as water temperature, oxygen levels, abundance of prey, or other physical characteristics of the habitat. Because turbidity and sedimentation changes in the Middle and Machias rivers are expected to be temporary and minor, and the designated Atlantic salmon critical habitat in the action area is primarily migration habitat, no measurable turbidity-related effects to critical habitat are likely.

Based on the above considerations, the turbidity effects to migrating Atlantic salmon adults and smolts are likely to be too small to be meaningfully measured or detected when added to the baseline and, therefore, will be insignificant. In addition, the temporary and minor increases in turbidity during construction when added to the action area baseline conditions will not adversely affect Atlantic salmon critical habitat.

6.1.2 Hydroacoustic Effects

Construction elements that may result in hydroacoustic effects to fish include installing and removing cofferdams.

6.1.2.1 Background Information on Fish and Underwater Noise

Under certain conditions, underwater sound generated from construction activities may cause behavioral or physiological changes to aquatic organisms. Behavioral changes often include avoidance of the action area, disruption of foraging attempts, or interruption of reproduction. Physiological effects vary depending on the duration and intensity of sound produced during construction. Aquatic organisms could suffer temporary or permanent hearing loss, or percussion-type injuries such as bruising, ruptures to capillaries, hemorrhaging of organ systems, damage to the swim bladder and internal organs, or death (Halvorsen et al. 2011).

The types of effect on and response from fishes to a sound source will depend on distance. The potential for effects declines as distance increases between the individual and the source. Very close to the source, effects may range from behavioral changes to mortality. Farther from the source mortality is no longer an issue, and effects range from behavioral to physiological. The nature of effects depends on several other factors, such as fish hearing sensitivity, source level, sounds propagation and resultant sound level at the fish, whether the fish stays near the source, and motivation level of the fish. Generally speaking, species are thought to have different tolerances to sound levels and may exhibit different responses to the same sound source.

The following are commonly used measures of sound:

- Peak sound pressure level (SPL): the maximum sound pressure level (highest level of sound) in a signal measured in dB re 1 µPa.
- Sound exposure level (SEL): the integral of the squared sound pressure over the duration of the pulse (e.g., a full pile driving strike). SEL is the integration over time of the square of the acoustic pressure in the signal and is thus an indication of the total acoustic energy received by an organism from a particular source (such as pile strikes). Measured in dB re 1µPa2-s.
- Single Strike SEL: the amount of energy in 1 strike of a pile.
- Cumulative SEL (cSEL or SELcum): the energy accumulated over multiple strikes. cSEL indicates the full energy to which an animal is exposed during any kind of signal. The rapidity with which the cSEL accumulates depends on the level of the single strike SEL. The actual level of accumulated energy (cSEL) is the logarithmic sum of the total number of single strike SELs. Thus, cSEL (dB) = Single-strike SEL + 10log10(N); where N is the number of strikes.
- Root Mean Square (RMS): the average level of a sound signal over a specific period of time.

NOAA Fisheries generally uses 150 dB RMS as the threshold for behavioral effects to listed fish species (Buehler et al. 2015). For the State Route 197 Bridge in Richmond, Maine, NOAA Fisheries used 150 dB re 1 µPa RMS as a conservative indicator of the sound level at which there is the potential for behavioral effects (NOAA Fisheries 2012b). Exposure to sound levels of 150 dB re 1 µPa RMS will not always result in behavioral modifications, and behavioral modifications will not always result in adverse effects (i.e., harm or harassment to listed species), but that there is the potential for behavioral response upon exposure to 150 dB re 1 µPa RMS (NOAA Fisheries 2012b).

In 2008, the Fisheries Habitat Working Group (FHWG) developed the Agreement in Principal for Interim Criteria for Injury to Fish from Pile Driving Activities, which identifies the following thresholds for onset of physical injury to fish (FHWG 2008):

- Peak SPL: 206 decibels relative to 1 micro-Pascal (dB re 1 μPa) [for fish of any size].
- cSEL of 187 decibels relative to 1 micro-Pascal-squared second (dB re 1μPa2-s) for fishes above 2 grams (0.07 ounces).
- cSEL of 183 dB re 1μPa2-s for fishes below 2 grams (0.07 ounces).

These are criteria for the onset of physiological effects and not levels at which fish are necessarily mortally damaged. These criteria apply to green sturgeon and Pacific salmon, and both USFWS and NOAA Fisheries have assumed the criteria can be applied to Atlantic salmon (FHWG 2008).

NOAA Fisheries has relied on these criteria in determining the potential for physiological effects in ESA Section 7 consultations. At this time, they represent the best available information on the thresholds at which physiological effects to salmon and sturgeon are likely to occur. Physiological effects may range from minor injuries, resulting in complete recovery, to death. The severity of injury is related to the distance from the pile being installed and the duration of exposure. The closer to the source and the greater the duration of the exposure, the higher likelihood of significant injury.

Ambient sound can be highly variable in shallow water areas, such as in lower tides of the Machias River. Primary sources of sound (including meteorological, hydrographic, and anthropogenic) change and the dominant source at any one time drives the sound level (Buehler et al. 2015). Ambient sound within the action area has not been measured.

For the Dike Bridge replacement and construction work, the primary activity that could result in elevated underwater sound pressure during construction is sheet pile cofferdam installation. The specific activity of concern is vibratory driving of sheet piles.

6.1.2.2 Potential for Hydroacoustic Effects

Pile Installation and Removal

Installation of the temporary bridge for routing traffic during construction will require the installation of 30-inch steel bent piles that will be first driven using a vibratory hammer and then seated using an impact hammer. Cofferdam construction will entail the use of a vibratory hammer to install a series of interlocking 24-inch-wide steel sheets. The substrate that the sheets are being driven into will determine the duration of the driving event for each pair of sheets. A pair of sheets that are driven into finer material will take approximately 15 minutes. A pair of sheets driven into material with larger rocks and firmer substrate can take up to 1 hour. Based on the substrates in both the Middle and Machias rivers, MaineDOT estimates each cofferdam on either side of the Dike Bridge will take approximately 15 days to install. Removal of the sheet piles with a vibratory hammer will take approximately10 days for each cofferdam.

Caltrans (2009) summarized records from numerous construction projects in the *Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish* and presented the expected noise levels for steel sheet piles and steel bent piles shown in Table 9, Table 10, and Table 11. The tables below were developed using the acoustics tool developed for use by the Greater Atlantic Regional Fisheries Office protected resource division staff.

Table 9. Proxy projects for estimating underwater noise

Project Location	**Water Depth (m)**	**Pile Size (inches)**	**Pile Type**	**Hammer Type**	**Attenuation rate (dB/10m)**
Florence, OR - Siuslaw River	3	30	Steel Pipe	Impact	5
Florence, OR - Siuslaw River	3	30	Steel Pipe	Vibratory	5
Not Available	15	24	AZ Steel Sheet	Vibratory	5

Table 10. Proxy-based estimates for underwater noise

Type of Pile	**Hammer Type**	**Estimated Peak Noise Level (dB_{Peak})**	**Estimated Pressure Level (dB_{RMS})**	**Estimated Single Strike Sound Exposure Level (dB_{sSEL})**
30-inch Steel Pipe	Impact	210	190	177
30-inch Steel Pipe	Vibratory	200	180	167
24-inch AZ Steel Sheet	Vibratory	182	165	165

Table 11. Estimated distances to sturgeon/salmon injury and behavioral thresholds

Type of Pile	**Hammer Type**	**Distance (m) to 206dB_{Peak} (injury)**	**Distance (m) to 150 dB_{sSEL} (surrogate for 187 dBcSEL injury)**	**Distance (m) to Behavioral Disturbance Threshold (150 dB_{RMS})**
30-inch Steel Pipe	Impact	18.0	64.0	90.0
30-inch Steel Pipe	Vibratory	NA	44.0	70.0
24-inch AZ Steel Sheet	Vibratory	NA	40.0	40.0

Based on this information, installation of the 30-inch steel bent piles with an impact hammer is likely to generate peak SPL of 210 dB. This level exceeds the peak SPL of 206 dB that is the threshold for the onset of physiological effects at 18 meters. Installation of the 30-inch steel bent piles with an impact hammer is likely to exceed the behavioral distance threshold of 150 dBRMS 1uPa out to 90 meters from the pile site. The use of an impact hammer to seat the 30-inch piles will be minimized to the maximum extent practicable.

6.1.2.3 Species Determinations

Injury

To minimize the potential for injury, MaineDOT will employ the soft start technique outlined in AMM 17. Underwater noise generated from an impact hammer to seat the steel bents for the temporary structure may cause physical harm to listed species to within 18 meters of each driven pile. Atlantic salmon adults and smolts could occur in the action area during this event. There is a low likelihood of Atlantic sturgeon and shortnose sturgeon occurring within 18 meters of impact pile driving events. Nonetheless, salmon individuals that enter the action area during the time outside of this protective window may sustain physical injury. The installation of the steel bent piles is likely to adversely affect Atlantic salmon adults.

Behavioral

At more than 18 meters and out to 90 meters, installation of the steel bent piles using an impact hammer is likely to result in behavioral responses, whereby listed species (if present) would avoid the construction site during noisy activities. Similarly, installation of steel bent piles and sheet piles using a vibratory hammer is likely to result in behavioral responses in listed species out to 70 meters.

MaineDOT does not expect that these temporary behavioral responses (avoidance) will have long-term consequences to any listed species that may encounter and subsequently avoid the sound field, and effects to the species will be negligible. There will still be unaffected areas of the Machias estuary available for migration and movement. Further, the effects on listed species caused by underwater noise from sheet pile installation and removal will be too small to be meaningfully measured or detected when added to the existing conditions, and, therefore, these effects will be insignificant. The absence of listed species early life stages (eggs/larvae) in the action area make effects to those life stages highly unlikely, and therefore discountable.

In summary, the hydroacoustic effects of installation of steel bent piles using an impact hammer at more than 18 meters to 90 meters and pile installation and removal using a vibratory hammer out to 70 meters may result in behavioral responses in sturgeon and salmon if present in the action area, but effects would be too small to be meaningfully measured or detected and, therefore, would be insignificant. Hydroacoustic effects resulting in behavioral responses are not likely to adversely affect salmon and sturgeon.

6.1.2.4 Critical Habitat Determination

Installation of piles using an impact hammer will be scheduled outside of the critical migration period from April 15 through June 15 to minimize effects to out-migrating salmon smolts and up-river migrating adult salmon. Sheet pile installation using a vibratory hammer could occur at any time during construction. Once pile installation is completed, noise conditions will return to those that occurred before the work started. Pile removal will be conducted using a vibratory hammer. Nonetheless, pile installation will not affect the action area's ability to provide unimpeded movements of salmon smolts and adults. The action area is already the site of impeded movement. The effects of temporary underwater noise generated during sheet pile installation and removal will be too small to be meaningfully measured, detected, or evaluated; therefore, effects will be insignificant.

6.1.3 Cofferdam Entrapment Effects

Sheet pile cofferdams are required for installing the new structure, and removing the old culvert structure. Fish may become entrapped during cofferdam construction with subsequent dewatering potentially resulting in injury or death. Sturgeon and salmon may also become entrapped if an existing cofferdam is overtopped during high river flows.

6.1.3.1 Species Determinations

Cofferdam installation will overlap with the potential presence of adult sturgeon and adult salmon in the action area. However, we expect that sturgeon and salmon will avoid the construction site during construction because of disturbance by in-water activity such as equipment and personnel. Therefore, it is extremely unlikely that a sturgeon and salmon will enter the area within the cofferdam during construction. Further, as previously mentioned, the likelihood listed species being present in the action during this time is low. Therefore, the chances of sturgeon or salmon becoming entrapped during cofferdam construction and dewatering are highly unlikely. Sturgeon or salmon becoming entrapped in the cofferdam by overtopping during high water levels is also possible, but unlikely as overtopping would only occur during an extreme flow event. As such, the effects of cofferdam entrapment are extremely unlikely to occur and, therefore, discountable.

6.1.3.2 Critical Habitat Determination

Incidental entrapment of listed species in cofferdams will have no effect on designated critical habitat for Atlantic salmon migration PBFs.

6.1.4 False Attraction

When migrating, Atlantic salmon sense waterflow and cold water inputs to help guide them to habitat used for holding and spawning (reference). Though salmon are known to migrate and spawn in their natal streams, straying from those areas is also a natural life history of some adult fish (reference). Migrating fish are attracted to these flows while they are migrating.

When Atlantic salmon approach a challenging barrier to navigate (natural or manmade) competing flows may lead them to a part of a barrier that is not navigable as compared to an area that a fish could successfully move upstream. The concept of competing flows is a common design parameter for upstream passage at a dam when a structural fishway is a passage solution. Flows and location of the fishway entrances attract the fish make a passage attempt. False attraction effects are most likely to affect Adult Atlantic salmon migrating upstream to spawn.

The in kind replacement will have flows that come out of the middle river for ~ 12 hours a day. These flows will generally have a velocity that is greater than 5 FPS.

Adult Atlantic salmon that are attracted to flow out of the Middle River that can't pass due to excessive water velocities may increase their exposure to predation. The estuary contains large predators that would opportunistically eat Atlantic salmon. This exposure is also part of the baseline conditions, but it is unknown if there is increased predation in that area currently.

False attraction that results in energy expenditures during failed passage attempts or additional time spent during the migration could reduce Atlantic salmon's ability to continue the spawning migration and successful spawning. These delays could result in effects on the Atlantic salmon's ability to spawn. The extra time spent during the migration may cause the adult salmon to use extra energy needed for the to finish the spawning migration and spawning (Rubenstein 2021). The delay may also expose salmon to additional predation pressure. It is reasonable to assume that migrating adult salmon could be falsely attracted to flows coming out of the Middle River.

6.1.4.1 Species Determinations

False attraction can be a stressor to migrating Atlantic salmon. The proposed flow conditions at the Dike Bridge could result in conditions with false attraction. The effect is reasonably certain to occur. Effects to some individuals maybe insignificant while predation and take of adult Atlantic salmon could occur in some instances. Therefore, the effect of false attraction resulting from the replace in kind scope is adverse.

6.1.4.2 Critical Habitat Determination

Migration without delay is a part of the function of migration PBF 1. The current dike and dike bridge may result in Altlantic salmon being falsely attracted into the Middle River. The proposed action will maintain that condition. This will result in an adverse effect to PBF 1s ability to aid in the recovery of Atlantic salmon.

6.1.5 Incidental Passage

There are anecdotal reports that there is fish passage through the current tide gate system at the Machias Dike. Striped bass have been angled on the upstream side of the Dike Bridge. It is unknown what the state of maintenance was when the fish passage events occurred. The replacement gates and new structures will likely function much more efficiently than the old gates. Adult Atlantic salmon that pass upstream may search for spawning sites but lack other salmon to spawn with.

Velocities during flow events are likely to exceed 15 fps on each tidal cycle. However, there are short timeframes that occur just as the tide in the Machias Estuary drops below water elevations upstream of the Dike and when water elevations in the Machias Estuary start to rise back to the level of the water levels above the dike that provide a very small window where a strong swimming fish could pass. Analysis from water elevations during normal tidal cycles suggest that time there may be ~15 or 30 minutes per tidal cycle with a chance for Atlantic salmon movement. These passage conditions with high velocities and half open tide gates are less than ideal. It is widely accepted that this type of tide gate is a full barrier to passage (NOAA Tide guidance).

Downstream passage for Atlantic salmon is also available for ~ 12 hours a day as the water levels in the Machias Estuary are lower than those upstream of the Dike. Entrapment of salmon in the Middle River is unlikely.

6.1.5.1 Species Determinations

Upstream passage of Atlantic salmon is highly unlikely. The structures also allow for downstream passage of any incidental passage into the Middle River. It is unlikely that effects from this will result in take, therefore the effects of incidental passage on Atlantic salmon are insignificant.

6.1.6 Temporary Structures

The culvert replacement project will require the placement of structures and fill (both temporary) into aquatic habitat. In-water structures and fill will include the temporary piles for cofferdams and detour bridge and potential fill associated with wet (rock) road for traffic to access the temporary bridge. Table 12 provides a summary of the structures and fill, whether permanent or temporary, and the estimated area of impact to habitat below the ordinary high water. Final design has not been completed, and these impacts are approximate and based on the preliminary design. Temporary footprints are based on typical construction scenarios, and professional opinions of construction experts and MaineDOT consultants.

Table 12. Approximate area of temporary and permanent in-water structures and fill associated with the Dike Bridge replacement project

Structure Impact Type	Temporary Impacts (sq. ft.)	Permanent Impacts (sq. ft.)
Approach fills for temporary bridge	40,000	0
Cofferdams	4,000	0
Riprap		8,000

Structure Impact Type	Temporary Impacts (sq. ft.)	Permanent Impacts (sq. ft.)
Causeway widening		9,000
Total temporary impacts	44,000	
Total permanent impacts		17,000

6.1.6.1 Species Determinations

It is possible any of the three listed species could occur in the action area, but only Atlantic salmon adults and smolts have any likelihood to occur when temporary structures are in place. Temporary in-water structures may affect adult salmon movements but only toward the Middle River, where movements are already impeded. Based on these considerations, we have determined effects are too small to be meaningfully measured, detected, or evaluated. Therefore, effects are insignificant.

6.1.6.2 Critical Habitat Determination

During construction, in-water structures will occupy 44,000 square feet of Atlantic salmon critical habitat, specifically migration habitat for adults and smolts. These in-water structures may impede movement of salmon individuals. However, the existing culvert structure is already an impediment to salmon migration, and the addition of these temporary structures will not add significant barriers to salmon movement. The structures will not affect salmon movements in the Machias River. The effects of in-water structures in the action area are too small to be meaningfully measured or detected and, therefore, are insignificant.

6.2 OPERATIONAL EFFECTS OF THE DIKE BRIDGE

in its current form, the Dike Bridge affects migratory movements of adult Atlantic salmon in the Middle River. The Maine DMR has mapped suitable rearing habitat in the Middle River (**Error! Reference source not found.**), and Atlantic salmon likely used the Middle River for spawning before the Dike Bridge was built. There is anecdotal evidence that the current flap gates allow for some fish passage.

Replacing the old culvert structure and flap gates with a similar structure will result small changes in landward flow of estuarine waters in the Middle River from its confluence with the Machias River. The new gates are likely to function better are blocking upstream flow. The bridge will continue to impede fish movement into the Middle River and its tributaries, making unavailable those aquatic habitats that have been inaccessible to large fishes for decades.

As discussed in the action proposal, the proposed flap gates open and close with changes in water elevations and flow. This movement of the gates will be slow enough that it is not expected to cause physical injury to Atlantic salmon of any life stage.

6.3 SPECIES DETERMINATIONS

The bridge replacement in-kind, the proposed action, is not likely to cause injury to Atlantic salmon when the gates are operating.

6.4 CRITICAL HABITAT DETERMINATION

In a recent joint memo signed on January 5, 2022 between the Army Department of Civil Works and National Oceanic and Atmospheric Administration, the interpretation of baseline effects of an action and effects of the proposed action were discussed. Though the memo was directed at hydropower dam projects, the application of how to analyze these effects appear applicable to the Machias Dike. FHWA is the action agency for this consultation and MaineDOT is the applicant. Both of these entities have the discretion to modify the previously authorized structure. Therefore the future effects of the Dike structure are considered as effects of the action. As stated in the baseline section, the action area contains PBFs for spawning and rearing as well as migration. The spawning and rearing PBFs are presumed to be present in the Middle River upstream of the Dike. However, the proposed action will not allow access for Atlantic salmon to utilize them. The function of the PBFs that are present within the action area will not be improved, or further degraded. The new culvert structure will continue to create an upstream migration barrier for most anadromous fishes, and the Middle River will continue to be inaccessible as it has been for more than 150 years.[4]

Though the conditions PBF functions are a pre-existing condition due to the presence of the dike and tide gates blocking tidal flow inland, they are considered effects of the proposed action. This is because they would not occur but for the presence of the Dike and the tide gates and they are reasonably certain to continue to occur.

The area immediately adjacent to the dike contains primarily migratory PBFs. PBFs M1, M3, and M4 are adversely affected by the migration barrier created by the Dike and the gated box culverts. M1 and M4 are PBFs that require migration sites free of physical and biological barriers. The proposed box culvert system will be a barrier to all upstream migration. The gated culvert system will allow for downstream fish passage when the tidal stage in the Machias estuary is lower than the water level in the Middle River. This condition would still cause delays in smolt migration and results in an adverse effect to PBF M4.

PBF M3 is partially functioning at the site due the fish community that uses the Machias River and estuary. However, blocking fish passage into the Middle River restricts fish passage for species such as rainbow smelt and herring. The habitat available in the Middle River could potentially allow for larger numbers of other native fish species that serve as a prey buffer for Atlantic salmon. Therefore, the action will have an adverse effect on PBF M3. The Dike's effects on water temperatures is unknown. It is reasonable to assume that limited estuarine

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[4] The Machias Dike was constructed in 1868.

flow into the Middle River does have an effect on water temperatures, but it is unknown if those temperatures reside outside of temperatures needed by Atlantic salmon smolts.

The new culvert structure will continue to create a migration barrier for adult Atlantic salmon, and the Middle River and its modeled rearing habitat will continue to be inaccessible as it has been for more than 150 years. Recent analysis has indicated that river systems that have dikes are likely to also see changes in operation due to sea level rise (Bemus et. al 2023). Higher ocean levels will result in less drainage because the gates will be open a smaller percentage of the time. The change in upstream water levels is currently unknown. MaineDOT can affect the amount of area that will be flooded in the future by adding more drainage capacity, as needed. The PBFs in the area upstream of the Dike are already adversely affected to passage barrier created by the proposed action. The habitat in the area areas immediately upstream of the dike would function as estuarine habitat without the presence of the dike. It is currently freshwater riverine that is seasonal inundated during high spring flows. Water levels expected throughout the life of the project are not expected to change this condition.

The spawning and rearing PBFs all existing upstream of the Dike and within the action area. The primary effect on these PBFs is the continued blockage of access to them by the proposed maintenance of the flow conditions by the new tide gates.

Cofferdams and water management strategies may also temporarily affect critical habitat. The areas occupied by temporary fills and water management devices are immediately adjacent to the dike and generally function as migratory habitat. Because the dike currently blocks all migration, these temporary effects will not have an adverse effect on the critical habitat in the action area.

7.0 EFFECTS DETERMINATIONS

MaineDOT, on behalf of FHWA, has analyzed the effects of the Dike Bridge replacement project on the endangered shortnose sturgeon, threatened GOM DPS of Atlantic sturgeon, endangered GOM DPS Atlantic salmon, and designated critical habitat for the GOM DPS Atlantic salmon. MaineDOT certifies that our effects analysis used the best scientific and commercial data available.

MaineDOT has determined that, when added to baseline conditions, effects from the stressors including in-water structures, underwater noise, sedimentation and turbidity, and cofferdam entrapment are either insignificant or extremely unlikely to occur. Therefore, MaineDOT has determined that the Dike Bridge replacement, as proposed, is **not likely to adversely affect shortnose sturgeon and Atlantic sturgeon, but likely to adversely affect Atlantic salmon** that may occur in the action area**.** In addition, the Dike Bridge replacement as proposed **will adversely affect designated critical habitat for Atlantic salmon** in the action area.

Table 13

Table 13. Summary of effects determinations for shortnose sturgeon, Atlantic sturgeon, and Atlantic salmon life stages, Dike Bridge replacement project.

Species	**Life Stage or Habitat**	**Temporary Structures**	**Underwater Noise**	**Turbidity**	**Cofferdam Entrapment**	**False Attraction**	**Incidental Passage**	**Operation**
Atlantic salmon	Adult-migration	Insignificant	Insignificant	Insignificant	Discountable	Adverse	Insignificant	Adverse
Atlantic salmon	Smolt (juvenile) - migration	Insignificant	Insignificant	Insignificant	Discountable	Insignificant	Insignificant	Insignificant
Atlantic sturgeon	Subadult	Insignificant	Insignificant	Insignificant	Discountable	Insignificant	Insignificant	Insignificant
Atlantic sturgeon	Adult	Insignificant	Insignificant	Insignificant	Discountable	Insignificant	Insignificant	Insignificant
Shortnose sturgeon	Insignificant	Insignificant	Insignificant	Discountable	Discountable	Insignificant	Insignificant	Insignificant

Table 14. summary of critical habitat effects.

Migratory primary biological feature	Status in the action area	Function following proposed action	Effect Determination
SR 1	Limited function	Maintain limited function	May affect, likely to adversely affect

SR 2	Limited function	Maintain limited function	May affect, likely to adversely affect
SR 3	Limited function	Maintain limited function	May affect, likely to adversely affect
SR 4	Limited function	Maintain limited function	May affect, likely to adversely affect
SR 5	Limited function	Maintain limited function	May affect, likely to adversely affect
SR 6	Limited function	Maintain limited function	May affect, likely to adversely affect
SR 7	Limited function	Maintain limited function	May affect, likely to adversely affect
M 1	Limited function	Maintain limited function	May affect, likely to adversely affect
M 2	Limited function	Maintain limited function	May affect, likely to adversely affect
M 3	Limited function	Maintain limited function	May affect, likely to adversely affect

M 4	Not functioning properly	Maintain not proper function	May affect, likely to adversely affect
M 5	Limited function	Maintain limited function	May affect, likely to adversely affect

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Appendix A LIST OF AVOIDANCE AND MINIMIZATION MEASURES FOR THE DIKE BRIDGE REPLACEMENT PROJECT

AMM 1. Pile driving with an impact hammer will be completed at low tide or within the December 1- March 31 window.

AMM 2. The Contractor will use a vibratory hammer to drive all piles to the fullest extent practicable. Impact-hammer pile driving will be necessary to seat 30-inch steel bent piles for temporary bridge structure. Steel bent pile size will be limited to 30 inches to minimize the potential for fish injury beyond 18 meters.

AMM 3. Breaching of cofferdams will occur at high slack tide to minimize water velocities upon release.

AMM 4. Before project construction begins, each Contractor must submit a Soil Erosion and Water Pollution Control Plan (SEWPCP) for review and approval of MaineDOT staff prior to the start of work. The plan includes the review of the implementation of any AMMs proposed. Prior to soil disturbance, the erosion control portion of the SEWPCP will be reviewed and in place.

AMM 5. Contractors will implement BMPs in accordance with the MaineDOT manual Best Management Practices for Erosion and Sedimentation Control (MaineDOT 2008; available at https://www.maine.gov/mdot/env/documents/bmp/BMP2008full.pdf.), which outlines means and methods to prevent sedimentation in streams during construction or heavy precipitation. The Contractor will maintain sediment and erosion controls throughout construction and until the site is deemed completely stable.

AMM 6. As a component of the SEWPCP required for the bridge replacement project, MaineDOT or their Contractor will develop and implement a Spill Prevention Control and Countermeasure Plan (SPCCP) designed to avoid stream impacts from hazardous chemicals, such as diesel fuel, oil, lubricants, and other hazardous materials. These measures include the following:

- Vehicle and equipment refueling activities typically occur at least 100 feet from any watercourse. However, the primary work for this project will occur on the bridge, and a 100-foot distance from the resource on either side of the river will not be possible to maintain. All refueling or equipment maintenance will take place away from the stream and in a careful manner that prevents chemical or other hazardous materials from entering the stream.
- All vehicles carrying fuel will have specific equipment and materials needed to contain or clean up any incidental spills at the Project sites. Equipment and materials will include spill kits appropriately sized for specific quantities of fuel, shovels, absorbent pads, straw bales, containment structures and liners, and/or booms.

- During use, all pumps and generators will have appropriate spill containment structures and/or absorbent pads in place.
- All equipment used for in-stream work will be cleaned of external oil, grease, dirt, and mud. Any leaks or accumulations of these materials will be corrected before entering areas that drain directly to streams or wetlands.

AMM 7. During construction, any disturbed soils will be temporary stabilized with BMPs, such as straw mulch, plastic sheeting, erosions control mix, or other appropriate BMPs. Disturbed areas with erodible soil can include, but are not limited to, temporary storage piles, access ways, partially constructed slopes, etc.

AMM 8. No equipment, materials, or machinery shall be stored, cleaned, fueled, or repaired within any wetland or watercourse; dumping of oil or other deleterious materials on the ground will be forbidden; the Contractor shall provide a means of catching, retaining, and properly disposing of drained oil, removed oil filters, or other deleterious material; and all oil spills shall be reported immediately to the appropriate regulatory body. Response to any contaminant release will follow protocols contained in the SPCCP.

AMM 9. Temporary roads (wet roads) in the project area will be constructed of clean, non-erodible material (i.e., plain riprap or large riprap per MaineDOT standard specifications) over geotextile fabric. No fill for temporary access (riprap) will be placed in the primary or bypass channel. Culverts will be installed where wet roads cross secondary channels to provide connectivity of flow and downstream fish passage.

AMM 10. All areas of temporary waterway or wetland fill will be restored to their original contour and character upon completion of the project. Temporary fill includes fill that received authorization and fill that mistakenly enters a resource (i.e., from slope failures, accidental broken sandbag cofferdams).

AMM 11. No heavy construction equipment will travel into or through any flowing streams with erodible substrate (e.g., sand, silt, and clay). Travel of heavy construction equipment into or through flowing streams and onto stream substrate will only occur when the stream substrate is non-erodible (e.g., ledge, cobble) and the Contractor has received approval from the MaineDOT or the MTA environmental field office staff.

AMM 12. Turbid water within a cofferdam during dewatering will be pumped to a sediment basin for filtration. The “Dirty Water” Treatment System will be installed according to MaineDOT’s Best Management Practices.

AMM 13. In those portions of the project area where fish are likely to occur, all intake pumps will have a fish screen installed, operated, and maintained. To prevent fish entrainment during water diversions, the Contractor will use a screen on each pump intake large enough so that the approach velocity does not exceed 0.06 meters per second (0.20 feet per second). Square or round screen face openings are not to exceed 2.38 millimeters (3/32 inch) on a diagonal. Criteria for slotted face openings will not exceed 1.75 millimeters (approximately 1/16 inch) in the narrow direction. These screen criteria follow those indicated by NOAA Fisheries. Intake hoses will be regularly monitored while pumping to minimize adverse effects to sturgeon.

AMM 14. Fresh concrete will be poured inside of a cofferdam (concrete seal) and will not contact flowing water (outside cofferdam).

AMM 15. Water pumped out of the cofferdam will be within one pH unit of background pH level of the resource (Machias River) (MaineDOT standard specifications). A representative of the MaineDOT Surface Water Quality Unit will periodically evaluate pH to determine whether the water is within the allowable tolerance to be pumped directly back into the river or whether it needs to be treated prior to discharge.

AMM 16. Demolition and debris removal and disposal will comply with Section 202.03 of MaineDOT's Standard Specifications. The Contractor will contain all demolition debris, including debris from wearing surface removal, saw cut slurry, dust, etc., and will prevent debris from entering any resource to the extent feasible. The Contractor will dispose of debris in accordance with the Maine Solid Waste Law (Title 38 M.R.S.A., Section 1301 et. seq.) and in compliance with applicable regulatory approvals. The demolition plan, containment, and disposal of demolition debris will be addressed in the Contractor's SEWPCP.

AMM 17. If pile driving is occurring during a time of year when ESA-listed species may be present, and the anticipated noise is above the behavioral noise threshold, a “soft start” is required to allow animals an opportunity to leave the project vicinity before sound pressure levels increase. In addition to using a soft start at the beginning of the work day for pile driving, one must also be used at any time following cessation of pile driving for a period of 30 minutes or longer. For impact pile driving: pile driving will commence with an initial set of three strikes by the hammer at 40% energy, followed by a one minute wait period, then two subsequent three-strike sets at 40% energy, with one-minute waiting periods, before initiating continuous impact driving. For vibratory pile installation: pile driving will be initiated for 15 seconds at reduced energy followed by a one-minute waiting period. This sequence of 15 seconds of reduced energy driving, one-minute waiting period will be repeated two additional times,

Route 1 Machias Dyke Bridge (#2246) Coastal Wetland Delineation Report

Machias, Maine

MDOT Project Pin: 16714.00

December 23, 2021

Prepared for:

Maine Department of Transportation
16 State House Station
Augusta, ME 04333

Prepared by:

Stantec Consulting Services Inc.
30 Park Drive
Topsham, ME 04086

December 23, 2021

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1.0 INTRODUCTION

The Maine Department of Transportation (MDOT) is evaluating improvements to the hydraulics of the tidal gates installed at the Route 1 Machias Dyke Bridge (#2246) over the Middle River in Machias, Maine (Project). In 2021, Stantec Consulting Services Inc. (Stantec) conducted a coastal wetland community characterization and delineation at the Machias Dyke Bridge to facilitate state and federal permitting for the Project. This report presents the results of these efforts.

2.0 METHODOLOGY

Stantec delineated and characterized the various native coastal wetland types based on the *Classification of Wetlands and Deepwater Habitats of the United States*.[1] The community boundaries were located using a Trimble® Global Positioning System (GPS) capable of submeter accuracy. The GPS data was collected and attributed using the approved MDOT data dictionary and post-processed in accordance with MDOT spatial data requirements. Representative photographs were taken as appropriate, and a Maine Department of Environmental Protection (MDEP) Coastal Wetland Characterization field form was completed for the wetland communities. At the request of MDOT, the field characterization did not include a delineation of published mean high water or highest annual tide elevations along the road embankment riprap for state and federal coastal wetland jurisdictional purposes.

3.0 RESULTS

The coastal wetland characterization was conducted on November 17, 2021. The field survey was initiated following high tide and observations of the tidal wetland communities continued until approximately 30 minutes before low tide.

3.1 PROJECT AREA SETTING

The Route 1 Machias Dyke Bridge is an approximately 900-foot long causeway over the Middle River at the Middle River confluence with the Machias River. The bridge and causeway is approximately 90 to 95 feet wide and consists of a paved two-lane roadway along with roadside parking stalls and the multi-use Sunrise Recreational Trail. Steep road embankments consisting of boulder riprap fill extend from the road surface to the coastal wetland. Several commercial businesses are located at each end of the bridge. Tidal gates under the bridge at the Middle River channel restrict intruding tides into the Middle River north

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[1] Federal Geographic Data Committee. 2013. Classification of Wetlands and Deepwater Habitats of the United States. FGDC-STD-004-2013. Second Edition. Wetlands Subcommittee, Federal Geographic Data Committee and U.S. Fish and Wildlife Service, Washington, DC.

of the bridge. A large impoundment is located north of the bridge as a result of the tidal gates and hydraulic constrictions of the bridge.

3.2 COASTAL WETLAND COMMUNITY CHARACTERIZATION

The delineated coastal wetland communities are shown on Figure 1. Representative photographs are provided in Appendix A and MDEP Coastal Wetland Characterization field forms are included in Appendix B.

A large estuarine mudflat (E2US2/3) dominates the coastal wetland community to the south of the bridge at the base of the road embankment riprap. This community consists of fine to medium grained sand and silt material with scattered gravels. It is largely unvegetated with the exception of scattered bladderwrack (*Fuscus vesiculosus*) anchored to the boulders and coarse substrates at the base of the road embankment riprap.

A small patch (approximately 640 square feet) of saltmarsh (E2EM1) is present in the western portion of the intertidal area between the tidal gates and an existing boat launch. This area supports salt-meadow cord grass (*Spartina patens*) and saltmarsh rush (*Juncus gerardii*).

To the north of the bridge, the Middle River impoundment consists of a brackish tidal impoundment that is permanently inundated (E1UB2/3) along most of the dyke bridge length. The intertidal shoreline along the impoundment is narrow, and rocky, consisting of cobble, gravel, and sand (E2US1/2) at the base of the boulder and rubble riprap roadside embankment.

A brackish tidal marsh is located in the southeastern corner of the impoundment north of the bridge and consists of persistent and non-persistent vegetation (E2EM1/2). Observable persistent vegetation included scattered occurrences of broad-leaf cat-tail (*Typha latifolia*), freshwater cord grass (*Spartina pectinata*), hybrid cord grass (*Spartina ×caespitosa*), reed canary grass (*Phalaris arundinacea*), and orach (*Atriplex* sp.). The area is periodically inundated at high tide. The vegetation cover of this area was much less compared with observation made by Stantec of this marsh area in October 2017, likely due to increase periods of inundation from tide gates decreased functionality.

A small intertidal mudflat (E2US2/3) is located in a cove in the southwest portion of the Middle River impoundment adjacent to the dyke bridge. This area has a sandy and muddy substrate with scattered gravel that is largely unvegetated. The presence of drift and wrack indicates that the area is inundated during high tide.

Table 1 summarizes the delineated coastal wetland communities.

Table 1. Summary of Coastal Wetland Communities

Resource Identifier	Resource Classification[1]	Comments
VA_01A; VA_01E	E2US2/3	Large intertidal mudflat located to south of dyke bridge; beginning at base of roadway riprap embankment; dominated by sand and silt
VC_01B	E2EM1/2	Area of brackish emergent tidal marsh in southeast corner of Middle River impoundment north of Route 1; significant reduction of vegetation compared with October 2017 observations.
VR_01C	R1UB2/3	Middle River channel at bridge downstream of Route 1
VC_01D	E2EM1	Small saltmarsh dominated by salt-meadow cord grass and saltmarsh rush between roadway and boat launch
VB_01F, VB_01H	E2US1/2 / E1UB2/3	Middle River impoundment. Intertidal rocky shoreline beginning at the base of road embankment, transitions to permanently inundated impoundment
VR_01G	R1UB2/3	Middle River channel at bridge upstream of Route 1
VA_01I	E2US2/3	Small unvegetated mudflat in southwest corner of Middle River impoundment to north of Route 1

[1] Wetland classification follows Federal Geographic Data Committee (2013):

E2US2/3 = Estuarine Intertidal Unconsolidated Shore with sand and mud substrates
E2EM1/2 = Estuarine Intertidal Emergent with persistent and non-persistent vegetation
E2EM1 = Estuarine Intertidal Emergent with persistent vegetation
E2US1/2 = Estuarine Intertidal Unconsolidated Shore with cobble, gravel, and sand
E1UB2/3 = Estuarine Subtidal Unconsolidated Bottom with sand and mud substrate
R1UB2/3 = Riverine Tidal with Unconsolidated Bottom with sand and mud substrate

FIGURES

Stantec

Legend

▭	Approximate Survey Limits
—	Wetland Community Outline
▨	Estuarine Intertidal Emergent with persistent and non-persistent vegetation
▨	Estuarine Intertidal Unconsolidated shore with sand and mud substrates
▨	Estuarine Intertidal Unconsolidated Shore/Estuarine Intertidal Unconsolidated Bottom with cobble/gravel and mud substrates
🟥	Estuarine Intertidal Emergent with persistent vegetation
▨	Riverine Tidal with Unconsolidated Bottom with sand and mud substrates
—	Riverine Tidal with Unconsolidated Bottom with sand and mud substrates

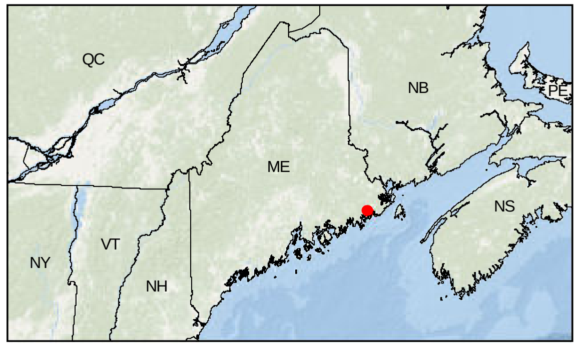
N

0 100 200 Feet

(At original document size of 11x17)
1:1,200

Notes

1. Coordinate System: NAD 1983 UTM Zone 19N
2. Data Sources: MEGIS, Stantec
3. Background: ESRI World Imagery Mapping Service
4. Wetland boundaries were located utilizing a Trimble GeoExplorer Series Receiver. Expected accuracy of GPS data is within 1 meter of the actual position.



Project Location

Prepared by KWH 2021-12-17
Review by MPA 2021-12-17

Machias, Maine

Client/Project 195602291

Maine Department of Transportation
16714.00 Machias Dyke Bridge (#2246)

Figure No.

1

Title

Coastal Wetland Community Delineation Map

V:\1956\active\195602291\03_data\gis_cad\gis\MXDs\02291_WetlandDelin_11x17.mxd Revised: 2021-12-21 By: khoward

APPENDICES

Appendix A REPRESENTATIVE PHOTOGRAPHS

Photo 1. Mudflat (VA_01A) south of Route 1, view to the east. Stantec. November 17, 2021.

Photo 2. Mudflat (VA_01A) south of Route 1, view to the west. Stantec. November 17, 2021.

Photo 3. Brackish emergent marsh (VC_01B) in southeastern portion of Middle River impoundment north of Route 1, view to the east. Stantec. November 17, 2021.

Photo 4. Saltmarsh (VC_01D) between Route 1 and boat launch at west end of dyke bridge, view to the east. Stantec. November 17, 2021.

Photo 5. Middle River impoundment and rocky shoreline north of Route 1 (VB_01F, VB_01H), view to the east. Stantec. November 17, 2021.

Photo 6. Unvegetated mudflat (VA_01I) in southwest corner of Middle River impoundment north of Route 1; view to the southeast. Stantec. November 17, 2021.

Photo 7. Middle River outlet at dyke bridge, north of Route 1, view to the west. Stantec. November 17, 2021.

Photo 8. Middle River outlet at dyke bridge, south of Route 1, view to the east. Stantec. November 17, 2021.

Appendix B MDEP COASTAL WETLAND CHARACTERIZATION FORMS

APPENDIX B: MDEP COASTAL WETLAND CHARACTERIZATION: INTERTIDAL & SHALLOW SUBTIDAL FIELD SURVEY CHECKLIST

NAME OF APPLICANT: Maine Department of Transportation PHONE: __________
APPLICATION TYPE: __________
ACTIVITY LOCATION: TOWN: Machias COUNTY: Washington

ACTIVITY DESCRIPTION: ☐ fill ☐ pier ☐ lobster pound ☐ shoreline stabilization
☐ dredge ☐ other: __________

DATE OF SURVEY: 11/17/2021 OBSERVER: Matt Arsenault

TIME OF SURVEY: 11:45AM-3:00PM TIDE AT SURVEY: Outgoing

SIZE OF DIRECT IMPACT OR FOOTPRINT (square feet):
Intertidal area: __________ Subtidal area: __________

SIZE OF INDIRECT IMPACT, if known (square feet):_ __________
Intertidal area: __________ Subtidal area: __________

HABITAT TYPES PRESENT (check all that apply): **North of Route 1**
☐ sand beach ☐ boulder/cobble beach ☐ sand flat ☒ mixed coarse & fines ☒ salt marsh
☐ ledge ☒ rocky shore ☒ mudflat (sediment depth, if known:____)

ENERGY: ☐ protected ☒ semi-protected ☐ partially exposed ☐ exposed

DRAINAGE: ☐ drains completely ☒ standing water ☐ pools ☐ stream or channel

SLOPE: ☐ >20% ☐ 10-20% ☐ 5-10% ☒ 0-5% ☐ variable

SHORELINE CHARACTER:
☐ bluff/bank (height from spring high tide:____) ☐ beach ☒ rocky ☐ vegetated

FRESHWATER SOURCES: ☐ stream ☒ river ☐ wetland ☒ stormwater

MARINE ORGANISMS PRESENT:

	absent	occasional	common	abundant
mussels	☒	☐	☐	☐
clams	☒	☐	☐	☐
marine worms	☒	☐	☐	☐
rockweed	☒	☐	☐	☐
eelgrass	☒	☐	☐	☐
lobsters	☒	☐	☐	☐
other	☐	☐	☐	☐

SIGNS OF SHORELINE OR INTERTIDAL EROSION? ☐ yes ☒ no

PREVIOUS ALTERATIONS? ☒ yes ☐ no

CURRENT USE OF SITE AND ADJACENT UPLAND:
☐ undeveloped ☐ residential ☒ commercial ☐ degraded ☐ recreational

PLEASE SUBMIT THE FOLLOWING:
☐ Photographs ☐ Overhead drawing (pink)

APPENDIX B: MDEP COASTAL WETLAND CHARACTERIZATION: INTERTIDAL & SHALLOW SUBTIDAL FIELD SURVEY CHECKLIST

NAME OF APPLICANT: Maine Department of Transportation PHONE:________________________
APPLICATION TYPE:________________________________
ACTIVITY LOCATION: TOWN: Machias COUNTY: Washington

ACTIVITY DESCRIPTION: ☐ fill ☐ pier ☐ lobster pound ☐ shoreline stabilization
☐ dredge ☐ other: ____

DATE OF SURVEY: 11/17/2021 OBSERVER: Matt Arsenault

TIME OF SURVEY: 11:45AM-3:00PM TIDE AT SURVEY: Outgoing

SIZE OF DIRECT IMPACT OR FOOTPRINT (square feet):
Intertidal area: __________________________Subtidal area:_____________________________

SIZE OF INDIRECT IMPACT, if known (square feet):_ ____
Intertidal area: _________________________Subtidal area: ________________________________

HABITAT TYPES PRESENT (check all that apply): **South of Route 1**
☐ sand beach ☐ boulder/cobble beach ☐ sand flat ☒ mixed coarse & fines ☒ salt marsh
☐ ledge ☐ rocky shore ☒ mudflat (sediment depth, if known:____)

ENERGY: ☐ protected ☒ semi-protected ☐ partially exposed ☐ exposed

DRAINAGE: ☒ drains completely ☐ standing water ☐ pools ☐ stream or channel

SLOPE: ☐ >20% ☐ 10-20% ☐ 5-10% ☒ 0-5% ☐ variable

SHORELINE CHARACTER:
☐ bluff/bank (height from spring high tide:____) ☐ beach ☒ rocky ☐ vegetated

FRESHWATER SOURCES: ☐ stream ☒ river ☐ wetland ☒ stormwater

MARINE ORGANISMS PRESENT:

	absent	occasional	common	abundant
mussels	☒	☐	☐	☐
clams	☐	☒	☐	☐
marine worms	☐	☒	☐	☐
rockweed	☐	☐	☒	☐
eelgrass	☒	☐	☐	☐
lobsters	☒	☐	☐	☐
other	☐	☐	☐	☐

SIGNS OF SHORELINE OR INTERTIDAL EROSION? ☐ yes ☒ no

PREVIOUS ALTERATIONS? ☒ yes ☐ no

CURRENT USE OF SITE AND ADJACENT UPLAND:
☐ undeveloped ☐ residential ☒ commercial ☐ degraded ☐ recreational

PLEASE SUBMIT THE FOLLOWING:
☐ Photographs ☐ Overhead drawing (pink)

APPENDIX 4 – ESSENTIAL FISH HABITAT CONSULTATION

1. 6/14/2024 NOAA EFH Consultation Conservation Recommendation Letter
2. 3/19/2024 FHWA EFH Consultation Letter and Assessment

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
GREATER ATLANTIC REGIONAL FISHERIES OFFICE
55 Great Republic Drive
Gloucester, MA 01930

June 14, 2024

Todd Jorgensen, Administrator
Federal Highways Administration, Maine Division
Edmund S. Muskie Federal Building
40 Western Avenue, Room 614
Augusta, ME 04330

Re: Essential Fish Habitat Consultation for the Machias Dike Bridge Replacement

Dear Mr. Jorgensen:

We have reviewed the Essential Fish Habitat (EFH) assessment provided by the Federal Highway Administration (FHWA) on March 19, 2024, for the Machias Dike Bridge project (proposed project) located on the Machias and Middle rivers in Machias, Maine. According to the EFH assessment, prepared by the Maine Department of Transportation (ME DOT) on behalf of the FHWA, the proposed project would replace the existing dike bridge with a series of box culverts with flap gates (identified as Alternative 1 in the EFH assessment). Although the EFH assessment indicates it is likely that the arrangement will include three, 10-foot-wide by 5-foot-tall box culverts, the final design and the construction methods used for the bridge, box culverts, and tide gates will be determined during later engineering reviews and are subject to change after the completion of the EFH consultation. Based on the current design the construction of the proposed replacement structure will result in approximately 32,400 square feet (sf) of permanent and 45,000 sf of temporary impacts to EFH, and will take approximately 3-4 years to complete. The operational impacts were not fully assessed, although the submitted EFH assessment indicates the proposed project would permanently eliminate all tidal exchange to the Middle River for the life of the proposed project (80-100 years, according to the EFH assessment). The Machias River and the Middle River has been designated as EFH for a number of federally-managed species, and supports numerous other NOAA trust resources, including diadromous fish. Based on the information presented in the EFH assessment, it is our determination that the proposed project would result in significant adverse impacts to managed species, their designated EFH, as well as a number of NOAA trust resources that fall under our consultation responsibilities of the Fish and Wildlife Coordination Act (FWCA) which are important for the productivity of the Machias and Middle rivers ecosystem. In particular, the proposed project would result in adverse impacts to EFH of all stages of winter flounder, including sensitive life stages of spawning adult, egg, and larvae habitat, and Atlantic salmon spawning migratory habitat. The Machias River is also one of eleven rivers in Maine designated as a Habitat Area of Particular Concern (HAPC) for Atlantic salmon because it supports one of the only remaining U.S. populations of naturally spawning Atlantic salmon that have historic river-specific characteristics.

We offer the following recommendations under the Magnuson-Stevens Fishery Conservation and Management Act (MSA) and the FWCA for the proposed project. In addition, we are providing comments to you in the appendix of this letter regarding substantial deficiencies we have identified in the EFH assessment for this proposed project. These comments provide the basis and rationale for our recommendations.

Consultation Responsibilities

In the Magnuson-Stevens Fishery Conservation and Management Act (MSA), Congress recognized that one of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats. Congress also determined that habitat considerations should receive increased attention for the conservation and management of fishery resources of the United States. As a result, one of the purposes of the MSA is to promote the conservation of EFH in the review of projects conducted under federal permits, licenses, or other authorities that affect or have the potential to affect such habitat. The MSA requires federal agencies to consult with the Secretary of Commerce, through NOAA Fisheries, with respect to “any action authorized, funded, or undertaken, or proposed to be authorized, funded, or undertaken, by such agency that may adversely affect any essential fish habitat identified under this Act,” 16 U.S.C. § 1855(b)(2).

The FWCA provides authority for our involvement in evaluating impacts to fish and wildlife from proposed federal actions that may affect waters of the United States. The FWCA requires that wildlife conservation be given equal consideration to other features of water resource development programs through planning, development, maintenance and coordination of wildlife conservation and rehabilitation. The FWCA does this by requiring federal action agencies to consult with us "with a view to the conservation of wildlife resources by preventing loss of and damage to such resources as well as providing for the development and improvement thereof in connection with such water-resource development" (16 USC 662). One of the reasons that Congress amended and strengthened the FWCA in 1958 was that it recognized that “[c]ommercial fish are of major importance to our nation[,]” and that federal permitting agencies needed general authority to require “in project construction and operation plans the needed measures for fish and wildlife conservation” (S.Rep. 85-1981 1958). As a result, our FWCA recommendations must be given full consideration by federal action agencies.

The comments and recommendations provided for this project through our statutory obligations under the MSA and FWCA will assist the FHWA in supporting the Administration's goals to combat the climate crisis in a manner that “conserves our lands, waters, and biodiversity” (E.O. 14008). The ME DOT and FHWA should give full consideration of these recommendations so that the project may contribute to the Administration’s efforts to help mitigate the effects of climate change in an environmentally responsible manner.

EFH Conservation Recommendations

In order to avoid, minimize, and offset significant impacts to EFH result of the proposed project, pursuant to Section 305(b)(4)(A) of the MSA, we recommend that you adopt the following EFH conservation recommendations (CRs). As noted above, these EFH CRs are based upon the best available science and represent a risk-averse approach in response to the deficiencies in the EFH assessment, the lack of specificity in the description of the proposed action, and the potential short and long-term synergistic, cumulative, and interactive climate change effects with this project. We recommend, pursuant to Section 305(b)(a)(A) of the MSA, that you adopt the following EFH conservation recommendations:

1. Bridge Alternative 10 (full-span, pile-supported bridge) should be selected as the preferred project alternative.

2. A plan should be developed to assess contaminated sediments and other materials that may exist in the existing dike structure and, if found at levels that exposure can cause adverse effects to aquatic organisms and/or humans, should be removed in a manner consistent with contaminated and hazardous material removal and remediation. The remediation plan should include implementing measures to prevent the release of contaminated sediments in adjacent areas of the Machias and Middle River.

3. A wetland delineation survey should be conducted to determine the type (i.e., salt marsh, brackish marsh, tidal fresh marsh, and unvegetated tidal habitats) and amount of tidally-influenced habitats in the Middle River. A wetland delineation report should be provided to NOAA Fisheries for our use in calculating the appropriate compensatory mitigation for the proposed project.

4. If Alternative 1 (in-kind replacement) is chosen as the preferred project alternative, a compensatory mitigation plan should be developed that offsets the losses of tidally-influenced wetlands and unvegetated habitats in the Middle River due to the exclusion of tidal waters from the installation of new tide gates in the structure. The amount of compensatory mitigation should be based on the results of a wetland delineation survey, as described above. At a minimum, a 3:1 ratio of compensatory mitigation to impact area should be used for calculations for the losses of tidal habitats in the Middle River.

   In addition, impacts to intertidal and subtidal habitat impacts in the Machias River and Middle River as a result of temporary (45,000 sf) and permanent (32,400 sf) of impacts from the construction of the replacement dike should be offset through implementation of a compensatory mitigation plan. To account for both permanent and temporal habitat losses over the 3-4 years of construction, at a minimum, the amount of compensatory mitigation should be based on a total area of 77,400 sf of existing intertidal and subtidal habitats. Using a 3:1 ratio of compensatory mitigation to impact area, a total of 232,200 sf of compensatory mitigation should be provided for the construction-related impacts.

Please note that Section 305(b)(4)(B) of the MSA requires you to provide us with a detailed written response to these EFH CRs, including a description of measures you have adopted that avoid, mitigate, or offset the impact of the project on EFH. In the case of a response that is inconsistent with our recommendations, Section 305(b)(4)(B) of the MSA also indicates that you must explain your reasons for not following the recommendations. Included in such reasoning would be the scientific justification for any disagreements with us over the anticipated effects of the proposed action and the measures needed to avoid, minimize, mitigate, or offset such effects pursuant to 50 CFR 600.920(k).

Please also note that a distinct and further EFH consultation must be reinitiated pursuant to 50 CFR 600.920(1) if new information becomes available or the project is revised in such a manner that affects the basis for the above EFH conservation recommendations.

Fish and Wildlife Coordination Act Recommendations

The FWCA provides authority for our involvement in evaluating impacts to fish and wildlife from proposed federal actions that may affect waters of the United States. The FWCA requires that wildlife conservation be given equal consideration to other features of water resource development programs through planning, development, maintenance and coordination of wildlife conservation and rehabilitation. Our FWCA recommendations must be given full consideration and are as follows:

1. In order to improve fish passage of diadromous species, the bridge Alternative 10 (full-span, pile-supported bridge) should be selected as the preferred project alternative.

Conclusion

We appreciate the opportunity to provide these EFH conservation recommendations. The conservation recommendations we provide in this letter are based on the information provided in the revised EFH assessment and will ensure that the adverse effects to EFH, federally-managed species, and other NOAA trust resources from this project are minimized and compensated. If you have any questions regarding our conservation recommendations or information in this letter, please contact Michael Johnson at 978-281-9130 or at mike.r.johnson@noaa.gov.

Sincerely,

Louis A. Chiarella

Louis A Chiarella
Assistant Regional Administrator
for Habitat and Ecosystem Services

cc:
Protected Resources (Anderson, Crocker, Bean)
NOAA Restoration Center (Catena, Bernier)
Office of Habitat Conservation (Robinson)
Maine Department of Transportation (Van Note, Chamberlain)
Maine Department of Marine Resources (Keliher)
U.S. Army Corps of Engineers (Turley, MacNeil, Breen)

Appendix
EFH Assessment Comments and Rationale for EFH Conservation Recommendations

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History of Coordination

Planning for the Machias Dike Bridge replacement project has been ongoing for over a decade and the approaches to replacement have varied through the years. We have been involved in a number of meetings and have provided technical assistance to ME DOT and FHWA regarding the impacts of various alternatives to NOAA trust resources. More recently, we have provided technical assistance letters to you in September 30, 2020 and November 22, 2021, in which we expressed our concerns about the climate vulnerability of an in-kind replacement of the structure and the substantial benefits of a bridge alternative that would provide full tidal transparency (i.e., pile-supported bridge spanning the entire mouth of the Middle River). Because of the substantial benefits it would provide in restoring diadromous fish and federally-managed fish access, restoring over 400 acres of salt marsh in the Middle River, and providing climate resiliency benefits to the project area, we have expressed our strong support for a pile-supported bridge alternative.

We were initially notified by FHWA of a target EFH consultation initiation date of December 16, 2022, which was subsequently modified on May 23, 2023 with a revised consultation initiation date of August 15, 2023. A draft EFH assessment was provided by FHWA on October 28, 2023. However, due to substantial deficiencies in the EFH assessment, we notified FHWA in a technical assistance letter, dated November 28, 2023, that we were unable to initiate the EFH consultation until additional information was provided in a revision of the EFH assessment. A revised EFH assessment was provided by FHWA on March 19, 2024, and we initiated the EFH consultation on May 1, 2024.

General EFH Determination Comments

Based on the information presented in the EFH assessment, it is our determination that the proposed project would result in significant adverse impacts to managed species, their designated EFH, as well as a number of NOAA trust resources that fall under our consultation responsibilities of the FWCA, which are important for the productivity of the Machias and Middle rivers ecosystem. In particular, the proposed project would result in adverse impacts to EFH of all stages of winter flounder, including sensitive life stages of spawning adult, egg, and larvae habitat, and Atlantic salmon spawning migratory habitat. The Machias River is also one of eleven rivers in Maine designated as a Habitat Area of Particular Concern (HAPC) for Atlantic salmon because it supports one of the only remaining U.S. populations of naturally spawning Atlantic salmon that have historic river-specific characteristics.

The existing dike bridge is currently restricting the ability of NOAA trust resources to access historic EFH and preventing the restoration of over 400 acres of tidal habitats in the Middle River. In addition, the proposed project would effectively eternalize and eliminate any opportunity for restoration of tidal habitats and access by species to the Middle River. According to the revised EFH assessment, tidal habitat restoration potential for the Middle River includes approximately 17 acres of high marsh, 208 acres of low marsh, and 191 acres of unvegetated habitats (e.g., intertidal mud flats and tidal riverbed). Furthermore, the proposed project would continue to have both short and long-term impacts to habitats important for diadromous fish, including alewife, blueback herring, rainbow smelt, American shad, and American eel. Project impacts include the immediate elimination of tidal flow to a combined area of at least 33 acres of salt marsh, brackish marsh, and tidal fresh marsh habitats that exist in the Middle River, resulting in the permanent loss of these habitats and their conversion to freshwater habitats. Tidal freshwater marshes are considered a valuable and rare wildlife habitat, which has received considerable conservation attention by the Maine Department of Agriculture, Conservation & Forestry. Because the proposed project would eliminate all diurnal tidal exchange to the Middle River, tidal freshwater marshes in the Middle River will be permanently lost in this system for the life of the proposed project. Despite our multiple requests, a wetland delineation survey and quantification of the habitats in the Middle River has not been provided by ME DOT. Information regarding proposed compensatory mitigation for the adverse effect to EFH and other NOAA trust resources was not included in the EFH assessment.

Although we agreed to initiate the EFH consultation on May 1, 2024, based on the available information, the revised EFH assessment does not accurately describe EFH in the project area or fully evaluate the direct, indirect, individual, cumulative, and synergistic adverse impacts to EFH and other NOAA trust resources due to the construction, operation, and maintenance of the proposed project.

Further complicating matters, the design height of the preferred alternative stated in the revised EFH assessment is not consistent with information provided to our Protected Resources Division in the Biological Assessment (BA) for the Endangered Species Act consultation. Specifically, the revised EFH assessment indicates the maximum height of Route 1 is expected to target 18.16 feet (ft.) NAVD88, while the BA indicates a maximum height of 13.1 ft. NAVD88. This inconsistency in proposed project design complicates the ability of NOAA Fisheries to fully assess the effects of the action on NOAA trust resources, and hinders our ability to assess adverse effects to EFH and provide effective EFH conservation recommendations. This also raises substantial questions regarding the scope of the proposed action that ME DOT and FHWA is pursuing for this project.

Our evaluation of impacts to EFH was also complicated by the lack of detail on project alternatives that may reduce the short and long-term impacts of the proposed project. The EFH assessment notes two other project alternatives were considered that would provide tidal exchange to the Middle River. However, a comparison of the short and long-term effects of the preferred alternative and other project alternatives, including an assessment of the climate effects, were not provided. The level of detail necessary to compare the proposed project and the other alternatives is not sufficient to evaluate distinct differences in the adverse effects to EFH and federally-managed species, and allow for the identification of measures to avoid and minimize adverse effects. We have determined the proposed structure represents long-term climate vulnerabilities to NOAA trust resources, as well as to the built environment in the project area.

Specific EFH Assessment Concerns

As noted above, we have previously requested information from ME DOT and FHWA that we deemed necessary to evaluate the full effects of the proposed project on EFH and other NOAA trust resources, most recently in a technical assistance letter to you on November 28, 2023. Unfortunately, information provided in the revised EFH assessment was insufficient to fully assess the effects of the project. A summary of the deficiencies in the EFH assessment are provided below.

Project Design Information

In our November 28, 2023 technical assistance letter, we requested design and engineering details for the proposed dike structure, and the size, number, and design of culverts and tide gates, including plan view and cross-sectional drawings. In response, the revised EFH assessment indicated that the "final design" of the proposed project will be completed only after the National Environmental Policy Act (NEPA) process is complete, and included citations from FHWA guidance and directives. The cited references described the "final design activities, property acquisition, purchase of construction materials or rolling stock, or project construction" that should only occur after issuance of a Finding of No Significant Impact or a combined final Environmental Impact Statement/Record of Decision. However, our requests for design and engineering information were not necessary to meet the "final design activities" stage, but rather information necessary to evaluate the full effects of the construction, operation, and maintenance of the proposed project on EFH and other NOAA trust resources. NEPA requires federal action agencies to evaluate the environmental impacts of a proposed action and reasonable alternatives to the proposed action and the significance of those impacts. The comparison of a proposed action and reasonable alternatives shall be based on the discussion of the impacts (§1502.16 Environmental Consequences).

Furthermore, Section §600.920(e)(3) of the EFH Final Rule requires that an EFH assessment include an analysis of the potential adverse effects of the action on EFH and the managed species. Section §600.920(e)(4) of the Final Rule describes additional information that, if appropriate, should be included in an EFH assessment, such as the results of an on-site inspection to evaluate the habitat and the site specific effects of the project and an analysis of alternatives to the action. Such analysis should include alternatives that could avoid or minimize adverse effects on EFH. The FHWA's guidance pertaining to final design requirements should not prohibit the ME DOT and FHWA from providing appropriate information, including project drawings necessary for NOAA Fisheries to assess the extent of the direct and indirect impacts to EFH from construction and the long-term impacts from the operation of the tide gates. Furthermore, the revised EFH assessment provides limited information regarding project alternatives that were considered, and insufficient information regarding comparative environmental impacts between the alternatives.

Construction-related Impacts

Section 2.0 of the revised EFH assessment indicates a preliminary plan view and construction limits was provided in Appendix B; however, that plan only depicts a temporary bypass bridge and cofferdams, and does not include details of the proposed dike structure, culverts, and tide gates necessary to evaluate the adverse effects to EFH. Although the plan view drawing shows a path for the concrete box culverts through the new dike, it does not depict tide gates. The EFH assessment also does not include cross-sectioning drawings with elevation data for the proposed dike structure, culvert, and tide gates. Furthermore, the plan view drawing does not depict the mean high water (MHW) or mean low water (MLW) lines, which we requested and indicated is necessary to evaluate the effects of the proposed project on EFH and federally-managed species.

The revised assessment states "Activities that could result in an adverse effect (pile driving with an impact hammer) will be completed outside of the water or within the December 1- March 31 window." This is an inaccurate statement because, as noted in Table 3 of the revised EFH assessment, much of the construction activities that will result in adverse effects to EFH will occur during all months of the year (i.e., placement of fill for the temporary access road, excavation/dredging and removal of portions of the existing dike structure, and sheet pile installation for cofferdams). The only time-of-year restriction (TOY) proposed is for noise producing activities from pile driving for the temporary bridge. Furthermore, the proposed work window for the temporary bypass bridge installation is from December 1 to March 31, which will not protect sensitive life stages of a number of federally-managed species and other NMFS trust resources. For example, adult winter flounder spawning, and egg and larvae development occur in the Machias River between March 15 and June 30; Atlantic salmon spawning migrations can occur from April to December; and downstream juvenile migration can occur in the project area from April to June; other diadromous fish present in the Machias River (e.g., alewife, blueback herring, and American shad) undergo spawning migrations in April through June. We have determined that sensitive life stages of these species will be impacted by the proposed project construction, and the revised EFH assessment does not describe these adverse effects or indicate any avoidance and minimization efforts will be employed.

Cofferdam and Access Fill Impacts

Our technical assistance letter requested the location and extent of the cofferdams proposed for the project in relation to the dike structure with MHW and MLW lines depicted. As noted above, Appendix B contains a plan view drawing for the temporary bypass bridge, access fill, and cofferdams, although it does not include MHW or MLW lines which inhibits our ability to assess the impacts to EFH and NOAA trust resources. The revised assessment indicates that proposed cofferdams will impact approximately 24,000 sf of habitat, although the amount and type of each habitat and EFH present in the project area that would be impacted was not provided. The project overview section states that "the MLW line is approximately 30 feet away from the existing dike footprint and the temporary work is likely to extend further than that into the Machias River". This suggests a majority, if not all, of the existing intertidal habitats adjacent to the project will be impacted and made inaccessible to federally-managed species during the 3-4 year construction duration. Furthermore, the revised assessment indicates that the TOY restriction proposed is limited to pile driving for the temporary bypass bridge. TOY restrictions are not proposed for the sheet pile installation of cofferdams, placement of access fill, and dredging/excavation of the existing dike. As a consequence, we have determined that sensitive NOAA trust resources in the project area, including demersal and sessile winter flounder eggs and larvae, will likely be injured or killed during construction.

Temporary Bridge and Approach Fill Impacts

The revised EFH assessment states that the temporary bypass bridge and approach fill will impact 21,000 sf, but does not provide information about the type of habitats that will be impacted, or how much of the impact will occur in intertidal and subtidal habitats. The revised EFH assessment indicates the proposed temporary bridge would include the installation of 35, 30"-diameter piles, suggesting an impact of approximately 1,000 sf. We therefore assume the remaining 20,000 sf of impacts are the result of fill for an approach road for the temporary bridge. However, the revised assessment provides no explanation of why the approach fill is needed, or a description of the material proposed for the fill. There is no information regarding how turbidity and sedimentation from the fill will be controlled and minimized to adjacent habitats, such as winter flounder spawning and egg development habitat and migration pathways for diadromous fish, or how impacts may be minimized with TOY restrictions. There is no information regarding the restoration of intertidal and subtidal habitats upon removal of the approach fill material and temporary bridge. Furthermore, the revised EFH assessment indicates the proposed temporary bridge will be located in the Machias River, but does not provide an explanation for why a temporary bridge could not be located in the Middle River. The existing dike and tide gates block federally-managed species and other NOAA trust resources from accessing the Middle River, and locating the temporary bridge there would minimize impacts to these species present in the Machias River, including Atlantic salmon and winter flounder.

Our November 28, 2023 technical assistance letter requested descriptions of proposed methods for controlling turbidity and sedimentation in wastewater and material excavated from the cofferdams, and how it will be prevented from impacting species and habitats in the Machias River and Middle River during the construction of the replacement dike structure and the demolition of the existing structure. Our letter also requested descriptions of proposed measures that will be implemented to monitor excessive turbidity and sedimentation, including contingencies in the event turbidity and sediment exceeds allowable levels (e.g., “stop-work” or revised work protocols). The revised EFH assessment does not assuage our concerns. For example, the revised assessment states “The configuration of the existing box culverts within the bridge structure will create challenges for installing temporary water control structures. It is likely there will be water leaks through the cribwork. Sandbags or other barrier methods placed on a surface are not likely to stop water flowing through the dike. Further, it is not possible to drive a traditional sheet pile through the cribwork structure.” The revised assessment also states that portions of the existing dike will have to be excavated prior to installing sheet pile walls of the cofferdams, which suggests excessively turbid water will enter adjacent areas in the Machias and Middle River and will result in adverse effects to EFH and other trust resources. The information in the revised EFH assessment suggests controlling turbidity and sedimentation impacts on adjacent habitats during construction will be very difficult, if not impossible, yet the revised assessment does not include any plans to control or monitor turbidity and sedimentation, nor any contingency plans that would reduce impacts to adjacent habitats should turbidity and sedimentation impacts be identified.

The lack of any proposed plan to monitor and control high turbidity and sedimentation from impacting adjacent habitats is troubling. This is particularly concerning because the Machias River supports sensitive life stages of federally-managed species, including winter flounder spawning, and egg and larval development habitat. High turbidity levels and sedimentation in the Machias River can also impact EFH for adult and juvenile Atlantic salmon and their movement to and from spawning and rearing habitats, including the Atlantic salmon HAPC for the Machias River. The EFH assessment fails to include any evaluations or assessments of effects to EFH from turbidity and sedimentation, and does not propose any TOY restrictions for excavation and fill placement, or sheet pile installation for cofferdams.

Deficiencies Assessing Potential Contaminated Sediments

Our November 28, 2023 technical assistance letter requested information related to testing for contaminated sediments and other materials used for construction of the existing dike structure, particularly for potentially hazardous materials (e.g., polycyclic aromatic hydrocarbons) and heavy metals. We indicated that a description of methods used to contain materials and sediments removed from the old dike, and prevent the release of contaminated sediments into the Machias and Middle River should be included in the assessment. The revised EFH assessment indicated that an initial site assessment was conducted to identify the presence of hazardous materials associated with the dike. However, details regarding the types of hazardous materials that were tested, how or where testing of hazardous material in the dike bridge was conducted was not discussed. The existing dike structure was constructed around 1870, during a time when industries, including shipyards, an iron foundry and machine shop, canned-food factories, printing establishments, and a silver mining company operated in Machias, Maine. There is a possibility that fill material used in the construction of the dike may contain hazardous materials, making it prudent to evaluate this prior to construction. The revised assessment states that ME DOT will ensure any unanticipated contamination or deleterious materials encountered during construction will be managed in accordance with applicable environmental regulations, but it is unclear what measures would be taken to identify and determine the presence of contaminated materials during construction. Testing for contaminated sediments during bridge construction and excavation is not a standard requirement for contractors, as it typically involves specific training and testing equipment onsite during project construction. We continue to be concerned that the release of contaminated sediments in the surrounding water column and benthic habitats poses a threat to EFH and other NOAA trust resources.

Operational-related Impacts

The revised EFH assessment does not provide a meaningful evaluation of the expected operational impacts to EFH for the preferred alternative or any comparative analyses for the project alternatives. Section 5.0 includes a subsection titled “Effects from new functioning tide gates” that describes a loss of tidal habitats in the Middle River. The revised assessment mentions the presence of salt marsh and several species of salt tolerant vegetation, and several tidal species observed on intertidal mudflats in the Middle River. The revised assessment only states that “The project will result in a reduction of the tidal freshwater portions of the 32.7 acres as well as the unknown amount of that area that may contain some salt tolerant vegetation. Any areas containing salt tolerant vegetation will undergo a conversion back to freshwater vegetation.”

The revised EFH assessment does not describe the methods used to estimate the amount of tidal freshwater habitats in the Middle River. Without such information, we have concerns with the accuracy of the quantification of existing habitats and the area of EFH that will be permanently impacted over the life of the proposed project. In our November 28, 2023 technical assistance letter, we requested that ME DOT conduct a wetland delineation survey in the Middle River to quantify the existing salt marsh and other tidally-influenced habitats, and assess the extent of losses due to the proposed project. This was not provided in the revised assessment and, despite our continued request to ME DOT and FHWA following the receipt of the March 19, 2024 revised EFH assessment, this information has still not been provided. In the absence of an in-situ wetlands assessment, it is unclear how the area of impact was determined. Indirect methods to quantify the type of salt tolerant wetlands in the Middle River, such as using hydrological modeling, are not an accepted form of wetland delineation used by wetland scientists, and natural resource and regulatory agencies. We continue to request ME DOT conduct a wetland delineation survey for the tidally-influenced habitats in the Middle River, and use the results to determine the effects of the proposed project.

Deficiencies Describing EFH in the Project Area

Our November 28, 2023 technical assistance letter requested a description of all EFH designated in the Middle River and Machias River, and this information should be used to describe adverse effects to EFH in Section 5.0 (Analysis of Potential Impacts on EFH) of the EFH assessment. Although Table 6 in Section 3.0 (Essential Fish Habitat Designations) of the revised assessment lists federally-managed species for which EFH is mapped in the Machias River, the information in the table is limited to depth and salinity preferences for each species relevant to the project area. The table does not describe the EFH for life stages of federally-managed species occurring in the project area, nor is a description of EFH provided in other sections of the EFH assessment. As one example, all life stages of winter flounder are designated in the project area. The EFH Omnibus Amendment identifies EFH for juvenile and adult winter flounder as mud, sand, rocky substrates with attached macroalgae, and tidal wetlands to the MHW line, all of which occur in the project area. Furthermore, the EFH Omnibus Amendment describes benthic habitats used by winter flounder eggs, including mud, muddy sand, sand, gravel, and macroalgae, can be unsuitable for eggs and reduce hatching success if exposed to excessive sedimentation (NEFMC 2017). Construction activities proposed for this project will result in turbidity and sedimentation on habitats used by spawning winter flounder adults and eggs within and outside of cofferdams during periods when these life stages are present in the action area. The revised EFH assessment fails to describe the EFH for winter flounder, or characterize the adverse effects of the proposed project.

The HAPC for Atlantic salmon is located in the Machias River approximately 800 ft. upstream of the project area. As such, migratory passage of Atlantic salmon may be adversely affected by the proposed project. The impacts to Atlantic salmon EFH include the restriction of the Machias River from the proposed temporary bridge and access road, cofferdams, noise from pile driving and other activities, and elevated turbidity in the river during construction. According to the revised EFH assessment, a large proportion of the intertidal habitat on the north side of the Machias River adjacent to the Machias Dike will be inaccessible to migrating salmon during project construction from cofferdams, the temporary bridge, and the temporary access road fill. Upon completion of the proposed project, approximately 16,200 sf of intertidal and subtidal habitats in the Machias River will be permanently filled by the new dike bridge structure. The revised EFH assessment fails to describe the potential adverse effects of the proposed project to Atlantic salmon EFH, specifically access to upstream spawning habitat and HAPC.

The deficiencies of the revised EFH assessment is particularly troubling because the descriptions of EFH designations in Section 3.0 (Essential Fish Habitat Designations) in the project area excludes the Middle River. The descriptions of habitats in the Middle River are included in a separate section (4.1 Aquatic Habitat). Furthermore, Section 3.0 states “The mapper appears to map the estuary of the Machias River as EFH and has a buffer from that area that extends upstream of the Dike into the Middle River.” Other sections of the revised assessment suggests ME DOT believes the Middle River is not designated as EFH, such as Section 2.1 (Proposed Scope), which states “16,200 square feet of impact would be to functioning EFH downstream of the Dike, and 16,200 square feet of impact would be to the areas in the Middle River.” For clarification, the EFH Mapper tool does not describe the Middle River as a "buffer" for EFH, and in fact clearly indicates the Middle River is designated as EFH for federally-managed species. This point was made very clear on pages 10 and 11 of our November 28, 2023 technical assistance letter to the FHWA and ME DOT. Specifically, we noted the Middle River is designated EFH for 20 federally managed species. The definition of EFH in the Final Rule is not dependent upon the ability of federally-managed species to currently access part or all of a project area. As noted in the EFH Consultation Requirements of the EFH Final Rule (§600.10), EFH "may include aquatic areas historically used by fish where appropriate". There is ample evidence the Middle River was formerly a tidally-influenced river used by fish and invertebrate species similar to the Machias River today. Both the Middle River and Machias River are designated as EFH, and the assessment for this proposed project should have appropriately described the adverse effects on all EFH in the project area.

Deficiencies in Adverse Effects Analysis on EFH
In our November 28, 2023 technical assistance letter we requested a description of all expected adverse effects to the EFH for life stages of federally-managed species designated in the project area, including from the construction of the proposed dike structure and the demolition of the existing dike structure. The second paragraph of Section 5.0 (Analysis of Potential Impacts on EFH) of the revised assessment indicates habitat alteration is listed as one of the primary causes of adverse effects to EFH in both construction and demolition activities. However, the project effects discussed in Section 5.0 is almost exclusively restricted to impacts to species, rather than habitats (EFH) used by federally-managed species. Section 5.0 discusses "false attraction" and "hydroacoustic effects" and describes the effects of the project to fish species. The EFH Final Rule at §600.810 defines an adverse effect to EFH as any impact that reduces the quality and/or quantity of EFH. Our November 28, 2023 technical assistance letter to you provided guidance on appropriate considerations and analysis in an EFH assessment. The exclusive focus on the effects to species, rather than the effects on EFH, is an inappropriate method of analyzing the effects of the action on EFH.

Section 5.0 of the revised assessment fails to provide sufficient information regarding the adverse effects on EFH from the proposed project. There is a lack of discussion in the assessment about adverse effects to EFH from the 45,000 sf of temporary and 32,400 sf of permanent impacts due to increasing the height of the dike bridge. As described in the revised EFH assessment, the preliminary estimate for the maximum dike bridge elevation could be as high as 18.16 ft. NAVD88 (final elevation for the new dike bridge has not been determined, but the assessment states this is the presumed height for assessing adverse effects to EFH). The existing maximum height of the dike bridge is about 11 ft. NAVD88, suggesting an approximate +7-foot elevation change at the high point of the dike. An assumed 3:1 side slope was used to calculate the new toe of slope, which will be 21 ft. from the center and 15 ft. near the ends of the dike. Should the height or other dimensions of the dike increase in the final design phase, the area of impact will need to be reevaluated. Furthermore, increases in the height or other dimensions of the proposed dike will also increase the extent of temporary impacts from access fill and cofferdams in the Machias and Middle River. Should the final design height or other dimensions of the bridge increase, we anticipate a need for FHWA to reinitiate the EFH consultation for the proposed project.

The discussions in the revised EFH assessment about habitat impacts refers to a loss of 640 sf of salt marsh in the Machias River, although the assessment does not describe the activities that would cause the impact or the effects to designated EFH in the project area. The only other reference to habitat impacts is in a subsection titled "Effects from new functioning tide gates", which describes the loss of tidal habitats in the Middle River. However, it does not fully describe the extent of tidal habitat losses, simply referring to a reduction of the tidal freshwater portions of the river by about 33 acres, as well as an "unknown amount of that area that may contain some salt tolerant vegetation." In our November 28 technical assistance letter, we requested that ME DOT conduct a survey of the area of existing salt and brackish marshes in the Middle River, quantify the existing habitats, and assess the extent of losses due to the proposed project. This information was not provided in the revised assessment. Furthermore, the revised assessment states "Any areas containing salt tolerant vegetation will undergo a conversion back to freshwater vegetation." This is an inaccurate characterization of the loss of tidal wetlands in the Middle River from the installation of new tide gates. The proposed project would continue the long-term impact to a historically tidal river with salt-tolerant habitats, and result in a permanent conversion to a freshwater system. Furthermore, the proposed project would effectively eliminate any potential future restoration of historic salt marsh, brackish marsh, tidal freshwater wetlands, and other intertidal and subtidal habitats in the Middle River.

Tidal freshwater marshes are mixed herbaceous marshes that receive daily tidal water level fluctuations, but minimal actual saltwater input, that occur in the freshwater reaches of coastal rivers. Tidal freshwater marshes are considered valuable wildlife habitat and have received considerable conservation attention by the Maine Department of Agriculture, Conservation & Forestry, which has designated this habitat type as "S1, Imperiled in Maine – At high risk of extirpation in the jurisdiction due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors." (https://www.maine.gov/dacf/mnap/features/communities/freshwatertidalmarsh.htm). The proposed project would eliminate all diurnal tidal exchange in the Middle River, resulting in the permanent elimination of this rare aquatic habitat type. The high diversity of fish and wildlife species associated with tidal fresh habitats in the Middle River will be permanently lost to this system for the life of the proposed project.

Climate Change Concerns

Our concerns regarding the climate implications for the proposed project have been expressed in our technical assistance letters to ME DOT and FHWA on September 30, 2020 and November 22, 2021. More recently, our technical assistance letter on November 28, 2023, requested you conduct a climate assessment to evaluate the synergistic, additive, and cumulative effects of the proposed project from sea level rise (SLR), storm surge, increased extreme rainfall and inland flooding, and warmer water temperatures on EFH and other NOAA trust resources. Furthermore, we requested the climate assessment evaluate the other bridge design alternatives that were considered, including an open culvert configuration (Alternative 4m) and a pile-supported bridge design (Alternative 10). According to the revised EFH assessment, the expected life span of the proposed dike bridge, culverts, and tide gates is 80-100 years. Therefore, the proposed structure will be subjected to numerous changes that will have substantial implications in the operation and the functional use of the structure.

We believe the design of a bridge structure should be informed by and be consistent with Maine Climate Council's recommendations for SLR, as well as the Maine Climate Action Plan's recommended use of natural climate solutions to increase carbon sequestration, and investing in climate-ready infrastructure (Maine Climate Council 2020). We do not believe the proposed project is consistent with guidance from the Maine Climate Council, and an appropriate evaluation of the short and long-term effects of climate change has not been conducted for the proposed project.

We have conducted a climate assessment that we believe accurately describes the implications of climate change and numerous vulnerabilities this project would represent for EFH. Our assessment indicates that the proposed structure would result in both short and long-term climate vulnerabilities to EFH and other NOAA trust resources, as well as to the built environment in the project area. The EFH Final Rule defines an adverse effect as any impact that "reduces the quality and/or quantity of EFH, and may include direct or indirect physical, chemical, or biological alterations of the waters or substrate." An adverse effect may include the loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality and/or quantity of EFH. Furthermore, the adverse effects to EFH may "result from actions occurring within EFH or outside of EFH and may include site specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions" (50 CFR 600.810). The "individual, cumulative and synergistic consequences of an action" should be considered in the context of other known effects in the project vicinity, which may include climate change if the assessment is based on the best available information and can reasonably project the directionality of climate change and overall extent of effects to the species and/or the habitats. The EFH regulations stipulate that federal agencies and NOAA Fisheries must use the best scientific information available regarding the effects of an action on EFH, and measures that can be taken to avoid, minimize, or offset such effects (50 CFR 600.920(d)). We have determined the proposed project would increase the climate vulnerability of EFH and other NOAA trust resources in the Machias and Middle River and would have synergistic, additive, and cumulative adverse effects on EFH.

Section 5.2.5 (Effects of preferred alternative combined with climate change) of the revised EFH assessment states that the proposed design accounts for "higher water in the coastal environment as well as increased precipitation and freshwater storms." We believe this is an inaccurate statement for several reasons. The revised assessment cites a November 2021 memo from Stantec that described water elevations for a Q1.1 flow during a 100-year storm surge with a SLR scenario of 3.9 ft. could be as high as 14.6 ft. NAVD88. The Stantec memo evaluated changes in water levels due to SLR and storm surge, but it does not appear to include inland flooding and extreme precipitation events caused by climate change. As noted in our November 28, 2023 letter, more frequent and intense extreme precipitation events and river flows will impact the proposed dike bridge structure, as well as the operation of tide gates and flow between the Middle River and Machias River. New England is experiencing more extreme precipitation events and this trend is projected to increase in the 21st century with corresponding higher air temperature (Easterling et al. 2017; Jong et al. 2023), which will result in higher maximum peak river flows in Maine (Hodgkins and Dudley 2013). Climate studies incorporating hydrological models have projected increased variability in streamflow, with greater frequencies of both high-flow and low-flow events predicted for much of the Northeast region (Demaria et al. 2016; Hayhoe et al. 2007).

The 3.9 ft. projection referenced in the Stantec memo refers to the Maine Climate Council's "commit to manage" SLR scenario for the year 2100. However, we believe the projected 14.6 ft. NAVD88 SLR and storm surge scenario for the project area described in the Stantec memo is extremely conservative and not representative of likely conditions over the life span of the project. Furthermore, the Stantec memo is not consistent with the results of a study commissioned by ME DOT for the Machias Dike Bridge, published in 2013 by the ME DOT Transportation Research Division (Maine DOT 2013 Technical Report 14-05; Douglas and Kirshen 2013). This study was conducted in response to recommendations in state legislation LD460, Resolve to Evaluate Climate Change Adaptation Options for the State, passed during the First Regular Session of the 124th Maine State Legislature in April 23, 2009 (http://www.mainelegislature.org/legis/bills/bills_124th/billtexts/SP016301.asp). This study should have been included in the revised EFH assessment, as the technical report evaluated the effects of inland river flooding, storm surge and SLR on the Machias Dike Bridge. Two bridge alternatives were evaluated in the study: an in-kind replacement with box culverts and a span bridge. The ME DOT technical report simulated the combined effects of inland river flooding and storm surge on flood elevations at the Machias Dike Bridge using a HEC-RAS, a river model developed by the Army Corps of Engineers. The analysis used the 100-year peak discharge for the Middle River under existing conditions and a 10% higher discharge for future conditions. It is important to note that the existing bridge conditions were simulated assuming that the tide gates were always open, as tide gates are not a bridge option in the HEC-RAS model. Consequently, the study's evaluation of inland flooding in the Middle River was very conservative because the tide gates of the proposed project will be closed when the water elevation in the Middle River is lower than the Machias River. The only discharge through the dike bridge structure will be when the tide gates are in an open position, which occurs approximately 12 hours per day on normal diurnal tide cycles. However, during heavy rainfall and inland flooding coinciding with coastal storm surge events, which is common in New England, abnormally high tidal elevations in the Machias River can limit the time the tide gates are open and discharge water from the Middle River. Consequently, inland flooding in the Middle River above the dike will likely be greater than the estimates obtained from the 2013 ME DOT technical report. Inland flooding in the Middle River due to the presence of the dike bridge will increase the adverse effects on EFH in both the Middle River and the Machias River from scour and erosion of river banks and wetland habitats, and impact water quality from higher water temperatures, lower dissolved oxygen, and greater inundation of vegetated wetlands and freshwater releases in the tidally-influenced Machias River.

The ME DOT technical report projected flooding and SLR to the year 2050, using a high SLR scenario of 1.7 ft. However, the proposed dike bridge is expected to have a lifespan of 80-100 years, which requires a longer time horizon to assess the effects of climate change on the project. At a minimum, SLR projections used in a climate change assessment for the proposed project should be consistent with the Maine Climate Council's "Commit to Manage" SLR recommendation of 3.9 ft. for the year 2100. The climate assessment should also include the Maine Climate Council's "Prepare to Manage" recommended SLR scenario of 8.8 ft. for the year

2100 (Maine Climate Council 2020). These scenarios were incorporated into state regulations as official SLR projections in 2022.

The revised EFH assessment indicated the proposed dike bridge maximum roadway height could be as high as 18.16 ft. NAVD88. The ME DOT technical report estimated a 100-year and 5-year storm surge height of 7.04 ft. and 5.95 ft., respectively, and a wave height of 1.0 ft. We have calculated the combined effect of SLR, inland river flooding, and 50-year and 100- year storm surge events on the proposed dike bridge using a 18.16 ft. NAVD88 elevation, as shown in the table below.

Storm surge return period (yrs.)	**Surge height (ft.)**	**Existing MHHW (ft. NAVD88)**	**Wave height (ft.)**	**“Commit to Manage” SLR elevation (ft. NAVD88)**	**“Commit to Manage” water level exceedance (ft.)**	**“Prepare to Manage” SLR elevation (ft. NAVD88)**	**“Prepare to Manage” water level exceedance (ft.)**
50	5.95	7.44	1.0	18.29	+0.13	23.19	+5.03
100	7.04	7.44	1.0	19.38	+1.22	24.28	+6.12

Table 1. Year 2100 storm surge, SLR projections, and water level exceedances for the proposed 18.16 ft. NAVD88 elevation for Machias Dike Bridge (adapted from 2013 ME DOT Technical Report 14-05).

As shown in Table 1, using the Maine Climate Council’s 2100 SLR ``Commit to Manage” and “Prepare to Manage” scenarios, the Machias Dike Bridge constructed with a roadway surface elevation of 18.16 NAVD88 would be inundated under both 50-year and 100-year storm surge events over the expected life of the project. Furthermore, using the shorter-term, 2050 SLR projections evaluated in the ME DOT technical report, the dike would be within less than a foot of inundation in a 100-year storm surge event (Table 2).

Storm surge return period (yrs.)	**Surge height (ft.)**	**Existing MHHW (ft. NAVD)**	**Wave height (ft.)**	**High (+1.7 ft.) SLR elevation (ft. NAVD88)**	**High (+1.7 ft.) SLR water level exceedance (ft. NAVD88)**
100	7.04	7.44	1.0	17.18	-0.98

Table 2. Year 2050 storm surge, SLR projections, and water level exceedances for the proposed 18.16 ft. NAVD88 elevation for Machias Dike Bridge (adapted from 2013 ME DOT Technical Report 14-05).

It is important to point out that the existing dike bridge is inundated by extreme high tides and storm surge multiple times per year (most recently in January 2024). Future climate change will worsen this condition. As noted in the Scientific Assessment of Climate Change and Its Effects in Maine report by the Scientific and Technical Subcommittee of the Maine Climate Council (MCC STS 2020), “a 1-foot increase in sea level, which could occur by 2050, would cause a “100-year storm” flood level to have a probability of occurring once in every 10 years. Not accounting for changes in storm intensity or frequency, this would result in a 10-fold increase in coastal flooding in Maine in the next 30 years.” It is likely that the proposed dike, if built at an elevation 18.16 ft. NAVD88, has the probability of being inundated seven or more times over the lifespan of the dike, and possibly twice by 2050. This would represent a considerable climate vulnerability for the project, and would likely result in considerable cost to repair and maintain the structure. Inundation of the proposed dike bridge would increase erosion and scour impacts to vegetated and unvegetated habitats in the Middle and Machias Rivers. Future repairs, improvements, and maintenance of the dike bridge due to damage from flood events and storm surge will result in increased adverse effects to EFH and other NOAA trust resources.

Furthermore, as discussed above, because the HEC-RAS used in the 2013 ME DOT technical report does not provide the ability to analyze tide gates in the model, the hydraulic simulations assumed that the tide gates were always open. However, this is not how flap tide gates will operate on the Machias Dike Bridge, which will remain closed for approximately 50% of the time in a 24-hour period. As future sea levels increase the tidal elevations, the tide gates will close for longer periods during an average tide cycle which can reduce the time water in the Middle River can exit through the tide gates. So while the HEC-RAS modeling provides useful information regarding flood water elevations at the dike under combined SLR and storm surge conditions, it should be interpreted as very conservative estimates of inland freshwater flooding potential for the proposed dike.

Our November 28, 2024 technical assistance letter requested information about how extreme precipitation, SLR, and flooding will affect the operation of the dike structure and tide gates, and how these changes will impact EFH, federally-managed species, and other NOAA trust resources in the project area. Section 5.2.5 (Effects of preferred alternative combined with climate change) of the revised assessment discussed "a chance of storms that could overtop a new structure" and "there could be erosion of shorelines and areas adjacent to the rip rap along the edge of the dike", but concluded "this is a potentially (sic) future effect, but do not believe the future effects can be quantified." While quantifying precise impacts to EFH from future changes in climate can be challenging, inland flooding, SLR projections and storm surge calculations for the project location are available. In fact, these calculations have already been completed for the proposed project in the ME DOT technical report (Maine DOT 2013 Technical Report 14-05; Douglas and Kirshen 2013). As noted above, based on the ME DOT technical report, inundation of the dike under climate scenarios are not simply theoretical, but highly probable. Some estimates of effects to EFH and other NOAA trust resources due to the proposed structure can be made, including the effects of higher sea level on vegetated intertidal wetlands, scour and erosion adjacent to the structure due to higher sea level and water velocity through the tide gates, and scour and erosion of habitats due to inundation of the dike structure. However, the revised EFH assessment failed to accurately quantify existing aquatic habitats in the Middle River, including intertidal vegetated and non-vegetated habitats, and subtidal habitat, nor does it provide any evaluation of the synergistic and cumulative impacts of the project with climate change.

Furthermore, the revised assessment does not assess the effects of increased water temperatures in the Middle River or how this may affect EFH and other trust resources. The revised assessment states "As water warms, water that is impounded by the Dike will also warm. Maintaining the impoundment will continue to have the effect of warming water. No monitoring of temperatures has been completed to understand the current effect of the Dike on water temperatures. Changing climate conditions are likely to warm the water in the impoundment to higher temperatures and continue the current effects that are occurring." The existing dike is likely causing elevated temperatures in the Middle River today due to restrictions in flow and from higher air temperatures from climate change. Temperatures of northern New England streams and rivers are projected to increase disproportionately higher than the national average over the 21st century (Letcher et al. 2016), which would have implications to habitats in the

Middle River. New England riverine habitats have been historically altered by a host of non-climate perturbations, including dams and tidal restrictions (Daley et al. 2009; Hall et al. 2012; US EPA 2016; Mattocks et al. 2017), which can exacerbate climate-related changes in temperature and streamflow. More extreme precipitation, extremes in river flows, higher water temperatures, and higher sea levels and storm surges will impact habitats, as well as the operation of tide gates and flow rates between the Machias River and Middle River. However, because ME DOT has not conducted any temperature monitoring to assess the conditions, the assessment does not provide any meaningful information from current or future water temperature impacts to habitats in the Middle River.

Our technical assistance letter on November 28, 2023 requested information regarding permanent impacts to EFH and other NOAA trust resources from any future plans to raise the elevation of the roadway and the dike structure to account for climate change. In response, the ME DOT noted in the revised EFH assessment that the height of the dike may be raised to adapt to future SLR. Section 2.1 (Proposed Scope) stated, “An adaptive approach to the height of the causeway is likely needed as the community continues to discuss its options. Accommodations completed today can also be completed in a way to account for future accommodations (i.e. height of the new causeway)”. The calculated area of impacts to EFH for the proposed project was based on an increase in the elevation of the dike approximately 7 ft. higher than the existing maximum height of 11 ft. NAVD88. As discussed above, our climate assessment raises concerns that there is a very high likelihood that the bridge will be subjected to inland flooding, storm surge, and SLR elevations near 19 ft. NAVD88 by 2050 and 24.3 ft. NAVD88 by 2100. Assuming the Machias Dike is constructed at a height of 18.16 ft. NAVD88, the dike may require additional vertical elevation increases of 12 ft. or more by 2100 in order to prevent inundation (assuming a minimum of approximately 5 ft. of freeboard at mean high tide for the low chord of the bridge is necessary to allow for 100-year storm surge events). This additional 12 ft. of increased bridge height, using the same 3:1 side slope assumption would, at a minimum, result in an additional 65,000 square ft. of impacts to EFH over the life of the project. Furthermore, increased expansion of the dike into the Machias and Middle Rivers will result in additional temporary impacts from cofferdams and access fill and adverse effects to EFH and other NOAA trust resources. These adverse effects should be assessed during the current EFH consultation. Any future changes in the height or other dimensions of the bridge that results in increased adverse effect to EFH would likely require reinitiation of the EFH consultation.

As noted above, the comments and recommendations provided for this project through our statutory obligations under the MSA and FWCA are intended to assist the FHWA in supporting the Administration's goals to combat the climate crisis in a manner that “conserves our lands, waters, and biodiversity” (E.O. 14008). ME DOT and FHWA should give full consideration of these recommendations in a manner such that the project may contribute to the Administration’s efforts to help mitigate climate change in an environmentally responsible manner.

Compensatory Mitigation

The revised EFH assessment indicates the construction of the proposed replacement structure will result in approximately 32,400 sf of permanent and 45,000 sf of temporary impacts to EFH. As discussed above, this area of impact is based on a maximum roadway elevation of 18.16 ft. NAVD88. Should the design height or other dimensions of the dike increase, the area of impact will correspondingly increase. Furthermore, the area of impact may increase if construction methods change, including cofferdams, the temporary bridge, and approach road fill. The habitat impacts in the Middle River due to the operation of new tide gates will permanently impact tidal fresh, brackish, and salt marshes, as well as other intertidal and subtidal habitats for the life of the proposed project. Our request for a wetland delineation survey, necessary to quantify existing habitats in the Middle River and determine project-related impacts, was not provided. Although ME DOT has estimated the existing tidally-influenced habitats in the Middle River to be approximately 33 acres, the methods used to estimate the habitat and the impacts related to tide gate operations are unknown. We assume ME DOT will be required to seek appropriate permit authorizations from the U.S. Army Corps of Engineers (USACE), pursuant to section 404 of the Clean Water Act and/or section 10 of the Rivers and Harbors Act. We have concerns that the calculations used to determine wetland jurisdiction and compensatory mitigation through the USACE permitting processes will not be based on standard wetland delineations. We continue to request a wetland delineation survey be conducted to determine the amount of tidally-influenced habitats in the Middle River for calculating appropriate compensatory mitigation for the proposed project.

The impacts from the construction of the in-kind replacement of the Machias Dike Bridge was estimated by ME DOT to be approximately 32,400 sf of permanent and 45,000 sf of temporary impacts to EFH. Furthermore, the revised EFH assessment indicates the project construction is estimated to take approximately 3-4 years to complete. This is a considerably long period of time that exceeds the general assumptions of what is considered to be temporary impacts. EFH will be partially or fully inaccessible by federally-managed species and other NOAA trust resources during the 3-4 years of project construction, and the approximately 45,000 sf habitat area could require a year or more time to recover from the prolonged impact. Therefore, compensatory mitigation should be provided for the permanent, as well as what is characterized as "temporary" impacts for this proposed project. Providing compensatory mitigation for long-duration construction projects greater than one year is not unprecedented. In fact, FHWA agreed to provide compensatory mitigation for approximately 40,000 sf of impacts from the placement of riprap to construct a construction equipment access road on the intertidal mudflats during the 3-year construction period for the Sarah Mildred Long Bridge in Portsmouth, New Hampshire in 2014. We believe the long duration of the proposed project will result in substantial temporal impacts to EFH that will require a period for recovery that exceeds what is typically considered "temporary" effects.

Deficiencies in Alternative Analyses

40 CFR 1502.14 of the NEPA regulations require action agencies to "a) evaluate reasonable alternatives to the proposed action, and, for alternatives that the agency eliminated from detailed study, briefly discuss the reasons for their elimination" and "(b) discuss each alternative considered in detail, including the proposed action, so that reviewers may evaluate their comparative merits." Furthermore, Section §600.920(e)(4) of the EFH Final Rule describes additional information that, if appropriate, should be included in an EFH assessment, including the results of an on-site inspection to evaluate the habitat and the site specific effects of the project and an analysis of alternatives to the action. The Final Rule indicates that the assessment should include alternatives that could avoid or minimize adverse effects on EFH.

As we noted in our technical assistance letter in November 2023, we advised you that an analysis of alternatives that identifies options to avoid and minimize adverse effects on EFH should be included in the EFH assessment. Furthermore, we requested ME DOT and FHWA include in the revised EFH assessment discussions why the preferred alternative (Alternative 1) was chosen over the pile-supported bridge (Alternative 10) and open culvert design (Alternative 4m), including an analysis of direct construction-related impacts, operational impacts, and long-term climate effects. These analyses should have included climate resilience costs and benefits, carbon sequestration potential, resilience for flooding upstream and downstream of the proposed dike structure, and for higher water temperatures in the project area. The revised EFH assessment does not include any rationale for why Alternative 1 was chosen over the other alternatives in terms of avoiding adverse effects to EFH, climate resiliency, carbon sequestration, flooding mitigation, or ecosystem services. The only reference in the revised assessment regarding a rationale for choosing Alternative 1 was in Section 2.0 (Project Description), which states "a fully gated culvert alternative will best meet the project's purpose and need", and will "improve the structure's condition, maintain the Sunrise Trail, provide for future rail use, and avoid flooding of hundreds of acres of land." Although Alternatives 4m and 10 would result in inundation of some land in the Middle River, the revised assessment does not describe the other alternative's comparative degree of flooding of structures on the Middle River, potential negative effects on property values, or the impacts to continuing uses of the land. Furthermore, the revised assessment does not describe why other alternatives would not meet the other stated project purpose and need. For example, a new pile-supported bridge design would presumably be constructed to meet the required safety and functional use criteria of a roadway, and would result in an improvement of the structure's condition.

Regarding the use of the Sunrise Trail and the potential future construction of a railway, the revised assessment did not provide any discussion on how the Sunrise Trail would be designed to accommodate the proposed in-kind dike replacement. We assume the existing Sunrise Trail elevations at the east and west approaches of the dike are less than 11 ft. NAVD88. According to the revised assessment, the maximum elevation of the in-kind dike replacement will be 18.16 ft. NAVD88, suggesting that the east and west bridge approaches for the Sunrise Trail would require an increase in elevation of approximately 7 feet and substantial fill placement to raise the elevation to match that of the proposed dike bridge elevation. However, the revised assessment does not include any information regarding construction modifications necessary to modify the Sunrise Trail elevations, including potential wetland impacts. Furthermore, the stated project purpose and need included providing potential future rail use on the Sunrise Trail corridor over the proposed dike bridge replacement. However, the revised EFH assessment does not address the feasibility of accommodating changes in surface elevation of a future rail line to 18.16 ft. NAVD88 over the Machias Dike Bridge. These changes may also result in substantial wetland impacts in areas adjacent to the existing structure.

The project design of the replacement bridge is presumably heavily dependent upon meeting the project's purpose and need, which consequently affects the project's size and adverse effects to EFH. We are troubled by the lack of detail and clarity in the EFH assessment, as well as an assessment of potential adverse effects, regarding the stated project purposes. The lack of information related to the design of the dike, including components of the project that ME DOT states are necessary for meeting the project's purpose and need, continues to challenge our ability to assess the adverse effects of the proposed project on EFH. An alternatives analysis should be conducted to evaluate the effects of meeting the project purpose and need for the preferred alternative, as well as the two project alternatives.

In our November 28, 2023 technical assistance letter to you we requested you evaluate the adverse effects to EFH and other NOAA trust resources from the preferred alternative in the Machias River and the Middle River relative to the other alternatives that have been analyzed for this project, including the span bridge (Alternative 10) and dike structure configured with open culverts (Alternative 4m). The full effects of alternatives for this project were not evaluated in the revised EFH assessment. We have included Table 3 from the revised assessment below, entitled “EFH impacts from three analyzed alternatives”.

Alternative	**Potential upstream areas subject to tides/ flooded normal tides**	**High marsh**	**Low marsh**	**Unvegetated**	**Fish passage conditions available**
1	0	0	0	0	0
4m	127	~13 acres	~ 60 acres	54 acres	52 %
10	403	~17 acres	~ 208	~191 acres	Full range of tides naturally available

Table 3. EFH impacts from three analyzed alternatives (from the revised EFH assessment, dated March 19, 2024.

Despite the title, Table 3 does not describe impacts to EFH. While all federally-managed species in the project area use tidal waters, and several species use marsh habitat for one or more life stages, an EFH assessment should describe the effects of a proposed action on EFH designated in the project area. There is no information in the table, or in subsequent sections of the revised EFH assessment, describing the adverse effects of the alternatives on EFH or the approximately 20 species of federally-managed species that EFH designated in the Middle River. Furthermore, the revised assessment does not consider the long-term effects to EFH from climate change, including extreme precipitation and inland flooding, SLR, and storm surge, for the three alternatives.

Although the information regarding alternatives analysis in the revised EFH assessment was insufficient, it is clear based on the limited information provided that the preferred alternative would result in substantially greater impacts to habitats in the project area. For example, Alternative 4m, would include one open culvert to allow tidal flow during all ebb and flood tides. As noted in the table, this alternative would restore approximately 127 acres of former tidal habitats, including habitats that are currently designated as EFH for federally-managed species, with diurnal flows, and would restore approximately 13 acres of high marsh, 60 acres of low marsh, and 54 acres of unvegetated, intertidal and subtidal habitats. This alternative has the potential to restore access to diadromous fish spawning habitat, including Atlantic salmon, in the Middle River.

Alternative 10 is a single span, pile-supported bridge between 120 and 150 ft. long, and would provide full tidal transparency with no flow restrictions. This alternative would restore approximately 403 acres of former tidal habitats, including habitats that are currently designated as EFH for federally-managed species, with diurnal flows, and would restore approximately 17 acres of high marsh, 208 acres of low marsh, and 191 acres of unvegetated, intertidal and subtidal habitats, according to ME DOT. This alternative would also restore unimpeded access to spawning habitats in the Middle River for diadromous fish, including Atlantic salmon, during all tides.

In comparison to Alternative 4m and 10, Alternative 1 would permanently eliminate all tidal flow to the Middle River, would permanently eliminate the potential for restoring historic and existing tidal habitats with diurnal flows, including areas designated EFH for federally-managed species for the 80-100-year life of the proposed project. This alternative would permanently eliminate access to spawning habitats in the Middle River for diadromous fish, including Atlantic salmon, alewife, blueback herring, rainbow smelt, American shad, and American eel. Furthermore, because the existing dike structure is porous to some degree and tidal waters leak through the existing dike, culverts, and tide gates during flood tides, an unquantified amount of salt marsh, brackish marsh, and other salt tolerant habitats occur in the Middle River would be permanently lost for the life of the proposed project. The entire Middle River system would be converted to an entirely freshwater system.

In addition to the operational impacts to EFH and other NOAA trust resources, Alternative 1 will result in, at a minimum, 32,400 sf of permanent impacts and 45,000 sf of temporary impacts to EFH in the Middle River and Machias River during construction. The EFH assessment does not include estimates of impacts to EFH for the other two bridge alternatives, 4m and 10, but we assume the removal of the existing dike and the construction of a pile-supported, single span bridge would result in the restoration of river bottom and intertidal habitats at the mouth of the Middle River and banks of the Machias River. Therefore, Alternative 10 would restore a substantial amount of subtidal and intertidal habitats that are currently impacted by the dike structure fill.

In addition to the relative differences between the alternatives in restoration potential for tidal wetlands and EFH for federally-managed species and other NOAA trust resources, the revised EFH assessment did not include information regarding the comparative adverse effects of the alternatives from the permanent conversion of existing and historic salt and brackish marsh habitats to freshwater wetlands. Specifically, salt marsh wetlands are known to provide climate resiliency to communities by adapting to SLR by migrating inland, reducing wave heights and attenuate storm surge, and reducing damage to landward property (Chmura et al. 2003; Duarte et al. 2013; Gedan et al. 2011; Temmerman et al. 2013). In addition, salt marshes have relatively high rates of sediment carbon burial compared to freshwater wetlands. For example, Mcleod et al. (2011) reported the long-term carbon burial rate of salt marsh wetlands ranges from 18 to 1,713 grams of carbon per meter per year (gC/m/yr), compared to an average sequestration rate of 8 to 149 gC m/yr for freshwater riverine marshes (Bernal and Mitsch 2012; Fennessy et al. 2018). Furthermore, freshwater wetlands can be significant sources of methane production relative to tidal wetlands, because high sulfate levels in tidal wetlands keep methane production low. Methane is a strong greenhouse gas, with an estimated global warming potential 25 times greater than CO_2 over 100 years (Boucher et al. 2009). Poffenbargar et al. (2011) reported polyhaline tidal marshes (salinity >18 ppt) had significantly lower methane emissions, and can be expected to decrease radiative forcing when created or restored, compared to fresh and brackish marshes.

As discussed in this letter, we have determined the preferred alternative will result in substantial negative climate implications to EFH and NOAA trust resources from higher water temperatures, sea level rise, storm surge, and more extreme precipitation patterns and flooding. Furthermore, the other design alternatives for this project would provide opportunities to reduce the vulnerability of climate change to natural ecosystems and the human-built environment. Given the considerable climate vulnerability the proposed structure would represent, the climate resiliency benefits of restoring coastal marsh habitat in the Middle River should be reconsidered for the project. As discussed above, the span bridge alternative would provide the best approach to restoring the habitat and stream function of the Middle River, as well as increasing the capacity for carbon sequestration by tidal marsh vegetation. This alternative is consistent with two of the primary strategies in the Maine Climate Action Plan: protecting and promoting natural climate solutions that increase carbon sequestration and investing in climate-ready infrastructure (Maine Climate Council 2020). In contrast, the proposed in-kind replacement of the dike bridge would be inconsistent with the two strategies recommended by the Maine Climate Action Plan.

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U.S. Department
of Transportation
Federal Highway Administration

Maine Division

40 Western Ave, Rm 614
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March 19, 2024

Sent Electronically

In Reply Refer To:
HDA-ME

Chris Boelke
Habitat and Ecosystem Services Chief
New England Branch
55 Great Republic Drive
NOAA Fisheries Office
Gloucester, MA 01930

Dear Mr. Boelke:

The purpose of this letter is to initiate expanded consultation pursuant to the Magnuson-Stevens Fishery Conservation and Management Act of 1976, as amended (16 U.S.C. 1801 et seq.) per expanded consultation procedures at 50 CFR 600.92(i) for a bridge replacement project that proposes to remove and replace Dike Bridge (Br. No. 2246) in Machias, Maine. The project will replace 4 existing 5x5 timber box culverts that carry Route 1 over the Middle River. The box culverts are located in the causeway that travels through the Middle River and situated adjacent to the Machias River Estuary. The replacement bridge is likely to be a series of concrete box culverts. The current box culverts have tide gates and the proposed replacement structures will also have tide gates.

On October 31, 2023, Maine Department of Transportation (MaineDOT) submitted a final draft Essential Fish Habitat (EFH) assessment on behalf of the Federal Highway Administration (FHWA) for review and comment based on previous technical assistance. As a result of that submission on November 28, 2023, via letter sent by email, National Marine Fisheries Service (NMFS) submitted comments and requested additional items necessary to begin consultation. FHWA and MaineDOT had follow-up questions ensuing a meeting with NMFS on January 31, 2023. Thus, FHWA, with MaineDOT assistance, has revised the EFH assessment to properly incorporate and consider the comments and additional items of concern identified by your office.

As previously identified, the project site is located within mapped Essential Fish Habitat (EFH) for coastal species and mapped EFH for Atlantic salmon.

The FHWA, as the action agency for this project, and MaineDOT have reviewed the available information for the project and conducted field visits to survey the project site. Based on this review, FHWA and MaineDOT are submitting the EFH assessment as an expanded EFH consultation and have determined the project will have no substantial adverse effect on EFH for coastal multi-species or Atlantic salmon.

This attached EFH assessment meets the submittal requirements of 50 CFR 600.92(e). At this time, FHWA requests Expanded EFH consultation and the regulatory timeframe be initiated and NMFS's EFH Conservation Recommendations be provided to the FHWA, pursuant to section 305(b)(4)(A) of the Magnuson-Stevens Act.

If you have any questions in the meantime, please contact me at (207) 512-4917 or gary.scholze@dot.gov.

Sincerely,

Gary Scholze
Environmental Protection Specialist

Enclosure

ecc:
Rachel LeVee, FHWA
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David Gardner, MaineDOT
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Contents

1.0 INTRODUCTION

Dike Bridge (bridge # 2246) in Machias is where Route 1 crosses the Middle River at its confluence with the Machias River Estuary. The causeway itself is 150 years old, and the culvert structure is 88 years old. The bridge sits amidst a 1,000-foot-long causeway and is roughly 200 feet from the southwest end and 800 feet from the northeast end. Along its entire length, the causeway supports U.S. Route 1, a paved roadway with two 12-foot-wide travel lanes each with 8-foot-wide shoulders (40 feet total width). The causeway also supports a parking lot, utilities, drainage, and the Down East Sunrise Trail. There is a public boat launch at the southwest end of the causeway.

Dike Bridge's four box culverts are each approximately 5.5 feet tall, 6 feet wide, and contained within a 130-foot-long timber box. On the downstream side, each culvert is fitted with a flap gate made of a reinforced concrete panel surrounded by a metal frame.

The interior of the causeway is composed of timber cribbing and fill. The slopes of the causeway are lined with riprap. On the Middle River side (upriver), riprap is interspersed with shrubs and herbs and borders an intertidal zone. Salt marsh occupies the area to the east. On the Machias River side (seaward), vegetation is sparse, and the intertidal zone is dominated by mudflat.

The entire culvert structure has sustained considerable damage. MaineDOT made repairs to the culvert structure in 2008 and again in 2021. In 2023, MaineDOT placed a temporary bridge over the series of culverts.

2.0 PROJECT DESCRIPTION

Final design of the in kind replacement alternative for the existing bridge, which is MaineDOT's preferred alternative, will be completed only after the National Environmental Policy Act (NEPA) process is complete, as required by NEPA. For a project undergoing a NEPA Environmental Assessment, including the Machias Dike Bridge project, the regulations of the Federal Highway Administration ("FHWA") at 23 CFR §771.113(a), https://www.ecfr.gov/current/title-23/chapter-I/subchapter-H/part-771/section-771.113, (the "FHWA NEPA Regulation") prohibit "final design activities" among other activities prior to the completion of the environmental review process for the project and the issuance of an environmental determination. *See also* FHWA Order 6640.1A, FWHA Policy on Permissible Project Related Activities During the NEPA Process, dated October 1, 2010, https://www.fhwa.dot.gov/legsregs/directives/orders/66401a.cfm (the "FHWA NEPA Directive") MaineDOT and its consultants have been working on developing project alternatives based on engineering experience, constructability, public comments, and regulatory agency comments. Some of these alternatives and their effects on natural resources were discussed with agency staff during multiple technical assistance meetings. Technical assistance was received from the NMFS during the process and a more directed technical assistance process and series of meetings occurring between June and October of 2021.

MaineDOT published a summary of project alternatives that resulted from the 2020-21 planning study. Three of the alternatives received further analysis to target the fish passage/ marsh effect questions. These three alternatives are generally explained below.

Alternative 1 – This alternative is the in kind replacement. It is MaineDOT's preferred alternative and the alternative that will be further discussed within this assessment.

Alternative 4m – This alternatives hasone culvert that does not have a flapper gate to allow for landward flow through that structure during high tides. This option was analyzed to understand how an open structure may flood upstream properties, what the improved fish passage opportunities could be and what the potential for restored upstream marsh could be. This alternative does improve fish passage and provided some tidal flow with marsh restoration potential (Table 1). Fish passage is available when the water levels downstream are in the upper portion of the tidal cycle. Fish would be able to move into the Middle River with the flow of water.

Alternative 10 – MaineDOT put together information on an alternative that was a single span bridge that would allow tidal exchange that was similar to what would occur if unimpeded by the dike. The alternative matrix lists a single span bridge that is between 120 and 150 feet long. This alternative would restore water levels and would provide a tidal regime that is close to what would be occurring without the presence of the Dike and gated culverts. This would also allow for increased upstream salt marsh areas shown in Table 1. Fish passage conditions would be available at times that would be similar to natural estuarine movements.

Table 1- EFH impacts from three analyzed alternatives

Alternative	Potential upstream areas subject to tides/ Flooded Normal tides	High Marsh	Low marsh	Unvegetated	Fish passage conditions available
1	0	0	0	0	0
4m	127*	~13 acres	~ 60 acres	54 acres	52 %
10	403	~17 acres	~ 208	~191 acres	Full range of tides

					naturally available

In November of 2023, MaineDOT announced that the preferred alternative is Alternative 1, replacing the bridge structure with culverts with gates that allow no upstream flow. The department believes a fully gated culvert alternative will best meet the project's purpose and need. This alternative will improve the structure's condition, maintain the Sunrise Trail, provide for future rail use, and avoid flooding of hundreds of acres of land.

2.1 PROPOSED SCOPE

MaineDOT is proposing to replace the existing bridge with a series of box culverts with fully functioning flap gates. Though final design may result in some changes, it is likely that the arrangement will be three 10 foot wide by 5 foot tall box culverts. These box culverts will be placed at a similar elevation to the existing structures.

The final locations will be determined during engineering reviews. Given MaineDOTs experience with in water construction projects, we can say that it is likely that at least one of the new culverts will be placed outside of the footprint of the existing box culverts. The planned culverts will be wider than the existing ones, which will improve the contractor's ability to manage water during construction. Because of the prohibition imposed by the FHWA NEPA Regulation and the FHWA NEPA Directive, at this time, MaineDOT does not have final construction drawings. We have provided a preliminary plan view and construction limits in Appendix B.

MaineDOT has reviewed existing sea level rise and storm surge information and discussed ongoing town projects to protect Machias from future storms and sea level rise ("SLR"). Addressing future protections must be a collaborative approach with the municipality. An adaptive approach to the height of the causeway is likely needed as the community continues to discuss its options. Accommodations completed today can also be completed in a way to account for future accommodations (i.e. height of the new causeway). MaineDOT provided a presentation and drawings to NMFS staff in August of 2021 that displayed preliminary design considerations for different alternatives under different SLR rise scenarios. One of these profiles is shown in the drawing in Appendix D. That scenario accounts for 4 feet of sea level rise on top of the FEMA base flood elevation and 1 foot of freeboard for storm surge. That represents an elevation that is slightly above expectations stated in Maine's four year climate action plan titled *Maine Won't Wait*. Due to design standards, the high point in the middle of the causeway could be as high as 18.16 feet NAVD 88. Though MaineDOT has not decided on a final elevation for the new dike bridge and causeway, that profile is reasonable to use to develop potential effects to EFH. The current high point in the Dike is ~ 11 feet NAVD88. This could require an elevation change of ~ 7 feet at the high point in the center of the dike. Using 3:1 slopes to assume impacts, this could bring the toe of slope out up to 21 feet from the existing in the center, and 15 out near the ends of the dike. This would occur along ~ 900 feet of the Dike.

This could result in up to 32,400 square feet of permanent impact. 16,200 square feet of impact would be to functioning EFH downstream of the Dike, and 16,200 square feet of impact would be to the areas in the Middle River.

All of these preliminary design details are subject to change during the final design of the project. MaineDOT will analyze whether any changes in project scope would result in a reinitiation of consultation. Under 50 CFR 600.920 (I), the action agency is required to reinitiate consultation if the plans for the action are substantially revised in a manner that may adversely affect EFH.

2.2 CONSTRUCTION

All construction elements of the project will be conducted in compliance with MaineDOT's Standard Specifications, as then in effect[1] (the "Standard Specifications"). The Standard Specifications are a compilation of provisions and requirements for the performance of any MaineDOT work and include measures that avoid and minimize effects to endangered species. These Avoidance and Minimization Measures ("AMMs") can be precautionary, avoidance, or protection procedures, such as timing restrictions or buffers around sensitive habitats and habitat features that are important to listed species. A list of all AMMs proposed for the project is located in Appendix A.

In addition to following MaineDOT AMMs, construction actions also include implementation of best management practices (BMPs). BMPs are methods, facilities, built elements, and techniques implemented or installed during project construction to prevent or reduce project impacts on natural resources, such as water quality, soil, and animal habitats. AMMs and BMPs are considered part of the proposed activity that will be implemented. They are not recommendations, guidelines, or suggestions. Each description below is followed by or references appropriate AMMs that address potential impacts from construction actions. AMMs are stated and numbered to ensure they can be clearly transferred in MaineDOT's contract process. The likely construction process is explained in the following text.

2.2.1 Project Overview

Conceptual schedules are a part of planning and help in the assessment of timeframes for minimizing effects to resources, i.e., biological, physical, and economic, and some elements may change. Project construction has not been scheduled but based on the anticipated project scope and MaineDOT's experience, will likely take approximately 3-4 years to complete. Hard to predict timing issues here come from utility relocations, maintaining access to the adjacent boat launch, and traffic maintenance. The potential occurrence of National Marine Fisheries Services (NMFS) trust species in the action area is explained in Section 6.0 of this document. EFH species such as winter flounder are likely to be present in the project area starting on March 15 of each year. The spring season has spawning and migration windows for multiple

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[1] MaineDOT's current Standard Specifications (March 2020) are at: http://maine.gov/mdot/contractors/publications/standardspec/

species that use the estuary and migrate in the Machias River. The location of the project and tidal fluctuation also do not make it possible to complete all the activities on the downstream side of the dike at low tide. The mean low tide line is approximately 30 feet away from the existing dike footprint. The temporary work is likely to extend further than that into the Machias River to allow for traffic maintenance. Because the trust species currently do not use the Middle River and taking into account the complexities of winter construction, MaineDOT believes that most in-water work could be conducted at any time of the year. (Table 3) Activities that could result in an adverse effect (pile driving with an impact hammer) will be completed outside of the water or within the December 1- March 31 window (AMM 1).

In addition, the Dike Bridge is located on Route 1, a high priority corridor in eastern Maine, and a protracted construction schedule would seriously affect traffic and economic conditions in the region. MaineDOT plans to maintain two-way traffic as much as possible throughout construction through the use of a temporary bridge as discussed below.

As provided in Section 107.4.2 of the Standard Specifications, a schedule of work listing the project construction activities using the Critical Path Method is created for a project only after the project contractor has been selected, usually in connection with a pre-construction meeting prior to the start of any on-site work. Though at this time it is unknown how a contractor may stage and schedule for this project, MaineDOT staff experienced in construction and similar projects worked together to create the following construction sequence. In water activities are in bold:

- Mobilization
- **Install temporary bridge (fill placement and pile driving)**
- **Install cofferdams around location of new box culverts**
- Excavate and install new box culverts with tide gates
- Backfill around box culverts
- **Remove cofferdams**
- **Install cofferdam around existing series of four box culverts**
- Remove old timber box culvert structures
- **Remove cofferdams**
- **Remove temporary bridge**
- **Addition of fill to raise the causeway**

2.2.2 Mobilization

2.2.2.1 Pre-Construction

MaineDOT will hold a pre-construction meeting with appropriate MaineDOT Environmental Office staff, other MaineDOT staff, and the MaineDOT construction crew or contractor(s) to review all procedures and requirements for avoiding and minimizing effects to listed species and to emphasize the importance of these protective measures. The Federal Highway Administration (FHWA),United States Army Corps of Engineers (USACE), and National Oceanic and Atmospheric Administration (NOAA) Fisheries staff will be notified of the meeting and encouraged to attend.

2.2.3 Bridge Construction

2.2.3.1 Temporary Bridge Construction

A temporary bridge is likely to be built downstream of the existing dike to allow for the maintenance of two-way traffic throughout project construction. The downstream location of the temporary bridge will allow traffic to be maintained and provide adequate work area to complete the project. The temporary bridge will likely be a combination of temporary fill and a pile-supported bridge. The amount and size of piles required to support the temporary bridge are currently unknown. However, it is reasonable to assume the temporary bridge will require a series of 5 bents that could each contain up to 7 piles. To minimize potential hydroacoustic effects to endangered species the pile size will be limited to 30 inches (AMM 2). Impact driving of these piles may be driven at low tide in the dry or during the December 1 to March 31 work window. (AMM 1). Temporary impacts from the temporary bridge will primarily come from temporary fill placed in the intertidal area. Additional impacts will come from the temporary support piles. Please see Sections 5 and 6 for additional discussion of the temporary impacts.

The temporary bridge will be built in stages. Temporary bents will be installed followed by the superstructure. The superstructure will be a series of steel supports that are attached above the water. It is expected that the temporary bridge could take 2-3 months to install.

Photo 1- Photo of Temporary Bridge

2.2.3.2 Cofferdam Installation

Means and methods of how the contractor is going to control water during project construction is unknown at this preliminary juncture of the project. This information typically becomes available only when the contractor submits plans for MaineDOT to review and approve. This approval usually occurs shortly after the preconstruction meeting for the project. The configuration of the existing box culverts within the bridge structure will create challenges for installing temporary water control structures. It is likely there will be water leaks through the cribwork. Sandbags or other barrier methods placed on a surface are not likely to stop water flowing through the dike. Further, it is not possible to drive a traditional sheet pile through the cribwork structure.

MaineDOT and its consultants familiar with bridge construction have shared their expertise to estimate potential effects of project construction on endangered species in the action area. Portions of the temporary cofferdams will likely consist of 24-inch AZ steel sheet piles. The sheets will likely be installed in the areas that are outside of the existing dike footprint. Cofferdams will be installed on both sides (landward and seaward) of the embankment to permit construction activities to occur in the dry.

Within the dike, the cofferdam is likely to have structure walls (i.e., sheet piles) supported by a frame. Inside the frame, methods to seal the cofferdam may include a combination of smaller sandbags, sheet plastic, and concrete. The existing dike will have to be excavated to allow for the placement of any of these walls. Sheet piles will be installed with a vibratory hammer mounted on an excavator or a crane. Fill may be used to connect the portion of the sheet pile cofferdam to the portion being constructed on the dike. This fill will be material that can be removed after project completion. The fill material may include sheet plastic to seal off waterflow. Once the cofferdam is installed, the interior will be pumped using high capacity water pumps. It may require that a concrete seal is placed in the bottom of the cofferdam to control the in flow of water during construction. Sealing that flow out of the work area will be a necessary part of the contractor’s plan to ensure that dirty water is discharged throughout the box culvert installation.

The dike site is unique in that there is no typical place for a vegetated buffer/BMP treatment. As discussed above, controlling water intrusion into the work area will be challenging. The placement of a BMP for any dirty water being removed from the cofferdam will be located on the Dike. Likely methods of dirty water treatment could be a large silt sock or containment systems that include hay bales and geotextile fabric to remove larger pieces of particulate from the water. The methods to seal out water flow should minimize any dirt water in the work area. The dirty water treatment system would be used in instances such as disturbance from excavation inside of the cofferdam.

The first cofferdam installation will contain the location for the new culvert structures. After the new culverts are installed, sheet piles will be removed and re-installed to isolate the site of the existing culvert structures. It is expected that cofferdams will be installed in water, but some may be installed during low tides, minimizing effects associated with in-water work. MaineDOT anticipates it will take approximately 3-4 weeks to install the upstream and downstream cofferdams to isolate each site. Each of the cofferdams could require ~ 50 sheet piles. The cofferdam installation process requires careful fitting of the sheets together, but generally, it takes ~ 30 mins of driving per sheet pile. The approximate locations of cofferdams are shown in Appendix B.

The use of pump systems to manage water flow during construction is not feasible due to the amount of water flow from the Middle River. The location of the new box culverts and cofferdam will allow water to continue to flow through the existing box culverts during construction of at least one of the new box culvert structures. Once the work area is sealed, the water should flow through the existing culverts as it does today. Water from the Middle River system will be allowed to flow out, and water from tidal fluctuations in the Machias River Estuary will be blocked from entering the Middle River. Though there has been some recent maintenance of the gate structures, the contractor may choose to further maintain the gates to help manage water during the bridge replacement project.

When removing the old box structures, the contractor will allow water to flow through any of the new box culverts that have been installed using the new gates to allow water out of the Middle River and not allowing flow in from the Machias River Estuary. A sealed cofferdam system that surrounds the area of the culvert removal will force the water to flow into the new culvert (s).

2.2.3.3 New Structure Installation

To begin placing the new culvert structures, the contractor must first remove portions of the old dike. This material will consist of larger stones and old cribwork pieces. The material underneath the location of the new boxes will potentially have to be excavated deeper than a typical box culvert installation to provide a stable location for installation.

The contractor will install a gravel material to set the new box culverts. The box culverts will then be installed section by section using a crane sitting on the dike. The sections of box culvert are fastened together and the joint between the sections is sealed. The contractor will install new tide gates on the downstream side of the new box culverts. These gates will be fastened to the culverts and hinged to allow flow from the Middle River downstream, and closed when water from the Machias River Estuary comes up and attempts to flow back into the Middle River. When the new culverts are installed, the contractor will backfill the new bridge with additional gravel and install riprap where necessary.

2.2.3.4 Cofferdam Relocation, removal and temporary bridge removal

Once the new box culverts are installed, the sheet pile cofferdam that surrounded them will be moved to the provide water control for the removal of old box culverts. Sheet piles will be removed with an excavator-mounted vibratory hammer. Water pumps will be shut off and the cofferdam will slowly be breached by using the vibratory hammer to remove a section of sheet pile, which will possibly cause a limited sediment release that may last up to several minutes.

Breaching of cofferdams will occur at high slack tide to minimize water velocities upon release (AMM3). At that time, water velocity and scours effects to the essential fish habitat downstream of the Dike will be minimized. Once the cofferdam is breached, contractors will remove the remainder of the sheet piles and pump system. If sandbags were used to seal the base of the cofferdams, they will also be removed. Any disturbed areas will be stabilized, and all permanent erosion control BMPs will be installed.

Once the old box culverts are removed, sheet piles will be removed with an excavator or crane-mounted vibratory hammer. Water pumps will be shut off and the cofferdam will slowly be breached by using the vibratory hammer to remove a section of sheet pile, which will possibly cause a limited sediment release that may last up to several minutes. Once the cofferdam is breached, contractors will remove the remainder of the sheet piles and pump system. There would also likely be short turbidity releases when removing each cofferdam sheet. If sandbags were used to seal the base of the cofferdams, they will also be removed. Any disturbed areas will be stabilized, and all permanent erosion control BMPs will be installed.

Once all of the new culverts are installed and the old culverts are removed, the temporary bridge will also be removed. The superstructure will be disassembled, and the piles will be extracted with a vibratory hammer similar to the removal of the sheet piles. Any fill that was placed as a temporary bridge approach will be removed.

Table 3. **Timing of in water activities specific to the Dike Bridge Construction**

Activity	Duration	Timing
Sheet pile/ fill installation upstream of Dike for cofferdam	3-4 weeks	Anytime
Sheet pile/ fill installation downstream of the Dike for cofferdam	3-4 weeks	Anytime
Installation of temporary bridge pile with a vibratory hammer	1-2 weeks	Anytime
Installation of temporary bridge pile with an impact hammer	1 week	In the dry or December 1–March 31
Removal of cofferdam/ fill upstream of Dike	1-2 weeks	Anytime
Removal of cofferdam downstream of Dike	1-2 weeks	Anytime
Removal of temporary bridge pile with a vibratory extractor	1 week	Anytime

2.3 OPERATION AND MAINTENANCE

The new tide gates that will be placed on the structure will operate similar to the current gates. They will be hinged at the top and placed on the downstream side of the new culvert structures. When the water elevation in the Machias River Estuary is greater than the Middle River impoundment, the gates will be shut, and water will not be allowed to flow upstream (north) of the dike. When the water elevation in the Machias River Estuary is lower than the Middle River impoundment, the gates will open and allow water to flow into the estuary. This type of gate is referred to as a flap gate. There is no motorized operation. New gates are likely to seal better and have more longevity than the older gates (Photo 2).

The gates are likely to made of a durable material (e.g., metal). MaineDOT will create an asset management plan for the Dike Bridge once final design is complete and predicted lifespans are known for the materials. This plan will ensure that funding is available for maintenance of the structure throughout its life cycle. The intended life of the crossing structure is 80-100 years. The intention is for the flap gates to function properly for the entire lifespan of the Dike Bridge.

MaineDOT maintenance staff travel this stretch of road regularly. Emphasis will be made for crews to complete regular debris inspection and removal throughout the year.

MaineDOT will inspect the Dike bridge every 2 years or more often as needed, consistent with the National Bridge Inspection Standards adopted by FHWA in 23 CFR part 650 Subpart C. Inspection of the gate structures will occur every other year. This inspection will include the condition and function of the flap gates. Any identified damage or needed repairs to the flap gate system will be addressed within the MaineDOT's three year work plan cycle.

Photo 2. Existing tide gates during a low tide in the Machias River Estuary

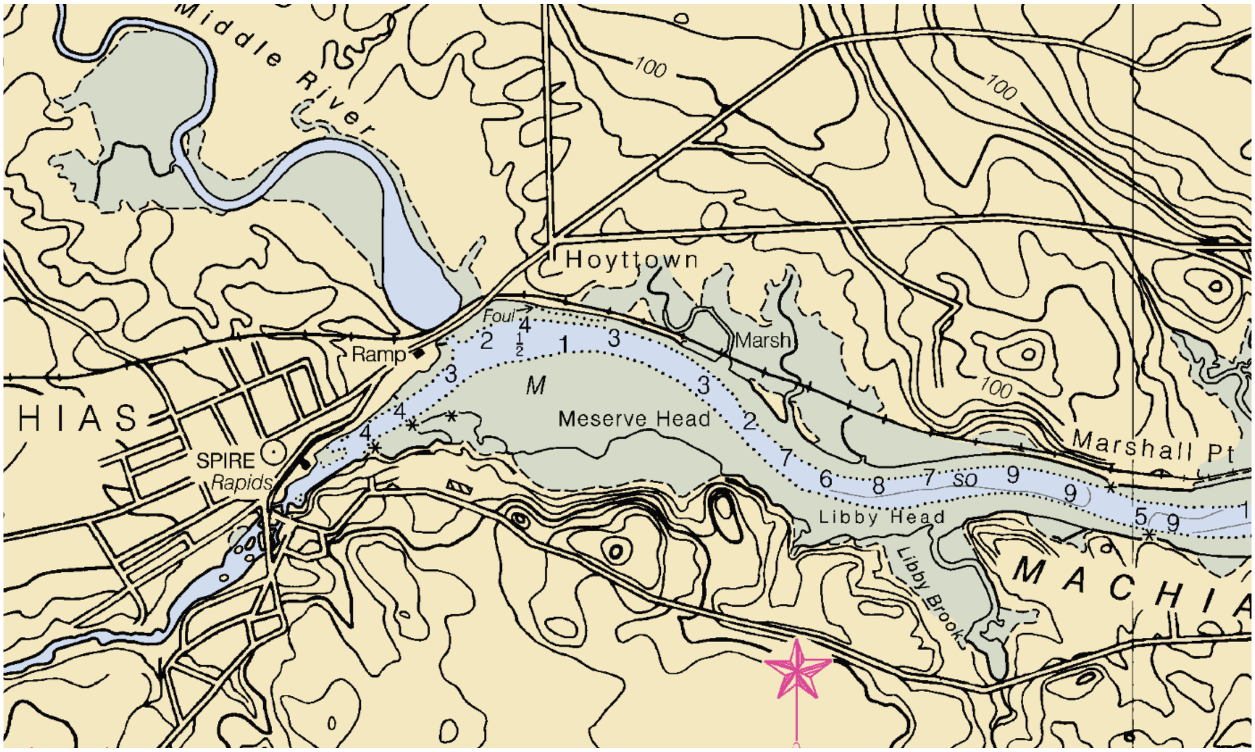


Figure 1- NOAA Nautical Chart for project area (depth in meters)

3.0 ESSENTIAL FISH HABITAT DESIGNATIONS

The EFH mapper was used to derive the species list in Table 5 below and the report can be found in Appendix F. The area of the Dike in the Middle River is mapped as Atlantic salmon EFH. The mapper appears to map the estuary of the Machias River as EFH and has a buffer from that area that extends upstream of the Dike into the Middle River. Table 5 also presents our rationale for stating that some of the listed EFHs are not present in the action area of the Dike.

Determination of the potential presence of EFH was completed using the information below in tables 4 and 5.

Table 4.- Summary of EFH characteristics in action area.

Water Depth	Substrate	Salinity	Water Temperature
0-4 Meters	Mudflat and fines	Mixing zone 5-25 ppt	Unknown

Table 5- Machiasport Tide Station Tidal Reference Tidal Datums (NAVD 88)

MHHW	6.45
Mean Tide Level	-0.21
MLLW	-6.85

Table 6.- Species and EFH found in the action area

Species	EFH Present?	Notes
Winter Flounder	Yes	
Little Skate	Yes	
Ocean Pout	Yes	Juveniles only
Pollock	Yes	Juveniles only
Silver Hake	yes	
Windowpane Flounder	Yes	
Winter Skate	Yes	
White Hake	Yes	Juveniles only
Scallop	No	Water too shallow
Wolffish	No	Water too shallow. Lack of spawning habitat
Haddock	No	Water too shallow
Atlantic Herring	No	Water too shallow
Atlantic cod	No	Salinity too low
Red Hake	No	Salinity too low
American Plaice	No	Water too shallow
Smooth Skate	No	Water too shallow
Thorny Skate	No	Water too shallow
Atlantic Mackerel	No	Water too shallow
Spiny Dogfish	No	Salinity too low
Atlantic salmon	Yes	Migratory corridor for adults and smolts

3.1 HABITAT AREAS OF PARTICULAR CONCERN

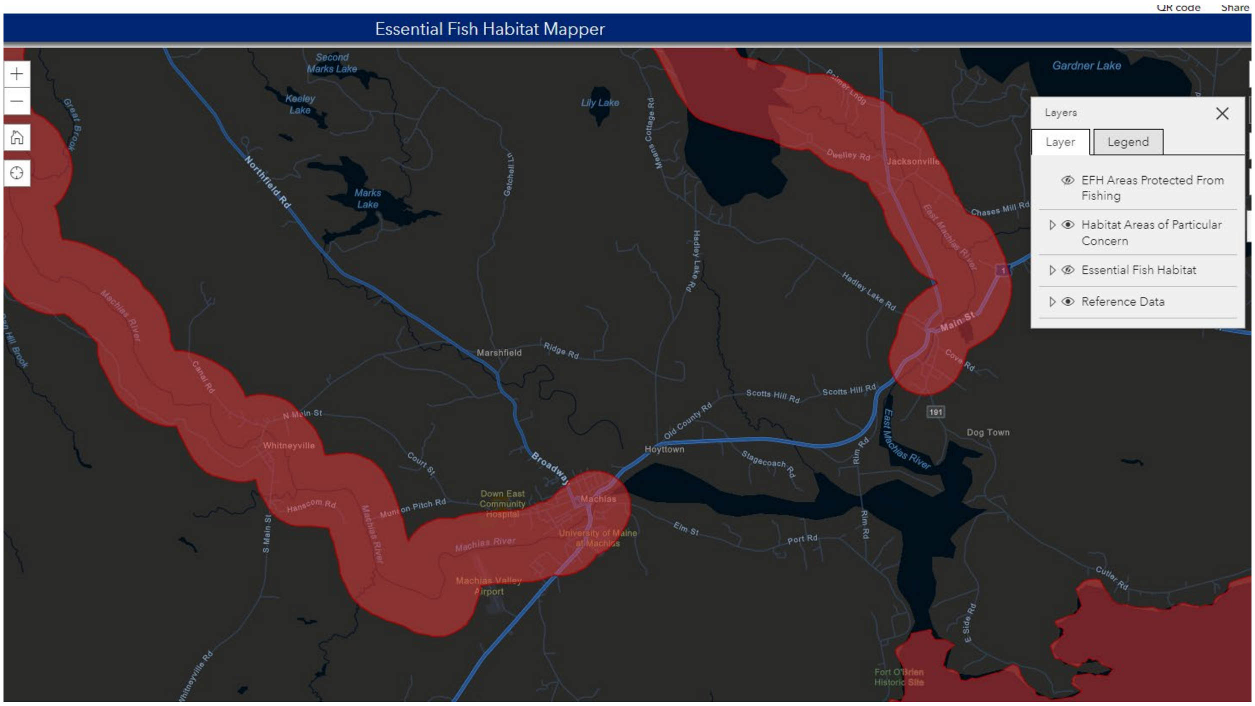


Figure 2. Mapped HAPC

The project is located adjacent to two different habitat areas of particular concern (HAPC). The Machias and East Machias River are listed and mapped as habitat areas of particular concern (see Figure 2 above). The Middle River is not mapped or listed HAPC. Juvenile Cod HAPC is also located in the Machias River Estuary and is approximately 4 miles downstream. The Dike Bridge replacement project is not located in and will have no effect on the HAPCs in the area.

4.0 ENVIRONMENTAL BASELINE

Stantec Consulting Services Inc. conducted a hydrologic and alternatives analysis (Stantec 2015), two coastal wetland characterizations (in 2017 and 2021), and a coastal wetland delineation (Stantec 2021b). Stream, aquatic habitat, and wetland conditions are described based on the observations made during these efforts.

There have been two different operational states during the beginning of the technical assistance process and development of other graphics by MaineDOT and its consultants. In late August of 2021, MaineDOT maintenance crews fixed one of the tide gates that had come into disrepair. This new gate resulted in improved functioning. Prior to the fix, the tidal flow in the Middle had likely slowly increased for years. Water level information in the Middle River was collected after the tide gate had been fixed. The Phase 2 hydraulic memo dated December

20,2021 provided to MaineDOT by its consultant shows that there has been a fluctuation of 1.5 feet of upstream water elevation (max of -0.5 NAVD 88) during median flows following the repair of the gate. These fluctuations represent leakage through the repaired gates and through the causeway itself.

Stantec also completed additional field visits to check and characterize wetlands in late November of 2021. They noted a significant reduction in vegetation from the visit they had completed in October of 2017. The phase 2 hydraulic memo also notes that under existing conditions, there are 32.7 acres of area that are inundated during median flows at a high tide.

4.1 AQUATIC HABITAT

4.1.1 Middle River

The Middle River flows under the Dike Bridge at its confluence with the Machias River. The watershed area is ~13.2 square miles. The watershed includes Marks, Second Marks, Six Mile, and Seavey lakes. Heading upstream, the river flows through marsh, small agricultural fields, low-density development, and forests that experience some logging. The bridge's gated culverts and causeway both affect hydrologic conditions in the Middle River. However, leakage through the culvert flap gates and the causeway contribute to landward flow during semi-diurnal flood tides.

The Middle River is tidal with flows affected by the US Route 1 causeway (embankment) and four tide gate structures (Photo 3 and Photo 4). Upstream of the crossing, the river is an intertidal impoundment (Photo 5). Shoreline substrates consist of boulders, cobble, gravel, sand, and silt (Photo 6), and wetland plants are present along the north side of the Dike Bridge embankment (Photo 7).

The embankment and tide gate structures are barriers to aquatic organism passage. However, the tide gates are in poor condition, and tidal flows enter the upstream impoundment. Mudflats are exposed at low tide (Photo 8), but the tidal range is <3 feet in the impoundment. The marsh bordering the impoundment is vegetated predominately by freshwater cordgrass (*Spartina pectinata*; Photo 9). Other species observed included saltmeadow cordgrass (*S. patens*), seaside plantain (*Plantago maritima*), seaside goldenrod (*Solidago sempervirens*), black-grass (*Juncus gerardii*), sea lavender (*Limonium carolinianum*), and silverweed (*Argentina anserina*).

Photo 3. Middle River box culvert and riprap shoreline during falling tide (Stantec 2017)

Photo 4. Middle River box culvert and riprap shoreline during rising tide

Photo 5. Shoreline of Middle River and embankment of Dike Bridge looking east

Photo 6. Riprap, mixed coarse, and fine substrate along north side of Dike Bridge

Photo 7. Looking northeast along embankment of Dike Bridge

Photo 8. Intertidal flat along eastern shore of impoundment north of Dike Bridge

Photo 9. Marsh dominated by freshwater cordgrass (*Spartina pectinata)* north of Dike Bridge along the Middle River

During the site visit on October 10, 2017, the out-going high tide delay in the impoundment was 3.5 hours. The Stantec biologist observed extensive algal mats on the shore of the embankment. Animals observed north of the Dike Bridge in the Middle River included acorn barnacle (*Semibalanus balanoides*), an amphipod (*Gammarus* sp.), common periwinkle (*Littorina littorea*), green crab (*Carcinus maenas*), herring gull (*Larus argentatus*), double-crested cormorant (*Phalacrocorax auritus*), and willet (*Tringa semipalmata*).

Table 7 briefly describes the wetlands delineated on November 17, 2021 as described in Stantec (2021b).

Table 7. Summary of coastal wetland communities

Resource Identifier	**Resource Classification**[1]	**Comments**
VA_01A; VA_01E	E2US2/3	Large intertidal mudflat located to south of Dike bridge; beginning at base of roadway riprap embankment; dominated by sand and silt
VC_01B	E2EM1/2	Area of brackish emergent tidal marsh in southeast corner of Middle River impoundment north of Route 1; significant reduction of vegetation compared with October 2017 observations.
VR_01C	R1UB2/3	Middle River channel at bridge downstream of Route 1

Resource Identifier	Resource Classification[1]	Comments
VC_01D	E2EM1	Small saltmarsh dominated by salt-meadow cord grass and saltmarsh rush between roadway and boat launch
VB_01F, VB_01H	E2US1/2 / E1UB2/3	Middle River impoundment. Intertidal rocky shoreline beginning at the base of road embankment, transitions to permanently inundated impoundment
VR_01G	R1UB2/3	Middle River channel at bridge upstream of Route 1
VA_01I	E2US2/3	Small unvegetated mudflat in southwest corner of Middle River impoundment to north of Route 1

[1] E2US2/3 = Estuarine Intertidal Unconsolidated Shore with sand and mud substrates
E2EM1/2 = Estuarine Intertidal Emergent with persistent and non-persistent vegetation
E2EM1 = Estuarine Intertidal Emergent with persistent vegetation
E2US1/2 = Estuarine Intertidal Unconsolidated Shore with cobble, gravel, and sand
E1UB2/3 = Estuarine Subtidal Unconsolidated Bottom with sand and mud substrate
R1UB2/3 = Riverine Tidal with Unconsolidated Bottom with sand and mud substrate

4.1.2 Machias River/Bay Estuary

The Machias River flows for ~60 miles and drains ~460 square miles before emptying into Machias Bay in downtown Machias, where it becomes tidal at the foot of the falls. Several sawmills and dams were constructed along the river in Machias where lumber was the main industry. Since restoration efforts removed the sawmill dams, the river now flows naturally. Heading upstream, the river travels through the towns of Machias and Whitneyville before flowing through an extensively forested landscape to the Machias Lakes at its headwaters.

The Dike Bridge is roughly 4 miles up the estuary from Machias Bay (assuming the mouth of the estuary is located south of Machiasport in Sanborn Cove). The mouth and head-of-tide for the Machias River is located ~0.6 miles southwest of the bridge at the falls in the center of town in Machias (Figure 1).

The Dike Bridge embankment is flanked with riprap that slopes down to cobble, gravel, and mudflats, all of which are exposed at low tide (Photo 10, Photo 11, Photo 12). Along the embankment, high salt marsh vegetation is limited to a few scattered patches (Photo 13). At low intertidal period, one can observe ~6-12 inches of wood debris and sawdust in the flats adjacent to the western end of the embankment, likely related to the area's significant lumber industry in the 19th century. On an outgoing tide, high flows pass through the culverts and out the gates with a 3-4-foot drop to the estuary (Photo 14 and Photo 15). On an incoming tide, the gates are closed (Photo 16), but water still enters the impoundment through the leaky gates and potentially through the causeway.

Photo 10. High intertidal riprap along Machias dike looking east.

Photo 11. Riprap and mixed coarse and fines in the mid-intertidal.

Photo 12. Mixed coarse and fines and mudflat in the lower intertidal.

Photo 13. A small patch of high salt marsh vegetation west of the bridge.

Photo 14. Looking west at tide gates on an outgoing tide.

Photo 15. Looking east at tide gates on an outgoing tide.

Photo 16. Looking east at tide gates on an incoming tide.

5.0 ANALYSIS OF POTENTIAL IMPACTS ON EFH

An adverse effect is defined as any impact that reduces quality and/or quantity of EFH. Adverse effects may include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality and/or quantity of EFH. Adverse effects are categorized as substantial or not substantial.

Bridge construction activities will primarily impact EFH through 1) habitat alteration, 2) increased suspended sediment and turbidity, and 3) underwater noise. Bridge demolition activities by mechanical techniques will primarily impact EFH through 1) habitat alteration (i.e. falling debris) and 2) increased suspended sediment and turbidity. Blasting is not expected to be utilized for this project.

5.1 EFH IMPACTS FROM FILL

The replacement of the Dike Bridge will require the placement of permanent fill and structures (either permanent or temporary) into aquatic habitat. The permanent fill will result from the increase in footprint from raising the Dike to address sea level rise and storm surge. There will be temporary fill to create the temporary traffic maintenance structure. There will also be temporary fill from cofferdam placement. Table 8 provides a summary of each structure requiring fill and its status (permanent or temporary).

Table 7. Temporary and permanent in-river structures associated with the Dike Bridge replacement project.

Structure Impact Type	Temporary Impacts (sq. ft.)	Permanent Impacts (sq. ft.)
Approach fills for temporary bridge	21,000	0
Cofferdams	24,000	0
Causeway widening		32,400
Total temporary impacts	45,000	
Total permanent impacts		32,400

It is likely that the project will also fill 640 square feet of salt marsh between the dike and boat landing in the southwest corner.

The raising of the dike could result in 16,200 square feet of impact to the EFH downstream of the dike. This will result in a permanent reduction of habitat that supports the spawning and juvenile rearing functions. The additional 16,200 square feet of new permanent fill may impact habitats upstream of the Dike. This will adversely affect the EFH by resulting in a permanent reduction in available EFH.

5.1.1 False Attraction

When migrating, Atlantic salmon and other sea run species sense waterflow and cold water inputs to help guide them to habitat used for holding and spawning. Though salmon are known to migrate and spawn in their natal streams, straying from those areas is also a natural life history of some adult fish. Migrating fish are attracted to these flows while they are migrating. When sea run species approach a challenging barrier to navigate (natural or manmade) competing flows may lead them to a part of a barrier that is not navigable as compared to an area where a fish could successfully move upstream. The concept of competing flows is a common design parameter for upstream passage at a dam when a structural fishway is a passage solution. Flows and location of the fishway entrances attract the fish to make a passage attempt. False attraction effects are most likely to affect adult sea run fish species migrating upstream to spawn.

The in kind replacement will have flows that come out of the Middle River for ~ 12 hours a day. These flows will generally have a velocity that is greater than 5 FPS.

Sea run fish that are attracted to flow out of the Middle River that can’t pass due to excessive water velocities may increase their exposure to predation. The estuary contains large predators that would opportunistically eat many different fish species. This exposure is also part of the baseline conditions, but it is unknown if there is increased predation in that area currently.

False attraction that results in energy expenditures during failed passage attempts or additional time spent during the migration could reduce any fishes’ ability to continue the spawning migration and successful spawning. These delays could result in effects on these species’ ability to spawn. For example, the extra time spent during the migration may cause the adult salmon to use extra energy needed for them to finish the spawning migration and spawning (Rubenstein 2021). The delay may also expose migrating fish to additional predation pressure.

If it occurs, false attraction could result in adverse effects on the EFH in the area of the project.

5.1.2 Effects from new functioning tide gates

As stated in Section 4, there is currently approximately 32.7 acres of area that is inundated at median flows during a high tide. After the installation of new gates, it is expected that this area will be reduced. There is an unknown amount of water that leaks through the causeway itself. The amount of saltwater currently leaking to the upstream side of the dike is unknown. The reduction in vegetation noted in the 2021 survey is likely to do the reduced salt water allowed upstream.

Though hard to predict, it is likely that there will be very little fluctuation of water levels upstream of the dike after the project is completed. Though the water level fluctuation will be different, freshwater marsh and the Middle River will still be present. The project will result in a reduction of the tidal freshwater portions of the 32.7 acres as well as the unknown amount of that area that may contain some salt tolerant vegetation. Any areas containing salt tolerant vegetation will undergo a conversion back to freshwater vegetation.

5.2 TEMPORARY EFH IMPACTS

5.2.1 Hydroacoustic Effects

Construction elements that may result in hydroacoustic effects to fish include installing and removing cofferdams.

5.2.1.1 Background Information on Fish and Underwater Noise

Under certain conditions, underwater sound generated from construction activities may cause behavioral or physiological changes to aquatic organisms. Behavioral changes often include avoidance of the action area, disruption of foraging attempts, or interruption of reproduction. Physiological effects vary depending on the duration and intensity of sound produced during construction. Aquatic organisms could suffer temporary or permanent hearing loss, or percussion-type injuries such as bruising, ruptures to capillaries, hemorrhaging of organ systems, damage to the swim bladder and internal organs, or death (Halvorsen et al. 2011).

The types of effect on and response from fishes to a sound source will depend on distance. The potential for effects declines as distance increases between the individual and the source. Very close to the source, effects may range from behavioral changes to mortality. Farther from the source mortality is no longer an issue, and effects range from behavioral to physiological. The nature of effects depends on several other factors, such as fish hearing sensitivity, source level, sounds propagation and resultant sound level at the fish, whether the fish stays near the source, and motivation level of the fish. Generally speaking, species are thought to have different tolerances to sound levels and may exhibit different responses to the same sound source.

The following are commonly used measures of sound:

- Peak sound pressure level (SPL): the maximum sound pressure level (highest level of sound) in a signal measured in dB re 1 µPa.
- Sound exposure level (SEL): the integral of the squared sound pressure over the duration of the pulse (e.g., a full pile driving strike). SEL is the integration over time of the square of the acoustic pressure in the signal and is thus an indication of the total acoustic energy received by an organism from a particular source (such as pile strikes). Measured in dB re 1µPa2-s.
- Single Strike SEL: the amount of energy in 1 strike of a pile.
- Cumulative SEL (cSEL or SELcum): the energy accumulated over multiple strikes. cSEL indicates the full energy to which an animal is exposed during any kind of signal. The rapidity with which the cSEL accumulates depends on the level of the single strike SEL. The actual level of accumulated energy (cSEL) is the logarithmic sum of the total number of single strike SELs. Thus, cSEL (dB) = Single-strike SEL + 10log10(N); where N is the number of strikes.
- Root Mean Square (RMS): the average level of a sound signal over a specific period of time.

NOAA Fisheries generally uses 150 dB RMS as the threshold for behavioral effects to listed fish species (Buehler et al. 2015). For the State Route 197 Bridge in Richmond, Maine, NOAA Fisheries used 150 dB re 1 µPa RMS as a conservative indicator of the sound level at which there is the potential for behavioral effects (NOAA Fisheries 2012b). Exposure to sound levels of 150 dB re 1 µPa RMS will not always result in behavioral modifications, and behavioral modifications will not always result in adverse effects (i.e., harm or harassment to listed species), but that there is the potential for behavioral response upon exposure to 150 dB re 1 µPa RMS (NOAA Fisheries 2012b).

In 2008, the Fisheries Habitat Working Group (FHWG) developed the Agreement in Principle for Interim Criteria for Injury to Fish from Pile Driving Activities, which identifies the following thresholds for onset of physical injury to fish (FHWG 2008):

- Peak SPL: 206 decibels relative to 1 micro-Pascal (dB re 1 µPa) [for fish of any size].
- cSEL of 187 decibels relative to 1 micro-Pascal-squared second (dB re 1µPa2-s) for fishes above 2 grams (0.07 ounces).
- cSEL of 183 dB re 1µPa2-s for fishes below 2 grams (0.07 ounces).

These are criteria for the onset of physiological effects and not levels at which fish are necessarily mortally damaged. These criteria apply to green sturgeon and Pacific salmon, and both USFWS and NOAA Fisheries have assumed the criteria can be applied to Atlantic salmon (FHWG 2008).

NOAA Fisheries has relied on these criteria in determining the potential for physiological effects in ESA Section 7 consultations. At this time, they represent the best available information on the thresholds at which physiological effects to EFH species and trust species are likely to occur. Physiological effects may range from minor injuries, resulting in complete recovery, to death. The severity of injury is related to the distance from the pile being installed and the duration of exposure. The closer to the source and the greater the duration of the exposure, the higher likelihood of significant injury.

Ambient sound can be highly variable in shallow water areas, such as in lower tides of the Machias River. Primary sources of sound (including meteorological, hydrographic, and anthropogenic) change and the dominant source at any one time drives the sound level (Buehler et al. 2015). Ambient sound within the action area has not been measured.

For the Dike Bridge replacement construction work, the primary activities that could result in elevated underwater sound pressure during construction is sheet pile cofferdam installation and pile driving for a temporary bridge. The specific activity of concern is vibratory driving of sheet piles.

5.2.1.2 Potential for Hydroacoustic Effects

Pile Installation and Removal

Installation of the temporary bridge for routing traffic during construction will require the installation of 30-inch steel bent piles that will be first driven using a vibratory hammer and then seated using an impact hammer. Cofferdam construction will entail the use of a vibratory hammer to install a series of interlocking 24-inch-wide steel sheets. The substrate that the sheets are being driven into will determine the duration of the driving event for each pair of sheets. A pair of sheets that are driven into finer material will take approximately 15 minutes. A pair of sheets driven into material with larger rocks and firmer substrate can take up to 1 hour. Based on the substrates in both the Middle and Machias rivers, MaineDOT estimates each cofferdam on either side of the Dike Bridge will take approximately 15 days to install. Removal of the sheet piles with a vibratory hammer will take approximately 10 days for each cofferdam.

Caltrans (2009) summarized records from numerous construction projects in the *Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish* and presented the expected noise levels for steel sheet piles and steel bent piles shown in Table 8, Table 9, and Table 10. The tables below were developed using the acoustics tool developed for use by the Greater Atlantic Regional Fisheries Office protected resource division staff. The numbers in the tables below are generated for Atlantic salmon and sturgeon effects, but can also be used as a proxy for other species.

Table 8. Proxy projects for estimating underwater noise

Project Location	**Water Depth (m)**	**Pile Size (inches)**	**Pile Type**	**Hammer Type**	**Attenuation rate (dB/10m)**
Florence, OR - Siuslaw River	3	30	Steel Pipe	Impact	5
Florence, OR - Siuslaw River	3	30	Steel Pipe	Vibratory	5
Not Available	15	24	AZ Steel Sheet	Vibratory	5

Table 9. Proxy-based estimates for underwater noise

Type of Pile	**Hammer Type**	**Estimated Peak Noise Level (dB_{Peak})**	**Estimated Pressure Level (dB_{RMS})**	**Estimated Single Strike Sound Exposure Level (dB_{sSEL})**
30-inch Steel Pipe	Impact	210	190	177
30-inch Steel Pipe	Vibratory	200	180	167
24-inch AZ Steel Sheet	Vibratory	182	165	165

Table 10. Estimated distances to sturgeon/salmon injury and behavioral thresholds

Type of Pile	**Hammer Type**	**Distance (m) to 206dB_{Peak} (injury)**	**Distance (m) to 150 dB_{sSEL} (surrogate for 187 dBcSEL injury)**	**Distance (m) to Behavioral Disturbance Threshold (150 dB_{RMS})**
30-inch Steel Pipe	Impact	18.0	64.0	90.0
30-inch Steel Pipe	Vibratory	NA	44.0	70.0
24-inch AZ Steel Sheet	Vibratory	NA	40.0	40.0

Based on this information, installation of the 30-inch steel bent piles with an impact hammer is likely to generate peak SPL of 210 dB. This level exceeds the peak SPL of 206 dB that is the threshold for the onset of physiological effects at 18 meters. Installation of the 30-inch steel bent piles with an impact hammer is likely to exceed the behavioral distance threshold of 150 dBRMS 1uPa out to 90 meters from the pile site. The use of an impact hammer to seat the 30-inch piles will be minimized to the maximum extent practicable.

5.2.1.3 Species Determinations

Injury

To minimize the potential for injury, MaineDOT will employ the soft start technique outlined in AMM 17. Underwater noise generated from an impact hammer to seat the steel bents for the temporary structure may cause physical harm to EFH listed fish and trust species within 18 meters of each driven pile. Individual trust species that enter the action area during the time outside of this protective window may sustain physical injury.

Behavioral

At more than 18 meters and out to 90 meters, installation of the steel bent piles using an impact hammer is likely to result in behavioral responses, whereby listed species (if present) would avoid the construction site during noisy activities. Similarly, installation of steel bent piles and sheet piles using a vibratory hammer is likely to result in behavioral responses in listed species out to 70 meters.

MaineDOT does not expect that these temporary behavioral responses (avoidance) will have long-term consequences to any listed species that may encounter and subsequently avoid the sound field, and effects to the species will be negligible. There will still be unaffected areas of the Machias estuary available for migration and movement. Further, the effects on listed species caused by underwater noise from sheet pile installation and removal will be too small to be meaningfully measured or detected when added to the existing conditions, and, therefore, these effects will be insignificant. The absence of listed species early life stages (eggs/larvae) in the action area make effects to those life stages highly unlikely, and therefore discountable.

In summary, the hydroacoustic effects of installation of steel bent piles using an impact hammer at more than 18 meters to 90 meters and pile installation and removal using a vibratory hammer out to 70 meters may result in behavioral responses to fish present in the action area, but effects would be too small to be meaningfully measured or detected and, therefore, would be insignificant.

5.2.2 Sedimentation and Turbidity

Several activities associated with construction of the new structure and demolition of the existing structure have potential to disturb sediments and increase turbidity. These actions include:

- Construction and removal of the temporary bridge;
- Construction and removal of the cofferdams; and

Based on available information, it is expected that construction activities may produce total suspended solid (TSS) concentrations of approximately 5.0 to 10.0 mg/L within approximately 300 feet of the activity. Potential adverse effects of these increases in turbidity on fish may include the following:

- reduction in feeding rates;
- increased mortality;
- physiological stress, including changes in cardiac output, ventilation rate, and blood sugar level;
- behavioral avoidance;
- physical injury (e.g., gill abrasion);
- reduction in macroinvertebrates as a prey source; and
- reduction in territorial behavior (Robertson et al. 2006, Newcombe 1994).

Effects on fish from short-term turbidity increases (hours or days) are generally temporary and are reversed when turbidity levels return to background levels (Robertson et al. 2006). Effects to Atlantic salmon worsen with increased levels of turbidity (Newcomb 1994). Juveniles and adults salmonids show minor physiological stress and sublethal effects at suspended sediment concentrations of 7 mg/L for a six day exposure and at 55 mg/L for a seven hour exposure (Newcomb and Jensen 1996). MaineDOT's Programmatic Biological Assessment (ATS PBA 2017) outlined biological responses for Atlantic salmon and classified them into three major categories. The three categories are behavioral responses, sub-lethal effects, and potential mortality, and they are defined below. The rates below can also be used to analyze effects to trust species in the project area.

- Behavioral response - The range of turbidity releases expected to result in behavioral reactions ranging from a startle response to avoidance.
  - 1-20 mg/L for 1 hour
  - 1 mg/L for 24 hours
- Sub-lethal effects – The ranges of turbidity releases expected to result in sub-lethal effects including stress, reduction in feeding rates, and increased respiration rates.
  - 20-22,026 mg/L for 1 hour
  - 1 mg/L for 6 days
- Potential mortality - A higher range of releases has the potential to result in fish mortality.
  - >22,026 mg/L for 1 hour
  - 7 mg/L for 30 months

5.2.3 Hazardous Materials

MaineDOT has completed an initial site assessment that was focused on hazardous materials. This environmental assessment did not indicate the presence of any hazardous materials associated with the Dike, however, MaineDOT and its contractors ensure any unanticipated contamination or deleterious materials encountered during construction are managed in accordance with applicable environmental regulations. Notifications to our regulatory partners are made as appropriate.

5.2.4 Upstream Habitat effects

The baseline condition at the site includes tidal fluctuation in 32.7 acres of area in the Middle River. Some of the plant communities in that area are found in brackish marshes, but no measurements of the extent of salinity have been taken. It is likely that not all of that 32.7 acres of area also receives saline water. Following the construction of the preferred alternative, that area may still be covered in water, but it would be from riverine flow as the new gates will not leak as the existing ones do.

As stated above, the area above the dike is currently in the buffer of what is mapped as coastal species EFH.

5.2.5 Effects of preferred alternative combined with climate change

MaineDOT is committing to ensuring the new dike bridge and causeway are more resilient to future climate change. This also includes continued involvement with projects undertaken by the municipality. Further, it includes design for higher water in the coastal environment as well as increased precipitation and freshwater storms. In the Phase 2 memo from Stantec, water elevations for a Q 1.1 flow during a 100 year storm surge and a SLR scenario of 3.9 feet above current highest astronomical tides could be as high as 14.6 feet NAVD 88. This is an example of data that MaineDOT is going to use when making a final determination on the height of the Dike. The draft road profile found in Appendix D again shows what this alternative may look like.

Even with responsible design of the Dike, there is a chance of storms that could overtop a new structure. During those events, there could be erosion of shorelines and areas adjacent to the rip rap along the edge of the dike. We recognize this is a potentially future effect, but do not believe the future effects can be quantified.

Maintaining the current fish passage barrier also may have future effects on climate resilient fish stocks. Allowing fish to migrate into the Middle River could give them access to cooler water as temperatures rise during climate change.

As water warms, water that is impounded by the Dike will also warm. Maintaining the impoundment will continue to have the effect of warming water. No monitoring of temperatures has been completed to understand the current effect of the Dike on water temperatures. Changing climate conditions are likely to warm the water in the impoundment to higher temperatures and continue the current effects that are occurring.

5.3 CONCLUSIONS REGARDING POTENTIAL PROJECT EFFECTS ON EFH

The preferred alternative will not result in restoration of fish passage or landward tidal flow into the Middle River. There are anecdotal reports that some striped bass currently move upstream of the Dike. They likely pass upstream during periods where the leaky gates allow for some upstream flow. There may be a short window of time where it is possible for a fish to move into the Middle River when slack tides turn to an outgoing tide. However, passage conditions are not within any of typical design parameters. The project will have an adverse effect on EFH from maintaining the existing passage conditions and upstream marsh condition.

5.4 MITIGATION

At this time, impacts from MaineDOT's preferred alternative are estimates as final design cannot be completed until the NEPA environmental review process has been completed. As stated above, there will be both temporary and permanent impacts to EFH and trust species as a result of this project. Construction of new tide gates will impact ~32 acres of habitat upstream of the Dike that currently experience some tidal water level fluctuation and some saline water in the vicinity of the Dike. There will also be additional fill upstream and downstream of the Dike as the Dike is raised to account for future ocean water levels and storms. These will be direct and permanent impacts. The habitat upstream of the Dike, though experiencing some tidal fluctuation, is currently not functional as it would be in a natural state. Fish passage is currently not available. The proposed action will not change that. Permanent impacts to EFH could be as much as 32,400 square feet.

MaineDOT commits to provide mitigation for the impacts to the baseline conditions. The final amounts and methods will be decided after final plans can be created. We do not commit to providing mitigation for any of the impacted areas that are being maintained in their baseline condition.

6.0 POTENTIAL IMPACTS TO TRUST SPECIES

It is likely that all of the trust species listed in table 10 below will be in the project area using the Machias River estuary. Though there is anecdotal reports of some fish occurring upstream of the Dike, there is effective no fish passage at the Dike in its current condition. The project scope will not improve that condition. It may also provide less opportunity for the occasional fish passage event demonstrated by the anecdotal reports. Also, the scope will not restore tidal flow to the marsh. That habitat would likely serve as nursery areas for any of the trust species below that may spawn in the surrounding rivers. Accordingly, the proposed scope will adversely affect the trust species listed below.

Table 10 Trust Species in project area

Species	Life stage	Timing	Notes
Alewife	Adult and juvenile	May- September	Migrating in and out of Machias River
Blueback Herring	Adult and juvenile	May- September	Migrating in and out of Machias River
Rainbow smelt	Adult and juvenile	March-April	Migrating and foraging into Machias River
Striped bass	Adults	June-September	Angler reports in impoundment. Foraging habitat
American eel	all	March- September	Assumed to be migrating into Machias and likely into the Middle River
Sea lamprey	All	May- July	Assumed to be migrating into Machias
Shortnose/Atlantic Sturgeon	Adult/Subadult	May-October	Coastal Migrations between Penobscot and St. John. Potential short duration foraging on migration
American shad	All	May-July	Assumed to be migrating into Machias

Appendix A- List of Avoidance and Minimization Measures for the Dike Bridge Replacement Project

AMM 1. Pile driving with an impact hammer will be completed at low tide or within the December 1- March 31 window.

AMM 2. The Contractor will use a vibratory hammer to drive all piles to the fullest extent practicable. Impact-hammer pile driving will be necessary to seat 30-inch steel bent piles for temporary bridge structure. Steel bent pile size will be limited to 30 inches to minimize the potential for fish injury beyond 18 meters.

AMM 3. Breaching of cofferdams will occur at high slack tide to minimize water velocities upon release.

AMM 4. Before project construction begins, each Contractor must submit a Soil Erosion and Water Pollution Control Plan (SEWPCP) for review and approval of MaineDOT staff prior to the start of work. The plan includes the review of the implementation of any AMMs proposed. Prior to soil disturbance, the erosion control portion of the SEWPCP will be reviewed and in place.

AMM 5. Contractors will implement BMPs in accordance with the MaineDOT manual Best Management Practices for Erosion and Sedimentation Control (MaineDOT 2008; available at https://www.maine.gov/mdot/env/documents/bmp/BMP2008full.pdf.), which outlines means and methods to prevent sedimentation in streams during construction or heavy precipitation. The Contractor will maintain sediment and erosion controls throughout construction and until the site is deemed completely stable.

AMM 6. As a component of the SEWPCP required for the bridge replacement project, MaineDOT or their Contractor will develop and implement a Spill Prevention Control and Countermeasure Plan (SPCCP) designed to avoid stream impacts from hazardous chemicals, such as diesel fuel, oil, lubricants, and other hazardous materials. These measures include the following:

- The primary work for this project will occur on the bridge, and a 100-foot distance from the resource on either side of the river will not be possible to maintain. All refueling or equipment maintenance in a careful manner that prevents chemical or other hazardous materials from entering the stream.

- All vehicles carrying fuel will have specific equipment and materials needed to contain or clean up any incidental spills at the Project sites. Equipment and materials will include spill kits appropriately sized for specific quantities of fuel, shovels, absorbent pads, straw bales, containment structures and liners, and/or booms.

- During use, all pumps and generators will have appropriate spill containment structures and/or absorbent pads in place.

- All equipment used for in-stream work will be cleaned of external oil, grease, dirt, and mud. Any leaks or accumulations of these materials will be corrected before entering areas that drain directly to streams or wetlands.

AMM 7. During construction, any disturbed soils will be temporary stabilized with BMPs, such as straw mulch, plastic sheeting, erosions control mix, or other appropriate BMPs. Disturbed areas with erodible soil can include, but are not limited to, temporary storage piles, access ways, partially constructed slopes, etc.

AMM 8. No equipment, materials, or machinery shall be stored, cleaned, fueled, or repaired within any wetland or watercourse; dumping of oil or other deleterious materials on the ground will be forbidden; the Contractor shall provide a means of catching, retaining, and properly disposing of drained oil, removed oil filters, or other deleterious material; and all oil spills shall be reported immediately to the appropriate regulatory body. Response to any contaminant release will follow protocols contained in the SPCCP.

AMM 9. Temporary roads (wet roads) in the project area will be constructed of clean, non-erodible material (i.e., plain riprap or large riprap per MaineDOT standard specifications) over geotextile fabric. No fill for temporary access (riprap) will be placed in the primary or bypass channel.

AMM 10. All areas of temporary waterway or wetland fill will be restored to their original contour and character upon completion of the project. Temporary fill includes fill that received authorization and fill that mistakenly enters a resource (i.e., from slope failures, accidental broken sandbag cofferdams).

AMM 11. No heavy construction equipment will travel into or through any flowing streams with erodible substrate (e.g., sand, silt, and clay). Travel of heavy construction equipment into or through flowing streams and onto stream substrate will only occur when the stream substrate is non-erodible (e.g., ledge, cobble) and the Contractor has received approval from the MaineDOT or the MTA environmental field office staff.

AMM 12. Turbid water within a cofferdam during dewatering will be pumped to a sediment basin for filtration. The “Dirty Water” Treatment System will be installed according to MaineDOT’s Best Management Practices.

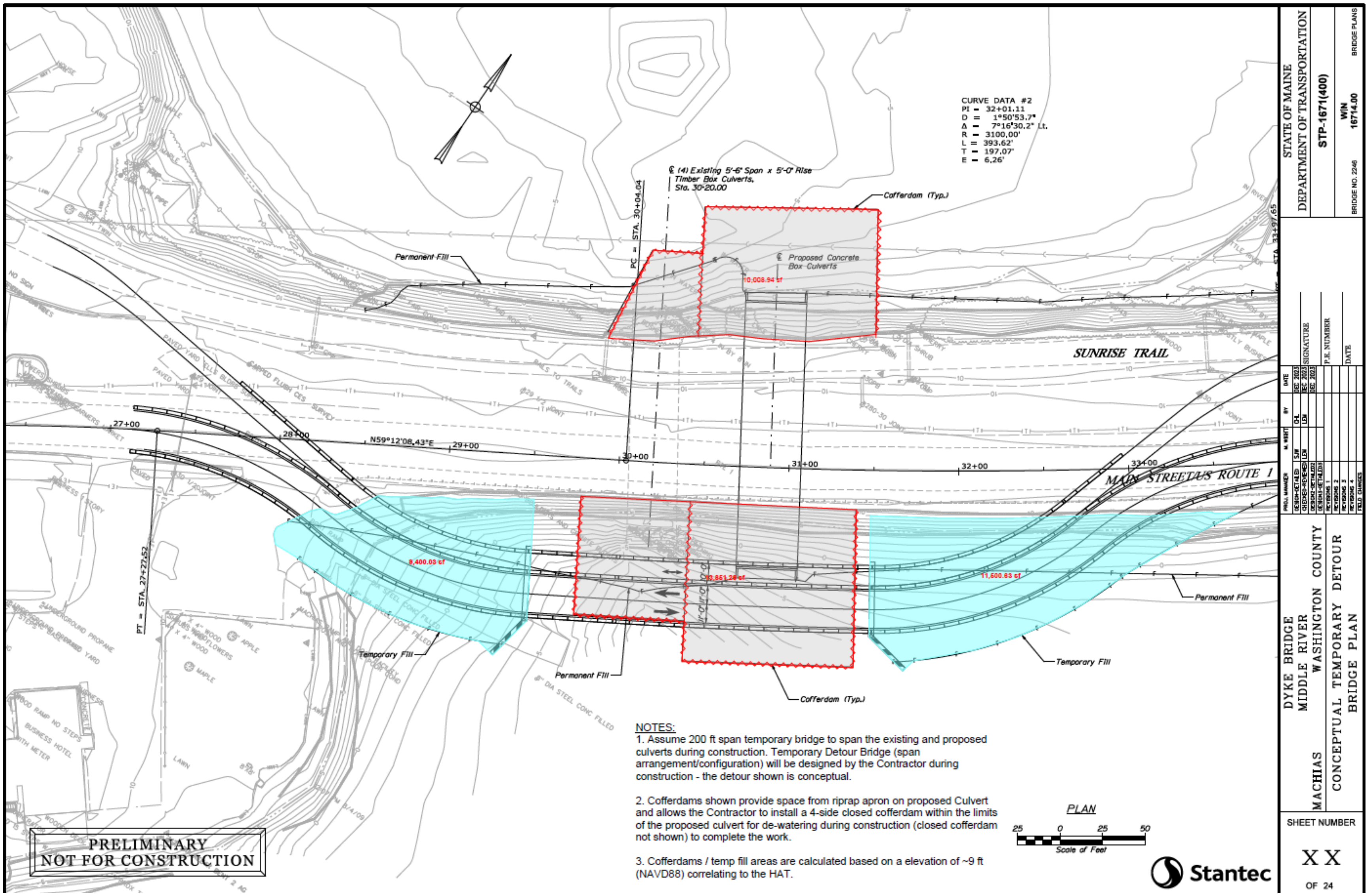
AMM 13. In those portions of the project area where fish are likely to occur, all intake pumps will have a fish screen installed, operated, and maintained. To prevent fish entrainment during water diversions, the Contractor will use a screen on each pump intake large enough so that the approach velocity does not exceed 0.06 meters per second (0.20 feet per second). Square or round screen face openings are not to exceed 2.38 millimeters (3/32 inch) on a diagonal. Criteria for slotted face openings will not exceed 1.75 millimeters (approximately 1/16 inch) in the narrow direction. These screen criteria follow those indicated by NOAA Fisheries.

AMM 14. Fresh concrete will be poured inside of a cofferdam (concrete seal) and will not contact flowing water (outside cofferdam).

AMM 15. Water pumped out of the cofferdam will be within one pH unit of background pH level of the resource (Machias River) (MaineDOT standard specifications). A representative of the MaineDOT Surface Water Quality Unit will periodically evaluate pH to determine whether the water is within the allowable tolerance to be pumped directly back into the river or whether it needs to be treated prior to discharge.

AMM 16. Demolition and debris removal and disposal will comply with Section 202.03 of MaineDOT's Standard Specifications. The Contractor will contain all demolition debris, including debris from wearing surface removal, saw cut slurry, dust, etc., and will prevent debris from entering any resource to the extent feasible. The Contractor will dispose of debris in accordance with the Maine Solid Waste Law (Title 38 M.R.S.A., Section 1301 et. seq.) and in compliance with applicable regulatory approvals. The demolition plan, containment, and disposal of demolition debris will be addressed in the Contractor's SEWPCP.

Appendix B – Construction Drawing (only for EFH consultation)



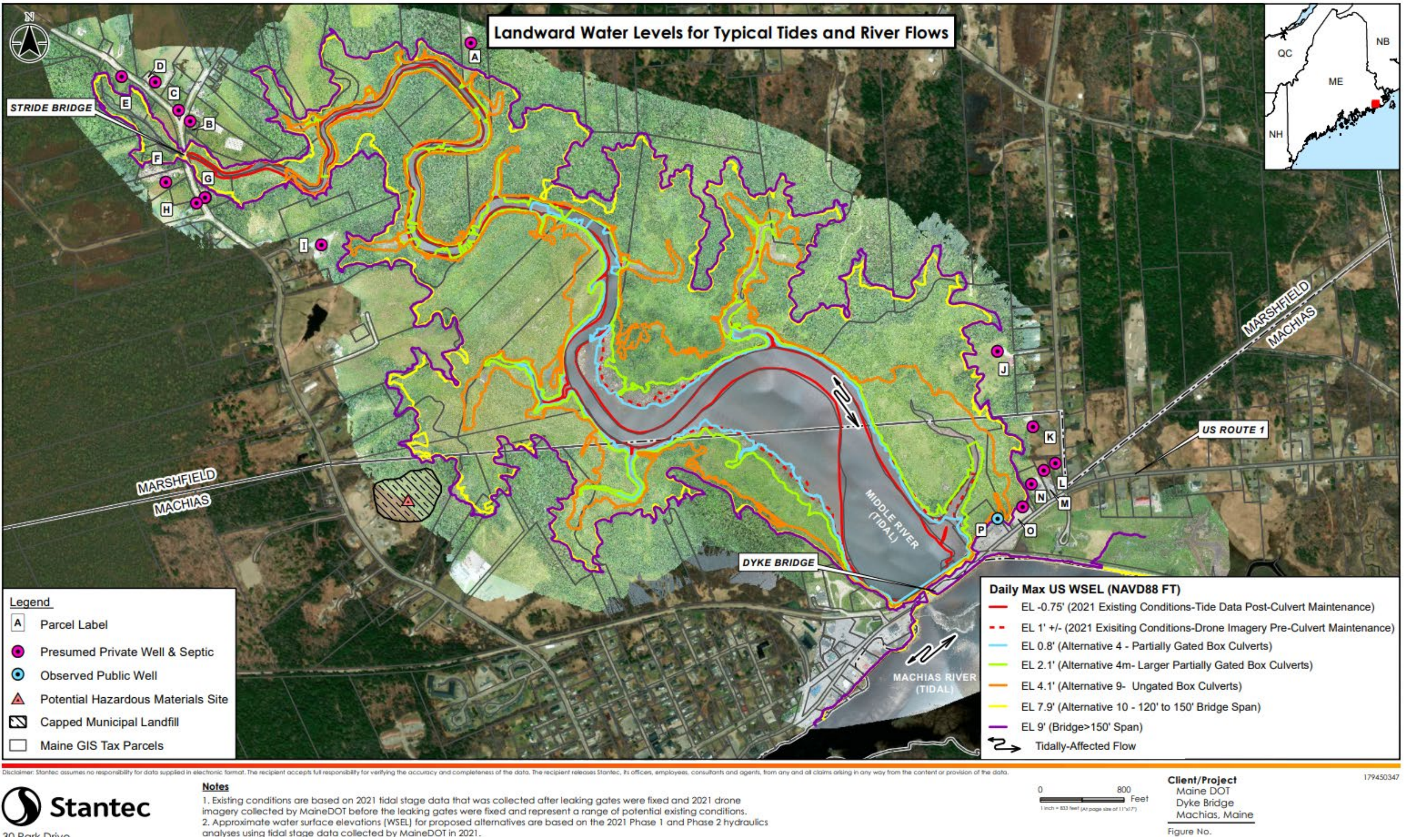
NOTES:

1. Assume 200 ft span temporary bridge to span the existing and proposed culverts during construction. Temporary Detour Bridge (span arrangement/configuration) will be designed by the Contractor during construction - the detour shown is conceptual.

2. Cofferdams shown provide space from riprap apron on proposed Culvert and allows the Contractor to install a 4-side closed cofferdam within the limits of the proposed culvert for de-watering during construction (closed cofferdam not shown) to complete the work.

3. Cofferdams / temp fill areas are calculated based on a elevation of ~9 ft (NAVD88) correlating to the HAT.

Appendix C- Inundation levels from different alternatives

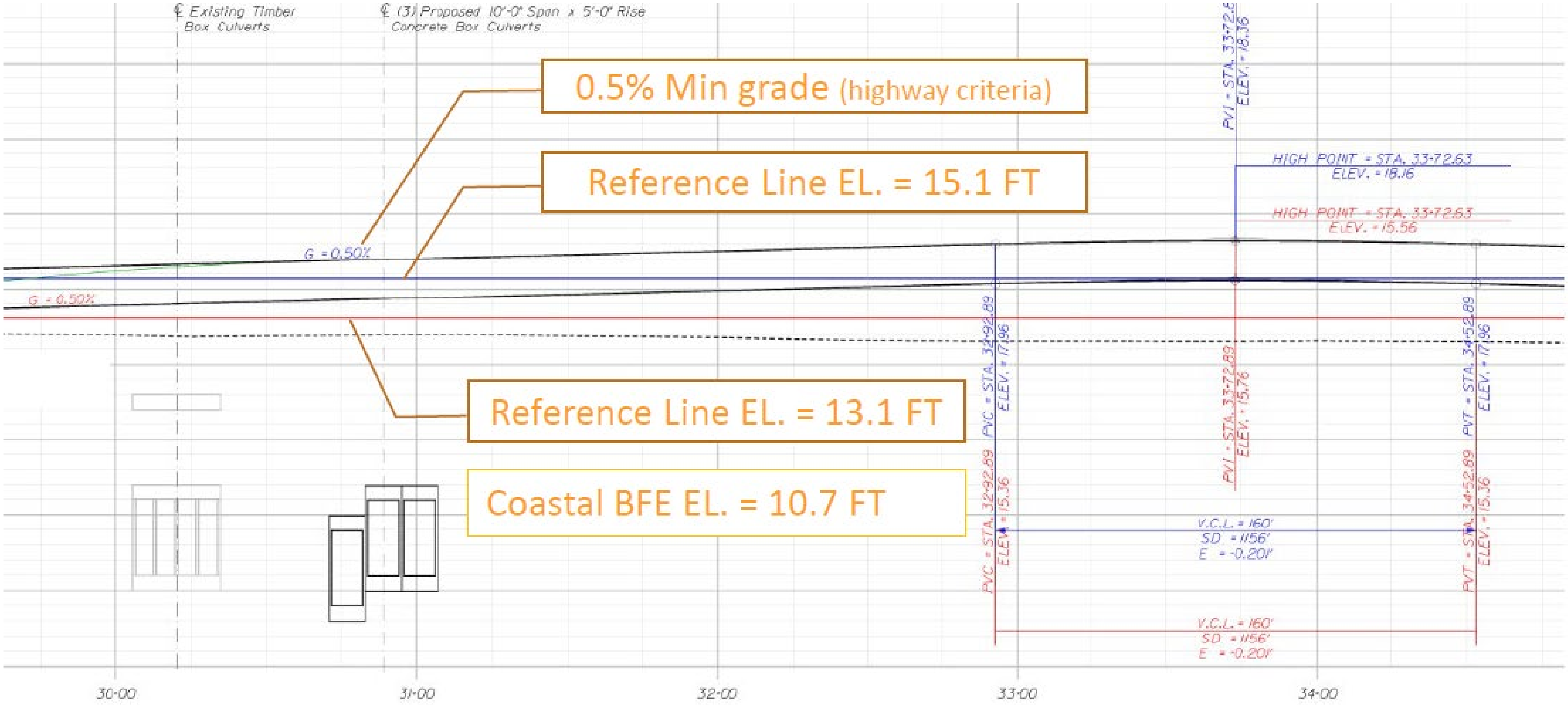


Disclaimer: Stantec assumes no responsibility for data supplied in electronic format. The recipient accepts full responsibility for verifying the accuracy and completeness of the data. The recipient releases Stantec, its officers, employees, consultants and agents, from any and all claims arising in any way from the content or provision of the data.

Notes

1. Existing conditions are based on 2021 tidal stage data that was collected after leaking gates were fixed and 2021 drone imagery collected by MaineDOT before the leaking gates were fixed and represent a range of potential existing conditions.
2. Approximate water surface elevations (WSEL) for proposed alternatives are based on the 2021 Phase 1 and Phase 2 hydraulics analyses using tidal stage data collected by MaineDOT in 2021.

Appendix D- Dike Profile Demonstrating Potential Raising


℄ Existing Timber Box Culverts
℄ (3) Proposed 10'-0" Span x 5'-0" Rise Concrete Box Culverts
0.5% Min grade (highway criteria)
Reference Line EL. = 15.1 FT
Reference Line EL. = 13.1 FT
Coastal BFE EL. = 10.7 FT
G = 0.50%
G = 0.50%
PVI = STA. 33+72.8
ELEV. = 18.36
HIGH POINT = STA. 33+72.63
ELEV. = 18.16
HIGH POINT = STA. 33+72.63
ELEV. = 15.56
PVC = STA. 32+92.89
ELEV. = 17.96
PVI = STA. 33+72.89
ELEV. = 15.76
PVT = STA. 34+52.89
ELEV. = 17.96
PVC = STA. 32+92.89
ELEV. = 15.36
PVT = STA. 34+52.89
ELEV. = 15.36
V.C.L. = 160'
SD = 1156'
E = -0.201'
V.C.L. = 160'
SD = 1156'
E = -0.201'
30+00
31+00
32+00
33+00
34+00

Appendix E- Stantec Salt Marsh Memo

Stantec **Memo**

To: Maine Department of Transportation
Augusta, Maine

From: Lori Benoit,
Michael Chelminski
Northampton MA Office

File: 197450347

Date: November 8, 2021

Reference: Estimated Elevation Ranges of Intertidal Habitats for Middle River / Dyke Bridge Alternatives

In support of the Dyke Bridge Replacement Project (Project) located on the Middle River in Machias, Maine, Stantec was tasked with estimating the extent of tidal wetland habitats for two previously vetted alternatives (4m and 10) for replacing existing flap gates at Dyke Bridge. Stantec reviewed existing background information and data on tidal hydrology and vegetation elevations and distribution in the following documents:

- Technical Report: Middle River Hydrologic and Alternatives Analysis, Stantec 2015
- Memo: Draft Phase 1 Hydraulic Analysis for Machias Dyke Bridge (#2246) Planning Phase Support Services, September 2, 2021, Stantec to MaineDOT (Stantec 2021)
- Data: SchoppeeMarsh_TidalRestrictionAssessment_Draft_Hydrodata.xls. Schoppee Marsh Tide Gate Removal Project hydrology, elevation, and vegetation data from BB USFWS GOMP/ DSF.

SIMULATED TIDAL STAGE STATISTICS

Stantec 2021 presents information obtained from the preliminary, unsteady-state numerical hydraulic model study for a range of potential alternatives for the Project, including simulated water surface elevations in the Middle River for Alternatives 4m and 10. Tidal statistics were generated for the two noted alternatives based on a hydraulic model simulation period of 34 days. Boundary conditions for the unsteady-state simulations included a constant inflow of 13.7 cubic feet per second representing a typical discharge of the Middle River and a time-varying water surface elevation at downstream boundary condition based on tidal stage data collected in the Machias River by MaineDOT in 2011.

Tidal stage statistics were developed based on the simulated water surface elevations in the Middle River landward (upstream) from Dyke Bridge using the National Oceanic and Atmospheric Administration online Tidal Analysis Datum Calculator tool[1]. Calculated tidal statistics are presented in Table 1.

Table 1. Estimated Tide Statistics for the Middle River for Alternatives 4m and 10

	Estimated Tide Statistics (ft, NAVD88)	
	Alt4m	**Alt10**
Mean Higher High Water	2.01	7.39
Mean High Water	1.87	6.87
Mean Tide level	-0.41	0.21
Mean Low Water	-2.68	-6.46
Mean Lower Low Water	-2.73	-6.66

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[1] CO-OPS Datum Calculator (noaa.gov)

Reference: **Estimated Elevation Ranges of Intertidal Habitats for Middle River / Dyke Bridge Alternatives**

ESTIMATED SALTMARSH RANGES

Based on this review, Stantec estimated potential elevation ranges for three habitat types of high marsh, low marsh, and unvegetated intertidal areas, and present the estimates in Table 1 with elevations referenced to the North American Vertical Datum of 1988 (NAVD88).

Table 2: Estimated Potential Saltmarsh Habitat Ranges

	Estimated Saltmarsh Habitat Ranges (ft, NAVD88)			
	Alternative 4m		**Alternative 10**	
Estimated Habitat	Low Range	High Range	Low Range	High Range
High Marsh	1.9	2.0	6.9	7.4
Low Marsh	0.8	1.9	3.8	6.9
Unvegetated intertidal/subtidal	-	0.8	-	3.8

The attached figures depict the estimated areas of high marsh, low marsh, and unvegetated intertidal and subtidal habitats based on the elevation ranges in Table 1 using a digital terrain model developed using LiDAR data. These figures include estimated areas for the evaluated habitat types. The estimated habitat areas were developed based on the assumption that salinities in the Middle River landward from Dyke Bridge would be similar to salinities in the Machias River seaward from the bridge.

Unvegetated intertidal habitat is a distinct habitat type but here has been temporarily lumped with subtidal habitat until updated bathymetric data becomes available. Predicted elevations for saltmarsh habitats may be revised as additional information becomes available. The estimated elevations and descriptions for intertidal habitats landward of Dyke Bridge under two alternatives are based also on the following assumptions:

1) High marsh formation is predicted at elevations between mean high water (MHW) and mean higher high water (MHHW), which are areas typically inundated with salt water during only the highest tides of the month.

2) High marsh is typically dominated by saltmeadow cordgrass (*Spartina patens*). Black grass (*Juncus gerardii*) may be found at the highest elevations/upper border of the high marsh. Saltwater cordgrass (*Spartina alterniflora*) may be found in the high marsh in slight depressions on the marsh surface (high saline pannes) along with glasswort species (*Salicornia* spp.)

3) Low marsh has the potential to establish from MHW to the approximate elevation of the mean tide level (MTL). In actuality, *S. alterniflora* often is not found at elevations as low as the mean tide level (MTL). Data for the unrestricted portion of Machias River does not show low marsh close to the "Diurnal Tide Level" in the Machias River at an elevation (El.) of 0.47 ft (see "Assessment Notes" tab of Schoppee Marsh Excel file) and which Stantec assumes approximates the MTL. At the seaward side (no restriction) of the Machias River, the data gathered by DSF shows low marsh at El. 4.99 ft. Based on this data point, approximately 5 ft above the MTL appears to not be vegetated. However, this one data point for unrestricted low marsh is insufficient information to assess the overall elevation distribution of low marsh in the tidal wetland with unrestricted flows. Also, the start of downstream (presumably downstream of tide gate in unrestricted flow Machias River) low marsh is shown at

Reference: **Estimated Elevation Ranges of Intertidal Habitats for Middle River / Dyke Bridge Alternatives**

approximately EL. 3.6 ft in the Schoppee Marsh Excel file . In this case, approximately 50% of the tide range between MTL and MHHW is unvegetated. This data is consistent with previously published findings indicating that ice scour may limit the lower extent of low marsh in northern New England salt marshes (Hardwick-Witman 1986) and this may explain lack of Spartina alterniflora at or near the MTL. Therefore, the lower limit of low marsh for both alternatives 4m and 10 was roughly estimated as the MHHW el. minus 50% of the tide range between the MTL and the MHHW.

4) *S. alterniflora* is the dominant, monotypic plant species of the low marsh.

5) Unvegetated intertidal areas (encompasses habitat called “mud flat”) are expected in the range from MTL to mean lower low water. Erosion caused by ice scour of mid-range intertidal areas may limit the lower extent of vegetated intertidal areas. Increased height of tidal flooding may inhibit *S. alterniflora* growth in the intertidal region below MHW particularly in locations such as the Gulf of Maine that experiences extreme tidal ranges.

6) At individual tidal sites, variations in microtopography and flood/drainage patterns, including those due to disturbances such as culverts and tide gates that cause tidal restrictions, may alter the elevations and predicted patterns at which high marsh, low marsh, and unvegetated tidal areas are established.

7) Estimated ranges of intertidal habitats for Alternative 10 were adjusted based on field-collected data at unrestricted Machias River intertidal sites. Notably, the extreme tide heights, and duration, and ice scour may preclude low marsh/ *S. alterniflora* establishment in a significant portion of the intertidal zone below MHW.

8) Under the Alternative 4m scenario, it was assumed that high marsh may become established in a narrow elevation range that will not be flooded daily but only on the highest predicted tides each month and based on restricted flow through the culverts that will limit the higher tidal heights.

MIDDLE RIVER STAGE-AREA CURVE

A stage-area (hypsometric) curve was developed from a digital terrain model (DTM) of land adjacent to the Middle River upstream from Dyke Bridge to the vicinity of Stride Bridge. The DTM was developed using existing LiDAR and was initially compiled for development of the project hydraulic model study program.

Figure 1 depicts the stage-area curve along with the estimated High Marsh and Low Marsh habitat elevation ranges for Alternatives 4m and 10 that are presented in Table 2. Table 3 presents the stage-area data in tabular format.

The stage-area data does not include areas for elevations below Elevation 0.0 ft which are largely in the current area that is inundated during normal tidal conditions in the Middle River upstream from Dyke Bridge. The estimated saltmarsh habitat ranges presented in Table 2 and in Figure 1 indicate that areas below Elevation 0.0 would be unvegetated intertidal/subtidal habitat for Alternative 4m and that areas below Elevation 4.5 ft would be unvegetated intertidal/subtidal habitat for Alternative 10.

Reference: **Estimated Elevation Ranges of Intertidal Habitats for Middle River / Dyke Bridge Alternatives**

Figure 1. Stage-Area Curve

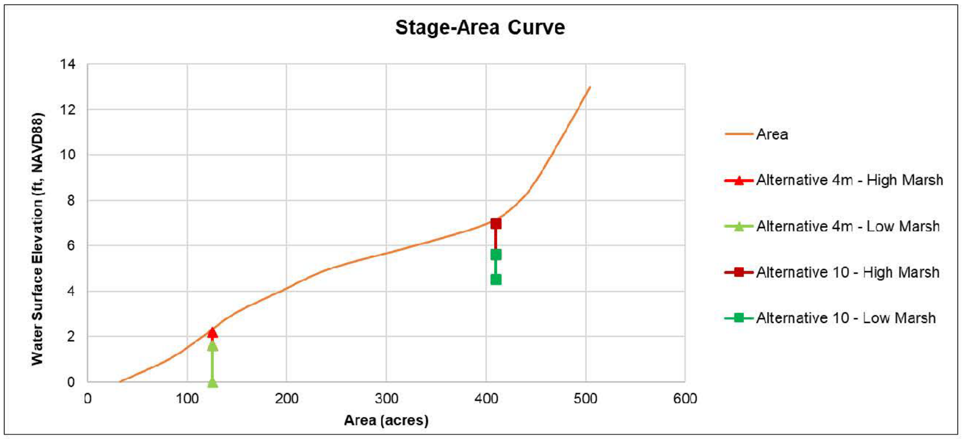

Table 3. Stage-Area Curve Data from Figure 1 for Middle River Upstream from Dyke Bridge

WSEL (ft, NAVD88)	Area (acres)
0	33
1	82
2	116
3	147
4	194
5	244
6	328
7	402
8	434
9	452
10	465
11	478
12	491
13	504

November 8, 2021

Reference: **Estimated Elevation Ranges of Intertidal Habitats for Middle River / Dyke Bridge Alternatives**

DATA LIMITATIONS AND CAVEATS

The methodology for collection of vegetation data by DSF is not provided. Using a series of transects from below MTL to the upland is a standard method for vegetation assessment. Identifying plants and community types on the fly in the field and taking vegetation and elevation data would not be recommended as this approach could introduce selection bias.

We are not able to determine from the DSF plant community and elevation data exactly which data applies to the Eastern Schoppee Marsh. That location has a partial tidal restriction (does not drain fully at low tide and does not reach full tidal height compared to the unrestricted Machias River) and could be skewing the data if it is grouped with the “unrestricted” data. Based on the presentation of three sets of tidal data (Machias River, Schoppee Marsh Restricted, and Schoppee Marsh Eastern), we would expect three sets of vegetation data that reflect the tidal regime in each location. However, plant community and elevation data is shown only as restricted vs. unrestricted. Are there any vegetation and elevation data specifically for the Eastern Schoppee Marsh? Of the three locations, the Eastern Schoppee Marsh may be most similar to the alternative 4m.

Elevations of vegetation community called “Low hypersaline panne – restricted” does not make sense given the elevations of the high marsh. Hypersaline pannes are embedded within the high marsh zone and are typically only a few millimeters lower in elevation than the surrounding S. patens-dominated high marsh. The elevation data for the pannes appear to be lower by a foot or more in elevation compared to the high marsh. It is possible that these areas are stunted and dying S. alterniflora areas caused by excessive duration of flooding upstream of the Schoppee tide gate.

The data assessment appears to be in the draft stage. Note comment by “WBennett” regarding the vegetation community classification: “Need to further evaluate the classification of different communities. Many irregularities exist and overlap.” We suggest proceeding with caution on using and interpreting the existing data for predicting locations/areas of salt marsh habitats for the different design alternatives. We may want to discuss the data with DSF, and additional data collection may be warranted.

Please contact Stantec with questions or comments regarding the information presented in this memo.

Stantec Consulting Services Inc.

11/08/2021

11/8/2021

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Attachment: Figure 1: Alternative 4m, Estimated Saltmarsh Habitat
Figure 2: Alternative 10, Estimated Saltmarsh Habitat

c. Tim Merritt, Stantec

Stantec

30 Park Drive
Topsham, ME USA 04086
Phone (207) 729-1199

Prepared by EPL on 2021-08-09
Reviewed by MBC on 2021-08-09

Notes

1. Approximate water surface elevations (WSEL) for proposed alternatives are based on the 2021 Phase 1 hydraulics analysis using tidal stage data collected by MaineDOT in 2011.
2. Coordinate System: NAD 1983 UTM Zone 19N FT
3. Vertical Datum: NAVD88
4. Aerial imagery in the project area was obtained by unmanned aircraft vehicle (UAV) by MaineDOT on July 20, 2021.
5. Aerial imagery surrounding the project area is provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).
6. TIN Surface information is based on survey data provided by the Maine Department of Transportation.

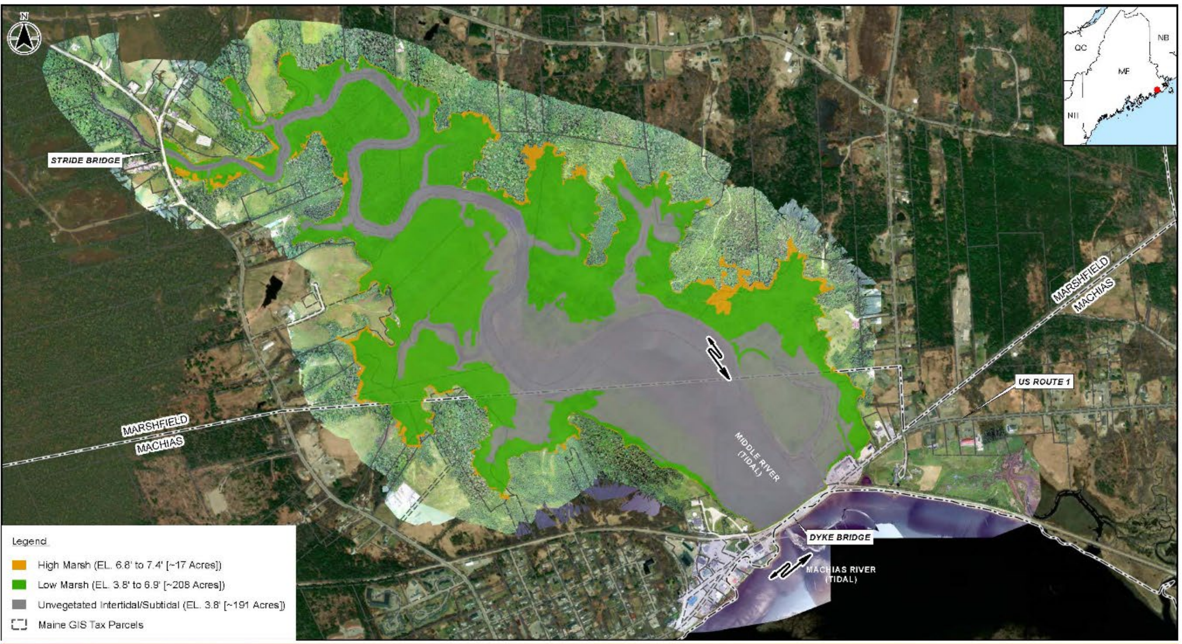
0 900 Feet

Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
1

Title Alternative 4m
Estimated Saltmarsh Habitat

11/9/2021



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6. TIN Surface information is based on survey data provided by the Maine Department of Transportation.

0 900 Feet

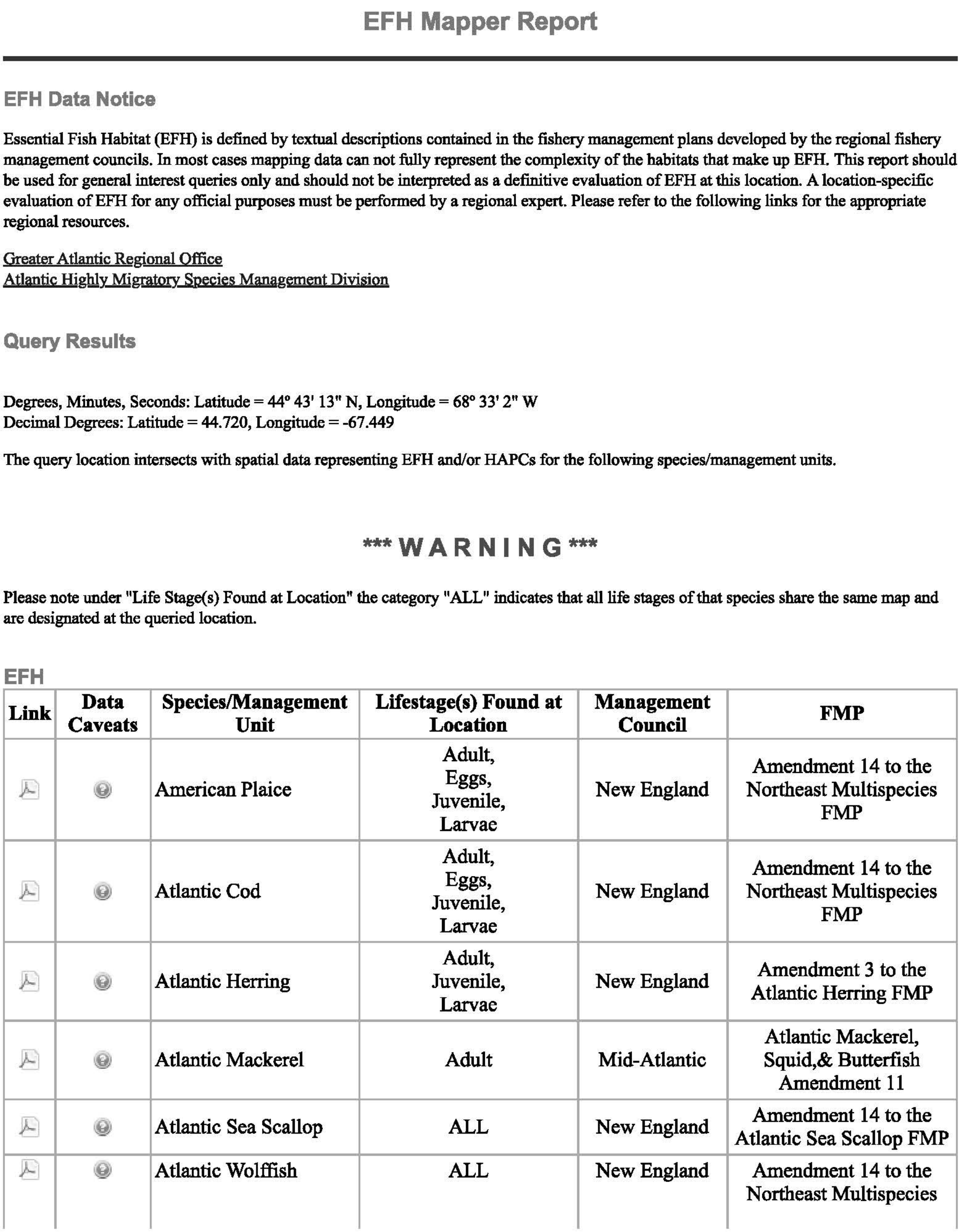
Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
2

Title Alternative 10
Estimated Saltmarsh Habitat

11/9/2021

Appendix F- EFH Mapper Report



EFH Mapper Report

EFH Data Notice

Essential Fish Habitat (EFH) is defined by textual descriptions contained in the fishery management plans developed by the regional fishery management councils. In most cases mapping data can not fully represent the complexity of the habitats that make up EFH. This report should be used for general interest queries only and should not be interpreted as a definitive evaluation of EFH at this location. A location-specific evaluation of EFH for any official purposes must be performed by a regional expert. Please refer to the following links for the appropriate regional resources.

Greater Atlantic Regional Office
Atlantic Highly Migratory Species Management Division

Query Results

Degrees, Minutes, Seconds: Latitude = 44° 43' 13" N, Longitude = 68° 33' 2" W
Decimal Degrees: Latitude = 44.720, Longitude = -67.449

The query location intersects with spatial data representing EFH and/or HAPCs for the following species/management units.

*** WARNING ***

Please note under "Life Stage(s) Found at Location" the category "ALL" indicates that all life stages of that species share the same map and are designated at the queried location.

EFH

Link	Data Caveats	Species/Management Unit	Lifestage(s) Found at Location	Management Council	FMP
📄	●	American Plaice	Adult, Eggs, Juvenile, Larvae	New England	Amendment 14 to the Northeast Multispecies FMP
📄	●	Atlantic Cod	Adult, Eggs, Juvenile, Larvae	New England	Amendment 14 to the Northeast Multispecies FMP
📄	●	Atlantic Herring	Adult, Juvenile, Larvae	New England	Amendment 3 to the Atlantic Herring FMP
📄	●	Atlantic Mackerel	Adult	Mid-Atlantic	Atlantic Mackerel, Squid,& Butterfish Amendment 11
📄	●	Atlantic Sea Scallop	ALL	New England	Amendment 14 to the Atlantic Sea Scallop FMP
📄	●	Atlantic Wolffish	ALL	New England	Amendment 14 to the Northeast Multispecies

Link	Data Caveats	Species/Management Unit	Lifestage(s) Found at Location	Management Council	FMP
					FMP
📄	❓	Haddock	Juvenile	New England	Amendment 14 to the Northeast Multispecies FMP
📄	❓	Little Skate	Adult, Juvenile	New England	Amendment 2 to the Northeast Skate Complex FMP
📄	❓	Ocean Pout	Adult, Eggs, Juvenile	New England	Amendment 14 to the Northeast Multispecies FMP
📄	❓	Pollock	Juvenile	New England	Amendment 14 to the Northeast Multispecies FMP
📄	❓	Red Hake	Adult, Eggs/Larvae/Juvenile	New England	Amendment 14 to the Northeast Multispecies FMP
📄	❓	Silver Hake	Adult	New England	Amendment 14 to the Northeast Multispecies FMP
📄	❓	Smooth Skate	Juvenile	New England	Amendment 2 to the Northeast Skate Complex FMP
📄	❓	Spiny Dogfish	Adult Male	Mid-Atlantic	Amendment 3 to the Spiny Dogfish FMP
📄	❓	Thorny Skate	Juvenile	New England	Amendment 2 to the Northeast Skate Complex FMP
📄	❓	White Hake	Adult, Juvenile	New England	Amendment 14 to the Northeast Multispecies FMP
📄	❓	Windowpane Flounder	Adult, Eggs, Juvenile, Larvae	New England	Amendment 14 to the Northeast Multispecies FMP
📄	❓	Winter Flounder	Eggs, Juvenile, Larvae/Adult	New England	Amendment 14 to the Northeast Multispecies FMP
📄	❓	Winter Skate	Juvenile	New England	Amendment 2 to the Northeast Skate Complex FMP

Pacific Salmon EFH

No Pacific Salmon Essential Fish Habitat (EFH) were identified at the report location.

Atlantic Salmon EFH / HAPC

Link	Data Caveat	Name	Designation	Lifestage	Management Council	FMP
📄	?	Coastal Areas	EFH	All	New England	Amendment 3 to the Atlantic Salmon FMP

HAPCs

No Habitat Areas of Particular Concern (HAPC) were identified at the report location.

EFH Areas Protected from Fishing

No EFH Areas Protected from Fishing (EFHA) were identified at the report location.

Spatial data does not currently exist for all the managed species in this area. The following is a list of species or management units for which there is no spatial data. ****For links to all EFH text descriptions see the complete data inventory: <u>open data inventory --></u>**
All EFH species have been mapped for the Greater Atlantic region, **Atlantic Highly Migratory Species EFH,** Bigeye Sand Tiger Shark, Bigeye Sixgill Shark, Caribbean Sharpnose Shark, Galapagos Shark, Narrowtooth Shark, Sevengill Shark, Sixgill Shark, Smooth Hammerhead Shark, Smalltail Shark

6.2 REFERENCES

Rubenstein, Sarah R., “Energetic Impacts of Passage Delays in Migrating Adult Atlantic Salmon” (2021). Electronic Theses and Dissertations. 3468. https://digitalcommons.library.umaine.edu/etd/3468

APPENDIX 5 – HYDRAULICS AND HYDROLOGY REPORTS

1. 6/30/2015 Report: Hydrologic and Alternatives Analyses, Dyke Bridge and Stride Bridge, Middle River, Machias, Maine
2. 12/7/2021 Memo: Bridge Opening Geometry Hydraulic Analysis for Machias Dike Bridge (#2246) Planning Phase Support Services
3. 9/16/2021 Memo: Phase 1 Hydraulic Analysis for Machias Dyke Bridge (#2246) Planning Phase Support Services
4. 12/20/2021 Memo: Phase 2 Hydraulic Analysis for Machias Dyke Bridge (#2246) Planning Phase Support Services
5. 9/6/2023 Memo: 16714 Machias Dyke Bridge #2246 – Flood Control Structure
6. 9/6/2023 Memo: 16714 Machias Dyke Bridge #2246 – Encroachment Determination
7. 1/26/2022 Memo: Preliminary Assessment - Potable Water Supplies/Septic Systems, Machias Dike Bridge Project, Machias, Maine. WIN 16714.0
8. 11/8/2021 Memo: Estimated Elevation Ranges of Intertidal Habitats for Middle River/Bridge Alternatives

Technical Report: Middle River Hydrologic and Alternatives Analyses

Hydrologic Analyses and Alternatives Evaluations, Dyke Bridge and Stride Bridge, Middle River, Machias, Maine

Prepared for:
Maine Department of Transportation
Attn.: Nathan Howard
Bureau of Planning
16 State House Station
Augusta, Maine 04333-0016

Prepared by:
Stantec Consulting Services Inc.
30 Park Drive
Topsham, Maine 04086

June 30, 2015

Sign-off Sheet

This document entitled Technical Report: Middle River Hydrologic and Alternatives Analyses was prepared by Stantec Consulting Services Inc. ("Stantec") for the account of the Maine Department of Transportation (the "Client"). Northstar Hydro, Inc. is a subcontractor to Stantec for this study and contributed to the preparation of this report.

11-02-2015
MICHAEL R.
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No. 10320

Prepared by ______________________
(signature)

Michael Chelminski, P.E., Principal, Stantec Consulting Services Inc.

ELLEN
KNIGHT O'BRIEN
No. 7945

Reviewed by ______________________
(signature)

Ellen O'Brien, P.E., President, Northstar Hydro.

This report was prepared for the MaineDOT Bureau of Planning by Stantec for work as part of State W.I.N. # 016714.00, Federal W.I.N. #BR-1671(400)X, and funded through Appropriation #9095.

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Executive Summary

The Maine Department of Transportation (MaineDOT) contracted with Stantec Consulting Services Inc. (Stantec) to perform hydrologic and hydraulic analyses to evaluate a range of bridge and/or culvert alternatives to replace the Dyke Bridge (#2246) and the Stride Bridge (#3973) over the Middle River in the vicinity of the Town of Machias, Maine. Dyke Bridge crosses the Middle River immediately landward of the confluence of the Middle River with the Machias River in the Town of Machias. Stride Bridge crosses the Middle River in the Town of Marshfield approximately 3 miles upstream from Dyke Bridge.

This study develops and evaluates a range of alternative bridge and/or culvert geometries at Dyke Bridge and Stride Bridge. The primary focus of this study is to evaluate potential replacement structures at the two bridges relative to existing conditions and potential sea-level rise. Seven general alternatives were evaluated at Dyke Bridge, and range from no-action (Alternative 1) and replacement in-kind (Alternative 2), alternative culvert systems with operable gates (e.g., self-regulating tide gates [SRTs]) as presented by Alternatives 3 and 4, to a large bridge and/or group of culverts (Alternatives 5, 6, and 7) that would provide for unhindered tidal exchange in the Middle River upstream (landward) from Dyke Bridge.

Evaluated alternatives at Stride Bridge where limited to retaining the existing culvert and replacement with a single-span bridge.

Factors that are considered in the development and evaluation of alternatives at Dyke Bridge in this report include:

1) Conveyance of tidal flow at Dyke Bridge;
2) Potential inundation of land upstream from Dyke Bridge that would result from increased tidal exchange;
3) Upstream fish passage at Dyke Bridge and impacts to upstream fish passage at Stride Bridge; and
4) The potential for evaluated alternatives to affect inundation of areas along the Middle River landward from Dyke Bridge for the evaluated sea-level rise conditions.

The primary tool for evaluation of alternatives is a numerical hydraulic model of the study reach of the Middle River from its confluence with the Machias River to Stride Bridge. The one-dimensional, unsteady-state numerical hydraulic model was developed using the U.S. Army Corps of Engineers HEC-RAS software system (HEC-RAS model). The model was developed using Lidar terrain data and bathymetric data collected by MaineDOT. Boundary condition and calibration data for the HEC-RAS model included tidal stage data and peak upland flow statistics provided by MaineDOT. The HEC-RAS model was calibrated and validated for existing conditions using tidal stage data provided by MaineDOT.

The preliminary alternative evaluation process was initiated with a review of information on SRTs, which are the basis of two of the general alternatives. Based on this review, it was determined that SRTs (Alternative 3) and “fish-friendly” SRTs (Alternative 4) are not practical technologies for replacement of the existing culvert and flap-gates system at Dyke Bridge and are not expected to improve upstream fish passage relative to other evaluated alternatives.

Three general alternatives were evaluated to provide for unhindered tidal exchange at Dyke Bridge. Based on this review, it was determined that a single-span bridge (Alternative 6) is a feasible alternative for replacement of the existing culverts at Dyke Bridge, but that a group of large culverts (Alternative 5) or a group of culverts along with a single-span bridge (Alternative 7) are not feasible alternatives at Dyke Bridge.

The HEC-RAS model was used to evaluate a set of the evaluated alternatives at Dyke Bridge and Stride Bridge. The HEC-RAS model was used to evaluate a broad range of alternatives; this study presents information and findings for approximately 100 unsteady-state flow scenarios. Based on information obtained from the HEC-RAS model and consideration of the four factors noted previously, it was identified that feasible alternatives at Dyke Bridge include:

- Replacement in-kind (Alternative 2) without flap gates on every culvert; and
- Replacement with a single-span bridge (Alternative 6).

Multiple scenarios were evaluated for replacement in-kind (Alternative 2). These scenarios evaluated four or five box culverts with up to two free-flowing culverts (no flap gate). These scenarios would provide for landward flow through the culverts without flap gates during flood tides and are expected to substantially improve upstream fish passage while limiting inundation of land along the Middle River landward from Dyke Bridge. Depending on the selected variation of Alternative 2, including the total number of culverts and the number of culverts with and without flap gates, this alternative can limit inundation of land upstream from Dyke Bridge while substantially improving upstream fish passage. Information developed as part of this study indicates that increasing typical tidal water surface elevations upstream from Dyke Bridge by more than 2 feet (ft) would result in regular tidal inundation of substantial areas of land.

Replacement with a single-span bridge (Alternative 6) would provide for volitional upstream fish passage and would result in substantial inundation of land along the Middle River landward from Dyke Bridge. Specifically, normal tidal water surface elevations would increase by 8 to 10 ft immediately landward from Dyke Bridge. Based on the results of the HEC-RAS model evaluations, the minimum length of a single-span bridge to provide unhindered tidal flow at Dyke Bridge is 60 ft with vertical abutments and would require dredging of a channel under the bridge and upstream into the Middle River.

Based on factors that are considered in this study and the study evaluations and findings, the primary constraints associated with replacement of the existing Dyke Bridge culvert systems are 1) upstream fish passage, and 2) inundation of land upstream from Dyke Bridge. Replacement in-kind (Alternative 2) with some free-flowing culverts can provide for improved upstream fish passage while limiting flooding of landward areas. Installation of a single-span bridge can provide for free-flowing conditions at Dyke Bridge and volitional upstream fish passage, but would result in substantial inundation of land upstream from Dyke Bridge.

1.0 INTRODUCTION

The Maine Department of Transportation (MaineDOT) contracted with Stantec Consulting Services Inc. (Stantec) to perform hydrologic and hydraulic analyses to evaluate a range of bridge and/or culvert alternatives to replace the Dyke Bridge (#2246) and the Stride Bridge (#3973) over the Middle River in the vicinity of the Town of Machias, Maine. Dyke Bridge crosses the Middle River immediately landward of the confluence of the Middle River with the Machias River in the Town of Machias. Stride Bridge crosses the Middle River in the Town of Marshfield approximately 3 miles upstream from Dyke Bridge. The project location is depicted in Figure 1.

The objective of this study is to develop and evaluate a range of alternative bridge and/or culvert geometries at the two subject bridges, and the primary focus is to evaluate potential alternatives for replacement structures at the two subject bridges. The evaluation of replacement includes consideration of the existing tidal restriction associated with Dyke Bridge, which severely limits tidal flow landward from Dyke Bridge. This study evaluates a range of alternatives at Dyke Bridge and two alternatives at Stride Bridge. The evaluated alternatives at Dyke Bridge include:

- Alternative 1: No Action;
- Alternative 2 (baseline): Replacement In-Kind without restoration of tidal flow;
- Alternative 2 (variations) :Replacement In-Kind with the following variations;
  - Replacement In-Kind with partial restoration of tidal flow;
  - Replacement with partial restoration of tidal flow and provisions for fish passage;
- Alternative 3: Replacement with self-regulating tide gates (SRTs);
- Alternative 4: Replacement with "fish-friendly" SRTs;
- Alternative 5: Replacement with multiple adjacent culverts to restore tidal flow;
- Alternative 6: Replacement with a traditional span bridge; and
- Alternative 7: Replacement with a traditional span bridge with some adjacent culverts.

The evaluated alternatives at Stride Bridge include:

1. Concrete invert lining;
2. Slip-lining; and
3. Other alternatives to be determined.

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Prepared by ABC on 2014-00-00
Reviewed by ABC on 2015-00-00

00963_DykeBridge_LOC.mxd

Notes
1. Coordinate System: NAD 1983 UTM Zone 19N
2. Data Sources include:USGS Imagery/Topo provided by The National Map Mapping Service (http://basemap.nationalmap.gov/arcgis/services/USGSImageryTopo).

Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
1

Title
Project Location Map
7/1/2015

2.0 EXISTING CONDITIONS

2.1 DYKE BRIDGE

Dyke Bridge is located on U.S. Route 1 and consists of an embankment structure with four box culverts that are fitted with flap gates. The embankment has a length of over 1,000 feet (ft) and is constructed of timber cribbing with rubble and earthen fill. The four box culverts, constructed of timber and stone masonry, are approximately 80 ft long, 5 ft wide, 5 ft high, and have top-hinged flap gates installed on the seaward side of each of the four culverts. The culverts and flap gates are deteriorated. A combination of factors, including leakage through the flap gates and the causeway, result in landward flow into the Middle River during semi-diurnal flood tides. Dyke Bridge is shown in Figure 2 along with relevant adjacent features.

2.2 STRIDE BRIDGE

Stride Bridge is located on State Route 192 and consists of an earthen embankment with a 12.5-ft-diameter corrugated metal pipe culvert (CMP) with the ends coped to the roadway embankment. Stride Bridge is shown in Figure 3.

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Reviewed by MRC on 2015-02-23

00963_DykeBridge_Aerial.mxd

Notes
1. Coordinate System: NAD 1983 UTM Zone 19N
2. Aerial imagery provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).

Legend

⇄ Dominant Upland Flow

Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
2

Title
Dyke Bridge Aerial
7/1/2015

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00963_StrideBridge_Aerial.mxd

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Legend

⇄ Dominant Upland Flow

Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
3

Title
Stride Bridge Aerial
7/1/2015

2.3 HYDROLOGY

MaineDOT design guidelines recommend evaluating the following combinations of upland stream flows with selected tidal stages. The following combinations were modeled as part of this study:

a. Everyday Tides with 1.1-year river flow;

b. Everyday Tides with 50-year river flow;

c. 50-year Storm Surge with 1.1 year river flow;

d. Surge to be superimposed at mid-rising, high tide, mid-falling and low tides.

These conditions were modeled with the addition of 100-year upland flow with typical tides.

2.3.1 Upland Hydrology

Boundary condition data for upland flows in the Middle River at Stride Bridge and Dyke Bridge were provided by MaineDOT and are included as Appendix A. A summary of peak flow statistics is provided in Table 1.

Table 1: Peak Flows

Location	*Drainage Area (sq. mi.)*	*Return-Interval Event (Years)*/Peak Flow (cfs)							
		1.1	*2*	*5*	*10*	*25*	*50*	*100*	*500*
Stride Bridge	9.41	130	265	213	522	670	787	912	1,221
Dyke Bridge	13.22	152	297	452	565	715	832	958	1,264

For model simulations of storm surge, a steady state upland flow of 152 cubic feet per second (cfs) was used to model flow in the Middle River. For model simulations combining typical tide cycles (1.1-year tide) with higher upland flows (50- and 100-year), flow hydrographs were developed for the Middle River. Hydrograph time to peak was assumed to be 12 hours and recession time was assumed to be 24 hours. Peak stream flow was assumed to occur at about 12 hours before the highest tide in the 1.1-year tide hydrograph. Hydrograph shape was assumed to be triangular. These assumptions should be evaluated for appropriateness for final evaluation and design of a selected alternative for replacement of the culverts at Dyke Bridge.

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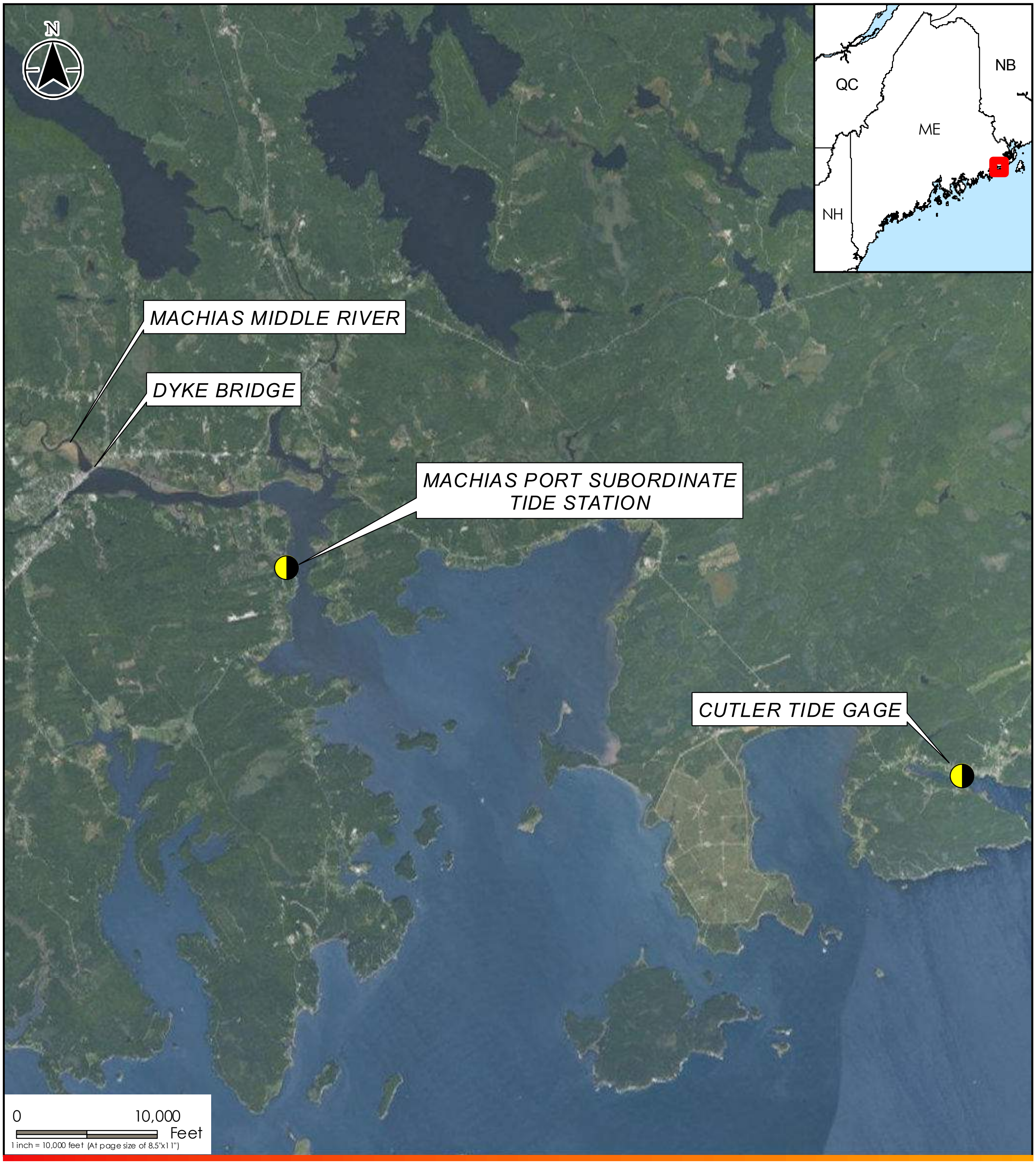

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00963_Gages.mxd

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2. Aerial imagery provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).

Legend

◐ Tide Gages

Client/Project

Maine DOT
Dyke Bridge
Machias, Maine

Figure No.

4

Title

NOAA Tide Stations

7/1/2015

2.3.2 Tidal Hydrology at Dyke Bridge

Sources of tide data used for this study include:

a. NOAA Recording tide gage data at Eastport, Cutler;

b. NOAA Predicted tide data at Subordinate Station on Machias River;

c. MaineDOT recorded data downstream of Dyke Bridge and Upstream of Dyke Bridge;

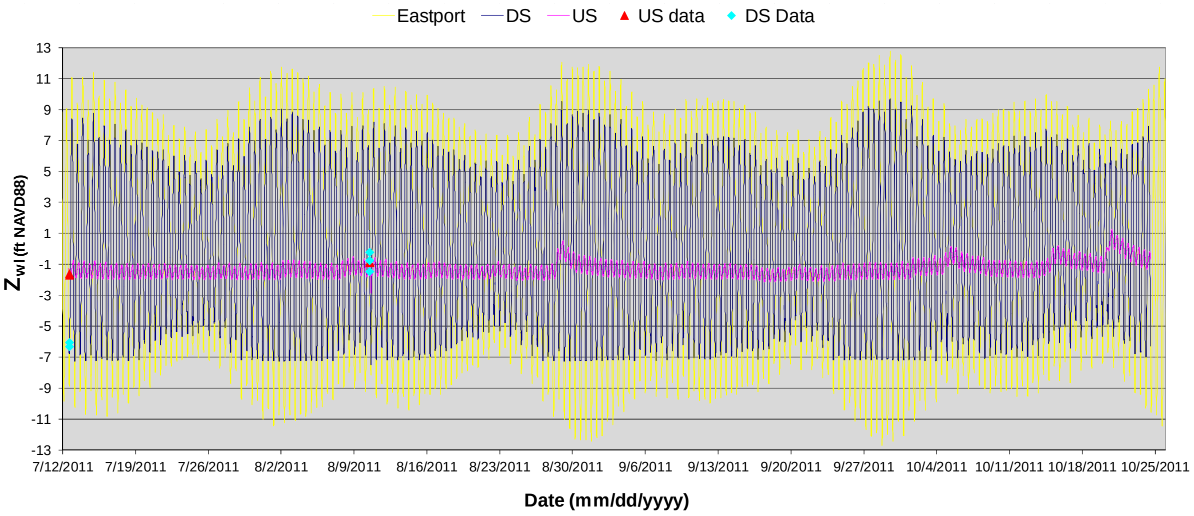
d. U.S. Army Corps of Engineers (USACE) Tidal Flood Profiles for Peak Storm Surge Elevations; and

e. MaineDOT provided guidance on calculation of surge hydrographs.

2.3.2.1 Recorded Tidal Stage Data- Project Data and NOAA Station Data

MaineDOT measured tidal stage data in the vicinity of Dyke Bridge in 2011 as part of this study. The tidal stage data were collected at two locations during the period from July 12, 2011, through October 24, 2011, using datalogging pressure transducers that recorded pressures at 5-minute intervals. The data were collected landward and seaward from Dyke Bridge in the Middle River and Machias River, respectively. These data were rectified by MaineDOT to the NAVD88 vertical datum in electronic file format and are plotted in Figure 5.

Figure 5: MaineDOT Tide Data, Downstream and Upstream of Dyke Bridge, July through October 2011



Tidal statistics were obtained for the tidal stage data collected in the Machias River seaward from Dyke Bridge by parsing-out the higher high tide, lower high tide, higher low tide, and lower low tide for the period from July 12, 2011, through October 24, 2011, using a parsing algorithm subroutine programmed in Visual Basic for Applications. Mean higher high water (MHHW) is calculated as the average of the higher high tide over each 24-hour period, and mean high water (MHW) is calculated as the average of the lower high tide over each 24-hour period. Mean low water (MLW) and mean lower low water (MLLW) area calculated as the average of the higher and lower (lowest) low tide over each 24-hour period. These site-specific calculations are compared to the predicted values of MHHW, MHW, MLW and MLLW at the Machiasport Tide Station and at the Cutler Tide Gage in Table 2, Table 3, and Table 4.

Review of Figure 5 indicates a low-end threshold for the data collected in the Machias River seaward from Dyke Bridge; this suggests that the datalogging pressure transducer was installed above the elevation of the lower low tides.

The parsed data was used to develop tidal statistics that are presented in Table 2, which includes the maximum, minimum, and average water surface elevations from the tidal stage data that was collected in the Machias River seaward from Dyke Bridge.

Table 2: Tidal Statistics from MaineDOT Data Set

Tidal Data (ft, NAVD88)						
Max.	**MHHW**	**MHW**	**Average**	**MLW**	**MLLW**	**Min.**
9.8	7.4	6.5	0.05	-6.4	-6.8	-7.5

Table 3 presents tidal statistics from National Oceanic and Atmospheric Administration tide stations at Eastport, Cutler Naval Base (Cutler), and Bar Harbor (Machias is located between Cutler and Bar Harbor along the coastline).

Table 3: Tidal Statistics from NOAA Stations

Station	Tidal Statistics (Elevation in feet)						
	MHHW	**MHW**	**NAVD88**	**MTL**	**MSL**	**MLW**	**MLLW**
Eastport	9.34’	8.86’	0’	-0.31’	-0.23’	-9.49’	-9.93’
Cutler	6.81’	6.39’	N/A	0.1’	0.0’	-6.37’	-6.75’
Bar Harbor	5.7’	5.28’	N/A	-0.1’	0.0’	-5.29’	-5.67’

Additional tidal data is available for Machias Port. This station is a subordinate tidal station, with predicted tides based on Eastport tides multiplied by 0.69.

Table 4: Tidal Statistics Predicted at Machias Port NOAA Subordinate Station

Station	Tidal Statistics (Elevations in feet)						
	MHHW	**MHW**	**NAVD88**	**MTL**	**MSL**	**MLW**	**MLLW**
Machias Port	6.45	6.11	0’	-0.21	-0.16’	-6.55	-6.85

Because the recorded data provided similar statistics to the NOAA station data at Cutler and Machiasport, the tidal data obtained by MaineDOT was used for stage boundary conditions at the downstream (seaward end) of the project for model runs where high upland flows were combined with normal tides, and where storm surge was added to typical tides.

2.3.2.2 Storm Surge Boundary Condition

A boundary condition representative of a Category 1 hurricane (approximately equivalent to a 50-year storm surge) is required for tidal bridge design and was developed for this study.

For the downstream storm surge boundary condition, an unsteady flow hydrograph representing a 50-year storm surge event was developed by combining typical tide data with predicted surge at Machias.

2.3.2.2.1 Daily Tide

Measured tide data in the Machias River immediately seaward from Dyke Bridge was obtained by MaineDOT from July 2011 through October of 2011. These data are in good agreement with predicted tide data from the referenced seaward locations, and were combined with a storm surge hydrograph to create a synthetic storm surge tide at the project site. Data from September 21 to 25, 2011 was used as a representative set of typical tide data. High tides ranged to a high of 7.3 ft and a low of -6.9 ft, and are in good agreement with the statistical MHHW and MLLW values of 7.4 ft and --6.8 ft computed for the data set (Table 2).

2.3.2.2.2 Storm Surge

The Maine coast experiences storm surge due to hurricanes and Nor'easter storms. MaineDOT recommends using a category 1 hurricane wind field to estimate a storm surge for a 50-year (2-percent annual return-interval) surge. This analysis is based on Phase III of Development of Hydraulic Computer Models to Analyze Tidal and Coastal Storm Hydraulic Conditions at Hydraulic Structures and two appendices – A: National Oceanic and Atmospheric Administration (NOAA) Predictions of Hurricane Properties and B- ADCIRC Station Results (Phase III Report). For this project, MaineDOT provided a spreadsheet for converting peak surge levels to a hurricane-type surge hydrograph.

ADCIRC predicted surge levels for Machias Bay as follows:

- 50-year surge: 2.16 ft. Hydrograph duration 15 hours
- 100-year surge: 2.79 ft. Hydrograph duration 15 hours

Section 2.1 of the Phase III Report predicts a maximum surge of 2.5 ft. This is based on a Radius of Maximum Winds of 51 nm and forward speed of 54 knots for 95% of storms in Downeast Maine. With a D value of 0.94, a resulting maximum surge level of 2.5 is calculated.

The maximum recorded surge at Cutler is 2.466 ft with a surge duration of 17 hours. The maximum recorded surge at Eastport is 2.523 ft.

2.3.2.2.3 Combined Peak Surge Plus Tide Data

The following list summarizes available information on storm tides, combined surge statistics (typical tide plus surge), and recorded high tide events at locations near the project area (Table 5).

- USACE 2012 Tidal Flood Profiles.
  - Eastport: 50-year 14.3 ft NAVD88
  - Machias Port: 50-year (Eastport multiplied by 0.69) 9.9 ft NAVD88
  - Cutler: 50-year 10.8 ft NAVD88
- FEMA Flood Insurance Study of Machias.
  - 100-year: 11.8 ft NAVD88
  - 100-year map, 1988, 12.5 ft NGVD29[1], 11.8 ft NAVD88
  - Based on outdated USACE Tidal Flood Profiles
- USACE Tidal Flood Profiles 2012 at Cutler:
  - 50-year 10.5 ft NAVD88
  - 100-year 10.8 ft NAVD88

Table 5: Recorded Highest Tides at Cutler NOAA Gage and Machias (Data from MaineDOT)

Date	Machias	Cutler
9/28/2011	9.55	9.9
9/29/2011	9.71	10.14
10/28/2011		10.7

---

[1] National Geodetic Vertical Datum of 1929

3.0 HEC-RAS HYDRAULIC MODEL

A one-dimensional, unsteady-state numerical hydraulic model was developed using the USACE HEC-RAS (versions 4.1 and 5.0 [beta]). HEC-RAS version 5.0 (beta) was used for project work beginning in April of 2015 at the suggestion of MaineDOT as this version of HEC-RAS includes automated routines for modeling flap gates. The hydraulic model was developed using information obtained from MaineDOT and other sources.

3.1 GEOMETRIC DATA

Geometric data for the revised HEC-RAS model was developed using topographic data provided by MaineDOT along with a limited number of bathymetric transects surveyed by MaineDOT. The layout of the HEC-RAS model domain is depicted in Figure 6, and Figure 7 depicts the geometric domain with color shading and the existing area that is normally wetted based on interpretation of aerial photography.

The HEC-RAS model domain was developed using the HEC-GeoRAS Geographic Information System (GIS) extension in ESRI ARC GIS software. The basis for this model was Lidar data provided by MaineDOT, which is depicted as the gray-shaded area in Figure 6. The Lidar data did not provide elevation coverage in persistently wetted areas landward (upstream) from Dyke Bridge. Bathymetric transects obtained by MaineDOT were therefore used to augment the Lidar data.

The GIS model was also used to develop an area-elevation dataset for the reach of the Middle River between Stride Bridge and Dyke Bridge. This curve is provided in Appendix B.

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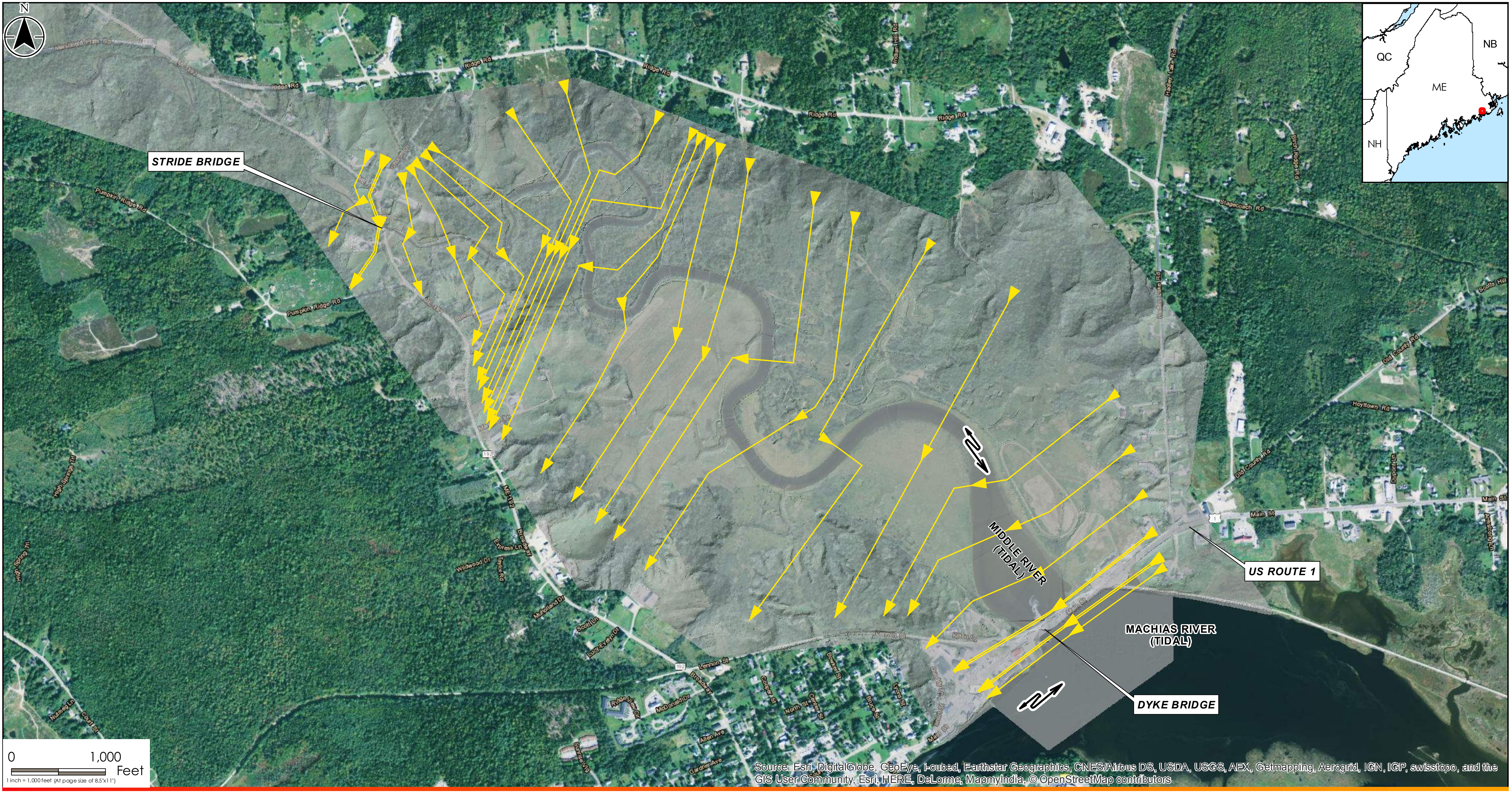

Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors

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Prepared by EPL on 2015-02-23
Reviewed by MRC on 2015-02-23

00963_DykeBridge11x17.mxd

Legend

▶▶▶	Cross Sections
▨	Maine DOT TIN Surface
⇄	Dominant Upland Flow

Notes

1. Coordinate System: NAD 1983 UTM Zone 19N FT
2. Aerial imagery provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).
3. TIN Surface information is based on survey data provided by the Maine Department of Transporation.

Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
6

Title
HEC-RAS Model Domain

7/1/2015

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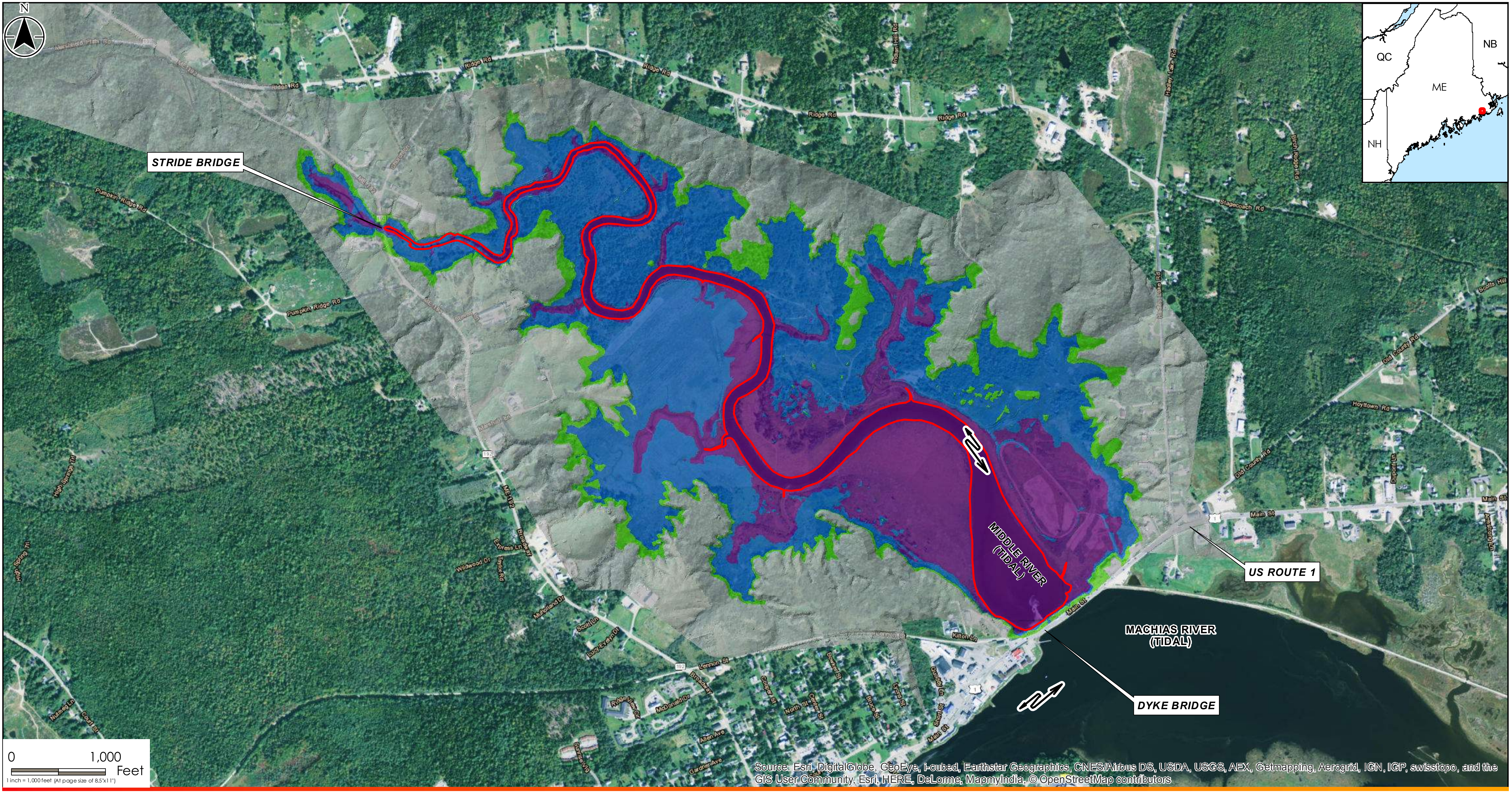

Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors

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Prepared by EPL on 2015-02-23
Reviewed by MRC on 2015-02-23

00963_DykeBridge11x17_elev.mxd

Legend
Water Surface Elevation (ft)

🟪	< 4
🟦	4 - 8
🟩	8 - 12
⬜	>12
—	Inundated Area
⇄	Dominant Upland Flow

Notes
1. Coordinate System: NAD 1983 UTM Zone 19N FT
2. Vertical Datum: NAVD88
3. Aerial imagery provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).
4. TIN Surface information is based on survey data provided by the Maine Department of Transporation.

Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
7

Title
Elevation Map

7/1/2015

3.2 BOUNDARY CONDITIONS

The following combinations of upland flow and tidal stage were selected for the hydraulic model at Dyke Bridge and Stride Bridge.

- Typical tides with 1.1-year river flow, upland flow modeled as steady state flow.
- Typical tides with 50-year river return-interval flow with the riverine flow hydrograph modeled as triangular hydrograph with 12 hour time to peak.
- Typical tides with 100-year return-interval flow with the riverine flow hydrograph modeled as triangular hydrograph with 12 hour time to peak.
- 50-year storm surge with 1.1 year river flow.
- Surge to be superimposed at mid-rising, high tide, mid-falling and low tides.

3.2.1 Middle River (Upland Flow)

Riverine peak flows in the Middle River were provided by MaineDOT and are included in Table 6. For this project, and to simplify boundary conditions, only the flows predicted for Dyke Bridge were used in the model, but were used as the boundary condition at the upstream end of the model upstream from Stride Bridge. This assumption and development and use of suitable upland flow hydrographs should be incorporated into final design analyses.

Table 6: Riverine Peak Flows in Middle River

Location	1.1-Year Return-Interval (cfs)	50- Year Return-Interval (cfs)	100- Year Return-Interval (cfs)
Stride Bridge	130	787	912
Dyke Bridge	152	832	958

3.2.2 Tidal Stage

3.2.2.1 Typical Tides

Typical (“everyday”) tide hydrographs are based on data recorded by MaineDOT from July 2011 to October of 2011 in the Machias River immediately seaward from Dyke Bridge. The data show a highest recorded tide elevation of 9.7 ft on September 29, 2011. At that time, the Cutler gage recorded an elevation of 10.1 ft.

Table 7: Summary of Tide Stage Information

Tide Stage/Date	Recorded at Machias (ft, NAVD88)	Cutler gage (ft, NAVD88)
MHHW	7.4	6.8
MHW	6.5	6.4
MLW	-6.5	-6.4
MLLW	-6.8	-6.8
lowest	-7.5	not applicable
9/24/2011	7.4	7.3
9/28/2011	9.55	9.9
9/29/2011	9.71	10.14
10/28/2011		10.7

3.2.2.2 Combinations of Riverine Peak Flows and Typical Tides

Riverine peak flows were combined with typical high tides as recorded in the MaineDOT data. An example of this combination is in HEC-RAS Plan No. 24, which models the existing culverts at Dyke Bridge and Stride Bridge, and imposes a 50-year peak flow hydrograph on a high tide. The 50-year return-interval hydrograph peak flow of 832 cfs passes Stride Bridge at 12:35 on 14 July, 2011. Corresponding water levels at Dyke Bridge are presented in Table 8.

Table 8: Combinations of Peak Upland Flows and Typical Tides at Dyke Bridge

Date and Time	High Water Level (ft, NAVD88)	50- Year Return-Interval Peak Flow (cfs)
July 14, 2011 at 22:25	8.4	832
July 14, 2011 at 10:35	7.0	832
July 14, 2011 at 23:05	8.8	832

Tidal and upland flow hydrographs were combined with that same timing. This combination should be reviewed for final design.

3.2.2.3 Combination of 1.1-year Riverine Peak Flow with Storm Surge Tides

For this study, the MHHW value for the MaineDOT recorded normal tide data downstream of Dyke Bridge was combined with a peak surge of 2.5 ft, with the following high and low values associated with timing of peak surge and tides. These tidal conditions were modeled with the 1.1-year return-interval peak flow (152 cfs) as the inflow (upstream) boundary condition. A precise recurrence interval has not been assigned to this surge level, but the difference between a 50-year and 100-year surge in this area is a few tenths of a foot. Based on data outlined in

Section 2.3.2.2.3, this tidal peak elevation should be reviewed for final design. The data suggests a value between 9.8 ft and 10.8 ft when the peak surge coincides with the peak high tide.

Table 9: Combinations of Upland Flow with Storm Surge Tides

Timing of Peak Surge	High Water Level (ft, NAVD88)	Low Water Level Before Peak Surge (ft, NAVD88)
Mid-Rising	8.0	-7.0
High Tide	9.8	-7.0
Mid-Falling	8.0	-7.0
Low-Tide	7.8	-7.0

4.0 MODEL BOUNDARY CONDITIONS

This section presents boundary condition scenarios requested by MaineDOT for evaluation with the study hydraulic model.

4.1 STEADY-STATE BOUNDARY CONDITIONS

Steady-state boundary conditions were modeled with specified inflow (upstream) boundary conditions and specified water surface elevations at the downstream (seaward) boundary condition. Steady-state boundary conditions are presented in Table 10.

Table 10: Steady-State Boundary Conditions

Case	Upland Runoff (Return-Interval Event)	Downstream (fixed stage)	Comments
Case 1	50-Year	MHW	-Gates assumed fully open. (4 ft height). Upstream elevation would be 9.9 ft. Upstream of Stride Bridge, the modeled elevation is 11.0 ft.
Case 2	50-Year	MLW	The applied water surface elevation for MLW is expected to result in very high calculated flow speeds for the span bridge alternatives at Dyke Bridge because the upstream channel elevation is well above the MLW elevation. Upstream of Dyke Bridge, water surface elevation would be 1.4 ft and 7.3 ft upstream of Stride Bridge.

Based on review of information, including the area-elevation curve that was developed as part of this project for the reach of the Middle River between Stride Bridge and Dyke Bridge and the HEC-RAS model results, it was determined that steady-state hydraulic analyses are of little practical utility for this study. The basis for this determination is that there is substantial hydrologic storage in the reach of the Middle River between the two project bridges relative to the volume of upland runoff hydrographs in the Middle River. This finding was validated as part of this study by 1) steady-state model simulations that depict overtopping of Dyke Bridge during moderate upland runoff flow events that predict overtopping of Dyke Bridge, and 2) unsteady-state model simulations with upland runoff hydrographs that do not result in overtopping of Dyke Bridge. The question of whether Dyke Bridge has been overtopped was discussed with MaineDOT during project meetings, and MaineDOT indicated that they are not aware of upland runoff events having resulted in overtopping of Dyke Bridge.

4.2 UNSTEADY-STATE BOUNDARY CONDITIONS

Unsteady-state boundary conditions were used for hydraulic model evaluations using the project HEC-RAS model. Unsteady-state boundary conditions are presented in Table 11. As noted in Section 4.1, trial runs using upland peak flows as a steady state input resulted in unrealistically high water surface elevations that do not account for storage along the reach of the Middle River between the two bridges. For this reason, upland flows were modeled as triangular hydrographs that were developed based on professional judgment.

Table 11: Unsteady-State Boundary Conditions

Case	Upland Runoff (Return-Interval Event)	Tidal Regime	Comments
Q1T1	1.1-Year-steady flow	Recorded Tides +9.0/-7.5	
Q50T1	50-Year-Hydrograph, peak = 824 cfs	Recorded Tides	Peak upland flow occurs at tides in range of 7.0 ft to 8.8 ft.
Q100T1	100-Year-Hydrograph = 958 cfs	Recorded Tides	Peak upland flow occurs at tides in range of 7.0 ft to 8.8 ft.
Q1T50M	1.1-Year	Category 1 Hurricane (2.5 ft peak)_ +9.8 ft /-6.9 ft	Peak of storm surge at mid-rising tide (8.0 ft)
Q1T50H	1.1-Year	Category 1 Hurricane (2.5 ft peak)	Peak of storm surge at high tide (9.8 ft)
Q1T50M	1.1-Year	Category 1 Hurricane – (2.5 ft peak)	Peak of storm surge at mid-falling tide (8.0 ft)
Q1T50L	1.1-Year	Category 1 Hurricane – (2.5 ft peak)	Peak of storm surge at low tide (7.8 ft)

4.3 SEA-LEVEL RISE SCENARIOS

Three sea-level rise (SLR) scenarios were evaluated for selected model simulations, including:

1) Current MHHW conditions;
2) Design Year (current) MHHW with Moderate (0.5 meter [1.64 ft]) SLR; and
3) Design Year (current) MHHW with High (1.0 meter [3.28 ft]) SLR.

5.0 PRELIMINARY EVALUATIONS – TYPICAL TIDES

This section presents information on the evaluation of project alternatives with typical tides and low streamflows in the Middle River as represented by tidal stage data collected by MaineDOT and a flow of 20 cfs in the Middle River, respectively.

5.1 EXISTING CONDITIONS AND REPLACEMENT IN-KIND

Hydraulic conditions at Dyke Bridge were evaluated for existing conditions (Alternative 1) and for replacement in-kind (Alternative 2). The objectives of these evaluations included:

1) Calibration and validation of the hydraulic model for existing conditions; and
2) Evaluation of replacement in-kind (i.e., with four 5 ft by 5 ft flap gates).

These evaluations were performed using tidal stage data collected by MaineDOT and an assumed normal upland flow in the Middle River of 20 cfs.

5.1.1 Alternative 1 - Existing Conditions

Existing conditions at Dyke Bridge were modeled in HEC-RAS using gates and operational rules. The use of gates and operational rules precludes modeling of culverts in combination with gates in HEC-RAS. The modeled approach therefore does not include effects of flow through culverts and gates; it solely evaluates hydraulic parameters (e.g., conveyance, losses) at the gate. This approach is analogous to flow through on overly-large culvert (i.e., losses are minimal and can be discounted) with a controlled gate at one end. This approach was used early in the project because HEC-RAS 4.1 did not include an option for modeling flap gates (Plan No. 87).

The existing Dyke Bridge culverts include four 5 ft by 5 ft wood and masonry box culverts with flap gates. Based on review of survey data provided by MaineDOT, including elevations of the culvert inverts and tidal stage data collected landward and seaward from Dyke Bridge, and preliminary model simulation, the existing culverts were modeled with heights of 4 ft and minimum gate openings of 0.35 ft. The reduced gate heights were used to address apparent blockage in the bottoms of the culverts as determined from bridge inspection reports provided by MaineDOT. The minimum gate opening was used to provide for landward flow during flood tides, which is apparent in visual observations and tidal stage data collected by MaineDOT in the Middle River landward from Dyke Bridge. The culverts and flap gates were modeled as sluice gates in HEC-RAS using operational rules programmed in the HEC-RAS unsteady-flow rules editor.

5.1.1.1 Existing Conditions Without Gate Operations

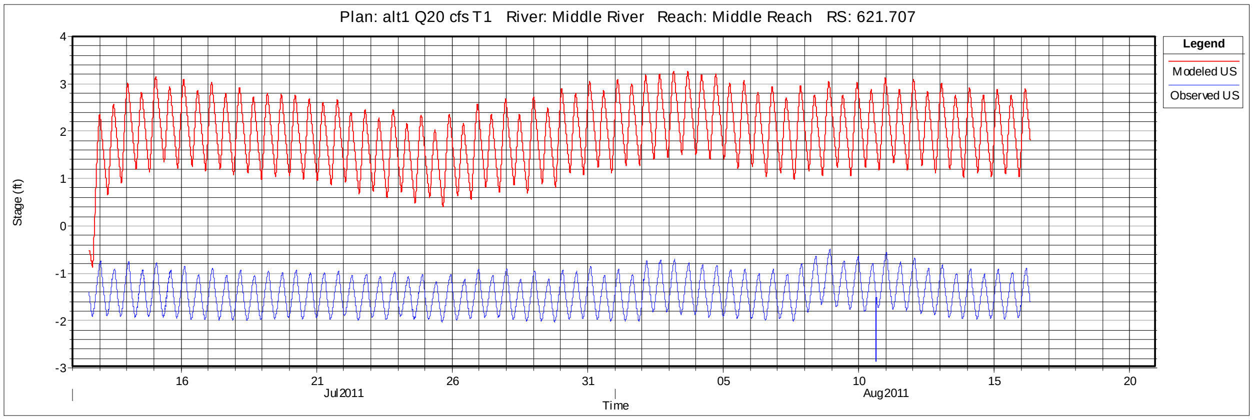
Existing conditions were initially evaluated without operational rules and the four gates set in the “open” position. Under this condition, the equilibrium water level in the landward reach of the

Middle River is simulated as the approximate average of the high and low water conditions (Plan No. 86).

This simulation reflects conditions that would result from removal or failure of the tide gates. Results of this simulation, including measured (“Observed US[2]”) and simulated (“Modeled US”) water surface elevations in the Middle River landward from Dyke Bridge, are depicted in Figure 8. It is apparent in this figure that removal or failure of the tide gates would increase in daily water surface elevations by up to 5 ft in the Middle River upstream from Dyke Bridge during typical tides with an upland flow in the Middle River of 20 cfs. The increase in water surface elevations by 5 ft reflects the difference between the maximum elevation of typical tides (elevation -1 ft) and the predicted maximum elevation of approximately 4 ft for typical tides.

Figure 9 presents the measured tidal stage data seaward from Dyke Bridge (“Observed DS[3]”) and the simulated water surface elevations landward from Dyke Bridge (“Modeled US”).

Figure 8: Alternative 1 (Existing Conditions) W/O Gate Operations (Measured and Simulated Water Surface Elevation Landward from Dyke Bridge)



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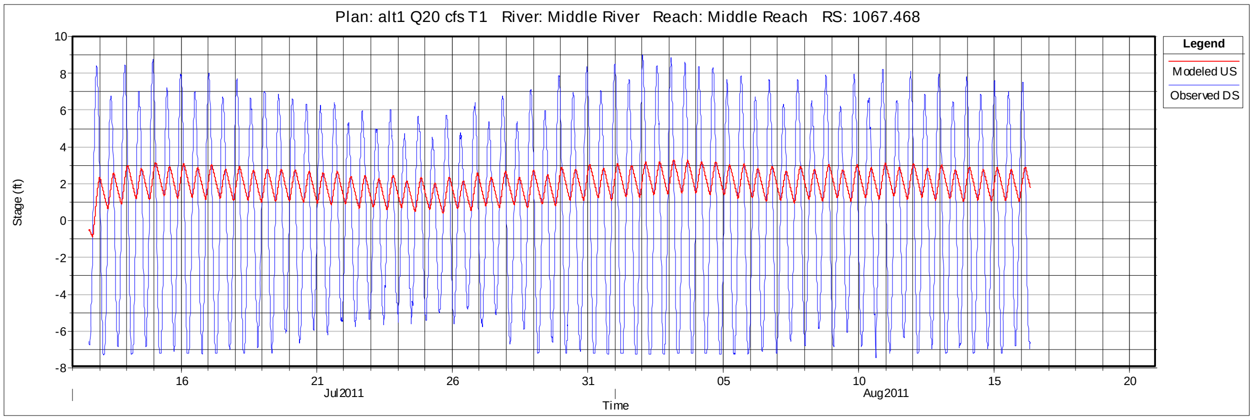
[2] “US” is used as an abbreviation for “upstream” (landward) from Dyke Bridge.
[3] “DS” is used as an abbreviation for “downstream” (seaward) from Dyke Bridge.

Figure 9: Alternative 1 (Existing Conditions) W/O Gate Operations (Simulated Landward and Measured Seaward Water Surface Elevations)



5.1.1.2 Existing Conditions With Gate Operations

Existing conditions were simulated using the HEC-RAS unsteady-flow rules option to reflect operation of the existing flapper gates and represents calibration of this model scenario to existing conditions (Plan No. 87). These rules were programmed as internal boundary conditions in HEC-RAS. The programmed rules were set to operate the four existing flap gates according to the same rules. The analysis for existing conditions with gate operations used a minimum gate opening of 0.35 ft to account for leakage through the existing gates and the causeway.

The rules for the existing conditions evaluation are shown in Figure 10. Figure 11 presents the simulated water surface elevations ("Modeled US") relative to the measured stage ("Observed US") landward from Dyke Bridge as measured by MaineDOT. The predicted water surface elevations range from approximately -2.0 ft to -0.7 ft for a period of time when data obtained by MaineDOT indicates water surface elevations of approximately -2.0 ft to -0.8 ft.

Table 12 presents invert information for the 4 existing box culverts.

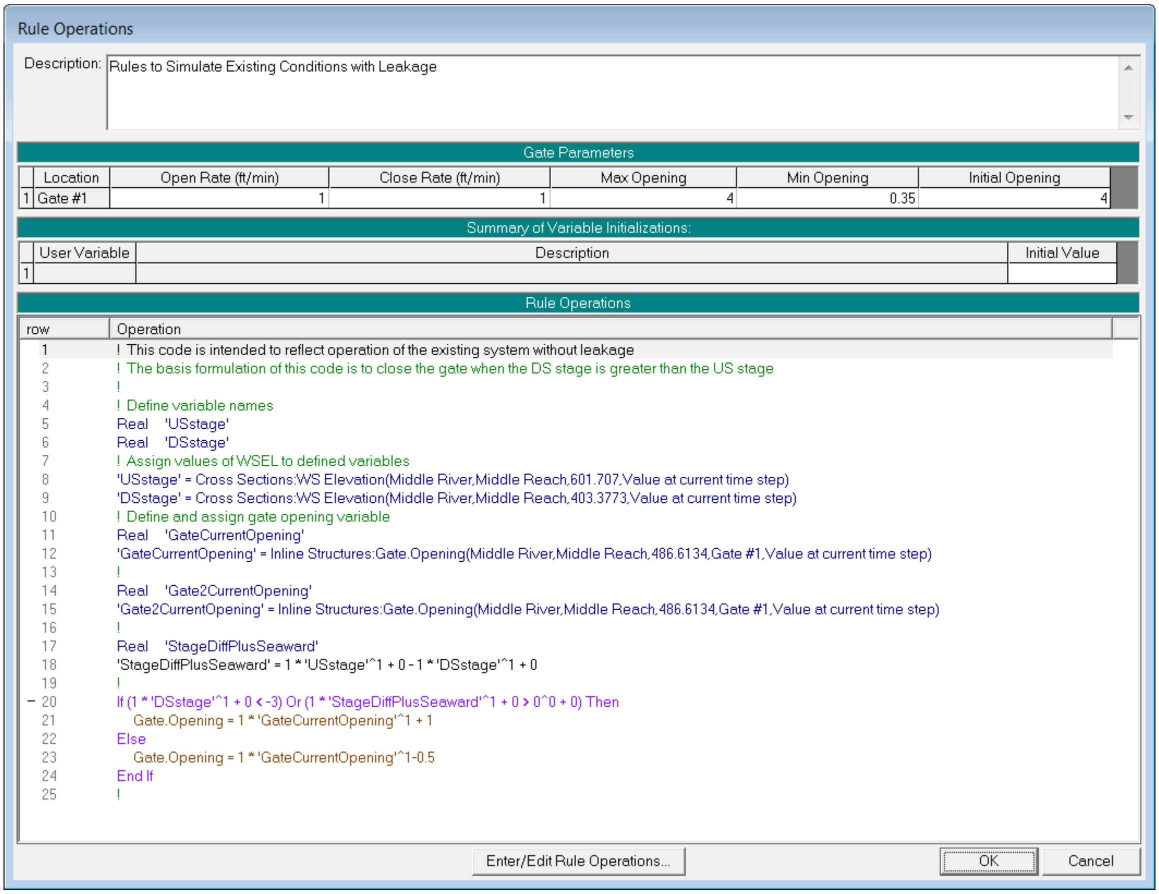
Table 12: Dyke Bridge Culvert Box Inverts

Location	Culvert	DS Invert	DS (Prev)	US (Prev)
east	Culvert #1	-4.0	-0.38	-3.8
center-east	Culvert #2	-4.0	-4.2	-4.2
center-west	Culvert #3	-4.5	-4.7	-4.7
west	Culvert #4	-3.6	-4.4	-4.4
	average	***-4.1***	***-3.4***	***-4.3***

Following review of the tidal stage data collected by MaineDOT and the reported invert elevations, it is apparent that debris likely limits outflow from the landward reach of the Middle

River. To accommodate debris, the modeled invert for existing conditions was set at an elevation of -3.1 ft, which is approximately 1 ft higher than the average invert elevation of the four culverts. The culvert height was reduced to 4 ft for this analysis to accommodate the apparent partial occlusion in the culverts.

Figure 10: Existing Conditions Rules



Description: Rules to Simulate Existing Conditions with Leakage

Gate Parameters

	Location	Open Rate (ft/min)	Close Rate (ft/min)	Max Opening	Min Opening	Initial Opening
1	Gate #1	1	1	4	0.35	4

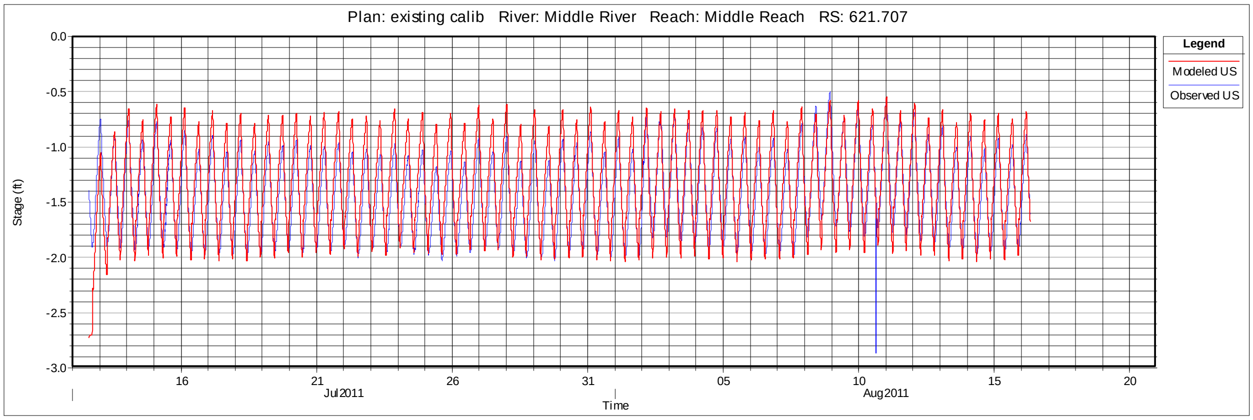
Summary of Variable Initializations:

	User Variable	Description	Initial Value
1			

Rule Operations

```
! This code is intended to reflect operation of the existing system without leakage
! The basis formulation of this code is to close the gate when the DS stage is greater than the US stage
!
! Define variable names
Real    'USstage'
Real    'DSstage'
! Assign values of WSEL to defined variables
'USstage' = Cross Sections:WS Elevation(Middle River,Middle Reach,601.707,Value at current time step)
'DSstage' = Cross Sections:WS Elevation(Middle River,Middle Reach,403.3773,Value at current time step)
! Define and assign gate opening variable
Real    'GateCurrentOpening'
'GateCurrentOpening' = Inline Structures:Gate.Opening(Middle River,Middle Reach,486.6134,Gate #1,Value at current time step)
!
Real    'Gate2CurrentOpening'
'Gate2CurrentOpening' = Inline Structures:Gate.Opening(Middle River,Middle Reach,486.6134,Gate #1,Value at current time step)
!
Real    'StageDiffPlusSeaward'
'StageDiffPlusSeaward' = 1 * 'USstage'^1 + 0 - 1 * 'DSstage'^1 + 0
!
If (1 * 'DSstage'^1 + 0 < -3) Or (1 * 'StageDiffPlusSeaward'^1 + 0 > 0^0 + 0) Then
   Gate.Opening = 1 * 'GateCurrentOpening'^1 + 1
Else
   Gate.Opening = 1 * 'GateCurrentOpening'^1-0.5
End If
!
```

Figure 11: Alternative 1 (Existing Conditions) with Gate Operations (Simulated and Observed)



5.1.2 Alternative 2 – Replacement In-Kind

Replacement in-kind with flap gates on four culverts was evaluated along with variations of replacement in-kind that evaluated eliminating flap gates on some of the culverts.

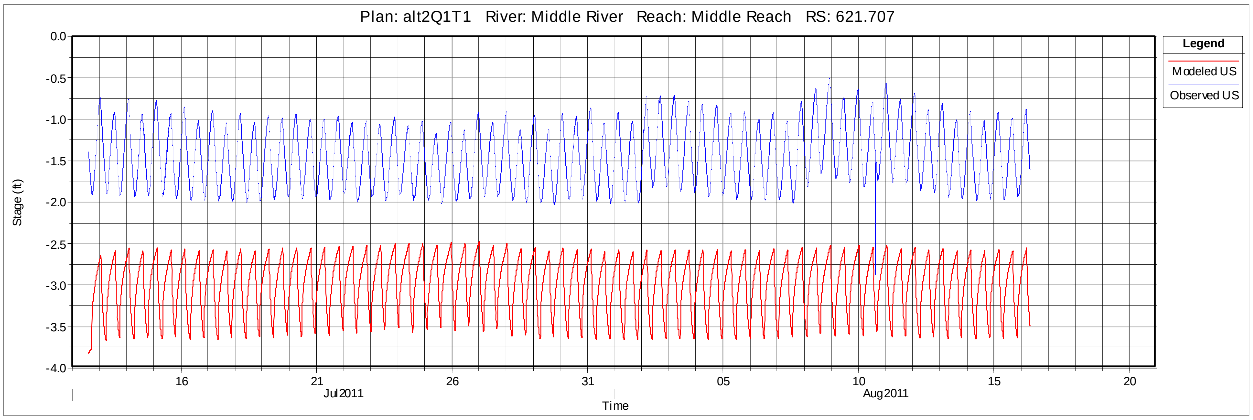
5.1.2.1 Replacement In-Kind (Plan No. 13[4])

Alternative 2 reflects in-kind replacement of the existing culvert and gate system. The model setup for this alternative did not include a minimum gate setting to account for leakage through the gates or the causeway. A pronounced effect of this simulation results from the lack of landward tidal flow, which results in very small semi-diurnal variation in stage that results from riverine inflows into the “impoundment” when the tide gates are “closed.” These conditions were simulated with upland flow of 20 cfs and typical tides represented using tidal stage data collected by MaineDOT seaward from Dyke Bridge in the Machias River.

---

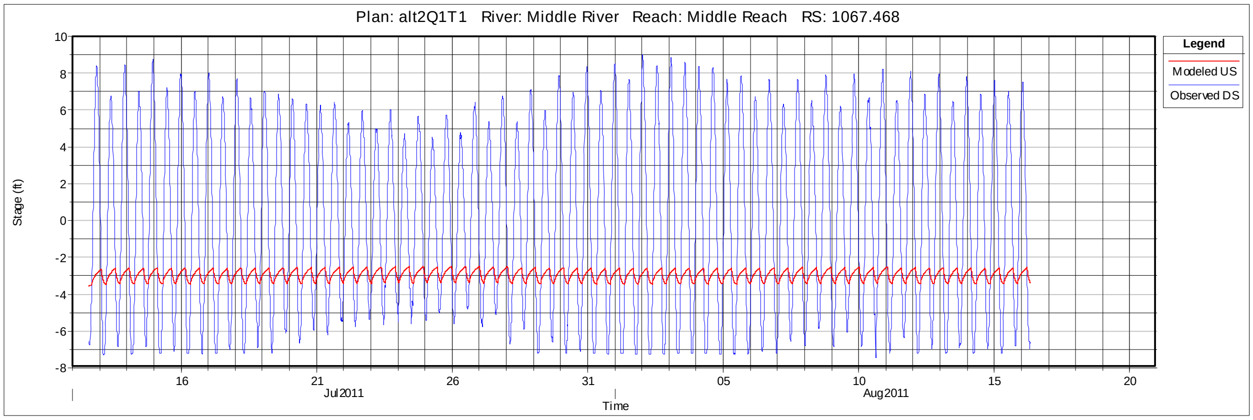
[4] This HEC-RAS model simulation was performed using Plan No. 13, which is setup to model the 1.1-year, return-interval flow with the inflow boundary condition changed from 151.6 cfs to 20 cfs for this simulation only.

Figure 12: Alternative 2 (Replacement In-Kind) (Simulated [Landward] and Observed [Landward])



Modeling of this alternative was performed using the invert elevations provided by MaineDOT with gate heights of 5 ft. For the MaineDOT recorded tide data, downstream of Dyke Bridge elevations vary from 9.0 ft to -7.5 ft. Upstream of Dyke Bridge, the simulated tidal elevations in the Middle River landward from Dyke Bridge range from -3.3 ft to -2.5 ft. The lower water surface elevations immediately landward from Dyke Bridge eliminate tidally-influenced changes in water surface elevations at Stride Bridge.

Figure 13: Alternative 2 (Replacement In-Kind) (Simulated and Observed, Landward and Seaward)



5.1.3 Replacement In-Kind With Variations for Flap Gate Operations

Replacement in-kind with variations for operations of flap gates were evaluated as a means to provide for improved upstream fish passage at Dyke Bridge. The objective of the modeled variations on Alternative 2 is to evaluate the potential to provide for landward flow at Dyke Bridge during the flood tide through culverts without gates. The modeled Alternative 2 variations include:

a. Five 5 ft x 5 ft culverts with flap gates on four of the culverts (Plan No. 82). Results of this simulation that include the observed upstream tide data are presented in Figure 14;

b. Four 5 ft x 5 ft culverts with flap gates on three of the culverts (Plan No. 83). Results of this simulation that include the observed upstream tide data are presented in Figure 15; and

c. Four 5 ft x 5 ft culverts with flap gates on two of the culverts (Plan No. 27). Results of this simulation that include the observed upstream tide data are presented in Figure 16.

Summary tables with the results of these simulations are included in Section 6.0.

The model simulation results with five box culverts with four flap gates (Figure 14) and four box culverts with three flap gates (Figure 15) are similar, and would result in maximum typical water surface elevations landward from Dyke Bridge that are approximately 1.5 ft to 2 ft higher (typical high tide elevations are approximately 0.5 ft and 1 ft, respectively) than current conditions (existing typical high tide elevation is approximately -1 ft). The low tide simulation results indicate that the alternative with five box culverts would result in low tide water surface elevations that are similar to existing conditions, whereas the simulation results with four box culverts indicate that low tide water surface elevations would be approximately 1 ft higher. The lower low tide elevations result from the increased capacity of the five culverts to discharge flow seaward during the ebb tide relative to the capacity of the single open culvert to provide for landward flow. A criteria for evaluating these alternatives is the ratio of culverts with landward conveyance and seaward conveyance, which is 0.2 for the alternative with five box culverts and four flap gates and 0.25 for the alternative with four box culverts and three flap gates.

The model simulation results with four box culverts and two flap gates (Figure 16), and has a ratio of culverts with landward conveyance and seaward conveyance of 0.5. The maximum typical high tide elevations for this alternative are approximately 3 ft higher (typical high tide elevation is approximately 2 ft) than existing conditions (existing typical high tide elevation is approximately -1 ft) and the low tide elevations are marginally higher than the maximum typical high tide elevations.

Figure 17 depicts approximate contour lines and shading associated with the maximum typical tidal water surface elevations in the Middle River landward from Dyke Bridge for these three variations of Alternative 2, including contour lines at elevations of 1 ft and 2 ft and a change in shading at an elevation of 4 ft. For reference, this figure also includes the area that is currently wetted during typical tidal conditions (approximate elevation of -1 ft). Note that the terrain data used to develop this figure (Lidar data provided by MaineDOT) did not include bathymetric data, and contour lines that extend across the channel of the Middle River are not accurate.

Figure 14: Five 5 ft x 5 ft Culverts with Flap Gates on Four Culverts (One Open)

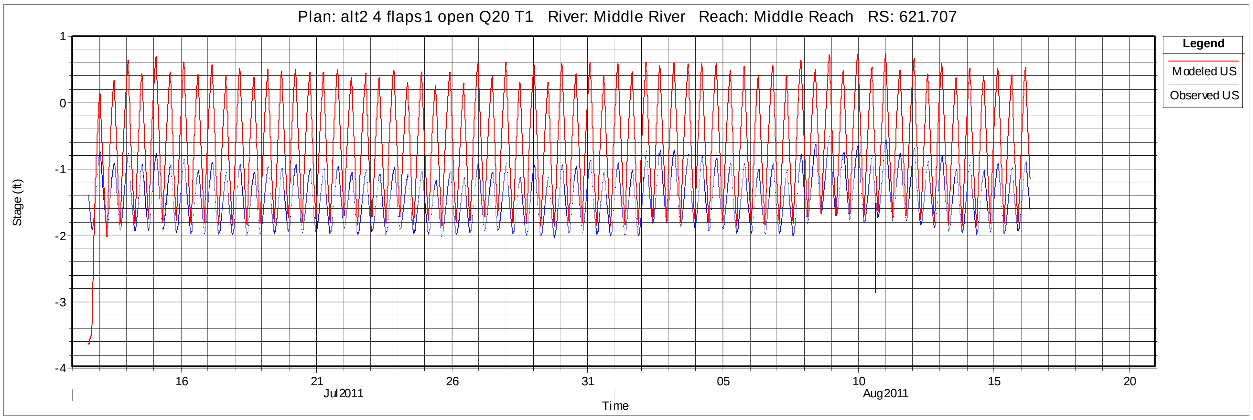


Figure 15: Four 5 ft x 5 ft Culverts with Flap Gates on Three Culverts (One Open)

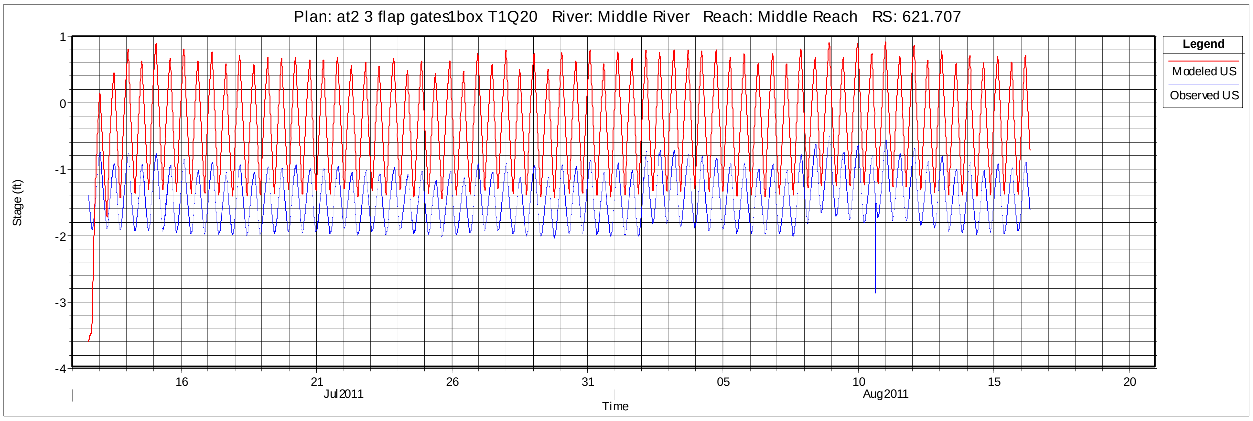
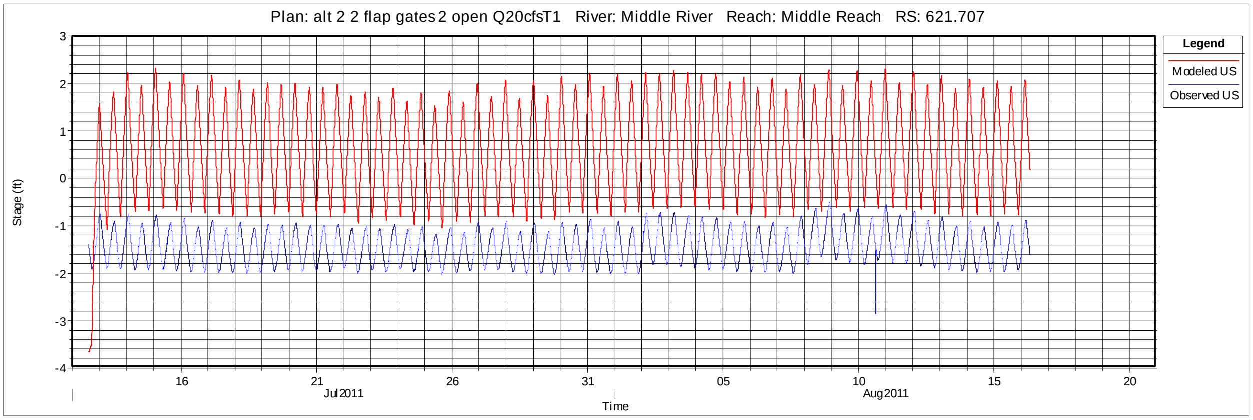
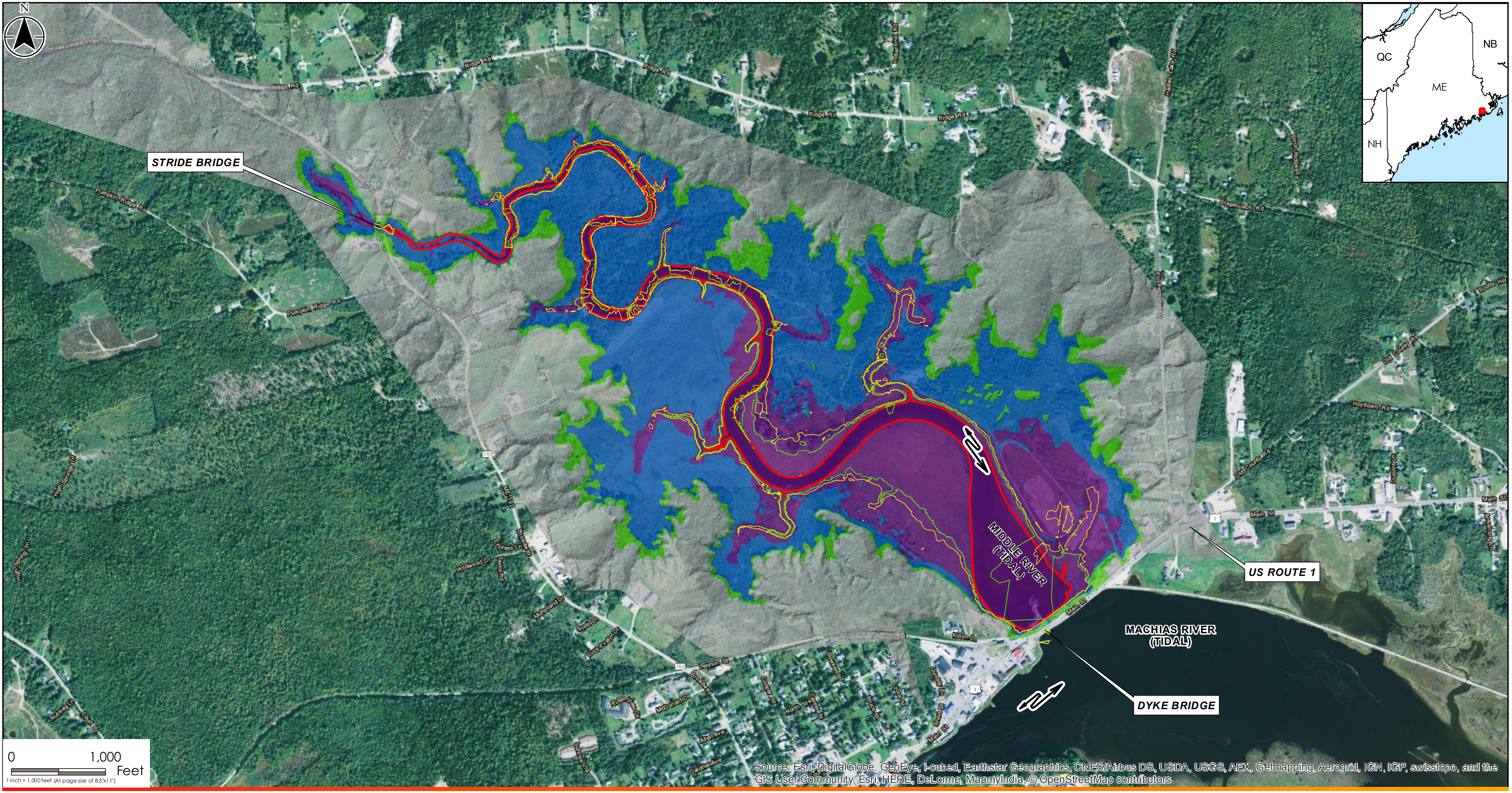


Figure 16: Four 5 ft x 5 ft Culverts with Flap Gates on Two the Culverts (Two Open)



\\us1241-f01\workgroup\1956\active\195600963\drawing\mxd\00963_DykeBridge11x17_cont.mxd Revised: 2015-07-01 By: ele



Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors

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Prepared by EPL on 2015-02-23
Reviewed by MRC on 2015-02-23

00963_DykeBridge11x17_cont.mxd

Legend

Water Surface Elevation (ft)

- 🟪 < 4
- 🟦 4 - 8
- 🟩 8 - 12
- ⬜ >12
- ⇄ Dominant Upland Flow
- ― Inundated Area
- ― 1' Contour
- ― 2' Contour

Notes

1. Coordinate System: NAD 1983 UTM Zone 19N FT
2. Vertical Datum: NAVD88
3. Aerial imagery provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).
4. TIN Surface information is based on survey data provided by the Maine Department of Transporation.

Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
17

Title
Contour Map

7/1/2015

5.2 SELF-REGULATING TIDE GATES

This section presents information on potential alternatives with self-regulating tide gates (SRTs).

5.2.1 Alternative 3 – SRT without Fish Passage

Alternative 3 reflects SRTs without provisions for upstream fish passage. This alternative could be implemented with a single large SRT or with multiple smaller SRTs. This alternative was not evaluated with the hydraulic model following review of SRT technologies as part of this alternative (reference Appendix C).

5.2.2 Alternative 4 – SRT with Fish Passage

Alternative 4 reflects SRTs with provisions for upstream fish passage. This alternative could be implemented with a single large SRT that would be operated to allow for upstream fish passage, multiple smaller SRTs that could be operated individually or collectively to provide for upstream fish passage, or single or multiple SRTs along with an ungated (free-flowing) culvert that would be intended to provide for upstream fish passage. This alternative was not evaluated with the hydraulic model following review of SRT technologies as part of this alternative (reference Appendix C).

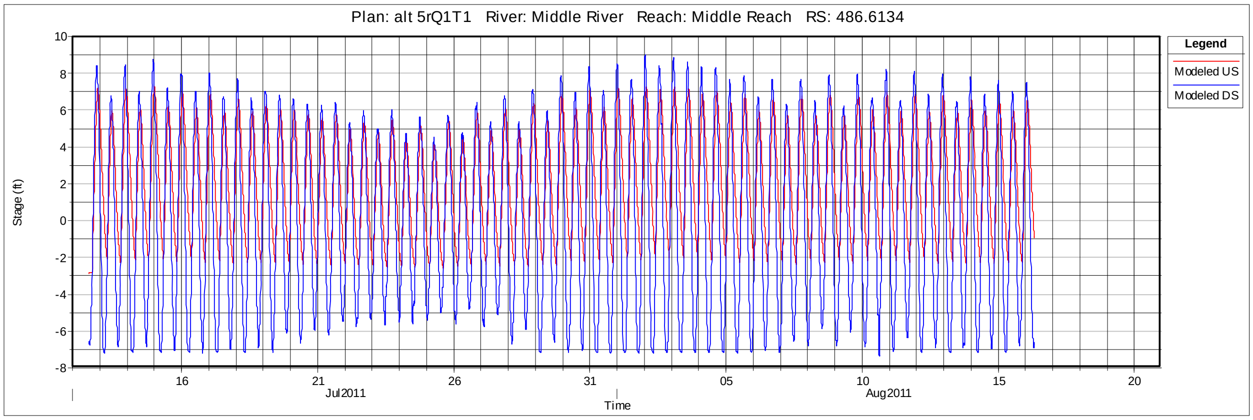
5.3 FREE-FLOWING ALTERNATIVES

This section presents alternatives that are intended to provide for restoration of tidal flow in the Middle River landward from Dyke Bridge to within 3 to 6 inches of conditions in the Machias River immediately seaward from Dyke Bridge.

5.3.1 Alternative 5 – Multiple Adjacent Culverts

Multiple geometries were evaluated for Alternative 5, which reflects multiple adjacent culverts that are intended to provide for tidal restoration. Model simulations were performed for an alternative comprised of five 12 ft (height) by 15 ft (width) box culverts with the inverts set at an elevation of -4.0 ft. Simulated water surface elevations (Figure 18) seaward (“Modeled DS”) and landward (“Modeled US”) from Dyke Bridge for this geometry and the 1.1-year return-interval upland flow simulations indicate that multiple adjacent culverts would not restore tidal stages to within 3 inches to 6 inches landward from Dyke Bridge. (Plan No. 17)

Figure 18: Alternative 5 – (4) 12’ (h) x 15’ (w) Box Culverts

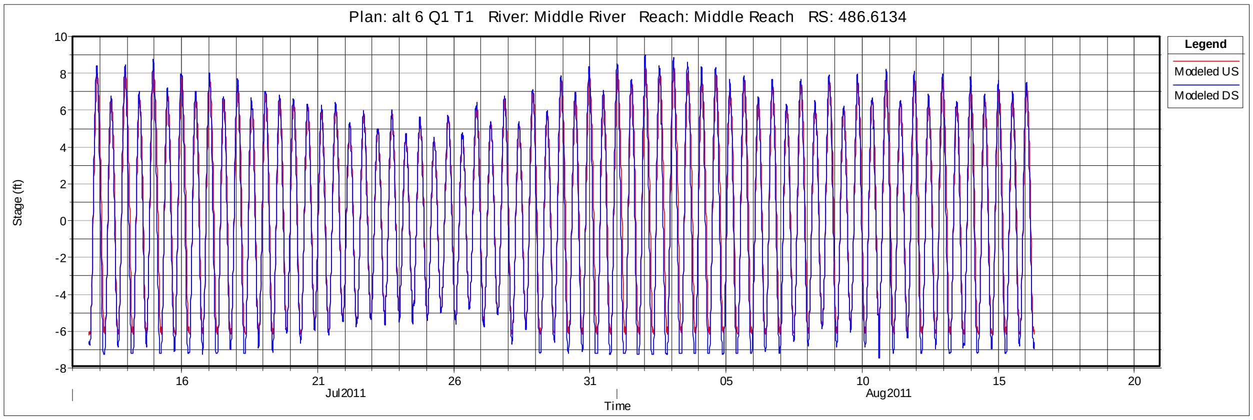


5.3.2 Alternative 6 – Span Bridge

Alternative 6 reflects a span bridge intended to provide for tidal restoration. This alternative was the first of the “free-flowing” alternatives to be evaluated as this alternative provides a means to bound the other free-flowing alternatives (Alternatives 5 and 7).

Based on the preliminary simulation results, a traditional span bridge would require a minimum span of 60 ft with vertical abutments to achieve close to the objectives of this alternative (Figure 19 - 1.1-year flow and tide is simulated in Plan No. 20 for this alternative). Based on the model results, a single-span bridge with a clear span of 60 ft would provide for landward tidal water surface elevations within 0.5 of the seaward tidal stage except during higher high tides, during which the landward tidal stage would be up to 1 ft below the seaward tidal stage.

Figure 19: Alternative 6 – 60-ft Clear Span Bridge



5.3.3 Alternative 7 – Span Bridge with Culverts

Alternative 7 as requested by MaineDOT reflects a span bridge with adjacent culverts intended to provide for tidal restoration. The suggested basis for this alternative is use of a smaller span (relative to Alternative 6) along with relief culverts in the causeway adjacent to the bridge.

An identified consideration for this alternative is whether to install the relief culvert inverts low enough to remain wetted at low tide or whether to install relief culverts that would convey flow during the peak tidal flow only.

Based on the preliminary model analyses and subsequent discussions with MaineDOT, it was determined that this alternative is not feasible relative to the single span bridge alternative (Alternative 6). This alternative was not modeled.

6.0 HYDRAULIC MODEL EVALUATION RESULTS

This section presents results of the hydraulic model evaluation performed as part of this study.

High upland flows and high tides were modeled for each bridge alternative as described in Section 5.0. Tide and flow combinations are as discussed in Sections 3.0 and 4.0.

Table 13 presents model results for existing conditions (Alternative 1). Table 14 presents model results for Alternative 2 (replacement in-kind with four 5 ft x 5 ft box culverts with flap gates) along with a variation on this alternative that is comprised of five 5 ft x 5 ft box culverts with four culverts have flap gates and one ungated, free-flowing culvert. Table 15 presents a summary of three variations on Alternative 2, including:

1) Five 5 ft x 5 ft culverts with flap gates on four culverts and one free-flow culvert;

2) Four 5 ft x 5 ft culverts with flap gates on three culverts and one free-flow culvert; and

3) Four 5 ft x 5 ft culverts with flap gates on two culverts and two free-flow culverts.

Table 16 presents model results for Alternative 5. This alternative is comprised of five 12 ft (h) x 15 ft (w) box culverts, and evaluated the potential to provide for full tidal restoration using culverts in lieu of a bridge.

Table 17 and Table 18 present model results for Alternative 6, which is represented by a 60-ft, single-span bridge, and include evaluation of higher roadway elevations as part of analyses that evaluated sea-level rise and slip-lining at Stride Bridge.

Table 19 presents a summary of results from the HEC-RAS model evaluations and result. Information on the HEC-RAS model setup, including identification of the HEC-RAS geometry, flow, and plan files, is provided in Appendix D.

Table 13: Summary of Model Results for Alternative 1 - Existing Conditions

Riverine Flow (cfs)	Tides (high/low)	Sea Level Rise (m)	Surge (ft)	Tide + Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
					High	Low	DS	US
1.1-year	**Recorded**							
152 - steady	+9.0/-7.5	none	none	9.0/-7.5	1	-0.9	1.4	1.8
		0.5 m		10.7/-5.6	1.4	-0.6	1.7	2.1
		1m		12.3/-4.22	4.5		4.6	4.7
50-year	**Recorded**							
824 steady	+9.0/-7.5	none	none	9.0/-7.5	6.7	4.4	6.9	8.3
Hydrograph	+9.0/-7.5	none	none	9.0/-7.5	3.7	-0.1	4.6	7.3
Hydrograph		0.5 m		10.7/-5.6	4.3	-0.6	4.7	7.3
Hydrograph		1m		12.3/-4.22	5.5	-0.05	5.5	7.3
100-year	**Recorded**							
958 -steady	+9.0/-7.5	none	none	9.0/-7.5	7.6	5.4	5.4	9.4
958 hydrograph	+9.0/-7.5	.5 m		10.7/-5.6	4.2	-1	4.2	8.1
hydrograph		1 m		12.3/-4.22	4.6	-0.7	5.1	8.1
Hydrograph		1m		12.3/-4.22	5.7	-0.5	5.7	8.1
1.1year	**Spring tides**		**2.5' surge**	**Surge at High Tide**				
1.1-year	7.3/-6.9	none	2.5	9.8/-7.0	0.6	-1.1	1.1	1.7
steady		0.5 m		11.4/-5.7	1.2	-0.7	1.5	2
		1m		13.1/-5.4	5.8	-1.9	5.9	5.9
1.1-year	**Spring tides**		**Surge timing**					
1.1-year	7.3/-6.9	none	MR	8/-7	0.6	-1	1.1	1.8
steady		none	MF	8/-7	0.6	-1.1	1.1	1.8
		none	L	7.8/-7	0.6	-1	1.1	1.8

Table 14: Summary of Model Results for Alternative 2 with One Variation on Alternative 2

Riverine Flow (cfs)	Tides (ft) (high/low)	Sea Level Rise (m)	Surge (ft)	Tide + Surge Downstream from Dyke Bridge (ft)	Four 5 ft x 5 ft Box Culverts				Five 5 ft x 5 ft Box Culverts with One Open			
					Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)		Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
					High	Low	DS	US	High	Low	DS	US
1.1-year	**Recorded**											
152 - steady	+9.0/-7.5	none	none	9.0/-7.5	0.08	-2.3	0.8	1.6	1.8	-0.7	2	2.3
		0.5 m		10.7/-5.6	0.5	-2	1	0.7	2.4	-0.24	2.6	
		1m		12.3/-4.22	3.6	-1.2	3.6	3.7	5	0.3	5	
50-year	**Recorded**											
Hydrograph	+9.0/-7.5	none	none	9.0/-7.5	3.2	-2.2	4.3	7.3	4	-1	4.8	7.3
		0.5 m		10.7/-5.6	3.5	-2	4.5	7.3				
		1m		12.3/-4.22	4.5	-1.3	5	7.3				
100-year	**Recorded**											
hydrograph	+9.0/-7.5	none	none	9.0/-7.5	3.5	-2.3	4.7	8.1	4.3	-0.9	5.1	8.1
		0.5 m		10.7/-5.6	3.8	-2	4.9	8.1				
		1m		12.3/-4.22	4.8	-1.5	5.4	8.1				
1.1year	**Spring tides**		**2.5' surge**	**Surge at High Tide**								
152 cfs steady flow	7.3/-6.9	none	2.5	9.8/-7.0	-0.17	-2.3	0.7	1.6	1.8	-1	2	2.3
		0.5 m		11.4/-5.4	0.4	-2	1	1.7	2.5	-0.4	2.8	2.9
		1m		13.1/-3.8	5.6	-1.1	5.7	5.7	6.3	0.5	6.3	6.3
1.1-year	**Spring tides**		Surge timing									
152 cfs - steady	7.3/-6.9	none	MR	8/-7	-0.1	-2.3	0.8	1.6				
		none	MF	8/-7								
		none	L	7.8/-7								

Table 15: Summary of Model Results for Alternative 2 Variations

Alternative 2 Variations	Riverine Flow (cfs)	Tides (ft) (high/low)	Sea Level Rise (m)	Surge (ft)	Tide + Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
						DS	US	DS	US
Five 5 ft x 5 ft box culverts with four flap gates and one open culvert Invert Elev.: -4.05 ft; Top of Road Elev.: 11 ft									
	20	9.0/-7.5	none	0	9.0/-7.5	9	0.7	0.8	0.8
	152			0		9	1.8	2	2.3
	152	7.3/-6.9	none	2.5	9.8/-7.0	9.8	1.8	2	2.3
Four 5 ft x 5 ft box culverts with three flap gates and one open culvert Invert Elev.: -4.05 ft; Top of Road Elev. 11 ft									
	20	9.0/-7.5	none	0	9.0/-7.5	9	0.9	0.9	1
	152			0		9	2.1	2.2	2.5
	152	7.3/-6.9	none	2.5	9.8/-7.0	9.8	2	2.2	2.5
Four 5 ft x 5 ft box culverts with two flap gates and two open culverts Invert Elev.: -4.05; Top of Road Elev.: 11 ft									
	20	9.0/-7.5	none	0	9.0/-7.5	9	2	2.3	2.3
	152			0		9	3.1	3.2	3.4
	152	7.3/-6.9	none	2.5	9.8/-7.0	9.8	3	3.1	3.3

Table 16: Summary of Model Results for Alternative 5 - Replacement with Five 12 ft x 15 ft Box Culverts with Top of Road at 17 ft

Riverine Flow (cfs)	Tides (ft) (high/low)	Sea Level Rise (m)	Surge (ft)	Tide + Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
					High	Low	DS	US
1.1-year	**Recorded**							
152 - steady	+9.0/-7.5	none	none	9.0/-7.5	7.3	-2.5	7.4	7.4
		0.5 m		10.7/-5.6	8.6	-2	8.6	8.7
		1m		12.3/-4.22	10.2	-0.6	10.2	10.3
50-year	**Recorded**							
Hydrograph	+9.0/-7.5	none	none	9.0/-7.5	7.5	-2.3	7.6	8.8
		0.5 m		10.7/-5.6	8.7	-2	8.7	9.8
		1m		12.3/-4.22	10.2	-0.6	10.2	11.1
100-year	**Recorded**							
hydrograph	+9.0/-7.5	none	none	9.0/-7.5	7.5	-2.3	7.7	9.3
		0.5 m		10.7/-5.6	8.8	-1.9	8.9	10.2
		1m		12.3/-4.22	10.2	-0.6	10.3	11.5
1.1year	**Spring tides**		**2.5' surge**	**Surge at High Tide**				
152 - steady	7.3/-6.9	none	2.5	9.8/-7.0	7.5	-2.6	7.5	7.6
		0.5 m		11.4/-5.4	8.8	-1.9	8.8	8.8
		1m		13.1/-4.0	10.6	-0.6	10.6	10.6
1.1-year	**Spring tides**		Surge timing					
152 - steady	7.3/-6.9	none	Mid-Flood	8/-7	6.9	-2.5	7	7
		none	Mid-Ebb	8/-7				
		none	L	7.8/-7				

Table 17: Summary of Model Results for Alternative 6 -60 ft Span at Dyke Bridge (Low Chord at 9 ft, Top of Road at Elev. 11 ft) with Multiple Alternatives at Stride Bridge (as noted) with Top of Road at Elev. 17 ft

Riverine Flow (cfs)	Tides (ft) (high/low)	Sea Level Rise (m)	Surge (ft)	Tide + Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
					High	Low	DS	US
1.1-year	**Recorded**							
152 - steady	+9.0/-7.5	none	none	9.0/-7.5	8.3	-6.1	8.5	8.5
		0.5 m		10.7/-5.6	9.8	-5.6	9.8	9.9
		1m		12.3/-4.22	11.2	-3.8	11.2	11.3
50-year	**Recorded**							
Hydrograph	+9.0/-7.5	none	none	9.0/-7.5	8.3	-6.1	8.3	9.5
		0.5 m		10.7/-5.6	9.8	-5.6	9.8	10.8
		1m		12.3/-4.22	11.2	-3.8	11.2	12.2
100-year	**Recorded**							
hydrograph	+9.0/-7.5	none	none	9.0/-7.5	8.4	-5.9	8.4	9.9
hydrograph		0.5 m		10.7/-5.6	9.9	-5.6	9.9	11.1
hydrograph		1m		12.3/-4.22	11.3	-3.7	11.3	12.6
1.1year	**Spring tides**		**2.5' surge**	**Surge at High Tide**				
1.1-year	7.3/-6.9	none	2.5	9.8/-7.0	8.9	-6.1	8.9	8.9
		0.5 m		11.4/-5.4	10.1	-5.3	10.1	10.2
		1 m		13.1/-3.7	11.5	-3.6	11.6	11.6
1.1-year	**Spring tides**		**Surge timing**					
1.1-year	7.3/-6.9	none	Mid-Flood	8/-7	7.7	-1.1	7.7	7.8
		0.5 m	Mid-Ebb	9.64/-5.4				
		1m	L	11.28/-3.7				

Table 18: Summary of Model Results for Alternative 6 - 60 ft Span at Dyke Bridge (Low Chord at 9 ft, Top of Road at Elev. 14.7 ft) with Multiple Alternatives at Stride Bridge (as noted) with Top of Road at Elev. 17 ft

Riverine Flow (cfs)	Stride Bridge Alternative	Tides (ft) (high/low)	Sea Level Rise (m)	Surge (ft)	Tide + Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
						High	Low	DS	US
1.1-year		Recorded							
	no change	9/-7.5	1m	none	12.3/-4.2	11.3	-3.8	11.3	11.4
	slip lined	9/-7.5	1m		12.3/-4.2	11.3	-3.8	11.3	11.4
50-year	no change	9/-7.5	none	none	9/-7.5				
Hydrograph			0.5 m		10.7/-5.9				
			1m		12.3/-4.2	11.2	-3.8	11.3	12.2
100-year	no change	9/-7.5	none	none	9/-7.5				
Hydrograph			0.5 m		10.7/-5.9				
			1m		12.3/-4.2	11.3	-3.8	11.3	12.6
50-year	slip lined	9/-7.5	none	none	9/-7.5	8.4	-6.1	8.4	9.8
Hydrograph			0.5 m		10.7/-5.9	9.8	-5.6	9.9	11.2
			1m		12.3/-4.2	11.3	-3.7	11.4	12.7
100-year	slip lined	9/-7.5	none	none	9/-7.5	8.3	-6.1	8.4	10.3
Hydrograph			0.5 m		10.7/-5.9	9.8	-5.6	9.9	11.7
			1m		12.3/-4.2	11.3	-3.8	11.4	13.2
		Spring			Surge=2.5 ft				
1.1-year	no change	7.3/-6.9	none	2.5	9.8/-6.9	8.7	-6.1	8.8	8.8
			0.5 m		11.4/-5.3	10.1	-5.2	10.2	10.2
			1m		13.1/-3.6	11.5	-3.6	11.7	11.7
					Mid Tide Surge				
1.1-year	no change	7.3/-6.9	none	2.5	8.0/-6.9				
			0.5 m		9.6/-5.3				
			1m		11.3/-3.6				
					High tide surge				
1.1-year	slip lined	7.3/-6.9	none	2.5	9.8/-6.9	8.9	-6.2	8.8	8.8
			0.5 m		11.4/-5.3	10.1	-5.1	10.1	10.2
			1 m		13.1/-3.6	11.7	-3.6	11.7	11.7
					Mid Tide Surge				
1.1-year	slip lined	7.3/-6.9	none	2.5	8.0/-6.9				
			0.5 m		9.6/-5.3				
			1 m		11.3/-3.6				

Table 19: Summary of Model Evaluations and Results

Bridge Geometry	Top of Roadway at Dyke Bridge (ft)	Dyke Bridge Geometry	Stride Bridge Geometry	Riverine Flow (cfs)	Tides (ft) (high/low)	SLR (m)	Surge (ft)	Tide+ Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
									High	Low	DS	US
Typical Tides, 1.1-year flow, SLR				**1.1-year**	**Recorded**			**DS of Dyke BR**				
1-Existing	elev 11	Existing	TR=12	152 - steady	+9.0/-7.5	none	none	+9.0/-7.5	1	-0.9	1.4	1.8
		4-4X5' boxes	inv -2.8/-2.5			0.5 m		+10.7/-5.6	1.4	-0.6	1.7	2.1
		w/ gates, inv -3.1	12.5' cmp			1m		+12.3/-4.22	4.5		4.6	4.7
2-replace	elev 11	replace ex, gates	TR=12	152 - steady	+9.0/-7.5	none	none	+9.0/-7.5	0.08	-2.3	0.8	1.6
		4-5X5 boxes,	inv -2.8/-2.5			0.5 m		+10.7/-5.6	0.5	-2	1	0.7
		inv -4.05	12.5' cmp			1m		+12.3/-4.22	3.6	-1.2	3.6	3.7
2 REV	elev 11	replace ex, gates	same	152 - steady	+9.0/-7.5	none	none	+9.0/-7.5	1.8	-0.7	2	2.4
		4 flap gates, 1 open box				0.5 m		+10.7/-5.6	2.4	-0.24	2.6	2.8
		inv -4.05				1m		+12.3/-4.22	5	0.3	5	5.1
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	152 - steady	+9.0/-7.5	none	none	+9.0/-7.5	7.3	-2.5	7.4	7.4
		bridge	invs -2.6/-2.5			0.5 m		+10.7/-5.6	8.6	-2	8.6	8.7
		inv = -5, n=.03	n=.015			1m		+12.3/-4.22	10.2	-0.6	10.2	10.3
6 - 60' span	elev 11	1- 60' span	TR=17	152 - steady	+9.0/-7.5	none	none	+9.0/-7.5	8.3	-6.1	8.5	8.5
		LC=9, TR=11	n=.028			0.5 m		+10.7/-5.6	9.8	-5.6	9.8	9.9
		invs -7.2/-8.0	invs -2.6/-2.5			1m		+12.3/-4.22	11.2	-3.8	11.2	11.3
Typical Tides, 50-year flow, SLR				**50-year**	**Recorded**							
1-Existing	elev 11	Existing	TR=12	824 steady	+9.0/-7.5	none	none	+9.0/-7.5	6.7	4.4	6.9	8.3
		4-4X5' boxes	inv -2.8/-2.5	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	3.7	-0.1	4.6	7.3
		w/ gates, inv -3.1	12.5' cmp	Hydrograph		0.5 m		+10.7/-5.6	4.3	-0.6	4.7	7.3
				Hydrograph		1m		+12.3/-4.22	5.5	-0.05	5.5	7.3
2-replace	elev 11	replace ex, gates	TR=12	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	3.2	-2.2	4.3	7.3
		4-5X5 boxes,	inv -2.8/-2.5	Hydrograph		0.5 m		+10.7/-5.6	3.5	-2	4.5	7.3
		inv -4.05	12.5' cmp	Hydrograph		1m		+12.3/-4.22	4.5	-1.3	5	7.3
2 REV	elev 11	replace ex, gates	same	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	4	-1	4.8	7.3
		4 flap gates, 1 open box		Hydrograph		0.5 m		+10.7/-5.6				
		inv -4.05		Hydrograph		1m		+12.3/-4.22				
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	7.5	-2.3	7.6	8.8
		bridge	invs -2.6/-2.5	Hydrograph		0.5 m		+10.7/-5.6	8.7	-2	8.7	9.8
		inv = -5, n=.03	n=.015	Hydrograph		1m		+12.3/-4.22	10.2	-0.6	10.2	11.1
6 - 60' span	elev 11	1- 60' span	TR=17	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	8.3	-6.1	8.3	9.5
		LC=9, TR=11	n=.028	Hydrograph		0.5 m		+10.7/-5.6	9.8	-5.6	9.8	10.8
		invs -7.2/-8.0	invs -2.6/-2.5	Hydrograph		1m		+12.3/-4.22	11.2	-3.8	11.2	12.2
Typical Tides, 100-year flows, plus SLR				**100-year**	**Recorded**							
1-Existing	elev 11	Existing	TR=12	958 -steady	+9.0/-7.5	none	none	+9.0/-7.5	7.6	5.4	5.4	9.4
		4-4X5' boxes	inv -2.8/-2.5	958 hydrograph	+9.0/-7.5	.5 m		+10.7/-5.6	4.2	-1	4.2	8.1
		w/ gates, inv -3.1	12.5' cmp	Hydrograph		1 m		+12.3/-4.22	4.6	-0.7	5.1	8.1
				Hydrograph		1m		+12.3/-4.22	5.7	-0.5	5.7	8.1
2-replace	elev 11	replace ex, gates	TR=12	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	3.5	-2.3	4.7	8.1
		4-5X5 boxes,	inv -2.8/-2.5	Hydrograph		0.5 m		+10.7/-5.6	3.8	-2	4.9	8.1
		inv -4.05	12.5' cmp	Hydrograph		1m		+12.3/-4.22	4.8	-1.5	5.4	8.1
2 REV	elev 11	replace ex, gates	same	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	4.3	-0.9	5.1	8.1
		4 flap gates, 1 open box		Hydrograph		0.5 m		+10.7/-5.6				
		inv -4.05		Hydrograph		1m		+12.3/-4.22				
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	7.5	-2.3	7.7	9.3
		bridge	invs -2.6/-2.5	Hydrograph		0.5 m		+10.7/-5.6	8.8	-1.9	8.9	10.2
		inv = -5, n=.03	n=.015	Hydrograph		1m		+12.3/-4.22	10.2	-0.6	10.3	11.5
6 - 60' span	elev 11	1- 60' span	TR=17	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	8.4	-5.9	8.4	9.9
		LC=9, TR=11	n=.028	Hydrograph		0.5 m		+10.7/-5.6	9.9	-5.6	9.9	11.1
		invs -7.2/-8.0	invs -2.6/-2.5	Hydrograph		1m		+12.3/-4.22	11.3	-3.7	11.3	12.6

Table 19: Summary of Model Evaluations and Results

Bridge Geometry	Top of Roadway at Dyke Bridge (ft)	Dyke Bridge Geometry	Stride Bridge Geometry	Riverine Flow (cfs)	Tides (ft) (high/low)	SLR (m)	Surge (ft)	Tide+ Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
									High	Low	DS	US
High Spring Tide plus Surge, 1.1-year flow, plus SLR				**1.1year**	**Spring tides**		**2.5' surge**					
1-Existing	elev 11	Existing	TR=12	1.1-year	7.3/-6.9	none	2.5	9.8/-7.0	0.6	-1.1	1.1	1.7
		4-4X5' boxes	inv -2.8/-2.5	steady		0.5 m		11.4/-5.7	1.2	-0.7	1.5	2
		w/ gates, inv -3.1	12.5' cmp			1m		13.1/-5.4	5.8	-1.9	5.9	5.9
2-replace	elev 11	replace ex, gates	TR=12	1.1-year	7.3/-6.9	none	2.5	9.8/-7.0	-0.17	-2.3	0.7	1.6
		4-5X5 boxes,	inv -2.8/-2.5			0.5 m		11.4/-5.4	0.4	-2	1	1.7
		inv -4.05	12.5' cmp			1m		13.1/-3.8	5.6	-1.1	5.7	5.7
2 REV	elev 11	replace ex, gates	same	1.1-year	7.3/-6.9	none	2.5	9.8/-7.0	1.8	-1	2	2.3
		4 flap gates, 1 open box				0.5 m		11.4/-5.4	2.5	-0.4	2.8	2.9
		inv -4.05				1m		13.1/-3.8	6.3	0.5	6.3	6.3
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	1.1-year	7.3/-6.9	none	2.5	9.8/-7.0	7.5	-2.6	7.5	7.6
		bridge	invs -2.6/-2.5			0.5 m		11.4/-5.4	8.8	-1.9	8.8	8.8
		inv = -5, n=.03	n=.015			1m		13.1/-4.0	10.6	-0.6	10.6	10.6
6 - 60' span	elev 11	1- 60' span	TR=17	1.1-year	7.3/-6.9	none	2.5	9.8/-7.0	8.9	-6.1	8.9	8.9
		LC=9, TR=11	n=.028			0.5 m		11.4/-5.4	10.1	-5.3	10.1	10.2
		invs -7.2/-8.0	invs -2.6/-2.5			1 m		13.1/-3.7	11.5	-3.6	11.6	11.6
1-Existing	Existing	Existing	Existing	1.1-year	7.3/-6.9	none	MR	8/-7	0.6	-1	1.1	1.8
				steady		none	MF	8/-7	0.6	-1.1	1.1	1.8
						none	L	7.8/-7	0.6	-1	1.1	1.8
2-replace	Same as Exist.	Same as Exist.	no change	1.1-year	7.3/-6.9	none	MR	8/-7	-0.1	-2.3	0.8	1.6
						none	MF	8/-7				
						none	L	7.8/-7				
5- 5 boxes	Same as Exist.	5- 15' boxes	no change	1.1-year	7.3/-6.9	none	MR	8/-7	6.9	-2.5	7	7
						none	MF	8/-7				
						none	L	7.8/-7				
6 - 60' span	Same as Exist.	1- 60' span	no change	1.1-year	7.3/-6.9	none	MR	8/-7	7.7	-1.1	7.7	7.8
						0.5 m	MF	9.64/-5.4				
						1m	L	11.28/-3.7				
Typical Tides, Flows Vary, Dyke BR and Stride BR Alternatives				**1.1-year**	**Recorded**							
6 - 60' span	**14.7'**	1- 60' span	no change	1.1-year	9/-7.5	1m	none	12.3/-4.2	11.3	-3.8	11.3	11.4
6 - 60' span	**14.7'**	1- 60' span	**slip lined**	1.1-year	9/-7.5	1m		12.3/-4.2	11.3	-3.8	11.3	11.4
6 - 60' span	**14.7'**	1- 60' span	no change	**50-year**	9/-7.5	none	none	9/-7.5				
				Hydrograph		0.5 m		10.7/-5.9				
						1m		12.3/-4.2	11.2	-3.8	11.3	12.2
6 - 60' span	**14.7'**	1- 60' span	no change	**100-year**	9/-7.5	none	none	9/-7.5				
				Hydrograph		0.5 m		10.7/-5.9				
						1m		12.3/-4.2	11.3	-3.8	11.3	12.6
6 - 60' span	**14.7'**	1- 60' span	**slip lined**	**50-year**	9/-7.5	none	none	9/-7.5	8.4	-6.1	8.4	9.8
				Hydrograph		0.5 m		10.7/-5.9	9.8	-5.6	9.9	11.2
						1m		12.3/-4.2	11.3	-3.7	11.4	12.7
6 - 60' span	**14.7'**	1- 60' span	**slip lined**	**100-year**	9/-7.5	none	none	9/-7.5	8.3	-6.1	8.4	10.3
				Hydrograph		0.5 m		10.7/-5.9	9.8	-5.6	9.9	11.7
						1m		12.3/-4.2	11.3	-3.8	11.4	13.2

Table 19: Summary of Model Evaluations, Results, and HEC-RAS Model Setup (Continued)

Bridge Geometry	Top of Roadway at Dyke Bridge (ft)	Dyke Bridge Geometry	Stride Bridge Geometry	Riverine Flow (cfs)	Tides (ft) (high/low)	SLR (m)	Surge (ft)	Tide+ Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
									High	Low	DS	US
Storm Surge Tides, 1.1-year flows, plus SLR, Dyke/Stride options					**Spring**			**Surge=2.5'**				
6 - 60' span	**14.7'**	1- 60' span	no change	**1.1-year**	7.3/-6.9	none	2.5	9.8/-6.9	8.7	-6.1	8.8	8.8
						0.5 m		11.4/-5.3	10.1	-5.2	10.2	10.2
						1m		13.1/-3.6	11.5	-3.6	11.7	11.7
								Mid Tide Surge				
Case 6 - 60' span	**14.7'**	1- 60' span	no change	**1.1-year**	7.3/-6.9	none	2.5	8.0/-6.9				
						0.5 m		9.6/-5.3				
						1m		11.3/-3.6				
								High tide surge				
Case 6 - 60' span	**14.7'**	1- 60' span	**slip lined**	1.1-year	7.3/-6.9	none	2.5	9.8/-6.9	8.9	-6.2	8.8	8.8
						0.5 m		11.4/-5.3	10.1	-5.1	10.1	10.2
						1 m		13.1/-3.6	11.7	-3.6	11.7	11.7
								Mid Tide Surge				
Case 6 - 60' span	**14.7'**	1- 60' span	**slip lined**	1.1-year	7.3/-6.9	none	2.5	8.0/-6.9				
						0.5 m		9.6/-5.3				
						1 m		11.3/-3.6				
Calibration Model Runs				**20 cfs**	**Recorded**							
Case 1	11	Existing	TR=12		+9.0/-7.5	none	none	9.0/-7.5	-0.55	-2	-0.49	-0.41
		4-4X5' boxes	inv -2.8/-2.5									
		w/ gates, inv -3.1	12.5' cmp									
Case 1	11	Existing	TR=12		+9.0/-7.5	none	none	9.0/-7.5	3.3	3.3	3.3	0.7
		4-4X5' boxes	inv -2.8/-2.5									
		NO gates, inv -3.1	12.5' cmp									
Alt 2 Replacement in kind options												
Alt 2 4 flap gates, 1 open box		4 5X5 flap gates	TR=12	20	+9.0/-7.5	none	none	9.0/-7.5	9	0.7	0.8	0.8
	11	one open 5X5	inv -2.8/-2.5	152					9	1.8	2	2.3
		inv -4.05	12.5' cmp									
alt 2 3 flaps 1 open		3 5X5 flap gates	TR=12	20	+9.0/-7.5	none	none	9.0/-7.5	9	0.9	0.9	1
		one open 5X5	inv -2.8/-2.5	152					9	2.1	2.2	2.5
		inv -4.05	12.5' cmp									
alt 2 2 flaps 1 open		2 5X5 flap gates	TR=12	20	+9.0/-7.5	none	none	9.0/-7.5	9	2	2.3	2.3
		two open 5X5	inv -2.8/-2.5	152					9	3.1	3.2	3.4

7.0 TECHNOLOGY REVIEW: SELF-REGULATION TIDE GATES

Stantec performed a technology review of SRTs as part of this study. This review included obtaining and reviewing information on SRTs and evaluating the potential suitability of SRTs as elements of Alternative 3 and “fish-friendly” SRTs as elements of Alternative 4. The compiled SRT technology review is provided in Appendix B.

7.1 SELF-REGULATING TIDE GATES

Review of information and discussions with SRT manufacturers indicated that SRTs can be constructed in virtually any size based on site-specific needs. Scaling-up of SRT designs would necessitate appropriate care of structural elements and consideration of hydraulic performance. In addition, mechanical components of scale-up SRTs would need to be appropriately designed.

SRT costs vary between manufacturers and specific designs. A rule-of-thumb provided by a designer and manufacturer of tide gates who was contacted as part of this study is $450 per square-foot of gate area for manufacturing smaller SRTs. Application of this rule to a 4 ft by 4 ft SRT would result in a cost of $7,200. Similarly, application of this rule to a 10 ft by 10 ft SRT would result in a cost of $45,000, which appears to be low and reflect that the rule-of-thumb is not linearly scalable to larger gates. Note that these costs do not include installation of SRTs or modifications to associated culvert systems, which may include construction of additional structural elements and design features intended to prevent movement of the culvert elements when there is differential hydraulic head at closed tide gates.

Maintenance requirements for SRTs will vary based on selected designs and size; it is expected that larger SRTs will require increased maintenance. Expected primary maintenance requirements include 1) maintaining the SRT mechanical systems, and 2) debris management. Potential failure of mechanical systems can result from wear resulting from regular operation of tide gates and damage from debris, such as flotsam (e.g., logs) and ice during winter months. Based on discussions with a manufacturer of tide gates, operation of tide gates at flow speeds of greater than 5 to 6 feet-per-second (fps) during closure of the tide gates can result in damage to the tide gate systems. Based on modeled conditions for this study, it is expected that flow speeds in excess of 6 fps could be encountered during gate closure if operation of tide gates requires gate closure when the hydraulic head between the seaward and landward sides of the tide gate is greater than approximately 0.6 ft.

Evaluation of hydraulic model simulation data for Alternative 5 indicates that the hydraulic head through culverts as part of that alternative would exceed 1 ft within 1 hour after the start of the flood tide and would exceed 2 ft later during each flood tide. These conditions would result in flow speeds in the range of 8 fps and 10 fps, respectively, through a tide gate installed on the seaward face of a culvert system. Note that additional hydraulic losses through the tide gates in addition to those that were calculated for the culverts would result in increased hydraulic head and flow speeds.

Consequences of failure of SRTs are relevant to this project. Because the Dyke Bridge and associated causeway are located on a waterway with a relatively large tributary watershed and the existing tidal regime landward from the bridge is suppressed, there are potential impacts that could result from failure of SRT gate systems in the “open” or “closed” positions. Failure of tides gates in the “open” position could result in increased tidal inundation landward from Dyke Bridge (this scenario is similar to what would result if the existing flap gates failed or were removed). Failure of tide gates in the “closed” position could result in accumulation of freshwater landward from the bridge. Given the relatively large volume of available hydrologic storage between Dyke Bridge and Stride Bridge, it is expected that failure of tide gates in the “open” position and resulting tidal inundation would result in increased impacts relative to failure of tide gates in “closed” positions.

Factors related to public safety include entrainment in the tide gates (including SRTs) and/or culverts. Culverts with widths that are less than small recreational watercraft pose impingement hazards, as small boats could become impinged across the culvert inlets; installation and operation of tide gates would increase the impingement hazard by reducing opening widths. The associated hazard increases at higher flow speeds through the tide gate or culvert. An additional factor related to public safety is that larger culvert and gate systems will have capacity for increased flow and a larger area of influence that could result in entrainment of boats and swimmers. While a bridge opening could have greater capacity, the reduced potential for impingement associated with a bridge would result in a decrease in potential hazards. These concerns are relevant to this project given the proximity of the state-owned boat launch that is located immediately seaward from the existing Dyke Bridge culverts.

The potential for sea level rise should be evaluated in the context of SLRs and resiliency of the Dyke Bridge causeway to limit landward inundation. This concern is particularly relevant to overtopping of the causeway during storm events, which could result in inundation of areas that are currently “protected” by the causeway. Even short-term inundation of the landward area with salt water could have pronounced effects on existing flora and fauna, such as die-off of salt-intolerant vegetation.

7.2 “FISH-FRIENDLY” SRTS

Some manufacturers of SRTs describe “fish-friendly” SRTs; information obtained as part of the SRT technology review indicates that some SRTs may be better suited than others for fish passage, and that these may be termed “fish-friendlier” but not necessarily fish-friendly.

Site-specific constraints appear to substantially limit the use of fish-friendlier SRTs at Dyke Bridge; these constraints largely follow on the factors that are identified for typical SRTs, and include functional limitations on the operational capabilities of SRTs related to hydraulic head and flow speeds.

The primary identified constraints to installation of fish-friendly SRTs at Dyke Bridge are associated with:

1) Operation of tide gates in a high-velocity environment; and

2) Relatively high-speed flow through the culvert and tide gate system during the ebb tide.

As discussed in the preceding section, operation of SRTs in high-velocity environments can result in damage to the tide gates. The applicability of fish-friendly SRTs at Dyke Bridge to provide for improved upstream fish passage is therefore substantially constrained by the large difference in water surface elevations seaward and landward from Dyke Bridge during the flood tide.

Based on the evaluation of culverts for Alternative 5, flow speeds through the evaluated culverts during the ebb tide would largely preclude upstream movement of slower-swimming fish, such as rainbow smelt (*Osmerus mordax*). In addition, the culvert inverts would need to be set at an elevation of approximately -8 ft (4 ft lower than the existing culverts) to have the culvert and tide gate invert below low tide elevations seaward from Dyke Bridge as a baseline requirement for upstream passage low tide. An expected consequence of lower culvert inverts is lowering of the low tide pool landward of Dyke Bridge by approximately 7 ft relative to existing conditions.

8.0 FISH PASSAGE

This study includes preliminary evaluation of fish passage at Dyke Bridge and Stride Bridge, including evaluation of “fish friendly” self-regulating tide gates (Alternative 4) at Dyke Bridge. This section presents information on and an evaluation of fish passage through SRTs and general and site-specific constraints to use of SRTs technologies at Dyke Bridge.

Identified effects on fish passage are addressed separately for Dyke Bridge and Stride Bridge. While there is interaction between the two sites, including effects of tidal stage associated with the evaluated alternatives at Dyke Bridge, the number of alternatives and scenarios evaluated as part of this study did not include direct evaluation of all of the potential combinations of alternatives at Dyke Bridge and Stride Bridge that may affect upstream fish passage at both sites.

Discussion of fish passage is focused on Dyke Bridge, where existing conditions for upstream fish passage are currently marginal, and is followed by a discussion of fish passage at Stride Bridge.

8.1 DYKE BRIDGE

8.1.1 Alternative 1: No Action

The existing flap gates at Dyke Bridge are deteriorated, and leakage through the flap gates and embankment results in some landward tidal flow. Landward flow through gaps in the flap gaps and/or unseated closure is possible but is expected to be limited except for very small-bodied fish that will pass through gaps. Analysis of the tidal stage data provided by MaineDOT for the period from July 11 through October 24, 2011 indicates that the temporal during of landward and seaward flow is evenly split (i.e., 50% landward and 50% seaward) during normal tides. The HEC-RAS model analysis of existing conditions for the period from July 12, 2011 through August 12, 2011, yielded the same percentages of landward and seaward flow.

As previously noted, landward flow at Dyke Bridge during flood tide results from leakage of the flap gates and leakage through the adjacent embankment, and therefore provides for very limited upstream fish passage. Based on observed conditions at Dyke Bridge, upstream fish passage during periods of seaward flow is expected to be limited to short duration periods when the tidal stage landward from Dyke Bridge is marginally higher than the seaward stage and the seaward stage is higher than the culvert barrel outlet inverts. When the seaward stage is below the culvert barrel outlet inverts, it is expected that flow over the riprap apron seaward from the Dyke Bridge culverts prevents upstream passage for fish due to high-speed flow and a leaping barrier associated with flow over the riprap apron.

8.1.2 Stride Bridge

The existing Stride Bridge culvert is persistently backwatered and the invert (elevation -2.5 ft) is below the lowest recorded water surface elevation upstream from Dyke Bridge, and is therefore expected to provide for good upstream fish passage during lower flow conditions. During high-flow conditions, this culvert may be a short-term barrier to upstream fish passage depending on backwater conditions (e.g., water surface elevations in the downstream reach of the river) and total flow.

8.2 ALTERNATIVE 2: REPLACEMENT IN-KIND WITHOUT RESTORATION OF TIDAL FLOW

8.2.1 Dyke Bridge

In-kind replacement of the culverts and flap gates at Dyke Bridge is expected to eliminate landward flow through the culverts and therefore eliminate landward movement of fish during the flood tide or the ebb tide when water surface elevations landward from Dyke Bridge are lower than the seaward water surface elevations. It is not expected that there would be more than incidental landward passage of fish through the flap gates when flow is seaward due to high-speed flow through the gates and flow over riprap apron seaward from the culvert.

8.2.2 Stride Bridge

This alternative could reduce daily variations in flow landward from Dyke Bridge and would therefore result in lower water surface elevations at Stride Bridge. These potential changes could result in increased downstream flow speeds at Stride Bridge. Lower tailwater elevations and increased flow speeds at Stride Bridge would decrease the potential for upstream fish passage relative to existing conditions. Note that reductions in tailwater surface elevations at Stride Bridge would be persistent at low flows for this alternative because of the loss of tidal affects.

8.3 ALTERNATIVE 2: REPLACEMENT IN-KIND WITH VARIATIONS FOR FLAP GATE OPERATIONS

This modified concept for Alternative 2 includes evaluation of box culverts at Dyke Bridge with flap gates on a subset of the culverts and at least one free-flowing culvert. The objective of having a persistently-open culvert(s) is to provide for unhindered landward flow when the flood tide is higher than the elevation of the culvert invert and the water surface elevation landward from Dyke Bridge.

8.3.1 Dyke Bridge

Three variations on Alternative 2 were evaluated:

a. Five 5 ft x 5 ft culverts with flap gates on four of the culverts (Plan No. 82). Results of this simulation that include the observed upstream tide data are presented in Figure 14;

b. Four 5 ft x 5 ft culverts with flap gates on three of the culverts (Plan No. 83). Results of this simulation that include the observed upstream tide data are presented in Figure 15; and

c. Four 5 ft x 5 ft culverts with flap gates on two of the culverts (Plan No. 27). Results of this simulation that include the observed upstream tide data are presented in Figure 16.

Table 20 presents information on the three evaluated variations of Alternative 2 and, for comparison, simulation results for existing conditions.

Table 20: Evaluation of Landward and Seaward Flow

Simulation	Typical High Tide (ft NAVD88)	Seaward Flow (%)	Landward Flow (%)
Existing Conditions	-1 ft	50%	50%
Five Culverts with one free-flowing (Plan No. 82)	0.5 ft	53%	47%
Four culverts with one free-flowing (Plan No. 83)	1 ft	55%	45%
Four culverts with two free-flowing (Plan No. 27)	2 ft	55%	45%

The three evaluated Alternative 2 variations result in higher water surface elevations landward from Dyke Bridge relative to existing conditions and small (3% to 5%) decreases in the duration of landward flow relative to existing conditions. While the duration of landward flow is decreased relative to existing conditions, the Alternative 2 variations provide for landward flow through an open box culvert. Note that existing landward flow results from the deteriorated condition of the existing culverts and flap gates, and that reconstruction of the culverts would result in no landward flow. The Alternative 2 variations are therefore expected to provide for substantial improvements to upstream fish passage at Dyke Bridge relative to existing conditions and in-kind replacement of the existing culvert system.

8.3.2 Stride Bridge

The Alternative 2 variations would result in higher typical tidal elevations landward from Dyke Bridge and could result in increased depths of water at Stride Bridge, which would result in lower flow speeds through the Stride Bridge stream crossing.

8.4 ALTERNATIVE 3: REPLACEMENT WITH PARTIAL RESTORATION OF TIDAL FLOW

8.4.1 Dyke Bridge

Installation of tide gates at Dyke Bridge that would allow for higher normal tides elevations landward from the bridge would result in increased landward flow during the flood tide through the bridge and could result in some improvement to upstream fish passage. The potential to improve upstream fish passage with tide gates would be heavily influence by the type of tide gate and operational regime.

8.4.2 Stride Bridge

Potential impacts to upstream fish passage at Stride Bridge could result from partial restoration of tidal flow at Dyke Bridge. Higher tidally-affected water surface elevations at Stride Bridge would result in lower flow speeds through the existing culvert and could result in flow reversal (i.e., landward flow), which would tend to improve upstream fish passage. If a tide gate was operated to provide lower water surface elevations landward from Dyke Bridge, this condition would result in higher flow speeds and reduced potential for upstream fish passage at Stride Bridge.

Note that the geometry of the HEC-RAS model was developed without detailed bathymetric information along some of the reach of the Middle River downstream from Stride Bridge, and it is therefore uncertain whether there are natural hydraulic controls (e.g., riffles) that would limit reductions in water surface elevations at Stride Bridge if a replacement culvert at Dyke Bridge resulted in lower low tide elevations landward from Dyke Bridge.

8.5 ALTERNATIVE 4: REPLACEMENT WITH PARTIAL RESTORATION OF TIDAL FLOW AND PROVISIONS FOR FISH PASSAGE

8.5.1 Dyke Bridge

Installation of tide gates with dedicated provisions for upstream fish passage at Dyke Bridge would allow for management of typical tidal water surface elevations landward from the bridge. Depending on the operational regime of tide gates and landward flow during flood tide, this alternative could improve upstream fish passage relative to existing conditions.

8.5.2 Stride Bridge

Potential impacts to upstream fish passage at Stride Bridge could result from partial restoration of tidal flow at Dyke Bridge and would largely depend on the tidal regime landward from Dyke Bridge. Higher tidally-affected water surface elevations at Stride Bridge would result in lower flow speeds through the existing culvert and could result in flow reversal (i.e., landward flow), which would tend to improve upstream fish passage. Lower water surface elevations could also result, which would result in high flow speeds through the culvert and reduced potential for upstream fish passage.

Note that the geometry of the HEC-RAS model was developed without detailed bathymetric information along some of the reach of the Middle River downstream from Stride Bridge. It is therefore uncertain whether there are natural hydraulic controls (e.g., riffles) downstream from Stride Bridge that would limit reductions in water surface elevations downstream from Stride Bridge if a replacement culvert at Dyke Bridge resulted in lower landward low tide elevations.

8.6 ALTERNATIVES 5, 6, AND 7: FULL TIDAL RESTORATION

Full restoration of tidal flow as part of Alternatives 5, 6, and 7 would result in improved upstream fish passage at Dyke Bridge. Achieving upstream fish passage for slower-swimming fish would, however, require construction of a new, lower channel through the footprint of the existing Dyke Bridge causeway and upstream along the Middle River. The need for a new channel is based on bathymetric data collected by MaineDOT landward from Dyke Bridge, which indicates that the bottom of the existing channel higher than low tide elevations downstream (seaward) from Dyke Bridge.

8.6.1 Dyke Bridge

Full tidal restoration at Dyke Bridge would improve upstream fish passage, but the extent of improvements would be substantially affected by the bottom elevation of the channel through the bridge opening and into the upstream reach of the Middle River. Based on the hydraulic model results and observed conditions, it is expected that full tidal restoration could result in high flow speeds through a full-restoration alternative unless a lower channel is constructed (e.g., dredge) within the footprint of the existing Dyke Bridge causeway and further upstream in the Middle River.

8.6.2 Stride Bridge

Potential impacts to upstream fish passage at Stride Bridge would result from full tidal restoration of tidal flow at Dyke Bridge. Higher tidally-affected water surface elevations at Stride Bridge would result in lower flow speeds through the existing culvert and, at higher tides, flow reversal (i.e., landward flow) at Stride Bridge. Higher water surface elevation and/or flow reversal would improve upstream fish passage, but lower water surface elevations, which could also result from a larger tidal range, would result in high flow speeds through the culvert.

Note that the geometry of the HEC-RAS model was developed without detailed bathymetric information along some of the reach of the Middle River downstream from Stride Bridge, and it is therefore uncertain whether there are natural hydraulic controls (e.g., riffles) that would limit reductions in water surface elevations at Stride Bridge if a replacement structure at Dyke Bridge resulted in lower low tide elevations landward from the Dyke Bridge causeway.

9.0 STRIDE BRIDGE REPLACEMENT OPPORTUNITIES

A preliminary evaluation for replacement of Stride Bridge was developed as part of this study. This evaluation was developed based on a minimum span of 37 ft as defined by 1.2-times the bankfull width of the Middle River at Stride Bridge of 31 ft as identified by MaineDOT.

The preliminary evaluation included review of geologic map data obtained from the Maine Geological Survey to assess potential subsurface conditions (e.g., potential presence of shallow bedrock) and hydrologic information that was used as part of this study.

Three potential, single-span options were evaluated:

1) A single, 1.2-times bankfull-width span with vertical abutments and a shallow foundation;

2) A single, 1.2-times bankfull-width span with sloped abutments and a deep foundation; and

3) A single, 1.0-time bankfull-width span with sloped abutments and a deep foundation.

A summary memo that presents information on potential replacement bridge geometries at Stride Bridge is included in Appendix E.

10.0 REFERENCES

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APPENDICES

Appendix C : SRT TECHNOLOGY REVIEW

Project Name:	Machias Causeway	**PIN:**	16714
Stream Name:	Middle River	**Town:**	Marshfield
Bridge Name:	Stride Bridge	**Bridge No.**	3973
Route No.	US 1	**USGS Quad:**	
Analysis by:	CSH	**Date:**	5/13/2014

Peak Flow Calculations by USGS Regression Equations (Hodgkins, 1999)

Enter data in blue cells only!

	km^2	mi^2	ac	***Enter data in [mi^2]***
A	24.38	9.41	6024.4	Watershed Area
W	3.05	1.18	753.7	Wetlands area (by NWI)
P_c	618573	4957554		watershed centroid (E, N; UTM 19N; meters)
County	Washington			*choose county from drop-down menu*
pptA	44.2			mean annual precipitation (inches; by look-up)
SG	0.00			sand & gravel aquifer as decimal fraction of watershed A

Worksheet prepared by:
Charles S. Hebson, PE
Environmental Office
Maine Dept. Transportation
Augusta, ME 04333-0016
207-557-1052
Charles.Hebson@maine.gov

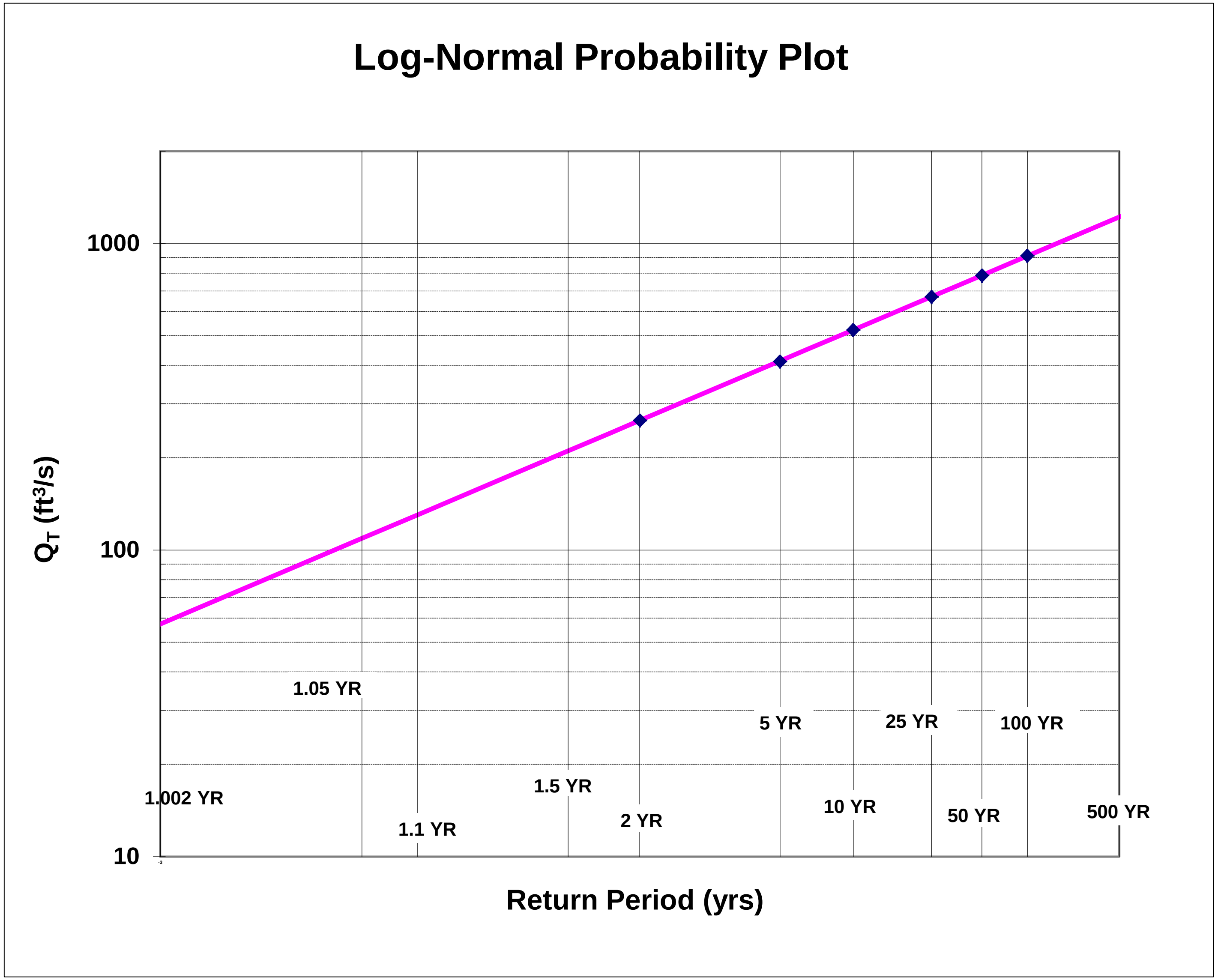
A (km^2)	24.38	**Conf Lvl**	0.67
W (%)	12.51		

Ret Pd T (yr)	**Peak Flow Estimate Lower**	**Q_T (m^3/s)**	**Upper**	**Q_T (ft^3/s)**
1.1		3.69		130.2
2	5.36	7.50	10.49	264.7
5	8.32	11.68	16.41	412.5
10	10.42	14.78	20.99	522.0
25	13.18	18.98	27.33	670.2
50	15.28	22.27	32.46	786.5
100	17.50	25.82	38.11	911.8
500	22.68	34.57	52.70	1220.6

Reference:

Hodgkins, G., 1999.
Estimating the magnitude of peak flows for streams
in Maine for selected recurrence intervals
Water-Resources Investigations Report 99-4008
US Geological Survey, Augusta, Maine

$Q_T = b \times A^a \times 10^{-wW}$


Log-Normal Probability Plot
QT (ft3/s)
1000
100
10
1.002 YR
1.05 YR
1.1 YR
1.5 YR
2 YR
5 YR
10 YR
25 YR
50 YR
100 YR
500 YR
Return Period (yrs)

Project Name: Machias Causeway
Stream Name: Middle River
Bridge Name: Stride Bridge
Route No. US 1
Analysis by: CSH

PIN: 16714
Town: Marshfield
Bridge No. 3973
USGS Quad:
Date: 5/13/2014

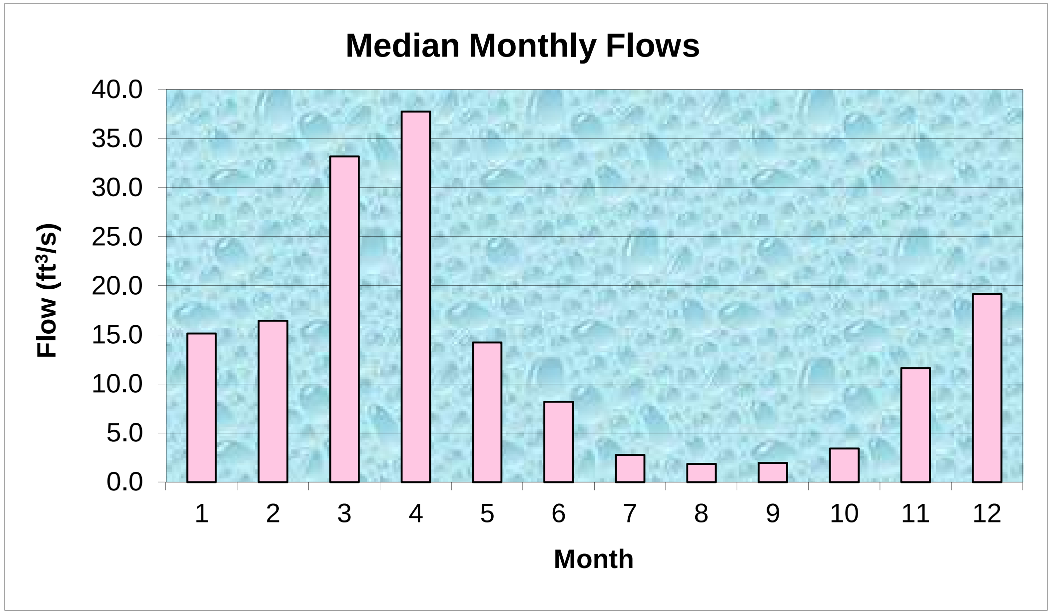
DO NOT ENTER ANY DATA ON THIS PAGE; EVERYTHING IS CALCULATED

MAINE MONTHLY MEDIAN FLOWS BY USGS REGRESSION EQUATIONS (2004)

Worksheet prepared by:
Charles S. Hebson, PE
Chief Hydrologist
Maine Dept. Transportation
Augusta, ME 04333-0016
207-624-3073
Charles.Hebson@maine.gov

	Value	**Variable**	**Explanation**
	9.413	*A*	Area (mi^2)
618573	4957554	P_c	Watershed centroid (E,N; UTM; Zone 19; meters)
	31.80	*DIST*	Distance from Coastal reference line (mi)
	44.2	*pptA*	Mean Annual Precipitation (inches)
	0.00	*SG*	Sand & Gravel Aquifer (decimal fraction of watershed area)

Month	**Q_{median}** (ft3/s)	(m^3/s)
Jan	**15.14**	0.4290
Feb	**16.44**	0.4658
Mar	**33.19**	0.9406
Apr	**37.77**	1.0702
May	**14.22**	0.4029
Jun	**8.19**	0.2322
Jul	**2.76**	0.0782
Aug	**1.87**	0.0531
Sep	**1.96**	0.0555
Oct	**3.41**	0.0967
Nov	**11.61**	0.3289
Dec	**19.15**	0.5426



Q_{bf}	**54.6**
ann avg	**19.1**
ann med	**9.7**
$Q_{1.002}$	**57.3**
$Q_{1.01}$	76.7
$Q_{1.05}$	109.1

W_{bf}	24.5	estimated bankfull width
d_{bf}	1.9	
Q_{bf}	186.4	assume v = 4ft/s


EAST
MANSFIELD
MANSFIELD

Project Name:	Machias Causeway	**PIN:**	16714
Stream Name:	Middle River	**Town:**	Machias
Bridge Name:	Dyke Bridge	**Bridge No.**	2246
Route No.	US 1	**USGS Quad:**	
Analysis by:	CSH	**Date:**	11/29/2011

Peak Flow Calculations by USGS Regression Equations (Hodgkins, 1999)

Enter data in blue cells only!

	km^2	mi^2	ac	***Enter data in [mi^2]***
A	34.24	13.22	8459.9	Watershed Area
W	5.25	2.03	1297.3	Wetlands area (by NWI)

P_c	620020	4956225	watershed centroid (E, N; UTM 19N; meters)
County	Washington		*choose county from drop-down menu*
pptA	44.2		mean annual precipitation (inches; by look-up)
SG	0.00		sand & gravel aquifer as decimal fraction of watershed A

A (km^2)	34.24	**Conf Lvl**	0.67
W (%)	15.33		

Worksheet prepared by:

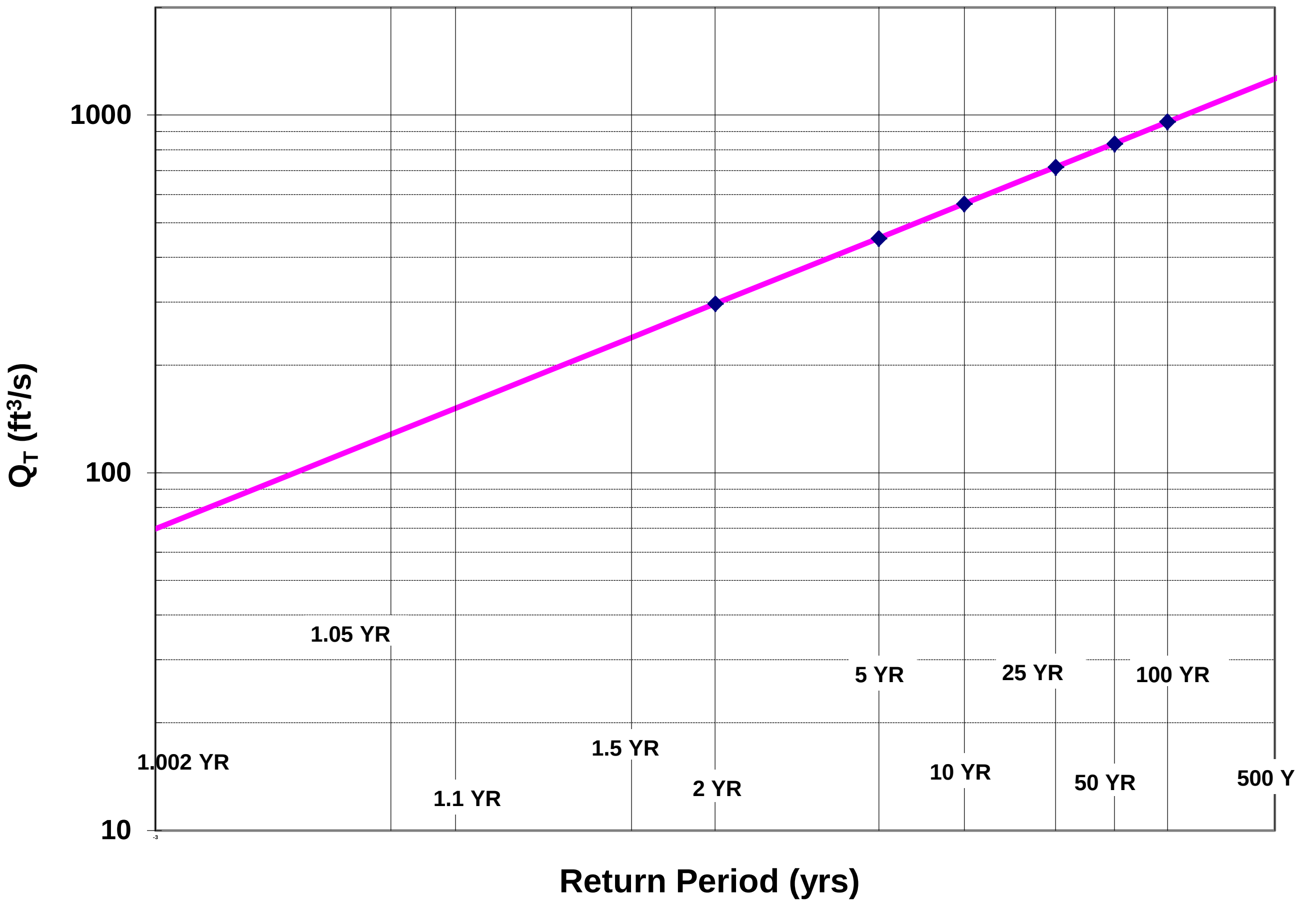
Charles S. Hebson, PE
Environmental Office
Maine Dept. Transportation
Augusta, ME 04333-0016
207-557-1052
Charles.Hebson@maine.gov

Ret Pd	**Peak Flow Estimate**			
T (yr)	**Lower**	**Q_T (m^3/s)**	**Upper**	**Q_T (ft^3/s)**
1.1		4.29		151.6
2	6.01	8.41	11.76	296.9
5	9.12	12.80	17.95	451.9
10	11.28	15.99	22.68	564.7
25	14.09	20.26	29.14	715.4
50	16.20	23.57	34.31	832.4
100	18.42	27.14	39.98	958.3
500	23.53	35.79	54.45	1263.9

Reference:

Hodgkins, G., 1999.
Estimating the magnitude of peak flows for streams
in Maine for selected recurrence intervals
Water-Resources Investigations Report 99-4008
US Geological Survey, Augusta, Maine

$Q_T = b \times A^a \times 10^{-wW}$



Log-Normal Probability Plot

Project Name:	Machias Causeway	**PIN:**	16714
Stream Name:	Middle River	**Town:**	Machias
Bridge Name:	Dyke Bridge	**Bridge No.**	2246
Route No.	US 1	**USGS Quad:**	
Analysis by:	CSH	**Date:**	11/29/2011

DO NOT ENTER ANY DATA ON THIS PAGE; EVERYTHING IS CALCULATED

MAINE MONTHLY MEDIAN FLOWS BY USGS REGRESSION EQUATIONS (2004)

Worksheet prepared by:
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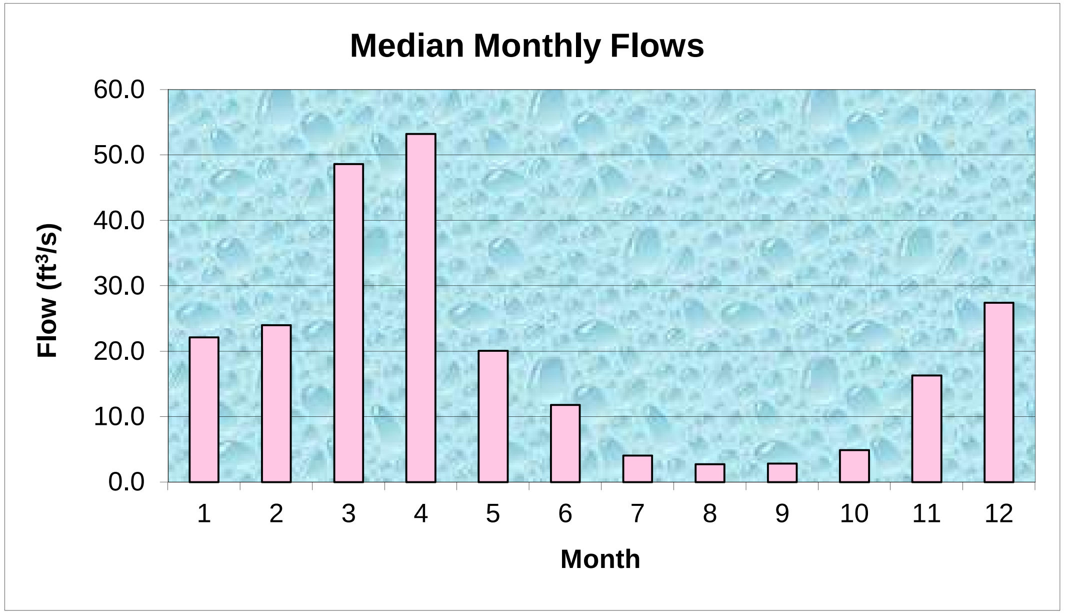
Chief Hydrologist
Maine Dept. Transportation
Augusta, ME 04333-0016
207-624-3073
Charles.Hebson@maine.gov

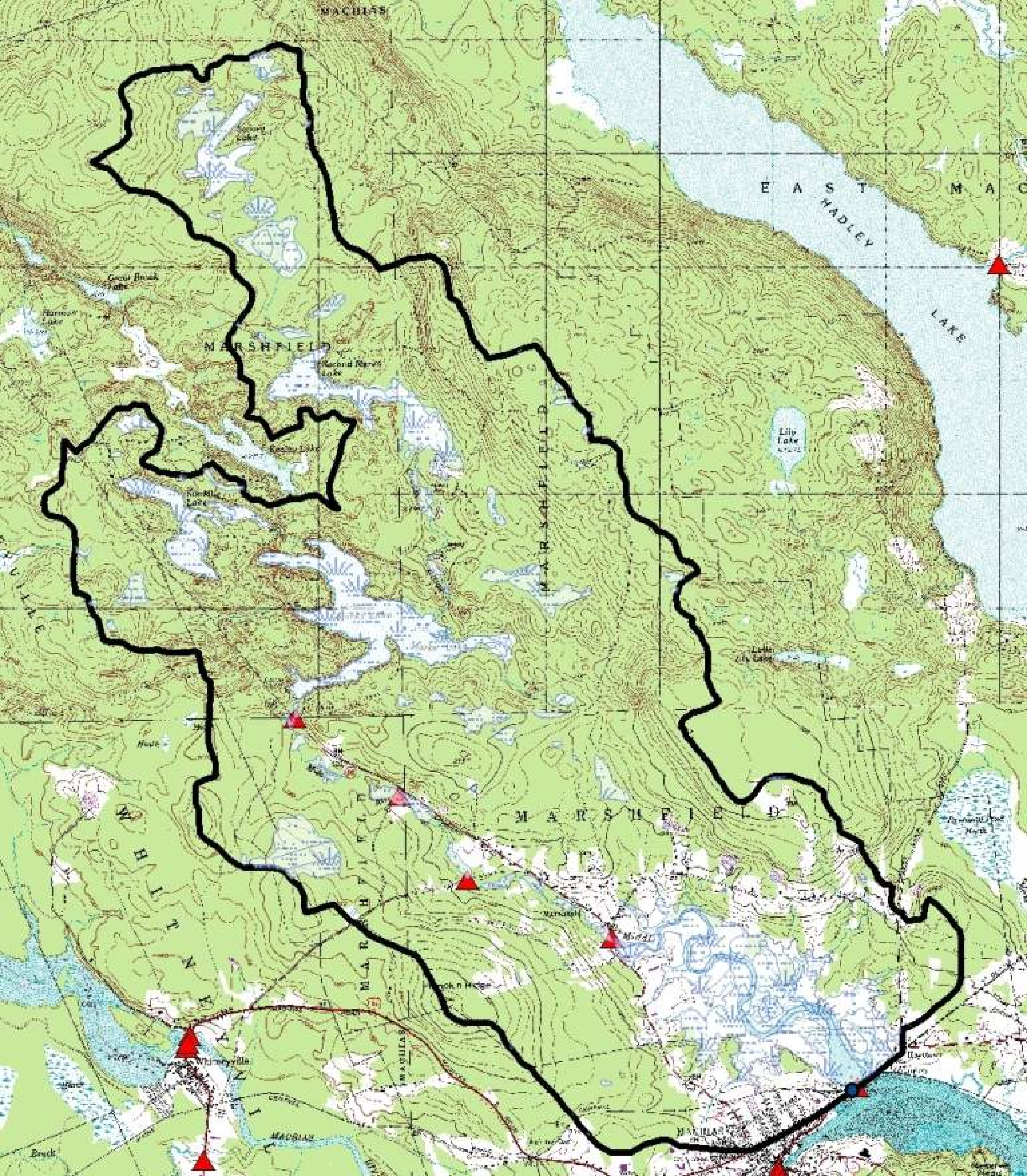
	Value	**Variable**	**Explanation**
	13.219	*A*	Area (mi^2)
620020	4956225	*P$_c$*	Watershed centroid (E,N; UTM; Zone 19; meters)
	30.65	*DIST*	Distance from Coastal reference line (mi)
	44.2	*pptA*	Mean Annual Precipitation (inches)
	0.00	*SG*	Sand & Gravel Aquifer (decimal fraction of watershed area)

Month	**Q$_{median}$** (ft3/s)	(m^3/s)
Jan	**22.14**	0.6273
Feb	**23.99**	0.6800
Mar	**48.61**	1.3775
Apr	**53.21**	1.5080
May	**20.10**	0.5696
Jun	**11.81**	0.3346
Jul	**4.08**	0.1156
Aug	**2.74**	0.0776
Sep	**2.84**	0.0805
Oct	**4.91**	0.1392
Nov	**16.32**	0.4625
Dec	**27.41**	0.7766

Q_{bf}	**78.1**
ann avg	**26.7**
ann med	**13.7**
$Q_{1.002}$	**69.7**
$Q_{1.01}$	91.8
$Q_{1.05}$	128.1

W_{bf}	29.2	estimated bankfull width
d_{bf}	2.3	
Q_{bf}	265.4	assume v = 4ft/s

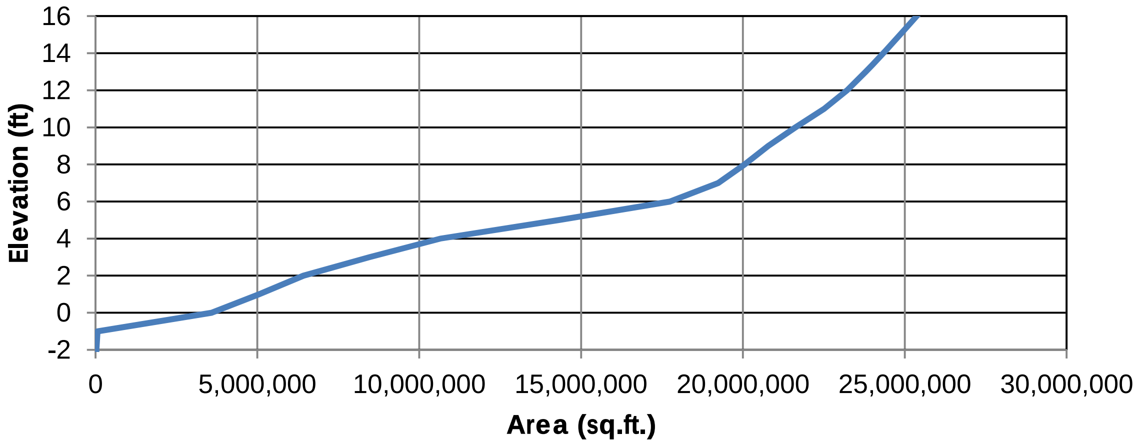



MACHIAS
EAST MA
HADLEY
LAKE
MARSHFIELD
MARSHFIELD
MARSHFIELD
Lily Lake
WHITNEY
Whitneyville
MACHIAS
MACHIAS

Appendix A :UPLAND HYDROLOGY

Appendix B: ELEVATION-AREA INFORMATION, MIDDLE RIVER LANDWARD FROM DYKE BRIDGE

Plot of Elevation-Area Data

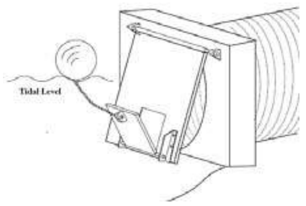
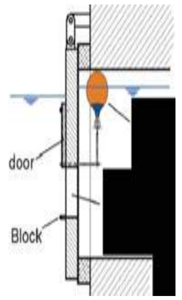
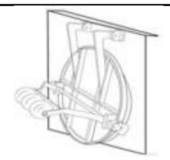


Tabular Elevation-Area Data

Elevation (ft NAVD88)	Area (sq. ft)	Area (acres)
-1	62,361	1.43
0	3,584,172	82.3
1	5,052,564	116
2	6,426,034	148
3	8,469,801	194
4	10,661,151	245
5	14,323,379	329
6	17,742,072	407
7	19,237,352	442
8	20,052,345	460
9	20,780,224	477
10	21,623,345	496
11	22,513,513	517
12	23,220,294	533
13	23,796,594	546
14	24,328,877	559
15	24,853,485	571
16	25,366,834	582

TYPE	MANUFACTURER	OPERATIONS	PASSIVE / ACTIVE	ALLOWS TIDAL FLUSHING?	ALLOWS US FISH PASSAGE?	GATE MATERIALS	PROS	CONS	NOTES	**IMAGES** (from manufacturers' websites)
TRADITIONAL TIDE GATES (most restrictive)										
Top-Hinged Tide Gate (THTG): cast iron and wood	Armtec (Hydro Gate), Golden Harvest, Waterman, Rodney Hunt	Round or square lid hinged at upper edge of pipe. Attached by single- or double-hinge system. Hydraulic head differential causes gate to open/close.	Passive (change in hydraulic head differential)	No (unless leaking or propped open)	Under limited range of flow conditions during ebb tide	Cast iron, wood (materials with higher restorative force)	Relatively simple, durable and reliable. Long lifespan. Efficient in preventing backflushing if sized, installed and maintained properly.	Landward impacts associated with impacts on tidal flushing, WSELs, AOP, water quality. Can trap floating debris (requiring maintenance). Conveyance reduced as weight to size ratio increases. Limited conveyance capacity and increased velocities at lower flows associated with reduced opening. THTGs expected to remain closed at least 50% of time. Heavier gates have higher restorative force resulting in 1) large hydraulic head differential required to open gate (resulting in opening only during brief period of ebb tide) and 2) increased velocity and turbulence through opening.	Traditionally, round THTGs are cast iron and rectangular THTGs are wood. Variable criteria in top-hinge flap gates include: opening size (e.g., radius), opening shape (e.g., round, rectangular), pivot radius (measured from top hinge), and duty (e.g., light/medium/heavy-duty).	
FISH-FRIENDLIER TIDE GATES (less restrictive)										
THTG: lighter materials	Golden Harvest, Nehalem Marine Manufacturing, Waterman, Rodney Hunt	Same as above.	Same as above	No (unless leaking or propped open)	Same as above	Aluminum, plastic, FRP, fiberglass (materials with lower restorative force)	Lighter materials may require significantly less hydraulic head differential to open in relation to THTGs made from traditional materials (e.g., cast iron, wood). Open for greater amount of time and with wider opening than heavier THTGs. Plastic and fiberglass gate may be less expensive than metal gates.	Lighter materials may not be as strong or durable, may include increased maintenance and repairs, are more easily damaged, and may have decreased lifespan. Landward impacts related to tidal flushing remain similar to THTGs constructed of heavier materials.		
THTG: radial	Unable to find current manufacturer.	Same as above.	Same as above	No (unless leaking or propped open)	Same as above	Spun aluminum	Lightweight and relatively inexpensive. Low restorative force.	Thin material can be vulnerable to damage from debris. Concave shape of gate may constrain passage of larger fish. Landward impacts related to tidal flushing remain similar to THTGs constructed of heavier materials.	Unable to find a current manufacturer of this style.	
THTG: flexible	Armtec (Hydro Gate), Plasti-Fab Inc.	Same as above.	Same as above	No (unless leaking or propped open)	Same as above	1"-thick neoprene cover mounted to steel frame	Quiet operations, low maintenance, low head loss, debris easily removed/flushed, no hinge pin wear points, no painting or lubrication required.	Flexible materials may be less durable. Landward impacts related to tidal flushing remain similar to THTGs constructed of heavier materials.	60" max width (per Hydro Gate).	
Duckbill	RedValve (Tideflex)	Opening is vertical slot (check valve) in stiff, yet deformable material mounted at DS end of pipe; default position of check valve is closed; deforms to open when hydraulic head differential is high enough.	Passive (change in hydraulic head differential)	No (unless leaking or propped open)	Thought to prevent US migration of some adult fish.	Flexible synthetic material	Simple, can be durable and reliable. Requires low hydraulic head differential to open valve. Can be self-cleaning (of debris). Flexible material may allow for formation of seal even around debris, allowing only minor leakage even when clogged with debris. Relative to DS flow, studies suggest performs equal to or better than THTGs.	Landward impacts associated with impacts on tidal flushing, WSELs, AOP, water quality. Small opening does not pass large debris; difficult to keep free from debris and debris removal can be difficult to remove. Potential for excessive head loss. Thought to allow downstream migration of juveniles but to prevent US migration of some adult fish.		

TYPE	MANUFACTURER	OPERATIONS	PASSIVE / ACTIVE	ALLOWS TIDAL FLUSHING?	ALLOWS US FISH PASSAGE?	GATE MATERIALS	PROS	CONS	NOTES	**IMAGES** (from manufacturers' websites)
FISH-FRIENDLIER TIDE GATES (less restrictive - *continued*)										
Motorized Slide Gate	Armtec (Hydro Gate), Waterman	Motorized vertical lift slide gate. Water levels monitored by sensors. Gate raises/lowers according to programmed parameters (e.g., water level elevations).	Active (Motorized vertical lift	Yes (depending on management)	Dependent on operations parameters	Metal	Allows for tidal flushing within desired parameters; allows for modification of parameters.	Requires electrical services at tide gate. Maintenance of motor, electrical supply and programming. Relatively complicated and expensive. Power outage can result in loss of control of gate.		
Manually Actuated Gate	Armtec (Hydro Gate), Plasti-Fab Inc., Rodney Hunt	Manually opened & closed. Approach can be applied to entire gate or to "trap door" within gate (see below).	Active (gate manually operated)	Yes (depending on management)	Dependent on operations parameters		Low cost	Requires manual operation / implementation of operational protocol.		
Side-Hinged Tide Gate (SHTG)	Armtec (Hydro Gate), Golden Harvest, Plasti-Fab Inc.	Top hinge installed closer to culvert opening than bottom hinge to create downward tilt which provides restorative force to enable gate to close at end of ebb tide.	Passive (change in hydraulic head differential)	No (unless leaking or propped open)	Under limited range of flow conditions during ebb tide	Wood, aluminum, stainless steel	Simple, can be durable and reliable, wide opening under lower flows (relative to THTGs), less likely to trap debris (compared to THTGs, duckbill style), reduced impingement hazard. Very small restorative force. Opens with smaller hydraulic head differential and stays open longer and wider than THTGs. Water velocities and turbulence through SHTGs are typically lower than through THTGs of similar size and weight. Increased opening duration and size (during ebb tide) reduces certain impacts associated with AOP, water quality and connectivity impacts relative to THTGs. Nehalem states SHTG capable of providing up to 30-40% more conveyance than THTG.	Landward impacts associated with impacts on tidal flushing, WSELs, AOP, water quality. Potential for increased wear on hinge mechanisms relative to THTGs. Support structure for gate is more difficult and costly to install. Angle of tilt must be set precisely and in such a way that it will not change over time.		 

TYPE	MANUFACTURER	OPERATIONS	PASSIVE / ACTIVE	ALLOWS TIDAL FLUSHING?	ALLOWS US FISH PASSAGE?	GATE MATERIALS	PROS	CONS	NOTES	**IMAGES** (from manufacturers' websites)
FISH FRIENDLIER GATE MODIFICATIONS (less restrictive)										
Pet Door / Trap Door (top-hinge, bottom-hinge, and side-hinge)	Nehalem Marine Manufacturing, Golden Harvest	Smaller gate placed within field of the tide gate. Smaller gate constructed to open with very low hydraulic head differential (lower than tide gate). Hinge may be mounted on top, bottom or side.	Passive (change in hydraulic head differential)	No (unless leaking or propped open); except Bottom-Hinged Trap Door which remains open for part of the flood tide.	Under limited range of flow conditions during ebb tide (and flood tide in case of bottom-hinged trap door)	Aluminum, plastic (materials with low restorative force)	Trap door requires lower hydraulic head differential to open (than tide gate on which it is mounted); may remain open for longer duration than gate; may improve flow and fish passage.	Trap door may clog with debris and may increase susceptibility of gate to debris jams.		 
Mitigator Fish Passage Device	Nehalem Marine Manufacturing	Floats mounted on gate rotate a block (cam) that props gate partially open during portion of rising tide. Can be mounted on THTG or on smaller aperture within larger gate (e.g., Pet Door).	Passive (change in hydraulic head differential)	Yes. Limited.	Under limited range of flow conditions during ebb tide and portion of flood tide.		Inexpensive and reliable.	Limited adjustability (opening limited to range of cam). Debris can foul float mount.	Size of cams determines size of opening during flood tide. Can be sized based on passage criteria of fish.	 
Permanent Hole		Permanent opening placed within field of larger tide gate. Allows for limited amount of bi-directional flow.	n/a	Yes. Limited.	Under appropriate flow conditions during ebb and flood tide.		Allows for limited tidal flushing, saltwater intrusion; may provide US and DS AOP through ebb and flood tides. May improve water quality, connectivity, AOP.	Uncontrolled opening.	Opening must be sized and located correctly to avoid/minimize high velocities and turbulence relative to fish passage criteria.	
Variable Backflow Flap Gate (VBFG)	Juel Tide Gates	Control mechanism retrofitted to SHTG or THTG. Gate closes on rising tide when "draft force" through culvert exceeds tension exerted by VBFG rigging device.	Passive (change in flow through culvert and hydraulic head differential)	Yes (within set parameters)	Under appropriate flow conditions during ebb and flood tide.		Appears to be a simple and relatively inexpensive retrofit.	Minimal information available for review (except promotional piece by the designer labeling the VBFG "ingenious").	Gate opens 80-90 degrees to headwall when WSEL at DS side of gate is ≤ WSEL at US side.	 

TYPE	**MANUFACTURER**	**OPERATIONS**	**PASSIVE / ACTIVE**	**ALLOWS TIDAL FLUSHING?**	**ALLOWS US FISH PASSAGE?**	**GATE MATERIALS**	**PROS**	**CONS**	**NOTES**	**IMAGES** (from manufacturers' websites)
SELF REGULATING TIDE GATES & SIMILAR (least restrictive)										
Buoyancy-Compensated THTG (SRT)	Waterman Industries, Golden Harvest	Gate is buoyant; rises with water level. Floats mounted to counterbalancing arm of gate frame are more buoyant than gate lid. Default position is open (gate floating on water). Position of floats controls WSEL "trip elevation" - WSEL at which gate closes on rising tide.	Passive (change in hydraulic head differential and WSEL)	Yes (within set parameters)	Under appropriate flow conditions during ebb and flood tides.		Relatively simple. Designed to remain open except when flood tide exceeds set elevation; allows tidal flushing within desired parameters. Relatively low maintenance. Because default position is open, may interfere least with fish passage.	Frame / floats can collect debris, affect operation and requiring maintenance. Float adjustment may be difficult and/or have limited range. During high flow events, submerged vent tubes may pass floodwater US. Gates may slam shut. Culvert may require vertical vents to prevent water hammer when gate closes. Cannot respond to FW elevs at US side (as compared to MTR [see below]).		
Muted Tidal Regulator (MTR)	Nehalem Marine Manufacturing	MTR unit mounts on US side of pipe in SHTG or THTG. Gate is closed by float located at US side of pipe. Control mechanism extends from float at US end to gate at DS end of pipe. During flood tide, gate remains open until target WSEL is reached at US side of pipe. Requires related infrastructure on both US and DS sides of pipe Closing is regulated by the WSEL at US side of the pipe - so can respond to conditions related to both tidal and FW flows/elevs.	Passive (change in WSEL at US side of pipe)	Yes (within set parameters)	Under appropriate flow conditions during ebb and flood tides.		Placement of MTR at US side of pipe allows for opening/closing of structure to respond to both landward and seaward WSELs (tidal & FW conditions); trip elevation is related to max elevation of backwater pool, not tidal elev., resulting in greater opportunity for connectivity, mixing, and passage. SHTG with MTR provides >50% more fish passage "time" relative to conventional THTG and SHTG applications (per Leo Kuntz). Kuntz states that failed SRTs are replaced with SHTG/MTR combos. Easily adjustable trip elevation.	Expensive. Includes many moving components.		

Appendix D : SUMMARY OF HEC-RAS MODEL SETUP

Appendix D: Summary of HEC-RAS Model Setup

Bridge Geometry	Top of Roadway at Dyke Bridge (ft)	Dyke Bridge Geometry	Stride Bridge Geometry	Riverine Flow (cfs)	Tides (ft) (high/low)	SLR (m)	Surge (ft)	HEC-RAS Model Files		
								Geometry File	Flow file	Plan
Typical Tides, 1.1-year flow, SLR				**1.1-year**	**Recorded**			**Q1.1 Recorded Tides SLR varies**		
1-Existing	elev 11	Existing	TR=12	152 - steady	+9.0/-7.5	none	none	Alternative 1r rev.g21	Alternative 1 US Rules Q1p1 .u5	alt1rq1Tide1.p10
		4-4X5' boxes	inv -2.8/-2.5			0.5 m		Alternative 1r rev.g21	Alternative 1 US Rules Q1p1HSLR .u11	alt1rq1Tide1Hslr.p11
		w/ gates, inv -3.1	12.5' cmp			1m		Alternative 1r rev.g21	Alternative 1 US Rules Q1p1FSLR .u12	alt1rq1Tide1Fslr.p12
2-replace	elev 11	replace ex, gates	TR=12	152 - steady	+9.0/-7.5	none	none	Alternative 2r.g12	Alternative 2 US Rules Q1p1 .u13	Alt2 R1 Q1p13
		4-5X5 boxes,	inv -2.8/-2.5			0.5 m		Alternative 2r.g12	Alt 2 US Rules Q1p1HSLR .u14	Alt2 R1 Q1p1 HSLR.p14
		inv -4.05	12.5' cmp			1m		Alternative 2r.g12	Alt 2 US Rules Q1p1FSLR .u15	Alt2 R1 Q1p1 FSLR.p15
2 REV	elev 11	replace ex, gates	same	152 - steady	+9.0/-7.5	none	none	Alternative 2 REV 4 gates 1box.g22	.u51	alt 2 REV Q1 T1.p84
		4 flap gates, 1 open box				0.5 m		Alternative 2 REV 4 gates 1box.g22	.u53	alt 2 REV Q1 T1 HSLR.p79
		inv -4.05				1m		Alternative 2 REV 4 gates 1box.g22	.u54	alt 2 REV Q1 T1 FSLR.p85
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	152 - steady	+9.0/-7.5	none	none	Alternative 5r.g13	Alternatives5-6-7 Free FlowingQ1p1.u16	alt 5rQ1T1.p17
		bridge	invs -2.6/-2.5			0.5 m		Alternative 5r.g13	Alternatives5-6-7 Free FlowingQ1p1 HSLR.u1	alt5r Q1 T1 HSLR.p18
		inv = -5, n=.03	n=.015			1m		Alternative 5r.g13	Alternatives5-6-7 Free FlowingQ1p1 FSLR.u18	alt5r Q1 T1 FSLR.p19
6 - 60' span	elev 11	1- 60' span	TR=17	152 - steady	+9.0/-7.5	none	none	Alternative 6.g09	Alternatives5-6-7 Free FlowingQ1p1.u16	alt 6 Q1 T1.p20
		LC=9, TR=11	n=.028			0.5 m		Alternative 6.g09	Alternatives5-6-7 Free FlowingQ1p1 HSLR.u1	alt 6 Q1 T1 HSLR.p21
		invs -7.2/-8.0	invs -2.6/-2.5			1m		Alternative 6.g09	Alternatives5-6-7 Free FlowingQ1p1 FSLR.u18	alt 6 Q1 T1 FSLT.p22
Typical Tides, 50-year flow, SLR				**50-year**	**Recorded**			**Q50**		
1-Existing	elev 11	Existing	TR=12	824 steady	+9.0/-7.5	none	none	Alternative 1r rev.g21	Alternative 1 US rules R Q50.u9	atr1r Q50 T1.p23
		4-4X5' boxes	inv -2.8/-2.5	Hydrograph	+9.0/-7.5	none	none	Alternative 1r rev.g21	Alternative 1 US rules R Q50Hydrograph.u10	alt1r q50HYD-T1.p24
		w/ gates, inv -3.1	12.5' cmp	Hydrograph		0.5 m		Alternative 1r rev.g21	Alternative 1 US rules R Q50Hyd- HSLR.u19	alt 1r q50HYD-T1HSLR.p25
				Hydrograph		1m		Alternative 1r.g11	Alternative 1 US rules R Q50Hyd-FSLR.u20	1r q50HYD-T1FSLR.p26
2-replace	elev 11	replace ex, gates	TR=12	Hydrograph	+9.0/-7.5	none	none	Alternative 2r.g12	Alternative 2 US Rules R Q50HYD p1 .u21	Alt2 R1 Q50HYD T1.p28
		4-5X5 boxes,	inv -2.8/-2.5	Hydrograph		0.5 m		Alternative 2r.g12	Alternative 2 R q50HYD T1 HSLR.u22	alt2 q50 HYD T1 HLSR.p29
		inv -4.05	12.5' cmp	Hydrograph		1m		Alternative 2r.g12	alt2R Q50HYD T1 FSLR.u23	alt2 q50 HYD T1 FLSR.p30
2 REV	elev 11	replace ex, gates	same	Hydrograph	+9.0/-7.5	none	none	Alternative 2 REV 4 gates 1box.g22	alt 2REV T50 Q1. u55	alt 2 rev T50 Q1.p89
		4 flap gates, 1 open box		Hydrograph		0.5 m		Alternative 2 REV 4 gates 1box.g22		
		inv -4.05		Hydrograph		1m		Alternative 2 REV 4 gates 1box.g22		
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	Hydrograph	+9.0/-7.5	none	none	Alternative 5r.g13	Alternatives 5-6-7 Q50HYD T1.u24	alt5 Q50HYD T1.p31
		bridge	invs -2.6/-2.5	Hydrograph		0.5 m		Alternative 5r.g13	Alternatives 5-6-7 Q50HYD T1 HSLR.u25	alt5 Q50HYD T1 HSLR.p32
		inv = -5, n=.03	n=.015	Hydrograph		1m		Alternative 5r.g13	Alternatives 5-6-7 Q50HYD T1 FSLR.u26	alt5 Q50HYD T1 FSLR.p33
6 - 60' span	elev 11	1- 60' span	TR=17	Hydrograph	+9.0/-7.5	none	none	Alternative 6.g09	Alternatives 5-6-7 Q50HYD T1.u24	alt6 Q50HYD T1.p34
		LC=9, TR=11	n=.028	Hydrograph		0.5 m		Alternative 6.g09	Alternatives 5-6-7 Q50HYD T1 HSLR.u25	alt6 Q50HYD T1 HSLR.p35
		invs -7.2/-8.0	invs -2.6/-2.5	Hydrograph		1m		Alternative 6.g09	Alternatives 5-6-7 Q50HYD T1 FSLR.u26	alt6 Q50HYD T1 FSLR.p36
Typical Tides, 100-year flows, plus SLR				**100-year**	**Recorded**			**Q100**		
1-Existing	elev 11	Existing	TR=12	958 -steady	+9.0/-7.5	none	none	Alternative 1r rev.g21	Alternative 1 US rules R Q100.u27	atr1r Q100 T1.p37
		4-4X5' boxes	inv -2.8/-2.5	958 hydrograph	+9.0/-7.5	.5 m		Alternative 1r rev.g21	Alternative 1 R Q100Hyd T1.u28	alt1r q100HYD-T1.p38
		w/ gates, inv -3.1	12.5' cmp	Hydrograph		1 m		Alternative 1r rev.g21	Alternative 1 R Q100Hyd T1HSLR.u36	alt1r q100HYD-T1HSLR.p52
				Hydrograph		1m		Alternative 1r rev.g21	Alternative 1 R Q100Hyd T1FSLR.u37	alt1r q100HYD-T1FSLR.p53
2-replace	elev 11	replace ex, gates	TR=12	Hydrograph	+9.0/-7.5	none	none	Alternative 2r.g12	Alternative 2 US Rules R Q100HYD p1 .u29	Alt2 R1 Q100HYD T1.p39
		4-5X5 boxes,	inv -2.8/-2.5	Hydrograph		0.5 m		Alternative 2r.g12	Alternative 2 US Rules R Q100HYD t1 HSLR .u3	Alt2 R1 Q100HYD T1 HSLR.p54
		inv -4.05	12.5' cmp	Hydrograph		1m		Alternative 2r.g12	Alternative 2 US Rules R Q100HYD T1 FSLR .u3	Alt2 R1 Q100HYD T1 FSLR.p55
2 REV	elev 11	replace ex, gates	same	Hydrograph	+9.0/-7.5	none	none	Alternative 2 REV 4 gates 1box.g22	Alt 2 REV q100 T1.u56	Alt 2 REV Q100 T1. p81
		4 flap gates, 1 open box		Hydrograph		0.5 m		Alternative 2 REV 4 gates 1box.g22		
		inv -4.05		Hydrograph		1m		Alternative 2 REV 4 gates 1box.g22		
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	Hydrograph	+9.0/-7.5	none	none	Alternative 5r.g13	Alternatives 5-6-7 Q100HYD T1.u30	alt5 Q100HYD T1.p40
		bridge	invs -2.6/-2.5	Hydrograph		0.5 m		Alternative 5r.g13	" HSLR.u40	" HSLR.p01
		inv = -5, n=.03	n=.015	Hydrograph		1m		Alternative 5r.g13	" FSLR.u41	" FSLR.p57
6 - 60' span	elev 11	1- 60' span	TR=17	Hydrograph	+9.0/-7.5	none	none	Alternative 6.g09	Alternatives 5-6-7 Q100HYD T1.u30	alt5 Q100HYD T1 FSLR.p41
		LC=9, TR=11	n=.028	Hydrograph		0.5 m		Alternative 6.g09	"HSLR.u40	" HSLR.p58
		invs -7.2/-8.0	invs -2.6/-2.5	Hydrograph		1m		Alternative 6.g09	" FSLR.u41	" FSLR.p59

Appendix D: Summary of HEC-RAS Model Setup (Continued)

Bridge Geometry	Top of Roadway at Dyke Bridge (ft)	Dyke Bridge Geometry	Stride Bridge Geometry	Riverine Flow (cfs)	Tides (ft) (high/low)	SLR (m)	Surge (ft)	HEC-RAS Model Files		
								Geometry File	Flow file	Plan
High Spring Tide plus Surge, 1.1-year flow, plus SLR				**1.1year**	**Spring tides**		**2.5' surge**	**Q1.1 50-year SURGE at HIGH TIDE SLR varies**		
1-Existing	elev 11	Existing	TR=12	1.1-year	7.3/-6.9	none	2.5	Alternative 1r rev.g21	Alternative1_Cat50yr_Q1H.u04	Alt 1r 50Tide Q1H.p42
		4-4X5' boxes	inv -2.8/-2.5	steady		0.5 m		Alternative 1r rev.g21	" HSLR.u44	" HSLR.p88
		w/ gates, inv -3.1	12.5' cmp			1m		Alternative 1r rev.g21	" FSLR.u45	" FSLR.p78
2-replace	elev 11	replace ex, gates	TR=12	1.1-year	7.3/-6.9	none	2.5	Alternative 2r.g12	Alternatives2r_Cat50yr_Q1p1_H.u06	alt2r 50yrtide q1 surgeathigh.p43
		4-5X5 boxes,	inv -2.8/-2.5			0.5 m		Alternative 2r.g12	" HSLR.u46	" HSLR.p16
		inv -4.05	12.5' cmp			1m		Alternative 2r.g12	" FSLR.u47	" FSLR.p56
2 REV	elev 11	replace ex, gates	same	1.1-year	7.3/-6.9	none	2.5	Alternative 2 REV 4 gates 1box.g22	Alt 2 REV q1 T50.u57	alt2REV q1 T50.p90
		4 flap gates, 1 open box				0.5 m		Alternative 2 REV 4 gates 1box.g22	Alt 2 REV q1 T50 HSLR.u58	alt 2 REV q1 T50 HSLR.p91
		inv -4.05				1m		Alternative 2 REV 4 gates 1box.g22	Alt 2 REV q1 T50 FSLR.u59	alt 2 REV q1 T50 FSLR.p92
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	1.1-year	7.3/-6.9	none	2.5	Alternative 5r.g13	Alternatives5r_Cat50yr_Q1p1_H.u03	alt5r 50yrtide q1 surgeathigh.p44
		bridge	invs -2.6/-2.5			0.5 m		Alternative 5r.g13	" HSLR.u43	" HSLR.p03
		inv = -5, n=.03	n=.015			1m		Alternative 5r.g13	"FSLR.u42	" FSLR.p02
6 - 60' span	elev 11	1- 60' span	TR=17	1.1-year	7.3/-6.9	none	2.5	Aternative 6.g09	Alternatives6_Cat50yr_Q1p1_H.u03	alt6 50yrtide q1 surgeathigh.p45
		LC=9, TR=11	n=.028			0.5 m		Aternative 6.g09	" HSLR.u43	" HSLR.p60
		invs -7.2/-8.0	invs -2.6/-2.5			1 m		Aternative 6.g09	" FSLR.u42	" FSLR.p61
1-Existing	Existing	Existing	Existing	1.1-year	7.3/-6.9	none	MR	Alternative 1r rev.g21	alternative1_Cat50yr_Q1MF.u031	alt 1r 50Tide Q1 surgeatMFT.p46
				steady		none	MF	Alternative 1r rev.g21	alternative1_Cat50yr_Q1ME.u032	alt 1r 50Tide Q1 surgeatME.p47
						none	L	Alternative 1r rev.g21	alternative1_Cat50yr_Q1L.u033	alt 1r 50Tide Q1 surgeatL.p48
2-replace	Same as Exist.	Same as Exist.	no change	1.1-year	7.3/-6.9	none	MR	Alternative 2r.g12	Alternatives2r_Cat50yr_Q1p1_MF.u34	alt2r 50T Q1 surge at MF tide.p49
						none	MF	Alternative 2r.g12	ME	ME
						none	L	Alternative 2r.g12	L	L
5- 5 boxes	Same as Exist.	5- 15' boxes	no change	1.1-year	7.3/-6.9	none	MR	Alternative 5r.g13	Alternatives5-6-7_Cat50yr_Q1p1_MF.u34	alt5r 50T Q1 surge at MF tide.p50
						none	MF	Alternative 5r.g13	ME	ME
						none	L	Alternative 5r.g13	L	L
6 - 60' span	Same as Exist.	1- 60' span	no change	1.1-year	7.3/-6.9	none	MR	Aternative 6.g09	Alternatives5-6-7_Cat50yr_Q1p1_MF.u35	alt6 50T Q1 surge at MF tide.p51
						0.5 m	MF	Aternative 6.g09	HSLR	HSLR
						1m	L	Aternative 6.g09	FSLR	FSLR
Typical Tides, Flows Vary, Dyke BR and Stride BR Alternatives				**1.1-year**	**Recorded**			**High Causeway at Route 1 plus check slip lined Stridge Bridge Q1.1, Q50, Q100 with Recorded Tide and SLR**		
6 - 60' span	**14.7'**	1- 60' span	no change	1.1-year	9/-7.5	1m	none	Alternative 6 elev14p7.g08	Alternatives 5-6-7FreeflowingQ1p1FSLR.u18	alt6 14p7 Q1T1FSLR.p62
6 - 60' span	**14.7'**	1- 60' span	**slip lined**	1.1-year	9/-7.5	1m		Alternative 6 elev14p7 slipline stride.g18	Alternatives 5-6-7FreeflowingQ1p1FSLR.u18	alt6 14p7 SL Q1T1FSLR.p63
6 - 60' span	**14.7'**	1- 60' span	no change	**50-year**	9/-7.5	none	none	Alternative 6 elev14p7.g08	Alternatives 5-6-7 Q50 T1.u24	
				Hydrograph		0.5 m		Alternative 6 elev14p7.g08	Alternatives 5-6-7 Q50 T1 HSLR.u25	
						1m		Alternative 6 elev14p7.g08	alt 5-6-7 Q50HYD T1 FSLR.u26	alt6 14p7 Q50 T1 FSLR.p64
6 - 60' span	**14.7'**	1- 60' span	no change	**100-year**	9/-7.5	none	none	Alternative 6 elev14p7.g08	alternatives 5-6-7 100HYD T1.u30	
				Hydrograph		0.5 m		Alternative 6 elev14p7.g08	"HSLR.u40	
						1m		Alternative 6 elev14p7.g08	" FSLR.u41	alt 6 14p7 Q100 T1 FSLR.p65
6 - 60' span	**14.7'**	1- 60' span	**slip lined**	**50-year**	9/-7.5	none	none	Alternative 6 elev14p7 slipline stride.g18	Alternatives 5-6-7 Q50 T1.u24	alt 6 14p7 SL Q50 T1.p66
				Hydrograph		0.5 m		Alternative 6 elev14p7 slipline stride.g18	Alternatives 5-6-7 Q50 T1 HSLR.u25	" HSLR.p67
						1m		Alternative 6 elev14p7 slipline stride.g18	alt 5-6-7 Q50HYD T1 FSLR.u26	" FSLR.p68
6 - 60' span	**14.7'**	1- 60' span	**slip lined**	**100-year**	9/-7.5	none	none	Alternative 6 elev14p7 slipline stride.g18	alternatives 5-6-7 100HYD T1.u30	alt6 14p7 SL Q100 T1.p69
				Hydrograph		0.5 m		Alternative 6 elev14p7 slipline stride.g18	"HSLR.u40	" HSLR.p70
						1m		Alternative 6 elev14p7 slipline stride.g18	" FSLR.u41	" FSLR.p71

Appendix D: Summary of HEC-RAS Model Setup (Continued)

Bridge Geometry	Top of Roadway at Dyke Bridge (ft)	Dyke Bridge Geometry	Stride Bridge Geometry	Riverine Flow (cfs)	Tides (ft) (high/low)	SLR (m)	Surge (ft)	HEC-RAS Model Files		
								Geometry File	Flow file	Plan
Storm Surge Tides, 1.1-year flows, plus SLR, Dyke/Stride options					**Spring**			**High Causeway at Route 1 plus check slip lined Stridge Bridge 50-year SURGE at High Spring Tide plus SLR**		
6 - 60' span	**14.7'**	1- 60' span	no change	**1.1-year**	7.3/-6.9	none	2.5	Alternative 6 elev14p7.g08	Alternatives6_Cat50yr_Q1p1_H.u03	alt 6 14p7 Q1 T50.p72
						0.5 m		Alternative 6 elev14p7.g08	" HSLR.u43	alt 6 14p7 Q1 T50 HSLR.p73
						1m		Alternative 6 elev14p7.g08	" FSLR.u42	alt 6 14p7 Q1 T50 FSLR.p74
Case 6 - 60' span	**14.7'**	1- 60' span	no change	**1.1-year**	7.3/-6.9	none	2.5	Alternative 6 elev14p7.g08		
						0.5 m		Alternative 6 elev14p7.g08		
						1m		Alternative 6 elev14p7.g08		
Case 6 - 60' span	**14.7'**	1- 60' span	**slip lined**	1.1-year	7.3/-6.9	none	2.5	Alternative 6 elev14p7 slipline stride.g18	Alternatives6_Cat50yr_Q1p1_H.u03	alt6 14p7 SL Q1 T50H.p76
						0.5 m		Alternative 6 elev14p7 slipline stride.g18	" HSLR.u43	alt6 14p7 SL Q1 T50H HSLR.p75
						1 m		Alternative 6 elev14p7 slipline stride.g18	" FSLR.u42	alt6 14p7 SL Q1 T50H FSLR.p77
Case 6 - 60' span	**14.7'**	1- 60' span	**slip lined**	1.1-year	7.3/-6.9	none	2.5	Alternative 6 elev14p7 slipline stride.g18		
						0.5 m		Alternative 6 elev14p7 slipline stride.g18		
						1 m		Alternative 6 elev14p7 slipline stride.g18		
Calibration Model Runs				**20 cfs**	**Recorded**					
Case 1	11	Existing	TR=12		+9.0/-7.5	none	none	Alternative 1r-rev.g21	Alt 1 rules rev.u52	Alt 1r gates 20 cfs T1.p87
		4-4X5' boxes	inv -2.8/-2.5							
		w/ gates, inv -3.1	12.5' cmp							
Case 1	11	Existing	TR=12		+9.0/-7.5	none	none	Alt 1 no gates.g20	Alternative 1 no gates 20 cfs T1.u50	alt 1 q20 T1 no gates.p86
		4-4X5' boxes	inv -2.8/-2.5							
		NO gates, inv -3.1	12.5' cmp							
Alt 2 Replacement in kind options										
Alt 2 4 flap gates, 1 open box		4 5X5 flap gates	TR=12	20	+9.0/-7.5	none	none	Alternative 2 REV 4 gates 1box.g22	alternative 2 REV no rules Q20T1.u61	alt2 4 flapgates 1 open box Q20cfsT1.p82
	11	one open 5X5	inv -2.8/-2.5	152				Alternative 2 REV 4 gates 1box.g22	alternative 2 REV no rules Q1T1.u51	alt2 4 flapgates 1 open box Q1cfsT1.p80
		inv -4.05	12.5' cmp							
alt 2 3 flaps 1 open		3 5X5 flap gates	TR=12	20	+9.0/-7.5	none	none	Alternative 2 3 flap gates 1 open.g02	alternative 2 REV no rules Q20T1.u61	alt2 3 flapgates 1 open box Q20cfsT1.p04
		one open 5X5	inv -2.8/-2.5	152				Alternative 2 3 flap gates 1 open.g02	alternative 2 REV no rules Q1T1.u51	alt2 3 flapgates 1 open box Q1cfsT1.p83
		inv -4.05	12.5' cmp							
alt 2 2 flaps 1 open		2 5X5 flap gates	TR=12	20	+9.0/-7.5	none	none	alternative 2 2 flap gates 2 open.g03	alternative 2 REV no rules Q20T1.u61	alt2 2 flapgates 2 open box Q20cfsT1.p27
		two open 5X5	inv -2.8/-2.5	152					alternative 2 REV no rules Q1T1.u51	alt2 2 flapgates 2 open box Q1T1.p06

Appendix E: MEMO ON STRIDE BRIDGE REHABILITATION AND REPLACEMENT OPTIONS

Stantec

Memo

To: Michael Chelminski
Topsham ME Office
From: Tim Merritt
Scarborough ME Office
File: 195600963, Task 208
Date: January 22, 2015

Reference: MaineDOT Stride Bridge – Rehab & Replacement Options

The following is a memo describing the rehab and replacement options for the Stride Bridge for your review/use:

STRIDE BRIDGE

Stride Bridge is located on the Middle River in Marshfield, Maine, and is comprised of a corrugated metal pipe (CMP) with a diameter of 12.5 feet (ft) that is approximately 40 ft long and mitered to the upstream and downstream slopes of the roadway embankment. The upstream and downstream invert elevations[1] of the culvert are -2.58 ft and -2.48 ft, respectively.

Hydraulic Conditions In the Middle River

Hydraulic conditions at Stride Bridge are affected by upland (riverine) flow and backwater conditions that propagate upstream from the downstream reach of the Middle River, including effects associated with regulation of landward tidal flow at Dyke Bridge. Peak riverine flows in the Middle River at Stride Bridge and Dyke Bridge were provided by MaineDOT and are provided in Table 1.

Table 1: Peak Flows

	Return-Interval Event (Years)/Peak Flow (cfs)							
Location	***1.1***	***2***	***5***	***10***	***25***	***50***	***100***	***500***
Stride Bridge	130	265	213	522	670	787	912	1,221
Dyke Bridge	152	297	452	565	715	832	958	1,264

Dyke Bridge is approximately 15,000 ft downstream (seaward) from Stride Bridge, and is comprised of a causeway with four box culverts that crosses the Middle River immediately upstream (landward[2]) from its confluence with the Machias River. Hydraulic conveyance at the Dyke Bridge is provided by four 5 ft x 5 ft box culverts with invert elevations of approximately -4 ft that have flap gates installed on the downstream (seaward) side of the culverts. The flap gates restrict landward tidal flow while allowing for downstream (seaward) flow of upland runoff from the Middle River.

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[1] Elevations provided by Maine DOT and referenced to the North American Vertical Datum of 1988 (NAVD88).

[2] "Landward" and "seaward" are used in addition to "upstream" and "downstream", respectively, to reflect bi-directional flow associated with tidal conditions in the Machias River.

The Machias River is tidally influenced immediately seaward from Dike Bridge; and Tidal stage parameters for the Machias River were developed for this study using data collected by Maine DOT; these statistics are presented in Table 1.

Table 2: Tidal Statistics for Machias River

Tidal Data (ft, NAVD88)						
Max.	**MHHW**	**MHW**	**Average**	**MLW**	**MLLW**	**Min.**
11.7	**9.3**	**8.4**	**2.0**	**-4.5**	**-4.8**	**-5.5**

Tidal stage data collected by Maine DOT in the Middle River immediately upstream (landward) from Dyke Bridge indicates that the normal tidal range is from elevation -0.5 (normal high tide) to elevation -2.0 (normal low tide).

Backwater effects associated with the existing tide gate system at Dyke Bridge result in persistent backwater effects in the upstream reach of the Middle River and minimum water surface elevations (approximately elevation -2.0 ft) that are above the invert of the Stride Bridge culvert.

BRIDGE REHABILITATION OPTIONS

As requested by Maine DOT, the evaluated rehabilitation options for the Stride Bridge are invert lining and sliplining.

The top half of existing culvert appears to be in good condition and the bottom half is corroding so invert lining could be appropriate for this structure. There have been several MaineDOT invert lining projects in the past several years and they generally consist of a 5 to 6 inch reinforced slab cast against the lower half of the corrugated metal pipe (CMP) with shear studs welded along the sides of the pipe to transfer load from the existing CMP to the new concrete invert lining. The exposed steel portion could also be coated or painted to help prolong the life of the structure. Invert lining would maintain the structural integrity of the original design as the lower portion continues to corrode and the MaineDOT Bridge Design Guide (BDG) estimates that it would extend the life of the structure for 25 years or more. The structural capacity would need to be evaluated further for this alternative, as the current bridge rating is below current AASHTO design loads.

Sliplining would be a longer term rehabilitation option where a slightly smaller pipe would be placed inside the existing and the space between would be filled with grout. The estimated life span of a sliplining, according to the BDG would be 75 years, as it is a complete replacement with a new pipe.

The main concerns with these rehabilitation alternatives are the following:

- The existing roadway width is only 23’ wide and sliplining or invert lining would not allow for any roadway widening;
- The hydraulic opening would be reduced;
- Fish passage may not be adequate.

Reference: MaineDOT Stride Bridge – Rehab and Replacement Options

BRIDGE REPLACEMENT OPTIONS

Replacement bridge alternatives for the Stride Bridge will depend on the actual subsurface information at the site and depth to bedrock. If bedrock is shallow, tall cantilever abutments bearing directly on bedrock could be used with a short superstructure just long enough to provide bankfull width plus the design safety factor. If the bedrock is very deep, integral or spill-through abutments with riprap protection sloping towards the channel would likely be needed and the superstructure would be a much longer span.

The Maine Geological Survey website has surficial geology maps available of the site which show “Qp” soils at the surface with bedrock outcrops (shown hatched) nearby, see Figure 1. The “Qp” designation indicates that Stride Bridge is on a silt and clay deposit, so the longer span integral or spill-through abutment alternative is the likely alternative, however site specific borings would be required to confirm how deep this layer is.

http://www.maine.gov/dacf/mgs/pubs/online/surficial/surficial.htm

Qps Qp	Glacial-marine deposits (Presumpscot Formation)

Silt, clay, and sand. Commonly a clayey silt, but sand is very abundant at the surface in some places. Locally fossiliferous. Map unit includes small areas of till, sand, and gravel that are not completely covered by marine sediment.

Qps: Mostly sand, but may be underlain by silt and clay. Moderate to high permeability. Fair to good drainage.

Qp : Mostly silt and clay. Low permeability. Poor drainage.

Figure 1 Clip from Maine Geological Survey’s *Reconnaissance Surficial Geology of the Machias Quadrangle, Maine* by Harold Borns, Jr. 1974.

The following are conceptual bridge replacement options for two different subsurface conditions:

Reference: MaineDOT Stride Bridge – Rehab and Replacement Options

1. **Shallow Bedrock @ 1.2x Bankfull Width with Vertical Abutments**: Full-height cantilever abutments at 1.2-times bankfull width (37' face-to-face). The superstructure would likely be 21" voided slabs with a varying leveling slab up to 6", spanning 40' bearing-to-bearing, similar to Fryeburg WIN 17872.00. The structure depth at the center of road would be about 30". The low chord of the bridge should have a minimum 2' freeboard from the Q10 water surface elevation (based on MHW) including wave heights, as described in the BDG.

    a. A precast concrete arch, such as a Conspan ®, could also be used with full-height abutments, but are not recommended due to the smaller hydraulic opening.

2. **Deep Foundation @ 1.2x Bankfull Width with Sloped Abutments:** Integral or spill-through abutments with sloping riprap (1.5H:1V) protection towards the channel. If the toe of riprap is at the edge of 1.2-times bankfull width and a 2'-6" shelf is provided in front of the abutment the span would be at least 76' (73' face-to-face abutments). NEXT beams or butted box beams would be the likely beam type for spans in this range. 36" NEXT F-beams with an 8" deck and 3" wearing surface would put the structure depth around 52", accounting for cross-slope. Similar to the first alternative 2' of freeboard should be provided over the Q10, which may require a significant profile raise.

3. **Deep Foundation @ 1.0x Bankfull Width with Sloped Abutments:** Similar to alternative 2, but starting the toe of riprap at bankfull width, since the sloping riprap provides much more hydraulic opening over the full-height cantilever abutment alternative. It would drop the span to around 70' and would likely reduce the structure depth to 48", by using a 32" NEXT beam vs. 36".

Based on the available information it has been assumed that no underground utilities exist in the immediate vicinity of Stride Bridge.

STANTEC CONSULTING SERVICES INC.

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Memo

To:	MaineDOT	From:	Michael R. Chelminski, P.E. Gordon E. Clark
File:	179450347	Date:	December 7, 2021

Reference: Bridge Opening Geometry Hydraulic Analysis for Machias Dike Bridge (#2246) Planning Phase Support Services

INTRODUCTION

This memo was prepared by Stantec Consulting Services Inc. (Stantec) under contract to the Maine Department of Transportation (MaineDOT) for Planning Phase Support Services (2020-2021 Planning Study) as part of the Dike Bridge Replacement Project (Project) located on the Middle River in Machias, Maine. MaineDOT is pursuing replacement of the existing infrastructure at Dike Bridge due to its poor condition with the objectives to provide adequate drainage from upland floods without overtopping the Route 1 roadway, provide adequate freeboard during tidal flood events, and accommodate fish passage to the extent practicable.

As part of the scope of services for the 2020-2021 Planning Study, Stantec developed and evaluated a bridge replacement alternative (Alternative 10). The initial Alternative 10 bridge geometry had an opening width (clear span[1]) of 100 feet (ft), a low chord elevation of 9.0 ft, a channel invert elevation[2] of -10 ft, and the spill-through abutment benches were at an elevation of 1.0 ft. This was a conceptual bridge geometry prior to any detailed bridge elevation, roadway profile, or sea-level rise discussions. As part of the ongoing design process and refinement of those elements, the clear span was increased to 116.5 ft, the low chord elevation was raised to 13.1 ft, the channel invert was raised 1.5 ft to an elevation of -8.5 ft, and the spill-through abutment benches were raised to an elevation of 10.42 ft. While the modified Alternative 10 bridge geometry has a greater clear span relative to the initial geometry, changes in the spill-through geometry and the higher channel invert resulted in decreased hydraulic capacity and increased flow speeds for the modified geometry. Note that the hydraulic model simulation results for the bridge alternative (Alternative 10) presented in this memo where developed using an updated hydraulic model geometry that incorporated bathymetric data collected in the Middle River by MaineDOT in the summer of 2021 whereas the previous bridge alternative simulations were performed using bathymetric data collected by MaineDOT prior to 2014.

This memo presents information obtained from hydraulic analyses of bridge opening widths (clear spans) of 116.5 ft, 150 ft, 200 ft, and 300 ft, under normal tidal conditions with typical (i.e., median) riverine flows to assess the range of hydraulic head gradients across the different bridge span geometries and associated flow speeds (Bridge Span Study). Flow speeds through the proposed structure replacement alternative is relevant to scour countermeasure design and fish passage at the Project site.

Attachment A contains stage hydrographs for the various bridge spans depicting existing (observed 2021) and proposed (simulated) conditions landward of Dike Bridge plotted with the 2021 seaward tidal data used

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[1] For the purposes of this memo, span refers to the “clear-span” effective opening conveyance width through the simulated bridge structures. Note that the 116.5-foot clear span corresponds to the previously analyzed 120-ft bridge span.

[2] Elevations are referenced to the North American Vertical Datum of 1988 (NAVD88) unless otherwise indicated.

as the downstream[3] forcing conditions in the model. Attachment B contains figures that present information related to simulated average flow speeds through the various bridge span geometries.

BACKGROUND

The first phase (Phase 1) of the hydraulic analyses included assessment of hydraulic conditions associated with five primary replacement alternatives for the Dike Bridge culvert, which is documented in the "Phase 1 Hydraulic Analysis for Machias Dyke Bridge (#2246) Planning Phase Support Services" dated September 2021 (Phase 1 Study). Phase 2 of the hydraulic analyses is currently in progress and builds on the previous work completed as part of Phase 1. Based on preliminary analysis of the results from the Alternative 10 simulations as part of the Phase 2 work, it was identified that flow speeds through the proposed structure were high, suggesting potential issues associated with both scour countermeasure design and volitional fish passage for some fish species at the Project site.

The goal of the Bridge Span Study is to assess a range of bridge span widths under typical flow and tidal conditions at the Project site to identify the sensitivity of opening width to flow speed. The objective of the Bridge Span Study is to identify a preferred bridge span for providing flow speeds that allow for volitional fish passage. Note that specific criteria for fish passage (e.g., target fish species, maximum allowable flow speed, designed range and tolerances for conditions suitable for volitional fish passage) have not been identified for the Project. Therefore, this memo presents information that is expected to assist in developing a general approach providing reasonably transparent tidal cycle conditions across a bridge alternative and thereby allow for volitional fish passage opportunities.

GEOMETRY DATA

The Bridge Span Study includes assessment of variations of the Alternative 10 geometry from the Phase 1 Study for increased spans and include 116.5-ft span (Alt 10-116.5), 150-ft span (Alt10-150), 200-ft span (Alt10-200), and 300-ft span (Alt10-300) opening widths. Each alternative geometry is identical with the exception of the opening widths in the bridge geometry as well as the cross-sections upstream and downstream from the bridge that vary to match the opening width of each bridge alternative geometry. Roadway embankments are modeled as bridge structures with a deck/roadway. Low-chord elevations were set at a constant elevation of 13.1 ft. The preliminary bridge low-chord elevation was selected to match the Town of Machias' "Phase 1" sea level rise protection plans to be above the highest astronomical tide (HAT) elevation of 9.8 ft and the FEMA BFE of 10.7 ft plus a freeboard allowance for at least 1.5 ft of sea level rise. It is expected that this would result in a roadway grade rise in the bridge area, however a detailed roadway grade vertical profile was not included as part of the Bridge Span Study since the results are not dependent on this geometry (e.g., the bridge is not overtopped in model simulations) because the hydraulic model analyses were performed for normal tides and without evaluation of sea level rise. Sloping, spill-through type abutments were defined at slopes of 1.75 horizontal to 1 vertical (1.75H:1V) and 2-ft-wide benches at elevations of 10.42 ft to provide access along each abutment adjacent to both bridge abutments. The channel elevation was set at -8.5 ft. The bridge was modeled using the Energy (Standard Step) approach in the bridge

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[3] "Downstream" and "upstream" are used in this report to describe the HEC-RAS model boundary conditions for consistency with boundary condition references in the HEC-RAS documentation. For reference, upstream generally refers to the landward direction and downstream generally refers to seaward direction.

routines. Ineffective flow areas were defined within the upstream and downstream cross-sections adjacent to the bridge at an approximately one-to-one aspect ratio.

BOUNDARY CONDITIONS

Upstream boundary conditions included the annual medial flow (50 percent [%] flow duration annual exceedance) as a constant inflow. Downstream boundary conditions included use of tidal stage data collected by MaineDOT at the Project site from mid-August to early October 2021. These data were used as the downstream boundary condition representing typical tidal conditions (i.e., "normal tide"). Additional information related to this tidal stage data is expected to be documented as part of the Phase 2 reporting.

RESULTS

The following section presents the results from the Bridge Span Study.

LANDWARD WATER SURFACE ELEVATION

The maximum and minimum upstream water surface elevations across the bridge span alternatives are presented in Table 1 along with preliminary results from Phase 2 modeling efforts for existing conditions and Alternative 4m for comparison purposes. In general, the evaluated bridge span alternatives resulted in maximum and minimum upstream water surface elevations that are within 0.3 ft and 0.5 ft, respectively. As the bridge span width increased, the larger the total range in upstream water surface elevation. The 116.5 ft geometry had a maximum tidal range of approximately 15.3 ft and the 300 ft geometry had a maximum tidal range of approximately 16.1 ft. For reference, the maximum and minimum elevations for the seaward tidal boundary condition is 8.2 and -8.0 ft, respectively (note this was previously 9.0 ft to -7.2 ft for maximum and minimum seaward tidal water surface elevations from the 2011 dataset used for Phase 1 modeling). Table 1 also presents estimated landward inundation for the evaluated alternatives relative to existing conditions as represented.

Table 1. Summary of maximum and minimum upstream (US) water surface elevations and landward inundation areas across the bridge alternatives with preliminary results from Phase 2 for Existing Conditions and Alternative 4m included for comparison purposes.

	Median Flow			Landward Inundation (intertidal area)	
Alternative	**Max US WSEL (NAVD, ft)**	**Min US WSEL (NAVD, ft)**	**US WSEL Range (ft)**	**Area (acres)**	**Increase (acres)**
Existing Conditions	-0.5	-2.0	1.5	32.7	n/a
Alternative 4m	2.1	-3.2	5.3	119	86
Alternative 10 – 116.5 ft	7.9	-7.4	15.3	431	398
Alternative 10 - 150 ft	8.1	-7.6	15.7	436	403
Alternative 10 - 200 ft	8.2	-7.8	16	437	405
Alternative 10 - 300 ft	8.2	-7.9	16.1	437	405

Attachment A contains the stage hydrographs that present the water surface elevation results plotted relative to simulation time. The observed landward data represents existing conditions landward of Dike Bridge and is included for comparison purposes. The seaward tide data is also included which represent the tidal forcing conditions for the model. Figures 1 through 4 present the full simulation with each figure representing one of the bridge span alternatives. Figure 5 presents an overview of a two-day tidal cycle with the headwater stage elevations upstream from the bridge alternatives plotted for comparison purposes. In general, as the bridge width increases, the closer the headwater stage elevations are to the downstream tidal signature.

FLOW SPEEDS

Flow speeds were calculated by dividing the discharge through the bridge with a representative (average) area through the prismatic, trapezoidal cross-sectional geometry at the bridge opening. Note that this approach results in a depth-averaged flow speed and does not account for variations in flow speed within the water column or laterally across the channel. Although more complex modeling approaches (e.g., two- or three-dimensional modeling) and/or physical modeling may assist in achieving a higher precision of flow distribution, the modeling approach used for this study with the accompanying assumptions and limitations was considered suitable for providing a general evaluation of bridge hydraulics that meet the needs of the Project.

The percent exceedance of average flow speeds for the modeled bridge alternatives are presented in Table 2, Table 3, and Table 4 for the full tidal spectrum, seaward flows only, and landward flows only, respectively. In general, as the bridge span width increases, the average flow speed through the bridge decreases. For example, the median average flow speed for the full tidal cycle for the 116.5- and 300-ft span bridge alternatives were 4.1 ft/s and 1.0 ft/s, respectively. In general, the flow speeds for the seaward flows were slightly greater than those for the landward flows, which is expected since the current is not working against the downstream riverine flows. However, the differences were very small and were not significantly different.

Attachment B contains figures that present information related to the modeled bridge geometries and average flow speed. Figure 6 graphically depicts the information in Table 2 and is considered representative of the system. Figures 7 through 14 present both the unsteady-state stage hydrograph for the full simulation time frame as well as for a select two-day tidal cycle for the bridge alternatives, including bridge headwater, tailwater, and average flow speeds through the bridge span for median annual (i.e. 50% exceedance) riverine flows and normal tidal boundary conditions. The figures depicting an example two-day tidal cycle are useful for examining the relationship between headwater and tailwater with flow speed. Negative flow speeds represent flow landward (upstream) and positive flow speeds represent flow seaward (downstream). The greatest flow speeds for each tidal cycle occur during the ebb tide when the difference in headwater and tailwater are the greatest. Similarly, the second greatest flow speed occurs during the flood tide. This is also reflected in the differences in the 95% exceedance tables comparing seaward (Table 3) and landward (Table 4) flow speeds, since the seaward flow speed is consistently higher than the landward for these higher flows. Note that the difference (delta) between the higher flows speeds for seaward and landward cycles diminishes as the bridge span width increases. For example, the difference between the 95% seaward and landward flow speeds is 0.9 ft/s for the 116.5-ft span bridge and 0.1 ft/s for the 300-ft span bridge.

For reference to simulated ambient flow speed conditions in the Middle River, Figure 15 presents simulated flow speeds at HEC-RAS cross-section 3028.072 in the Middle River approximately 2,500 ft upstream from Dike Bridge along with several fish passage maximum flow speed criteria[4], including an all-species criterion of

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[4] Criteria are based on the values presented in the *Federal Interagency Nature-like Fishway Passage Design Guidelines for Atlantic Coast Diadromous Fishes* by Turek, J., Haro, A., & Towler, B., and published in May

0.75 feet per second (ft/s) as additionally suggested by stakeholders as part of the Project planning phase. Information presented in Figure 15 indicates that regular ebb tide (seaward) flow speeds typically exceed the all-species criterion of 0.75 ft/s and, at times, exceed a flow speed of 3 ft/s. A similar evaluation of minimum depths of water identifies that typical depths at this cross-section are approximately 1 ft except during higher low tides when depths approach up to approximately 2 ft.

2016 by the National Marine Fisheries Service, the U.S. Geological Survey, and the U.S. Fish and Wildlife Service.

Table 2. Percent exceedance of average flow speeds (ft/s) through modeled bridge alternatives for landward and seaward flows (i.e., full tidal spectrum)

Percent Exceedance	Alt10-116.5 ft	Alt10-150 ft	Alt10-200 ft	Alt10-300 ft
95%	8.4	5.9	4.1	2.5
90%	7.8	5.5	3.8	2.3
75%	6.4	4.3	2.9	1.7
50%	4.1	2.5	1.7	1.0
25%	1.9	1.1	0.7	0.4
10%	0.6	0.3	0.2	0.1

Table 3. Percent exceedance of average flow speeds (ft/s) through modeled bridge alternatives for seaward flows only

Percent Exceedance	Alt10-116.5 ft	Alt10-150 ft	Alt10-200 ft	Alt10-300 ft
95%	8.8	6.2	4.2	2.5
90%	8.1	5.6	3.8	2.3
75%	6.5	4.2	2.8	1.6
50%	4.1	2.4	1.6	0.9
25%	2.0	1.2	0.7	0.4
10%	0.8	0.5	0.3	0.2

Table 4. Percent exceedance of average flow speeds (ft/s) through modeled bridge alternatives for landward flows only

Percent Exceedance	Alt10-116.5 ft	Alt10-150 ft	Alt10-200 ft	Alt10-300 ft
95%	7.9	5.7	4.0	2.4
90%	7.5	5.4	3.8	2.3
75%	6.3	4.4	3.0	1.8
50%	4.2	2.7	1.8	1.1
25%	1.7	1.0	0.6	0.3
10%	0.5	0.3	0.2	0.1

Simulated depths of water through the bridge vary with tidal conditions and range from approximately 1 ft at low tide to more than 15 ft at high tide. The minimum simulated depths of water for the 116.5 ft span bridge were marginally (approximately 0.5 ft) higher than those for the longer evaluated bridge spans. Differences in minimum depths of water for the longer evaluated bridge spans differed by approximately 0.1 to 0.3 ft.

SUMMARY

This memo provides information related to the hydraulic performance of various bridge spans, with a specific focus on headwater and tailwater differentials and flow speed. While these data may be used to assess the degree of tidal transparency and degree of volitional fish passage for each geometry, it does not evaluate performance related to either of these two criteria. For example, maximum stage elevations are within approximately 0.5 ft of the tidal range for each alternative; however, this may not be acceptable or meet the criteria for “full tidal transparency”. The minimum water surface elevations for the 116.5-ft span bridge alternative are higher than the seaward tide and the results for the other alternatives and appear to result from confined flow through the narrow bridge opening.

The evaluated bridge alternatives have the underlying channel at an elevation of -8.5 ft and therefore similar to the elevation of lower low tides. During low tides, depths of water in the channel are approximately 1 ft with marginally deeper flow (depths slightly greater than 1 ft) for the 116.5-ft span bridge alternative, suggesting possible minor improved flow depth conditions for upstream fish passage compared to the larger span alternatives. Shallow flow at low tide for the bridge alternatives could necessitate construction of a defined “low-flow” channel through the bridge opening to meet minimum depth criteria for upstream fish passage. Similarly, this study has identified the percentage of time in which certain flow speeds occur under various bridge span alternatives; however, in the absence of a defined target fish species and associated performance criteria, evaluation of volitional fish passage performance is not possible. It is recommended that these criteria (e.g., target fish species) be defined to assist in selection of a preferred bridge span alternative to be carried forth as part of the Phase 2 analysis.

Comparison of the estimated areas of intertidal habitat for the four evaluated bridge alternatives suggest that the alternatives are relatively similar with less than 2% variance between evaluated alternatives. Note that the tide data from the Machias River collected by MaineDOT in 2021 has lower maximum water surface elevations compared to data collected by MaineDOT in 2011, which was used and documented as part of the Phase 1 Study. However, the results presented in this study provide an opportunity for relative comparison of simulated areas of intertidal habitat between evaluated bridge alternatives which is not sensitive to the differences between these two data sets.

Information on fish passage criteria were provided by stakeholders and include a flow speed criterion of 0.75 ft/s. Information obtained from the HEC-RAS model in the Middle River at a cross-section approximately 2,500 ft upstream from Dike Bridge indicates that ebb tide (seaward) flows exceed this value and exceed 3 ft/s during regular tidal conditions. In addition, depths of water at this cross-section are approximately 1 ft except during higher low tides when depths approach up to approximately 2 ft.

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2/17/2022
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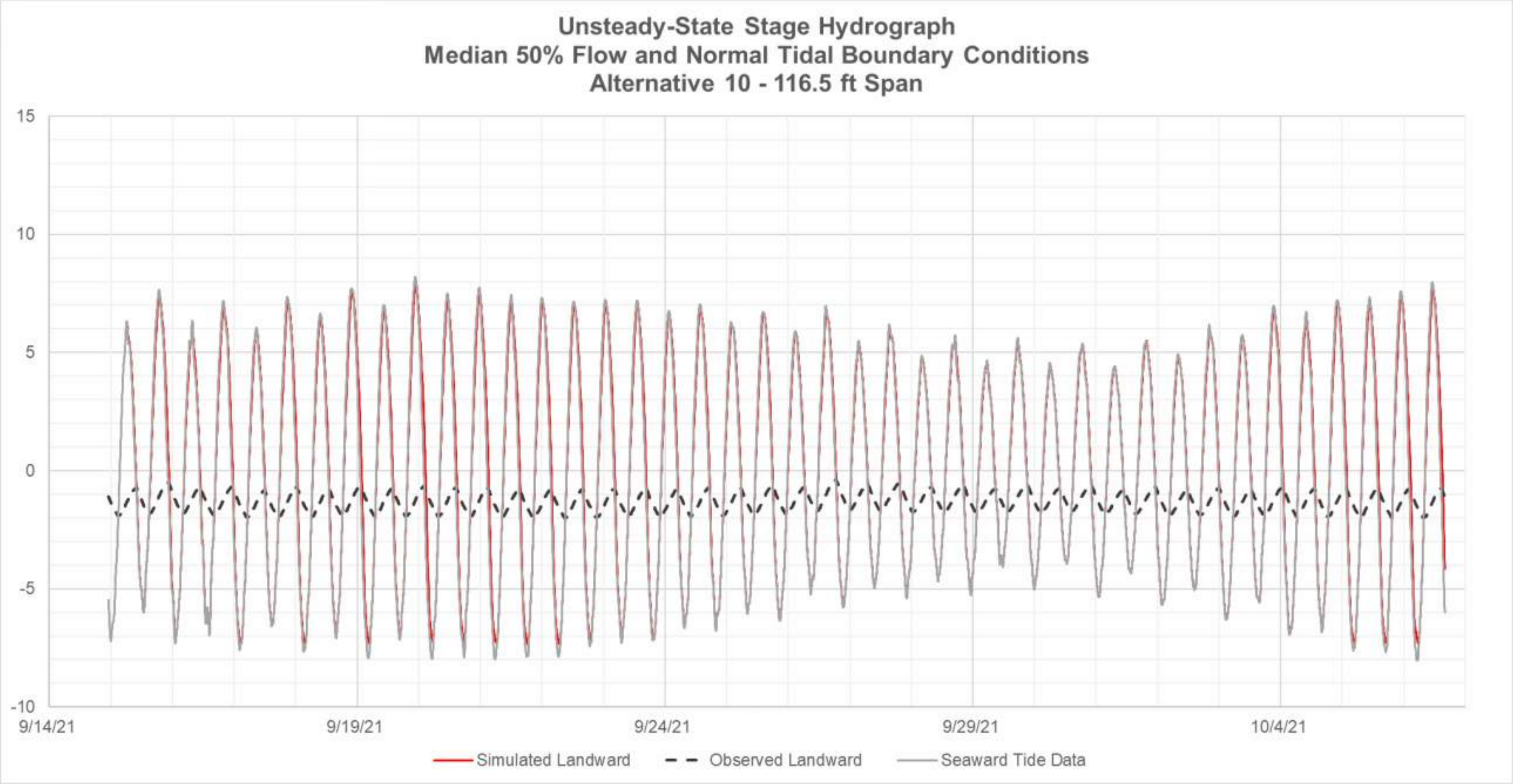
Attachment: Attachment A – Unsteady-State Stage Hydrographs
Attachment B – Flow Speed Figures

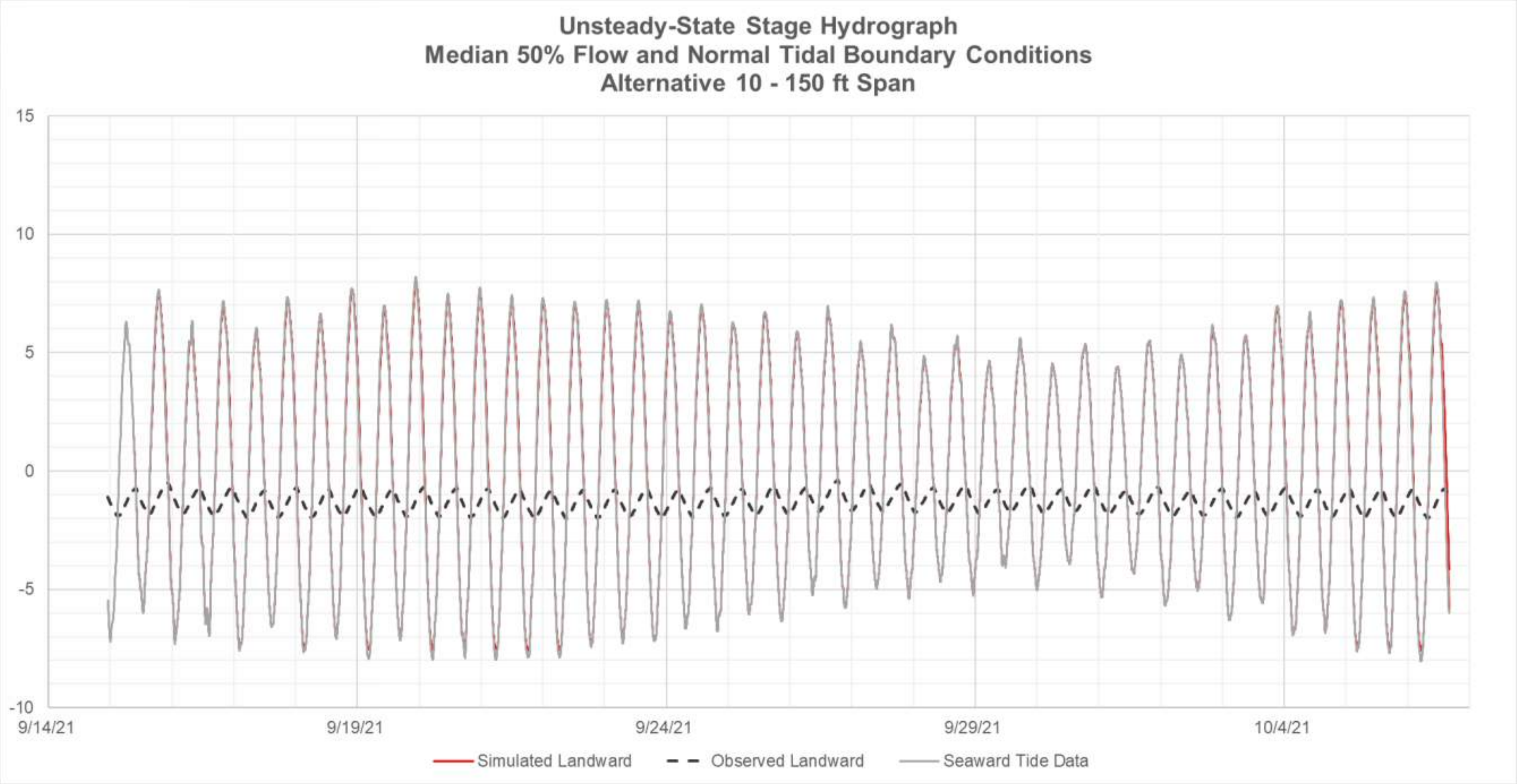
c. Tim Merritt
Sarah Williams

ATTACHMENT A

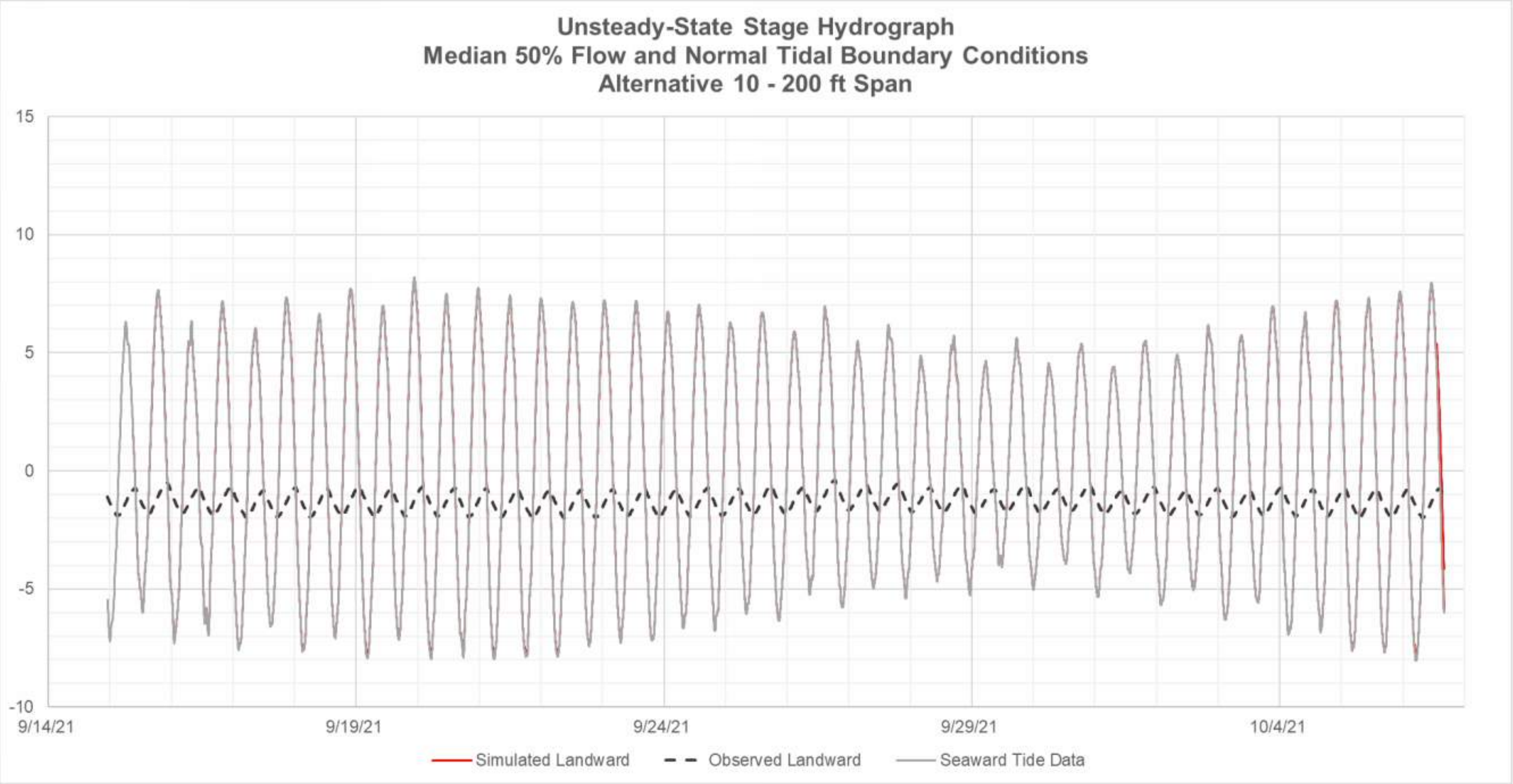
Reference: **Bridge Opening Geometry Hydraulic Analysis for Machias Dike Bridge (#2246) Planning Phase Support Services**

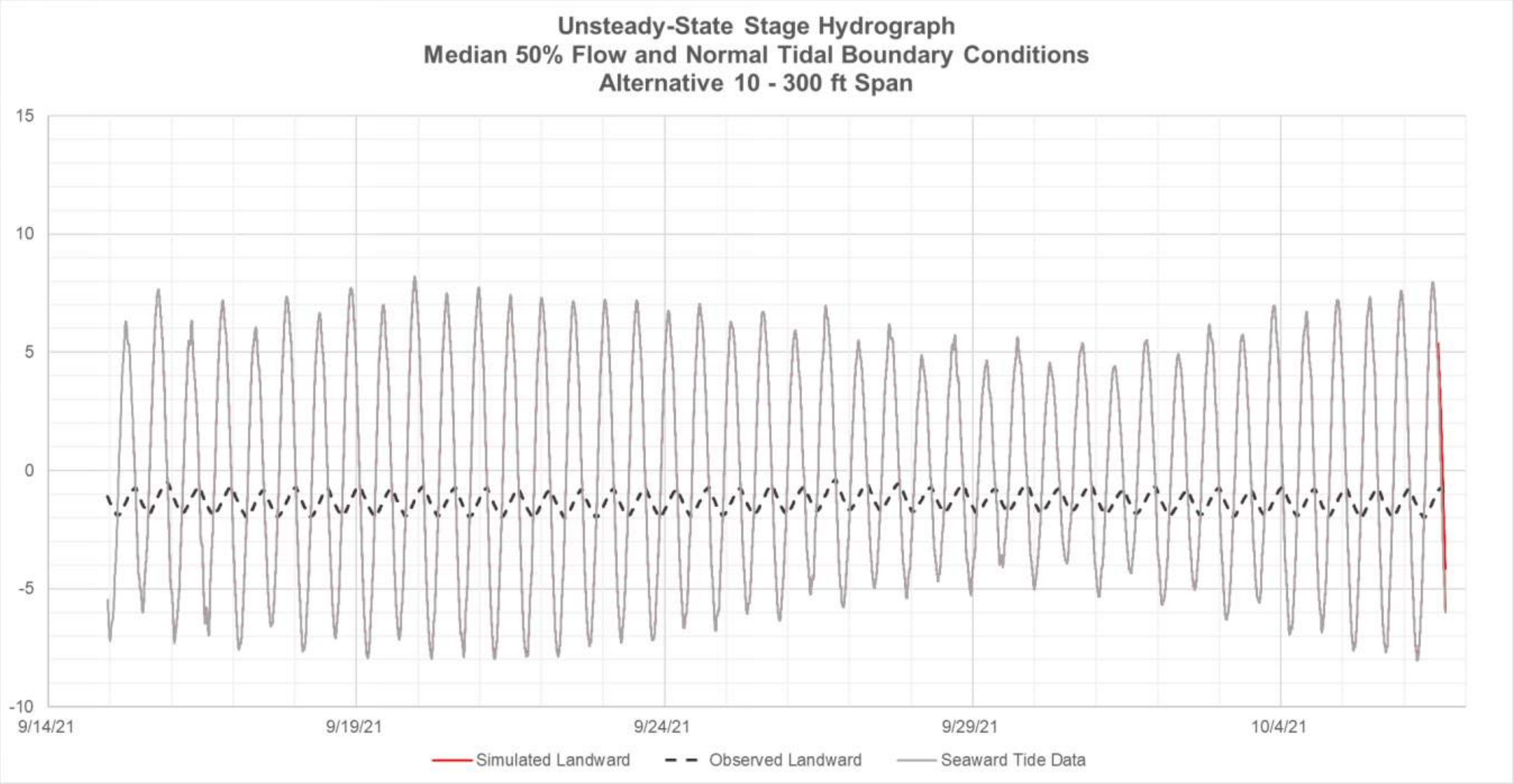


Reference: **Bridge Opening Geometry Hydraulic Analysis for Machias Dike Bridge (#2246) Planning Phase Support Services**

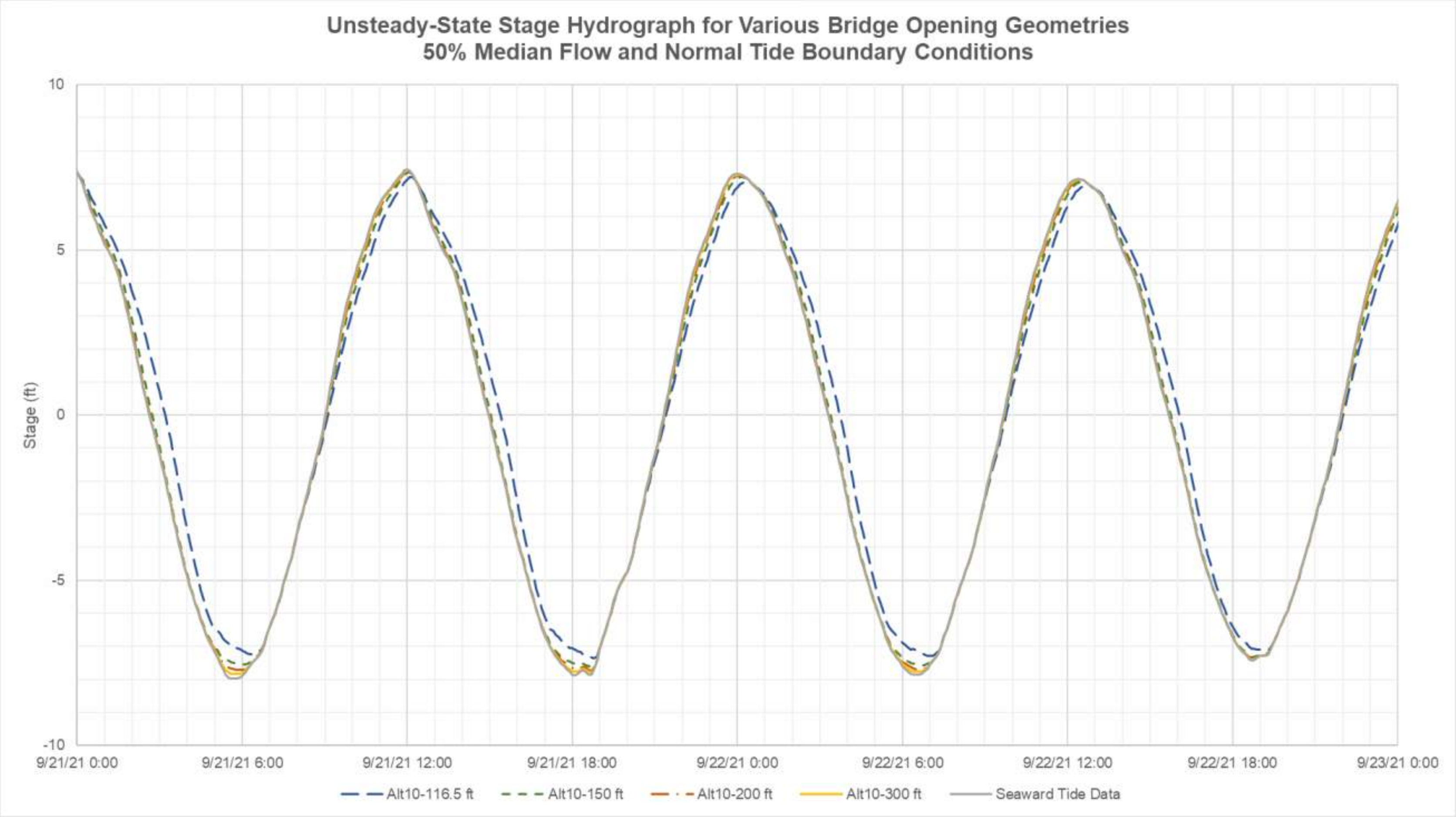


Reference: **Bridge Opening Geometry Hydraulic Analysis for Machias Dike Bridge (#2246) Planning Phase Support Services**




Unsteady-State Stage Hydrograph
Median 50% Flow and Normal Tidal Boundary Conditions
Alternative 10 - 300 ft Span
15
10
5
0
-5
-10
9/14/21
9/19/21
9/24/21
9/29/21
10/4/21
Simulated Landward
Observed Landward
Seaward Tide Data

Reference: **Bridge Opening Geometry Hydraulic Analysis for Machias Dike Bridge (#2246) Planning Phase Support Services**



ATTACHMENT B

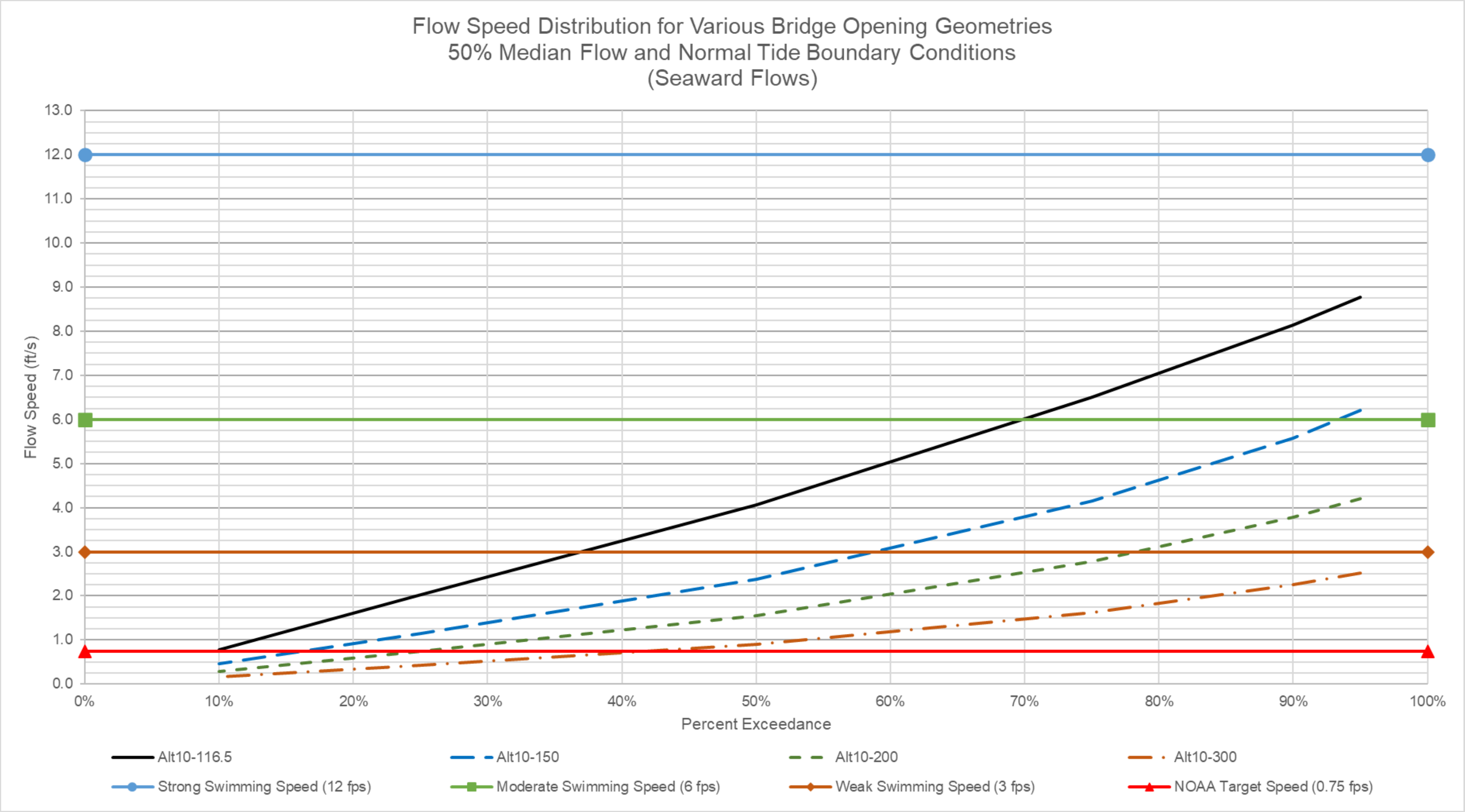


Figure 6. Flow speed versus percent exceedance for median annual (i.e. 50% exceedance) riverine flows and normal tidal boundary conditions across various bridge opening geometries for the seaward (ebb tide) flow spectrum with fish passage criteria

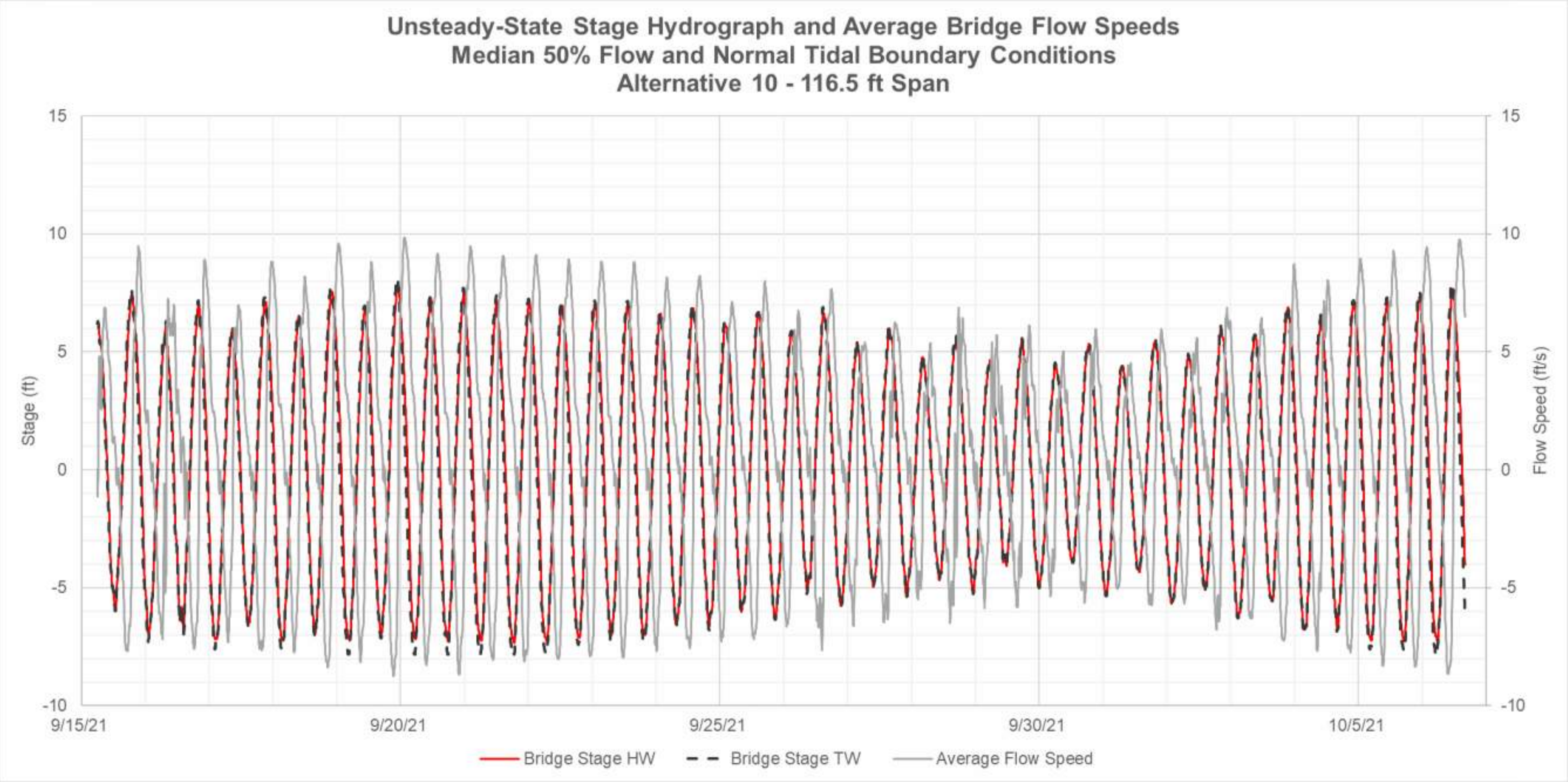


Figure 7. Unsteady-state stage hydrograph for full simulation time frame for bridge headwater (HW), tailwater (TW), and average flow speeds through the bridge opening for median annual (i.e. 50% exceedance) riverine flows and normal tidal boundary conditions for a 116.5 ft span opening

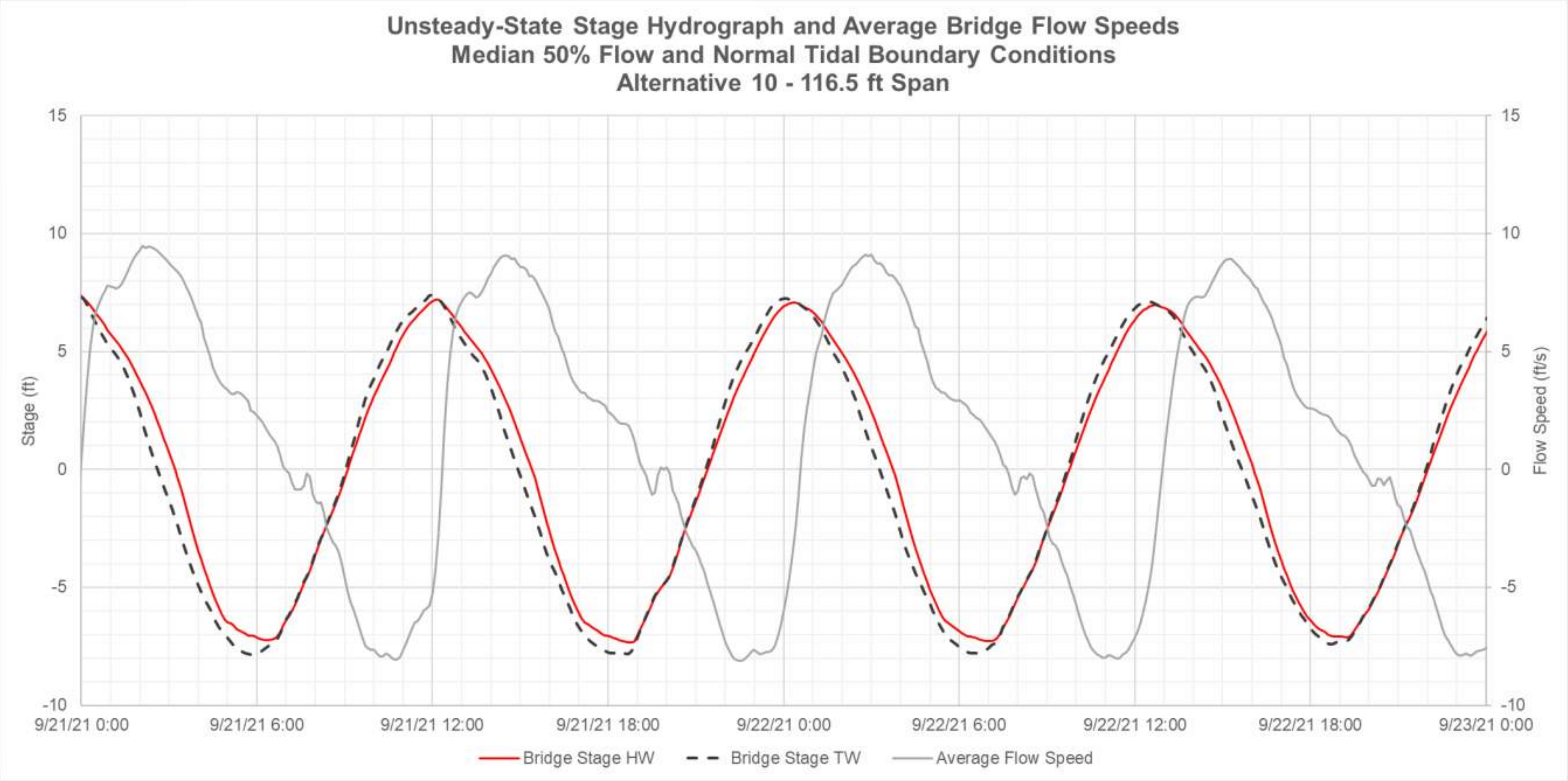


Figure 8. Unsteady-state stage hydrograph from 9/21/21 to 9/23/21 for bridge headwater (HW), tailwater (TW), and average flow speeds through the bridge opening for median annual (i.e. 50% exceedance) riverine flows and normal tidal boundary conditions for a 116.5 ft span opening

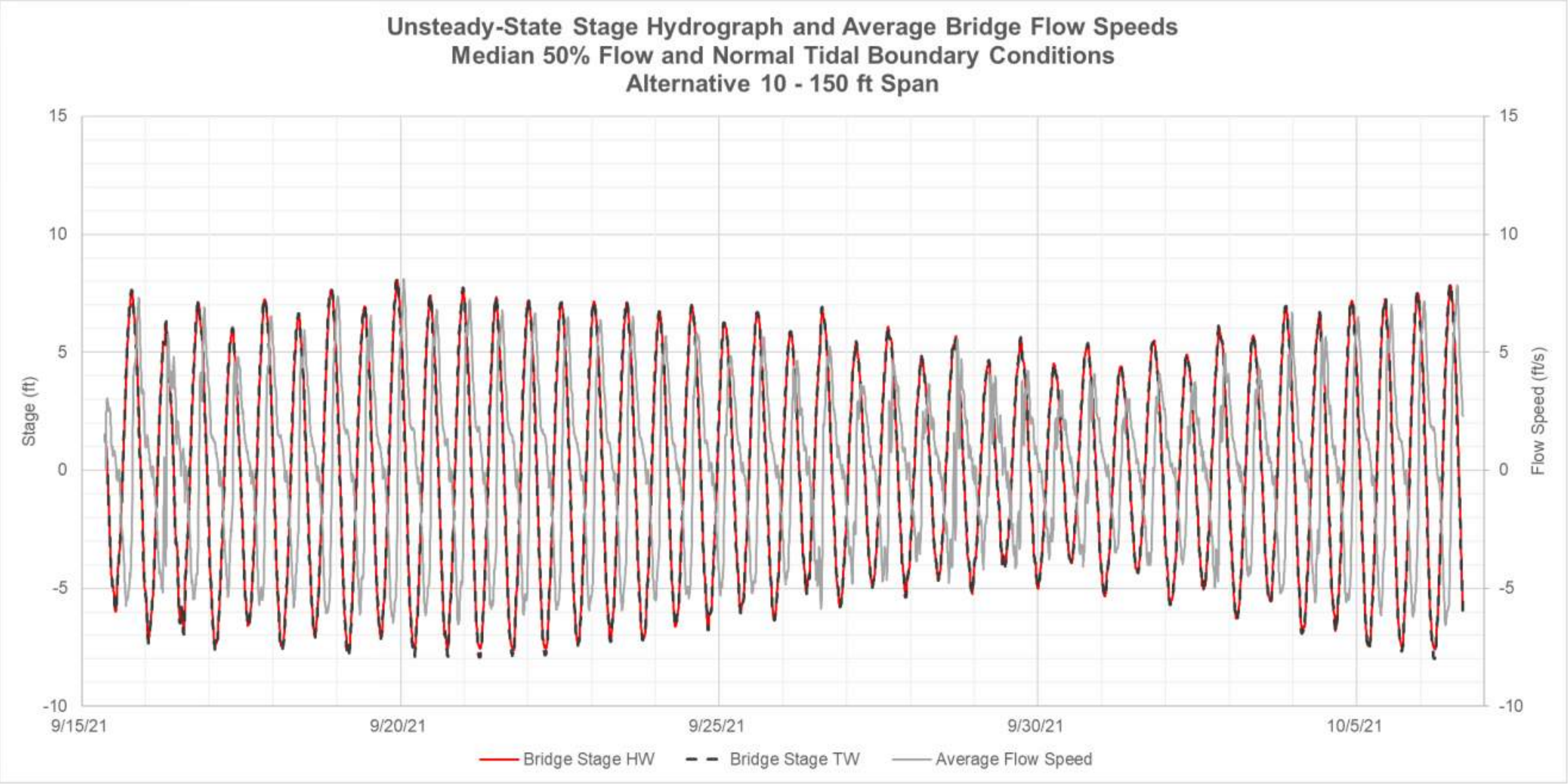


Figure 9. Unsteady-state stage hydrograph for full simulation time frame for bridge headwater (HW), tailwater (TW), and average flow speeds through the bridge opening for median annual (i.e. 50% exceedance) riverine flows and normal tidal boundary conditions for a 150 ft span opening

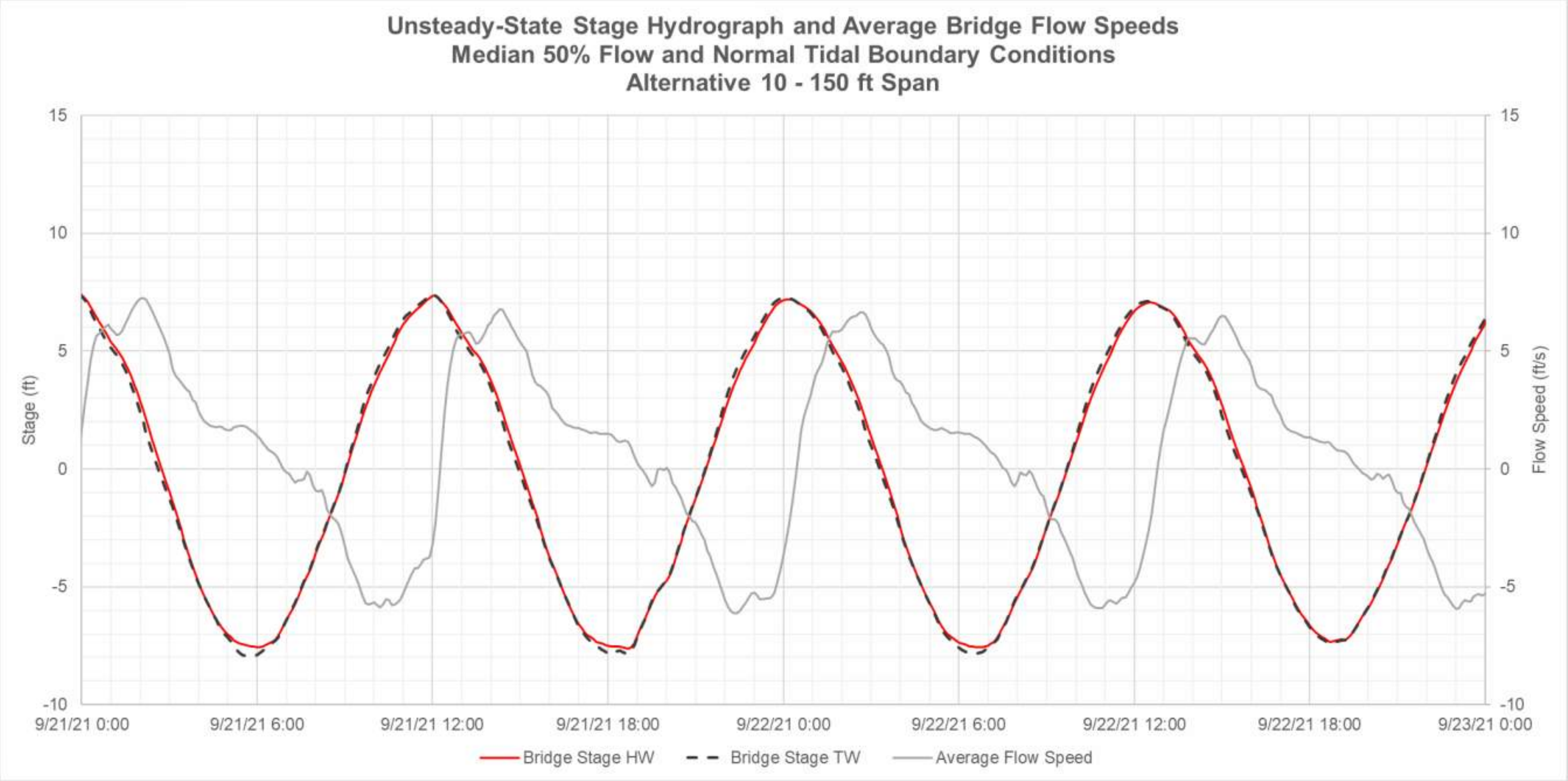


Figure 10. Unsteady-state stage hydrograph from 9/21/21 to 9/23/21 for bridge headwater (HW), tailwater (TW), and average flow speeds through the bridge opening for median annual (i.e. 50% exceedance) riverine flows and normal tidal boundary conditions for a 150 ft span opening

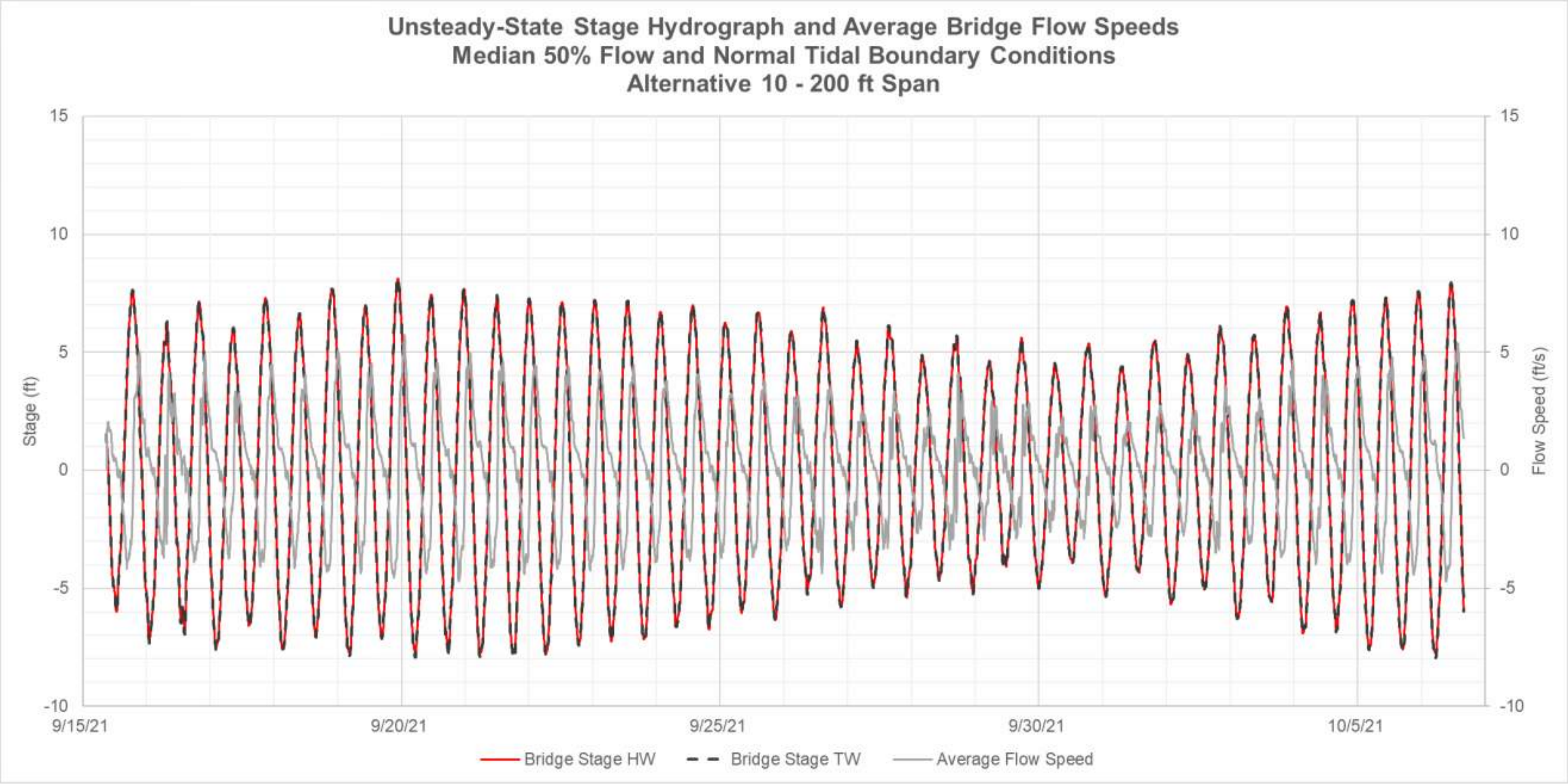


Figure 11. Unsteady-state stage hydrograph for full simulation time frame for bridge headwater (HW), tailwater (TW), and average flow speeds through the bridge opening for median annual (i.e. 50% exceedance) riverine flows and normal tidal boundary conditions for a 200 ft span opening

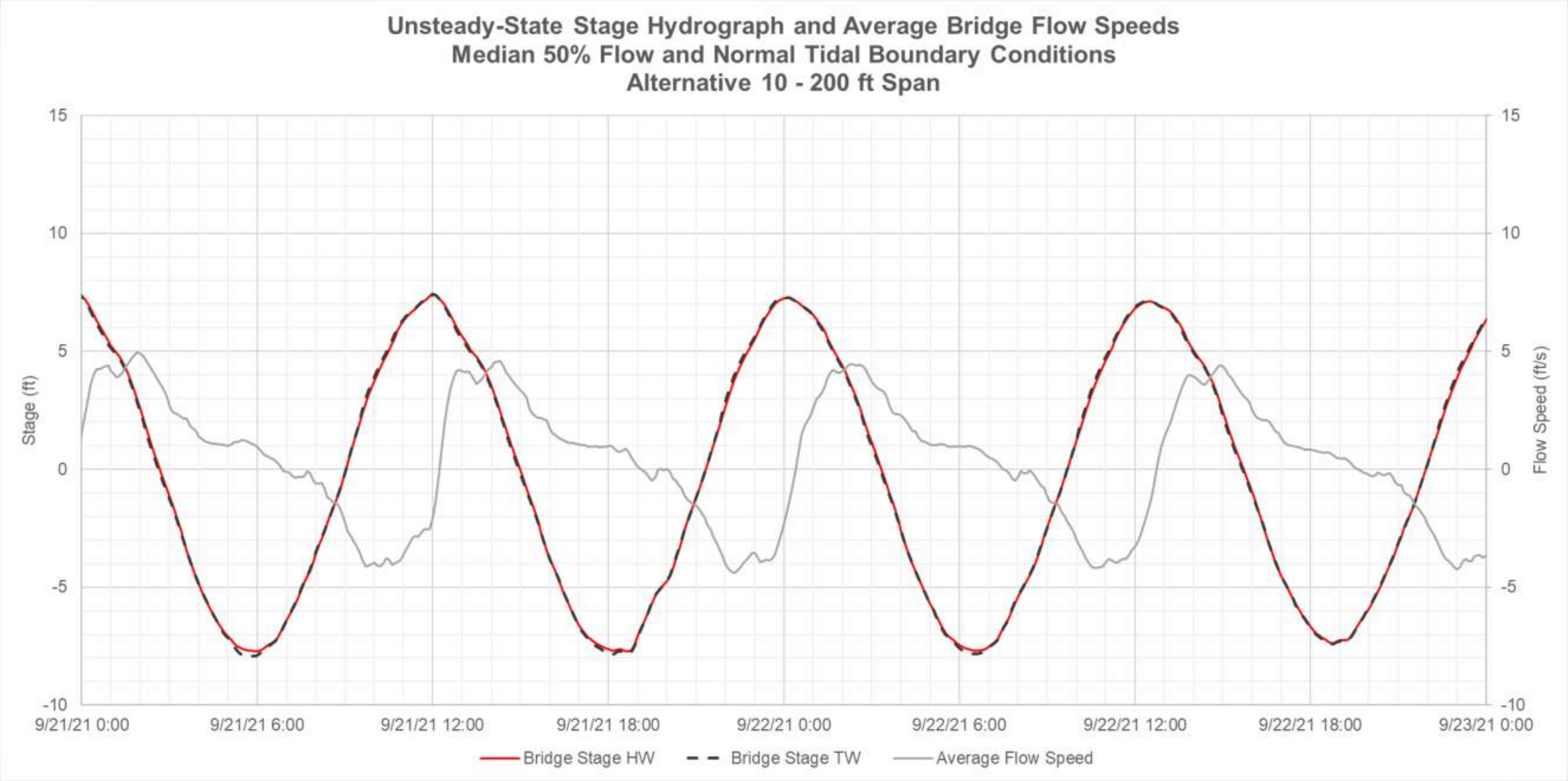


Figure 12. Unsteady-state stage hydrograph from 9/21/21 to 9/23/21 for bridge headwater (HW), tailwater (TW), and average flow speeds through the bridge opening for median annual (i.e. 50% exceedance) riverine flows and normal tidal boundary conditions for a 200 ft span opening

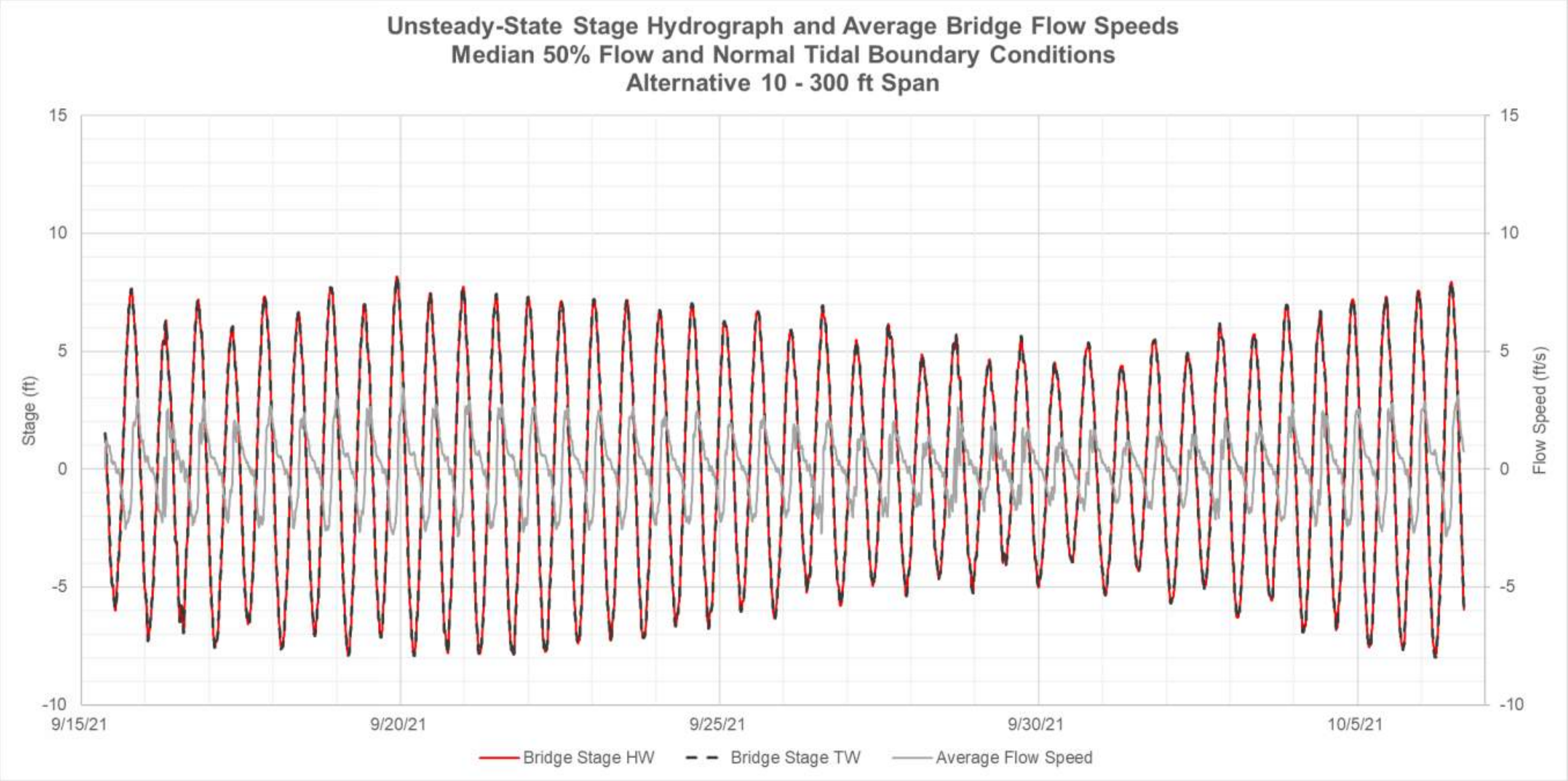


Figure 13. Unsteady-state stage hydrograph for full simulation time frame for bridge headwater (HW), tailwater (TW), and average flow speeds through the bridge opening for median annual (i.e. 50% exceedance) riverine flows and normal tidal boundary conditions for a 300 ft span opening

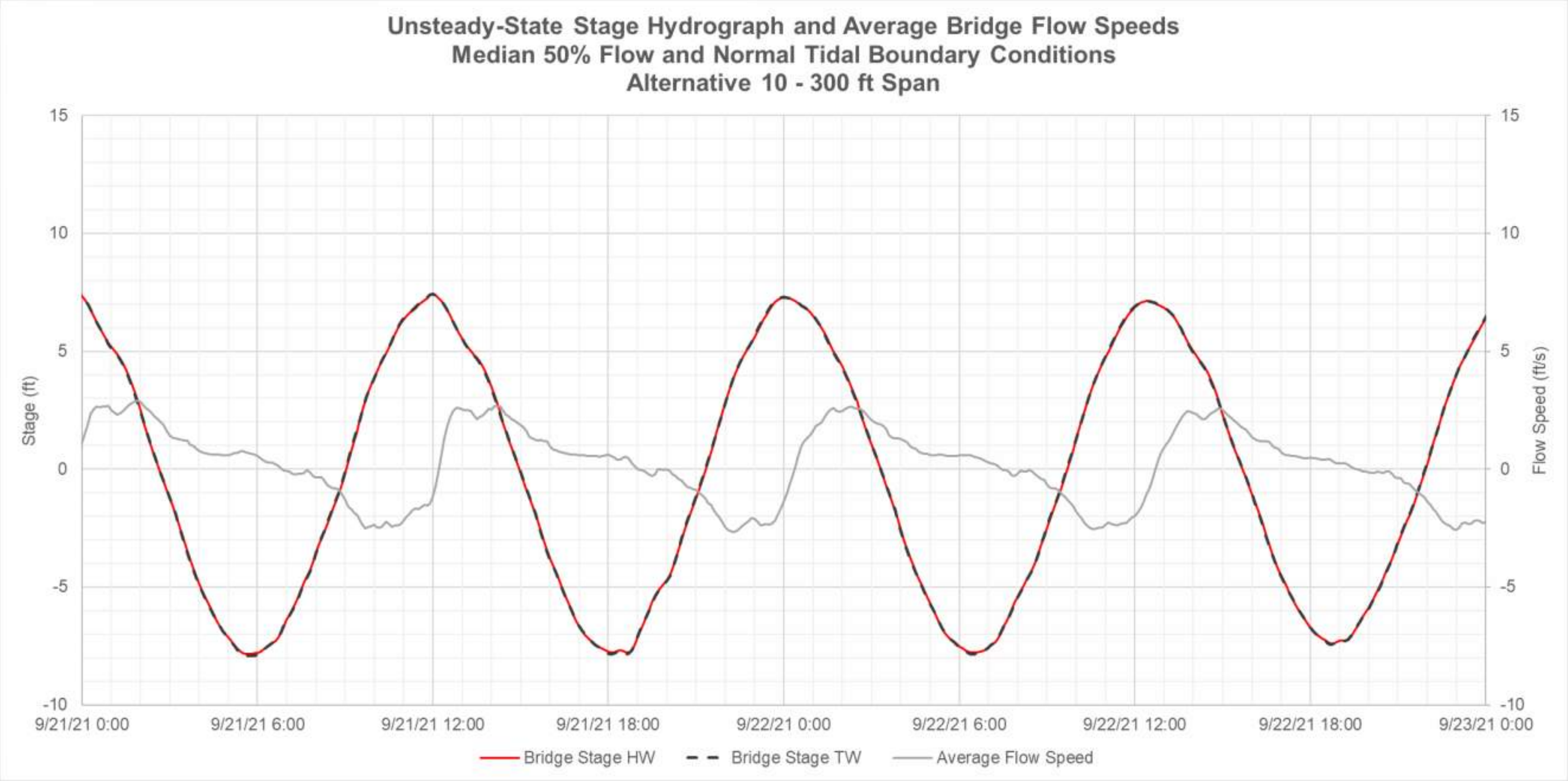


Figure 14. Unsteady-state stage hydrograph from 9/21/21 to 9/23/21 for bridge headwater (HW), tailwater (TW), and average flow speeds through the bridge opening for median annual (i.e. 50% exceedance) riverine flows and normal tidal boundary conditions for a 300 ft span opening

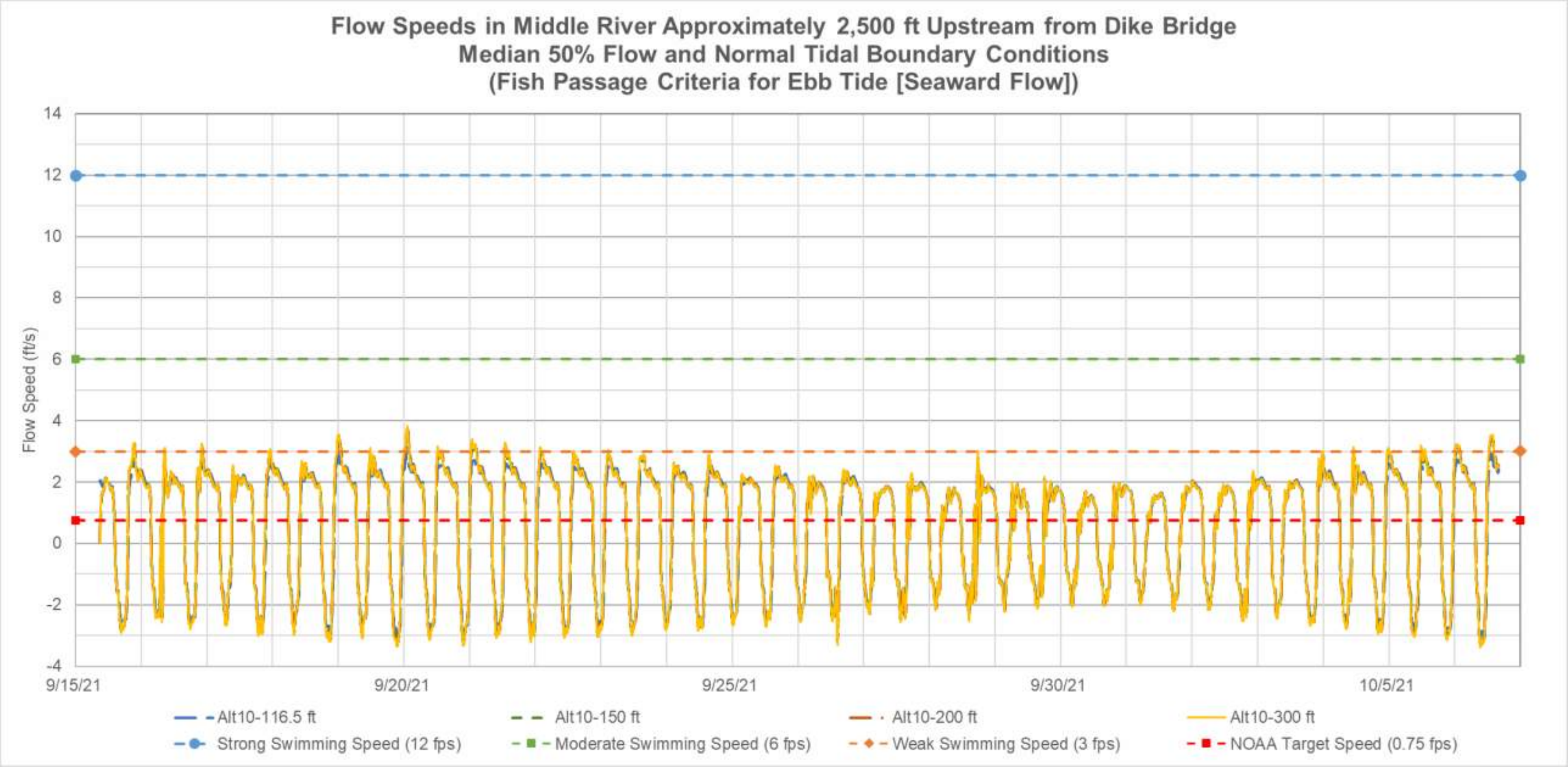


Figure 15. Unsteady-state stage flow speeds at HEC-RAS cross-section 3028.072 in the Middle River approximately 2,500 ft upstream from Dike Bridge for median annual (i.e. 50% exceedance) riverine flows and normal tidal boundary conditions with fish passage criteria overlain on seaward (ebb tide) flows

MEMORANDUM

MAINE DEPARTMENT OF TRANSPORTATION
ENVIRONMENTAL OFFICE

Child Street, SHS 16, Augusta, ME 04330

(207-624-3000)

To: Martin Rooney and David Gardner

From: Dwight Doughty
Hydrogeologist/Manager, Groundwater and Hazardous Waste Division,
MaineDOT Environmental Office

Date: January 26, 2022

Subject: Preliminary Assessment - Potable Water Supplies/Septic Systems, Machias Dike Bridge Project, Machias, Maine. WIN 16714.00

Overview

The Maine Department of Transportation (MaineDOT) is evaluating several structural alternatives relative to repairing and/or replacing the Machias Dike Bridge. Many of the alternatives may result in elevated water levels within upstream sections of the Middle River estuary. As shown on Figure 1, depending on the selected alternative, surface water levels may increase by roughly 9 feet in the estuary during a high tide cycle. Elevated water levels will locally influence groundwater and surface water flow patterns.

MaineDOT is continuing to study the alternatives and gather information to better understand the anthropogenic and environmental impacts associated with each. Recently, MaineDOT's Environmental Office (MaineDOT-ENV) performed a Preliminary Assessment to evaluate potential impacts to existing potable water supplies and subsurface sanitary disposal systems that may result from anticipated surface water level increases. The Assessment suggests several water supplies and septic systems positioned immediately adjacent to the estuary will be impacted by rising waters.

Background

Increased surface water levels in the Middle River estuary will inundate some existing terrestrial areas. The increase will also influence shallow, localized groundwater flow and quality. Current groundwater and surface water conditions were used as a baseline to assess what these conditions will look like with a 9-foot surface water level increase.

Essentially surface water levels will increase from the existing 0.0-feet above mean sea level (msl) to approximately 9-feet msl. Terrestrial areas within this inundated zone will be impacted by direct surface water contact. Groundwater flow and quality will also be influenced within this elevational zone. Additionally, it is anticipated that some groundwater mounding may occur in areas upgradient of the 9-foot msl mark. For this evaluation, it was conservatively assumed that the elevation zone from 9.0-feet msl to 16-feet msl may be impacted by increasing groundwater levels.

Characterization

Investigative techniques used during this assessment included data review, site reconnaissance, interviews, and water quality information. A review of each follows.

Data Review

Using aerial photographs, the Maine Drinking Water Program public water supply database, the Maine Geological Survey Water Well database, Machias and Marshfield tax records, and Machias water/wastewater utility plan information, MaineDOT-ENV personnel preliminary identified 16 properties that, based on their hydrogeologic setting, may have potable water supply or subsurface disposal system impacts as a result of rising surface waters and/or changing groundwater patterns. These properties are shown on Figure 1 (Lot A – Lot P).

Site Reconnaissance & Interviews

MaineDOT-ENV personnel conducted several site inspections of the study area to assess and evaluate the information collected during the Data Review phase. These inspections validated the defined locations and confirmed that additional information was warranted.

MaineDOT reached out to the 16 property owners by US Mail and where possible, by in-person visits. Contact was made with 13 of the owners (one was a former owner – property recently sold). Information on water supply wells and septic systems were obtained and 11 of the owners allowed water quality samples to be collected. Attachment I presents field data sheets and water quality chemistry for 11 properties (two field data sheets are also provided for the properties that were not sampled).

Discussions with Machias Wastewater Treatment facility personnel indicates Lot P, Lot O, Lot N and Lot M are connected to their service (See Figure 1). The remaining properties of interest treat wastewater through onsite subsurface disposal systems.

Potable Water Quality

Water quality samples were collected from the potable water supplies servicing 11 properties of interest. Samples were obtained from Lot A, Lot C, Lot D, Lot E, Lot H, Lot

J, Lot K, Lot L, Lot M, Lot O and Lot P (see Figure 1). As mentioned previously, with the exception Lot F, owners of the remaining properties did not respond to MaineDOT's contact efforts. According to the owner of Lot F, the shallow, dug well on the property is not used for potable water purposes.

Samples were analyzed for a "typical residential" suite of chemical parameters. Northeast Laboratories of Winslow, Maine performed the analyses. Sample results are included in Attachment I.

Findings

Based on anticipated surface water level increases and associated localized, groundwater changes, the data review and reconnaissance efforts noted that 16 properties in the study area have hydrogeologic settings that may be influenced by rising waters. Specifically, cultural features on these properties such as potable water supplies and subsurface disposal systems could be adversely affected.

Site visits and discussions with property owners proved helpful in understanding the potential for impacts at the identified properties. Well data from Lot B, Lot C, Lot D and Lot E indicates bedrock wells at these properties are of moderate depth and have relatively high yields and strong upward gradients. These are hydrogeologic characteristics that will work favorably in combating any quality or quantity issues associated with rising surface water levels. Subsurface disposal field data from these properties indicates the systems are positioned at elevations well above levels where anticipated groundwater and surface water issues may exist. Information from Lot A, Lot H, Lot J and Lot K found similar findings – bedrock water supply wells and septic systems are well removed from any potential localized water level changes. In general, water quality data for these bedrock wells appear to meet relevant and applicable water quality standards.

Lot L, Lot M and Lot P have bedrock water supply wells; all three displayed elevated levels of chloride with Lot L and Lot P exceeding the 250 mg/L secondary water quality standard. Chloride levels in well water from Lot M was analyzed at 170 mg/L. Lot P is regulated as a Public Water Supply by the Maine Drinking Water Program. The hydrogeologic positioning of these water supply wells suggests saltwater inundation may be influencing water quality. These properties manage wastewater through the Machias Wastewater Treatment Facility. Anticipated surface water level changes will most likely exacerbate water quality concerns in these wells.

Lot O utilizes a shallow dug well for potable water. Water quality data indicates there are currently some potability concerns. Wastewater is managed through the Machias Wastewater Treatment Facility. Although contact was not made with this property owner, information from abutting property owners suggest Lot N is similar to Lot O and has a shallow dug well and also discharges wastewater effluent to the municipal sewer system.

It is believed that rising surface water levels will adversely affect the potability of these shallow, dug wells.

Discussions with the owner of Lot F noted that the site has a shallow dug well located adjacent to the Middle River. This well is not used for consumption. A water quality sample was not collected. Specifics relative to the onsite septic system indicate it is an older design located in the central portion of the developed property. The hydrogeologic positioning of this parcel suggests the well and septic system will be impacted by changing surface and groundwater patterns.

MaineDOT was unable to contact the owners of Lot G and Lot I. Reconnaissance of the area and discussions with neighbors suggest Lot I utilizes a bedrock water supply well and onsite subsurface disposal system. Both features appear to be positioned outside any anticipated surface and groundwaters pattern changes.

Lot G appears to have a shallow dug well located adjacent to the Middle River. Observations indicate an onsite septic system exists behind the home. The low-lying elevation of this parcel and positioning of the well and septic system suggest both will be affected by rising water levels.

Closing

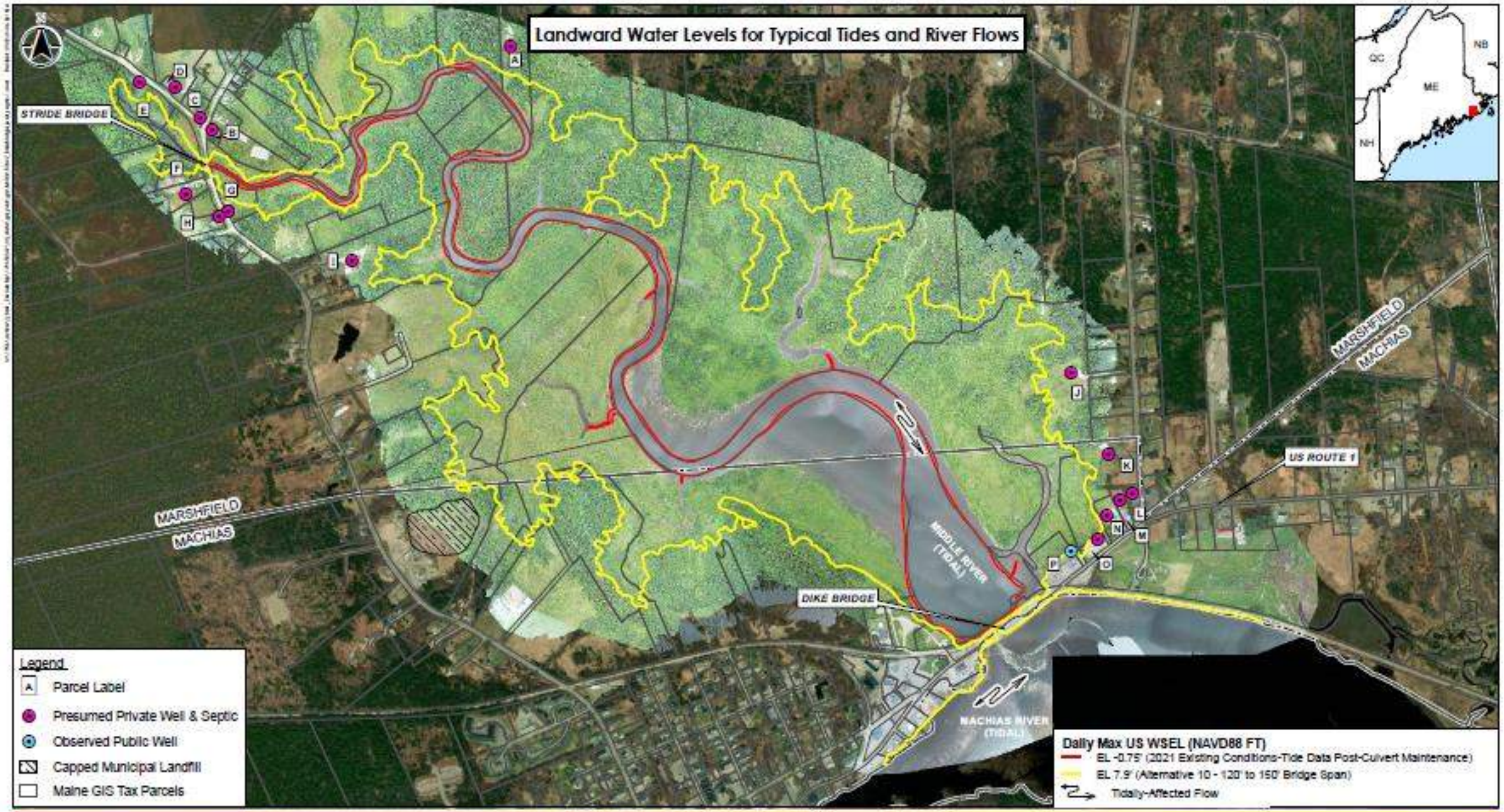
Work associated with the Machias Dike Bridge project may increase surface water levels in the Middle River estuary by up to 9-feet over current conditions during high tide. The elevated water levels will locally influence groundwater and surface water flow patterns.

Recent studies completed by MaineDOT's Environmental Office indicates that increased groundwater and surface water levels in the estuary area will impact several potable water supplies and subsurface disposal systems proximal to the Middle River. Impacts are anticipated in two distinct areas: Marshfield – Lot F and Lot G, and Machias – Lot L, Lot M, Lot N, Lot O and Lot P (see Figure 1).

Existing conditions indicate properties in the Machias area (Lot L – Lot P) are experiencing water quality issues that may be related to saltwater intrusion. Anticipated changes in surface and groundwater patterns will most likely exacerbate these issues.

The hydrogeologic setting of Lot F and Lot G, located in Marshfield and adjacent to the Middle River, suggests potable water supplies and subsurface disposal systems on these parcels will be impacted by rising waters in the Middle River. Parcel sizes and configurations limit locating replacement water supplies and septic systems on these properties.

Should you have any questions, please do not hesitate to call.



Stantec

30 Park Drive
Topsham, ME USA 04086
Phone (207) 729-1199

Prepared by RPL on 2021-12-06
Reviewed by TM on 2021-12-06
30147_DikeBridge_well_septic-1.mxd

Notes

1. Existing conditions are based on 2021 tidal stage data that was collected after leaking gates were fixed and 2021 drone imagery collected by MaineDOT before the leaking gates were fixed and represent a range of potential existing conditions.
2. Approximate water surface elevations (WSEL) for proposed alternatives are based on the 2021 Phase 1 and Phase 2 hydraulics analyses using tidal stage data collected by MaineDOT in 2021.
3. Coordinate System: NAD 1983 UTM Zone 19N FT
4. Vertical Datum: NAVD88
5. Aerial imagery in the project area was obtained by unmanned aircraft vehicle (UAV) by MaineDOT on July 20, 2021.
6. Aerial imagery surrounding the project area is provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).
7. TIN Surface information is based on survey data provided by the Maine Department of Transportation.

0 500 Feet

DRAFT

179450367

Client/Project
Maine DOT
Dike Bridge
Machias, Maine

Figure No.
Well/Septic-1

Title
Landward Water Levels for
Typical Tides and River Flows
1/6/2022

ATTACHMENT I

Project #: 016714.00 | **Sample No:** | **Date:**

Occupant Info:

SCOTT HENNESSEY
First Name Last Name

PO BOX 313
Address

MACHIAS ME 04654
Town State Zip

Phone

Owner Info (If different):

First Name Last Name

183 RIDGE ROAD MAILING
Address

MARSHFIELD ME
Town State Zip

Phone

Owner Questionnaire:

1. Number of water supplies (in use and not in use): 1
2. Is this water supply located on the property? [✓ Yes] No
3. Type: [✓ Drilled, Above Ground] Drilled, Below Ground Dug Spring Well Point Lake Unknown Other:
4. Well depth (ft):
5. Construction material: Cement Tiles Clay Tiles Brick Granite/Rock/Stone Metal [✓ Steel Casing] PCV Other:
6. End Use: Eating Lodging Nursing Home [✓ Private Home] Foster Care Children Nursery School Hospital Several Families School Day Care Other
7. Type of filtration: [✓ None] Reverse Osmosis Radon Sediment Chlorinator pH Ultraviolet Charcoal Water Softener Other:
8. Frequency in which well runs dry: [✓ Never] Once a Month Occasionally Yearly Monthly
9. Water quality issues: [✓ None] Sand Sediment Hard Iron Salty Rust Minerals/Metallic Odor Other:
10. Distance from water supply to road (ft): <50 50 - 100 100 - 150 [✓ >150]
11. Distance from water supply to septic tank (ft) <50 50 - 100 [✓ 100 - 150] >150
12. Number of people using water supply:

Other Comments: OUTSIDE FAUCET

GPS: North/Latitude: N 44°44'6.60" W ~~East~~/Longitude 67°27'58.6" Error:

SEPTIC
N 44°44'5.16"
W 67°27'58.62"

Northeast Laboratory Services

P.O. BOX 788
Waterville Maine, 04901-0788

227 China Road
Winslow Maine, 04901

Administrative Offices
Phone: 1-207-873-7711
Fax: 1-207-873-7022

Customer Service
Phone: 1-800-244-8378
Fax: 1-207-873-7022

Certificate of Analysis

Attention: David Philbrook
Maine Dept of Transportation
State House Station 16
Augusta, ME 04333

Lab ID Number: 302112147
P.O. Number: 302112147 Hennessey
Date/Time Collected: 10/7/2021 11:45
Date/Time Received: 10/7/2021 16:00
Date Reported: 10/8/2021

Owner: Scott Hennessey
Location Machias ME
Sample Type: Potability

Legend
✓ Meets Acceptable EPA Limits
⚠ See Notation
✗ Does Not Meet EPA Limits

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Chloride, Total	✓	11	250	mg/L	SM 4500Cl- E		10/8/2021 / 10:28	0.50
Fluoride	✓	1.8	4.0	mg/L	SM 4500F E		10/8/2021 / 11:30	0.40

A 1/2 dilution was performed in order to bring the concentration of Fluoride into the calibration range. The reporting limit has been adjusted accordingly.

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Nitrite-Nitrogen, Total	✓	<0.20	1	mg/L	NECi Method 1.0		10/7/2021 / 16:38	0.20
Nitrate-Nitrogen, Total	✓	<0.50	10	mg/L	NECi Method 1.0		10/7/2021 / 16:47	0.50
Arsenic, Total	✓	<1.000	10.0	µg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:37	1.000
Lead Total	✓	<1.000	15.0	µg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:37	1.000
Uranium Total	✓	11.8	30	µg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:37	1.000
Copper Total	✓	0.00478	1.3	mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:37	0.001
Iron Total	✓	<0.050	0.3	mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:37	0.050
Manganese Total	✓	<0.001	.05	mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:37	0.001
Sodium Total	⚠	24.2		mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:37	0.001

*This sample is at or above the MEG of 20 mg/L of Sodium established by the MECDC. Sodium is not listed as a primary nor secondary contaminant of concern by the USEPA. See Notation 1.

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Hardness by calculation		32		mg/L	SM 2340B	10/7/2021 / 17:00	10/8/2021 / 11:37	10
Calcium, Total		8.64		mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:37	1.000
Magnesium, Total		2.49		mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:37	1.000
pH Electrometric	✓	7.32	6.5 to 8.5	stu@25C	EPA 150.1		10/7/2021 / 16:40	2.0
Total Coliform Colilert18	✓	Absent		/100mL	SM9223B	10/7/2021 / 17:17	10/8/2021/ 13:03	0
E.Coli - Colilert Precence/Absent	✓	Absent	Absent	/100mL	SM9223B	10/7/2021 / 17:17	10/8/2021/ 13:03	0

Comments:

✓ For the above tests only, this water meets acceptable EPA Limits.

All samples analyzed for Nitrate-N and/or Nitrite-N samples must be thermally preserved to 4±2°C. However, the Maine CDC Drinking Water Program will accept non-thermally preserved test results.

LOT B

Project #: 016714.00	**Sample No:**	**Date:**

Occupant Info:

ABBIE GETCHELL,HEIRS OF LOT B
First Name

7 CHURCH LANE
Address

MARSHFIELD ME 04654
Town State Zip

Phone

Owner Info (If different):

C/O ALISON SAVARD
First Name Last Name

PO BOX 94
Address

EAST MACHIAS ME 04630
Town State Zip

Phone

Owner Questionnaire:

1. Number of water supplies (in use and not in use): one
2. Is this water supply located on the property? [✓ Yes] No
3. Type: [✓ Drilled], Above Ground Drilled, Below Ground Dug Spring Well Point Lake Unknown Other:
4. Well depth (ft): 85'
5. Construction material: Cement Tiles Clay Tiles Brick Granite/Rock/Stone Metal [✓ Steel Casing] PCV Other:
6. End Use: Eating Lodging Nursing Home [✓ Private Home] Foster Care Children Nursery School Hospital Several Families School Day Care Other
7. Type of filtration: None Reverse Osmosis Radon Sediment Chlorinator pH Ultraviolet Charcoal Water Softener Other:
8. Frequency in which well runs dry: Never Once a Month Occasionally Yearly Monthly / 50 gpm
9. Water quality issues: None Sand Sediment Hard Iron Salty Rust Minerals/Metallic Odor Other:
10. Distance from water supply to road (ft): <50 [✓ 50 - 100] 100 - 150 >150
11. Distance from water supply to septic tank (ft) <50 50 - 100 [✓ 100 - 150] >150
12. Number of people using water supply:

Other Comments: see Below

GPS: North/Latitude: East/Longitude Error:

④ Received email from alison on 9/24/2021 (11:12am to Dev Ambrose). well in question drilled in 1981 by Lawrence Lord - depth of 85'. pump @ 35'; rates at 50gpm. She has sold property. (unable to make contact)

Project #: 016714.00 | **Sample No:** N.E.L. | **Date:** 10-7-21

Occupant Info:

~~JESSICA & TROY~~ ~~LOOK~~
Last Name

153 NORTHFIELD ROAD

MARSHFIELD ME 04654
Town State Zip

607-207-0136
Phone

Owner Info (If different): NEW OWNER

CRYSTALL RICHARD
First Name Last Name

Address

Town State Zip

Phone

Owner Questionnaire:

1. Number of water supplies (in use and not in use): 1
2. Is this water supply located on the property? [✓ Yes] No
3. Type: [✓ Drilled, Above Ground] Drilled, Below Ground Dug Spring Well Point Lake Unknown Other:
4. Well depth (ft):
5. Construction material: Cement Tiles Clay Tiles Brick Granite/Rock/Stone Metal [✓ Steel Casing] PCV Other:
6. End Use: Eating Lodging Nursing Home [✓ Private Home] Foster Care Children Nursery School Hospital Several Families School Day Care Other
7. Type of filtration: [✓ None] Reverse Osmosis Radon Sediment Chlorinator pH Ultraviolet Charcoal Water Softener Other:
8. Frequency in which well runs dry: [✓ Never] Once a Month Occasionally Yearly Monthly
9. Water quality issues: [✓ None] Sand Sediment Hard Iron Salty Rust Minerals/Metallic Odor Other:
10. Distance from water supply to road (ft): [✓ <50] 50 - 100 100 - 150 >150
11. Distance from water supply to septic tank (ft) <50 [✓ 50 - 100] 100 - 150 >150
12. Number of people using water supply:

Other Comments: KIT SINK (OWNER)

GPS: North/Latitude: 44°43'59.51" ~~East~~ W/Longitude 67°28'35.95" Error:

N 44°44'0.25"
SEPTIC
W 67°28'36.32"

Northeast Laboratory Services

P.O. BOX 788
Waterville Maine, 04901-0788

227 China Road
Winslow Maine, 04901

Administrative Offices
Phone: 1-207-873-7711
Fax: 1-207-873-7022

Customer Service
Phone: 1-800-244-8378
Fax: 1-207-873-7022

Certificate of Analysis

Attention: David Philbrook
Maine Dept of Transportation
State House Station 16
Augusta, ME 04333

Lab ID Number: 302112148
P.O. Number: 302112148 Richard
Date/Time Collected: 10/7/2021 12:30
Date/Time Received: 10/7/2021 16:00
Date Reported: 10/8/2021

Owner: Crystall Richard
Location: Marshfield ME
Sample Type: Potability

Legend
- ✓ Meets Acceptable EPA Limits
- ⚠ See Notation
- ✗ Does Not Meet EPA Limits

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Chloride, Total	✓	9.2	250	mg/L	SM 4500Cl- E		10/8/2021 / 10:29	0.50
Fluoride	✓	0.22	4.0	mg/L	SM 4500F E		10/8/2021 / 11:19	0.20
Nitrite-Nitrogen, Total	✓	<0.20	1	mg/L	NECi Method 1.0		10/7/2021 / 16:38	0.20
Nitrate-Nitrogen, Total	✓	<0.50	10	mg/L	NECi Method 1.0		10/7/2021 / 16:48	0.50
Arsenic, Total	✓	<1.000	10.0	µg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:39	1.000
Lead Total	✓	<1.000	15.0	µg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:39	1.000
Uranium Total	✓	2.97	30	µg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:39	1.000
Copper Total	✓	0.0217	1.3	mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:39	0.001
Iron Total	✓	<0.050	0.3	mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:39	0.050
Manganese Total	✓	<0.001	.05	mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:39	0.001
Sodium Total	✓	10.9		mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:39	0.001
Hardness by calculation		110		mg/L	SM 2340B	10/7/2021 / 17:00	10/8/2021 / 11:39	10
Calcium, Total		25.2		mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:39	1.000
Magnesium, Total		12.2		mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:39	1.000
pH Electrometric	✓	6.65	6.5 to 8.5	stu@25C	EPA 150.1		10/7/2021 / 16:44	2.0
Total Coliform Colilert18	✓	Absent		/100mL	SM9223B	10/7/2021 / 17:17	10/8/2021/ 13:03	0
E.Coli - Colilert Precence/Absent	✓	Absent	Absent	/100mL	SM9223B	10/7/2021 / 17:17	10/8/2021/ 13:03	0

Comments:

✓ For the above tests only, this water meets acceptable EPA Limits.

All samples analyzed for Nitrate-N and/or Nitrite-N samples must be thermally preserved to 4±2°C. However, the Maine CDC Drinking Water Program will accept non-thermally preserved test results.

Project #: 016714.00	**Sample No:**	**Date:** 10-7-21

Occupant Info:

WILLIAM GETCHELL
First Name Last Name

163 NORTHFIELD ROAD

MARSHFIELD ME 04654
Town State Zip

207-446-0283
Phone

Owner Info (If different):

First Name Last Name

Address

Town State Zip

Phone

Owner Questionnaire:

1. Number of water supplies (in use and not in use): 1
2. Is this water supply located on the property? [✓ Yes] No
3. Type: Drilled, Above Ground Drilled, Below Ground Dug Spring Well Point Lake Unknown Other:
4. Well depth (ft):
5. Construction material: Cement Tiles Clay Tiles Brick Granite/Rock/Stone Metal Steel Casing PCV Other:
6. End Use: Eating Lodging Nursing Home Private Home Foster Care Children Nursery School Hospital Several Families School Day Care Other
7. Type of filtration: None Reverse Osmosis Radon Sediment Chlorinator pH Ultraviolet Charcoal Water Softener Other:
8. Frequency in which well runs dry: Never Once a Month Occasionally Yearly Monthly
9. Water quality issues: None Sand Sediment Hard Iron Salty Rust Minerals/Metallic Odor Other:
10. Distance from water supply to road (ft): <50 50 - 100 100 - 150 >150
11. Distance from water supply to septic tank (ft) <50 50 - 100 100 - 150 >150
12. Number of people using water supply:

Other Comments:

GPS: North/Latitude: N 44°44'3.23" East/Longitude 67°28'37.40" Error:

SEPTIC

Northeast Laboratory Services

P.O. BOX 788
Waterville Maine, 04901-0788

227 China Road
Winslow Maine, 04901

Administrative Offices
Phone: 1-207-873-7711
Fax: 1-207-873-7022

Customer Service
Phone: 1-800-244-8378
Fax: 1-207-873-7022

Certificate of Analysis

Attention: David Philbrook
Maine Dept of Transportation
State House Station 16
Augusta, ME 04333

Lab ID Number: 302112145
P.O. Number: 302112145 Getchell
Date/Time Collected: 10/7/2021 10:15
Date/Time Received: 10/7/2021 16:00
Date Reported: 10/8/2021

Owner: William Getchell
Location Machias ME
Sample Type: Potability

Legend
✓ Meets Acceptable EPA Limits
⚠ See Notation
✗ Does Not Meet EPA Limits

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Chloride, Total	✓	13	250	mg/L	SM 4500Cl- E		10/8/2021 / 10:28	0.50
Fluoride	✓	1.2	4.0	mg/L	SM 4500F E		10/8/2021 / 12:16	0.40
A 1/2 dilution was performed in order to bring the concentration of Fluoride into the calibration range. The reporting limit has been adjusted accordingly.								
Nitrite-Nitrogen, Total	✓	<0.20	1	mg/L	NECi Method 1.0		10/7/2021 / 16:37	0.20
Nitrate-Nitrogen, Total	✓	<0.50	10	mg/L	NECi Method 1.0		10/7/2021 / 16:46	0.50
Arsenic, Total	✓	<1.000	10.0	µg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:33	1.000
Lead Total	✓	<1.000	15.0	µg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:33	1.000
Uranium Total	✓	14.0	30	µg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:33	1.000
Copper Total	✓	0.00544	1.3	mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:33	0.001
Iron Total	✓	0.0556	0.3	mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:33	0.050
Manganese Total	✓	0.0153	.05	mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:33	0.001
Sodium Total	⚠	41.3		mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:33	0.001
*This sample is at or above the MEG of 20 mg/L of Sodium established by the MECDC. Sodium is not listed as a primary nor secondary contaminant of concern by the USEPA. See Notation 1.								
Hardness by calculation		31		mg/L	SM 2340B	10/7/2021 / 17:00	10/8/2021 / 11:33	10
Calcium, Total		7.63		mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:33	1.000
Magnesium, Total		3.00		mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:33	1.000
pH Electrometric	✓	7.00	6.5 to 8.5	stu@25C	EPA 150.1		10/7/2021 / 16:36	2.0
Total Coliform Colilert18	⚠	Present		/100mL	SM9223B	10/7/2021 / 17:17	10/8/2021/ 13:03	0
*According to the EPA Revised Coliform rule a total coliform positive result is a potential problem necessitating further investigation. See notation 4.								
E.Coli - Colilert Precence/Absent	✓	Absent	Absent	/100mL	SM9223B	10/7/2021 / 17:17	10/8/2021/ 13:03	0

Comments:

⚠ This water requires further investigation due to a positive total coliform result. See notation 4.

All samples analyzed for Nitrate-N and/or Nitrite-N samples must be thermally preserved to 4±2°C. However, the Maine CDC Drinking Water Program will accept non-thermally preserved test results.

Project #: 016714.00 | **Sample No:** | **Date:** 10-7-21

Occupant Info:

VERNAL MERCHANT
First Name Last Name

182 NORTHFIELD ROAD
Address

MARSHFIELD ME 04654
Town State Zip

207-263-849
Phone

Owner Info (If different):

ERNEST VANDERMAST
First Name Last Name

Address

Town State Zip

Phone

Owner Questionnaire:

1. Number of water supplies (in use and not in use): ____________
2. Is this water supply located on the property? Yes No
3. Type: Drilled, Above Ground Drilled, Below Ground Dug Spring Well Point Lake Unknown Other: ____________
4. Well depth (ft): ____________
5. Construction material: Cement Tiles Clay Tiles Brick Granite/Rock/Stone Metal [✓ Steel Casing] PCV Other: ____________
6. End Use: Eating Lodging Nursing Home [✓ Private Home] Foster Care Children Nursery School Hospital Several Families School Day Care Other
7. Type of filtration: [✓ None] Reverse Osmosis Radon Sediment Chlorinator pH Ultraviolet Charcoal Water Softener Other: ____________
8. Frequency in which well runs dry: [✓ Never] Once a Month Occasionally Yearly Monthly
9. Water quality issues: [✓ None] Sand Sediment Hard Iron Salty Rust Minerals/Metallic Odor Other: ____________
10. Distance from water supply to road (ft): [✓ <50] 50 - 100 100 - 150 >150
11. Distance from water supply to septic tank (ft) <50 [✓ 50 - 100] 100 - 150 >150
12. Number of people using water supply: ____________

Other Comments: KIT SINK

GPS: [✓ North]/Latitude: 44°44'2.61" East/Longitude 67°28'44.02" Error: ____________

SEPTIC 44°44'2.71" 67°28'45.06"

ERNEST VANDERMAST

Northeast Laboratory Services

P.O. BOX 788
Waterville Maine, 04901-0788

227 China Road
Winslow Maine, 04901

Administrative Offices
Phone: 1-207-873-7711
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Customer Service
Phone: 1-800-244-8378
Fax: 1-207-873-7022

Certificate of Analysis

Attention: David Philbrook
Maine Dept of Transportation
State House Station 16
Augusta, ME 04333

Lab ID Number: 302112146
P.O. Number: 302112146 Merchant
Date/Time Collected: 10/7/2021 11:00
Date/Time Received: 10/7/2021 16:00
Date Reported: 10/8/2021

Owner: Vernal Merchant
Location Machias
Sample Type: Potability

Legend
- ✓ Meets Acceptable EPA Limits
- ⚠ See Notation
- ✗ Does Not Meet EPA Limits

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Chloride, Total	✓	10	250	mg/L	SM 4500Cl- E		10/8/2021 / 10:28	0.50
Fluoride	✓	0.84	4.0	mg/L	SM 4500F E		10/8/2021 / 12:01	0.20
Nitrite-Nitrogen, Total	✓	<0.20	1	mg/L	NECi Method 1.0		10/7/2021 / 16:38	0.20
Nitrate-Nitrogen, Total	✓	0.57	10	mg/L	NECi Method 1.0		10/7/2021 / 16:47	0.50
Arsenic, Total	✓	<1.000	10.0	µg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:35	1.000
Lead Total	✓	<1.000	15.0	µg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:35	1.000
Uranium Total	✓	8.92	30	µg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:35	1.000
Copper Total	✓	0.0109	1.3	mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:35	0.001
Iron Total	✓	<0.050	0.3	mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:35	0.050
Manganese Total	✓	<0.001	.05	mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:35	0.001
Sodium Total	⚠	20.9		mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:35	0.001
*This sample is at or above the MEG of 20 mg/L of Sodium established by the MECDC. Sodium is not listed as a primary nor secondary contaminant of concern by the USEPA. See Notation 1.								
Hardness by calculation		42		mg/L	SM 2340B	10/7/2021 / 17:00	10/8/2021 / 11:35	10
Calcium, Total		11.3		mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:35	1.000
Magnesium, Total		3.39		mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:35	1.000
pH Electrometric	✓	6.53	6.5 to 8.5	stu@25C	EPA 150.1		10/7/2021 / 16:38	2.0
Total Coliform Colilert18	✓	Absent		/100mL	SM9223B	10/7/2021 / 17:17	10/8/2021/ 13:03	0
E.Coli - Colilert Precence/Absent	✓	Absent	Absent	/100mL	SM9223B	10/7/2021 / 17:17	10/8/2021/ 13:03	0

Comments:

✓ For the above tests only, this water meets acceptable EPA Limits.

All samples analyzed for Nitrate-N and/or Nitrite-N samples must be thermally preserved to 4±2°C. However, the Maine CDC Drinking Water Program will accept non-thermally preserved test results.

Project #: 016714.00	**Sample No:**	**Date:**

Occupant Info:

WILLIAM **GRANT** LOT F
First Name Last Name

132 NORTHFIELD ROAD

MARSHFIELD ME 04654
Town State Zip

207-263-4403
Phone

Owner Info (If different):

First Name Last Name

Address

Town State Zip

Phone

Owner Questionnaire:

1. Number of water supplies (in use and not in use): one

2. Is this water supply located on the property? [✓ Yes] No

3. Type: Drilled, Above Ground Drilled, Below Ground [✓ Dug] Spring Well Point Lake Unknown Other:

4. Well depth (ft): unknown

5. Construction material: [✓ Cement Tiles] Clay Tiles Brick Granite/Rock/Stone Metal Steel Casing PCV Other:

6. End Use: Eating Lodging Nursing Home Private Home Foster Care Children Nursery School Hospital Several Families School Day Care [✓ Other] car repair

7. Type of filtration: [✓ None] Reverse Osmosis Radon Sediment Chlorinator pH Ultraviolet Charcoal Water Softener Other:

8. Frequency in which well runs dry: [✓ Never] Once a Month Occasionally Yearly Monthly

9. Water quality issues: None Sand Sediment Hard Iron Salty Rust Minerals/Metallic Odor Other: not used for consumption

10. Distance from water supply to road (ft): <50 50 - 100 [✓ 100 - 150] >150

11. Distance from water supply to septic tank (ft) <50 [✓ 50 - 100] 100 - 150 >150

12. Number of people using water supply: Business

Other Comments: telephone conversation on 12/28/21 12:10pm

GPS: North/Latitude: East/Longitude Error:

Dug well located near middle room – not used
for drinking; came with house
Septic may not be properly working

Project #: 016714.00	**Sample No:**	**Date:** 12-1-21

Occupant Info:

DOUGLAS GETCHELL
First Name Last Name

9 PUMPKIN RIDGE ROAD

MARSHFIELD ME 04654
Town State Zip

207-604-2428
Phone

Owner Info (If different):

C/O DOUGLAS GETCHELL
First Name Last Name

248 HIGH STREET
Address

SANFORD ME 04073
Town State Zip

Phone

Owner Questionnaire:

1. Number of water supplies (in use and not in use): ____________
2. Is this water supply located on the property? Yes No
3. Type: [✓ Drilled, Above Ground] Drilled, Below Ground Dug Spring Well Point Lake Unknown Other: ____________
4. Well depth (ft): 265'
5. Construction material: Cement Tiles Clay Tiles Brick Granite/Rock/Stone Metal [✓ Steel Casing] PCV Other: ____________
6. End Use: Eating Lodging Nursing Home [✓ Private Home] Foster Care Children Nursery School Hospital Several Families School Day Care Other
7. Type of filtration: [✓ None] Reverse Osmosis Radon Sediment Chlorinator pH Ultraviolet Charcoal Water Softener Other: ____________
8. Frequency in which well runs dry: Never Once a Month Occasionally Yearly Monthly
9. Water quality issues: [✓ None] Sand Sediment Hard Iron Salty Rust Minerals/Metallic Odor Other: ____________
10. Distance from water supply to road (ft): <50 [✓ 50 - 100] 100 - 150 >150
11. Distance from water supply to septic tank (ft) <50 50 - 100 [✓ 100 - 150] >150
12. Number of people using water supply: ____________

Other Comments: KIT SINK

GPS: North/Latitude: 44°43'49.65 East/Longitude 67°28'35.92 Error: ____________

Northeast Laboratory Services

P.O. BOX 788
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Administrative Offices
Phone: 1-207-873-7711
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Customer Service
Phone: 1-800-244-8378
Fax: 1-207-873-7022

Certificate of Analysis

Attention: David Philbrook
Maine Dept of Transportation
State House Station 16
Augusta, ME 04333

Lab ID Number: 302114338
P.O. Number: 302114338 Getchell
Date/Time Collected: 12/1/2021 10:45
Date/Time Received: 12/1/2021 15:46
Date Reported: 12/2/2021

Owner: Douglas Getchell
Location: Machias
Sample Type: Potability

Legend
✓ Meets Acceptable EPA Limits
⚠ See Notation
⊗ Does Not Meet EPA Limits

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Chloride, Total	✓	23	250	mg/L	SM 4500Cl- E		12/2/2021 / 09:04	2.5
A 1/5 dilution was performed in order to bring the concentration of Chloride, Total into the calibration range. The reporting limit has been adjusted accordingly.								
Fluoride	✓	<0.20	4.0	mg/L	SM 4500F E		12/2/2021 / 09:25	0.20
Nitrite-Nitrogen, Total	✓	<0.20	1	mg/L	NECi Method 1.0		12/1/2021 / 16:20	0.20
Nitrate-Nitrogen, Total	✓	<0.50	10	mg/L	NECi Method 1.0		12/1/2021 / 16:30	0.50
Arsenic, Total	✓	<1.000	10.0	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:25	1.000
Lead Total	✓	1.54	15.0	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:25	1.000
Uranium Total	✓	<1.000	30	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:25	1.000
Copper Total	✓	0.0479	1.3	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:25	0.001
Iron Total	✓	0.0653	0.3	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:25	0.050
Manganese Total	✓	0.00146	.05	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:25	0.001
Sodium Total	✓	10.7		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:25	0.001
Hardness by calculation		51		mg/L	SM 2340B	12/1/2021 / 17:00	12/2/2021 / 11:25	10
Calcium, Total		12.4		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:25	1.000
Magnesium, Total		4.80		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:25	1.000
pH Electrometric	⚠	5.78	6.5 to 8.5	stu@25C	EPA 150.1		12/1/2021 / 16:26	2.0
*This sample is below the SMCL pH 6.5-8.5 range established by the USEPA. See Notation 3.								
Total Coliform Colilert18	✓	<1		MPN/100mL	SM9223B	12/1/2021 / 16:42	12/2/2021/ 10:42	1
E.Coli - Colilert Enumeration	✓	<1	1	MPN/100mL	SM9223B	12/1/2021 / 16:42	12/2/2021/ 10:42	1

Comments:

✓ For the above tests only, this water meets acceptable EPA Limits.

J

Project #: 016714.00	**Sample No:**	**Date:** 12-1-21

Occupant Info:

CHRISTOPHER & LAUREN SPRAGUE
First Name Last Name

58 HADLEY LAKE ROAD
Address

MARSHFIELD ME 04654
Town State Zip

Phone

Owner Info (If different):

First Name Last Name

Address

Town State Zip

Phone

Owner Questionnaire:

1. Number of water supplies (in use and not in use): ______
2. Is this water supply located on the property? Yes No
3. Type: Drilled, Above Ground Drilled, Below Ground Dug Spring Well Point Lake Unknown Other: ______
4. Well depth (ft): 280
5. Construction material: Cement Tiles Clay Tiles Brick Granite/Rock/Stone Metal [✓ Steel Casing] PCV Other: ______
6. End Use: Eating Lodging Nursing Home [✓ Private Home] Foster Care Children Nursery School Hospital Several Families School Day Care Other
7. Type of filtration: None Reverse Osmosis Radon Sediment Chlorinator pH Ultraviolet Charcoal Water Softener Other: ______
8. Frequency in which well runs dry: Never Once a Month Occasionally Yearly Monthly
9. Water quality issues: None Sand Sediment Hard Iron Salty Rust Minerals/Metallic Odor Other: ______
10. Distance from water supply to road (ft): <50 50 - 100 100 - 150 [✓ >150]
11. Distance from water supply to septic tank (ft) <50 50 - 100 100 - 150 [✓ >150]
12. Number of people using water supply: ______

Other Comments: ______

GPS: North/Latitude: N 44°43 36.2976 East/Longitude W 67°26 47.89 Error: ______

SEPTIC

N 44°43'34.39
W 67°26'49.4441

~~N 44°43'23.27~~
~~W 67°26.40.69~~

Northeast Laboratory Services

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Winslow Maine, 04901

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Fax: 1-207-873-7022

Customer Service
Phone: 1-800-244-8378
Fax: 1-207-873-7022

Certificate of Analysis

Attention: David Philbrook
Maine Dept of Transportation
State House Station 16
Augusta, ME 04333

Lab ID Number: 302114339
P.O. Number: 302114339 Sprague
Date/Time Collected: 12/1/2021 12:30
Date/Time Received: 12/1/2021 15:46
Date Reported: 12/2/2021

Owner: Christopher Sprague
Location Machias
Sample Type: Potability

Legend
- ✓ Meets Acceptable EPA Limits
- ⚠ See Notation
- ✗ Does Not Meet EPA Limits

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Chloride, Total	✓	24	250	mg/L	SM 4500Cl- E		12/2/2021 / 09:04	2.5

A 1/5 dilution was performed in order to bring the concentration of Chloride, Total into the calibration range. The reporting limit has been adjusted accordingly.

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Fluoride	✓	1.8	4.0	mg/L	SM 4500F E		12/2/2021 / 09:43	0.40

A 1/2 dilution was performed in order to bring the concentration of Fluoride into the calibration range. The reporting limit has been adjusted accordingly.

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Nitrite-Nitrogen, Total	✓	<0.20	1	mg/L	NECi Method 1.0		12/1/2021 / 16:21	0.20
Nitrate-Nitrogen, Total	✓	<0.50	10	mg/L	NECi Method 1.0		12/1/2021 / 16:31	0.50
Arsenic, Total	✓	1.91	10.0	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:27	1.000
Lead Total	✓	<1.000	15.0	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:27	1.000
Uranium Total	✓	4.68	30	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:27	1.000
Copper Total	✓	0.00136	1.3	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:27	0.001
Iron Total	✓	<0.050	0.3	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:27	0.050
Manganese Total	⚠	0.100	.05	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:27	0.001

*This sample is at or above the SMCL of 0.05 mg/L of Manganese established by the USEPA and at or below the MEG of 0.3 mg/L of Manganese established by the MECDC. See Notation 1 and Notation 3.

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Sodium Total	⚠	54.0		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:49	0.002

A 1/2 dilution was performed in order to bring the concentration of Sodium Total into the calibration range. The reporting limit has been adjusted accordingly.

*This sample is at or above the MEG of 20 mg/L of Sodium established by the MECDC. Sodium is not listed as a primary nor secondary contaminant of concern by the USEPA. See Notation 1.

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Hardness by calculation		47		mg/L	SM 2340B	12/1/2021 / 17:00	12/2/2021 / 11:27	10
Calcium, Total		14.6		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:27	1.000
Magnesium, Total		2.64		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:27	1.000
pH Electrometric	✓	7.51	6.5 to 8.5	stu@25C	EPA 150.1		12/1/2021 / 16:30	2.0
Total Coliform Colilert18	✓	<1		MPN/100mL	SM9223B	12/1/2021 / 16:42	12/2/2021/ 10:42	1
E.Coli - Colilert Enumeration	✓	<1	1	MPN/100mL	SM9223B	12/1/2021 / 16:42	12/2/2021/ 10:42	1

Ⓚ

Project #: 016714.00	**Sample No:**	**Date:** 12-1-21

Occupant Info:
WCARC
First Name Last Name

Address

Town State Zip

Phone

Owner Info (If different):
Tom MICHAUD
First Name Last Name

Address

Town State Zip

Phone

Lot Information: Map: ____ Lot: ____ Town: ____

Owner Questionnaire:

1. Number of water supplies (in use and not in use): ____
2. Is this water supply located on the property? Yes No
3. Type: [✓ Drilled, Above Ground] Drilled, Below Ground Dug Spring Well Point Lake Unknown Other: ____
4. Well depth (ft): ____
5. Construction material: Cement Tiles Clay Tiles Brick Granite/Rock/Stone Metal [✓ Steel Casing] PCV Other: ____
6. End Use: Eating Lodging Nursing Home Private Home Foster Care Children Nursery School Hospital Several Families School Day Care [✓ Other] OFFICE BLDG
7. Type of filtration: [✓ None] Reverse Osmosis Radon Sediment Chlorinator pH Ultraviolet Charcoal Water Softener Other: ____
8. Frequency in which well runs dry: [✓ Never] Once a Month Occasionally Yearly Monthly
9. Water quality issues: [✓ None] Sand Sediment Hard Iron Salty Rust Minerals/Metallic Odor Other: ____
10. Distance from water supply to road (ft): <50 [✓ 50 - 100] 100 - 150 >150
11. Distance from water supply to septic tank (ft) <50 50 - 100 [✓ 100 - 150] >150
12. Number of people using water supply: ____

Other Comments: UTILITY SINK

GPS: North/Latitude: ____ East/Longitude ____ Error: ____

N44°43'.27.07 W 67°26'42179

Northeast Laboratory Services

P.O. BOX 788
Waterville Maine, 04901-0788

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Winslow Maine, 04901

Administrative Offices
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Customer Service
Phone: 1-800-244-8378
Fax: 1-207-873-7022

Certificate of Analysis

Attention: David Philbrook
Maine Dept of Transportation
State House Station 16
Augusta, ME 04333

Lab ID Number: 302114337
P.O. Number: 302114337 WCARC
Date/Time Collected: 12/1/2021 11:05
Date/Time Received: 12/1/2021 15:46
Date Reported: 12/2/2021

Owner: WCARC T Michaud
Location 26 Hadley Lake Rd Machais
Sample Type: Potability

Legend
- ✓ Meets Acceptable EPA Limits
- ⚠ See Notation
- ⊗ Does Not Meet EPA Limits

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Chloride, Total	✓	27	250	mg/L	SM 4500Cl- E		12/2/2021 / 09:04	2.5
A 1/5 dilution was performed in order to bring the concentration of Chloride, Total into the calibration range. The reporting limit has been adjusted accordingly.								
Fluoride	✓	1.5	4.0	mg/L	SM 4500F E		12/2/2021 / 09:42	0.40
A 1/2 dilution was performed in order to bring the concentration of Fluoride into the calibration range. The reporting limit has been adjusted accordingly.								
Nitrite-Nitrogen, Total	✓	<0.20	1	mg/L	NECi Method 1.0		12/1/2021 / 16:20	0.20
Nitrate-Nitrogen, Total	✓	<0.50	10	mg/L	NECi Method 1.0		12/1/2021 / 16:29	0.50
Arsenic, Total	✓	3.01	10.0	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:19	1.000
Lead Total	✓	<1.000	15.0	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:19	1.000
Uranium Total	✓	2.55	30	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:19	1.000
Copper Total	✓	<0.001	1.3	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:19	0.001
Iron Total	✓	0.207	0.3	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:19	0.050
Manganese Total	⚠	0.200	.05	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:19	0.001
*This sample is at or above the SMCL of 0.05 mg/L of Manganese established by the USEPA and at or below the MEG of 0.3 mg/L of Manganese established by the MECDC. See Notation 1 and Notation 3.								
Sodium Total	✓	18.1		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:19	0.001
Hardness by calculation		140		mg/L	SM 2340B	12/1/2021 / 17:00	12/2/2021 / 11:19	10
Calcium, Total		35.9		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:19	1.000
Magnesium, Total		13.1		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:19	1.000
pH Electrometric	✓	7.47	6.5 to 8.5	stu@25C	EPA 150.1		12/1/2021 / 16:20	2.0
Total Coliform Colilert18	⚠	1		MPN/100mL	SM9223B	12/1/2021 / 16:42	12/2/2021/ 10:42	1
*According to the EPA Revised Coliform rule a total coliform positive result is a potential problem necessitating further investigation. See notation 4.								
E.Coli - Colilert Enumeration	✓	<1	1	MPN/100mL	SM9223B	12/1/2021 / 16:42	12/2/2021/ 10:42	1

L

Project #: 016714.00	**Sample No:**	**Date:** 12-1-21

Occupant Info:

JASON **SMITH**
First Name Last Name

10 HADLEY LAKE ROAD

MACHIAS **ME** **04654**
Town State Zip

Phone

Owner Info (If different):

C/O JASON **SMITH**
First Name Last Name

PO BOX 474
Address

MACHIAS **ME** **04654**
Town State Zip

Phone

Owner Questionnaire:

1. Number of water supplies (in use and not in use):
2. Is this water supply located on the property? Yes No
3. Type: [✓ Drilled, Above Ground] Drilled, Below Ground Dug Spring Well Point Lake Unknown Other:
4. Well depth (ft):
5. Construction material: Cement Tiles Clay Tiles Brick Granite/Rock/Stone Metal [✓ Steel Casing] PCV Other:
6. End Use: Eating Lodging Nursing Home [✓ Private Home] Foster Care Children Nursery School Hospital Several Families School Day Care Other
7. Type of filtration: [✓ None] Reverse Osmosis Radon Sediment Chlorinator pH Ultraviolet Charcoal Water Softener Other:
8. Frequency in which well runs dry: [✓ Never] Once a Month Occasionally Yearly Monthly
9. Water quality issues: [✓ None] Sand Sediment Hard Iron Salty Rust Minerals/Metallic Odor Other:
10. Distance from water supply to road (ft): <50 [✓ 50 - 100] 100 - 150 >150
11. Distance from water supply to septic tank (ft) <50 50 - 100 [✓ 100 - 150] >150
12. Number of people using water supply:

Other Comments: PRESS TANK

GPS: North/Latitude: East/Longitude Error:

N. 44° 43' 23.27
W 67° 26.4069

Northeast Laboratory Services

P.O. BOX 788
Waterville Maine, 04901-0788

227 China Road
Winslow Maine, 04901

Administrative Offices
Phone: 1-207-873-7711
Fax: 1-207-873-7022

Customer Service
Phone: 1-800-244-8378
Fax: 1-207-873-7022

Certificate of Analysis

Attention: David Philbrook
Maine Dept of Transportation
State House Station 16
Augusta, ME 04333

Lab ID Number:	302114340	
P.O. Number:	302114340 Smith	
Date/Time Collected:	12/1/2021	12:10
Date/Time Received:	12/1/2021	15:46
Date Reported:	12/2/2021	

Owner: Jason Smith
Location Machias
Sample Type: Potability

Legend
✓ Meets Acceptable EPA Limits
⚠ See Notation
✗ Does Not Meet EPA Limits

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Chloride, Total	⚠	400	250	mg/L	SM 4500Cl- E		12/2/2021 / 09:32	25.0
A 1/50 dilution was performed in order to bring the concentration of Chloride, Total into the calibration range. The reporting limit has been adjusted accordingly. This sample is at or above the SMCL of 250 mg/L of Chloride established by the USEPA. See Notation 3.								
Fluoride	✓	0.66	4.0	mg/L	SM 4500F E		12/2/2021 / 09:26	0.20
Nitrite-Nitrogen, Total	✓	<0.20	1	mg/L	NECi Method 1.0		12/1/2021 / 16:22	0.20
Nitrate-Nitrogen, Total	✓	<0.50	10	mg/L	NECi Method 1.0		12/1/2021 / 16:32	0.50
Sodium Total	⚠	46.1		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:29	0.001
*This sample is at or above the MEG of 20 mg/L of Sodium established by the MECDC. Sodium is not listed as a primary nor secondary contaminant of concern by the USEPA. See Notation 1.								
Arsenic, Total	✓	2.64	10.0	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:29	1.000
Lead Total	✓	1.56	15.0	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:29	1.000
Uranium Total	✓	15.2	30	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:29	1.000
Copper Total	✓	0.00769	1.3	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:29	0.001
Iron Total	✓	0.131	0.3	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:29	0.050
Manganese Total	⚠	0.578	.05	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:51	0.005
A 1/5 dilution was performed in order to bring the concentration of Manganese Total into the calibration range. The reporting limit has been adjusted accordingly. *This sample is above the SMCL of 0.05 mg/L of Manganese established by the USEPA and at or above the MEG of 0.3 mg/L of Manganese established by the MECDC. This source should be monitored due to potential health risks in public drinking water supplies. See Notation 1 and Notation 3.								
Hardness by calculation		580		mg/L	SM 2340B	12/1/2021 / 17:00	12/2/2021 / 11:51	10
A 1/5 dilution was performed in order to bring the concentration of Hardness by calculation into the calibration range. The reporting limit has been adjusted accordingly.								
Calcium, Total		162		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:51	5.000
A 1/5 dilution was performed in order to bring the concentration of Calcium, Total into the calibration range. The reporting limit has been adjusted accordingly.								
Magnesium, Total		42.9		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:29	1.000
pH Electrometric	✓	7.55	6.5 to 8.5	stu@25C	EPA 150.1		12/1/2021 / 16:32	2.0
Total Coliform Colilert18	⚠	25		MPN/100mL	SM9223B	12/1/2021 / 16:42	12/2/2021/ 10:42	1

M

Project #: 016714.00	**Sample No:**	**Date:** 12-1-21

Occupant Info:

MACHIAS FAMILY **PHARMACY**
First Name / Last Name

194 MAINE STREET
Address

MACHIAS **ME** **04654**
Town State Zip

Phone

Owner Info (If different):

BENJAMIN **OKAFOR**
First Name Last Name

PO BOX 301
Address

MACHIAS **ME** **04654**
Town State Zip

207-255-888
Phone

Owner Questionnaire:

1. Number of water supplies (in use and not in use): ____________
2. Is this water supply located on the property? [✓ Yes] No
3. Type: Drilled, Above Ground [✓ Drilled, Below Ground] Dug Spring Well Point Lake Unknown Other: ____________
4. Well depth (ft): ____________
5. Construction material: Cement Tiles Clay Tiles Brick Granite/Rock/Stone Metal Steel Casing PCV Other: ____________
6. End Use: Eating Lodging Nursing Home Private Home Foster Care Children Nursery School Hospital Several Families School Day Care Other
7. Type of filtration: None Reverse Osmosis Radon Sediment Chlorinator pH Ultraviolet Charcoal Water Softener Other: ____________
8. Frequency in which well runs dry: Never Once a Month Occasionally Yearly Monthly
9. Water quality issues: None Sand Sediment Hard Iron Salty Rust Minerals/Metallic Odor Other: ____________
10. Distance from water supply to road (ft): <50 50 - 100 100 - 150 >150
11. Distance from water supply to septic tank (ft) <50 50 - 100 100 - 150 >150
12. Number of people using water supply: ____________

Other Comments: ____________

GPS: North/Latitude: ____________ East/Longitude ____________ Error: ____________

WELL - N 44.43° 22.8
APPROX! W 67° 26' 43.26

Northeast Laboratory Services

P.O. BOX 788
Waterville Maine, 04901-0788

227 China Road
Winslow Maine, 04901

Administrative Offices
Phone: 1-207-873-7711
Fax: 1-207-873-7022

Customer Service
Phone: 1-800-244-8378
Fax: 1-207-873-7022

Certificate of Analysis

Attention: David Philbrook
Maine Dept of Transportation
State House Station 16
Augusta, ME 04333

Lab ID Number: 302114335
P.O. Number: 302114335 Machais Pharmacy
Date/Time Collected: 12/1/2021 11:55
Date/Time Received: 12/1/2021 15:46
Date Reported: 12/2/2021

Owner: Machais Pharmacy
Location Machais
Sample Type: Potability

Legend
✓ Meets Acceptable EPA Limits
⚠ See Notation
✗ Does Not Meet EPA Limits

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Chloride, Total	✓	170	250	mg/L	SM 4500Cl- E		12/2/2021 / 09:17	5.0

A 1/10 dilution was performed in order to bring the concentration of Chloride, Total into the calibration range. The reporting limit has been adjusted accordingly.

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Fluoride	✓	0.47	4.0	mg/L	SM 4500F E		12/2/2021 / 09:24	0.20
Nitrite-Nitrogen, Total	✓	<0.20	1	mg/L	NECi Method 1.0		12/1/2021 / 16:18	0.20
Nitrate-Nitrogen, Total	✓	<0.50	10	mg/L	NECi Method 1.0		12/1/2021 / 16:27	0.50
Arsenic, Total	✓	1.45	10.0	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:15	1.000
Lead Total	✓	1.43	15.0	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:15	1.000
Uranium Total	✓	<1.000	30	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:15	1.000
Copper Total	✓	0.00589	1.3	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:15	0.001
Iron Total	✓	<0.050	0.3	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:15	0.050
Manganese Total	✓	0.00787	.05	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:15	0.001
Sodium Total	⚠	196		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:45	0.005

A 1/5 dilution was performed in order to bring the concentration of Sodium Total into the calibration range. The reporting limit has been adjusted accordingly.

*This sample is at or above the MEG of 20 mg/L of Sodium established by the MECDC. Sodium is not listed as a primary nor secondary contaminant of concern by the USEPA. See Notation 1.

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Hardness by calculation		<10		mg/L	SM 2340B	12/1/2021 / 17:00	12/2/2021 / 11:15	10
Calcium, Total		1.15		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:15	1.000
Magnesium, Total		<1.000		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:15	1.000
pH Electrometric	✓	7.07	6.5 to 8.5	stu@25C	EPA 150.1		12/1/2021 / 16:16	2.0
Total Coliform Colilert18	✓	<1		MPN/100mL	SM9223B	12/1/2021 / 16:42	12/2/2021/ 10:42	1
E.Coli - Colilert Enumeration	✓	<1	1	MPN/100mL	SM9223B	12/1/2021 / 16:42	12/2/2021/ 10:42	1

Comments:

✓ For the above tests only, this water meets acceptable EPA Limits.

Project #: 016714.00 | **Sample No:** NEL | **Date:** 10-7-21

Occupant Info:

SHAWN **HARTFORD**
First Name Last Name

189 MAIN STREET
Address

MACHIAS **ME** **04654**
Town State Zip

207-461-5057
Phone

Owner Info (If different): MAIL ADDRESS

RT
SHAWN **HARFORD**
First Name Last Name

PO BOX 23
Address

COLUMBIA FALLS **ME** **04623**
State Zip

207-461-5057
Phone

Owner Questionnaire:

1. Number of water supplies (in use and not in use): 1
2. Is this water supply located on the property? [✓ Yes] No
3. Type: Drilled, Above Ground Drilled, Below Ground [✓ Dug] Spring Well Point Lake Unknown Other:
4. Well depth (ft): 10' 4' DIA
5. Construction material: Cement Tiles Clay Tiles Brick [✓ Granite/Rock/Stone] Metal Steel Casing PCV Other:
6. End Use: Eating Lodging Nursing Home Private Home Foster Care Children Nursery School Hospital Several Families School Day Care [✓ Other]
7. Type of filtration: [✓ None] Reverse Osmosis Radon Sediment Chlorinator pH Ultraviolet Charcoal Water Softener Other:
8. Frequency in which well runs dry: [✓ Never] Once a Month Occasionally Yearly Monthly
9. Water quality issues: [✓ None] Sand Sediment Hard Iron Salty Rust Minerals/Metallic Odor Other:
10. Distance from water supply to road (ft): <50 [✓ 50 - 100] 100 - 150 >150
11. Distance from water supply to septic tank (ft) <50 ~~50 - 100~~ ~~100 - 150~~ >150 TOWN SEWER
12. Number of people using water supply:

Other Comments:

GPS: North/Latitude: 44° 43' 26.02 East/Longitude 67° 26' 45.63 Error:

Northeast Laboratory Services

P.O. BOX 788
Waterville Maine, 04901-0788

227 China Road
Winslow Maine, 04901

Administrative Offices
Phone: 1-207-873-7711
Fax: 1-207-873-7022

Customer Service
Phone: 1-800-244-8378
Fax: 1-207-873-7022

Certificate of Analysis

Attention: Dave Philbrook
Maine Dept of Transportation
State House Station 16
Augusta, ME 04333

Lab ID Number: 302112144
P.O. Number: 302112144 Hartford
Date/Time Collected: 10/7/2021 10:00
Date/Time Received: 10/7/2021 16:00
Date Reported: 10/8/2021

Owner: Shawn Hartford
Location Machias
Sample Type: Potability

Legend
✓ Meets Acceptable EPA Limits
⚠ See Notation
✗ Does Not Meet EPA Limits

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Chloride, Total	✓	18	250	mg/L	SM 4500Cl- E		10/8/2021 / 10:28	0.50
Fluoride	✓	<0.20	4.0	mg/L	SM 4500F E		10/8/2021 / 12:01	0.20
Nitrite-Nitrogen, Total	✓	<0.20	1	mg/L	NECi Method 1.0		10/7/2021 / 16:37	0.20
Nitrate-Nitrogen, Total	⚠	6.8	10	mg/L	NECi Method 1.0		10/7/2021 / 17:00	2.5

A 1/5 dilution was performed in order to bring the concentration of Nitrate-Nitrogen, Total into the calibration range. The reporting limit has been adjusted accordingly.

*This sample is close to the MCL of 10 mg/L of Nitrate established by the USEPA and the MEG of 10 mg/L of Nitrate established by the MECDC. This source should be monitored due to potential health risks in drinking water supplies. See Notation 1 and Notation 2.

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Arsenic, Total	✓	2.68	10.0	µg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:31	1.000
Lead Total	✓	8.26	15.0	µg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:31	1.000
Uranium Total	✓	<1.000	30	µg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:31	1.000
Copper Total	✓	0.0970	1.3	mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:31	0.001
Iron Total	⚠	2.24	0.3	mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:31	0.050

*This sample is at or above the SMCL of 0.3 mg/L of Iron established by the USEPA and at or below the MEG of 5 mg/L of Iron established by the MECDC. See Notation 1 and Notation 3.

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Manganese Total	✓	0.0150	.05	mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:31	0.001
Sodium Total	⚠	24.5		mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:31	0.001

*This sample is at or above the MEG of 20 mg/L of Sodium established by the MECDC. Sodium is not listed as a primary nor secondary contaminant of concern by the USEPA. See Notation 1.

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Hardness by calculation		40		mg/L	SM 2340B	10/7/2021 / 17:00	10/8/2021 / 11:31	10
Calcium, Total		12.7		mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:31	1.000
Magnesium, Total		2.07		mg/L	EPA 200.8	10/7/2021 / 17:00	10/8/2021 / 11:31	1.000
pH Electrometric	⚠	5.47	6.5 to 8.5	stu@25C	EPA 150.1		10/7/2021 / 16:34	2.0

*This sample is below the SMCL pH 6.5-8.5 range established by the USEPA. See Notation 3.

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Total Coliform Colilert18	⚠	Present		/100mL	SM9223B	10/7/2021 / 17:17	10/8/2021/ 13:03	0

*According to the EPA Revised Coliform rule a total coliform positive result is a potential problem necessitating further investigation. See notation 4.

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
E.Coli - Colilert Precence/Absent	✗	Present	Absent	/100mL	SM9223B	10/7/2021 / 17:17	10/8/2021/ 13:03	0

*This sample is out of USEPA compliance for public drinking water systems due to the presence of E . coli bacteria.
Please see the enclosed interpretation sheet for more information, including procedures for well disinfection. Kit to follow. See Notation 2.

(P)

Project #: 016714.00
Sample No:
Date: 12-1-21

Occupant Info:

DUNKIN/CAUSEWAY COMMONS
First Name Last Name

182 MAIN STREET
Address

MACHIAS ME 04654
Town State Zip

Phone

Owner Info (If different): MAINT. MIKE SEBASTIAO 207-263-6656

TOM MICHAUD
First Name Last Name

CAUSEWAY COMMONS PO BOX84

MACHIAS ME 04654
Town State Zip

207-255-859
Phone

Owner Questionnaire:

1. Number of water supplies (in use and not in use): 1
2. Is this water supply located on the property? Yes No
3. Type: Drilled, Above Ground [✓ Drilled, Below Ground] Dug Spring Well Point Lake Unknown Other:
4. Well depth (ft): 100'
5. Construction material: Cement Tiles Clay Tiles Brick Granite/Rock/Stone Metal Steel Casing PCV Other:
6. End Use: Eating Lodging Nursing Home Private Home Foster Care Children Nursery School Hospital Several Families School Day Care [✓ Other] BUSINESS
7. Type of filtration: None [✓ Reverse Osmosis] Radon Sediment Chlorinator pH Ultraviolet Charcoal Water Softener Other:
8. Frequency in which well runs dry: [✓ Never] Once a Month Occasionally Yearly Monthly
9. Water quality issues: None Sand Sediment Hard Iron [✓ Salty] Rust Minerals/Metallic Odor Other:
10. Distance from water supply to road (ft): <50 [✓ 50 - 100] 100 - 150 >150
11. Distance from water supply to septic tank (ft) <50 50 - 100 100 - 150 >150 CITY SEWER
12. Number of people using water supply:

Other Comments: PRESS TANK

GPS: North/Latitude: N 44°43'18.48 East/Longitude W 67°26'48.33. Error:

CITY SEWER

Northeast Laboratory Services

P.O. BOX 788
Waterville Maine, 04901-0788

227 China Road
Winslow Maine, 04901

Administrative Offices
Phone: 1-207-873-7711
Fax: 1-207-873-7022

Customer Service
Phone: 1-800-244-8378
Fax: 1-207-873-7022

Certificate of Analysis

Attention: David Philbrook
Maine Dept of Transportation
State House Station 16
Augusta, ME 04333

Lab ID Number: 302114336
P.O. Number: 302114336 Causeway
Date/Time Collected: 12/1/2021 11:20
Date/Time Received: 12/1/2021 15:46
Date Reported: 12/2/2021

Owner: Causeway Commons Michaud
Location Machais
Sample Type: Potability

Legend
- ✓ Meets Acceptable EPA Limits
- ⚠ See Notation
- ✖ Does Not Meet EPA Limits

Parameter:		Your Result:	EPA LIMIT:	Unit:	Method:	Preparation Date/Time	Analysis Date/Time:	Reporting Limit:
Chloride, Total	⚠	470	250	mg/L	SM 4500Cl- E		12/2/2021 / 09:27	25.0
A 1/50 dilution was performed in order to bring the concentration of Chloride, Total into the calibration range. The reporting limit has been adjusted accordingly.								
This sample is at or above the SMCL of 250 mg/L of Chloride established by the USEPA. See Notation 3.								
Fluoride	✓	1.6	4.0	mg/L	SM 4500F E		12/2/2021 / 09:41	0.40
A 1/2 dilution was performed in order to bring the concentration of Fluoride into the calibration range. The reporting limit has been adjusted accordingly.								
Nitrite-Nitrogen, Total	✓	<0.20	1	mg/L	NECi Method 1.0		12/1/2021 / 16:19	0.20
Nitrate-Nitrogen, Total	✓	<0.50	10	mg/L	NECi Method 1.0		12/1/2021 / 16:29	0.50
Arsenic, Total	✓	<1.000	10.0	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:17	1.000
Lead Total	✓	5.28	15.0	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:17	1.000
Uranium Total	✓	2.85	30	µg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:17	1.000
Copper Total	✓	0.0336	1.3	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:17	0.001
Iron Total	⚠	0.764	0.3	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:17	0.050
*This sample is at or above the SMCL of 0.3 mg/L of Iron established by the USEPA and at or below the MEG of 5 mg/L of Iron established by the MECDC. See Notation 1 and Notation 3.								
Manganese Total	⚠	0.130	.05	mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:17	0.001
*This sample is at or above the SMCL of 0.05 mg/L of Manganese established by the USEPA and at or below the MEG of 0.3 mg/L of Manganese established by the MECDC. See Notation 1 and Notation 3.								
Sodium Total	⚠	160		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:47	0.005
A 1/5 dilution was performed in order to bring the concentration of Sodium Total into the calibration range. The reporting limit has been adjusted accordingly.								
*This sample is at or above the MEG of 20 mg/L of Sodium established by the MECDC. Sodium is not listed as a primary nor secondary contaminant of concern by the USEPA. See Notation 1.								
Hardness by calculation		390		mg/L	SM 2340B	12/1/2021 / 17:00	12/2/2021 / 11:47	10
A 1/5 dilution was performed in order to bring the concentration of Hardness by calculation into the calibration range. The reporting limit has been adjusted accordingly.								
Calcium, Total		111		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:47	5.000
A 1/5 dilution was performed in order to bring the concentration of Calcium, Total into the calibration range. The reporting limit has been adjusted accordingly.								
Magnesium, Total		26.6		mg/L	EPA 200.8	12/1/2021 / 17:00	12/2/2021 / 11:17	1.000

Certificate of Analysis

pH Electrometric	✓	6.61	6.5 to 8.5	stu@25C	EPA 150.1		12/1/2021 / 16:18	2.0
Total Coliform Colilert18	✓	<1		MPN/100mL	SM9223B	12/1/2021 / 16:42	12/2/2021/ 10:42	1
E.Coli - Colilert Enumeration	✓	<1	1	MPN/100mL	SM9223B	12/1/2021 / 16:42	12/2/2021/ 10:42	1

Comments:

✓ For the above tests only, this water meets acceptable EPA Limits.

All samples analyzed for Nitrate-N and/or Nitrite-N samples must be thermally preserved to 4±2°C. However, the Maine CDC Drinking Water Program will accept non-thermally preserved test results.

The following Notations may be referenced above.

Notation 1: The Maximum Exposure Guideline (MEG) is a health-based guideline set by the Maine Center for Disease Control and Prevention (MECDC). MEGs are recommendations for concentrations of chemical contaminants for all drinking water systems below which there is minimal risk of a harmful health effect resulting from long-term ingestion of contaminated water. These recommendations can be found online at <http://www.maine.gov/dhhs/mecdc/environmental-health/eohp/wells/documents/megtable2016.pdf>. Please contact one of the State of Maine's Bureau of Health Toxicologists, toll free, at 1-866-292-3474 for more information.

Notation 2: The Maximum Contamination Level (MCL) is set by the United States Environmental Protection Agency (USEPA) through the National Primary Drinking Water Regulations and are legally enforceable drinking water standards that apply to all public water systems. These regulations can be found online at <http://water.epa.gov/drink/contaminants/index.cfm> or by calling the Safe Drinking Water Hotline at 1-800-426-4791. Contaminants at or above the MCL are considered to impart potential negative health effects.

Notation 3: The Secondary Maximum Contamination Level (SMCL) is set by the United States Environmental Protection Agency (USEPA) through the National Secondary Drinking Water Regulations and these contaminants are not considered to present a risk to human health at the SMCL. These regulations can be found online at <http://water.epa.gov/drink/contaminants/secondarystandards.cfm> or by calling the Safe Drinking Water Hotline at 1-800-426-4791. Contaminants at or above (or below, only for pH) the SMCL may cause aesthetic considerations, such as taste, color and/or odor.

Notation 4: According to the EPA revised total coliform rule (effective April 1st, 2016) total coliform bacteria are no longer considered a primary contaminant. Total coliform bacteria are still used as indicator organisms for the presence of pathogens. Their presence in drinking water may indicate there is a route for pathogens (certain bacteria, viruses or protozoa) to enter the drinking water. Even though there is no longer an EPA limit, the presence of total coliform bacteria in drinking water is a problem requiring further action and investigation. If your water has tested positive for total coliform bacteria it is important to examine your water system and take action to eliminate the total coliform bacteria when possible. Please see the well disinfection procedure for more information @ <http://www.nelabservices.com/pdf/Well-Disinfection-Instructions.pdf>.

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Authorized By
Megan Bushover, Laboratory Technical Director

12/2/2021
Review Date

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Stantec

Memo

To:	MaineDOT	From:	Michael Chelminski. P.E. Gordon E. Clark
File:	179450347	Date:	September 16, 2021

Reference: Phase 1 Hydraulic Analysis for Machias Dyke Bridge (#2246) Planning Phase Support Services

This memo was prepared by Stantec Consulting Services Inc. (Stantec) under contract to the Maine Department of Transportation (MaineDOT) for Planning Phase Support Services as part of the Dyke Bridge Replacement Project (Project) located on the Middle River in Machias, Maine. MaineDOT is pursuing replacement of the existing infrastructure at Dyke Bridge due to its poor condition with the objectives to provide adequate drainage from upland floods without overtopping the Route 1 roadway, provide adequate freeboard during tidal flood events, and accommodate fish passage to the extent practicable.

As part of this scope of services for the Project, Stantec performed a hydraulic analysis (Hydraulic Study) to assess hydraulic conditions associated with the primary replacement alternatives for the Dyke Bridge culvert. This memo documents the methodology and results of the hydraulic modeling for the primary replacement alternatives as part of the Hydraulic Study in support of the ongoing planning phase of the Project (2020-2021 Planning Study).

Appendix A contains the unsteady-state stage hydrograph simulation results from the hydraulic model. Appendix B contains a figure that depicts mapped water surface elevations[1] (WSELs) along the Middle River upstream (landward) from Dyke Bridge for the primary alternatives.

This memo includes revisions to Alternative 10 (single-span bridge alternative) relative to previous versions of this memo and references apparent changes in the normal tidal WSELs in the Middle River upstream from Dyke Bridge. Changes to Alternative 10 include 1) increasing the span of the bridge from 100 feet (ft) to 120 ft, 2) changes to the spill-through abutment geometries, and 3) raising the bottom of channel elevation under the bridge. Observations during Project studies in 2021 identified that the normal tidal WSELs in the Middle River landward from Dyke Bridge may have risen relative to information obtained by MaineDOT in 2011. In August 2021, MaineDOT installed equipment to collect additional tidal stage data in the Middle River upstream from Dyke Bridge and in the Machias River downstream (seaward) from the bridge.

BACKGROUND

Dyke Bridge (#2246) caries Route 1 over the Middle River in the Town of Machias. Route 1 is a highway corridor priority 2, has an estimated daily traffic volume of 9,250 vehicles per day, and is functionally classified as a minor arterial roadway. The existing structure at Dyke Bridge is a four-cell, timber culvert supported by timber cribbing with rubble and earthen fill. A buried concrete slab that was previously installed as a remedial repair is located over the culvert. The four box culverts are approximately 130 ft long, 6 ft wide, and 5.5 ft high, and have top-hinged flap-gates installed on the seaward side of each of the four culverts. The culvert array is skewed 90 degrees to the roadway that carries two-way vehicular traffic via two 12 foot (ft) +/- lanes with 8 ft +/- shoulders on a bituminous wearing surface. Dyke Bridge needs improvement due to large spalls, heavy scaling, wide cracks, loss of and rotted timber members, and the need for urgent and unscheduled

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[1] Elevations are referenced to the North American Vertical Datum of 1988 (NAVD88).

repairs. The primary purpose and need for the Project are addressing the structure’s condition and the safety of the traveling public along with preserving the adjacent Calais Branch Rail Corridor.

While the existing structure restricts tidal flow, the culvert is adequate to drain upland floods without overtopping the bridge or the adjacent approach embankments. There is no apparent flood history associated with the conveyance of the existing culvert or a need to increase the hydraulic opening. However, freeboard may be inadequate to prevent overtopping of the roadway during the 100-year tidal flood event. The proposed structure configuration and opening are being driven by the need to improve the upstream fish passage while mitigating potential landward flooding during the normal daily riverine and tidal conditions. Sea level rise accommodation involves consideration of the Maine Climate Council guidance and coordination with the adjacent Town of Machias sea wall project, which may involve a phased approach. These elements represent some of the secondary purpose and needs for the Project.

Previous work for the Project has included a 2015 tidal hydraulic and alternatives analyses study prepared by Stantec for MaineDOT (2015 Study), which then progressed to a 2019 preliminary design effort by Stantec for MaineDOT that included additional hydraulic analysis of selected potential replacement alternatives (2019 PDR Study). Due to regulatory agency concerns regarding fish passage, including Atlantic salmon (*Salmo salar*) that are listed under the Endangered Species Act and associated regulatory agency opposition to a replacement-in-kind alternative, competing concerns for landward flooding impacts on historic property, and adjacent sea level rise mitigation and boat launch projects by the Town of Machias, MaineDOT decided to transition the Project back to MaineDOT Planning as the 2020-2021 Planning Study.

The proposed hydraulic studies for this phase of the Project are focused on evaluating a set of potential alternatives relative to regulatory agency request for improved upstream fish passage and potential analysis and channel design needs for replacement of the existing culverts with a bridge structure. The 2015 Study and 2019 PDR Study used varying approaches for modeling of the existing and proposed conditions using the then current version of the U.S. Army Corps of Engineers Hydrologic Engineering Center River Analysis System (HEC-RAS) software (e.g., HEC-RAS v5.0.0 to HEC-RAS v5.0.5). Modeling of the existing culverts with flap-gates for the 2015 Study required use of atypical methods (i.e., HEC-RAS “Rules”). The current version of HEC-RAS (i.e., HEC-RAS v5.0.7) includes integrated “tide-gate” routines for culverts. Therefore, it was proposed that for the Project the hydraulic models would use the most current non-beta version of HEC-RAS. This approach allows for better comparison and standardization of the evaluated alternatives relative to existing conditions.

The Project Hydraulic Study includes a two-phased hydraulic analysis approach. The first phase of the Hydraulic Study generally includes:

1. Unsteady-state modeling of conditions with normal tide data as represented by tidal stage data collected by MaineDOT in 2011 with the 50th percentile (median) flow in the Middle River; and
2. Steady-state modeling of the 100-year peak flow in the Middle River with mean high water (MHW) and mean low water (MLW) downstream boundary conditions.

Item (1) above is intended to reflect typical conditions and be suitable for evaluation of upstream (landward) fish passage at Dyke Bridge and identification of land that would be regularly inundated along the Middle River landward from Dyke Bridge. Item (2) above is intended as a check on the peak WSELs as represented by the Federal Emergency Management Agency (FEMA) Base Flood Elevation (BFE). In addition, the first phase of the Hydraulic Study includes unsteady-state flow analysis of a 1.1- and 10-year riverine flow condition for the bridge replacement alternative only (Alternative 10). This memo documents the **first phase** of the Hydraulic Study as part of the Project.

For the first phase of the Hydraulic Study, a group of primary alternatives was selected to assess 1) potential improvements to upstream fish passage at Dyke Bridge and 2) changes in normal tidal WSELs landward from Dyke Bridge. The hydraulic analyses evaluated the potential for improved fish passage and impacts to land adjacent to the landward impoundment along the Middle River under normal tidal conditions and typical riverine flows. Data obtained from the first phase of the Hydraulic Study will help determine and inform the duration of advective landward fish passage relative to existing conditions and areas of land that would be inundated if normal tidal exchange results in higher typical WSELs.

The hydraulic analyses in the first phase of the Hydraulic Study includes 1) existing conditions and 2) five primary alternatives. The five primary alternatives were identified as representative of the range of potential alternatives that were previously identified in early Project phases. Stantec developed the 2020-2021 Alternatives Matrix (Matrix), which provides a comprehensive overview of replacement alternatives for the Project. This matrix is not included in this document but is referenced in this memo. The existing conditions and primary alternatives are summarized below.

1. Existing Conditions: The primary objective for revising the past modeling for this alternative is to provide opportunity for calibration of the HEC-RAS model using the newly available integrated "tide gate" routines. Existing conditions is included in the hydraulic analysis effort for calibration and relative comparison of the evaluated alternatives.

2. Replacement in Kind (Alternative 1 in the Matrix): This alternative is based on replacement of the existing culvert system with four 5 ft by 5 ft box culverts with flap-gates that prevent landward ("upstream") flow. This alternative was modeled as part of the Middle River Hydrologic and Alternatives Analysis (2015 Study and 2019 PDR Study). This alternative is being evaluated as the baseline alternative at Dyke Bridge for comparison with the other evaluated alternatives. MaineDOT proposed this as the recommended alternative in 2019, but Stantec understands that it is no longer considered to be a viable recommended alternative because it does not provide opportunities for upstream fish passage based on the assumption that new, non-leaking flap-gates would be installed as part of this alternative. Note that Alternative 6 in the Matrix (slip-lining of the four existing culverts with new flap gates and installation of two culverts with flap-gates to maintain the existing conveyance capacity) would be designed to have similar hydraulic performance (e.g., design flow capacity) to this replacement in kind alternative and it is therefore expected that information obtained from hydraulic analysis of Alternative 1 would inform the general performance of Alternative 6 identified in the Matrix.

3. Alternative 4 in the Matrix: This alternative includes replacement with five box culverts with dimensions that are similar to the existing culverts (e.g., 5 ft by 5 ft) with flap-gates on four of the culverts and unrestricted, bidirectional flow in the fifth culvert. The objective of having a culvert without a flap-gate is to allow some landward flow and associated opportunities for upstream fish passage. Upstream fish passage would be provided by advection (i.e., fish would move with landward flow during the flood tide). This alternative assumes that the culvert inverts are at a common elevation but that this elevation may be below the invert of the existing culverts. The objective of modeling this alternative for the Hydraulic Study is to provide a consistent baseline for comparison with the other evaluated alternatives. This alternative is hydraulicly similar to Alternatives 2 to 4 and the initial culvert phase of Alternative 8 in the Matrix.

4. Alternative 4 in the Matrix with Modifications: This alternative was not in the 2020 Alternatives Matrix but includes replacement with three box culverts with large internal dimensions to address minimum fish passage dimensions for addressing expressed regulatory agency concerns. This alternative includes three 10 ft by 10 ft culverts with flap-gates on two of the culverts and unrestricted, bidirectional flow in the third culvert. The objective of having a culvert without a flap-gate is to allow some landward flow and associated opportunities for upstream fish passage. Upstream fish passage would be provided by advection (i.e., fish would move with landward flow during the flood tide). This alternative assumes that the culvert inverts are at elevation -6.05 ft (2 ft below the existing culvert outlet inverts). This alternative has been further refined as noted in the hydraulic modeling section (Methodology/Geometry Data section of this memo) below and has been added to the refined Matrix.

5. Alternative 9 in the Matrix: This alternative includes replacement of the existing culvert system with four 5 ft by 5 ft box culverts without flap-gates to provide unrestricted landward flow through the culverts. Hydraulic analysis of this alternative is intended to provide information on impacts associated with an ungated culvert system. Note that the hydraulic conveyance capacity of this alternative is similar to that of Alternative 7 in the Matrix (slip-lining of the four existing culverts and installation of two without flap-gates to maintain the existing conveyance capacity). It is therefore expected that information obtained from hydraulic analysis of Alternative 9 would inform the general performance of Alternative 7 in the Matrix. This alternative is also hydraulically similar to an alternative that included the use of fewer larger culverts (e.g., two 10 ft by 5 ft box culverts).

6. Alternative 10 in the Matrix: This alternative includes replacement of the existing culvert system with a bridge with a span of 75 ft to 125 ft. Information obtained from hydraulic model analysis of this alternative would be used along with other information to quantitatively identify potential scour in the landward embayment due to substantial restoration of tidal exchange. This would also provide a scour baseline to qualitatively assess scour potential for the other larger bridge alternatives. This alternative would substantially provide volitional fish passage and could be used as a comparison relative to the other evaluated alternatives, including evaluating whether seaward flows during the ebb tide may be too high for some target fish species (e.g., rainbow smelt) to migrate upstream through the bridge under normal tidal conditions. From a hydraulic perspective, this alternative is intended to be representative of Alternatives 10 to 12 and their variations, as well as the future bridge phase of Alternative 8, as presented in the Matrix. It will provide a baseline indication of how much additional landward flooding will occur under normal daily conditions with a bridge option, as the other bridge options would only be worse on this metric.

METHODOLOGY

Hydraulic modeling simulations of existing conditions and the primary alternatives were performed by modifying the numerical, hydraulic model that Stantec developed previously for this Project as described in the 2015 Study and 2019 PDR Study. As previously noted, the first phase of the Hydraulic Study included evaluations with steady- and unsteady-state flow regimes. The following sections document the development of the hydraulic model, including the geometric data, boundary conditions, flow regimes, and model scenarios.

HYDRAULIC MODEL

A one-dimensional, steady- and unsteady-state numerical hydraulic model (Model) was developed using HEC-RAS (v. 5.0.7) as part of the Hydraulic Study. The 2015 Study and 2019 PDR Study used earlier versions of HEC-RAS; however, the analyses reported in this memo used the current, non-beta version of HEC-RAS, which includes integration of automated flap-gate routines on culvert structures.

One shortcoming of the integrated flap-gate routines is the inability to assign individual culverts flap-gates within a group of culverts in an inline structure. The flap-gate routines can either be assigned to none of the culverts or all the culverts. Several of the primary alternatives evaluated as part of the Study include bidirectional flow (i.e., no flap-gate(s)) on one or more culvert barrels with flap-gates on the remaining culvert barrels. To apply the flap-gate routines in the Model, a “dummy reach” was developed that represented a cloned parallel reach that extends approximately 500 ft upstream and 200 ft downstream of Dyke Bridge. Additional details related to this geometry modification are documented in the Geometry Section below.

GEOMETRY DATA

Geometric data for the Model was developed using topographic data provided by MaineDOT along with a limited number of bathymetric transects surveyed by MaineDOT. Minor modifications to these transects were incorporated in the Model to increase the numerical stability during unsteady-state simulations of low-flow conditions. A “dummy-reach” (Dummy Reach) was inserted to connect upstream and downstream of Dyke Bridge (bifurcated geometry). This created two parallel reaches, which provided the ability to model the bidirectional flow culverts while still using the integrated culvert flap-gate routines. See Figure 1 for a schematic overview of the Model geometry with the parallel reaches at Dyke Bridge. Note that the flap-gate routines in HEC-RAS are based on relative WSEL differences upstream and downstream of the culvert and do not account for other factors (e.g., the weight of the water column at the location of a submerged flap gate).

The cross-sectional geometry in the parallel reaches were cloned and are identical between the two parallel reaches. Blocked obstructions were defined between corresponding similar cross-sections in the cloned parallel reaches to be symmetrical, which allowed for maintaining similar hydraulic storage during unsteady-state simulation. For example, the cross-sectional flow storage between cross-sections at Station (Sta.) 601 and 621 in the Dummy Reach (Parallel Reach 1) and Middle Reach 2 (Parallel Reach 2) is approximately equal to the cross-sectional flow storage between these stations in a single thread channel model used as part of the 2015 Study and the 2019 PDR Study. Alternative 10 evaluated as part of the first phase of the Hydraulic Study is a single thread channel model and is therefore similar to the single thread channel model used as part of the 2015 Study and the 2019 PDR Study (see the description in the Alternative 10 Section below).

The following sections document the geometric data for the Model, representing a total of six different geometries that correspond to the existing condition geometry and the five primary alternative geometries. For information related to the development of the geometric data for the Model used in the rest of the domain, refer to Section 3.0 of the Stantec 2015 Report.

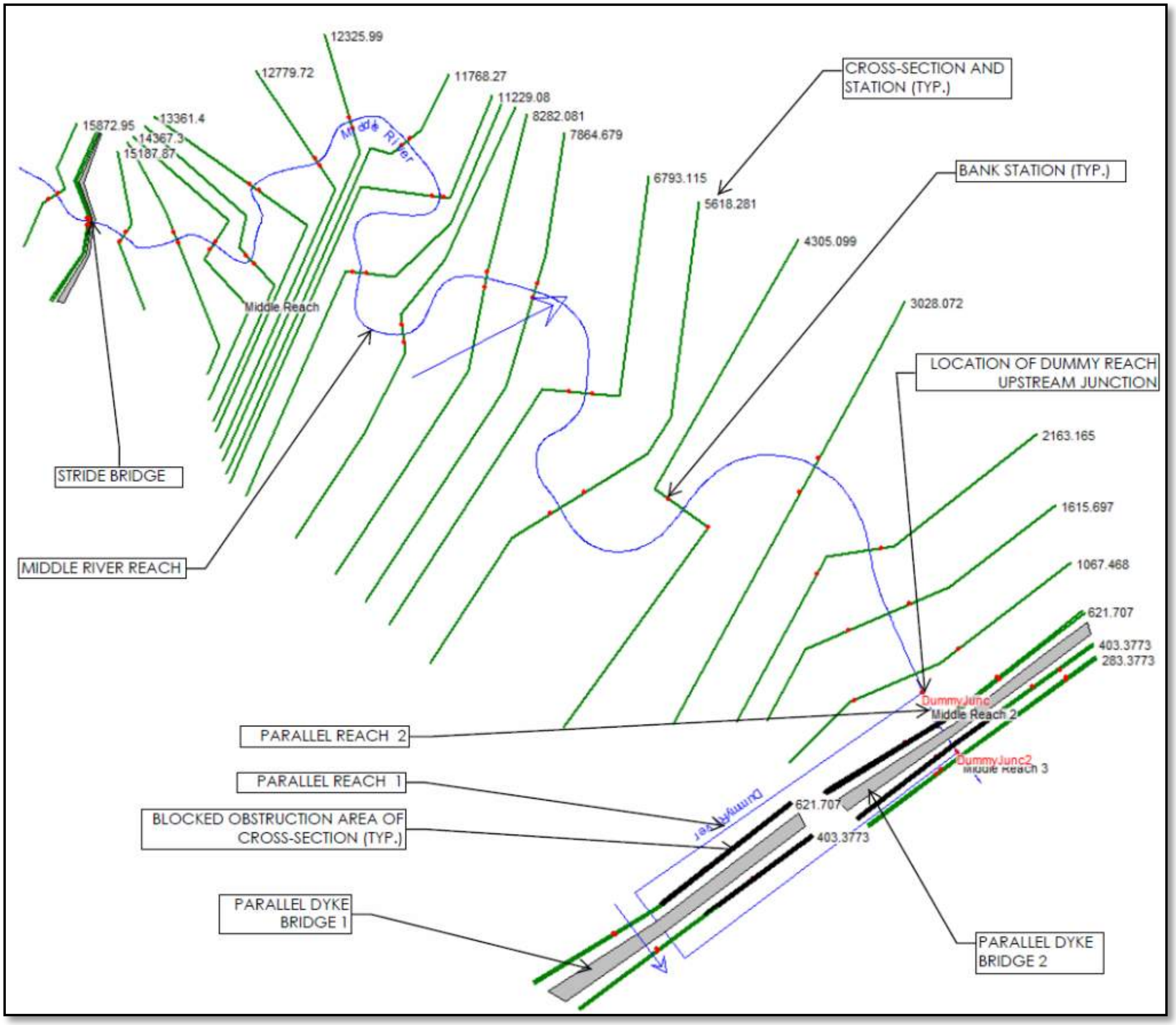

Figure 1. Overview of the general geometric schematic of the Model with the parallel reaches parametrized

Existing

The existing conditions geometry (“ex”[2]) is based on the bifurcated geometry approach that includes the cloned reach. The bifurcated geometry approach was used primarily to facilitate model calibration and for consistency of approaches across the Model simulations, since the primary alternatives also were based on the bifurcated geometry approach. The roadway embankment is modeled as two inline structures, one on each parallel reach, with one box culvert fitted with a flap-gate on Parallel Reach 1 and three box culverts fitted with flap-gates on Parallel Reach 2. The four box culverts have top-hinged flap-gates installed on the seaward side of each of the four culverts. The existing culverts and flap-gates are deteriorated, which results in partial blockage of the culverts and leakage. The integrated flap-gate routines in HEC-RAS do not allow for leakage. To accommodate leakage, a 0.35 ft high by 12 ft wide opening with the invert at -4.1 ft was used in the Model with no flap-gate for the duration of the simulation. The geometry of this “leakage opening” was determined based on an iterative calibration process comparing the simulation data to the observed data.

The existing conditions culverts were modeled with heights of 4 ft and widths of 5 ft, with the inverts of the culverts at elevation -3.1 ft. Culvert invert selection was based on review of survey data provided by MaineDOT, including elevations of the culvert inverts. The reduced culvert heights and invert elevations were used to address apparent blockages in the bottoms of the culverts (e.g., stone, debris) as determined from bridge inspection reports provided by MaineDOT and result in the Model’s culvert inverts being approximately one foot higher than the average surveyed invert elevations of -4.05 ft. The existing culverts were modeled as 130 ft long with an entrance loss coefficient of 0.5 and an exit loss coefficient of 1. Manning’s n values in the culvert were set at 0.018 to represent some of the debris and additional roughness within the culverts due to their existing condition. The culverts were modeled using the FHWA Chart #16 (corrugated metal box culvert) and Scale #1 (90 degree headwall), which was determined to be most representative of existing conditions.

Alternative 1

The Alternative 1 (replacement-in-kind) geometry (“alt01”) is based on the bifurcated geometry approach. The roadway embankment is modeled as two inline structures, one on each parallel reach, with one box culvert fitted with a flap-gate on Parallel Reach 1 and three box culverts fitted with flap-gates on Parallel Reach 2. Alternative 1 culverts were modeled with heights of 5 ft and widths of 5 ft, with the inverts of the culverts at elevation -4.05 ft. The Manning’s n for the culverts were assumed to be the same for the top and bottom at 0.012. A 130 ft culvert length was used with an entrance loss coefficient of 0.5 and an exit loss coefficient of 1. The culverts were modeled using the FHWA Chart #10 Scale #1 approach corresponding to 90 degree headwall with inlet edges chamfered three-quarters of an inch.

Alternative 4

The Alternative 4 geometry (“alt04”) is based on the bifurcated geometry approach. The roadway embankment is modeled as two inline structures, one on each parallel reach, with one box culvert (no flap-gates) on Parallel Reach 1 and four box culverts fitted with flap-gates on Parallel Reach 2. Alternative 4 culverts, both with and without flap-gates, were modeled with heights of 5 ft and widths of 5 ft, with the inverts of the culverts at elevation -6.05 ft. The Manning’s n for the culverts were assumed to be the same for the top and bottom at 0.012. A 130 ft culvert length was used with an entrance loss coefficient of 0.5 and an exit loss

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[2] Abbreviations in quotes are provided for clarity as they are combined in the HEC-RAS Plan file names that are depicted on graphics in this memo.

coefficient of 1. The culverts were modeled using the FHWA Chart #10 Scale #1 approach corresponding to 90 degree headwall with inlet edges chamfered three-quarters of an inch.

Alternative 4 Modified

The Alternative 4 modified geometry (“alt04m”) is based on the bifurcated geometry approach. The roadway embankment is modeled as two inline structures, one on each parallel reach, with one box culvert (no flap-gates) on Parallel Reach 1 and two box culverts fitted with flap-gates on Parallel Reach 2. The Alternative 4 Modified culvert on Parallel Reach 1 was modeled with a height of 5 ft, width of 10 ft, and the invert of the culvert at elevation -6.05 ft. Alternative 4 Modified culverts on Parallel Reach 2 were modeled with heights of 5 ft, widths of 10 ft, and the inverts at -4.05 ft. Note that this is a refinement from the culvert geometry indicated earlier in this memo (Background Section). Based on preliminary analysis results and discussion with MaineDOT on March 29, 2021, it was decided that the box culvert heights should be reduced from 10 ft to 5 ft to better match the overall opening to hydraulic conveyance needs (i.e., reduce landward flows during flood tides) and reduce landward water surface levels. The open culvert invert was lowered with the intent of further improving fish passage for a wider range of tidal flows and the 10ft width was maintained to address fish injury concerns. The Manning’s n for the culverts were assumed to be the same for the top and bottom at 0.012. A 130 ft culvert length was used with an entrance loss coefficient of 0.5 and an exit loss coefficient of 1. The culverts were modeled using the FHWA Chart #10 Scale #1 approach corresponding to 90 degree headwall with inlet edges chamfered three-quarters of an inch.

Alternative 9

The Alternative 9 geometry (“alt09”) is based on the bifurcated geometry approach. The roadway embankment is modeled as two inline structures, one on each parallel reach, with two box culverts on Parallel Reach 1 and two box culverts on Parallel Reach 2. The four culverts were modeled without flap-gates, heights of 5 ft, widths of 5 ft, and the inverts at -4.05 ft. The Manning’s n for the culverts were assigned as 0.012 for the top and bottom at. A 130 ft culvert length was used with an entrance loss coefficient of 0.5 and an exit loss coefficient of 1. The culverts were modeled using the FHWA Chart #10 Scale #1 approach corresponding to 90 degree headwall with inlet edges chamfered three-quarters of an inch.

Alternative 10

The Alternative 10 geometry (“alt10m2_20210812”) is the only geometry in the first phase of the Hydraulic Study that uses a single thread channel instead of the bifurcated geometry approach. The roadway embankment is modeled as a bridge structure with a deck/roadway. The Alternative 10 bridge was modeled with bridge span of 120 ft and a clear span of 116.5 ft and a low-chord elevation of 13.1 ft. Sloping, spill-through type abutments were defined at slopes of 1.75 horizontal to 1 vertical (1.75H:1V) and 2-ft-wide benches at elevations of 10.42 ft to provide access along each abutment adjacent to both bridge abutments. The channel elevation was set at -8.5 ft. The preliminary bridge low-chord elevation was selected to match the Town of Machias’ Phase 1 sea level rise protection plans to be above the highest astronomical tide (HAT) elevation of 9.8 ft and the FEMA BFE of 10.7 ft plus a freeboard allowance for at least 1.5 ft of sea level rise. This results in a roadway grade raise of approximately 7 ft in the bridge area. Modeling of this alternative included changes to some of the HEC-RAS cross sections in the Middle River upstream (landward) from Dyke Bridge to have a lower and more defined channel. These geometric changes were made to improve the numerical stability of the unsteady-state HEC-RAS model and reflect expected erosion of sediment in the Middle River if a bridge were installed at Dyke Bridge. The bridge was modeled using the Energy (Standard

Step) approach in the bridge routines. Ineffective areas were defined within the upstream and downstream cross-sections adjacent to the bridge at an approximately one-to-one aspect ratio.

BOUNDARY CONDITIONS

Boundary conditions for the Model included both steady- and unsteady-state regimes, which are documented in the following sections.

Steady-State Boundary Conditions

The upstream[3] boundary conditions for steady-state simulations included the 100-year peak flow. Peak flows were calculated and provided by MaineDOT and are referenced in the Stantec 2015 Study. Peak flows for steady-state boundary conditions at Dyke Bridge and Stride Bridge[4] used in the Model are presented in Table 1. The steady-state upstream flows were input to the Model at locations landward of Stride Bridge and Dyke Bridge. Under steady-state conditions, these upstream, inland flows are simulated as a constant flow value (e.g., not a hydrograph) with no attenuation due to potential storage in the Model domain.

Table 1. Drainage areas and peak upland flows for upstream steady-state boundary conditions at Dyke Bridge and Stride Bridge

Location	Drainage Area (sq. mi.)	100-Year Return-Interval Event Peak Flow (cfs)
		100
Stride Bridge	9.41	912
Dyke Bridge	13.22	958

Note that the use of the bifurcated geometry approach resulted in the need to split flow between the two parallel reaches just upstream of Dyke Bridge. The initial conditions flows at the upstream junction were divided equally in half for the steady-state modeling and then recombined at the junction downstream of Dyke Bridge. Flow splits at the Model junctions were then calculated by the HEC-RAS model.

The downstream boundary conditions for the steady-state flow simulations were set at the downstream (seaward) limit of the Model assuming constant values of 6.1 ft for MHW and -6.6 ft for MLW. The MHW and MLW tidal values were based on predicted tides at the Machiasport tide station (National Oceanic and Atmospheric Administration [NOAA] Station # 8411467) as described in the 2015 Study. Predicted tides at this station are based on the Eastport, Maine recording tide gage, adjusted for height (multiply by 0.61) and time (add 1 minute for high, subtract 9 minutes for low). Table 2 presents tidal statistics developed from data collected by MaineDOT in the Machias River seaward from Dyke Bridge in 2011 and provides a comparison to the values predicted at the Machiasport tide station (see Section 2.3.2 in the 2015 Study to reference how these tidal statistics were developed). In addition, Table 3 presents tidal statistics from other adjacent NOAA

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[3] "Upstream" and "downstream" are used in this report to describe the HEC-RAS model boundary conditions for consistency with boundary condition references in the HEC-RAS documentation. For reference, upstream generally refers to the landward direction and downstream generally refers to seaward direction.
[4] Stride Bridge is located landward from Dyke Bridge and is included in the project HEC-RAS model that was developed for a previous study of Dyke Bridge. Alternatives at Stride Bridge were not evaluated as part of the Hydraulic Study.

tide stations at Eastport, Cutler Naval Base (Cutler), and Bar Harbor (Machias is located between Cutler and Bar Harbor along the coastline). Reference tidal datums for the Machias River seaward from Dyke Bridge based on the Machiasport tide station and NAVD88 are summarized in Table 4.

Table 2. Tidal Statistics from 2011 MaineDOT Data Set (see the 2015 Study for details).

Tidal Data (ft, NAVD88)						
Max.	**MHHW**[a]	**MHW**[b]	**Average**	**MLW**[c]	**MLLW**[d]	**Min.**
9.8	7.4	6.5	0.05	-6.4	-6.8	-7.5

Table 3. Tidal Statistics from NOAA Stations

Station	Tidal Statistics (Elevation in ft)						
	MHHW	**MHW**	**NAVD88**	**MTL**	**MSL**	**MLW**	**MLLW**
Eastport	9.34	8.86	0	-0.31	-0.23	-9.49	-9.93
Cutler	6.81	6.39	N/A	0.1	0.0	-6.37	-6.75
Bar Harbor	5.7	5.28	N/A	-0.1	0.0	-5.29	-5.67

Table 4. Tidal Statistics Predicted at Machiasport NOAA Subordinate Station

Station	Tidal Statistics (Elevations reference to ft NAVD88)						
	MHHW	**MHW**	**NAVD88**	**MTL**	**MSL**	**MLW**	**MLLW**
Machiasport	6.45	6.11	0.0	-0.21	-0.16	-6.55	-6.85

[a] "Mean Higher High Water"
[b] "Mean High Water"
[c] "Mean Low Water"
[d] "Mean Lower Low Water"

Unsteady-State Boundary Conditions

The upstream boundary conditions for the unsteady-state simulations included peak flow values for the annual median flow (50% flow duration annual exceedance), 1-year peak flow (note the 1.1-year or the peak flow with an annual exceedance of 0.91 [91%] was used as representative of the 1-year peak flow), and the 10-year peak flow (i.e., annual exceedance probability of 0.1 [10%]). Upstream boundary conditions are summarized in Table 5 below.

Table 5. Peak upland flows for upstream unsteady-state boundary conditions

Location	Return-Interval Event (Years) / Peak Flow (cfs)		
	50% Median Flow	**1.1**	**10**
Upstream Model Boundary	13.7	152	565

Note that while the annual median flow upstream inflow unsteady-state boundary condition was used across all of the alternatives, only Alternative 10 was modeled with the 1.1- and 10-year peak flows during the first phase of the Hydraulic Study and as documented in this report. Reporting on these flows for a reduced list of preferred alternatives will be included in the second phase of the Hydraulic Study.

Downstream boundary conditions used in the unsteady-state simulations was a normal tidal stage hydrograph based on a selected set of MaineDOT recorded data used as “normal tide” boundary conditions. MaineDOT collected tidal stage data at the Project site from mid-July to later October 2011 that were used as the downstream boundary condition representing typical tidal conditions. The tidal stage data were collected at two locations using datalogging pressure transducers that recorded pressure at 5-minute intervals at locations landward and seaward from Dyke Bridge in the Middle River and Machias River, respectively, and post-processed by MaineDOT to develop tidal stage and elevation data. A subset of these data (July 12 to August 17, 2011) was selected for the first phase of the Hydraulic Study that represents a range of tide levels typical of this location with high-tide elevations ranging from 4.5 to 9.0 ft and low-tide elevations ranging from -4.7 to -7.2 ft. The data subset of the seaward datalogger tide values were used for the downstream boundary condition of the unsteady-state flow model as representing typical, normal tides. For additional detail on this tidal dataset, refer to the Stantec 2015 Study.

CALIBRATION

Tidal stage data collected landward and seaward from Dyke Bridge provided an opportunity for calibration of the Model. The bidirectional “leakage gate” included allows for landward flow during flood tides, which is apparent in visual observations and tidal stage data collected by MaineDOT in the Middle River landward from Dyke Bridge. Coefficients and gate sizes within the inline gate editor in HEC-RAS were modified until a satisfactory calibration was achieved that accounted for leakage based on visual comparison of observed and simulated upstream WSELs. Leakage is accounted for in the existing conditions geometry through use of a gate opening with a height of 0.35 ft, a width of 12 ft, and an invert at -4.1 ft.

Figure 2 presents the simulation results of the final calibrated existing conditions model compared to the observed landward data. Stantec reviewed U.S. Geological Survey (USGS) stream gages in the vicinity of the Project area and identified that higher WSELs in the observed upstream stage hydrographs in Figure 2 appear to coincide with peaks in WSELs at the USGS gages. Stantec expects that these peaks are the result of precipitation and subsequent runoff and higher flows that are not reflected in the Model upstream boundary conditions for the unsteady-state simulations.

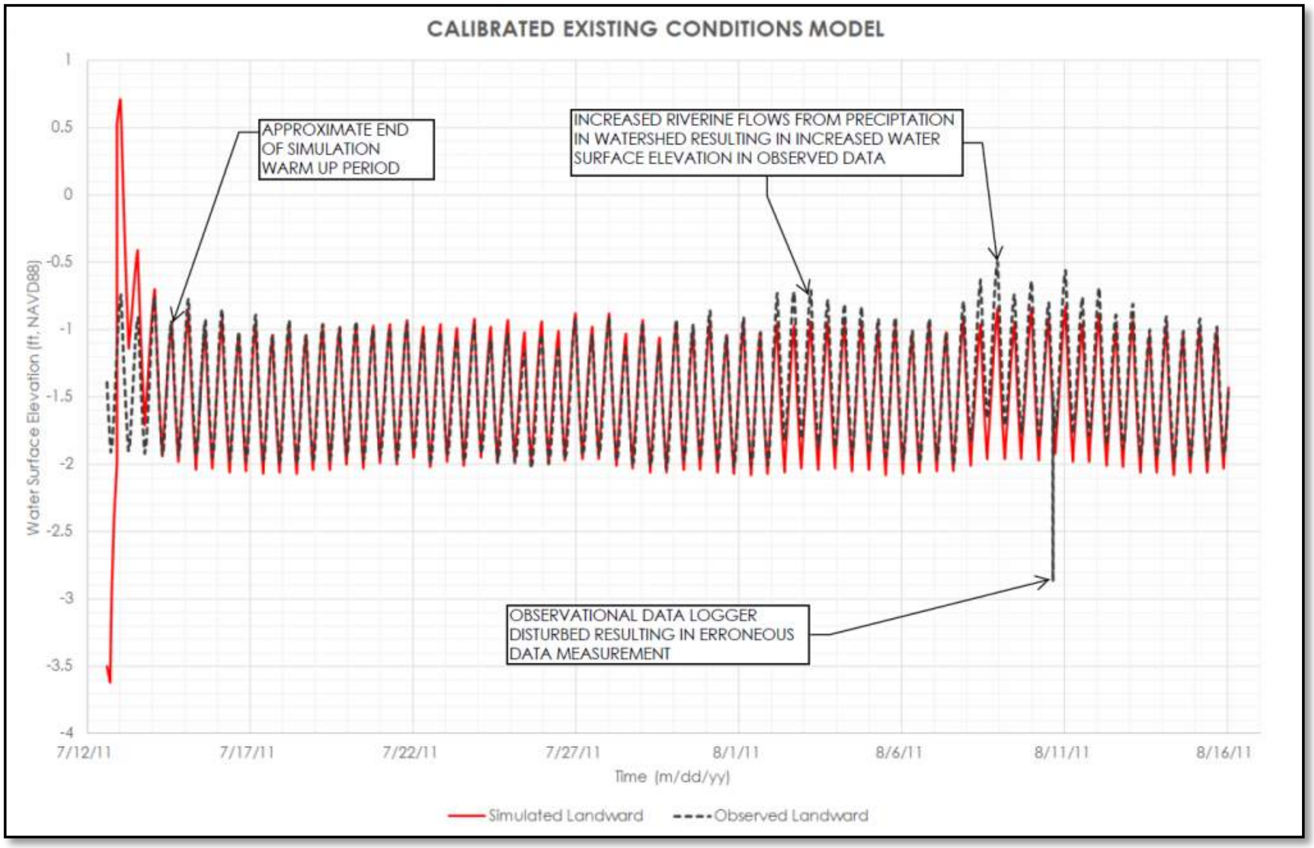

Figure 2. Final calibrated existing conditions simulation results compared to observed data

MODEL SCENARIOS

Model efforts as part of the first phase of the Hydraulic Study included 20 independent simulations (model scenarios) that consisted of unique geometries and boundary conditions combined together in HEC-RAS Plan files. These simulations included 12 steady-state and 8 unsteady-state scenarios. Table 6 presents a summary of the model scenarios used as part of the first phase of the Study and presented in this report including the plan name, geometry name, flow name, and HEC-RAS file names.

Table 6. Summary of unique model scenarios performed as part the first phase of the Study

Simulation No.	ScenarioID	Plan Name	Plan File	Geometry Name	Geometry File	Flow Name	Flow File
1	ex_ss_q100_mlw	ex_ss_mlw	2021_machias_phs1.p01	ex	2021_machias_phs1.g01	ss_mlw	2021_machias_phs1.f01
2	ex_ss_q100_mhw	ex_ss_mhw	2021_machias_phs1.p02	ex	2021_machias_phs1.g01	ss_mhw	2021_machias_phs1.f02
3	ex_us_fd50per_normtide	ex_us_fd50per_normtide	2021_machias_phs1.p03	ex	2021_machias_phs1.g01	us_fd50per_normtide	2021_machias_phs1.u01
4	alt01_ss_q100_mlw	alt01_ss_mlw	2021_machias_phs1.p04	alt01	2021_machias_phs1.g02	ss_mlw	2021_machias_phs1.f01
5	alt01_ss_q100_mhw	alt01_ss_mhw	2021_machias_phs1.p05	alt01	2021_machias_phs1.g02	ss_mhw	2021_machias_phs1.f02
6	alt01_us_fd50per_normtide	alt01_us_fd50per_normtide	2021_machias_phs1.p06	alt01	2021_machias_phs1.g02	us_fd50per_normtide	2021_machias_phs1.u01
7	alt04_ss_q100_mlw	alt04_ss_mhw	2021_machias_phs1.p07	alt04	2021_machias_phs1.g03	ss_mhw	2021_machias_phs1.f01
8	alt04_ss_q100_mhw	alt04_ss_mhw	2021_machias_phs1.p08	alt04	2021_machias_phs1.g03	ss_mhw	2021_machias_phs1.f02
9	alt04_us_fd50per_normtide	alt04_us_fd50per_normtide	2021_machias_phs1.p09	alt04	2021_machias_phs1.g03	us_fd50per_normtide	2021_machias_phs1.u01
10	alt04m_ss_q100_mlw	alt04m_ss_mhw	2021_machias_phs1.p10	alt04m	2021_machias_phs1.g04	ss_mhw	2021_machias_phs1.f01
11	alt04m_ss_q100_mhw	alt04m_ss_mhw	2021_machias_phs1.p11	alt04m	2021_machias_phs1.g04	ss_mhw	2021_machias_phs1.f02
12	alt04m_us_fd50per_normtide	alt04m_us_fd50per_normtide	2021_machias_phs1.p12	alt04m	2021_machias_phs1.g04	us_fd50per_normtide	2021_machias_phs1.u01
13	alt09_ss_q100_mlw	alt09_ss_mhw	2021_machias_phs1.p13	alt09	2021_machias_phs1.g05	ss_mhw	2021_machias_phs1.f01
14	alt09_ss_q100_mhw	alt09_ss_mhw	2021_machias_phs1.p14	alt09	2021_machias_phs1.g05	ss_mhw	2021_machias_phs1.f02
15	alt09_us_fd50per_normtide	alt09_us_fd50per_normtide	2021_machias_phs1.p15	alt09	2021_machias_phs1.g05	us_fd50per_normtide	2021_machias_phs1.u01
16	alt10m2_ss_q100_mlw	alt10m2_ss_mhw	2021_machias_phs1.p25	alt10m2_20210812	2021_machias_phs1.g08	ss_mhw	2021_machias_phs1.f01
17	alt10m2_ss_q100_mhw	alt10m2_ss_mhw	2021_machias_phs1.p26	alt10m2_20210812	2021_machias_phs1.g08	ss_mhw	2021_machias_phs1.f02
18	alt10m2_us_fd50per_normtide	alt10_us_fd50per_normtide	2021_machias_phs1.p22	alt10m2_20210812	2021_machias_phs1.g08	us_fd50per_normtide	2021_machias_phs1.u01
19	alt10m2_us_q001_normtide	alt10m2_us_q001_normtide	2021_machias_phs1.p23	alt10m2_20210812	2021_machias_phs1.g08	us_q001_normtide	2021_machias_phs1.u02
20	alt10m2_us_q010_normtide	alt10m2_us_q010_normtide	2021_machias_phs1.p24	alt10m2_20210812	2021_machias_phs1.g08	us_q010_normtide	2021_machias_phs1.u03

RESULTS

The following sections summarize the hydraulic Model simulation results for the steady- and unsteady-state scenarios.

STEADY STATE

A total of 12 steady-state simulations were performed as part of the Study. Table 7 below presents a summary of results from the steady-state Model simulations. The results are presented based on the WSELs upstream (US) and downstream (DS) of Dyke Bridge.

Table 7. Summary of maximum steady-state WSELs upstream (US) and downstream (DS) from Dyke Bridge

	Q100 with MLW		Q100 with MHW	
Alternative	US WSEL (ft)	DS WSEL (ft)	US WSEL (ft)	DS WSEL (ft)
Existing Conditions	5.1	-6.6	10.2	6.1
Alternative 1	3.4	-6.6	8.7	6.1
Alternative 4	0.1	-6.6	7.8	6.1
Alternative 4m	0.8	-6.6	7.3	6.1
Alternative 9	3.4	-6.6	8.7	6.1
Alternative 10	-6.5	-6.5	6.1	6.1

For the steady-state simulations with the downstream MLW boundary condition, the highest upstream WSEL was for the Existing Conditions alternative. This result is consistent with the reduced conveyance through the existing culverts due to accumulated debris. Alternative 1 and Alternative 9, which have the same culvert geometry and subsequent seaward hydraulic capacities, had the highest upstream WSEL of 3.4 ft compared to the other alternatives, which is approximately 1.7 ft lower than the WSELs for the Existing Conditions alternative (5.1 ft). Alternative 4 had a lower upstream WSEL compared to Alternative 4m due to the lower culvert inverts in Alternative 4. The lowest upstream WSEL from the alternatives was Alternative 10, which is approximately equal to the elevation of the downstream MLW boundary condition. Note that Alternative 10 assumes that existing sediment landward from Dyke Bridge would be dredged as part of or eroded as a result of this alternative.

For the steady-state simulations with the downstream MHW boundary condition, the highest upstream WSEL was for the Existing Conditions alternative. This result is consistent with the reduced conveyance due to accumulated debris in the existing culverts. Similar to the MLW simulation results, Alternative 1 and Alternative 9 have similar upstream WSELs due to having the same culvert geometry and subsequent seaward hydraulic capacities. Alternative 4 and Alternative 4m have lower upstream WSELs compared to Alternative 1 and Alternative 9 due to the increased hydraulic capacity of these alternatives. Alternative 4m has a slightly reduced upstream WSEL compared to Alternative 4 due to the slightly greater hydraulic capacity of the three 5-ft by 10-ft box culverts compared to the five 5-ft by 5-ft box culverts. Alternative 10, which represents a 116.5 ft bridge clear span geometry, had the lowest upstream WSEL and the upstream WSEL was the same as the downstream boundary condition suggesting that the bridge is able to convey the full 100-year flow with no backwatering upstream from Dyke Bridge.

UNSTEADY STATE

Eight unsteady-state simulations were performed as part of the Study. Appendix A contains figures representing the stage hydrograph output. The observed MaineDOT stage data landward of Dyke Bridge was included in the flow stage hydrographs to compare differences between the existing and proposed scenarios under normal flow conditions. Note that with the exception of the 1.1- and 10-year peak flows used as riverine conditions evaluated in Alternative 10, the riverine flows across the simulations were the median 50% stream flow.

Maximum upstream and downstream WSELs and the total change between these values were calculated for each of the alternatives. In addition, the percentage of time flow was being conveyed landward (i.e., flows moving from the sea (downstream) towards land (upstream)) at Dyke Bridge were calculated based on the simulation results. The maximum WSELs in the Middle River for normal tidal and median flow riverine flow conditions from the first phase of the Hydraulic Study simulations are reported in Table 8 below, along with the upstream WSEL range and percentage of time over the simulation for landward flow. The maximum WSELs in the Middle River for normal tidal and the 1.1- and 10-year riverine flow conditions based on the Hydraulic Study simulations are reported in Table 9. For discussion related to this section, see the Discussion Section below.

Table 8. Summary of maximum upstream WSELs for normal tidal and median riverine flow conditions, approximate total range of WSELs, and percentage of time estimated that landward flows are greater than seaward flows

Alternative	Max US WSEL (ft)	Min US WSEL (ft)	US WSEL Range (ft)	Percentage of Time for Landward Flows
Existing Conditions	-0.8	-2.1	1.3	58%
Alternative 1	-2.5	-3.4	0.9	0%
Alternative 4	0.8	-4.8	5.6	59%
Alternative 4m	2.3	-3.0	5.3	52%
Alternative 9	4.1	-0.5	4.6	41%
Alternative 10	8.6	-7.0	15.6	41%

Table 9. Summary of maximum upstream WSELs for normal tidal and the 1.1- and 10-year storm flow riverine conditions and approximate total range of WSELs for Alternative 10

Alternative	Max US WSEL (ft)	Min US WSEL (ft)	US WSEL Range (ft)
Alternative 10 (1.1-Year Peak Flow)	8.6	-7.0	15.6
Alternative 10 (10-Year Peak Flow)	8.7	-5.5	14.2

INUNDATED LAND FOR NORMAL TIDAL AND RIVER FLOW CONDITIONS

This section summarizes areas of inundated land upstream from Dyke Bridge for the six evaluated alternatives based on 1) a WSEL-area relationship (stage-area curve) and 2) the unsteady-state simulation results for the maximum WSELs during normal tidal and riverine flow conditions from the first phase of the Hydraulic Study simulations presented in Table 8. Reference Appendix B for a figure that depicts WSEL contours associated with the Study alternatives in the area adjacent to the Middle River upstream from Dyke Bridge.

The stage-area curve was developed using the existing terrain model that was compiled for the HEC-RAS Model and is depicted in Figure 3. Note that Figure 3 does not include areas for elevations below Elevation 0.0 ft which are largely in the current area that is inundated during normal tidal conditions in the Middle River upstream from Dyke Bridge. Detailed bathymetric data was not available for this area and this stage-area curve is intended for use in evaluating inundation areas associated with WSELs that are higher than the current normal tidal and riverine flow conditions. Table 10 presents the stage-area curve data developed for the Middle River upstream from Dyke Bridge in tabular format.

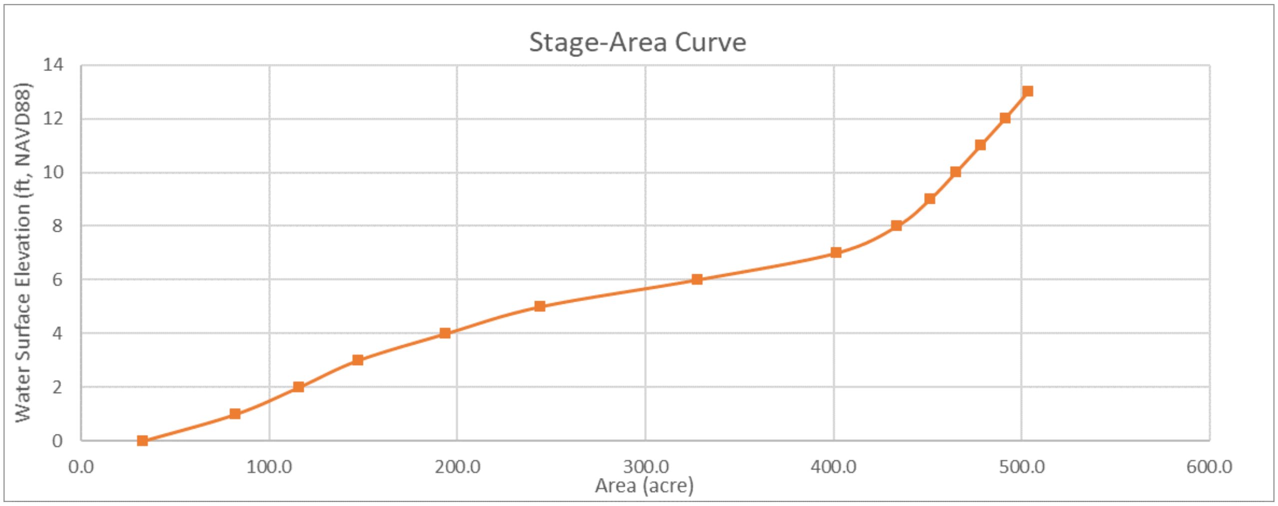

Figure 3. Stage-Area Curve for Middle River Upstream from Dyke Bridge

Table 10. Stage-Area Curve Data from Figure 3 for Middle River Upstream from Dyke Bridge

WSEL (ft, NAVD88)	Area (acre)
0	33
1	82
2	116
3	147
4	194
5	244
6	328
7	402
8	434
9	452
10	465
11	478
12	491
13	504

Table 11 presents the maximum upstream WSELs for normal tidal and riverine flow conditions based on the information presented in Table 8. The “Increased Inundation Area” in Table 11 reflects estimated inundated areas in the Middle River with normal tidal and riverine flow conditions upstream from Dyke Bridge above elevation 0.0 ft and exclusive of the existing, regularly inundated area (~33 acres). Table 11 depicts an inundation range based on 1) tidal stage data in the Middle River collected by MaineDOT in 2011 and 2) preliminary observations by Stantec and aerial photographs collected by MaineDOT using a drone in 2021 that indicate that the normal tidal WSELs have increased the regularly inundated area in the Middle River by approximately 45 acres. The lower value in the “Increased Inundation Area” range represents the estimated current (2021) condition and the higher value reflects the 2011 tidal stage data.

Table 11. Inundated areas and increased inundated areas for maximum upstream WSELs for normal tidal and riverine flow conditions

Alternative	Max US WSEL (ft)	Inundation Area (acres)	Increased Inundation Area (acres)
Existing Conditions	-0.7	<33 acres	n/a
Alternative 1	-2.5	<33 acres	n/a
Alternative 4	0.8	73	0 - 40
Alternative 4m	2.3	125	47 - 92
Alternative 9	4.1	201	123 - 168
Alternative 10	8.6	445	367 - 412

DISCUSSION

This section presents discussion of the hydraulic model simulation results for the first phase of the Hydraulic Study as part of the Project. As presented in Table 8 and depicted in the stage hydrographs presented in Appendix A, WSELs in the Middle River upstream from Dyke Bridge for median riverine flows in the Middle River and normal tidal conditions in the Machias River varied for the evaluated alternatives. In addition to evaluating the median riverine flow, this first phase of the Hydraulic Study evaluated the 1.1- and 10-year peak flows in the Middle River for Alternative 10 (bridge alternative) consistent with MaineDOT's guidance for evaluating bridges. Additional hydraulic studies will be performed, including analyses of peak flows, as part of the second phase of the Hydraulic Study.

Alternative 1 represents conditions in which the upstream maximum and minimum WSELs for the typical tidal conditions are -2.5 ft and -3.4 ft, respectively, and are the lowest compared to the other evaluated alternatives. Figure A-1 depicts the simulated and existing WSELs in the Middle River landward from Dyke Bridge for Alternative 1 with the median riverine flow and normal tidal stage boundary conditions. This is due to the increased hydraulic capacity compared to existing conditions, which had less hydraulic capacity due to blockage, and flap-gates with no leakage. The Existing Conditions alternative had the second lowest upstream WSEL (-0.7 ft). Without any leakage or bidirectional flow, the normal tide and riverine conditions maximum WSEL landward of Dyke Bridge is anticipated to be approximately 1.8 ft lower compared to existing conditions under Alternative 1. Similarly, the normal tide and riverine conditions minimum WSEL landward of Dyke Bridge is anticipated to be approximately 1.3 ft lower compared to existing conditions under Alternative 1 due to the increased hydraulic capacity of the culverts without any debris blockage and the resulting capacity to discharge flow from the Middle River to the Machias River seaward at Dyke Bridge.

Alternative 10 represents the conditions for which the upstream maximum WSEL is the highest (8.6 ft), the upstream minimum WSEL is the lowest (-7.0 ft), and the upstream water surface range is the greatest (15.6 ft) compared to the other model simulations. This is due to the large hydraulic capacity of the bridge and the ability for this alternative structure to provide a full tidal exchange with minimal losses through the bridge opening. Figure A-5 depicts the simulated and existing WSELs in the Middle River landward from Dyke Bridge for Alternative 10 with the median riverine flow and normal tidal stage boundary conditions.

Alternatives 4, 4m, and 9 represent hydraulic conditions that are in between the Existing Conditions alternative and Alternative 10 simulation results. Figures A-2, A-3, and A-4 depict the simulated and existing WSELs in the Middle River landward from Dyke Bridge for Alternative 4, 4M, and 9, respectively, with the median riverine flow and normal tidal stage boundary conditions. Alternative 4 and Alternative 4m represent conditions that include a combination of bidirectional flow culverts with other culverts that have flap-gates. The benefit of these alternatives is that landward fish passage could be accommodated during flood tides through the bidirectional flow culvert. However, the flows would be attenuated enough as to not result in the full tidal exchange that would significantly raise landward WSELs. The maximum upstream WSEL during normal tide and riverine flow conditions is approximately 1.5 ft lower under Alternative 4 compared to Alternative 4m, which is the result from the additional hydraulic capacity of the larger bidirectional flow culvert in Alternative 4m providing additional landward flow during flood tides. However, Alternative 4 results in an overall lower minimum upstream WSEL compared to Alternative 4m, which is likely the result of the lower inverts of the culverts with flap-gates in Alternative 4 allowing for additional drainage seaward, although both alternatives are relatively similar.

Alternative 9 provides an increased opportunity for landward flow during flood tides since the four 5-ft by 5-ft culverts do not have any flap gates. The only alternative that provides more landward flow during the flood-cycle tidal exchange is Alternative 10. Although the hydraulic capacity of Alternative 9 during seaward flows is the same as Alternative 1, the minimum upstream WSEL is about 2.9 ft greater due to the increased landward tidal exchange under Alternative 9. With the exception of Alternative 10, Alternative 9 results in the highest WSELs landward of Dyke Bridge for both flood and ebb tidal cycles with a maximum upstream WSEL of 4.1 ft and a minimum upstream WSEL of -0.5 ft.

The upstream WSEL ranges varied across the alternatives evaluated. The upstream WSEL ranges are presented in Table 8 and are proportional to the amplitude of the rise and fall limbs of the stage hydrographs presented in Appendix B. For example, Alternative 10 had the greatest upstream WSEL range of 15.6 ft, which corresponds to also having the largest amplitude in the stage hydrograph in Figure A-5. Similarly, Alternative 1 had the smallest upstream WSEL range compared to the other alternatives and had the smallest amplitude in the stage hydrograph in Figure A-1. Alternatives that provided increased drainage from landward to seaward during ebb tides and also provided increased opportunity for landward flow during flood tides generally resulted in greater upstream WSEL ranges relative to their maximum and minimum simulated upstream WSEL values. For example, with the exception of Alternative 10, Alternatives 4 and 4m provided the greatest range of upstream WSEL elevations and therefore increased tidal exchange.

Table 8 presents the percentage of time over the simulation period for landward flow for existing conditions and the evaluated alternatives. This information is provided as an indicator of potential landward fish passage by advection (i.e., movement of fish in the direction of flow) for comparison with existing conditions and amongst the evaluated alternatives. The time-of-landward flow statistic does not address potential quality of upstream fish passage conditions. For example, this statistic does not differentiate between flow through irregular, and potentially narrow, gaps in the existing flap gates versus the open culverts that were modeled as part of Alternatives 4, 4m, and 9. More detailed evaluation of fish passage would require identification of specific fish passage criteria (e.g., minimum depths of water) and evaluation of hydraulic conditions at each timestep in the unsteady-state hydraulic model.

Of the evaluated alternatives, Alternatives 4 and 4m provide the greatest percentage of time in which landward flows (flows conveyed downstream to upstream during flood tides) are greater than percentage of time of seaward flows (flows conveyed upstream to downstream during ebb tides). Alternative 4 reflects the highest percentage of time in which landward flows are greater than seaward due to the generally lower maximum upstream WSELs compared to the other alternatives. Since the landward WSELs are generally less for Alternative 4, this results in a greater percentage of time during which the downstream seaward WSELs are greater than the upstream landward WSELs, and therefore a greater amount of time in which the bidirectional flow culvert is conveying flow landward. For the opposite reason, Alterative 9 results in the lowest percentage of time of landward flows compared to seaward out of the alternatives simulated with bidirectional flow. Note that Alternative 1 (replacement-in-kind) with fully functional flap-gates do not result in any landward flow.

In general, the Alternative 10 maximum and minimum upstream WSELs across the median 50% flow and the 1.1- and 10-year peak flows were generally the same with very small simulated differences (reference Figures A-5, A-6, and A-7 in Appendix A). The only notable apparent changes between these scenarios are the slight increases in the upstream minimum WSELs during the ebb tide for increasing flows. However, the changes are relatively minimal. Further refinement of the bathymetry upstream in the model anticipated in the second phase of the Hydraulic Study may affect these results, since the ebb tide results in low flow conditions in the upstream channel of Middle River.

Based on the results of the steady-state simulation results, none of the primary alternatives evaluated as part of the first phase of the Hydraulic Study appear to increase the existing base-flood elevation (BFE) as defined by the Federal Emergency Management Agency (FEMA). FEMA reports the BFE at the area of Dyke Bridge as 11 ft. The existing conditions modeled under similar hydraulic conditions with the 100-year riverine flow and the mean high water downstream boundary condition results in a WSEL of approximately 10.2 ft. Primary alternatives evaluated as part of the first phase of the Hydraulic Study produced WSELs that were lower than both the FEMA BFE of 11 ft and the existing conditions simulated WSEL of 10.2 ft. Therefore, no increase in the BFE is anticipated to occur for the evaluated primary alternatives.

Simulation results from primary alternatives analyzed as part of the first phase of the Hydraulic Study provide some insight related to potential changes on hydraulic conditions, for both fish passage and hydraulic capacity, at Stride Bridge located upstream from Dyke Bridge on the Middle River. In general, alternatives that provide increased landward tidal exchange during flood ties and increase the maximum upstream WSELs also result in increased tailwater elevations at Stride Bridge. Under normal tidal and median flow riverine conditions, flow appears to be moving landward at Stride Bridge as well, which would likely provide increased opportunities for landward fish passage by advection. In addition, higher tailwater conditions at Stride Bridge would result in lower flow speeds through the culvert, which would also provide additional opportunity for fish passage. With respect to hydraulic capacity, for the alternative that resulted in the greatest upstream WSEL (Alternative 10 with 10-year peak flow riverine condition), the culvert at Stride Bridge is only flowing partially-full, suggesting that the culvert still likely has adequate hydraulic capacity. Additional quantitative evaluation of Stride Bridge is recommended to further these initial conclusions (e.g., evaluate whether freeboard is still adequate during the design hydraulic conditions).

Based on the simulation results for the first phase of the Hydraulic Study, the bridge geometry in Alternative 10 with a clear span of 116.5 ft between the bridge abutments provides conditions that substantially result in full tidal exchange with minimal (i.e., less than 0.2 ft) head losses through the bridge opening. This is due to the relatively large hydraulic capacity of the bridge compared to the other modeled alternatives. Although the 116.5 ft clear span bridge geometry still represents a hydraulic constriction at this location and accelerates flow through the opening, results from this first phase of hydraulic analysis suggest that a larger bridge opening would not provide significantly greater reductions in head losses across the bridge and therefore would also likely not result in significant additional hydraulic benefits for volitional fish passage.

It is anticipated that Alternative 10 would result in the greatest changes to the morphology of the upstream channel of the Middle River in the vicinity of Dyke Bridge due to the larger opening compared to the other alternatives. A more natural, and larger flux of sediment is expected compared to the culvert alternatives due to the increased tidal exchange and flow capacity through the bridge structure. Over time, a quasi-steady dynamic equilibrium of sediment flux landward and seaward is expected as the channel of the Middle River adjusts, and it is likely that the river may align with the historic channel bed through this process if the bridge is located adjacent to the historic channel.

SUMMARY

Following here is a bulleted summary of findings from the initial phase of the Hydraulic Study.

1. Alternative 1 does not provide upstream fish passage opportunities and therefore may not meet Project goals and objectives.

2. Alternatives 4, 4m, 9, and 10 will result in higher WSELs upstream from Dyke Bridge during normal tidal and riverine flow conditions relative to existing conditions.

3. No increases in the FEMA BFE are anticipated for the evaluated primary alternatives that were modeled as part of Phase 1 of the Hydraulic Study.

4. Alternative 4 and Alternative 4m have similar hydraulic characteristics. Alternative 4 results in lower maximum upstream WSELs compared to Alternative 4m. Alternative 4m may provide safer fish passage due to the increased size of the structure.

5. With the exception of Alternative 10, Alternative 4 and Alternative 4m appear to represent the alternatives with the greatest tidal exchange as represented by the amplitude of their stage hydrographs as well as the increased range of upstream maximum and minimum WSELs compared to the other alternatives.

6. Alternative 4 and Alternative 4m result in the greatest percentage of time in which landward flows are greater than seaward flows, which will promote advectional fish passage.

7. Alternatives 4, 4m, and 9 pose public safety risks associated with boat impingement. Additional design considerations may be required.

8. Alternative 10 has volitional, unrestricted fish passage, since the full tidal exchange is occurring at Dyke Bridge. However, the increased upstream WSELs may be an issue for property owners along the upstream reach of the Middle River. Alternative 10 also represents an alternative that would result in least likelihood of safety concerns from boat impingement, but may still pose a low headroom safety risk to boats at higher tides.

9. Based on the 2011 tide data collected by MaineDOT, Alternative 10 would result in regular inundation of approximately 412 acres of land that is not currently inundated on a regular basis. This is compared to 40 and 92 acres for Alternatives 4 and 4m, respectively.

10. Bridge alternatives that provide a clear span greater than Alternative 10 (116.5 ft) are not necessary to achieve volitional fish passage and restore full tidal exchange landward of the Dyke Bridge.

11. Alternative 10 would result in development of a larger channel morphology through this reach of the Middle River due to the larger span compared to the other culvert alternatives. Transport of sediment is expected to be greater under this alternative.

12. Primary alternatives evaluated that increase the upstream WSELs during normal tidal and median flow riverine conditions (i.e., Alternative 4, Alternative 4m, Alternative 9, Alternative 10) would likely result in increased fish passage opportunities at Stride Bridge, either by upstream passage through advection during flood tides, or by increasing the tailwater elevation at Stride Bridge, which would lower the velocities through the culvert barrel thereby facilitating passage.

13. Additional quantitative evaluations of the hydraulic conditions at Stride Bridge are recommended to assess if hydraulic design criteria (e.g., freeboard) are adequate when coupled with the hydraulic changes to the Middle River reach from the replacement alternatives proposed at Dyke Bridge.

14. Following on observations and information obtained during Project field studies in the summer of 2021, MaineDOT installed datalogging pressure transducers in the Middle River upstream from Dyke Bridge and in the Machias River downstream from the bridge in August 2021 to collect updated tidal stage data.

15. The second phase of the Hydraulic Study will evaluate a broader range of high-flow conditions, including peak riverine flows in the Middle River, tidal storm surge events in the Machias River, and sea-level rise, and will provide information to evaluate potential changes to flood elevations in the Middle River landward from Dyke Bridge.

APPENDIX A – UNSTEADY-STATE STAGE HYDROGRAPHS

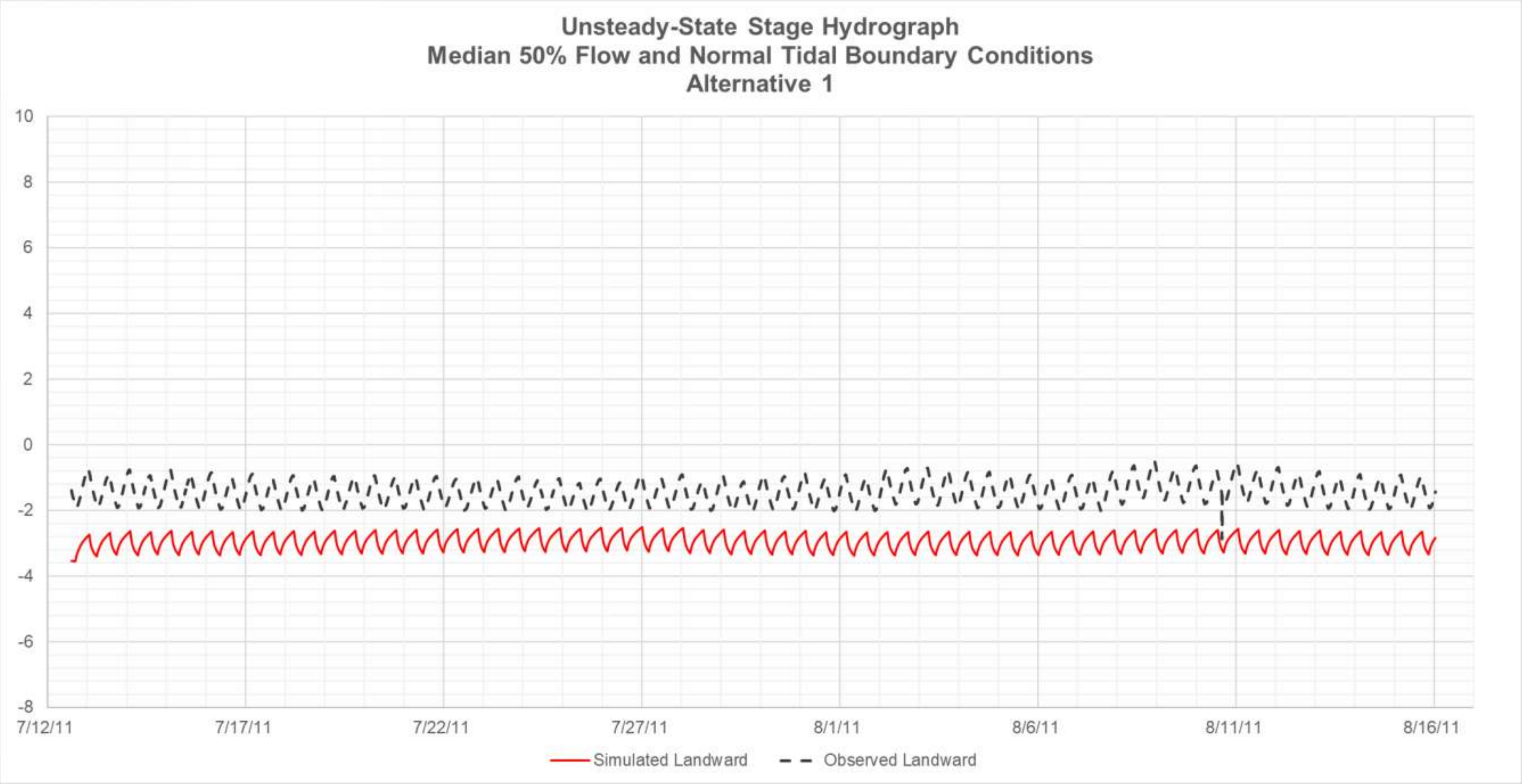

Figure A - 1. Unsteady-state stage hydrography simulation results for Alternative 1 for the median riverine flow upstream boundary condition and the normal tidal stage downstream boundary condition

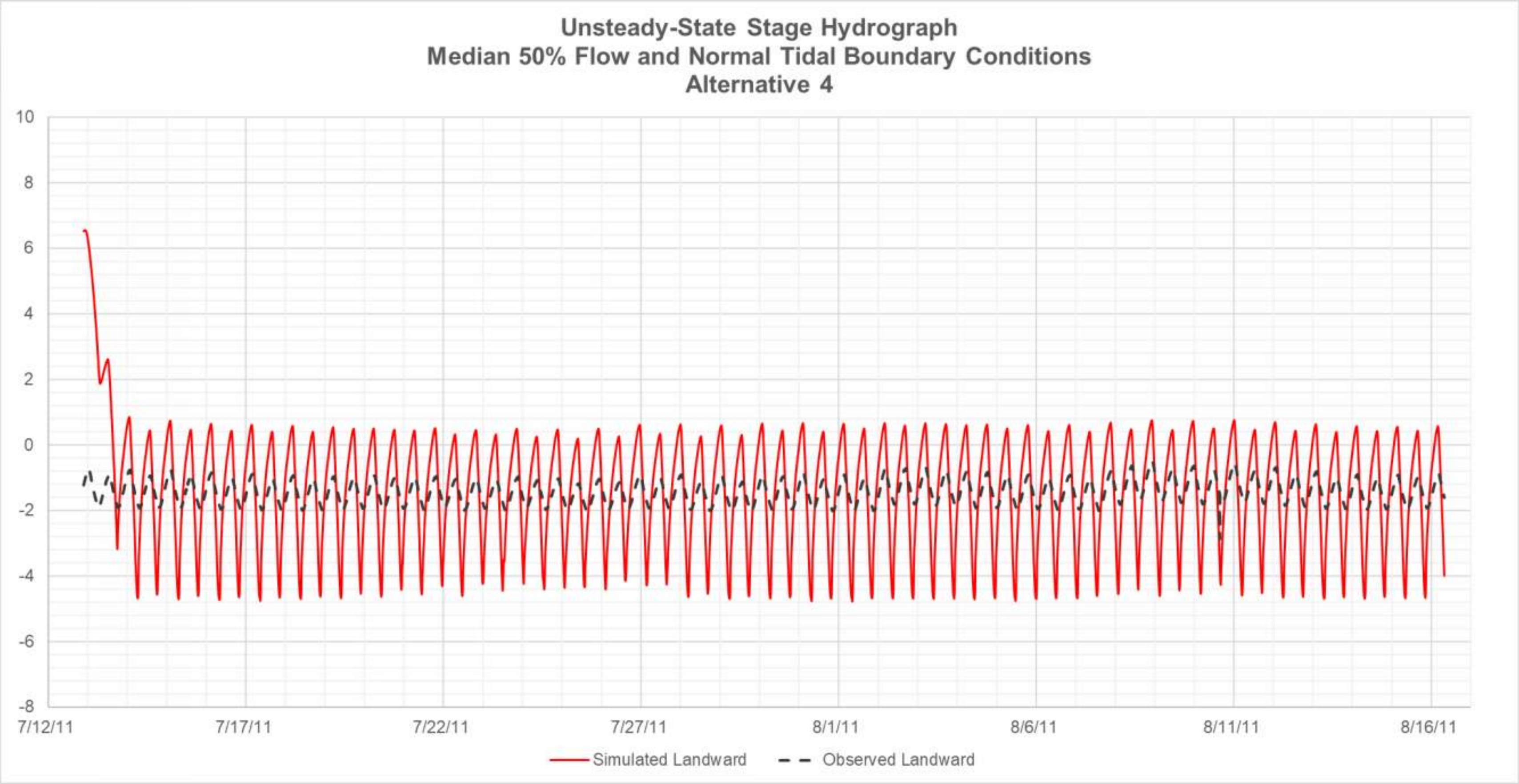

Figure A - 2. Unsteady-state stage hydrography simulation results for Alternative 4 for the median riverine flow upstream boundary condition and the normal tidal stage downstream boundary condition

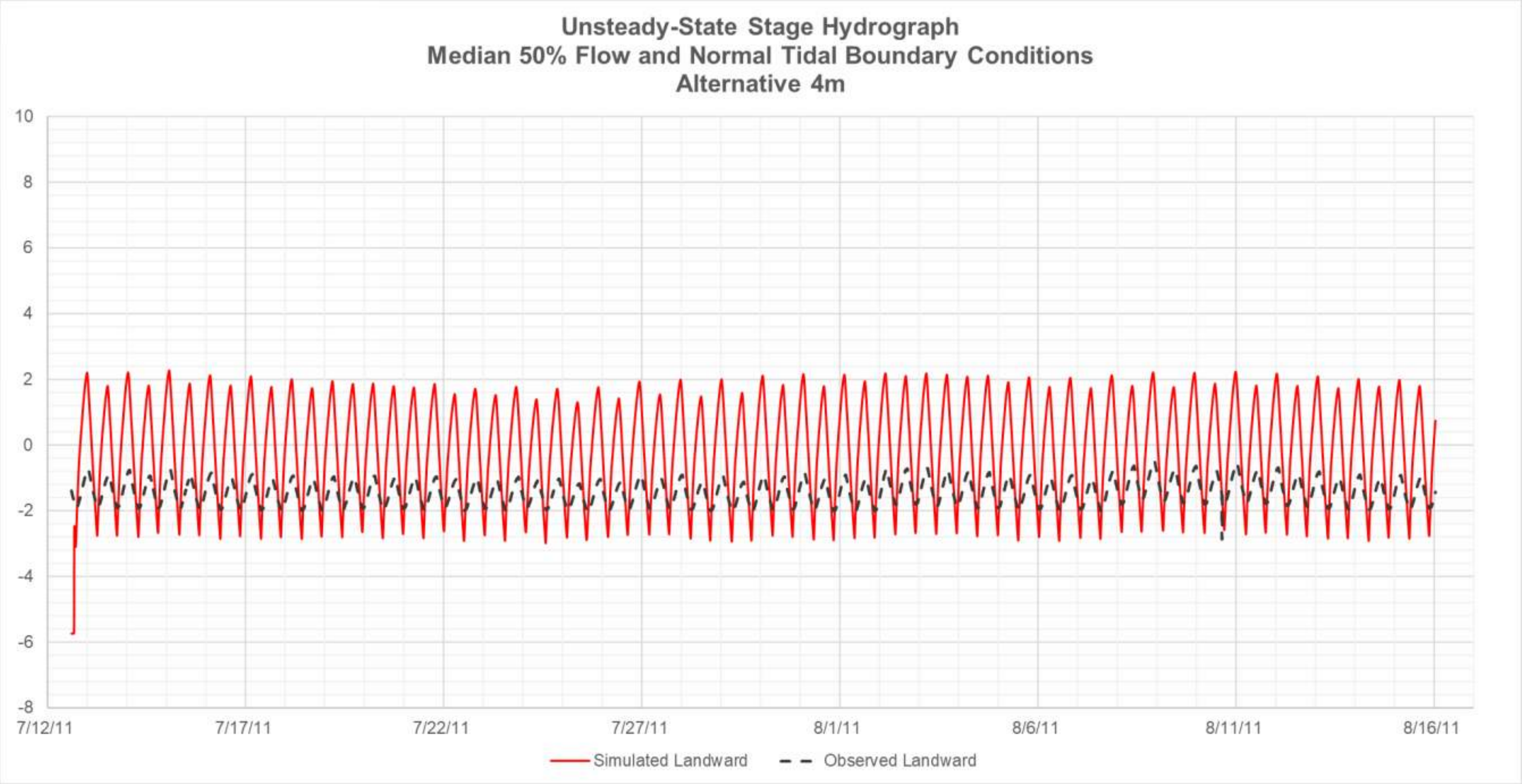

Figure A - 3. Unsteady-state stage hydrography simulation results for Alternative 4m for the median riverine flow upstream boundary condition and the normal tidal stage downstream boundary condition

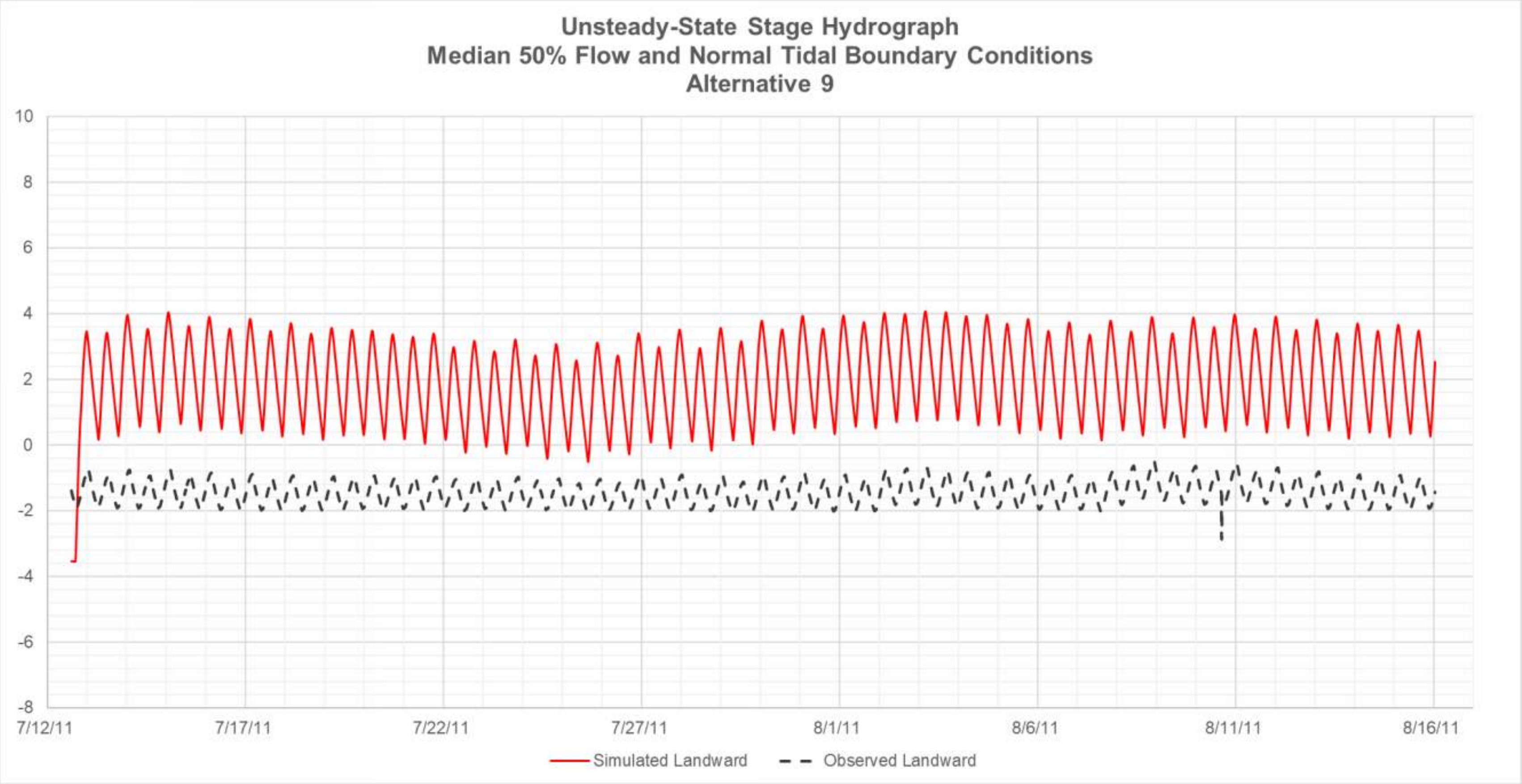

Figure A - 4. Unsteady-state stage hydrography simulation results for Alternative 9 for the median riverine flow upstream boundary condition and the normal tidal stage downstream boundary condition

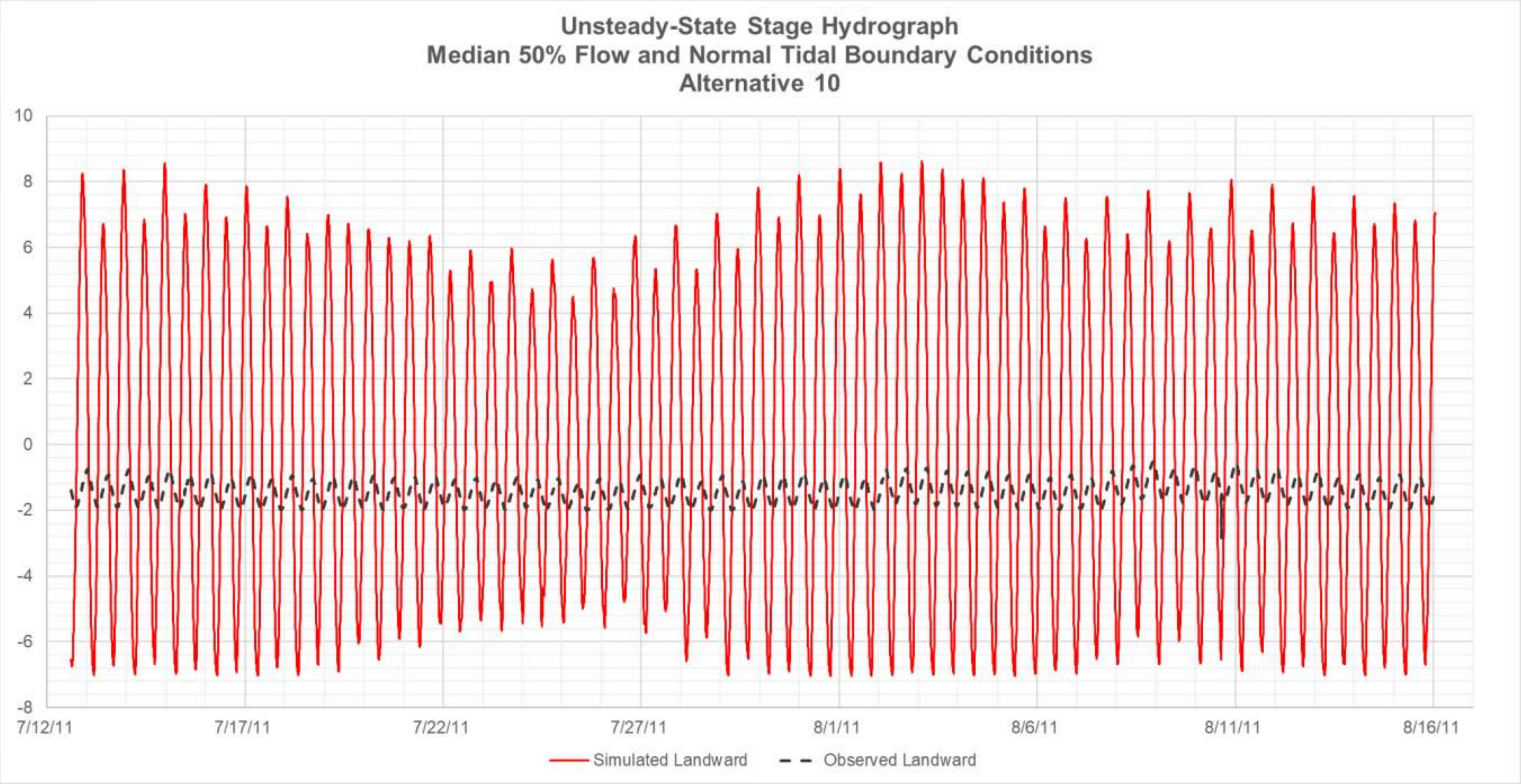

Figure A - 5. Unsteady-state stage hydrography simulation results for Alternative 10 for the median riverine flow upstream boundary condition and the normal tidal stage downstream boundary condition

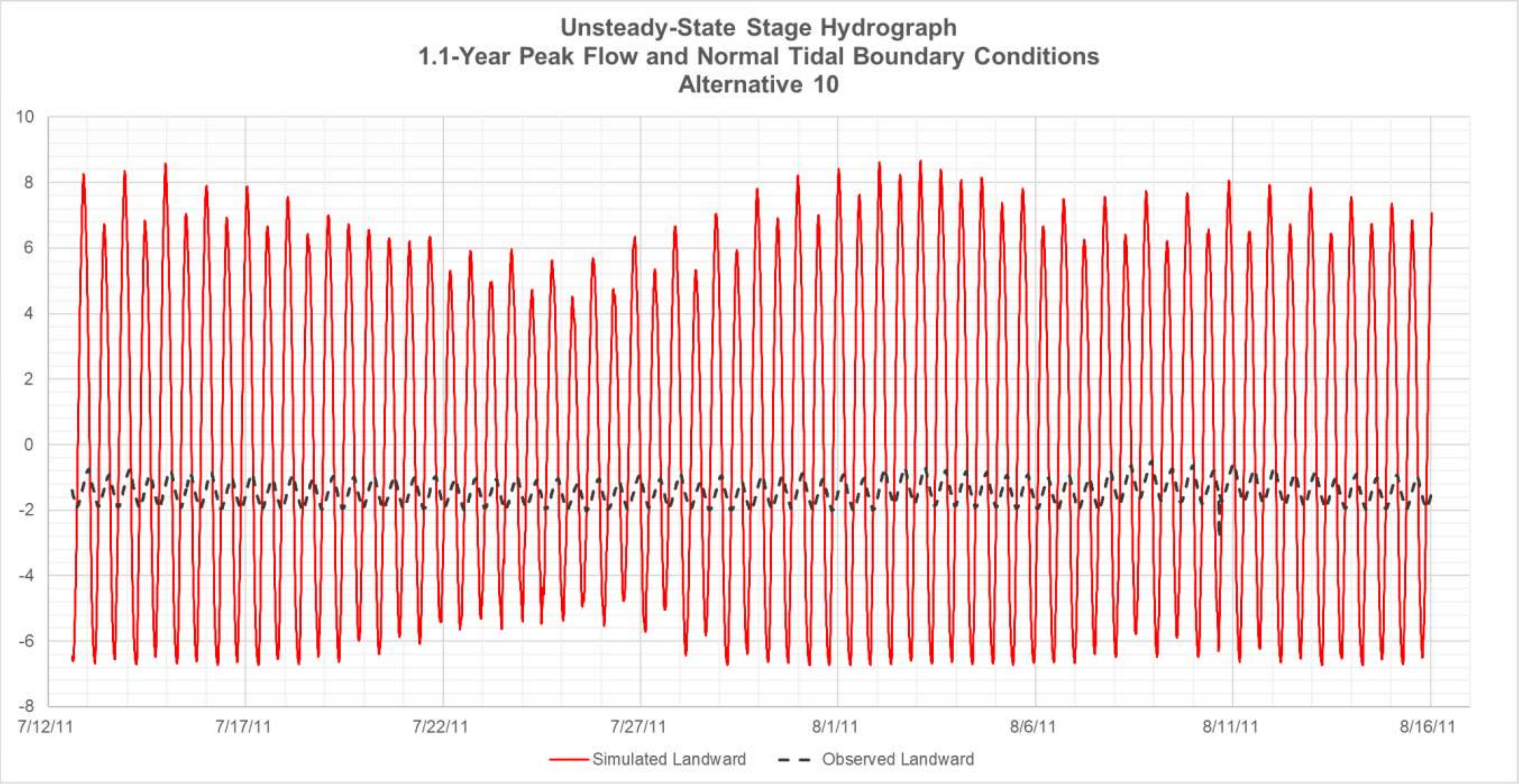

Figure A - 6. Unsteady-state stage hydrography simulation results for Alternative 10 for the 1.1-year peak flow riverine flow upstream boundary condition and the normal tidal stage downstream boundary condition

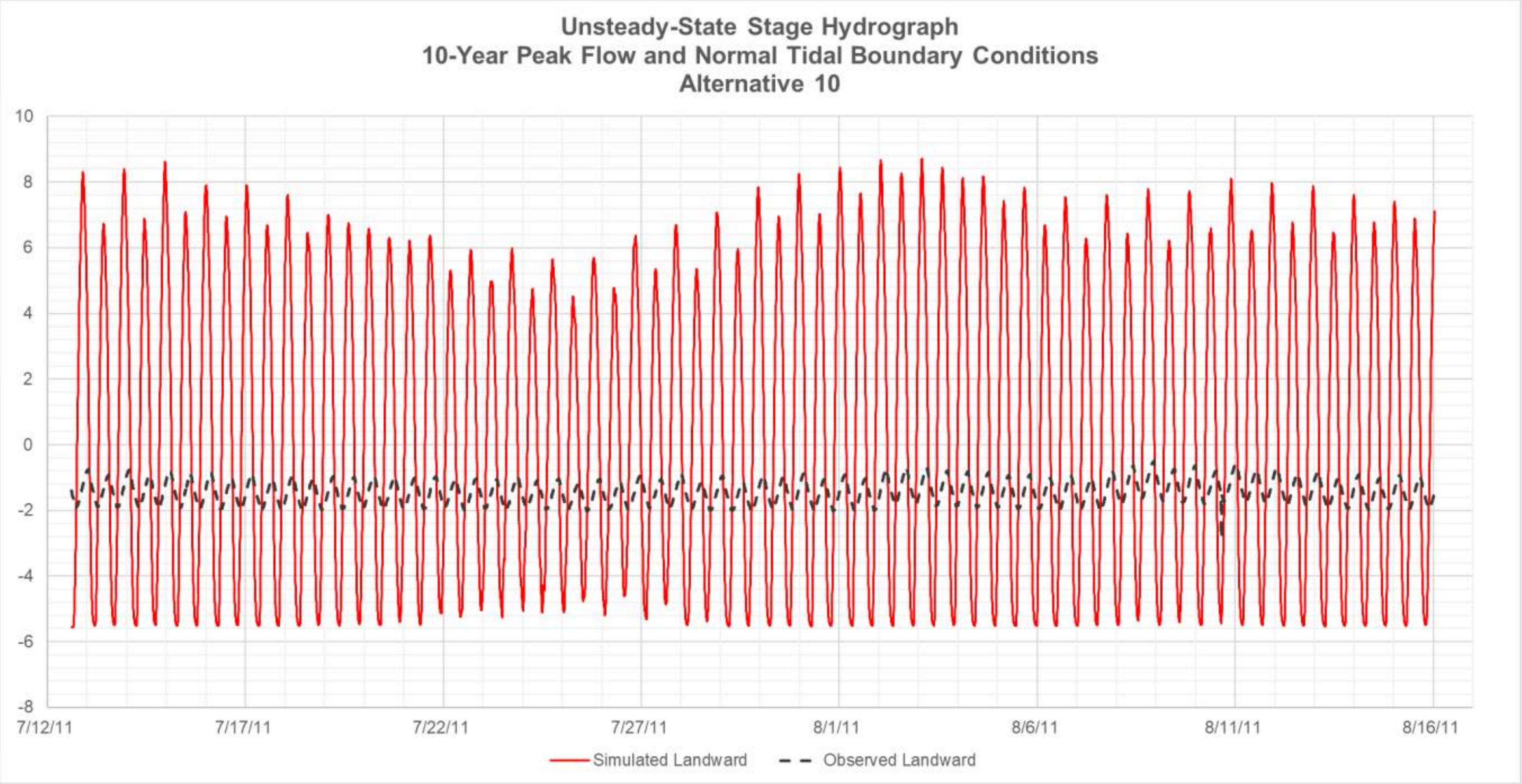

Figure A - 7. Unsteady-state stage hydrography simulation results for Alternative 10 for the 10-year peak flow riverine upstream boundary condition and the normal tidal stage downstream boundary condition

APPENDIX B – MAPPED WATER SURFACE ELEVATIONS ALONG MIDDLE RIVER UPSTREAM FROM DYKE BRIDGE FOR PRIMARY ALTERNATIVES

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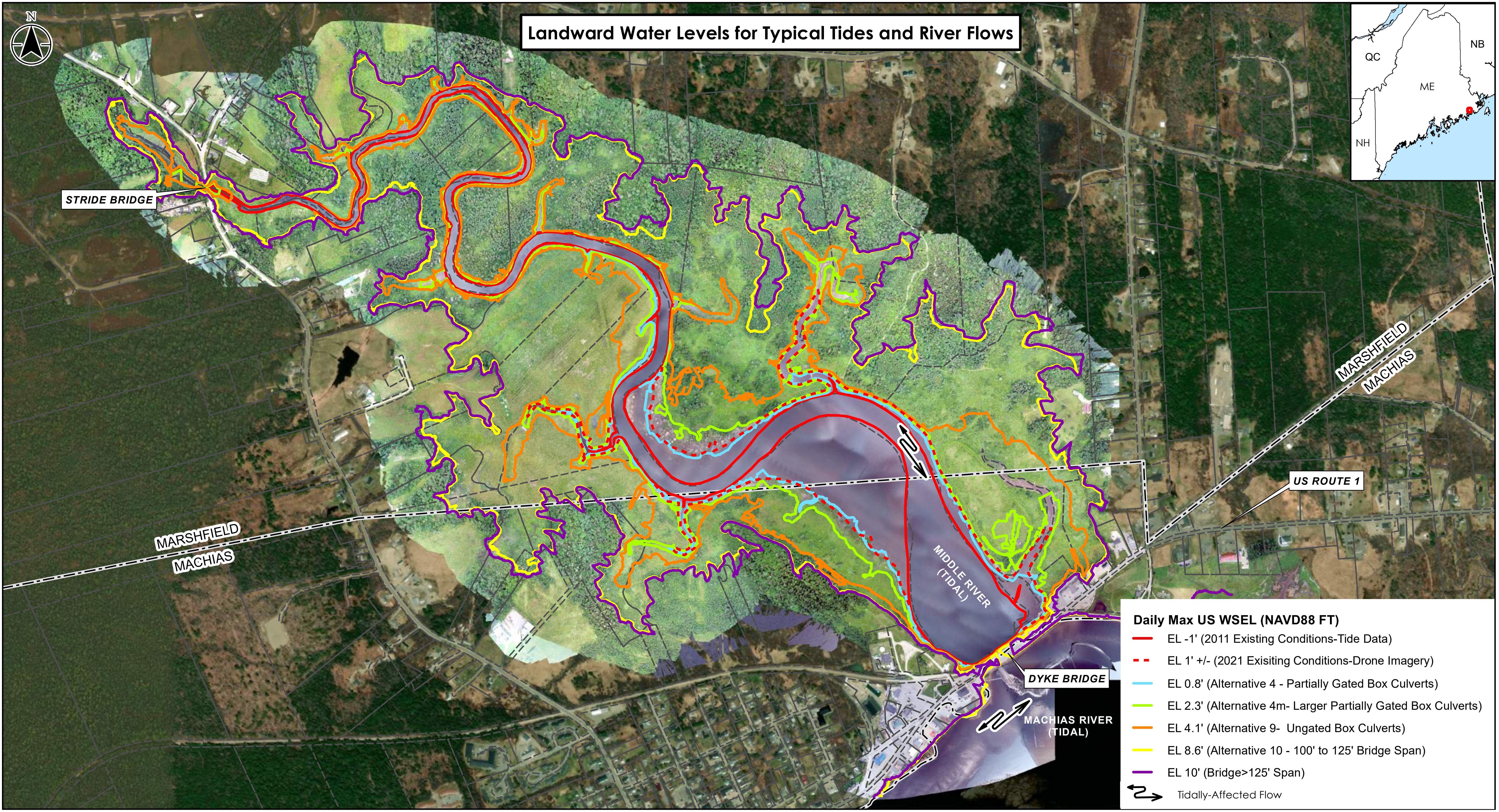
Landward Water Levels for Typical Tides and River Flows



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Prepared by EPL on 2021-08-09
Reviewed by MRC on 2021-08-09

50347_DykeBridge_11x17_Alt-Cont_hydraulics.mxd

Notes

1. Existing conditions are based on 2011 tidal stage data and 2021 drone imagery collected by MaineDOT. **Collection of 2021 tidal stage data is pending and will affect existing condition mapping.**
2. Approximate water surface elevations (WSEL) for proposed alternatives are based on the 2021 Phase 1 hydraulics analysis using tidal stage data collected by MaineDOT in 2011.
3. Coordinate System: NAD 1983 UTM Zone 19N FT
4. Vertical Datum: NAVD88
5. Aerial imagery in the project area was obtained by unmanned aircraft vehicle (UAV) by MaineDOT on July 20, 2021.
6. Aerial imagery surrounding the project area is provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).
7. TIN Surface information is based on survey data provided by the Maine Department of Transportation.

Legend

⌜⌟ Maine GIS Tax Parcels

0 800 Feet
1 inch = 833 feet (At page size of 11"x17")

Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
B-1

Title Landward Water Levels for Typical Tides and River Flows
9/16/2021

Stantec

2/17/2022
MICHAEL R. CHELMINSKI
No. 10320

PHASE 2 MEMO

Memo

To: MaineDOT

From: Michael R. Chelminski, P.E.
Gordon E. Clark

Project/File: 179450347

Date: December 20, 2021

Reference: Phase 2 Hydraulic Analysis for Machias Dike Bridge (#2246) Planning Phase Support Services

1.0 INTRODUCTION

This memo was prepared by Stantec Consulting Services Inc. (Stantec) under contract to the Maine Department of Transportation (MaineDOT) for Planning Phase Support Services (2020-2021 Planning Study) as part of the Dike Bridge Replacement Project (Project) located on the Middle River in Machias, Maine. MaineDOT is pursuing replacement of the existing infrastructure at Dike Bridge due to its poor condition with the objectives to provide adequate drainage from upland floods without overtopping the Route 1 roadway, provide adequate freeboard during tidal flood events, provide sea-level-rise resiliency, and accommodate fish passage to the extent practicable.

As part of this scope of services for the 2020-2021 Planning Study, Stantec performed hydraulic analyses to assess hydraulic conditions associated with replacement alternatives for the Dike Bridge culvert. The first phase (Phase 1) of the hydraulic analyses included assessment of hydraulic conditions associated with five primary replacement alternatives for the Dike Bridge culvert, which is documented in the “Phase 1 Hydraulic Analysis for Machias Dike Bridge (#2246) Planning Phase Support Services” dated September 2021 (Phase 1 Study). Phase 2 of the hydraulic analyses builds on the previous work completed as part of Phase 1 and includes evaluation of hydraulic performance across a wider range of conditions for two refined alternatives (Alternative 4m - larger partially gated box culverts and Alternative 10 - 120 ft bridge). This memo documents the **second phase** (Phase 2) of the hydraulic analysis for the 2020-2021 Planning Study (Phase 2 Study), including the methodology and results of the hydraulic modeling for the primary replacement alternatives. Implications on upstream (landward) fish passage into the Middle River through the refined alternatives, preliminary recommendations for scour countermeasures, and evaluation of potential impacts and sediment management approaches related to development of a new channel in the landward area for the bridge alternative are discussed.

Appendix A contains the unsteady-state stage hydrograph simulation results from the hydraulic model. Appendix B contains figures that depict mapped water surface elevations[1] (WSELs) along the Middle River upstream from Dike Bridge for the refined alternatives. Appendix C contains a conceptual sketch of the anticipated channel in the landward embayment and in the expected footprint of the existing embankment of Dike Bridge for estimating impacts to regulated resources and construction costs. Appendix D contains figures depicting the U.S. Army Corps of Engineers (USACE) navigation channel bathymetry on the seaward side of Dike Bridge.

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[1] Elevations are referenced to the North American Vertical Datum of 1988 (NAVD88).

2.0 BACKGROUND[2]

The proposed hydraulic studies for the 2020-2021 Planning Study are focused on evaluating potential alternatives relative to regulatory agency request for improved upstream fish passage, and potential analysis and channel design needs for replacement of the existing culverts with a bridge structure. The Project hydraulic analyses include a two-phased hydraulic analysis approach. Phase 1 is presented in the September 2021 Phase 1 Study Memo. Phase 1 of the hydraulic analysis was performed for the five primary alternatives and simulated the following conditions:

1. Unsteady-state modeling of conditions with normal tide data as represented by tidal stage data collected by MaineDOT in 2011 with the 50th percentile (median) flow in the Middle River;
2. Unsteady-state modeling of conditions with normal tide data as represented by tidal stage data collected by MaineDOT in 2011 with the 1.1-year (Q1.1) and 10-year (Q10) riverine flow conditions for the bridge replacement alternative only (Alternative 10); and
3. Steady-state modeling of the 100-year (Q100) peak flow in the Middle River with mean high water (MHW) and mean low water (MLW) downstream boundary conditions.

The Phase 2 of the hydraulic analyses was performed for the two refined alternatives that were identified by MaineDOT following the Phase 1 Study. The Phase 2 hydraulic model simulations were developed for the following conditions:

1. Unsteady-state modeling of conditions with normal tide data as represented by updated tidal stage data collected by MaineDOT (2021) with the 50th percentile (median), 1.1-year, and 10-year flows in the Middle River;
2. Unsteady-state modeling of conditions with 1.5 feet (ft) and 3.9 ft of sea-level rise (SLR) on the normal tide hydrograph based on the updated tidal stage data collected by MaineDOT in 2021 with the 50th percentile (median), 1.1-year, and 10-year flows in the Middle River;
3. Unsteady-state modeling of conditions with the 100-year tidal surge for high tide with the 1.1-year and 10-year flows in the Middle River;
4. Unsteady-state modeling of conditions with 1.5 ft and 3.9 ft of SLR on the 100-year tidal surge for high tide with the 1.1-year and 10-year flows in the Middle River; and
5. Steady-state modeling of the 50-year (Q50) and 100-year peak flows in the Middle River with MHW and MLW downstream boundary conditions.

Phase 2 hydraulic analyses included updates to the normal tidal regime used for Phase 1, which was based on 2011 tidal data collected by MaineDOT, with tidal data collected by MaineDOT in 2021. The normal tidal regime data were used in both the Phase 1 Study and Phase 2 Study for establishing a baseline for existing conditions and for simulation of the evaluated alternatives. Interim repairs to the Dike Bridge culvert flap gates by MaineDOT in August 2021 prompted MaineDOT to collect updated tidal stage data in the Middle River upstream and in the Machias River downstream (seaward) from Dike Bridge. The tidal stage data collected by Maine DOT in 2021 were used to recalibrate the existing conditions Phase 2 hydraulic model (see Section 3.4) to establish baseline conditions across the simulation scenarios.

The objective of the Phase 2 hydraulic analyses is to build on the work completed as part of Phase 1 and include assessment of the refined alternatives for the following:

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[2] For additional Project background information refer to Section 1.0 in the September 2021 Phase 1 Study Memo.

1. Potential improvements to upstream fish passage at Dike Bridge (e.g., duration of advective landward fish passage relative to existing conditions, typical flow speeds through structure opening, water depths at lower tides);
2. Changes in water surface elevations (WSELs) landward from Dike Bridge (e.g., areas of land that would be inundated if normal tidal exchange results in higher typical WSELs);
3. Hydraulic performance for the 100-year high tide surge scenario (e.g., overtopping, freeboard)
4. Changes in hydraulic characteristics and performance as a result of SLR (e.g., upstream fish passage criteria, changes in WSELs landward from Dike Bridge, overtopping and freeboard);
5. Preliminary scour countermeasure design (e.g., stable riprap sizing); and
6. Potential impacts and preliminary sediment management approaches related to development of a new channel in the landward area for the bridge alternative as well as considerations for the area immediately seaward of the proposed bridge location.

The Phase 2 Study includes evaluation of 1) existing conditions and 2) two refined alternatives. The two refined alternatives were identified following review of the work performed as part of Phase 1 and represent MaineDOT's two refined alternative approaches for a replacement structure at Dike Bridge. Stantec developed the 2020-2021 Alternatives Matrix (Matrix), which provides a comprehensive overview of replacement alternatives for the Project. For information related to how the refined alternatives align with the Matrix, refer to the September 2021 Phase 1 Study Memo. For details related to the parameterization of the geometries of the refined alternatives for the hydraulic model, refer to Section 3.2 in this memo.

3.0 METHODOLOGY

Hydraulic modeling simulations of existing conditions and the refined alternatives were performed using the numerical, hydraulic model that Stantec developed as part of Phase 1 of the 2020-2021 Planning Study and builds on previous work (refer to the September 2021 Phase 1 Study Memo for information related to previous methodologies). The Phase 2 Study included evaluations with steady- and unsteady-state flow regimes. The following sections document the development of the hydraulic model, including the geometric data, boundary conditions, flow regimes, and model scenarios.

3.1 HYDRAULIC MODEL

A one-dimensional, steady- and unsteady-state numerical hydraulic model (Model) was developed using HEC-RAS (v. 5.0.7) for the Phase 2 Study, which includes integration of automated flap-gate routines on culvert structures. Hydraulic studies performed prior to those as part of the 2020-2021 Planning Study used an earlier version of HEC-RAS, which did not include integration of automated flap-gate routines on culvert structures.

One shortcoming of the integrated flap-gate routines is the inability to assign individual culverts flap-gates within a group of culverts in an inline structure. The flap-gate routines can either be assigned to none of the culverts or all the culverts. Alternative 4m includes bidirectional flow (i.e., no flap-gate) on one culvert barrel with flap-gates on the remaining two culvert barrels. To apply the flap-gate routines in the Model, a "dummy reach" was developed that represented a cloned parallel reach that extends approximately 500 ft upstream and 200 ft downstream of Dike Bridge. Additional details related to this geometry modification are documented in Section 3.2 (Geometry Data) in this memo.

3.2 GEOMETRY DATA

Geometric data for the Phase 2 Study Model was developed using bathymetric and topographic data provided by MaineDOT, including a limited number of bathymetric transects surveyed by MaineDOT before 2014 and augmented with bathymetric data collected in the Middle River by MaineDOT in 2021 after substantial completion of the Phase 1 Study. In addition, minor modifications to geometry transects were incorporated in the Model to increase the numerical stability during unsteady-state simulations of low-flow conditions. Normal ineffective flow areas were parameterized along the approximate top of banks along the Middle River landward from Dike Bridge. Note that normal ineffective flow areas landward of Dike Bridge upstream of the recommended expansion/contraction ineffective flow areas (see HEC-RAS documentation) were not included in the Phase 1 Study hydraulic model, but were identified during the Phase 2 Study modeling as beneficial to improving model stability and accuracy and were included as part of the Phase 2 Study.

A “dummy-reach” (Dummy Reach) was inserted to connect upstream and downstream of Dike Bridge (bifurcated geometry). This created two parallel reaches, which provided the ability to model the bidirectional flow culvert as part of Alternative 4m while still using the integrated culvert flap-gate routines. Alternative 10 was evaluated using a single thread channel. For additional information related to the bifurcated geometry approach, including a schematic overview of the Model geometry with the parallel reaches at Dike Bridge, refer to the September 2021 Phase 1 Study Memo.

The following sections document the geometric data for the Phase 2 Study Model, representing a total of three different geometries that correspond to the existing condition geometry and the two refined alternative geometries. For information related to the development of the geometric data for the Model used in the rest of the domain, refer to the September 2021 Phase 1 Study Memo.

3.2.1 Existing

The existing conditions geometry (“ex”[3]) was based on the bifurcated geometry approach that includes the cloned, dummy reach. The bifurcated geometry approach was used primarily to facilitate model calibration and for consistency of approaches across the Model simulations, since Alternative 4m also was based on the bifurcated geometry approach. The roadway embankment was modeled as two inline structures, one on each parallel reach, with one box culvert fitted with a flap-gate on Parallel Reach 1 and three box culverts fitted with flap-gates on Parallel Reach 2. The four box culverts have top-hinged flap-gates installed on the seaward side of each of the four culverts. The existing culverts and flap-gates are deteriorated, which results in partial blockage of the culverts and leakage. The integrated flap-gate routines in HEC-RAS do not allow for leakage. To accommodate leakage, a 0.35 ft high by 17 ft wide opening with the invert at -4.1 ft was used in the Model with no flap-gate for the duration of the simulation. The geometry of this “leakage opening” was determined based on an iterative calibration process comparing the simulation data to the observed data (see Section 3.4) and varied slightly from the leakage opening that was 12 ft wide as part of the Phase 1 Study.

The existing conditions culverts were modeled with heights of 4 ft and widths of 5 ft, with the culvert inverts at elevation -3.1 ft. Culvert invert selection was based on review of survey data provided by MaineDOT, including elevations of the culvert inverts. The reduced culvert heights and invert elevations were used to address apparent blockages in the bottoms of the culverts (e.g., stone, debris) as determined from bridge inspection reports provided by MaineDOT and result in the Model’s culvert inverts being approximately one foot higher than the average surveyed invert elevations of -4.05 ft. The existing culverts were modeled as 130 ft long with an entrance loss coefficient of 0.5 and an exit loss coefficient of 1. Manning’s n values in the culvert were set at 0.018 to represent some of the debris and additional roughness within the culverts due to their existing condition. The culverts were modeled using the FHWA Chart #16 (corrugated metal box culvert) and Scale #1 (90-degree headwall), which was determined to be most representative of existing conditions. Ineffective flow

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[3] Abbreviations in quotes are provided for clarity as they are combined in the HEC-RAS Plan file names that are depicted on graphics in this memo.

areas were defined within the upstream and downstream cross-sections adjacent to the bridge at an approximately one-to-one aspect ratio.

3.2.2 Alternative 4m

The Alternative 4m geometry (“alt04m”) was based on the bifurcated geometry approach. The roadway embankment was modeled as two inline structures, one on each parallel reach, with one box culvert (no flap-gates) on Parallel Reach 1 and two box culverts fitted with flap-gates on Parallel Reach 2. The Alternative 4m culvert on Parallel Reach 1 was modeled with a height of 5 ft, width of 10 ft, and the invert of the culvert at elevation -6.05 ft. Alternative 4m culverts on Parallel Reach 2 were modeled with heights of 5 ft, widths of 10 ft, and the inverts at -4.05 ft.

Based on preliminary analysis results and discussion with MaineDOT on March 29, 2021, it was decided that the box culvert heights should be reduced from 10 ft to 5 ft to better match the overall opening to hydraulic conveyance needs (i.e., reduce landward flows during flood tides) and reduce landward water surface levels. The open culvert invert was lowered with the intent of further improving fish passage for a wider range of tidal flows and the 10-ft width was maintained to address fish injury concerns. The Manning’s n for the culverts were assumed to be the same for the top and bottom at 0.012. A 130-ft culvert length was used with an entrance loss coefficient of 0.5 and an exit loss coefficient of 1. The culverts were modeled using the FHWA Chart #10 Scale #1 approach corresponding to 90-degree headwall with inlet edges chamfered three-quarters of an inch. Ineffective flow areas were defined within the upstream and downstream cross-sections adjacent to the bridge at an approximately one-to-one aspect ratio.

3.2.3 Alternative 10

The Alternative 10 geometry (“alt10”) uses a single thread channel instead of the bifurcated geometry approach. The roadway embankment was modeled as a bridge structure with a deck/roadway. The Alternative 10 bridge was modeled with bridge span of 120 ft and a clear span of 116.5 ft and a low-chord elevation of 13.1 ft. Sloping, spill-through type abutments were defined at slopes of 1.75 horizontal to 1 vertical (1.75H:1V) and 2-ft-wide benches at elevations of 10.42 ft to provide access along each abutment adjacent to both bridge abutments. The channel elevation was set at -8.5 ft. The preliminary bridge low-chord elevation was selected to match the Town of Machias’ “Phase 1” SLR protection plans to be above the highest astronomical tide (HAT) elevation of 9.8 ft and the Federal Emergency Management Agency (FEMA) Base Flood Elevation (BFE) of 10.7 ft plus a freeboard allowance for at least 1.5 ft of SLR. This results in a roadway grade raise of approximately 7 ft in the bridge area. Modeling of this alternative included changes to some of the HEC-RAS cross sections in the Middle River upstream (landward) from Dike Bridge to have a lower and more defined channel. These geometric changes were made to improve the numerical stability of the unsteady-state HEC-RAS model and reflect expected erosion of sediment in the Middle River if a bridge were installed at Dike Bridge. The bridge was modeled using the Energy (Standard Step) approach in the bridge routines. Ineffective flow areas were defined within the upstream and downstream cross-sections adjacent to the bridge at an approximately one-to-one aspect ratio.

3.3 BOUNDARY CONDITIONS

Boundary conditions for the Model included both steady- and unsteady-state regimes, which are documented in the following sections.

3.3.1 Steady-State Boundary Conditions

The upstream[4] boundary conditions for steady-state simulations as part of the 2020-2021 Planning Study included the 50- and 100-year peak flows. Peak flows were calculated and provided by MaineDOT and are referenced in previous studies (see the September 2021 Phase 1 Study Memo). Peak flows for steady-state boundary conditions at Dike Bridge and Stride Bridge[5] used in the Model are presented in Table 1. The steady-state upstream flows were input to the Model at locations landward of Stride Bridge and Dike Bridge. Under steady-state conditions, these upstream, inland flows are simulated as a constant flow value (e.g., not a hydrograph) with no attenuation due to potential storage in the Model domain.

Table 1. Drainage areas and peak upland flows for upstream steady-state boundary conditions at Dike Bridge and Stride Bridge

Location	Drainage Area (sq. mi.)	50-Year Return-Interval Event Peak Flow (cfs*)	100-Year Return-Interval Event Peak Flow (cfs)
Stride Bridge	9.41	787	912
Dike Bridge	13.22	832	958

*cfs - "cubic feet per second"

Note that the use of the bifurcated geometry approach resulted in the need to split flow between the two parallel reaches just upstream of Dike Bridge. The initial conditions flows at the upstream junction were divided equally in half for the steady-state modeling and then recombined at the junction downstream of Dike Bridge. Flow splits at the Model junctions were then calculated by the HEC-RAS model.

The downstream boundary conditions for the steady-state flow simulations were set at the downstream (seaward) limit of the Model assuming constant values of 6.1 ft for MHW and -6.6 ft for MLW. See the September 2021 Phase 1 Study Memo for additional information related to the basis for these downstream boundary conditions, including tidal statistics tables.

3.3.2 Unsteady-State Boundary Conditions

The following section documents the unsteady-state upstream and downstream boundary conditions for the Phase 2 Study.

3.3.2.1 Upstream Boundary Conditions

The upstream boundary conditions for the unsteady-state simulations included peak flow values for the annual median flow (i.e., 50% flow duration annual exceedance), 1-year peak flow (note the 1.1-year or the peak flow with an annual exceedance of 0.91 [91%] is used as representative of the 1-year peak flow), and the 10-year

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[4] "Upstream" and "downstream" are used in this report to describe the HEC-RAS model boundary conditions for consistency with boundary condition references in the HEC-RAS documentation. For reference, upstream generally refers to the landward direction and downstream generally refers to seaward direction.

[5] Stride Bridge is located landward from Dike Bridge and is included in the project HEC-RAS model that was developed for a previous study of Dike Bridge. Alternatives at Stride Bridge were not evaluated as part of the 2020-2021 Planning Study.

peak flow (i.e., annual exceedance probability of 0.1 [10%]). Upstream boundary conditions are summarized in Table 2 below.

Table 2. Peak upland flows for upstream unsteady-state boundary conditions

	Return-Interval Event (Years) / Peak Flow (cfs)		
Location	**50% Median Flow**	**1.1**	**10**
Upstream Model Boundary	13.7	152	565

3.3.2.2 Downstream Boundary Conditions

Downstream boundary conditions for "normal tide" conditions used in the unsteady-state simulations included use of tidal stage data collected by MaineDOT at the Project site from mid-August to early October 2021. These data were used as the downstream boundary condition representing typical tidal conditions. The tidal stage data were collected at two locations using datalogging pressure transducers that recorded pressure at 5-minute intervals at locations landward and seaward from Dike Bridge in the Middle River and Machias River, respectively, and post-processed by MaineDOT to develop tidal stage and elevation data. A subset of these data (September 14 to October 6, 2021) were selected for the Phase 2 Study, which represents a range of tide levels typical of this location with high-tide elevations ranging from 4.4 ft to 8.2 ft and low-tide elevations ranging from -3.9 to -8.0 ft. Note that this is compared to 4.5 to 9.0 ft and -4.7 to -7.2 ft for high- and low-tides, respectively, from the 2011 MaineDOT tidal data used as part of the Phase 1 modeling. The data subset of the seaward datalogger tide values were used for the downstream boundary condition of the unsteady-state flow model as representing typical, normal tides.

Additional downstream boundary conditions included derivations of this MaineDOT 2021 tidal data set. A summary of downstream boundary condition data used for the Phase 2 Study includes:

1. A normal tidal stage hydrograph based on a selected set of MaineDOT recorded data from September and October 2021 used as "normal tide" boundary conditions;
2. Two future SLR tidal stage hydrographs developed by adding 1.5 and 3.9 ft to the 2021 MaineDOT normal tidal stage hydrograph data;
3. A 100-year high tide surge stage hydrograph based on a subset of the 2021 MaineDOT tidal stage hydrograph data (for additional details related to the development of the 100-year high tide surge stage hydrograph, refer to Section 3.3.2.3); and
4. Two future SLR, 100-year high tide surge stage hydrographs developed by adding 1.5 ft and 3.9 ft to the 100-year high tide surge stage hydrograph (see item (3) above).

See Table 3 for a summary of the maximum and minimum high tides and low tides across the six downstream boundary conditions.

Table 3. Summary of range of minimum and maximum high- and low-tide stage hydrograph values across the Phase 2 downstream boundary conditions

Downstream Boundary Condition Description	High Tide		Low Tide	
	Minimum	Maximum	Minimum	Maximum
Normal Tide	4.39	8.19	-8.04	-3.94
Normal Tide +1.5 ft SLR	5.89	9.69	-6.54	-2.44
Normal Tide +3.9 ft SLR	8.29	12.09	-4.14	-0.04
100-Year High Tide Surge	4.46	10.70	-7.97	-4.98
100-Year High Tide Surge +1.5 ft SLR	5.96	12.20	-6.47	-3.48
100-Year High Tide Surge +3.9 ft SLR	8.36	14.60	-4.07	-1.08

3.3.2.3 100-Year Tidal Surge Hydrograph Development

A 100-year tidal surge hydrograph was developed to evaluate potential flooding associated with a tidal surge storm event. The tidal surge hydrograph was developed using guidance from MaineDOT, information presented in the report "Technical Report: Middle River Hydrologic and Alternatives Analyses" dated June 30, 2015, that was prepared for MaineDOT by Stantec (Stantec 2015), and information obtained from the current FEMA Flood Insurance Study for the Project area.

Stantec 2015 included development of a 100-year tidal surge hydrograph with a duration of 50 hours and an amplitude of 2.5 ft. This hydrograph was mapped onto tidal stage data collected by MaineDOT in 2021 to generate a synthetic storm surge hydrograph with a maximum water surface elevation of 10.7 ft in the Machias River seaward from Dike Bridge. The basis for selection of a maximum water surface elevation of 10.7 ft is that this is the elevation of the existing FEMA BFE in the Machias River.

3.4 CALIBRATION

The Phase 1 Study hydraulic model was calibrated based on the 2011 MaineDOT tidal data. Due to the updated normal tide downstream boundary condition that uses the 2021 MaineDOT data (see Section 3.3.2.2), the Phase 2 Study Model required recalibration to provide an accurate baseline for the existing conditions scenarios.

The bidirectional "leakage gate" included in the existing conditions geometry (see Section 3.1) allows for landward flow during flood tides, which is apparent in visual observations and the tidal stage data collected by MaineDOT in the Middle River landward from Dike Bridge. Similar to previous calibration efforts, gate parameters within the inline gate editor in HEC-RAS were modified until a satisfactory calibration was achieved that accounted for leakage based on visual comparison of observed and simulated upstream WSELs. Leakage was accounted for in the existing conditions geometry through use of a gate opening with a height of 0.35 ft, a width of 17 ft, and an invert at -4.1 ft (see Section 3.2.1). Figure 1 presents the simulation results of the final calibrated Model for existing conditions with a normal tide and typical riverine flows (i.e., 50% Median Flow) compared to the observed landward data.

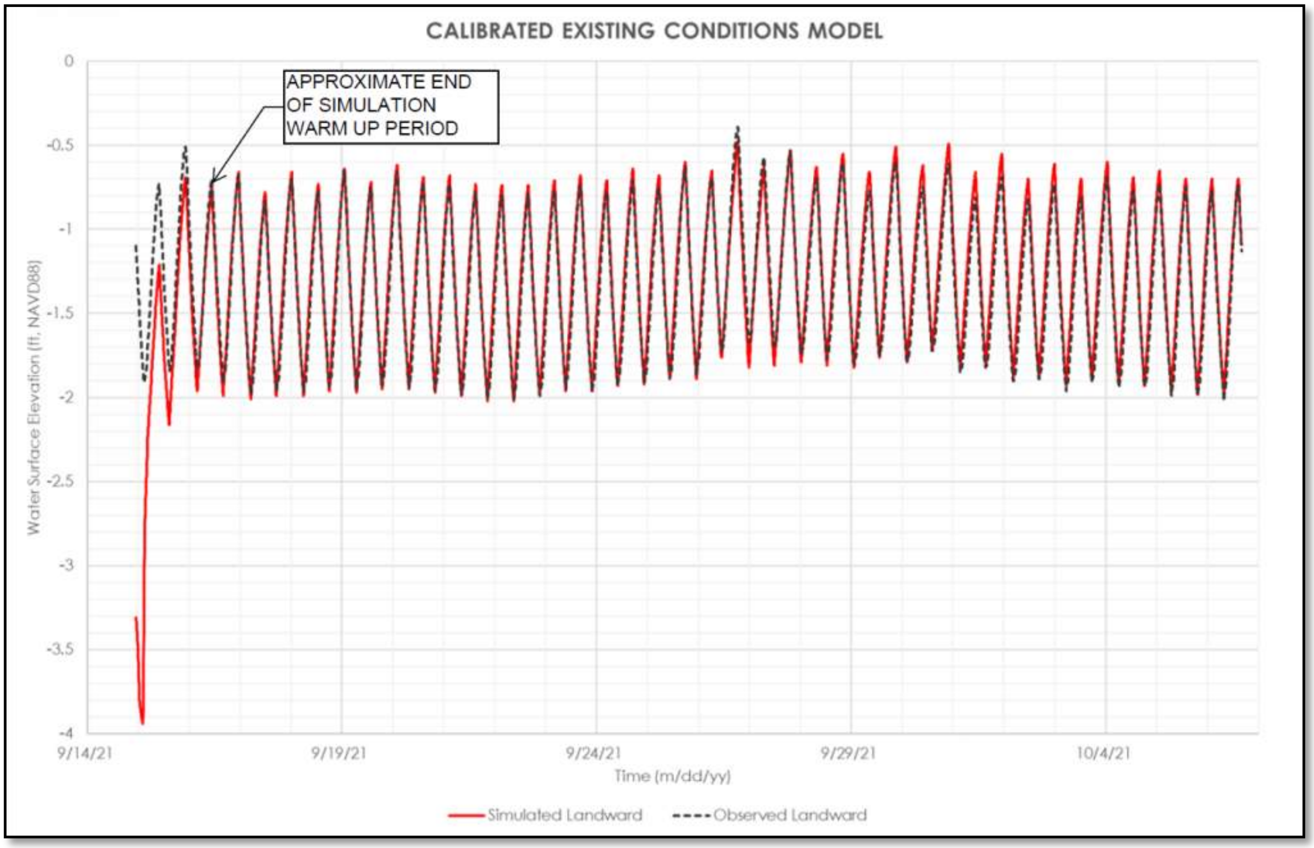

Figure 1. Final calibrated existing conditions Phase 2 Study simulation results compared to observed data

3.5 MODEL SCENARIOS

Hydraulic modeling efforts as part of the Phase 2 Study included 57 independent simulations (Model scenarios) that consisted of the unique geometries (see Section 3.2) and boundary conditions (see Section 3.3) combined together in HEC-RAS "plan" files. These simulations included 12 steady-state and 45 unsteady-state scenarios for a total of 57 plans. Table 4 presents a summary of the model scenarios used as part of the Phase 2 Study and presented in this report including the plan name, geometry name, flow name, and HEC-RAS file names.

Table 4. Summary of unique model scenarios performed as part of the Phase 2 Study

Simulation No.	ScenarioID	Plan Name	Plan File	Geom. Name	Geom. File	Flow Name	Flow File
1	ex_ss_q050_mlw	ex_ss_mlw	2021_machias_phs2.p04	ex	2021_machias_phs1.g01	ss_mlw	2021_machias_phs1.f01
2	ex_ss_q050_mhw	ex_ss_mhw	2021_machias_phs2.p02	ex	2021_machias_phs1.g01	ss_mhw	2021_machias_phs1.f02
3	ex_ss_q100_mlw	ex_ss_mlw	2021_machias_phs2.p04	ex	2021_machias_phs1.g01	ss_mlw	2021_machias_phs1.f01
4	ex_ss_q100_mhw	ex_ss_mhw	2021_machias_phs2.p02	ex	2021_machias_phs1.g01	ss_mhw	2021_machias_phs1.f02
5	alt04m_ss_q050_mlw	alt04m_ss_mlw	2021_machias_phs1.p49	alt04m	2021_machias_phs1.g04	ss_mlw	2021_machias_phs1.f01
6	alt04m_ss_q050_mhw	alt04m_ss_mhw	2021_machias_phs1.p50	alt04m	2021_machias_phs1.g04	ss_mhw	2021_machias_phs1.f02
7	alt04m_ss_q100_mlw	alt04m_ss_mlw	2021_machias_phs1.p49	alt04m	2021_machias_phs1.g04	ss_mlw	2021_machias_phs1.f01
8	alt04m_ss_q100_mhw	alt04m_ss_mhw	2021_machias_phs1.p50	alt04m	2021_machias_phs1.g04	ss_mhw	2021_machias_phs1.f02
9	alt10_ss_q050_mlw	alt10_ss_mlw	2021_machias_phs1.p51	alt10	2021_machias_phs1.g08	ss_mlw-singlethread	2021_machias_phs1.f03
10	alt10_ss_q050_mhw	alt10_ss_mhw	2021_machias_phs1.p52	alt10	2021_machias_phs1.g08	ss_mhw-singlethread	2021_machias_phs1.f04
11	alt10_ss_q100_mlw	alt10_ss_mlw	2021_machias_phs1.p51	alt10	2021_machias_phs1.g08	ss_mlw-singlethread	2021_machias_phs1.f03
12	alt10_ss_q100_mhw	alt10_ss_mhw	2021_machias_phs1.p52	alt10	2021_machias_phs1.g08	ss_mhw-singlethread	2021_machias_phs1.f04
13	ex_us_fd50per_normtide	ex_us_fd50per_normtide	2021_machias_phs2.p03	ex	2021_machias_phs2.g01	us_fd50per_normtide	2021_machias_phs2.u01
14	ex_us_q001_normtide	ex_us_q001_normtide	2021_machias_phs2.p05	ex	2021_machias_phs2.g01	us_q001_normtide	2021_machias_phs2.u02
15	ex_us_q010_normtide	ex_us_q010_normtide	2021_machias_phs2.p06	ex	2021_machias_phs2.g01	us_q010_normtide	2021_machias_phs2.u03
16	ex_us_fd50per_SLR1p5	ex_us_fd50per_SLR1p5	2021_machias_phs2.p09	ex	2021_machias_phs2.g01	us_fd50per_SLR1p5	2021_machias_phs2.u07
17	ex_us_q001_SLR1p5	ex_us_q001_SLR1p5	2021_machias_phs2.p16	ex	2021_machias_phs2.g01	us_q001_SLR1p5	2021_machias_phs2.u11
18	ex_us_q010_SLR1p5	ex_us_q010_SLR1p5	2021_machias_phs2.p25	ex	2021_machias_phs2.g01	us_q010_SLR1p5	2021_machias_phs2.u13
19	ex_us_fd50per_SLR3p9	ex_us_fd50per_SLR3p9	2021_machias_phs2.p10	ex	2021_machias_phs2.g01	us_fd50per_SLR3p9	2021_machias_phs2.u08
20	ex_us_q001_SLR3p9	ex_us_q001_SLR3p9	2021_machias_phs2.p17	ex	2021_machias_phs2.g01	us_q001_SLR3p9	2021_machias_phs2.u12
21	ex_us_q010_SLR3p9	ex_us_q010_SLR3p9	2021_machias_phs2.p26	ex	2021_machias_phs2.g01	us_q010_SLR3p9	2021_machias_phs2.u14
22	ex_us_q001_surge-high	ex_us_q001_surge-high	2021_machias_phs2.p31	ex	2021_machias_phs2.g01	us_q001_surge-high	2021_machias_phs2.u19
23	ex_us_q010_surge-high	ex_us_q010_surge-high	2021_machias_phs2.p32	ex	2021_machias_phs2.g01	us_q010_surge-high	2021_machias_phs2.u20
24	ex_us_q001_surgehigh-SLR1p5	ex_us_q001_surgehigh-SLR1p5	2021_machias_phs2.p37	ex	2021_machias_phs2.g01	us_q001_surgehigh-SLR1p5	2021_machias_phs2.u23
25	ex_us_q010_surgehigh-SLR1p5	ex_us_q010_surgehigh-SLR1p5	2021_machias_phs2.p39	ex	2021_machias_phs2.g01	us_q010_surgehigh-SLR1p5	2021_machias_phs2.u24
26	ex_us_q001_surgehigh-SLR3p9	ex_us_q001_surgehigh-SLR3p9	2021_machias_phs2.p43	ex	2021_machias_phs2.g01	us_q001_surgehigh-SLR3p9	2021_machias_phs2.u27
27	ex_us_q010_surgehigh-SLR3p9	ex_us_q010_surgehigh-SLR3p9	2021_machias_phs2.p46	ex	2021_machias_phs2.g01	us_q010_surgehigh-SLR3p9	2021_machias_phs2.u29
28	alt04m_us_fd50per_normtide	alt04m_us_fd50per_normtide	2021_machias_phs2.p12	alt04m	2021_machias_phs2.g04	us_fd50per_normtide	2021_machias_phs2.u01
29	alt04m_us_q001_normtide	alt04m_us_q001_normtide	2021_machias_phs2.p07	alt04m	2021_machias_phs2.g04	us_q001_normtide	2021_machias_phs2.u02
30	alt04m_us_q010_normtide	alt04m_us_q010_normtide	2021_machias_phs2.p08	alt04m	2021_machias_phs2.g04	us_q010_normtide	2021_machias_phs2.u03
31	alt04m_us_fd50per_SLR1p5	alt04m_us_fd50per_SLR1p5	2021_machias_phs2.p11	alt04m	2021_machias_phs2.g04	us_fd50per_SLR1p5	2021_machias_phs2.u07
32	alt04m_us_q001_SLR1p5	alt04m_us_q001_SLR1p5	2021_machias_phs2.p18	alt04m	2021_machias_phs2.g04	us_q001_SLR1p5	2021_machias_phs2.u11
33	alt04m_us_q010_SLR1p5	alt04m_us_q010_SLR1p5	2021_machias_phs2.p27	alt04m	2021_machias_phs2.g04	us_q010_SLR1p5	2021_machias_phs2.u13

Simulation No.	ScenarioID	Plan Name	Plan File	Geom. Name	Geom. File	Flow Name	Flow File
34	alt04m_us_fd50per_SLR3p9	alt04m_us_fd50per_SLR3p9	2021_machias_phs2.p13	alt04m	2021_machias_phs2.g04	us_fd50per_SLR3p9	2021_machias_phs2.u08
35	alt04m_us_q001_SLR3p9	alt04m_us_q001_SLR3p9	2021_machias_phs2.p19	alt04m	2021_machias_phs2.g04	us_q001_SLR3p9	2021_machias_phs2.u12
36	alt04m_us_q010_SLR3p9	alt04m_us_q010_SLR3p9	2021_machias_phs2.p28	alt04m	2021_machias_phs2.g04	us_q010_SLR3p9	2021_machias_phs2.u14
37	alt04m_us_q001_surge-high	alt04m_us_q001_surge-high	2021_machias_phs2.p33	alt04m	2021_machias_phs2.g04	us_q001_surge-high	2021_machias_phs2.u19
38	alt04m_us_q010_surge-high	alt04m_us_q010_surge-high	2021_machias_phs2.p34	alt04m	2021_machias_phs2.g04	us_q010_surge-high	2021_machias_phs2.u20
39	alt04m_us_q001_surgehigh-SLR1p5	alt04m_us_q001_surgehigh-SLR1p5	2021_machias_phs2.p38	alt04m	2021_machias_phs2.g04	us_q001_surgehigh-SLR1p5	2021_machias_phs2.u23
40	alt04m_us_q010_surgehigh-SLR1p5	alt04m_us_q010_surgehigh-SLR1p5	2021_machias_phs2.p40	alt04m	2021_machias_phs2.g04	us_q010_surgehigh-SLR1p5	2021_machias_phs2.u24
41	alt04m_us_q001_surgehigh-SLR3p9	alt04m_us_q001_surgehigh-SLR3p9	2021_machias_phs2.p44	alt04m	2021_machias_phs2.g04	us_q001_surgehigh-SLR3p9	2021_machias_phs2.u27
42	alt04m_us_q010_surgehigh-SLR3p9	alt04m_us_q010_surgehigh-SLR3p9	2021_machias_phs2.p47	alt04m	2021_machias_phs2.g04	us_q010_surgehigh-SLR3p9	2021_machias_phs2.u29
43	alt10_us_fd50per_normtide	alt10_us_fd50per_normtide	2021_machias_phs2.p22	alt10	2021_machias_phs2.g08	us_fd50per_normtide-singlethread	2021_machias_phs2.u04
44	alt10_us_q001_normtide	alt10_us_q001_normtide	2021_machias_phs2.p23	alt10	2021_machias_phs2.g08	us_q001_normtide-singlethread	2021_machias_phs2.u05
45	alt10_us_q010_normtide	alt10_us_q010_normtide	2021_machias_phs2.p24	alt10	2021_machias_phs2.g08	us_q010_normtide-singlethread	2021_machias_phs2.u06
46	alt10_us_fd50per_SLR1p5	alt10_us_fd50per_SLR1p5	2021_machias_phs2.p14	alt10	2021_machias_phs2.g08	us_fd50per_SLR1p5-singlethread	2021_machias_phs2.u09
47	alt10_us_q001_SLR1p5	alt10_us_q001_SLR1p5	2021_machias_phs2.p20	alt10	2021_machias_phs2.g08	us_q001_SLR1p5-singlethread	2021_machias_phs2.u15
48	alt10_us_q010_SLR1p5	alt10_us_q010_SLR1p5	2021_machias_phs2.p29	alt10	2021_machias_phs2.g08	us_q010_SLR1p5-singlethread	2021_machias_phs2.u17
49	alt10_us_fd50per_SLR3p9	alt10_us_fd50per_SLR3p9	2021_machias_phs2.p15	alt10	2021_machias_phs2.g08	us_fd50per_SLR3p9-singlethread	2021_machias_phs2.u10
50	alt10_us_q001_SLR3p9	alt10_us_q001_SLR3p9	2021_machias_phs2.p21	alt10	2021_machias_phs2.g08	us_q001_SLR3p9-singlethread	2021_machias_phs2.u16
51	alt10_us_q010_SLR3p9	alt10_us_q010_SLR3p9	2021_machias_phs2.p30	alt10	2021_machias_phs2.g08	us_q010_SLR3p9-singlethread	2021_machias_phs2.u18
52	alt10_us_q001_surge-high	alt10_us_q001_surge-high	2021_machias_phs2.p35	alt10	2021_machias_phs2.g08	us_q001_surge-high-singlethread	2021_machias_phs2.u21
53	alt10_us_q010_surge-high	alt10_us_q010_surge-high	2021_machias_phs2.p36	alt10	2021_machias_phs2.g08	us_q010_surge-high-singlethread	2021_machias_phs2.u22
54	alt10_us_q001_surgehigh-SLR1p5	alt10_us_q001_surgehigh-SLR1p5	2021_machias_phs2.p41	alt10	2021_machias_phs2.g08	us_q001_surgehigh-SLR1p5-singlethread	2021_machias_phs2.u25
55	alt10_us_q010_surgehigh-SLR1p5	alt10_us_q010_surgehigh-SLR1p5	2021_machias_phs2.p42	alt10	2021_machias_phs2.g08	us_q010_surgehigh-SLR1p5-singlethread	2021_machias_phs2.u26
56	alt10_us_q001_surgehigh-SLR3p9	alt10_us_q001_surgehigh-SLR3p9	2021_machias_phs2.p45	alt10	2021_machias_phs2.g08	us_q001_surgehigh-SLR3p9-singlethread	2021_machias_phs2.u28
57	alt10_us_q010_surgehigh-SLR3p9	alt10_us_q010_surgehigh-SLR3p9	2021_machias_phs2.p48	alt10	2021_machias_phs2.g08	us_q010_surgehigh-SLR3p9-singlethread	2021_machias_phs2.u30

4.0 RESULTS

The following sections summarize the hydraulic Model simulation results for the steady- and unsteady-state scenarios.

4.1 STEADY-STATE

A total of 12 steady-state simulations were performed as part of the Study. Table 5 presents a summary of results from the steady-state Model simulations. The results are presented based on the WSELs upstream (US) and downstream (DS) of Dike Bridge.

Table 5. Summary of upstream and downstream WSELs across steady-state simulations. Note that values in parenthesis are WSELs previously reported in the Phase 1 Study that changed as part of the Phase 2 Study*.

	Q50 with MLW		Q50 with MHW		Q100 with MLW		Q100 with MHW	
Alternative	**US WSEL (ft)**	**DS WSEL (ft)**	**US WSEL (ft)**	**DS WSEL (ft)**	**US WSEL (ft)**	**DS WSEL (ft)**	**US WSEL (ft)**	**DS WSEL (ft)**
Existing Conditions	1.6	-6.6	7.5	6.1	1.9 (5.9)	-6.6	8.0 (10.9)	6.1
Alternative 04m	0.1	-6.6	6.6	6.1	0.5 (0.8)	-6.6	6.8 (7.3)	6.1
Alternative 10	-4.9	-6.8	6.1	6.1	-4.6 (-5.0)	-6.7	6.1 (6.1)	6.1

*Note: Some values in this table were updated during the Phase 2 Study reporting and reflect some differences from the Phase 1 Study reporting.

Note that the Phase 1 Study included evaluation of the 100-year peak flow scenario for these three alternatives and reported values that varied from those reported herein. Apparent differences in reported values between the Phase 1 and Phase 2 modeling are due to 1) a recalibrated existing conditions model, 2) updated bathymetric data, and 3) more extensive use of ineffective flow areas landward of Dike Bridge along the Middle River identified during Phase 2 to improve model stability and accuracy.

4.2 UNSTEADY STATE

A total of 45 unsteady-state simulations were performed as part of the Phase 2 Study. Appendix A contains figures representing the stage hydrograph simulation outputs. The observed MaineDOT 2021 stage data landward of Dike Bridge was included in the flow stage hydrographs, with the exception of the scenarios that included the 100-year high tide surge downstream boundary condition with and without SLR, to compare differences between the exiting and proposed scenarios.

Maximum upstream and downstream WSELs and the total change between these values were calculated for each of the modeled scenarios. In addition, the percentage of time flow was being conveyed landward (i.e., flows moving from the sea [downstream] towards land [upstream]) at Dike Bridge were calculated based on the simulation results. The maximum WSELs in the Middle River and upstream WSEL range for the normal tide, normal tide with 1.5 ft of SLR, and normal tide with 3.9 ft of SLR downstream boundary conditions are presented in Tables 6, 7, and 8, respectively. A summary of maximum upstream WSELs from the unsteady-state simulations for the 100-year surge for high tide is presented in Table 9. Percentage of time of landward flow for the duration of the simulation are presented in Table 10. For discussion related to the results presented in this section, see Section 5.0.

Table 6. Summary of maximum, minimum, and maximum range of WSELs from the unsteady-state simulations for the normal tide downstream boundary conditions

Alternative	Median Flow			Q1.1-Year			Q10-Year		
	Max US WSEL	Min US WSEL	Range	Max US WSEL	Min US WSEL	Range	Max US WSEL	Min US WSEL	Range
Existing Conditions	-0.5	-2.0	1.5	1.4	-0.2	1.6	5.2	3.5	1.7
Alternative 4m	2.1	-3.2	5.3	2.7	-2.1	4.8	4.1	0.3	3.8
Alternative 10	7.9	-7.4	15.3	7.9	-6.9	14.8	8.0	-5.5	13.4

Table 7. Summary of maximum, minimum, and maximum range of WSELs from the unsteady-state simulations for the normal tide plus 1.5 ft of SLR downstream boundary conditions

Alternative	Median Flow			Q1.1-Year			Q10-Year		
	Max US WSEL	Min US WSEL	Range	Max US WSEL	Min US WSEL	Range	Max US WSEL	Min US WSEL	Range
Existing Conditions	0.1	-1.7	1.8	1.9	0.2	1.7	5.9	4.3	1.6
Alternative 4m	2.7	-2.2	4.9	3.3	-1.2	4.5	4.7	1.3	3.5
Alternative 10	9.3	-6.3	15.7	9.4	-6.2	15.5	9.4	-5.2	14.6

Table 8. Summary of maximum, minimum, and maximum range of WSELs from the unsteady-state simulations for the normal tide plus 3.9 ft of SLR downstream boundary conditions

Alternative	Median Flow			Q1.1-Year			Q10-Year		
	Max US WSEL	Min US WSEL	Range	Max US WSEL	Min US WSEL	Range	Max US WSEL	Min US WSEL	Range
Existing Conditions	5.4	-0.6	6.0	6.2	1.3	4.9	9.0	5.6	3.5
Alternative 4m	3.9	-0.5	4.4	4.4	0.4	4.0	6.1	3.1	3.0
Alternative 10	11.7	-3.9	15.6	11.7	-3.8	15.6	11.8	-3.5	15.2

Table 9. Summary of maximum upstream WSELs from the unsteady-state simulations for the 100-Year surge for high tide

Alternative	Q1.1-Year	Q10-Year	Q1.1-Year (1.5 ft SLR)	Q10-Year (1.5 ft SLR)	Q1.1-Year (3.9 ft SLR)	Q10-Year (3.9 ft SLR)
	Max US WSEL	Max US WSEL	Max US WSEL	Max US WSEL	Max US WSEL	Max US WSEL
Existing Conditions	1.5	5.5	5.5	7.8	14.6	14.6
Alternative 4m	3.1	4.5	3.6	5.1	4.5	6.1
Alternative 10	10.1	10.1	11.5	11.6	13.9	13.9

Table 10. Summary of percent landward flow for typical, median (50%) riverine flows and normal tide downstream boundary conditions

Alternative	Normal Tide	Normal Tide +1.5 ft SLR	Normal Tide +3.9 ft SLR
Existing Conditions	57%	63%	68%
Alternative 4m	53%	57%	62%
Alternative 10	44%	46%	48%

4.3 INUNDATED LAND FOR NORMAL TIDAL AND RIVER FLOW CONDITIONS

This section summarizes areas of inundated land upstream from Dike Bridge for the two refined alternatives based on 1) an elevation-area relationship (stage-area curve) and 2) the unsteady-state simulation results for the maximum WSELs during normal tidal and riverine flow conditions from the Phase 2 Study (see Table 6). Reference Appendix B for figures that depict WSEL contours for selected conditions for the Phase 2 Study alternatives in the area adjacent to the Middle River upstream from Dike Bridge.

The stage-area curve is presented in the September 2021 Phase 1 Study Memo and was developed using the existing terrain model that was compiled for the Phase 2 Study Model. Refer to the September 2021 Phase 1 Study memo for details related to the stage-area curve development.

Table 11 presents the maximum upstream WSELs for normal tidal and riverine flow conditions based on the stage-area curve relationships. The “Increased Inundation Area” in Table 11 reflects estimated inundated areas in the Middle River with normal tidal and riverine flow conditions upstream from Dike Bridge above elevation 0.0 ft and exclusive of the existing, regularly inundated area (~33 acres). Table 11 depicts an inundation area based on 1) tidal stage data in the Middle River collected by MaineDOT in 2021 and 2) additional bathymetric data collected by MaineDOT in 2021.

Table 11. Inundated areas and increased inundated areas for maximum upstream WSELs for normal tidal and riverine flow conditions

Alternative	Max US WSEL (ft)	Inundation Area (acres)	Increased Inundation Area (acres)
Existing Conditions	-0.5	32.7	n/a
Alternative 4m	2.1	119	86
Alternative 10	7.9	431	398

4.4 FISH PASSAGE

Hydraulic parameters related to fish passage, including flow speed and depth of flow, were evaluated for the bridge alternative (Alternative 10) based on the results of the model simulations. Results from this evaluation are presented in this section and are relevant to discussion of fish passage for the refined alternatives as part of the Project.

Flow speeds were calculated by dividing the discharge through the bridge with a representative (average) area through the prismatic, trapezoidal cross-sectional geometry at the bridge opening. Note that this approach results in a depth-averaged flow speed and does not account for variations in flow speed within the water column or laterally across the channel. Although more complex modeling approaches (e.g., two- or three-dimensional modeling) and/or physical modeling could assist in achieving a higher precision of flow distribution, the modeling approach used for this study with the accompanying assumptions and limitations was considered suitable for providing a general evaluation of bridge hydraulics that meet the needs of the Project.

The percent exceedance of average flow speeds for the modeled bridge alternatives are presented in Table 12 for the full tidal spectrum (i.e., All Flows), landward flows only (i.e., Landward), and seaward flows only (i.e., Seaward). In general, the flow speeds for the seaward flows were slightly greater than those for the landward flows, which is expected since the current is not working against the downstream riverine flows. However, the differences were very small and were not significantly different.

Table 12. Summary of average flow speed (feet per second [ft/s]) percent exceedance distributions through the Alternative 10 bridge opening for median (50%) riverine flows and normal tide boundary conditions for landward flows only, seaward flows only, and all flows for the simulation duration.

Percent Exceedance	Landward (ft/s)	Seaward (ft/s)	All Flows (ft/s)
95%	7.9	8.8	8.4
90%	7.5	8.1	7.8
75%	6.3	6.5	6.4
50%	4.2	4.1	4.1
25%	1.7	2.0	1.9
10%	0.5	0.8	0.6

Figure 2 graphically depicts the information in Table 12 for seaward flows, since these flows correspond with upstream fish passage conditions. Fish passage maximum swimming speed criteria[6] are also presented in Figure 2, which are based on general categories of strong, moderate, and weak swimming species with maximum flow speed criteria of 12 ft/s, 6 ft/s, and 3 ft/s, respectively. In addition, an all-species criterion of 0.75 ft/s as additionally suggested by Project stakeholders as part of the Project planning phase is included.

Figure 3 and Figure 4 present the unsteady-state stage hydrograph for the full simulation time frame as well as for a select two-day tidal cycle for Alternative 10 with bridge headwater (HW), tailwater (TW), and average flow speeds through the bridge span for median annual (i.e. 50% exceedance) riverine flows and normal tidal boundary conditions. The two-day tidal cycle presented in Figure 4 is useful for examining the relationship between headwater and tailwater with flow speed. Negative flow speeds represent flow landward (upstream) and positive flow speeds represent flow seaward (downstream). The greatest flow speeds for each tidal cycle occur during the ebb tide when the difference in headwater and tailwater are the greatest. Similarly, the second greatest flow speed occurs during the flood tide. This is also reflected in the differences in the 95% exceedance flows comparing seaward and landward flow speeds in Table 12, since the seaward flow speed is higher than the landward for these higher flows.

Flow depths in the bridge were calculated by taking the average of the headwater and tailwater WSELs and comparing to the proposed channel elevation through the bridge (-8.5 ft). A close up of typical depths of flow through the Alternative 10 bridge opening during the simulation with median (50%) riverine flows and normal tide boundary conditions are presented in Figure 5

For reference to simulated ambient flow speed conditions in the Middle River, Figure 5 presents simulated flow speeds at HEC-RAS cross-section 3028.072 in the Middle River approximately 2,500 ft upstream from Dike Bridge along with the general fish passage maximum flow speed criteria thresholds. Information presented in Figure 5 indicates that regular ebb tide (seaward) flow speeds typically exceed the all-species criterion of 0.75 ft/s and, at times, exceed a flow speed of 3 ft/s. A similar evaluation of minimum depths of water identifies that typical depths at this cross-section are approximately 1 ft except during higher low tides when depths approach up to approximately 2 ft.

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[6] Criteria are based on the values presented in the *Federal Interagency Nature-like Fishway Passage Design Guidelines for Atlantic Coast Diadromous Fishes* by Turek, J., Haro, A., & Towler, B., and published in May 2016 by the National Marine Fisheries Service, the U.S. Geological Survey, and the U.S. Fish and Wildlife Service.

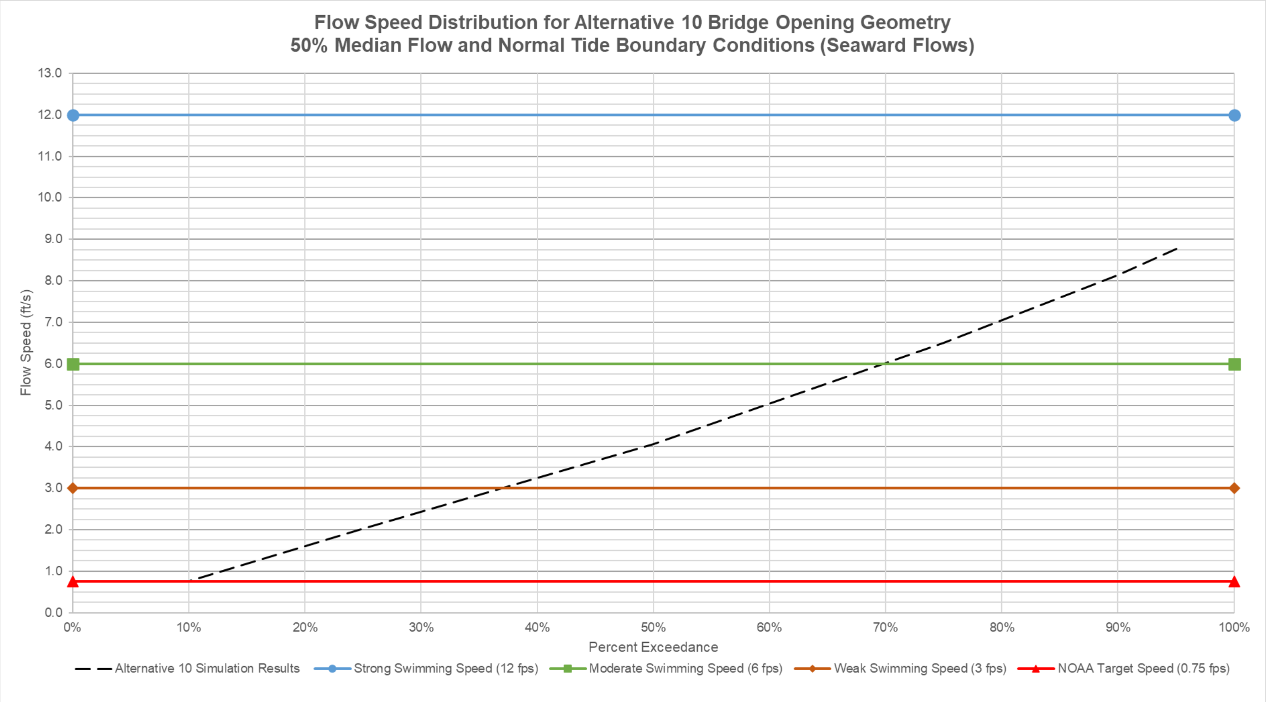

Figure 2. Flow speed distribution for the Alternative 10 bridge opening geometry for seaward flows only with fish passage flow speed criteria for ebb tide

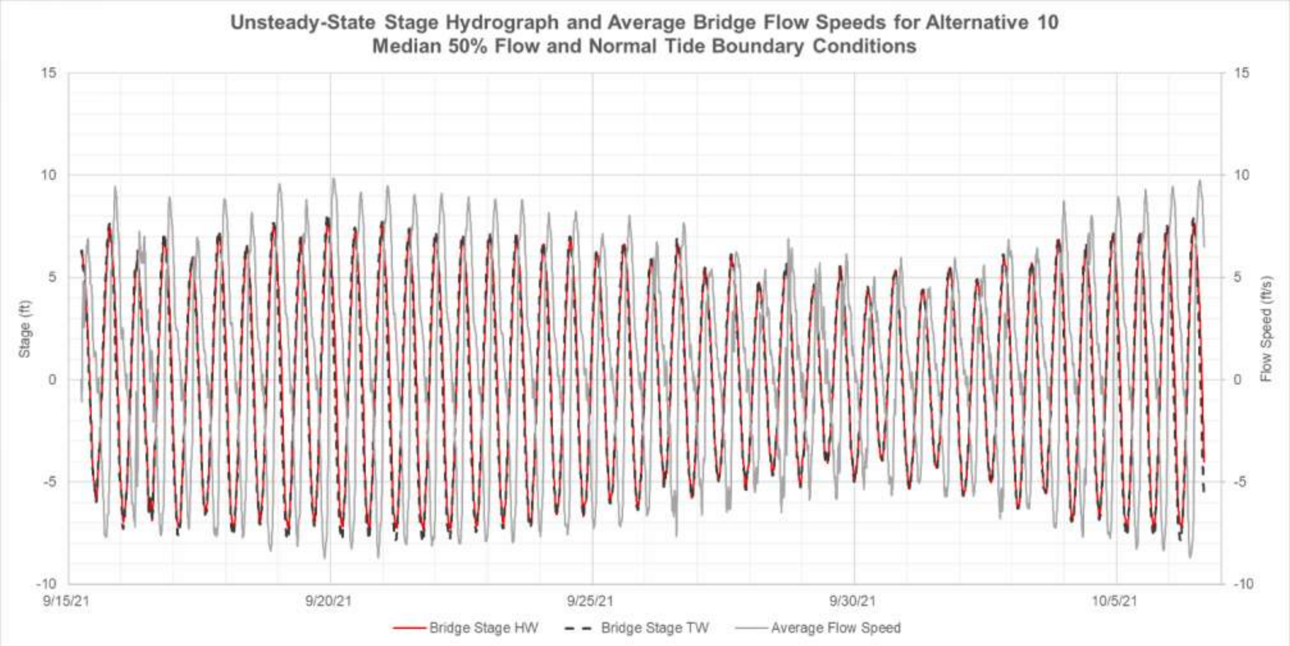

Figure 3. Unsteady-state stage hydrograph and average flow speeds through the bridge for Alternative 10 for median (50%) riverine flows and normal tide boundary conditions.

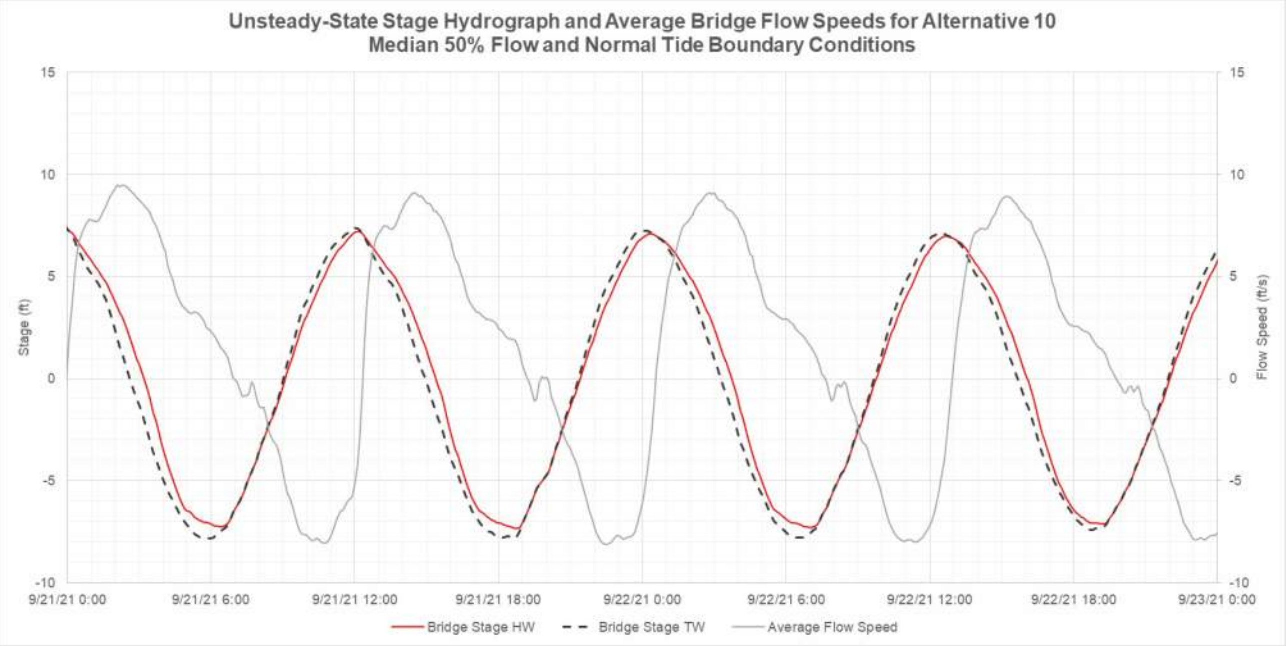

Figure 4. Close-up of typical unsteady-state stage hydrograph and average flow speeds through the bridge for Alternative 10 for median (50%) riverine flows and normal tide boundary conditions.

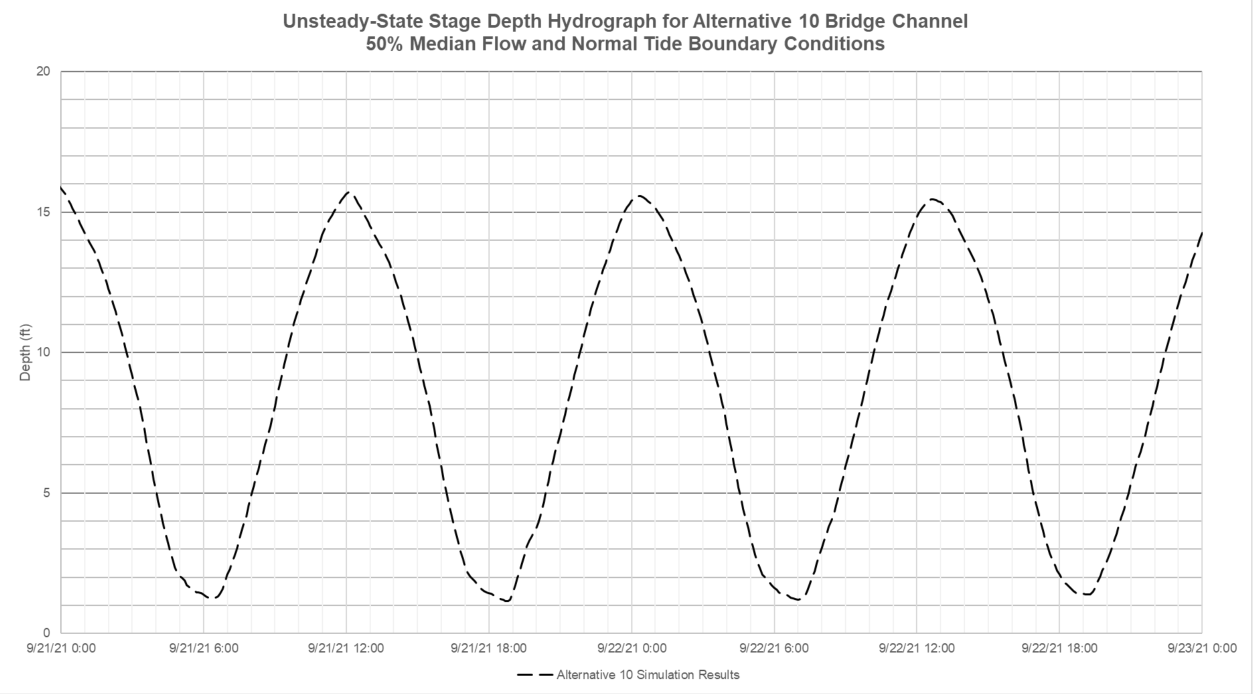

Figure 5. Close-up of the typical unsteady-state depth hydrograph for flow through the Alternative 10 bridge opening.

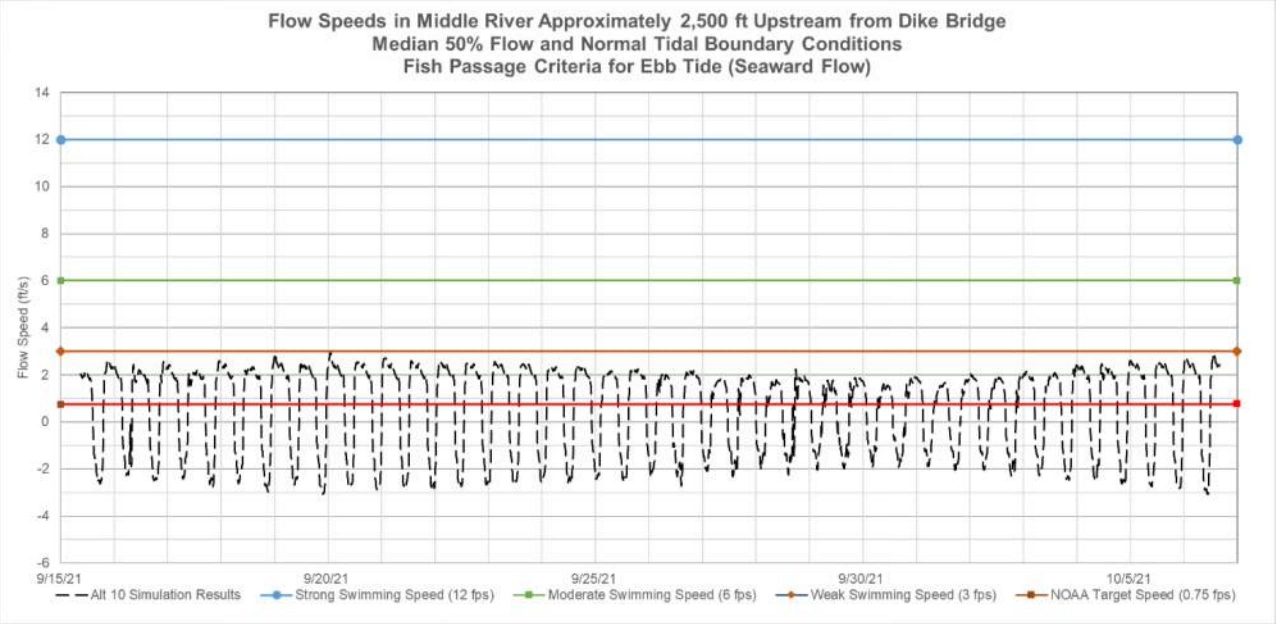

Figure 6. Overview of the Alternative 10 average bridge flow speeds for median (50%) riverine flow and normal tide boundary conditions with fish passage criteria for ebb tide.

4.5 PRELIMINARY SCOUR COUNTERMEASURE DESIGN

Scour countermeasure rock armor sizing was assessed from the model results using the method presented in the US Army Corps of Engineers (USACE) Engineering Manual EM-1110-2-1601 (Hydraulic Design of Flood Control Channels)[7]. The USACE approach is the method recommended in the National Cooperative Highway Research Program NCHRP 568 Report and as recommended in the Federal Highway Administration Hydraulic Engineering Circular No. 23 Design Guidelines #4 and #14.

Input parameters for calculation of the rock armor size were obtained from the Model and professional judgement. The D_{30} is determined and D_{50} is then calculated based on a uniformity ratio (D_{85}/D_{15}) of 2. Input parameters that were used to calculate the rock material D_{30} include depth of water and flow speed, a safety factor (Sf) of 1.1, a stability coefficient (CS) of 0.3 (corresponding to angular rock), a vertical velocity coefficient (CV) of 1.0 corresponding to a straight channel alignment, and a rock armor thickness coefficient (CT) of 1.3 corresponding to a rock armor thickness of more than two-times the material D_{50} or greater than the D_{100}. The side-slope correction factor (K1) was set at 0.9 based on an angle of repose of angular rock of 40 degrees and a maximum side slope of 3.5 horizontal: 1 vertical (approximately 16 degrees). The unit weight of water (Y_W) was set at 62.4 pounds per cubic foot (pcf) and the unit weight of the rock material (Y_S) was set as 156 pcf based on a specific gravity of 2.5. Note that this approach is limited to longitudinal (parallel to the direction of flow) channel bed slopes of less than 2% and that the ratio of the D_{30} to the channel depth at the design flow is greater than or equal to 0.02 (i.e., the depth of water is less than 50-times the D_{30}).

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[7] USACE. 1994. *Hydraulic design of flood control channels*. Engineer manual 1110-2-1601.

A stable rock size was calculated for the Alternative 10 bridge using the estimated average flow speed and depth of flow in the middle of the proposed bridge channel for the median, 1.1-, and 10-year flows. Seaward and landward flow directions were both used in the calculation. The median D_{50} rock size was determined to be approximately 2.47, 2.51, and 2.71 ft for the typical, median (50%) flow, and 1.1- and 10-year peak flows, respectively. These results suggest that the approximate size of stable rock armor material for scour countermeasures would need to have a nominal diameter of approximately 3 ft, which is consistent with MaineDOT's "Heavy Riprap" material specification. Note that the Phase 2 Study Model results indicate that maximum discharges for simulations with the median (50%) riverine flow and normal tide boundary conditions results in maximum discharges of approximately 10,000 cfs that are substantially greater than the evaluated peak flow riverine discharges (e.g., the 100-year peak flow in the Middle River at Dike Bridge is 958 cfs). Unlike typical riverine bridges, regular tidal conditions are therefore specifically relevant to design of scour countermeasures for Alternative 10.

5.0 DISCUSSION

This section presents discussion of the hydraulic model simulation results for the Phase 2 Study as part of the Project including discussion on WSELs landward of Dike Bridge, inundated land, fish passage, preliminary scour countermeasure design, and dredging and sediment transport considerations.

5.1 LANDWARD WATER SURFACE ELEVATIONS

There are minor variations between results presented in this memo compared to the results presented in the September 2021 Phase 1 Study Memo. These variations can be attributed to (1) updated downstream tide data that was collected in 2021 by MaineDOT and supersedes the previous 2011 tidal dataset, (2) updated bathymetric data, and (3) additional normal ineffective flow areas along the banks of the Middle River upstream of Dike Bridge, where identified and included during Phase 2 to improve Model stability and accuracy. In general, these variations are minor and do not appear to represent significant deviations from the Phase 1 Study findings.

Both Alternative 4m and Alternative 10 provide increases in the upstream tidal range across the range of scenarios modeled. Alternative 4m provides significantly less of a landward tidal range compared to Alternative 10 (e.g., 5.3 ft versus 15.3 ft during normal flows and normal tides, see Table 6). Alternative 10 provides a greater hydraulic conveyance capacity compared to existing conditions and Alternative 4m due to the larger effective, cross-sectional area and therefore was less sensitive to increases in maximum landward WSELs with increased flow. Overall, as the upstream inflows increase, maximum and minimum landward WSELs increase and the ranges (difference between maximum and minimum landward surface elevations during the simulation period) decrease.

SLR results in higher maximum and minimum WSELs landward from Dike Bridge (see Table 7 and Table 8). For the existing-conditions simulations, the maximum landward WSELs increases from approximately -0.5 ft to 0.1 ft, representing an increase in approximately 0.6 ft, for the 1.5-ft SLR increase to the normal tidal range under median flow conditions. Similarly, 1.5 ft of SLR under median flow conditions also results in approximately 0.6 ft of increase in the landward maximum WSELs for Alternative 4m. The Alternative 10 bridge approaches tidal transparency and consequently results in a comparatively greater increase in landward maximum WSELs as a result of SLR. For example, 1.5 ft of SLR results in an increase from a maximum landward WSEL of 7.9 ft to 9.3 ft (1.4-ft increase) for Alternative 10 under median riverine flow conditions.

The maximum tidal stage for the normal tide with 3.9 ft of SLR was approximately 12.1 ft, which was above the top elevation of the existing Dike Bridge roadway (see Table 3). Therefore, under the existing conditions simulations, it is expected that the existing Dike Bridge would be overtopped and that landward WSELs and resulting flooding would occur under this SLR scenario. This is reflected in the dramatic increase in maximum landward WSEL under the existing conditions simulations for 3.9 ft of SLR (see Table 8). The variations in landward tidal amplitude, and specifically the peak high-tide stages, occurring during spring tides for the 3.9 ft of SLR downstream normal tide boundary condition appears to result in perturbations in the landward existing conditions scenario WSELs (see Figures A.13, A.19, A.25, A.37, and A.43 in Appendix A). The maximum elevation of the perturbations occur during the peak stage of the spring tide series and dampen as riverine flow increases (e.g., comparing Figures A.13 to A.25). The apparent cause of the perturbations is landward flow over Dike Bridge during spring tides with 3.9 ft of SLR, consequent surcharging in the Middle River, and limited seaward discharge on the ebb tide. Simulations for Alternative 4m do not result in similar perturbations and appear to reflect increased seaward discharge capacity with Alternative 4m as well as no overtopping. More refined modeling may be necessary to resolve the complex hydraulic occurring during these overtopping events within the vicinity of the bridge under existing conditions. However, it is unlikely that the existing configuration at Dike Bridge would be present under the 3.9-ft SLR scenario, which is based on potential end-of-century climate change scenarios and is rather included to provide approximately relative comparisons between alternatives. Note that the refined alternatives evaluated assume that the top of the roadway would be greater than the maximum tidal stage for SLR boundary conditions and no overtopping would occur.

5.2 INUNDATED AREA LANDWARD OF DIKE BRIDGE

Both alternatives will result in an increase in inundation area. Of the two refined alternatives, Alternative 10 will result in the largest increase in inundated area landward of Dike Bridge. The increased inundated land area is a result of the more transparent tidal regime as part of the Alternative 10 bridge. The single bidirectional flow culvert used on one of the three culverts in Alternative 4m will also result in increased inundation relative to existing conditions but not to the degree of Alternative 10.

5.3 UPSTREAM FISH PASSAGE

Upstream fish passage was preliminarily assessed for the refined alternatives, which are discussed and summarized in this section.

Alternative 4m includes two gated culverts that allow for seaward flow and a single, ungated culvert that allows for bi-directional flow to facilitate landward (upstream) fish passage at Dike Bridge. When the seaward tide WSEL is greater than the landward WSEL, there are opportunities for upstream fish passage via advection through the ungated culvert. Fish species interested in migrating upstream would benefit from the mass-movement of the flood tide through the ungated culvert and would be advected through the culvert upstream into the inundated area landward of Dike Bridge following which migrating fish species would either take refuge in the lower energy areas or continue traveling upstream along the Middle River. Based on analysis of percentage of time in which seaward flows would be occurring through the ungated culvert, it was determined that under normal riverine flows and normal (astronomical) tides, Alternative 4m offers upstream fish passage via advection for 53%, 57%, and 62% of the time for existing normal tides, 1.5-ft SLR, and 3.9-ft SLR, respectively.

Results from the flow speed evaluation through the Alternative 10 bridge opening provides an opportunity to assess typical flow and tidal conditions against fish passage criteria. Headwater and tailwater differentials and flow speed were evaluated. The objective of the flow speed evaluation was to identify flow speeds that may allow for volitional fish passage. Note that specific criteria for fish passage (e.g., target fish species, maximum allowable flow speed, designed range and tolerances for conditions suitable for volitional fish passage) have not been identified for the Project. Therefore, this memo presents information that is expected to assist in developing a general approach providing reasonably transparent tidal cycle conditions across a bridge alternative and thereby allow for volitional fish passage opportunities.

The evaluated bridge alternatives have the underlying channel at an elevation of -8.5 ft and therefore similar to the elevation of lower low tides. During low tides, depths of water in the channel are approximately 1 ft. Shallow flow at low tide could necessitate construction of a defined "low-flow" channel through the bridge opening to meet minimum depth criteria for upstream fish passage. A low-flow channel would need to extend well beyond the upstream limits of any proposed bridge near-field dredging and riprap apron in order to tie into the existing channel. Similarly, results identify the percentage of time in which certain flow speeds occur; however, in the absence of a defined target fish species and associated performance criteria, evaluation of volitional fish passage performance is not possible. It is recommended that these criteria (e.g., target fish species) be defined.

Information on fish passage criteria were provided by stakeholders and include a flow speed criterion of 0.75 ft/s. Information obtained from the HEC-RAS model in the Middle River at a cross-section approximately 2,500 ft upstream from Dike Bridge indicates that ebb tide (seaward) flows exceed this value and exceed 3 ft/s during regular tidal conditions. In addition, depths of water at this cross-section are approximately 1 ft except during higher low tides when depths approach up to approximately 2 ft.

5.4 SCOUR COUNTERMEASURES

Preliminary scour countermeasure design calculations suggest that stable rock armor sizes would have a nominal diameter of approximately 3 ft (heavy riprap). The relatively large size of this preliminary scour countermeasure rock size is due to periods during the tidal cycle where the depths of flow are shallow and the flow speeds are the greatest. The maximum seaward flow speed is greater than the maximum landward flow speed during the simulation period; therefore, the seaward flows govern the rock sizing for the scour countermeasure design. It is further recommended that the selected alternative include considerations for ice and debris loading in addition to the expected hydraulic loading effects.

5.5 DREDGING AND SEDIMENT TRANSPORT

Selection of a bridge replacement alternative for the Project would require consideration for "active", or "passive" development of an upstream channel. Active channel development refers to the process of dredging a channel in the anticipated alignment in advance of installation of the bridge. Passive channel development refers to the process of near-field dredging within the vicinity of the proposed replacement structure (e.g., channel through the bridge and immediately upstream and downstream), and then relying on natural sediment transport processes to mobilize sediment downstream. The opportunities of active channel development primarily include (1) reduced transport of sediment downstream and (2) reduced likelihood of requiring dredging to address shoaling in the Machias River seaward from Dike Bridge following completion of the Project. The opportunities of passive channel development primarily include (1) reduced costs in the short-term associated with the Project and (2) eliminating risks associated with dredging upstream without a prior knowledge on where the channel may actually form. Note that in addition to the areas landward of Dike Bridge that may require dredging, dredging of the existing mud flat areas immediately downstream of the bridge would also likely be required.

Appendix C contains a figure that depicts the anticipated alignment and conceptual area where a channel would be anticipated to head-cut upstream after installation of a bridge (i.e., Alternative 10). Based on the bathymetric data, it is estimated that greater than 20,000 cubic yards (CY) of sediment would be displaced by this conceptual channel alignment. If no upstream dredging is proposed as part of the Project, it is anticipated that this volume of sediment would become mobilized in the near-term, shortly after completion of the bridge installation, which would all be relocated to the USACE navigation channel adjacent to the municipal boat launch on the Machias River adjacent to the southwest end of Dike Bridge. Appendix D contains figures that depict the USACE navigation channel in the areas immediately downstream of Dike Bridge in the Machias River.

Note that a utility (sewer) pipeline crosses the Middle River about 25 ft upstream of Dike Bridge. The vertical profile and horizontal location of the pipeline are not well defined. Additional information related to this utility infrastructure is required to better inform potential design solutions for the Project.

6.0 SUMMARY

The following is a bulleted summary of findings from the Phase 2 Study.

1. Both Alternative 4m and Alternative 10 will result in higher WSELs and increased land inundation upstream from Dike Bridge.
2. Alternative 10 would result in the greatest increase in inundation area upstream from Dike Bridge. Increased upstream WSELs may be an issue for property owners along the upstream reach of the Middle River.
3. Alternative 10 has the greatest tidal exchange and qualitatively appears to approach tidal transparency landward of Dike Bridge. Additional preliminary analysis of various bridge sizes suggests that increasing the bridge span beyond 120 ft provide relatively small (e.g., approximately 2%) increases in intertidal habitat acreage.
4. Alternative 10 has opportunities for volitional upstream fish passage. Results identify the percentage of time in which certain flow speeds occur; however, in the absence of a defined target fish species and associated performance criteria, evaluation of volitional fish passage performance was not possible. It is recommended that these criteria (e.g., target fish species) be defined. The results also identify that depths of flow through the bridge would be relatively shallow (e.g., less than 1.5 ft) at and near low tide.
5. Alternative 4m provides enhanced opportunities for fish passage compared to existing conditions due to the larger culvert opening and an ungated culvert. Fish passage would generally be through the process of advection through the bi-directional (i.e., ungated) culvert opening when the seaward WSELs are greater than landward WSELs.
6. Information on fish passage criteria were provided by stakeholders and include a flow speed criterion of 0.75 ft/s. Information obtained from the HEC-RAS model in the Middle River at a cross-section approximately 2,500 ft upstream from Dike Bridge indicates that ebb tide (seaward) flows exceed this value and exceed 3 ft/s during regular tidal conditions. This ambient condition suggests that the lower 0.75 ft/s criterion is too conservative and may be inappropriate for evaluating fish passage for Alternative 10.
7. Increased WSELs in the Middle River for the two refined alternatives may result in increased fish passage opportunities at Stride Bridge, either by upstream passage through advection during flood tides, or by increasing the tailwater elevation at Stride Bridge, which would lower velocities through the culvert barrel thereby facilitating passage.

8. Additional hydraulic evaluations at Stride Bridge are recommended to assess if hydraulic design criteria (e.g., freeboard) are adequate when coupled with the hydraulic changes to the Middle River reach from the replacement alternatives proposed at Dike Bridge.

9. Preliminary scour countermeasure design calculations suggest that stable riprap armor sizes would have a nominal diameter of approximately 3 ft (MaineDOT Heavy Riprap) for Alternative 10. The relatively large size of this preliminary scour countermeasure riprap size is due to periods during the tidal cycle where the depths of flow are shallow and the flow speeds are the greatest.

10. Alternative 4m would require energy dissipation on the seaward side of Dike Bridge. It is expected that boulders would need to be placed adjacent to the seaward side of the Alternative 4m culverts to control scour. Scour countermeasures would be required adjacent to the landward side of the Alternative 4m culverts but would be more limited (relative to the seaward side) due to a persistent backwater condition. The spatial extent of scour countermeasures on the landward side of the ungated Alternative 4m culvert would need to be larger than for the two gated culverts.

11. The spatial extent of scour countermeasures adjacent to the ends of the Alternative 4m culverts would be smaller than those for Alternative 10.

12. Alternative 10 would result in development of a larger channel morphology through the reach landward of the Dike Bridge in the Middle River due to the larger span and lower invert compared to Alternative 4m. Greater than 20,000 CY of sediment is estimated to be mobilized landward of the estimated near-field dredge and riprap apron area.

13. Upstream mobilization of sediment for Alternative 10 would likely have implications on the downstream USACE navigation channel in the Machias River where shoaling already exists adjacent to the boat launch. Additional investigation is recommended.

14. No increases in the FEMA BFE are anticipated for the refined alternatives that were modeled as part of the Phase 2 Study when considering the non-SLR flood events.

15. Alternative 4m results in the lowest WSELs in the Middle River during the 100-year high-tide surge and 1.1-year riverine peak flow with 1.5 ft and 3.9 ft SLR scenarios relative to the existing condition and Alternative 10 simulations.

16. The existing condition with the 100-year high tide surge and 1.1-year riverine peak flow with 3.9 ft of SLR results in overtopping of Dike Bridge and the highest WSELs in the Middle River. This condition results from no resiliency measures (e.g., seawalls) for the existing condition simulations.

17. Analyses as part of this study did not consider potential impacts to public safety or navigation.

APPENDIX A UNSTEADY-STAGE HYDROGRAPHS

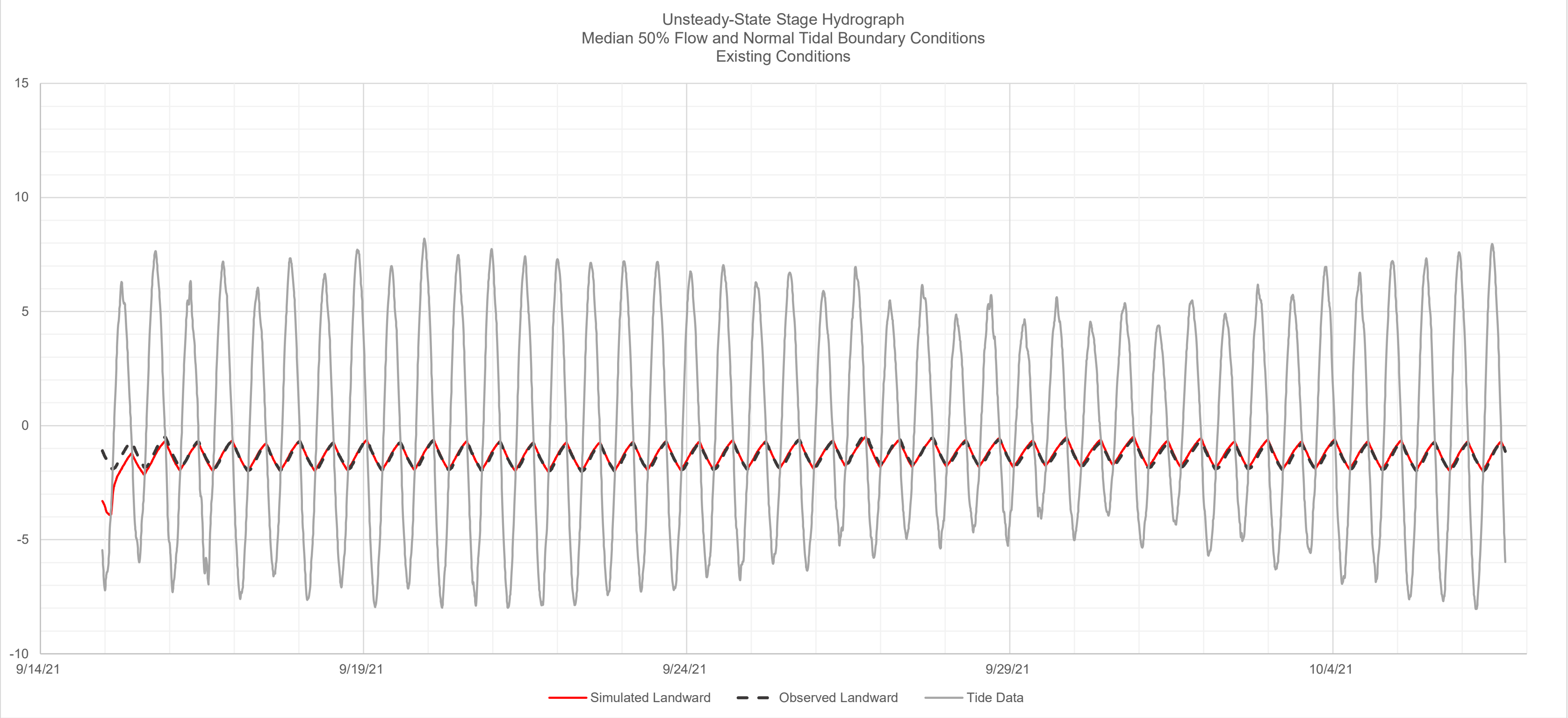

Figure A.1 - Unsteady-state stage hydrograph for median riverine flow and normal tide boundary conditions.

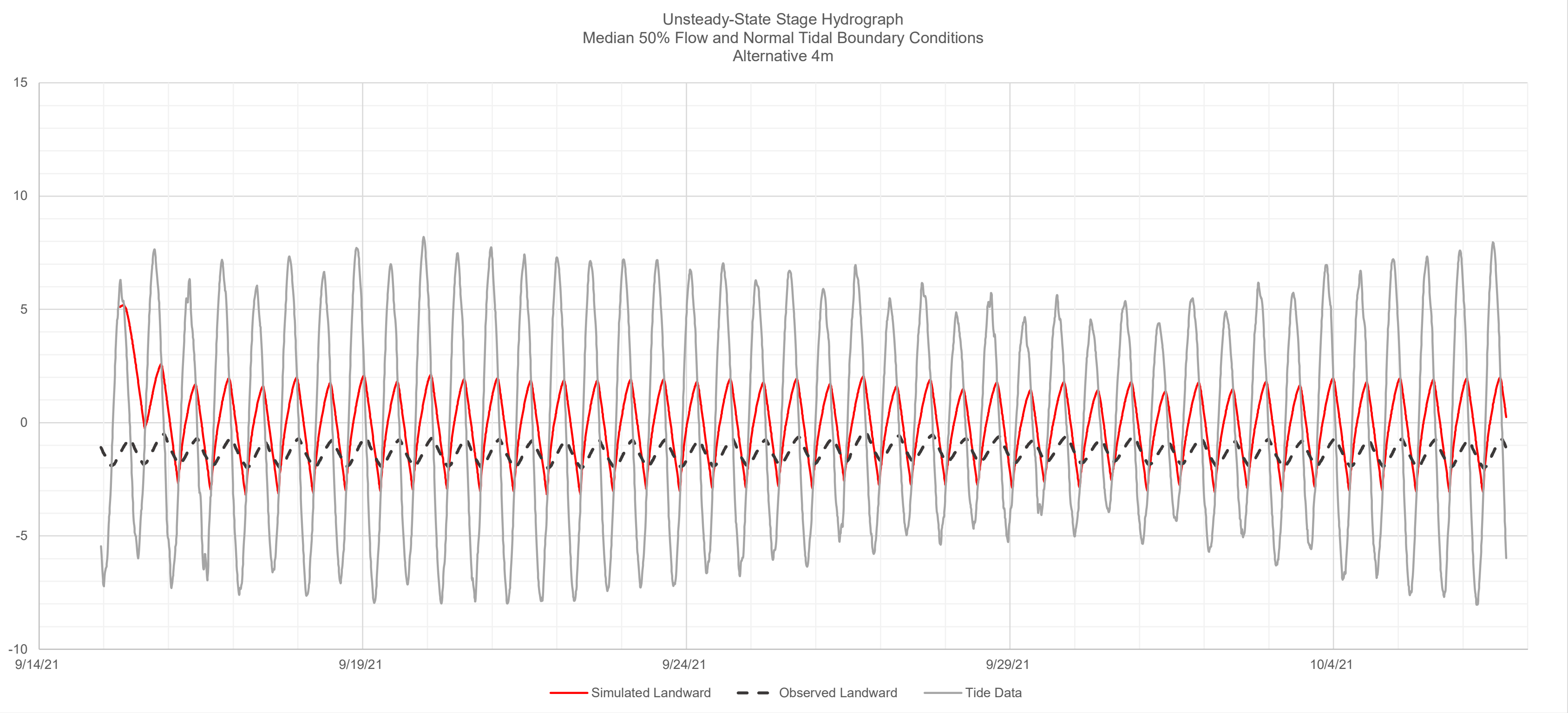

Figure A.2 - Unsteady-state stage hydrograph for median riverine flow and normal tide boundary conditions.

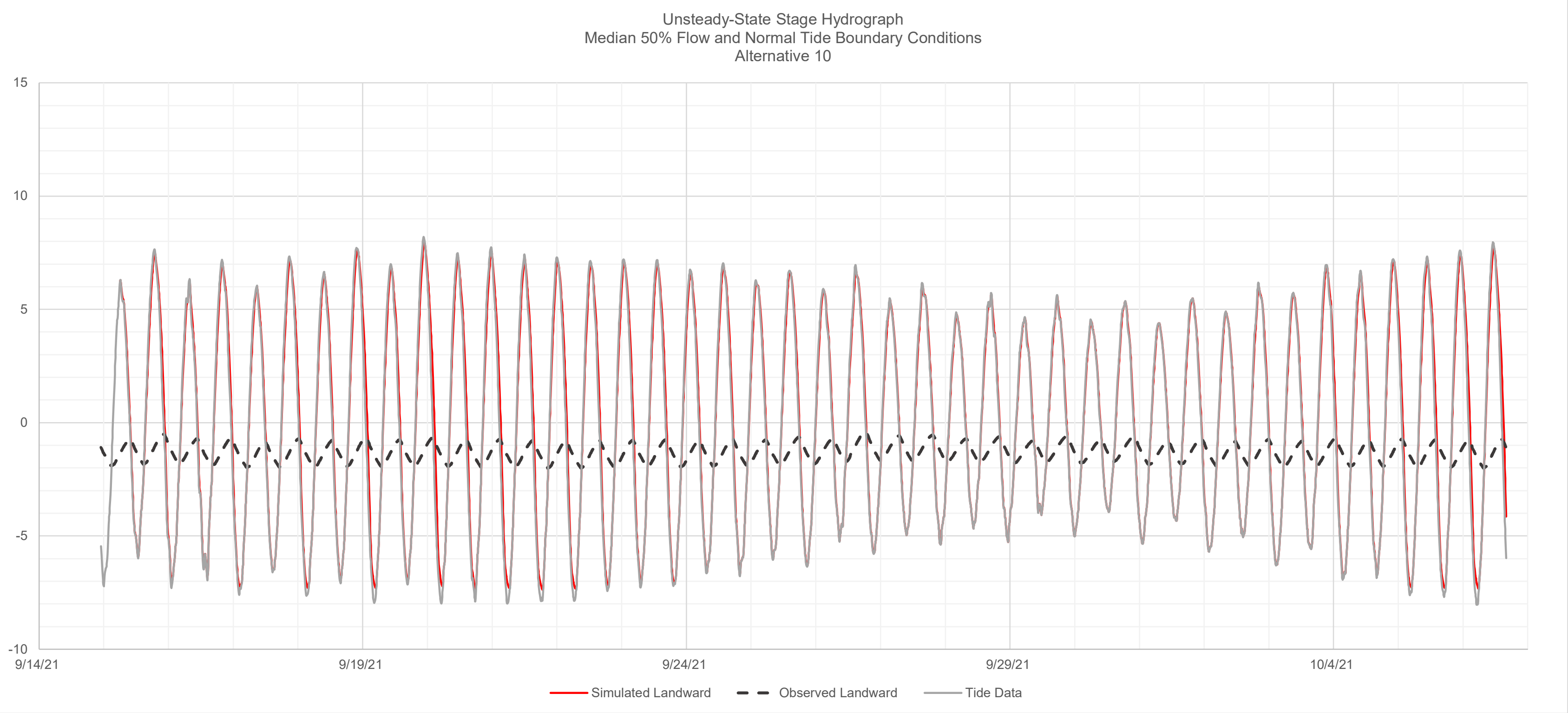

Figure A.3 - Unsteady-state stage hydrograph for median riverine flow and normal tide boundary conditions.

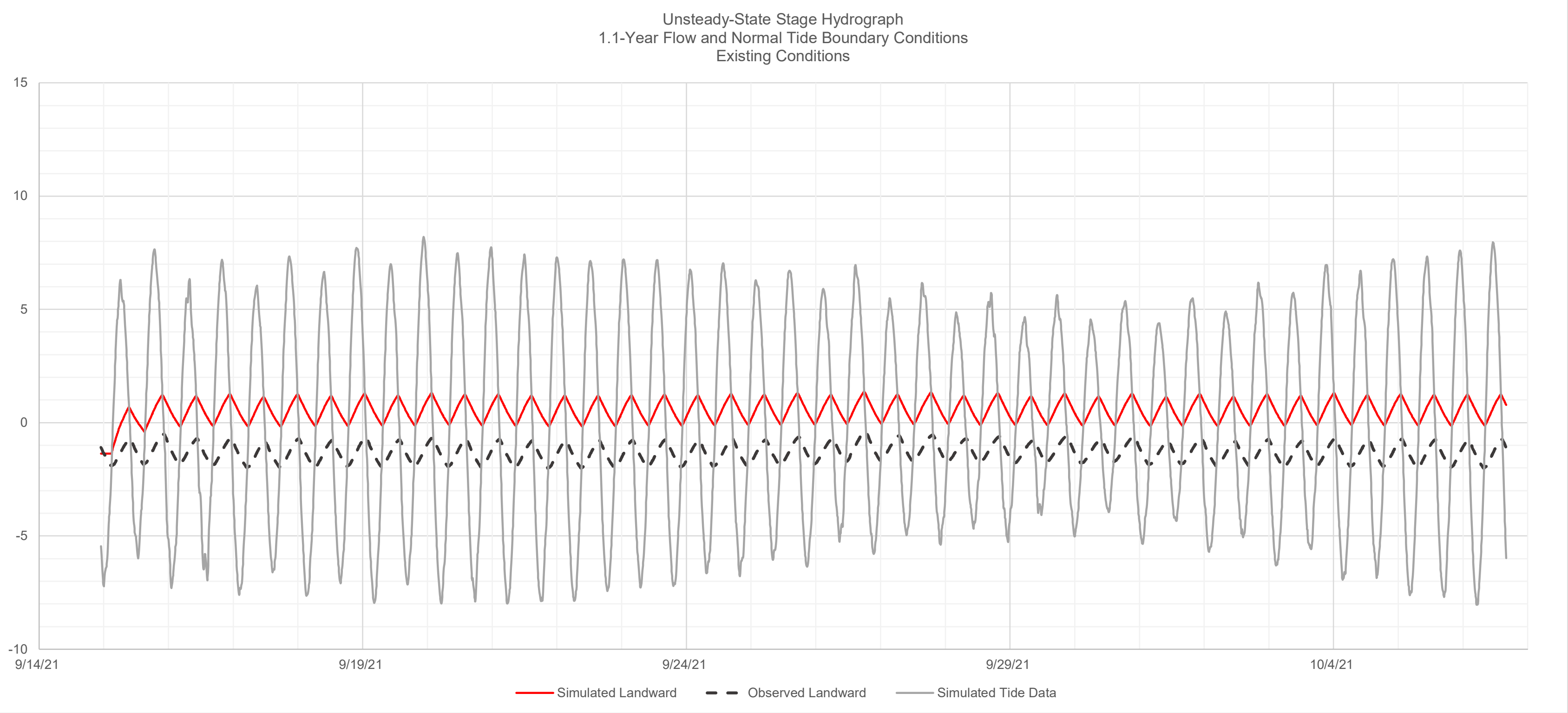

Figure A.4 - Unsteady-state stage hydrograph for 1.1-year riverine flow and normal tide boundary conditions.

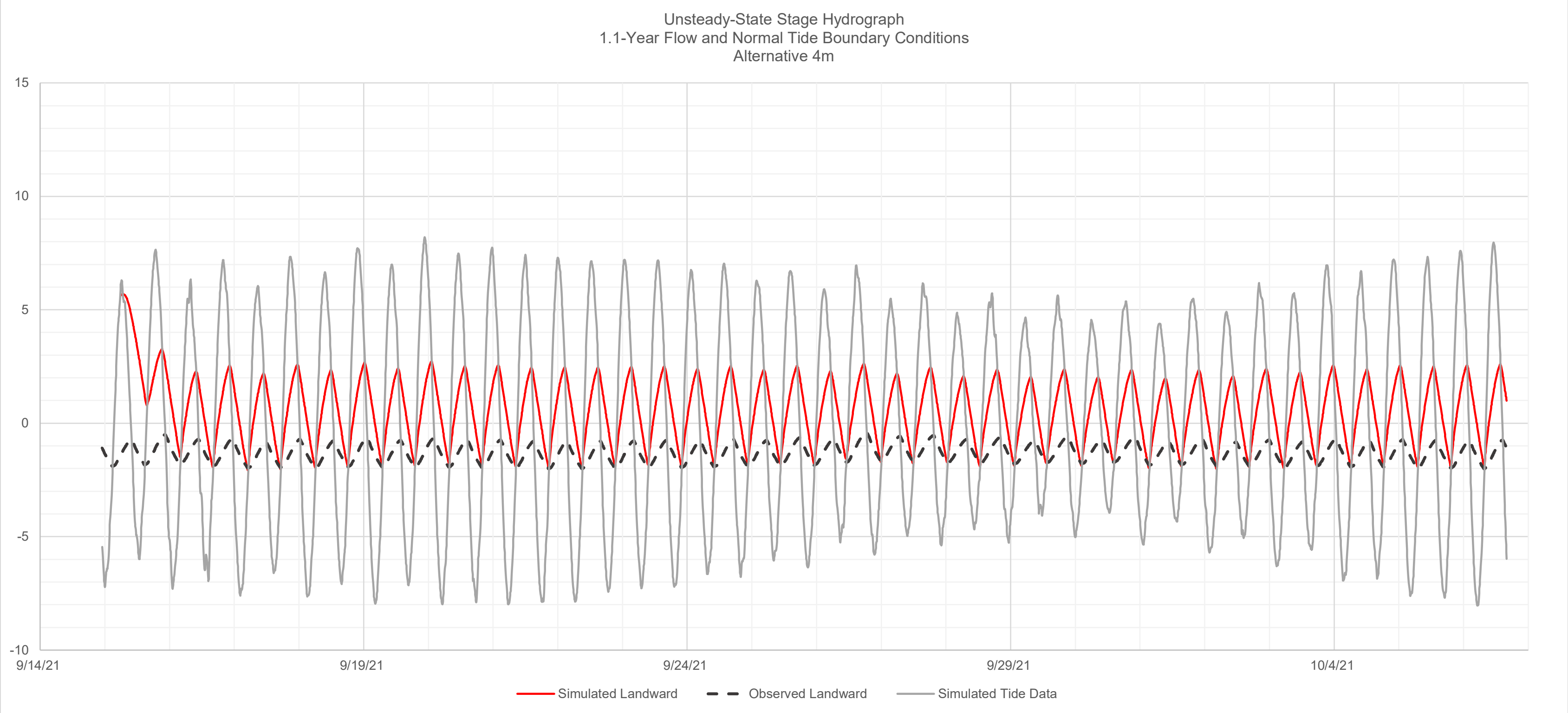

Figure A.5 - Unsteady-state stage hydrograph for 1.1-year riverine flow and normal tide boundary conditions.

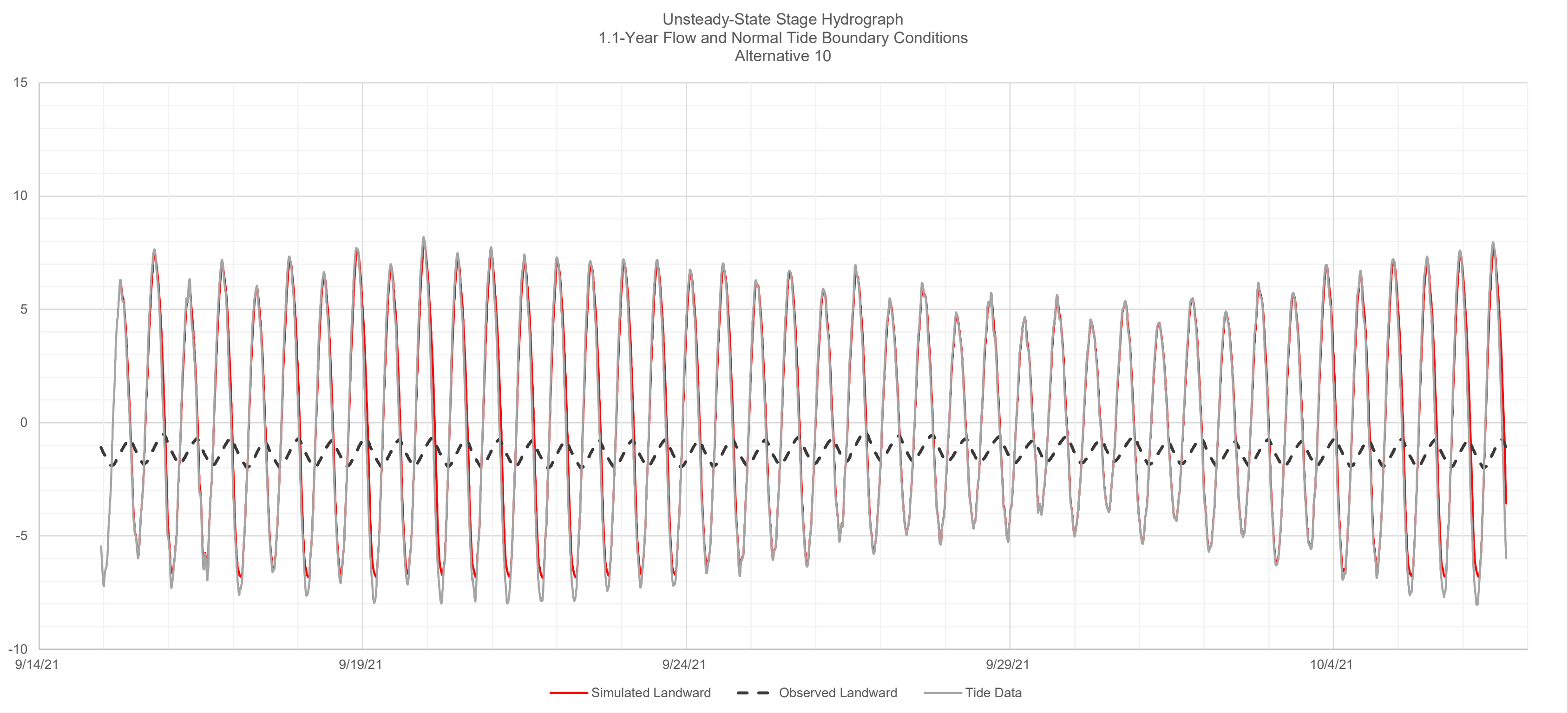

Figure A.6 - Unsteady-state stage hydrograph for 1.1-year riverine flow and normal tide boundary conditions.

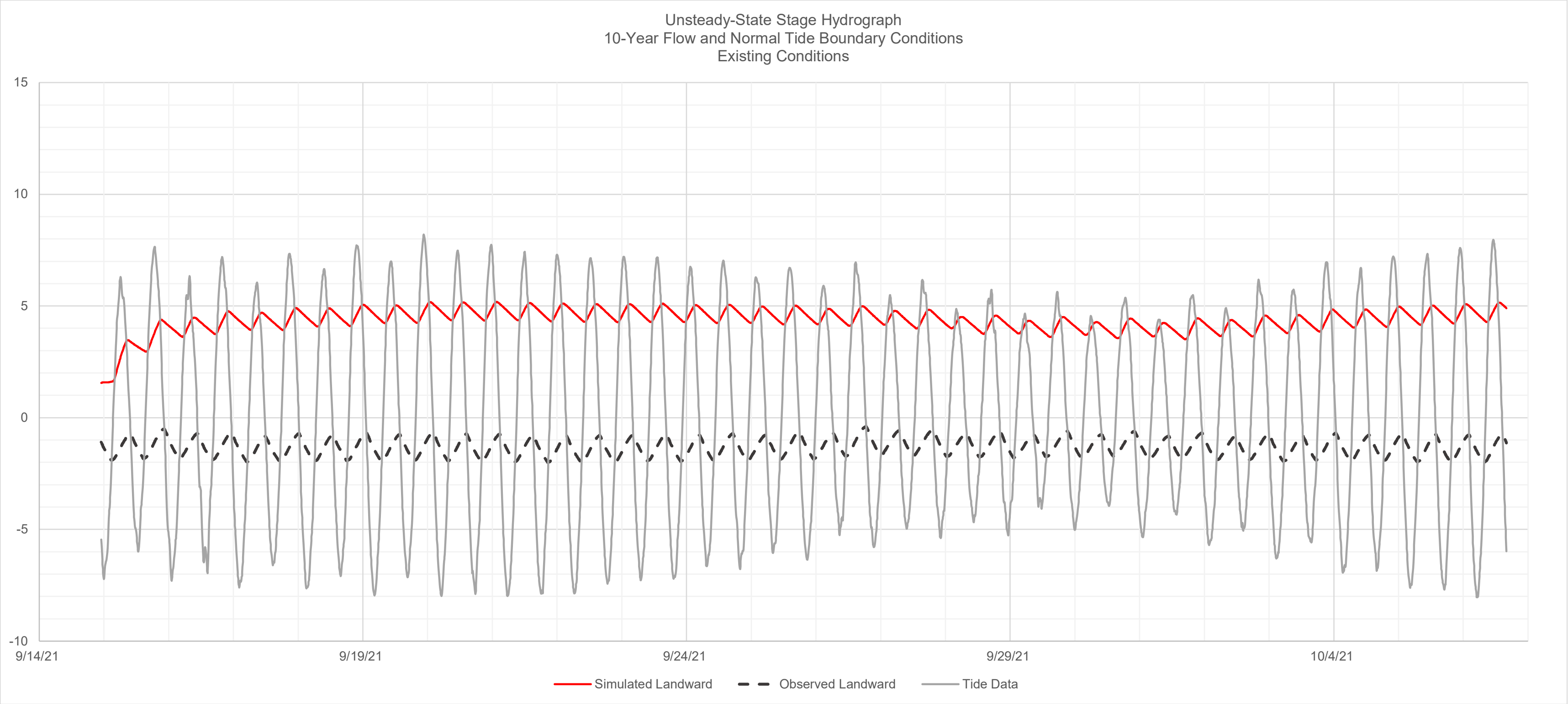

Figure A.7 - Unsteady-state stage hydrograph for 10-year riverine flow and normal tide boundary conditions.

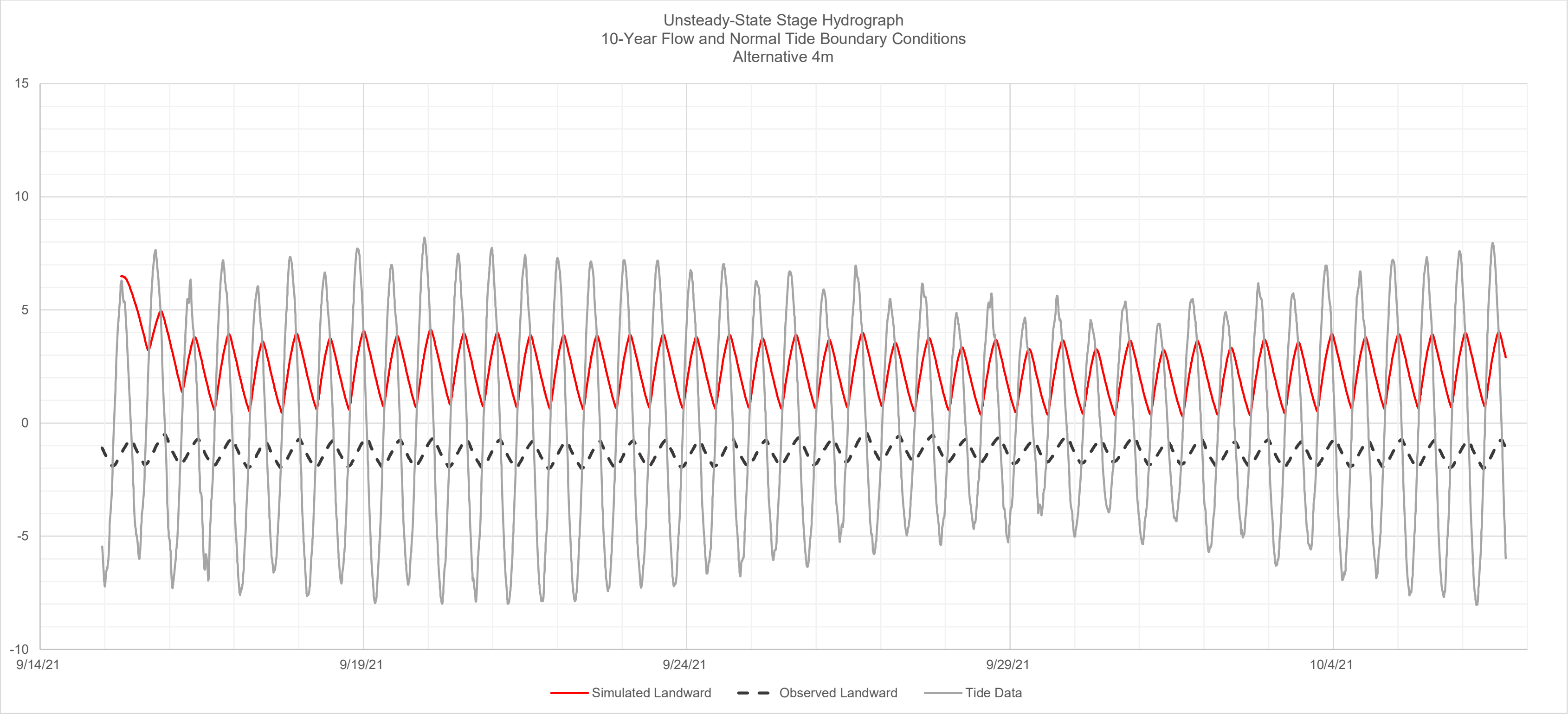

Figure A.8 - Unsteady-state stage hydrograph for 10-year riverine flow and normal tide boundary conditions.

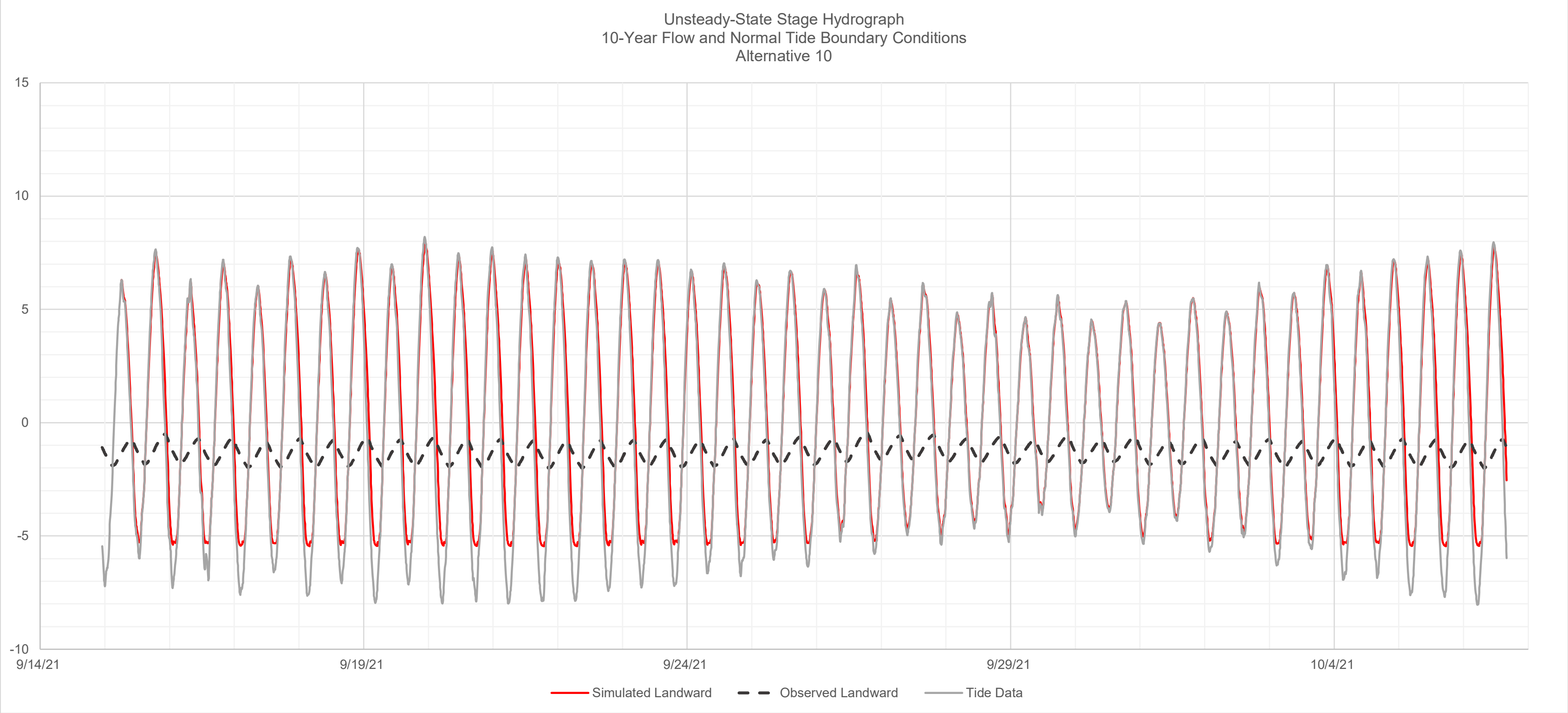

Figure A.9 - Unsteady-state stage hydrograph for 10-year riverine flow and normal tide boundary conditions.

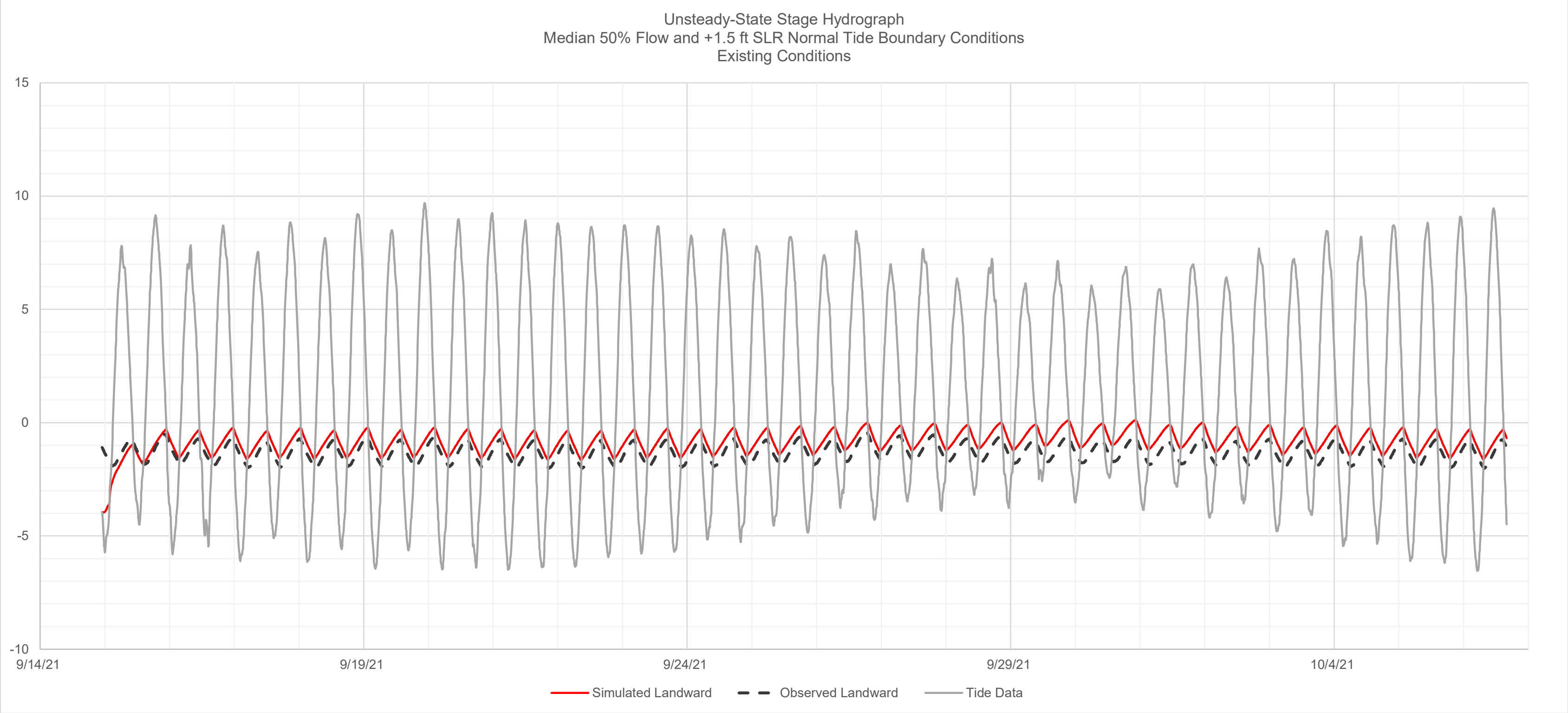

Figure A.10 - Unsteady-state stage hydrograph for median riverine flow and +1.5 ft sea-level rise normal tide boundary conditions.

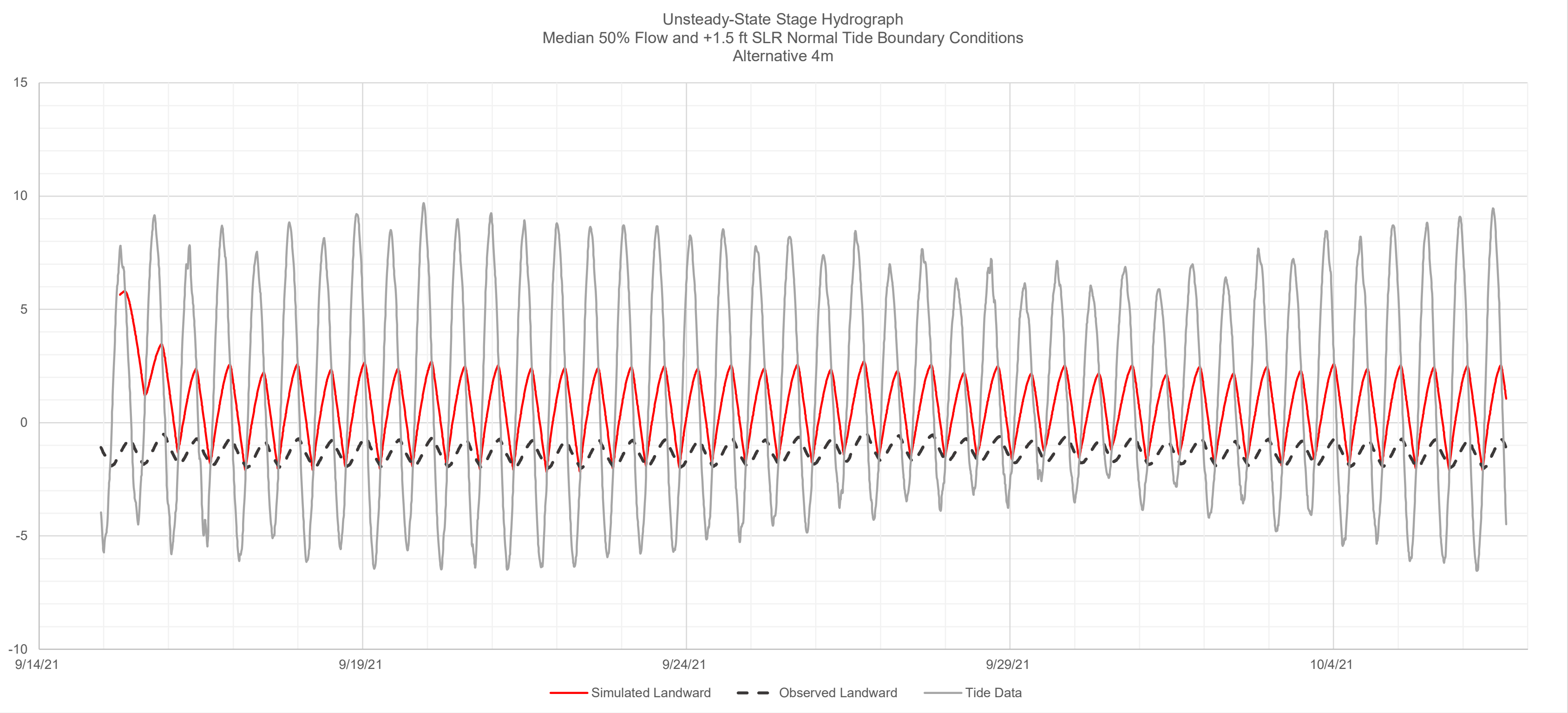

Figure A.11 - Unsteady-state stage hydrograph for median riverine flow and +1.5 ft sea-level rise normal tide boundary conditions.

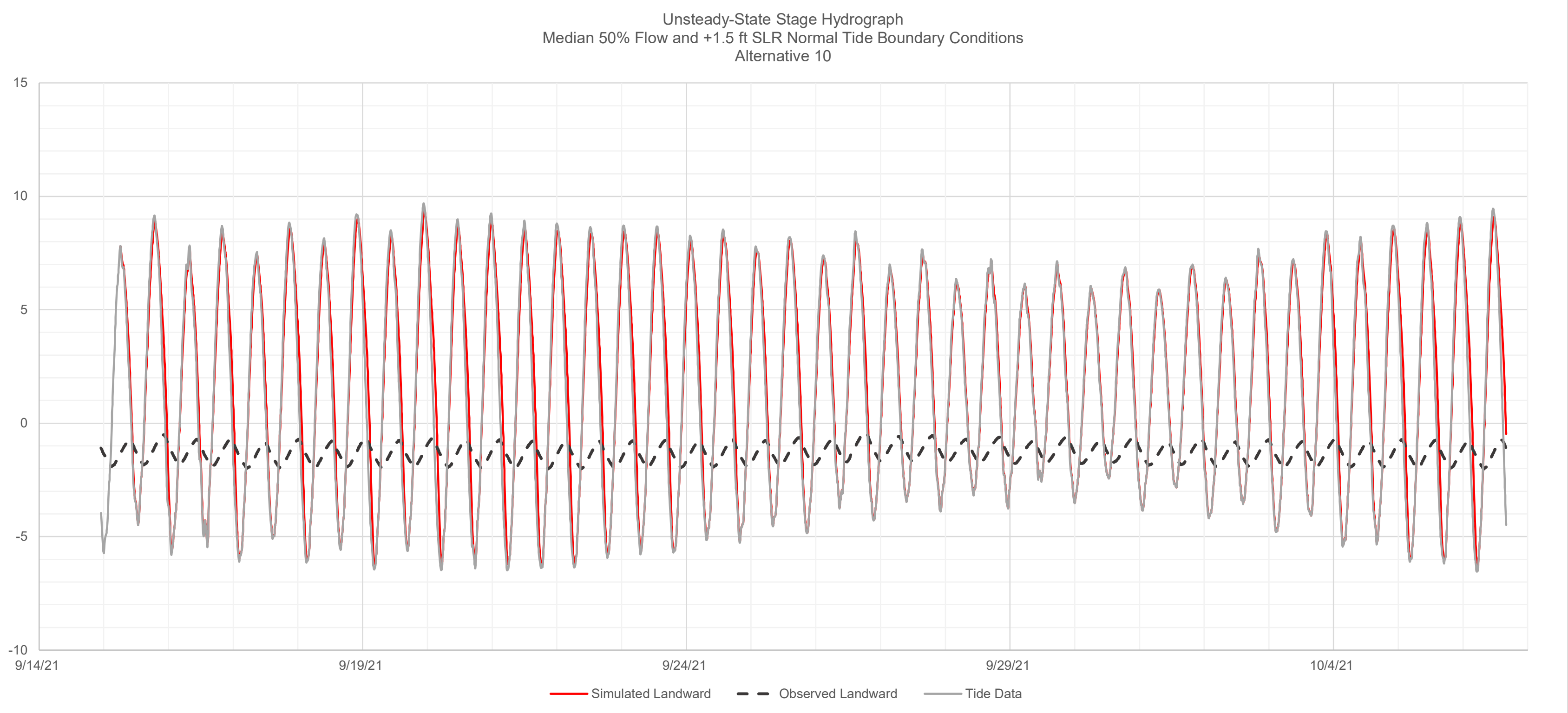

Figure A.12 - Unsteady-state stage hydrograph for median riverine flow and +1.5 ft sea-level rise normal tide boundary conditions.

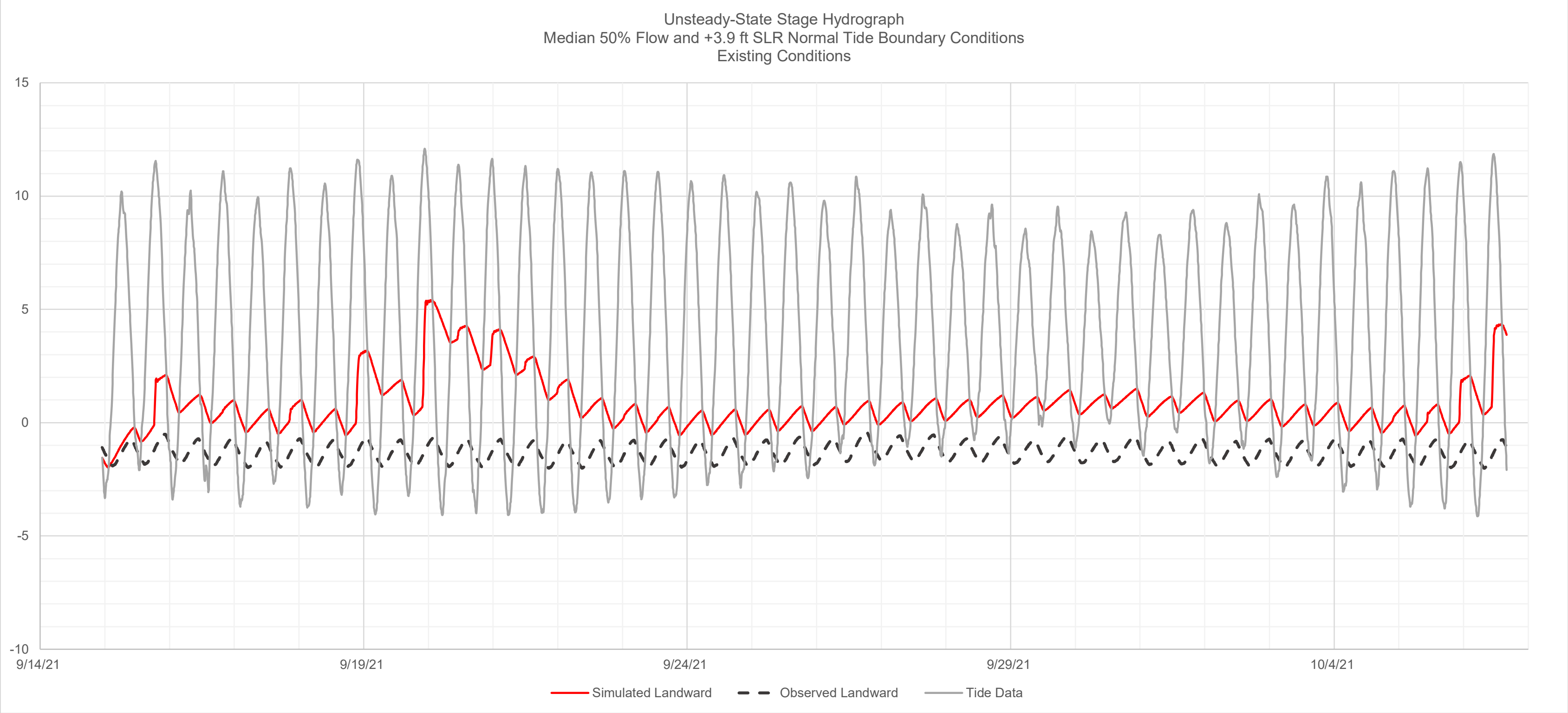

Figure A.13 - Unsteady-state stage hydrograph for median riverine flow and +3.9 ft sea-level rise normal tide boundary conditions.

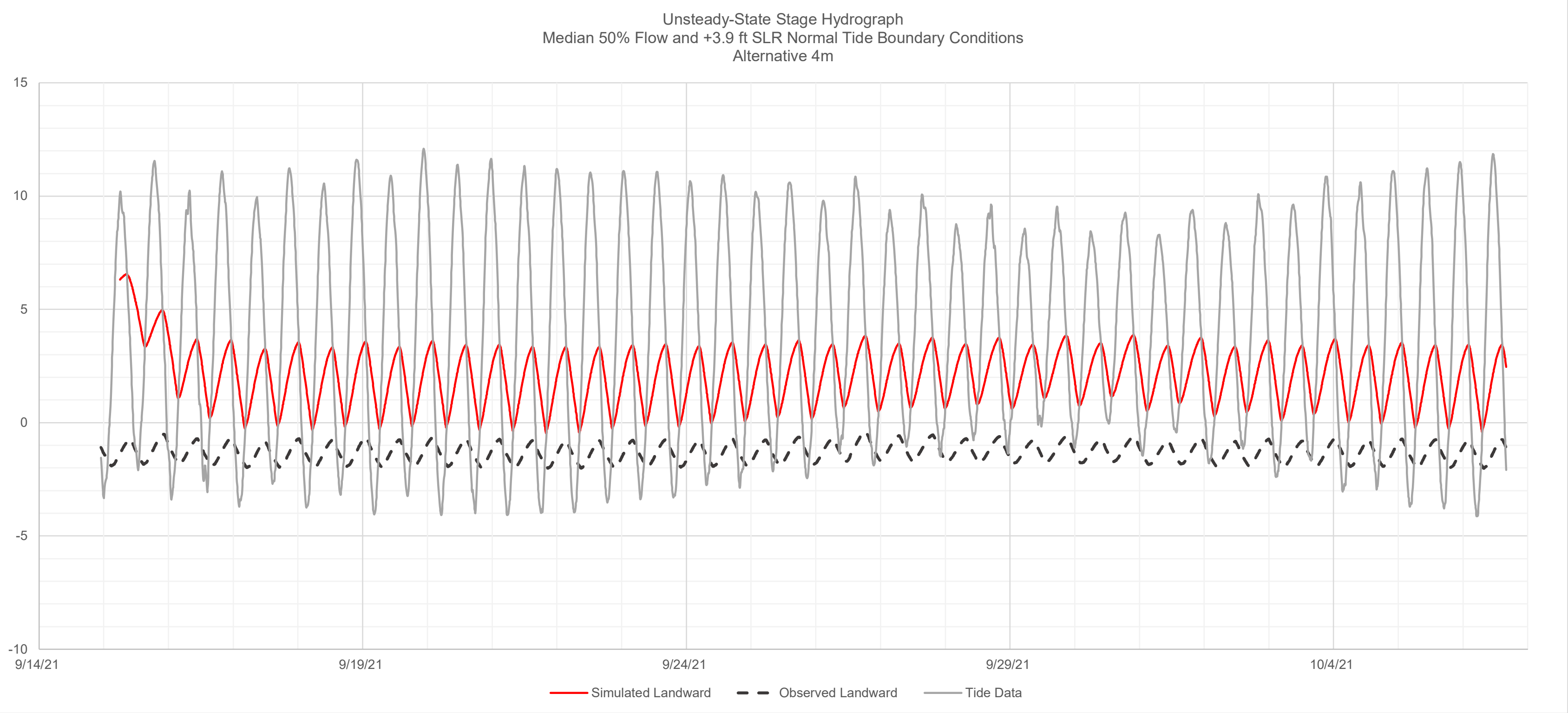

Figure A.14 - Unsteady-state stage hydrograph for median riverine flow and +3.9 ft sea-level rise normal tide boundary conditions.

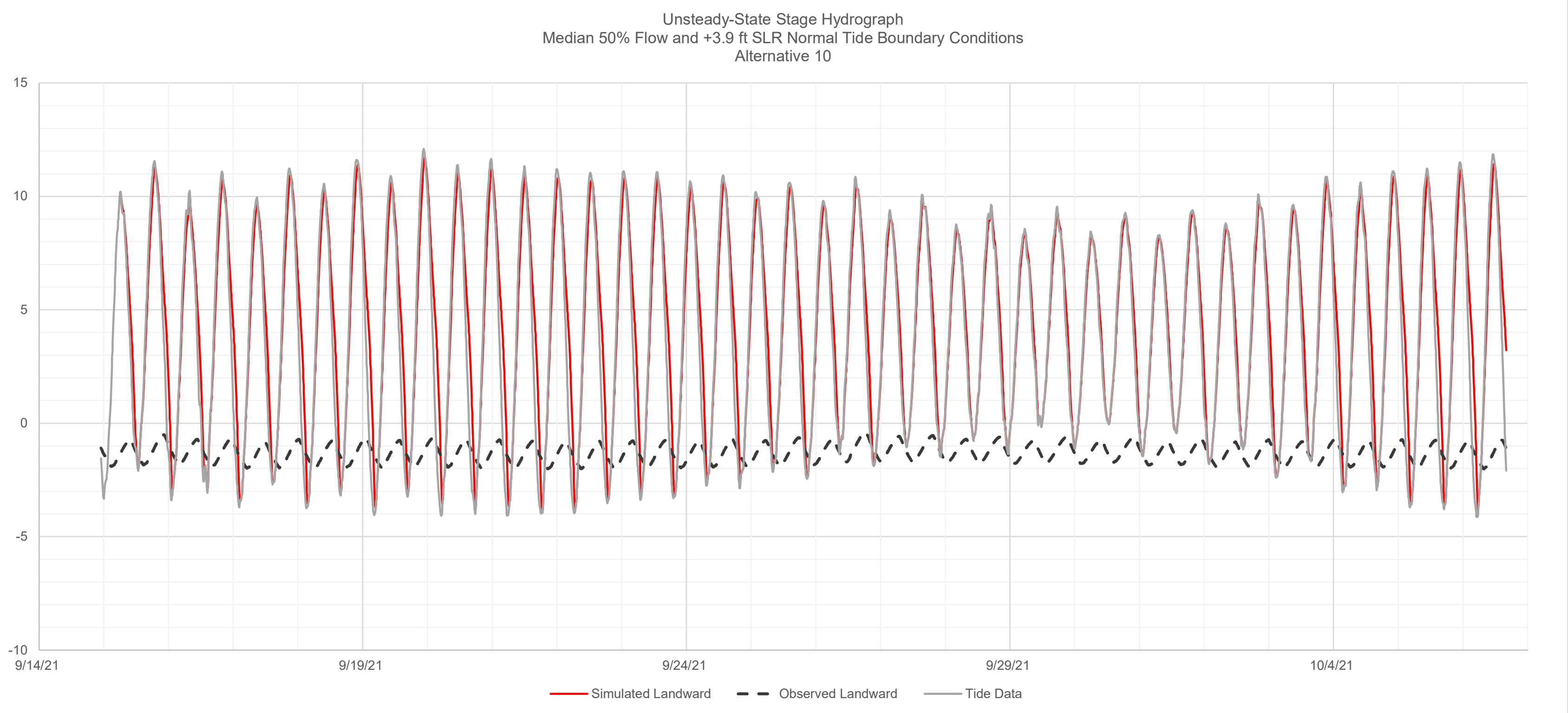

Figure A.15 - Unsteady-state stage hydrograph for median riverine flow and +3.9 ft sea-level rise normal tide boundary conditions.

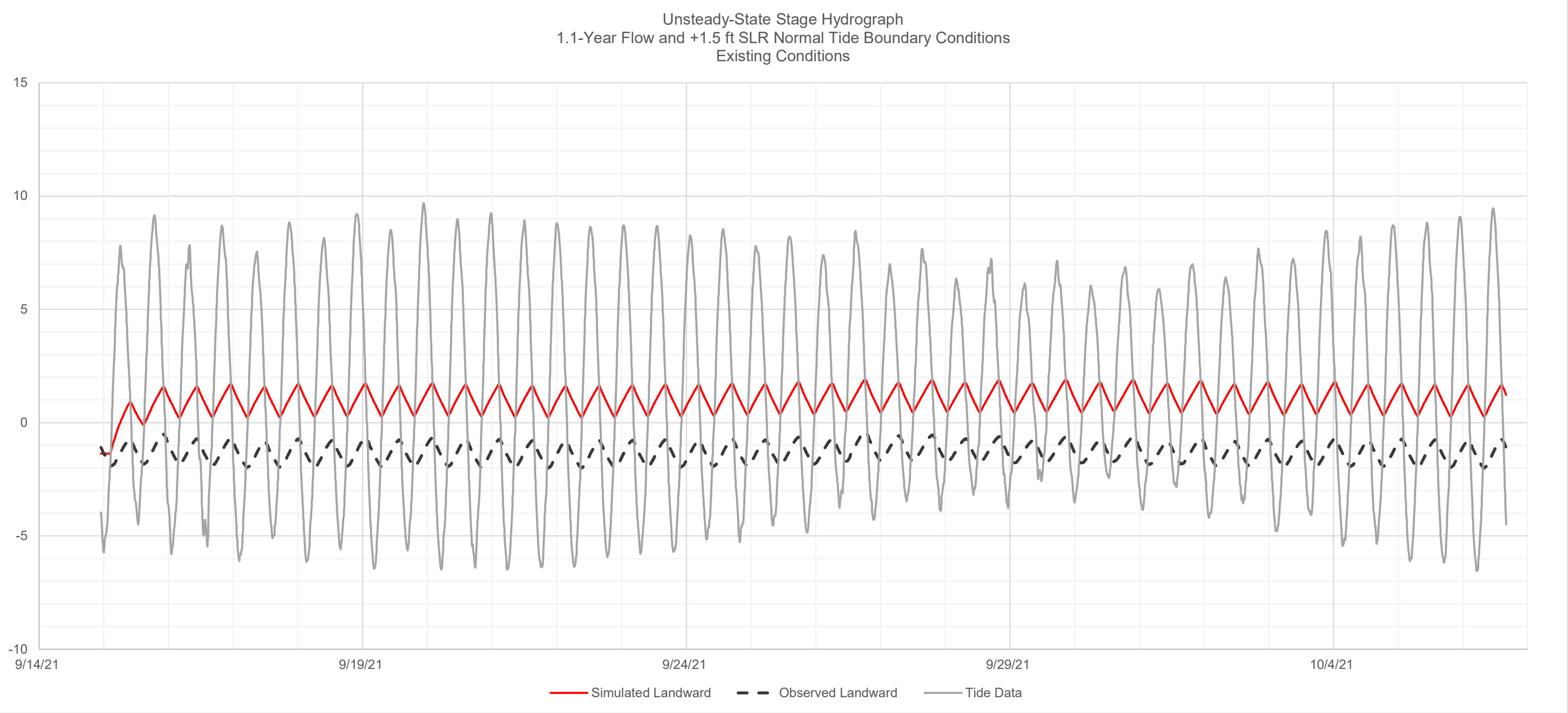

Figure A.16 - Unsteady-state stage hydrograph for 1.1-year riverine flow and +1.5 ft sea-level rise normal tide boundary conditions.

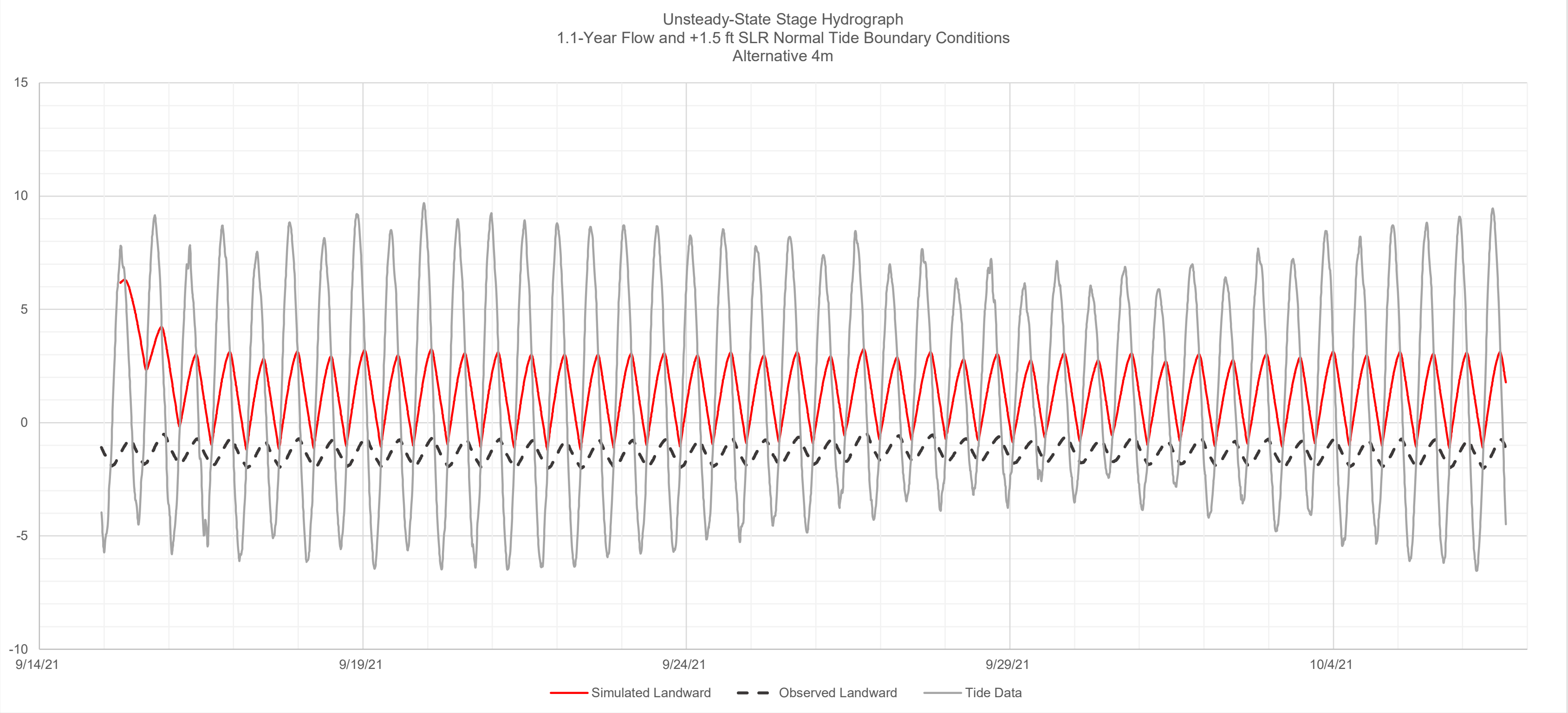

Figure A.17 - Unsteady-state stage hydrograph for 1.1-year riverine flow and +1.5 ft sea-level rise normal tide boundary conditions.

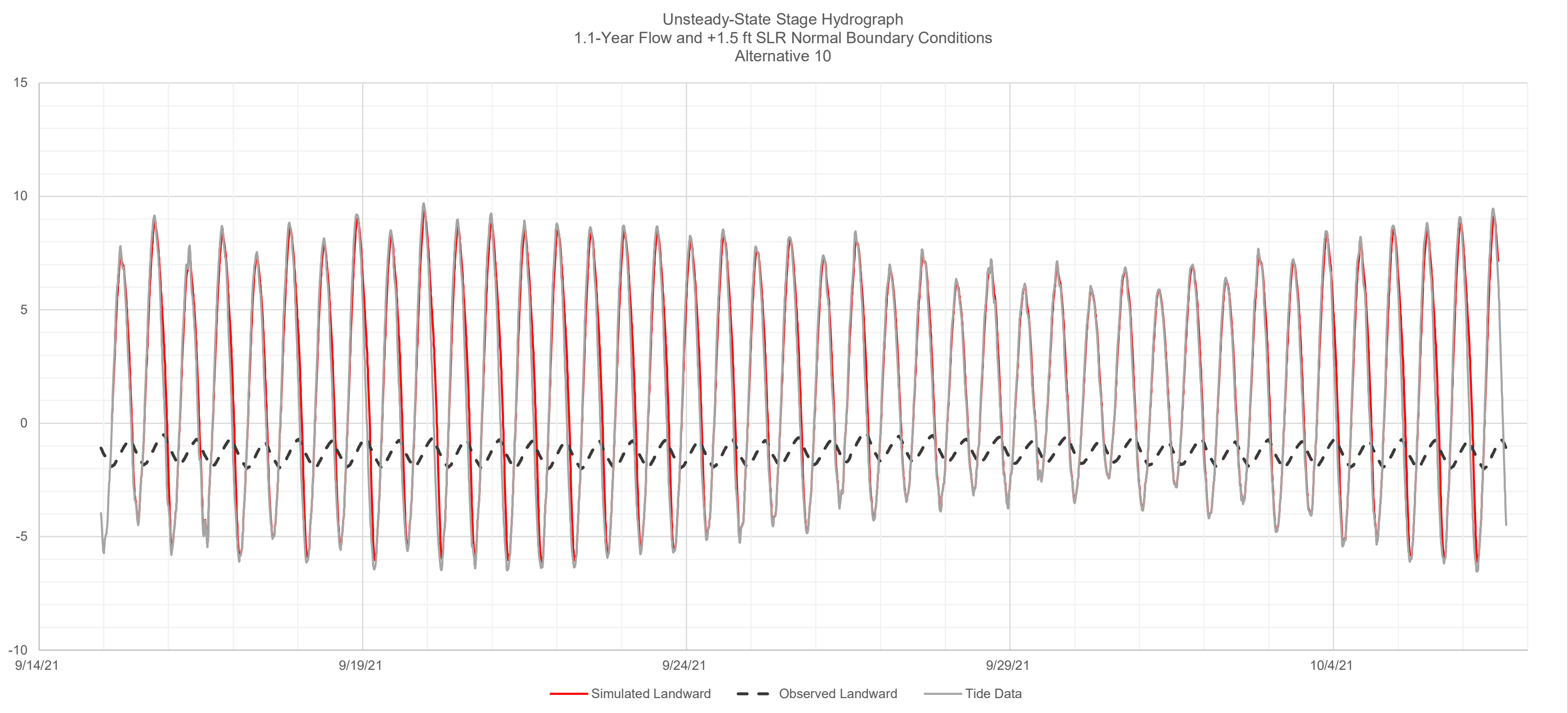

Figure A.18 - Unsteady-state stage hydrograph for 1.1-year riverine flow and +1.5 ft sea-level rise normal tide boundary conditions.

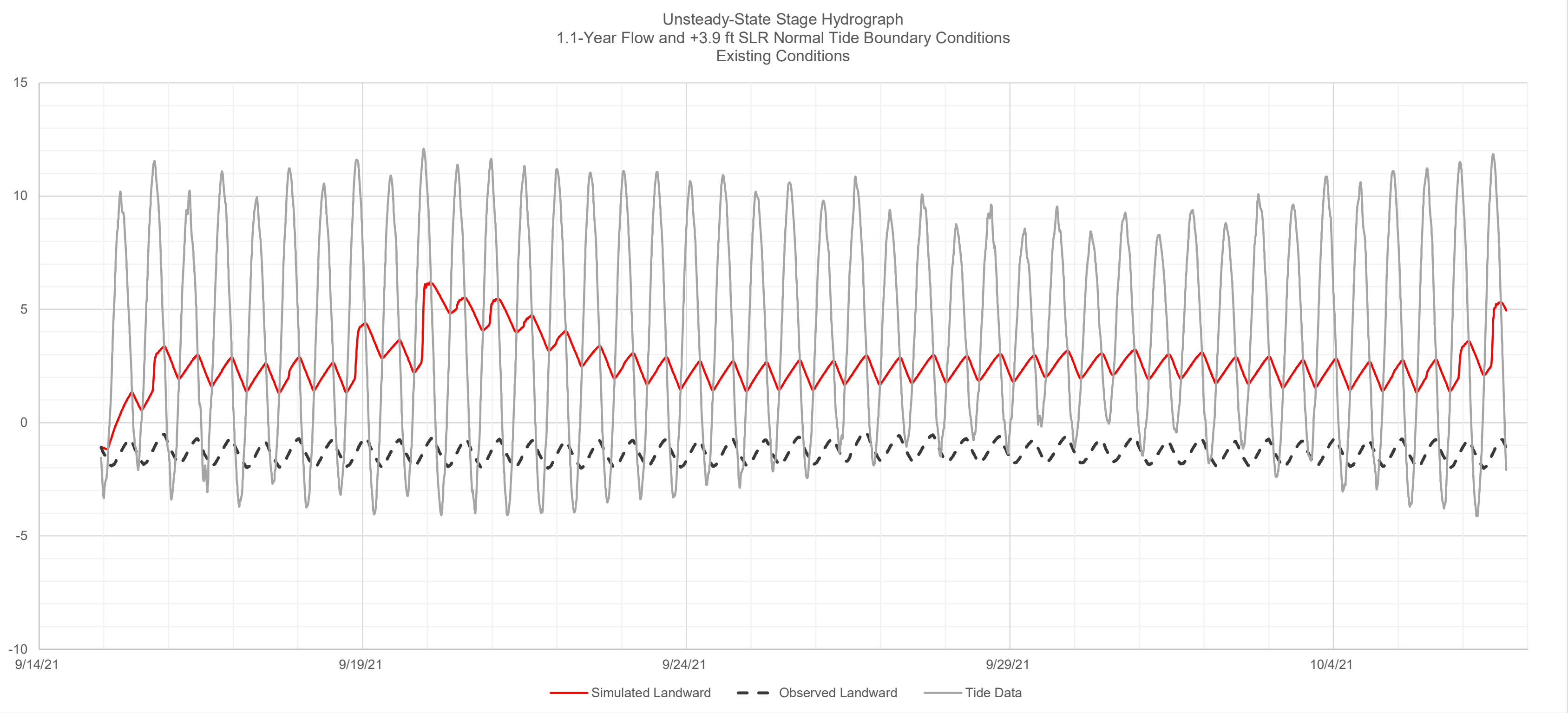

Figure A.19 - Unsteady-state stage hydrograph for 1.1-year riverine flow and +3.9 ft sea-level rise normal tide boundary conditions.

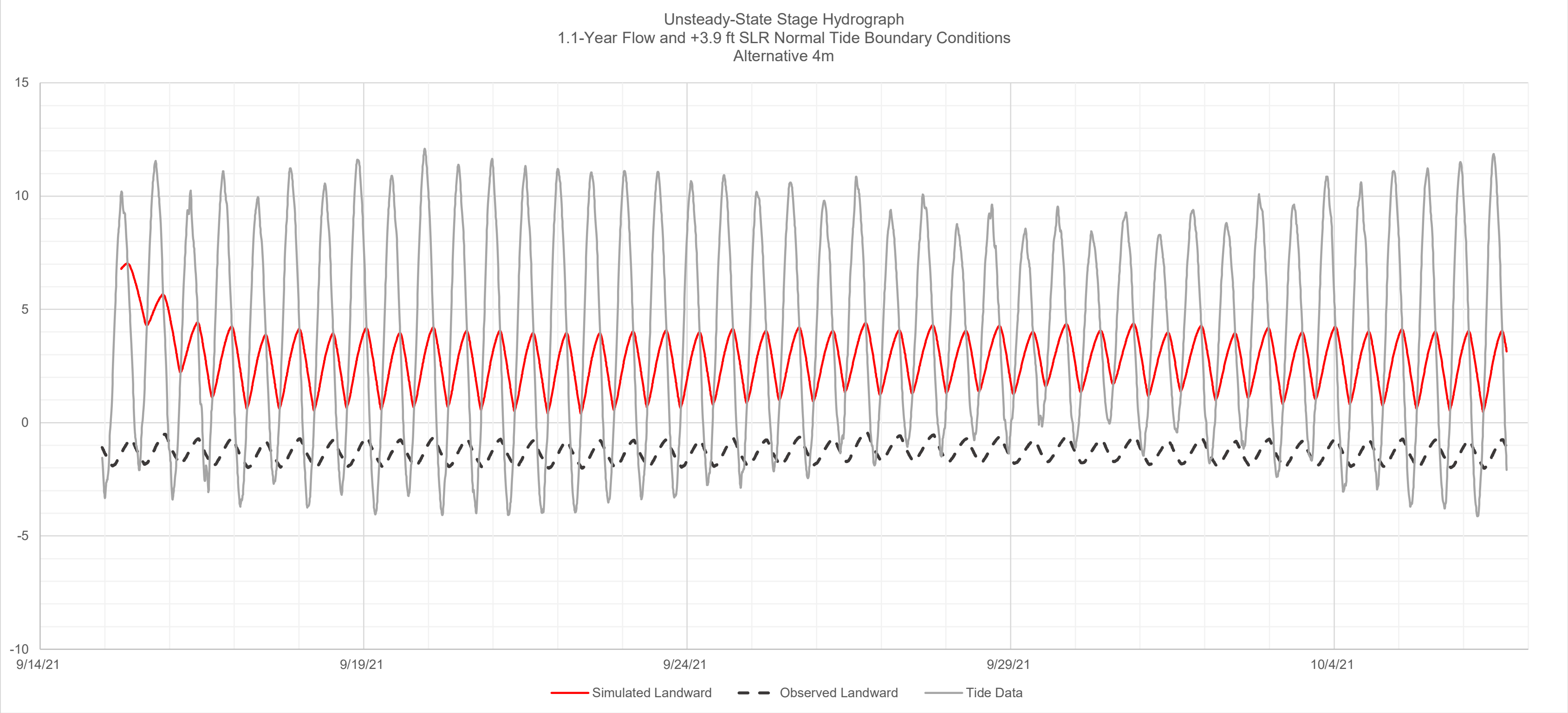

Figure A.20 - Unsteady-state stage hydrograph for 1.1-year riverine flow and +3.9 ft sea-level rise normal tide boundary conditions.

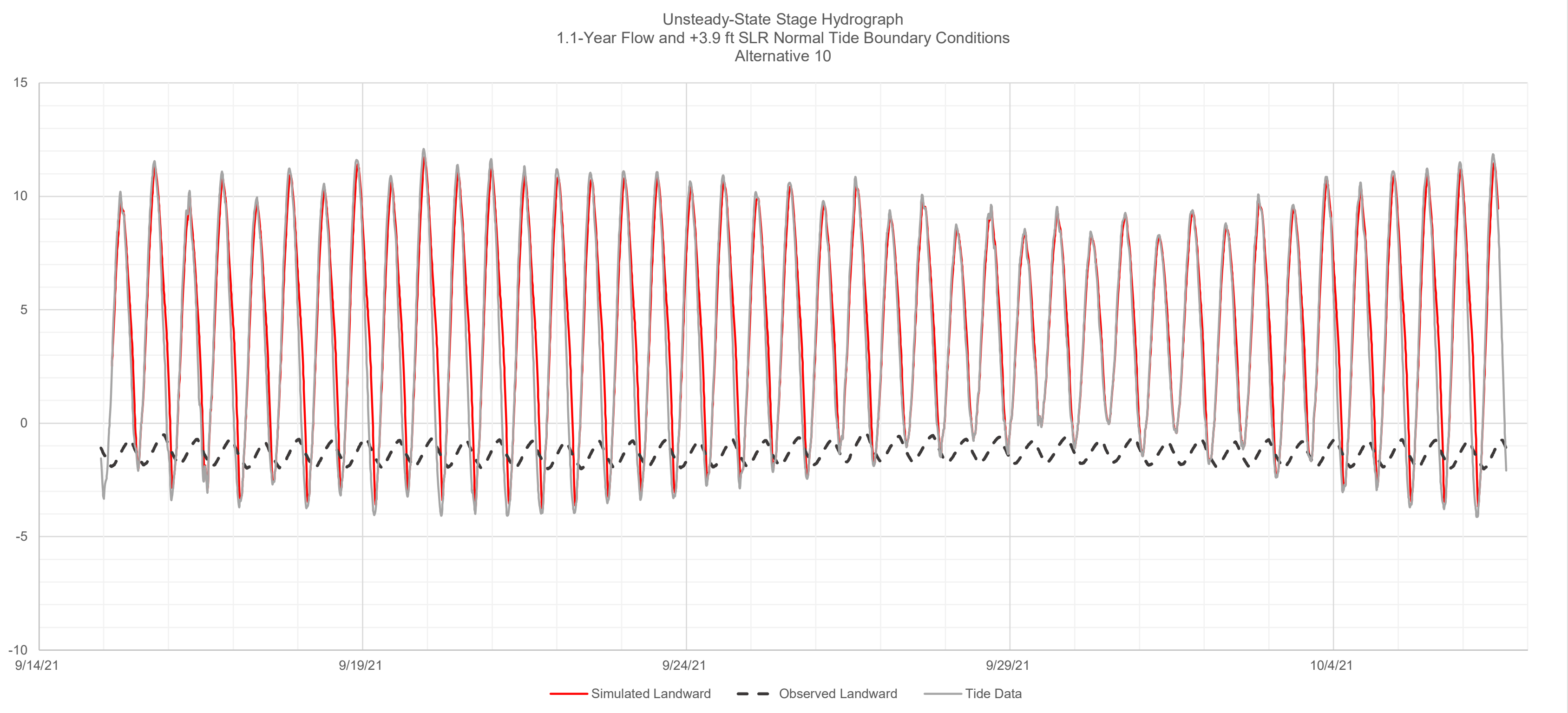

Figure A.21 - Unsteady-state stage hydrograph for 1.1-year riverine flow and +3.9 ft sea-level rise normal tide boundary conditions.

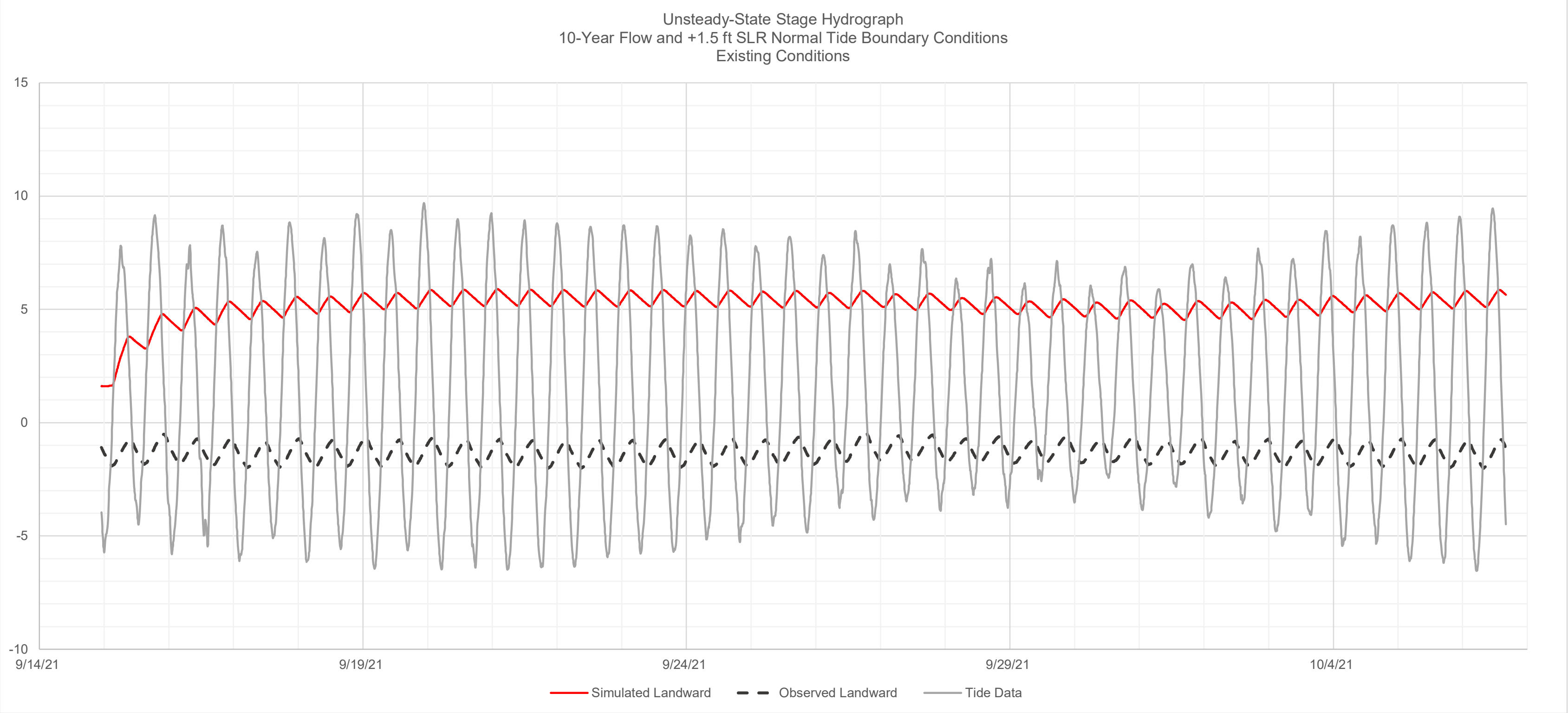

Figure A.22 - Unsteady-state stage hydrograph for 10-year riverine flow and +1.5 ft sea-level rise normal tide boundary conditions.

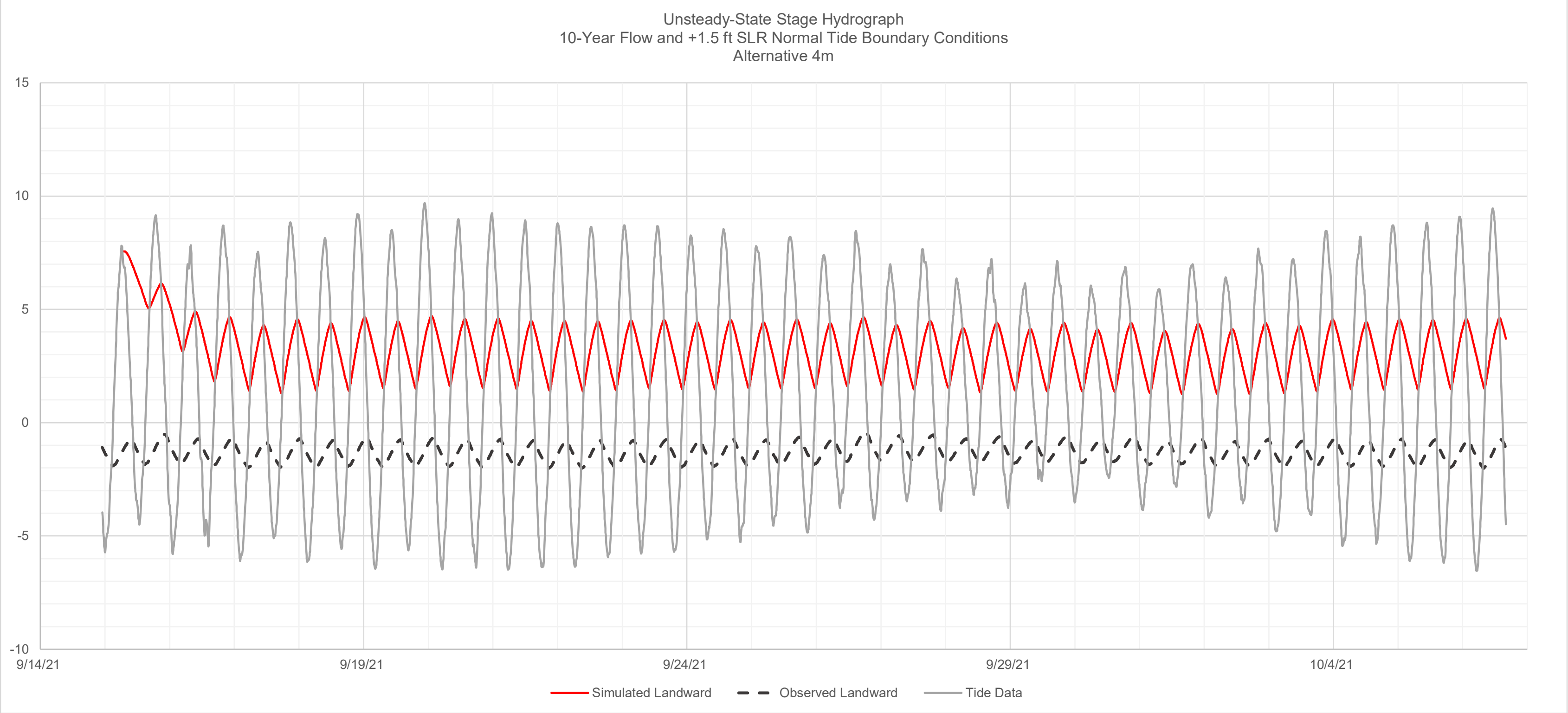

Figure A.23 - Unsteady-state stage hydrograph for 10-year riverine flow and +1.5 ft sea-level rise normal tide boundary conditions.

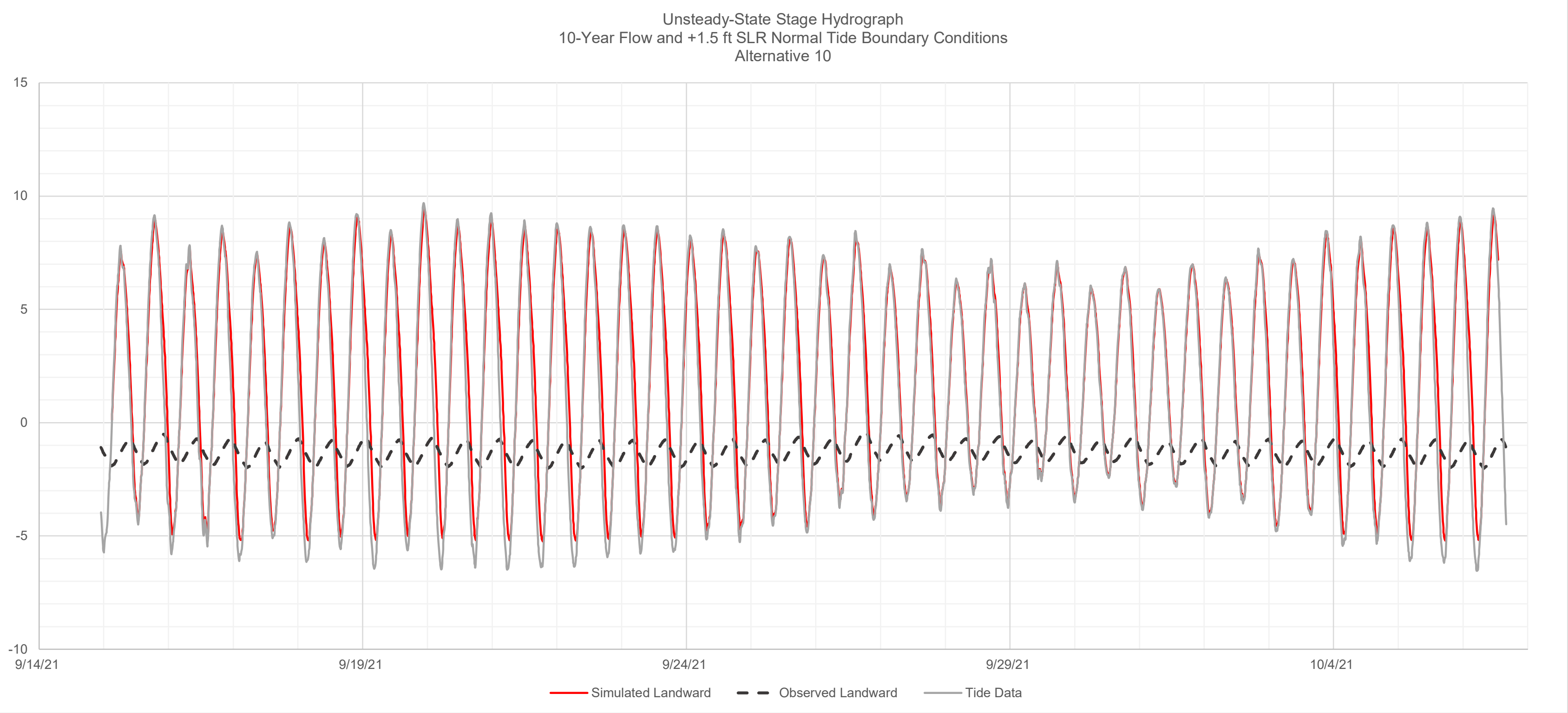

Figure A.24 - Unsteady-state stage hydrograph for 10-year riverine flow and +1.5 ft sea-level rise normal tide boundary conditions.

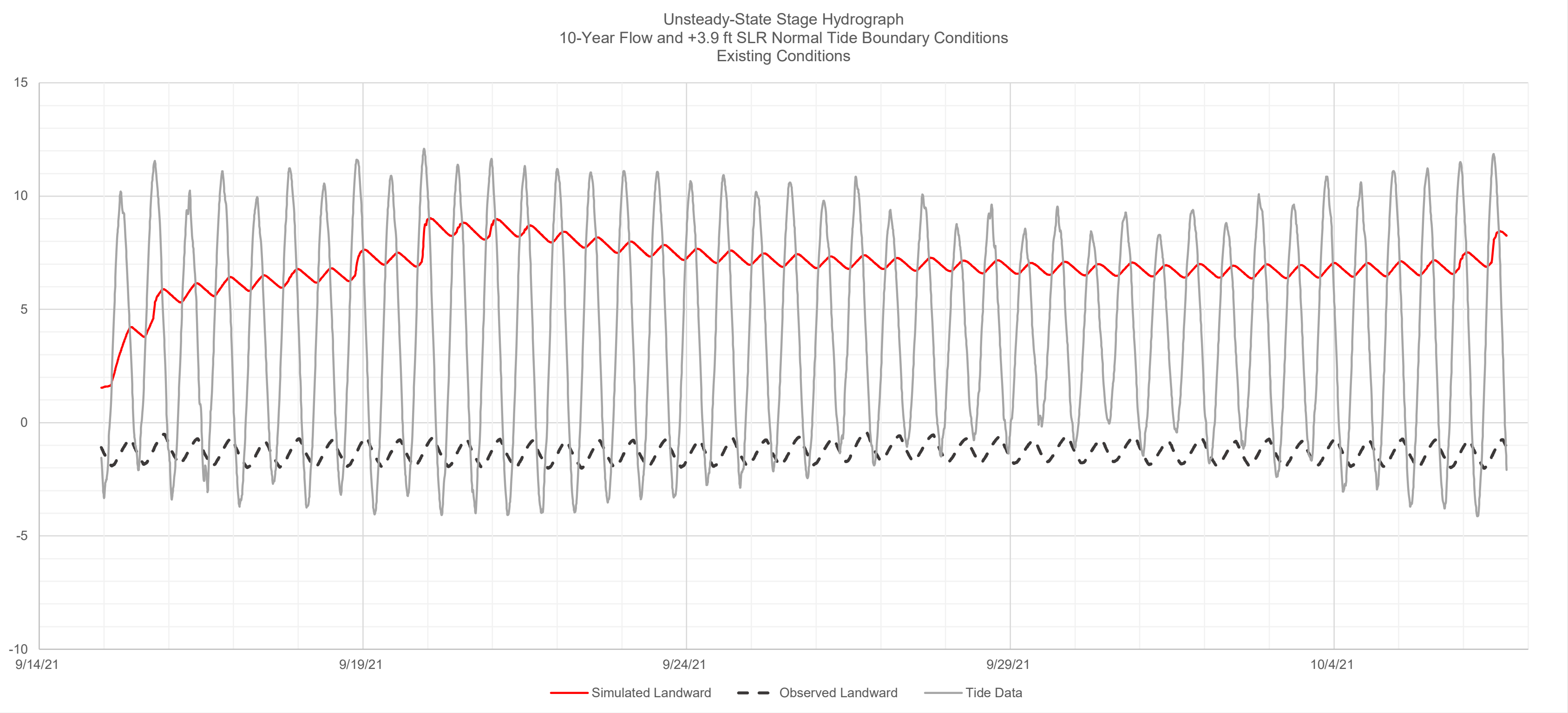

Figure A.25 - Unsteady-state stage hydrograph for 10-year riverine flow and +3.9 ft sea-level rise normal tide boundary conditions.

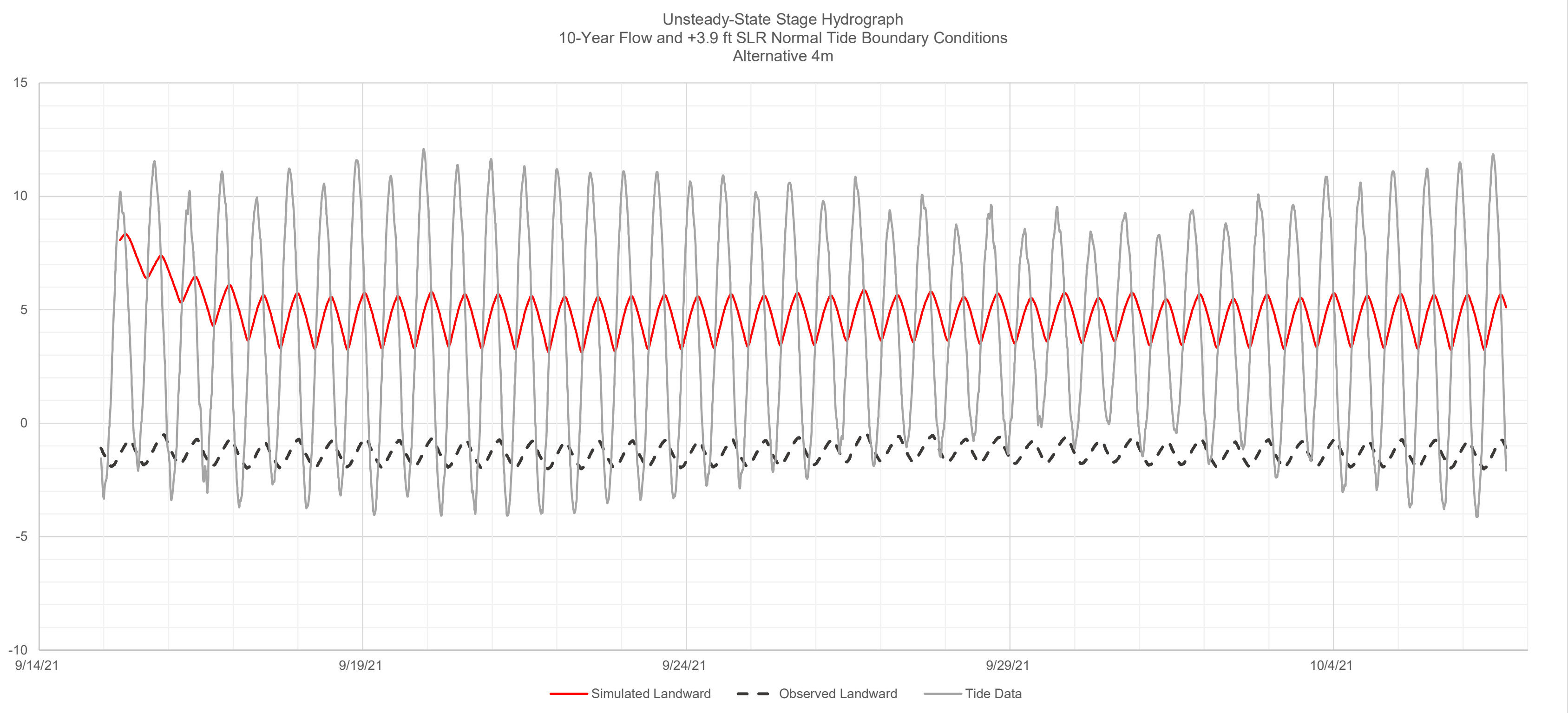

Figure A.26 - Unsteady-state stage hydrograph for 10-year riverine flow and +3.9 ft sea-level rise normal tide boundary conditions.

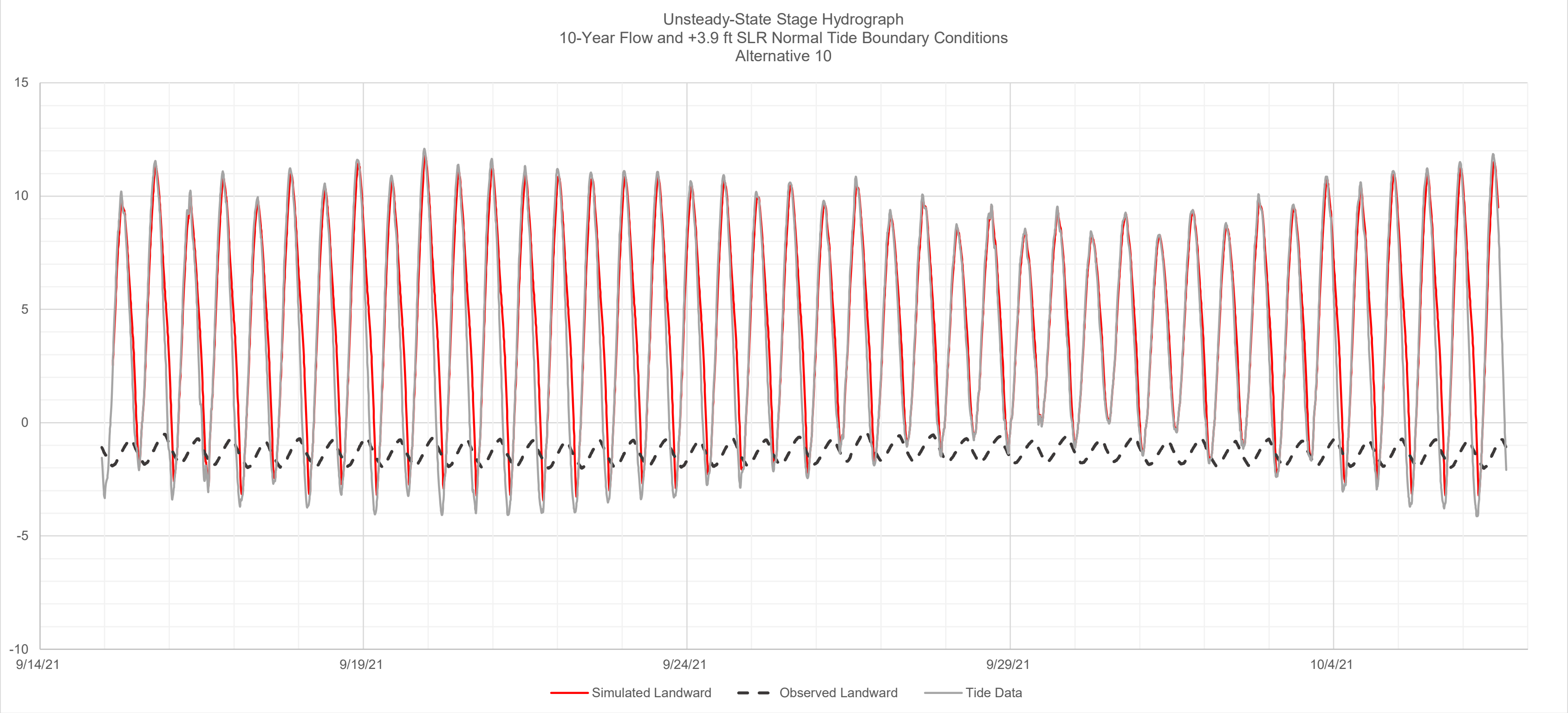

Figure A.27 - Unsteady-state stage hydrograph for 10-year riverine flow and +3.9 ft sea-level rise normal tide boundary conditions.

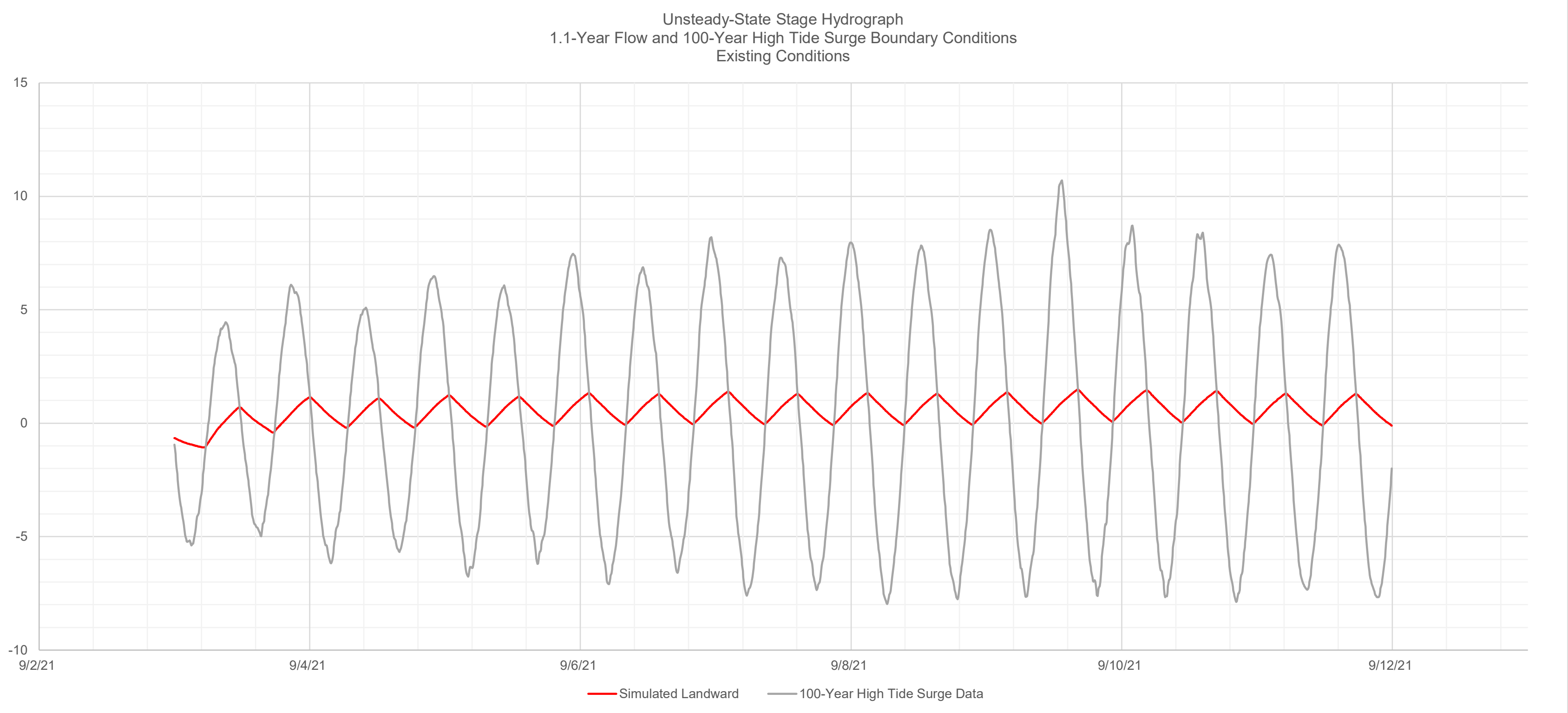

Figure A.28 - Unsteady-state stage hydrograph for 1.1-year riverine flow and 100-year high tide surge boundary conditions.

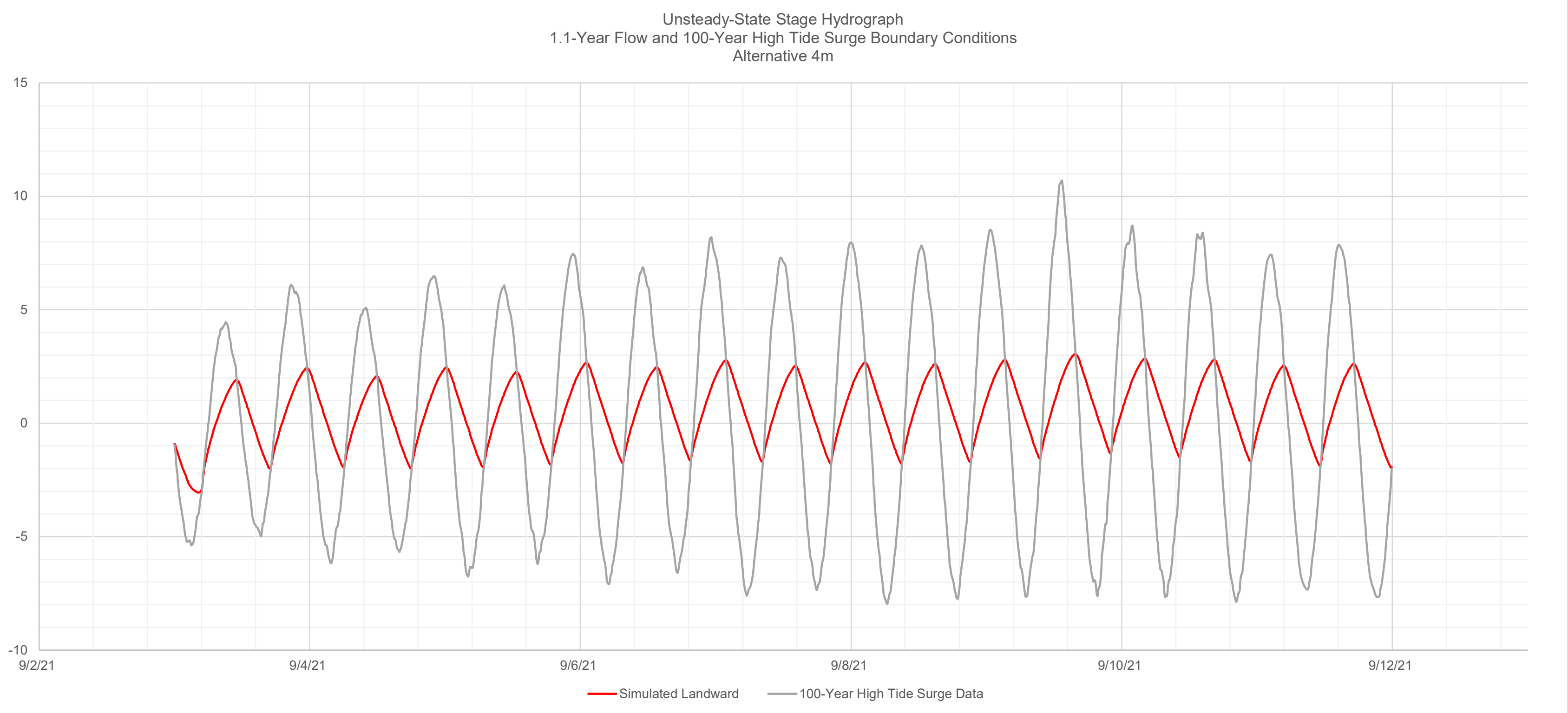

Figure A.29 - Unsteady-state stage hydrograph for 1.1-year riverine flow and 100-year high tide surge boundary conditions.

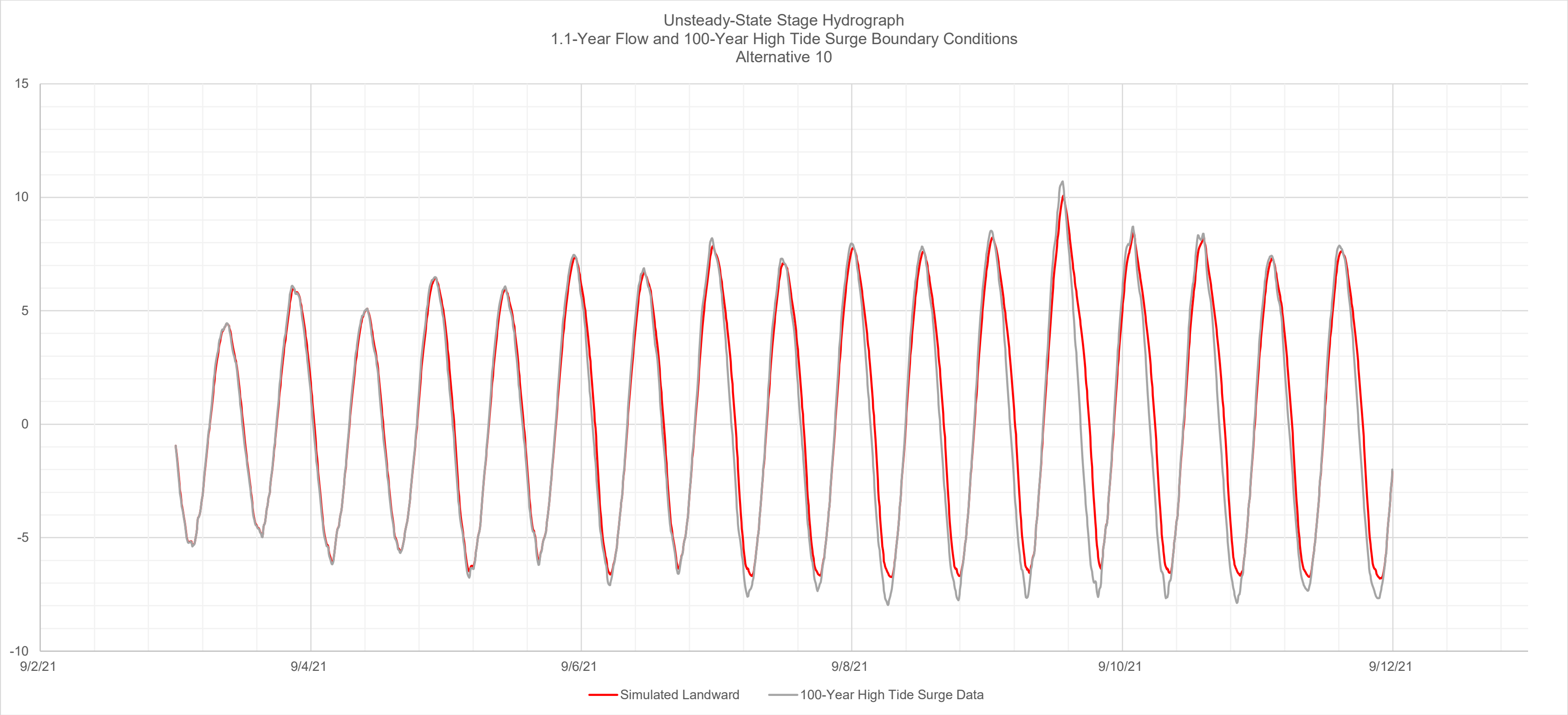

Figure A.30 - Unsteady-state stage hydrograph for 1.1-year riverine flow and 100-year high tide surge boundary conditions.

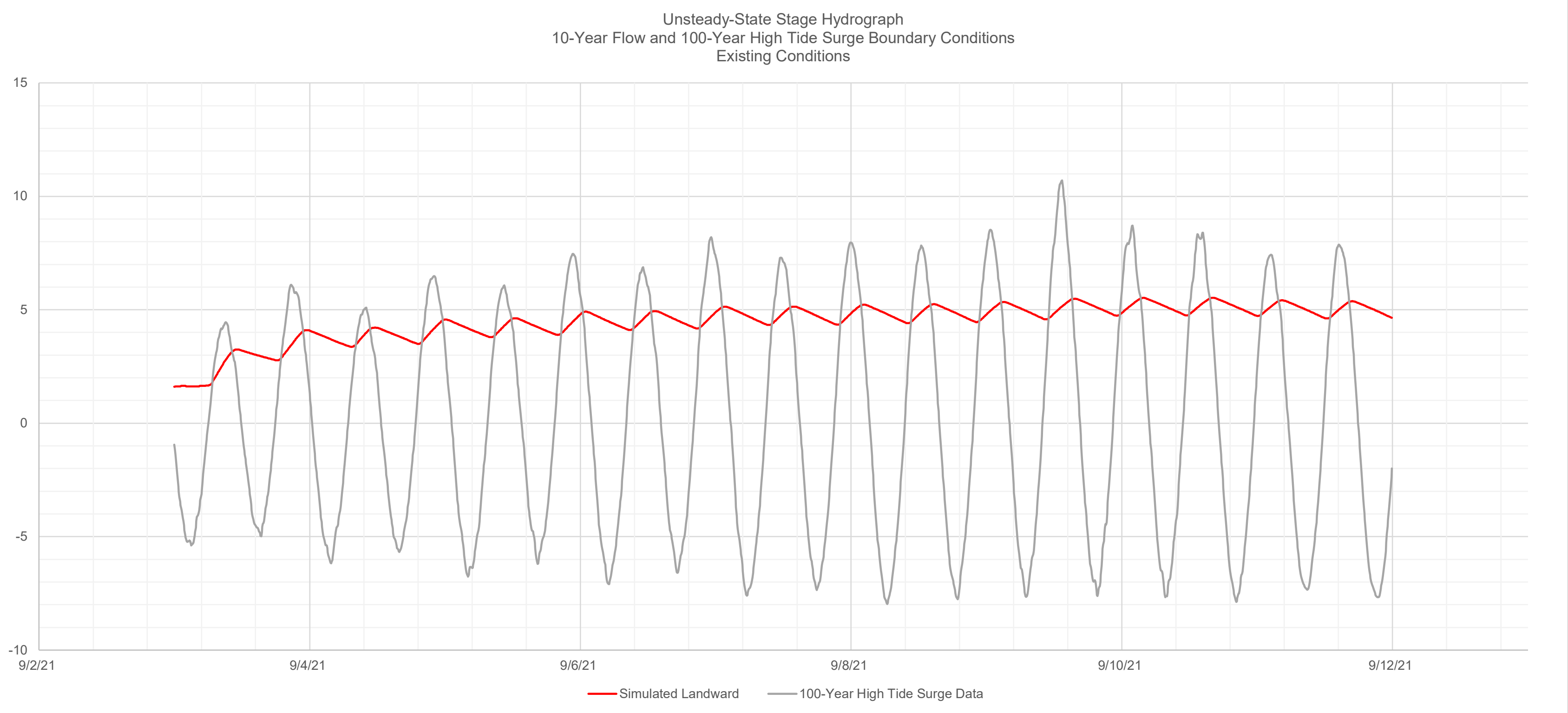

Figure A.31 - Unsteady-state stage hydrograph for 10-year riverine flow and 100-year high tide surge boundary conditions.

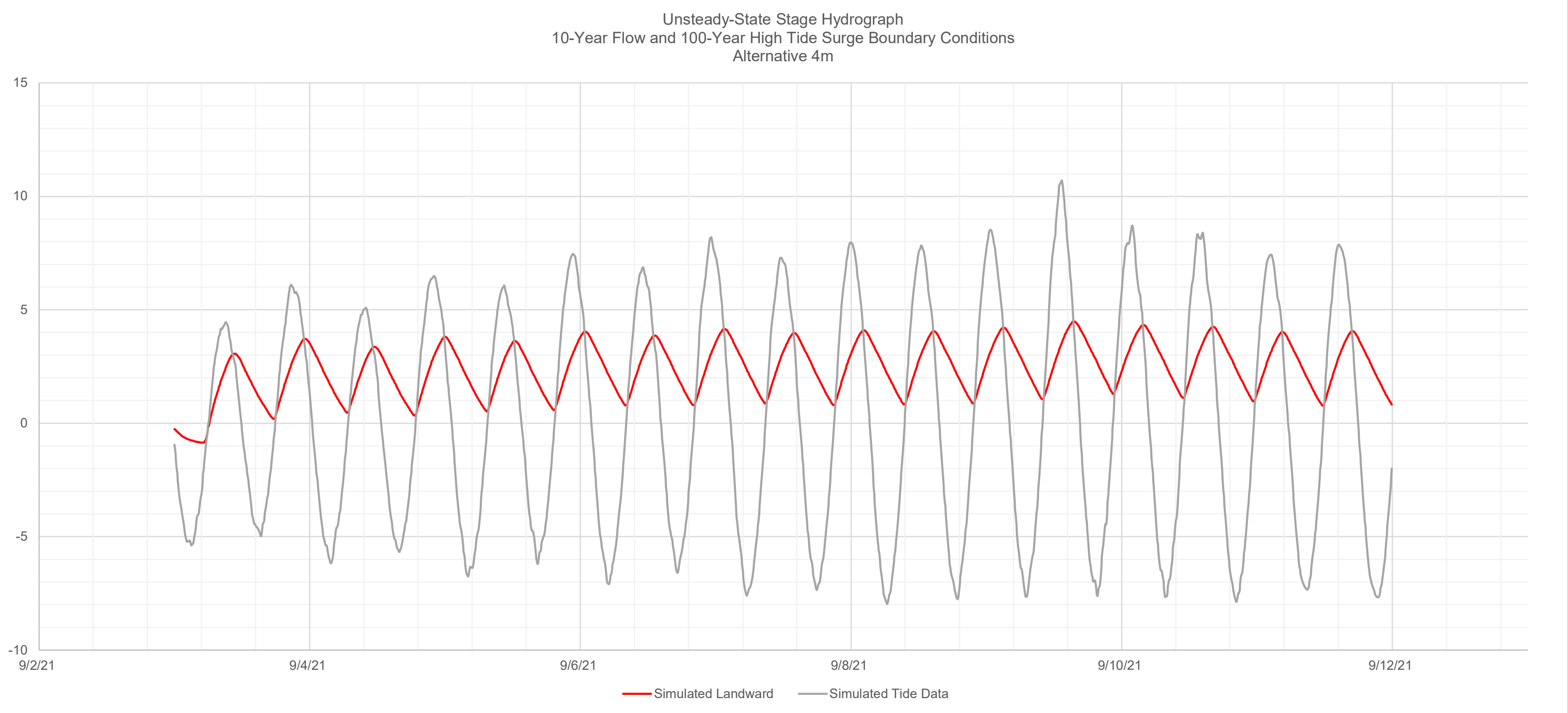

Figure A.32 - Unsteady-state stage hydrograph for 10-year riverine flow and 100-year high tide surge boundary conditions.

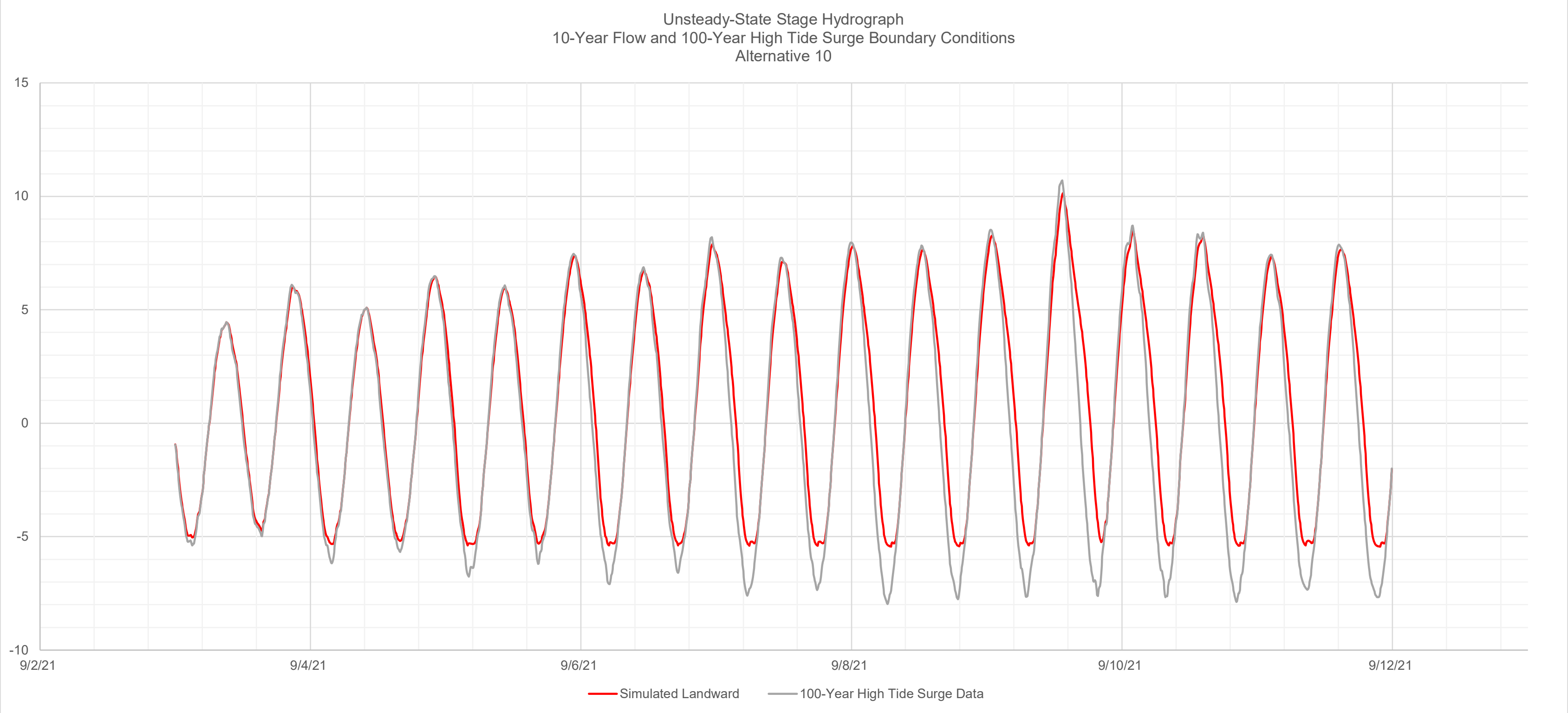

Figure A.33 - Unsteady-state stage hydrograph for 10-year riverine flow and 100-year high tide surge boundary conditions.

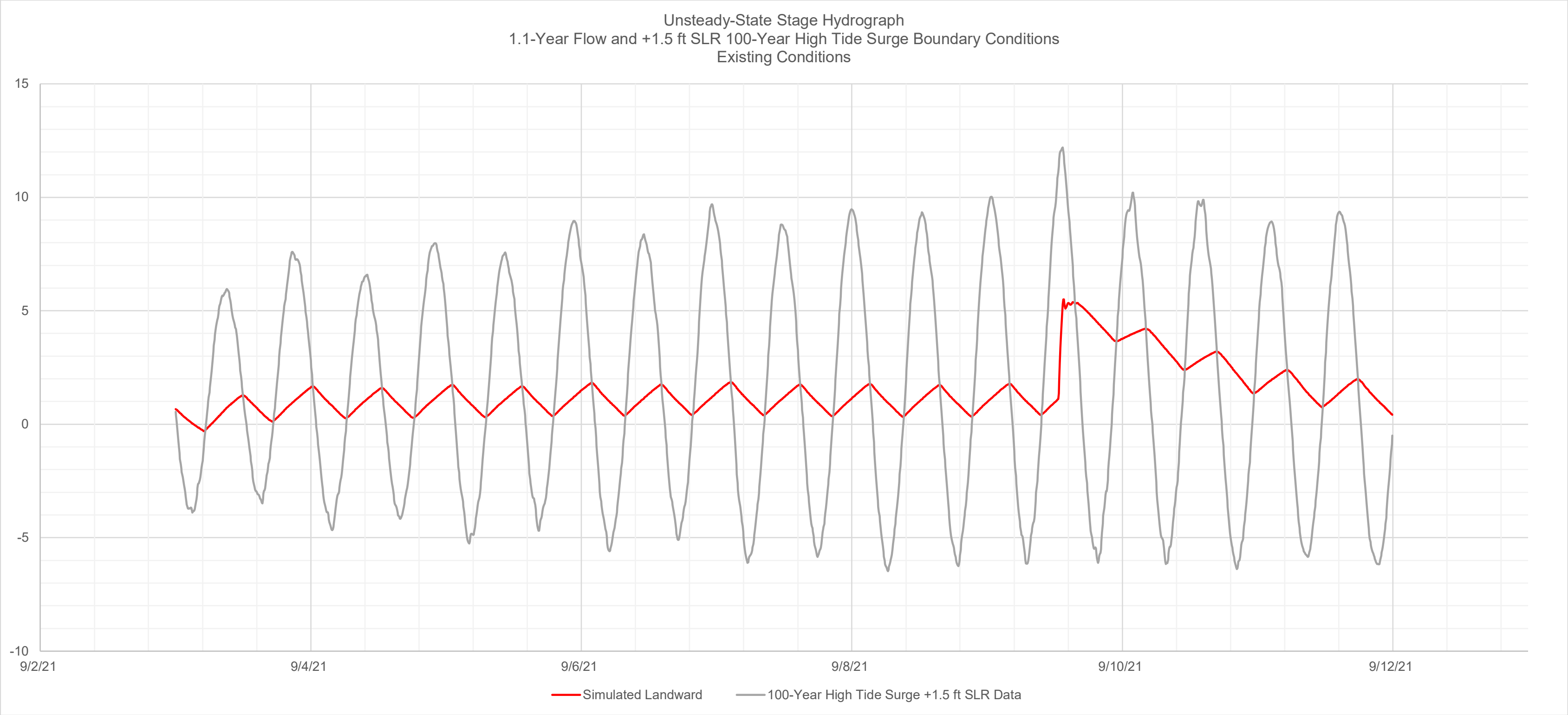

Figure A.34 - Unsteady-state stage hydrograph for 1.1-year riverine flow and +1.5 ft sea-level rise on the 100-year high tide surge boundary conditions.

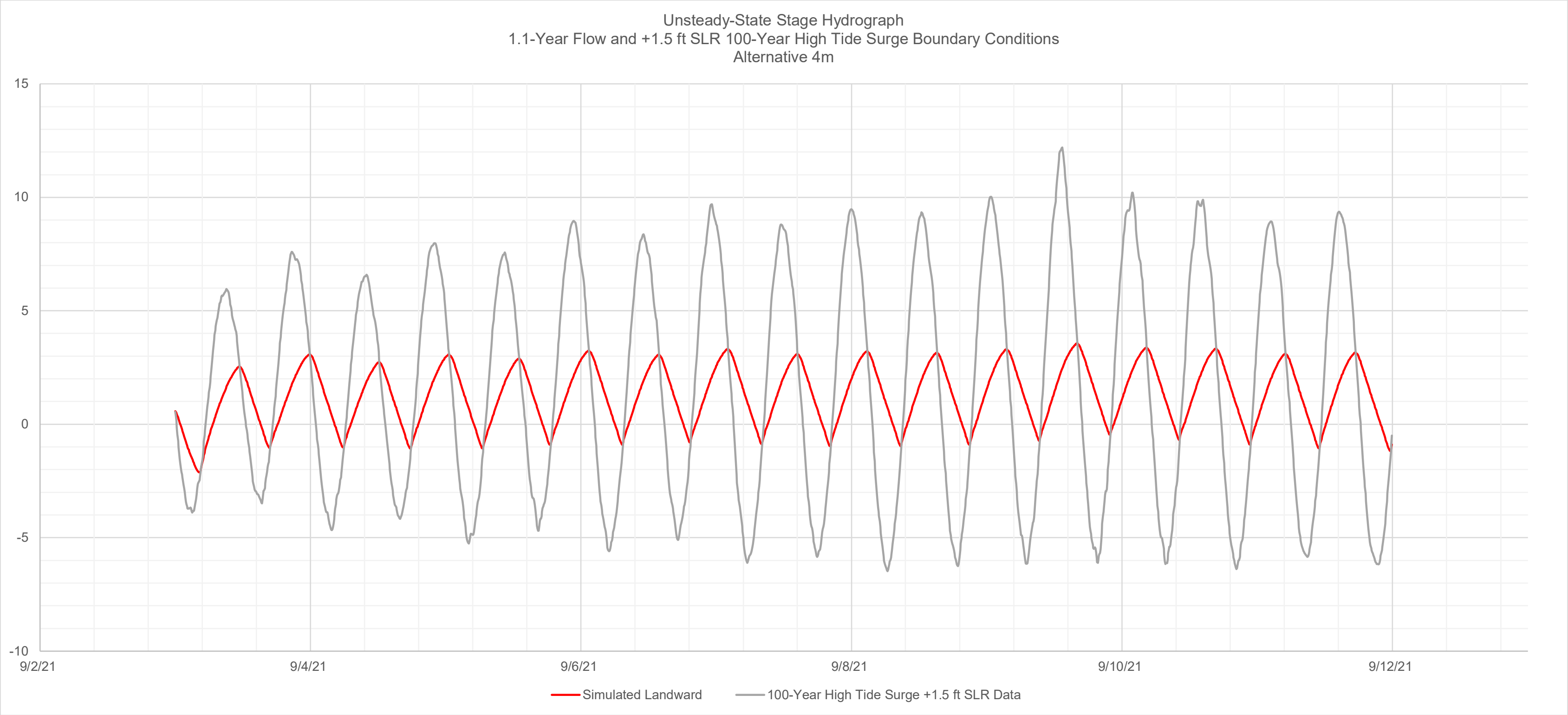

Figure A.35 - Unsteady-state stage hydrograph for 1.1-year riverine flow and +1.5 ft sea-level rise on the 100-year high tide surge boundary conditions.

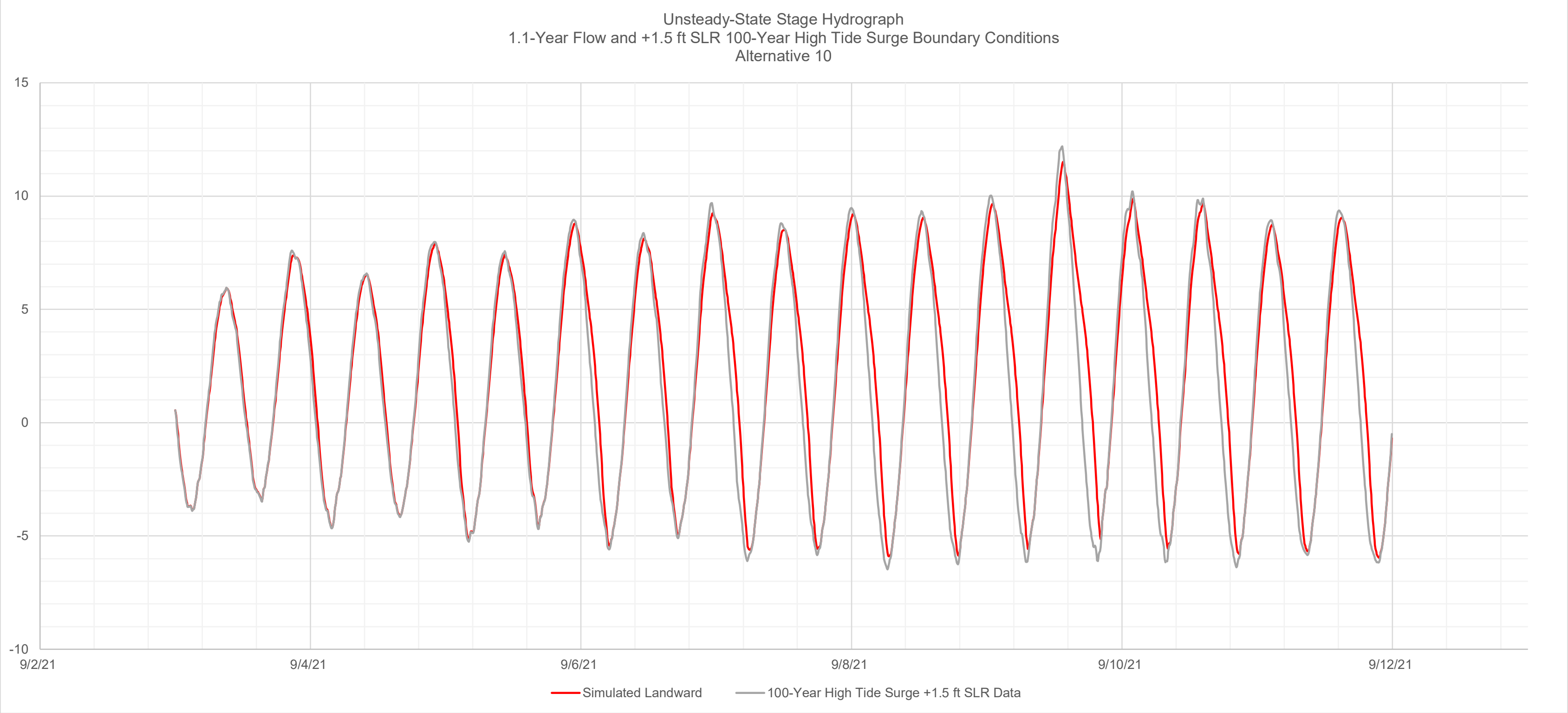

Figure A.36 - Unsteady-state stage hydrograph for 1.1-year riverine flow and +1.5 ft sea-level rise on the 100-year high tide surge boundary conditions.

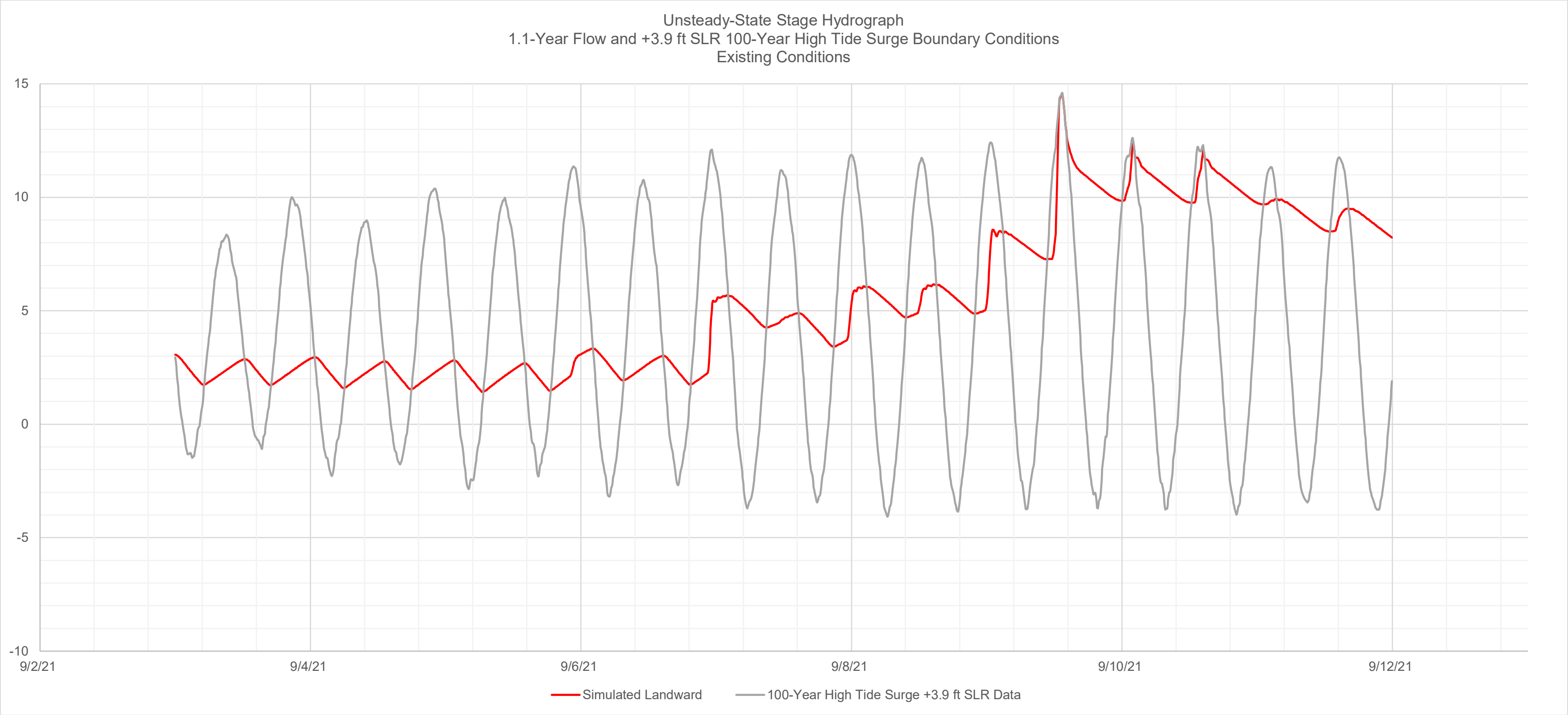

Figure A.37 - Unsteady-state stage hydrograph for 1.1-year riverine flow and +3.9 ft sea-level rise on the 100-year high tide surge boundary conditions.

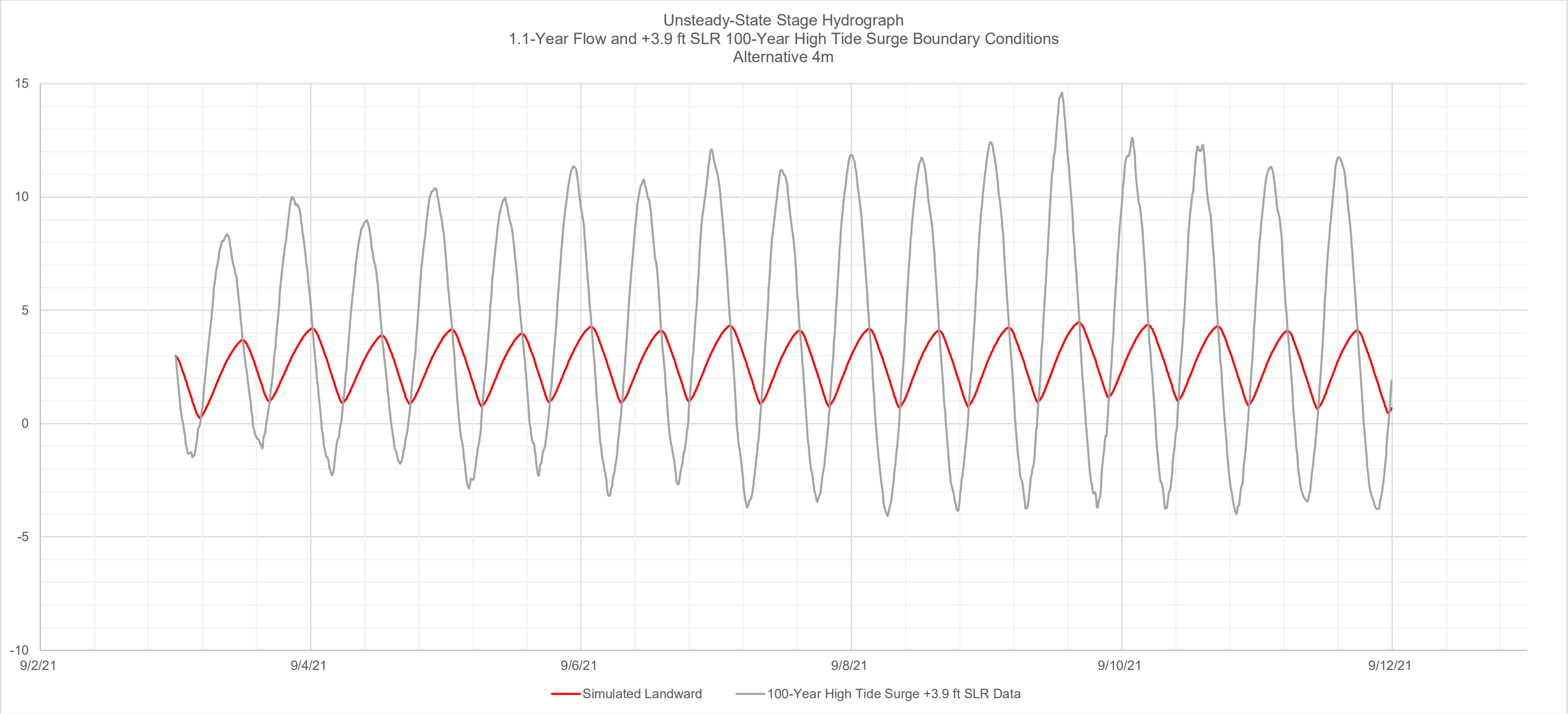

Figure A.38 - Unsteady-state stage hydrograph for 1.1-year riverine flow and +3.9 ft sea-level rise on the 100-year high tide surge boundary conditions.

Figure A.39 - Unsteady-state stage hydrograph for 1.1-year riverine flow and +3.9 ft sea-level rise on the 100-year high tide surge boundary conditions.

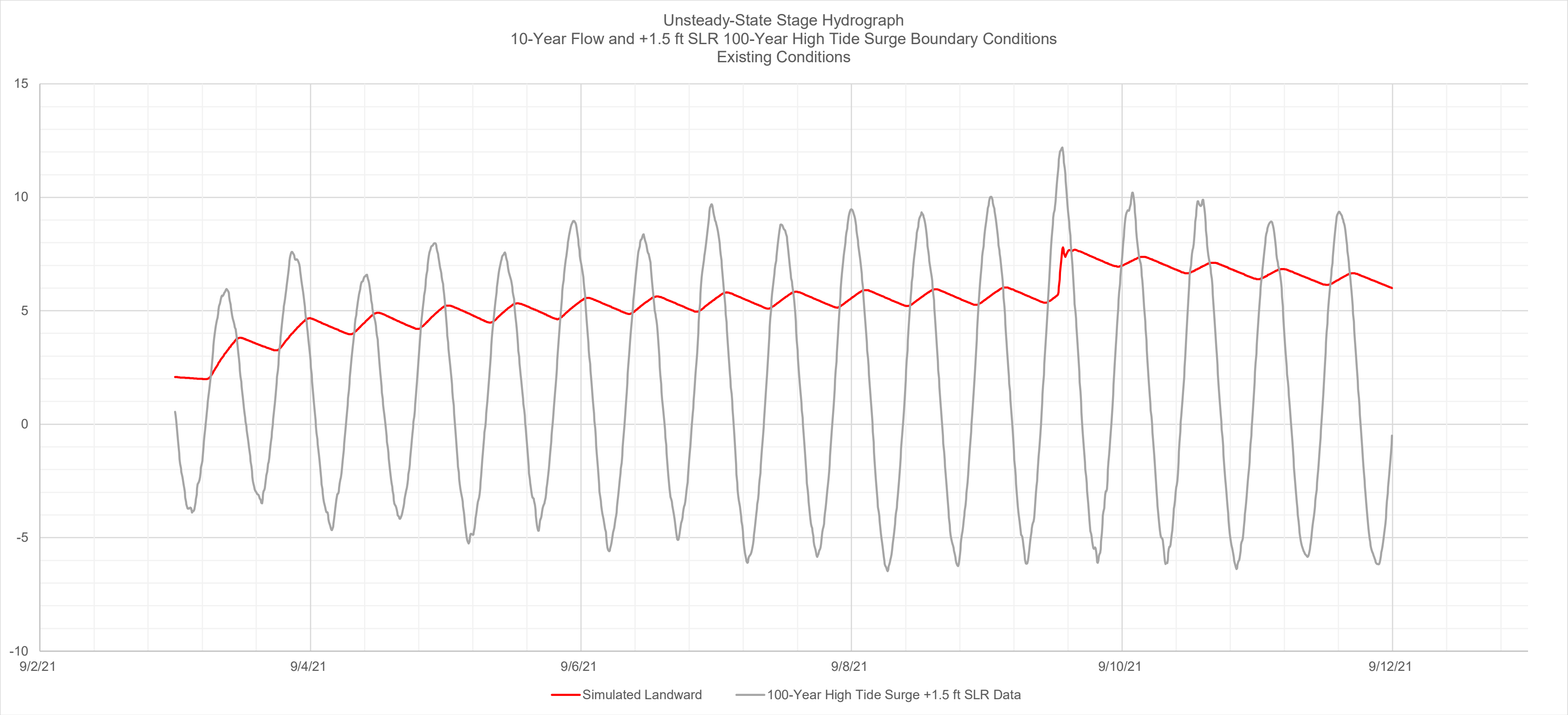

Figure A.40 - Unsteady-state stage hydrograph for 10-year riverine flow and +1.5 ft sea-level rise on the 100-year high tide surge boundary conditions.

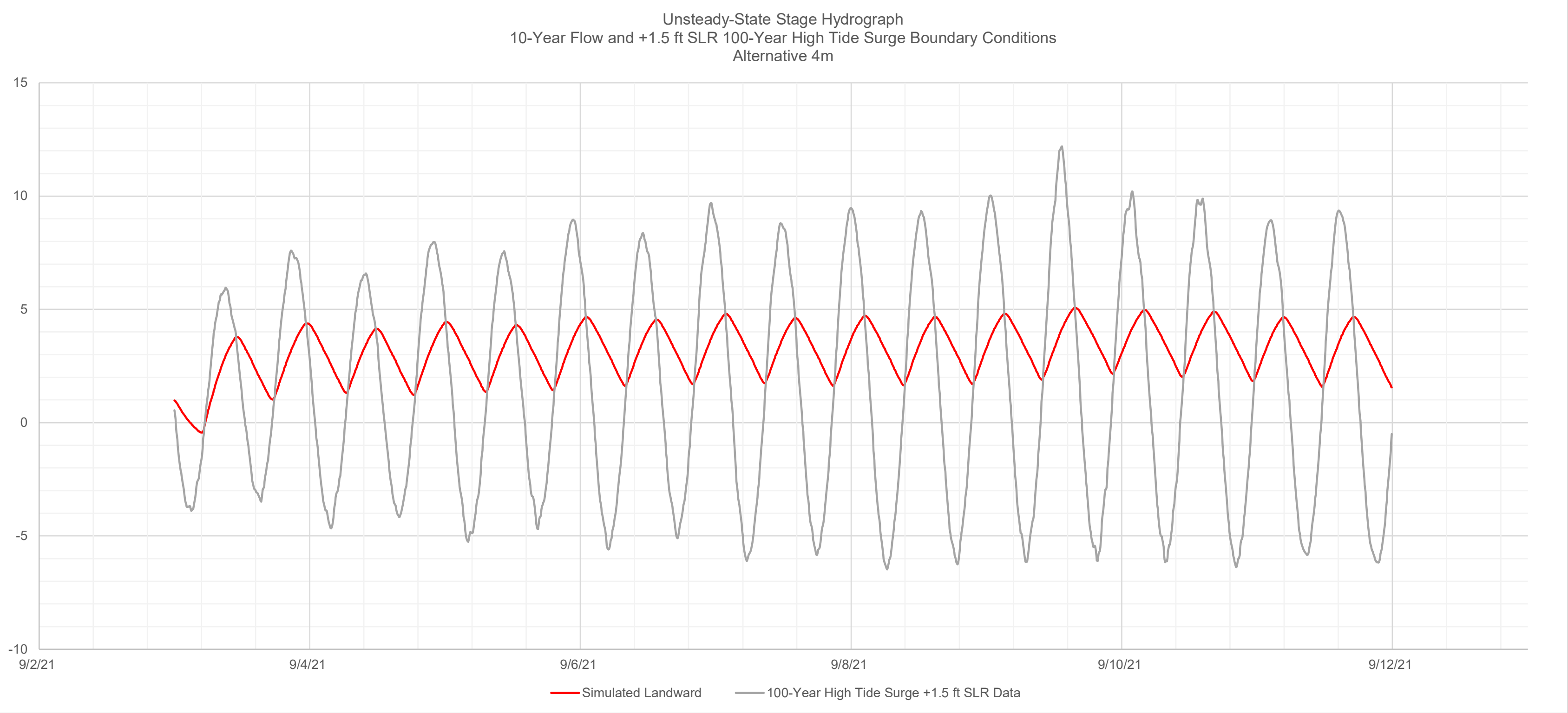

Figure A.41 - Unsteady-state stage hydrograph for 10-year riverine flow and +1.5 ft sea-level rise on the 100-year high tide surge boundary conditions.

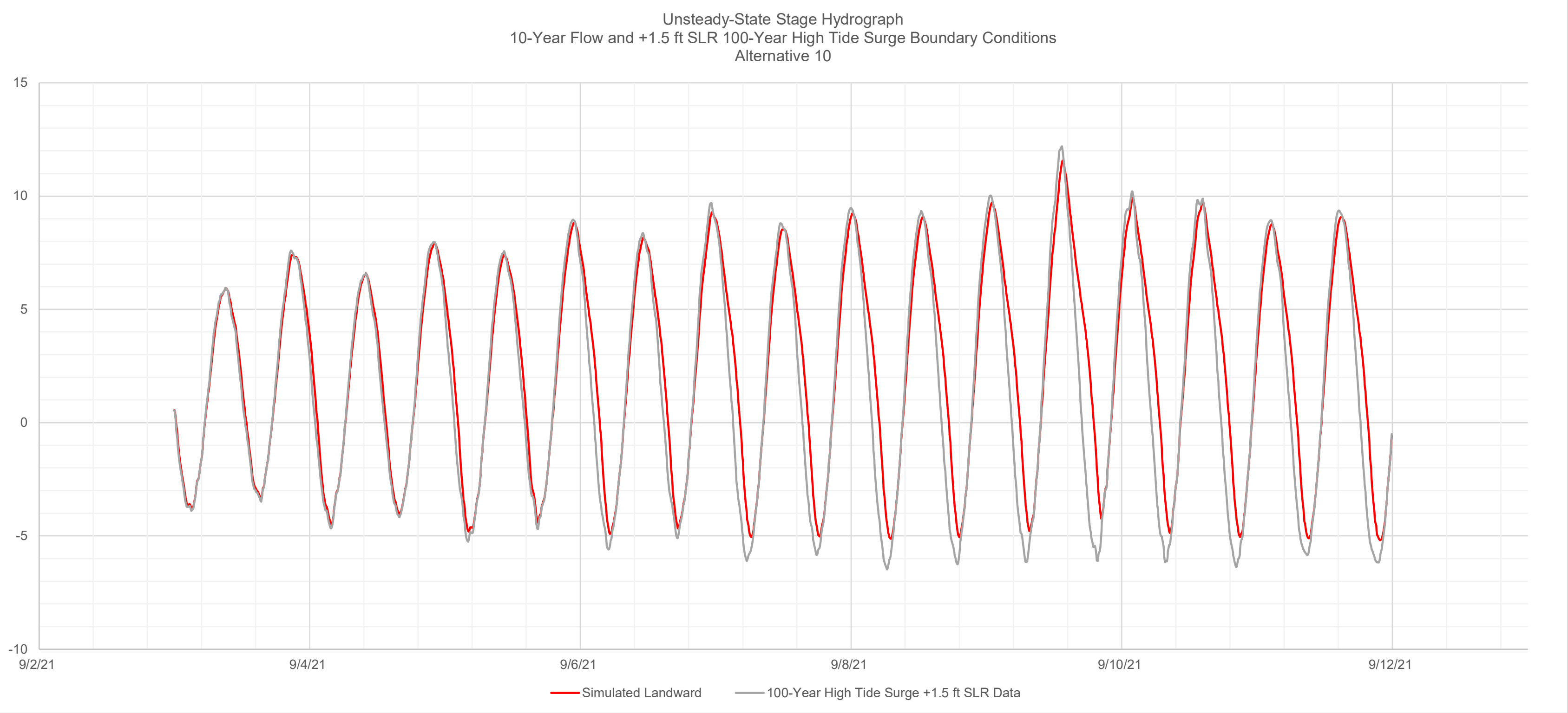

Figure A.42 - Unsteady-state stage hydrograph for 10-year riverine flow and +1.5 ft sea-level rise on the 100-year high tide surge boundary conditions.

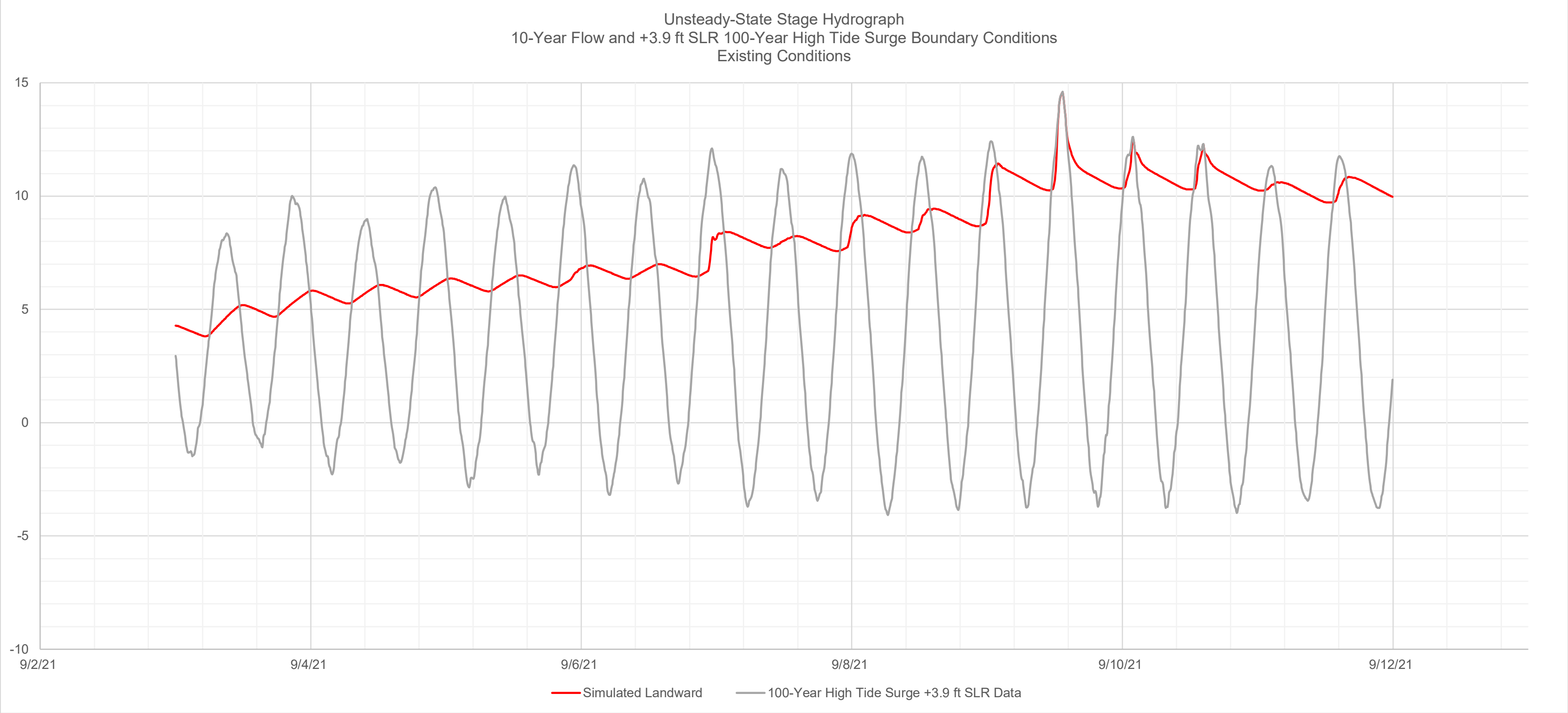

Figure A.43 - Unsteady-state stage hydrograph for 10-year riverine flow and +3.9 ft sea-level rise on the 100-year high tide surge boundary conditions.

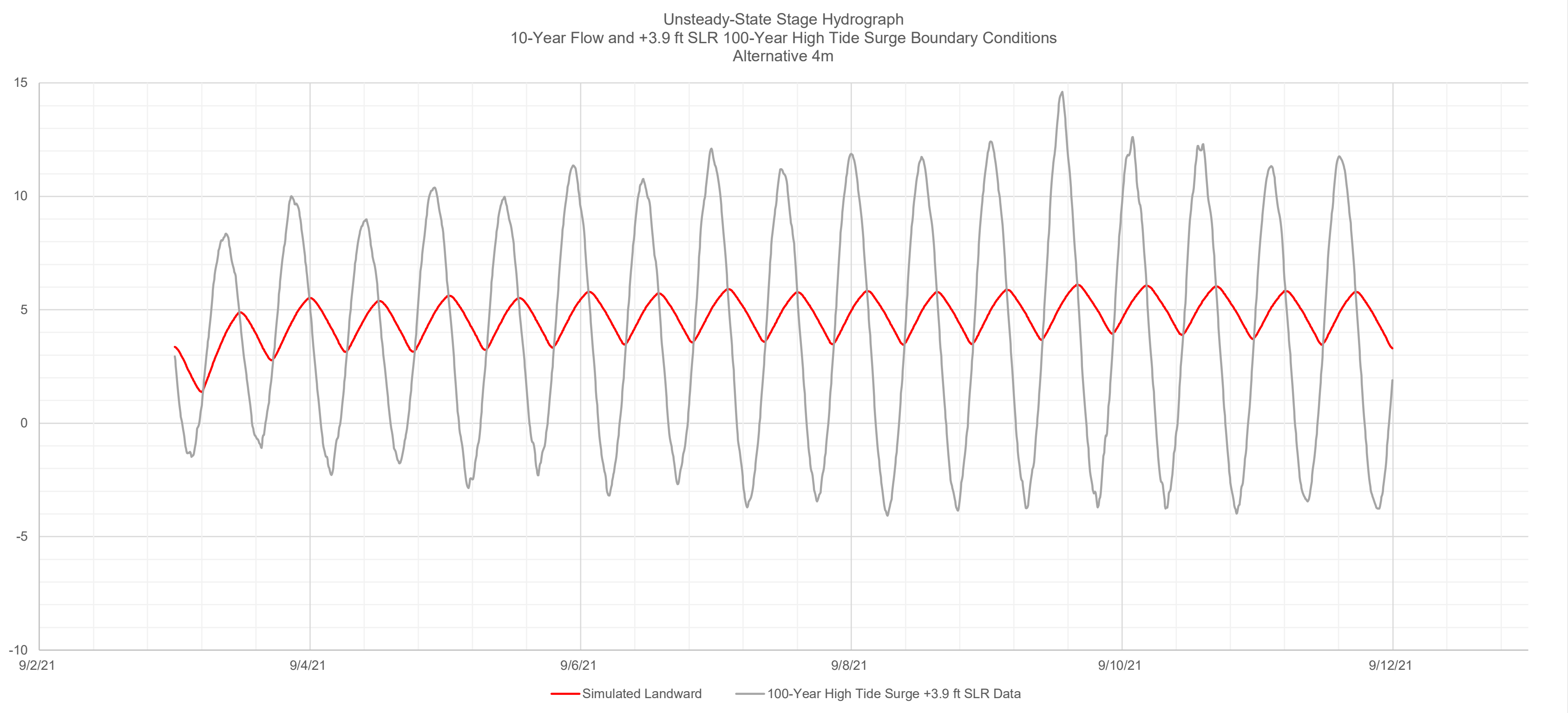

Figure A.44 - Unsteady-state stage hydrograph for 10-year riverine flow and +3.9 ft sea-level rise on the 100-year high tide surge boundary conditions.

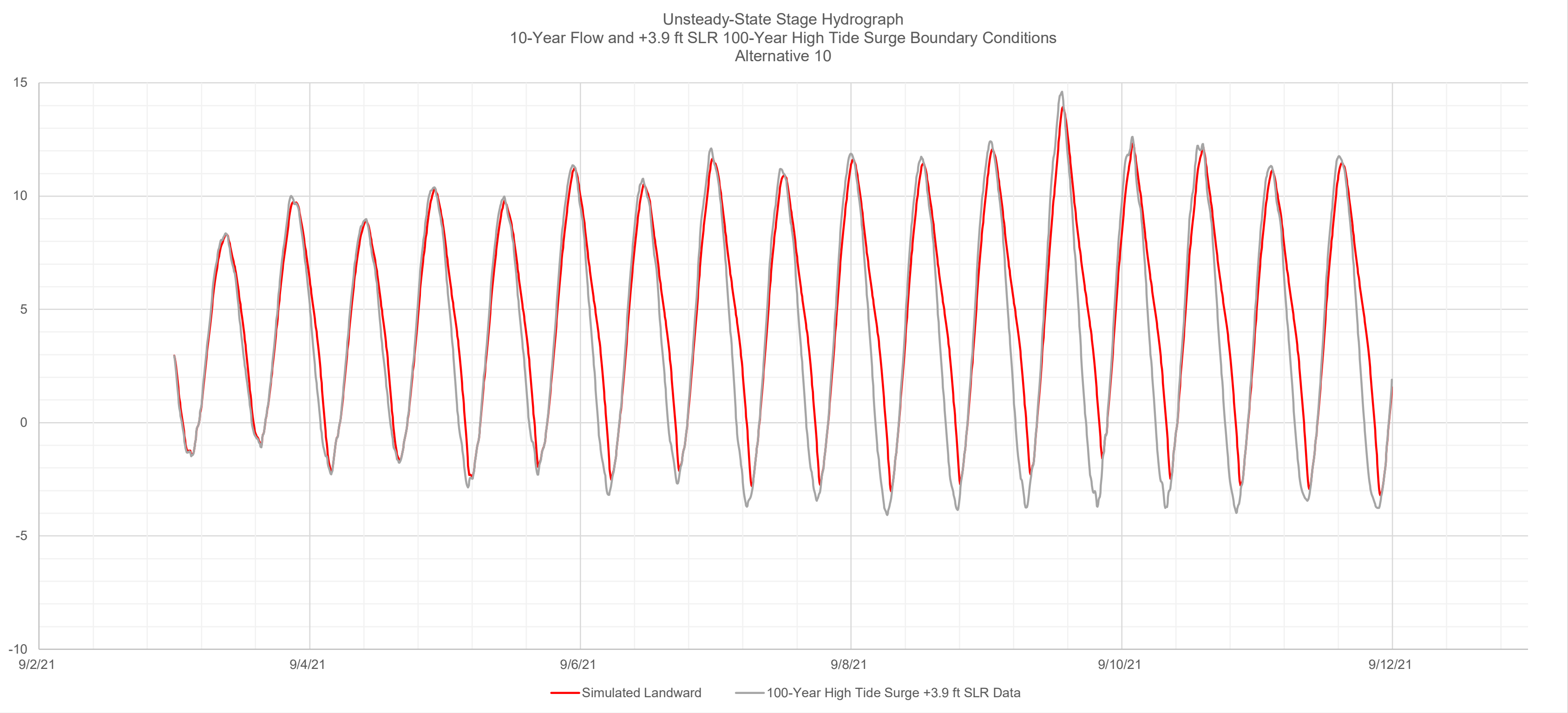

Figure A.45 - Unsteady-state stage hydrograph for 10-year riverine flow and +3.9 ft sea-level rise on the 100-year high tide surge boundary conditions.

APPENDIX B INUNDATION FIGURES

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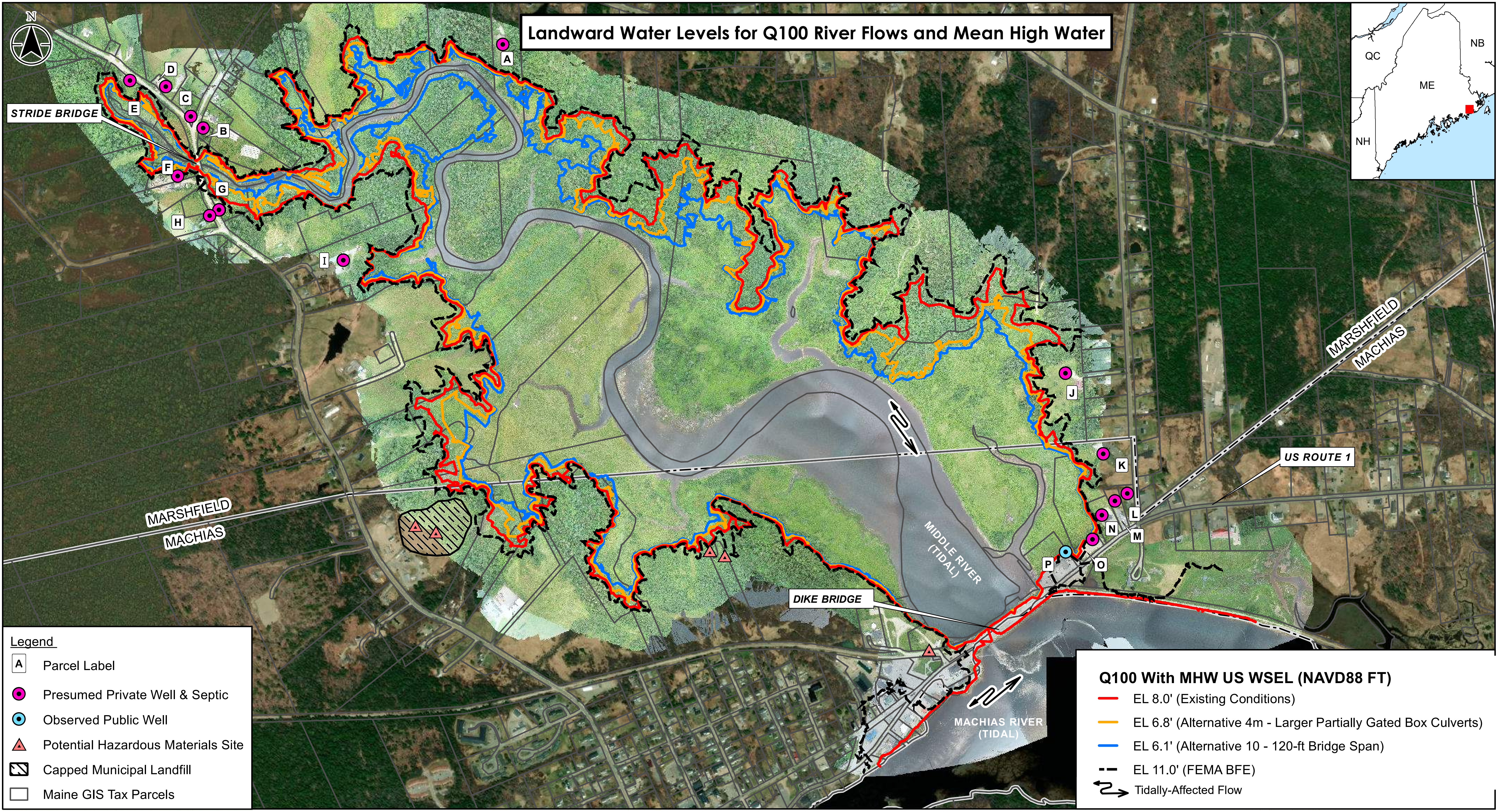
Landward Water Levels for Q100 River Flows and Mean High Water



Stantec

30 Park Drive
Topsham, ME USA 04086
Phone (207) 729-1199

Prepared by EPL on 2021-12-06
Reviewed by TM on 2021-12-06
50347_DykeBridge_Q100_MHW.mxd

Notes

1. Existing conditions are based on 2021 tidal stage data that was collected after leaking gates were fixed and 2021 drone imagery collected by MaineDOT before the leaking gates were fixed and represent a range of potential existing conditions.
2. Approximate water surface elevations (WSEL) for proposed alternatives are based on the 2021 Phase 1 and Phase 2 hydraulics analyses using tidal stage data collected by MaineDOT in 2021.
3. Coordinate System: NAD 1983 UTM Zone 19N FT
4. Vertical Datum: NAVD88
5. Aerial imagery in the project area was obtained by unmanned aircraft vehicle (UAV) by MaineDOT on July 20, 2021.
6. Aerial imagery surrounding the project area is provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).
7. TIN Surface information is based on survey data provided by the Maine Department of Transportation.

0 800 Feet
1 inch = 833 feet (At page size of 11"x17")

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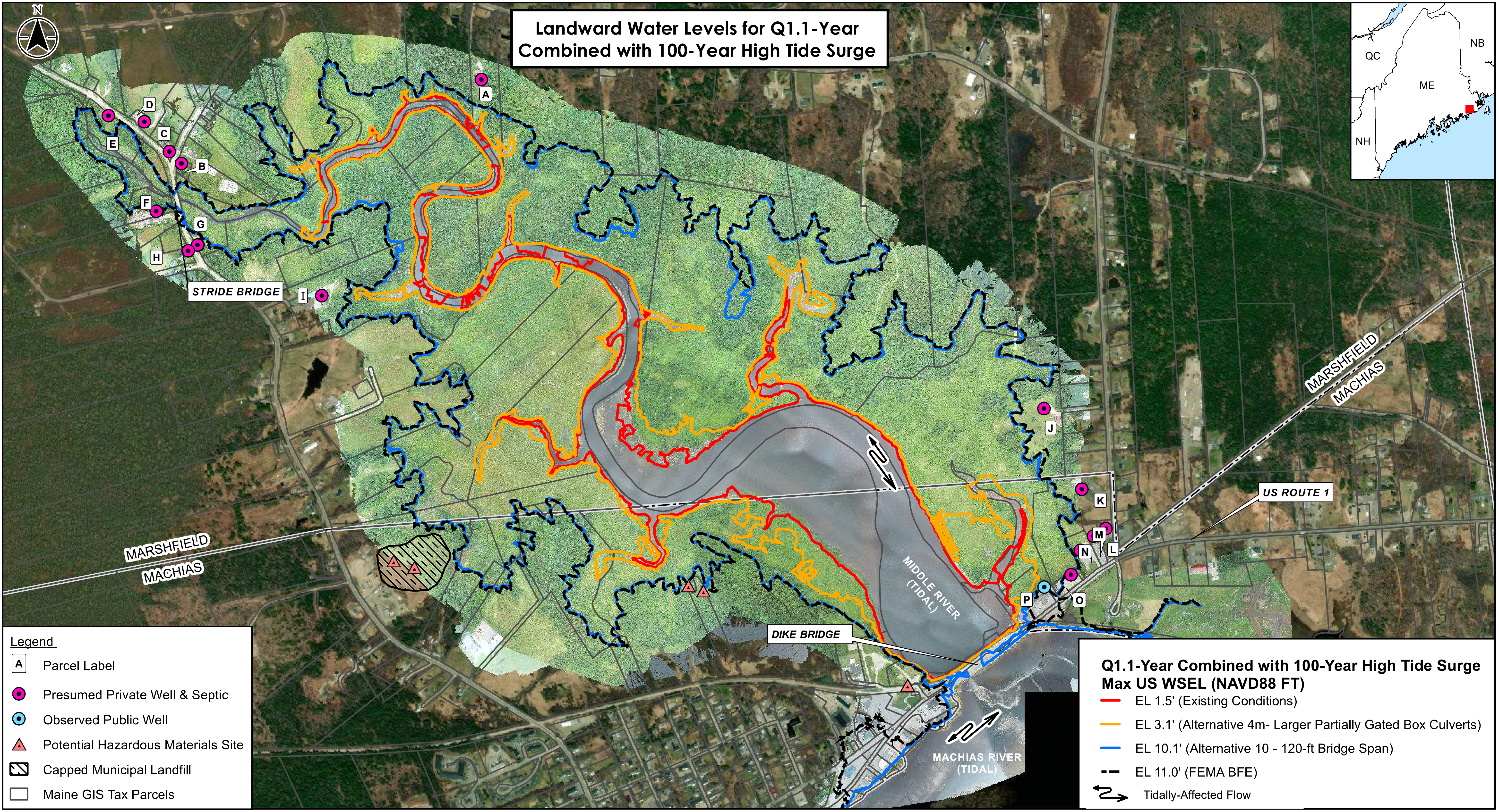
179450347

Client/Project
Maine DOT
Dike Bridge
Machias, Maine

Figure No.
B.1

Title
Landward Water Levels for
Q100 River Flows and Mean High Water
12/20/2021

Landward Water Levels for Q1.1-Year Combined with 100-Year High Tide Surge



Stantec
30 Park Drive
Topsham, ME USA 04086
Phone (207) 729-1199

Prepared by EPL on 2021-12-06
Reviewed by TM on 2021-12-06
50347_DykeBridge_100yr_Q1p1_norm.mxd

Notes

1. Existing conditions are based on 2021 tidal stage data that was collected after leaking gates were fixed and 2021 drone imagery collected by MaineDOT before the leaking gates were fixed and represent a range of potential existing conditions.
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4. Vertical Datum: NAVD88
5. Aerial imagery in the project area was obtained by unmanned aircraft vehicle (UAV) by MaineDOT on July 20, 2021.
6. Aerial imagery surrounding the project area is provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).
7. TIN Surface information is based on survey data provided by the Maine Department of Transportation.

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Client/Project
Maine DOT
Dike Bridge
Machias, Maine

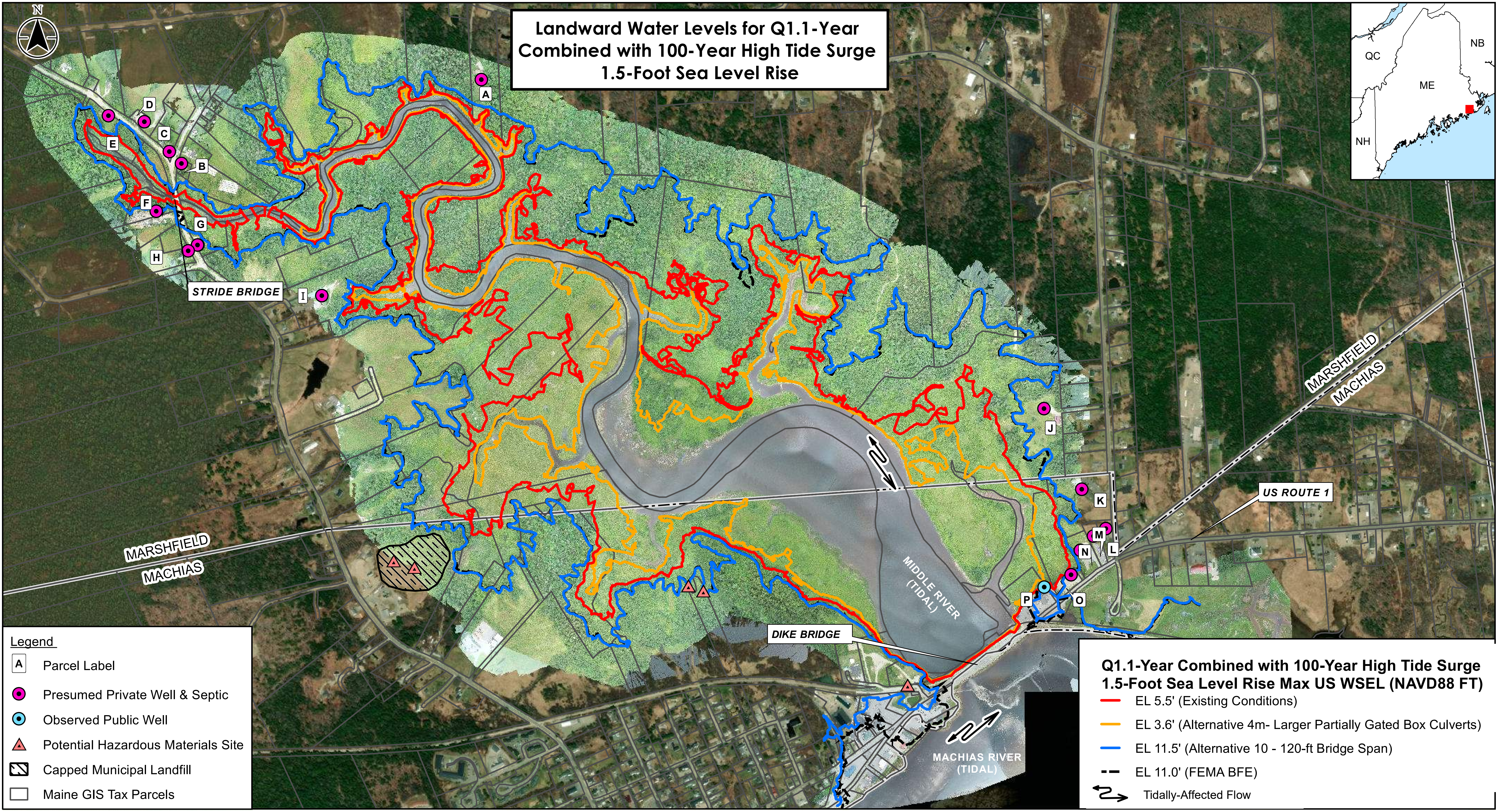
Figure No.
B.2

Title
Landward Water Levels for Q1.1-Year Combined with 100-Year High Tide Surge

12/20/2021

V:\1956\active\0_Task_Ownership\179450347\03_data\gis_cad\gis\MXDs\50347_DykeBridge_100yr_Q1p_p5_SLR.mxd Revised: 2021-12-20 By: ELe

Landward Water Levels for Q1.1-Year Combined with 100-Year High Tide Surge 1.5-Foot Sea Level Rise



Legend

A	Parcel Label
●	Presumed Private Well & Septic
◉	Observed Public Well
▲	Potential Hazardous Materials Site
▨	Capped Municipal Landfill
☐	Maine GIS Tax Parcels

Q1.1-Year Combined with 100-Year High Tide Surge 1.5-Foot Sea Level Rise Max US WSEL (NAVD88 FT)

🟥	EL 5.5' (Existing Conditions)
🟧	EL 3.6' (Alternative 4m- Larger Partially Gated Box Culverts)
🟦	EL 11.5' (Alternative 10 - 120-ft Bridge Span)
‒ ‒	EL 11.0' (FEMA BFE)
⇄	Tidally-Affected Flow

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30 Park Drive
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Phone (207) 729-1199

Prepared by EPL on 2021-12-06
Reviewed by TM on 2021-12-06
50347_DykeBridge_100yr_Q1p_p5_SLR.mxd

Notes

1. Existing conditions are based on 2021 tidal stage data that was collected after leaking gates were fixed and 2021 drone imagery collected by MaineDOT before the leaking gates were fixed and represent a range of potential existing conditions.
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3. Coordinate System: NAD 1983 UTM Zone 19N FT
4. Vertical Datum: NAVD88
5. Aerial imagery in the project area was obtained by unmanned aircraft vehicle (UAV) by MaineDOT on July 20, 2021.
6. Aerial imagery surrounding the project area is provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).
7. TIN Surface information is based on survey data provided by the Maine Department of Transportation.

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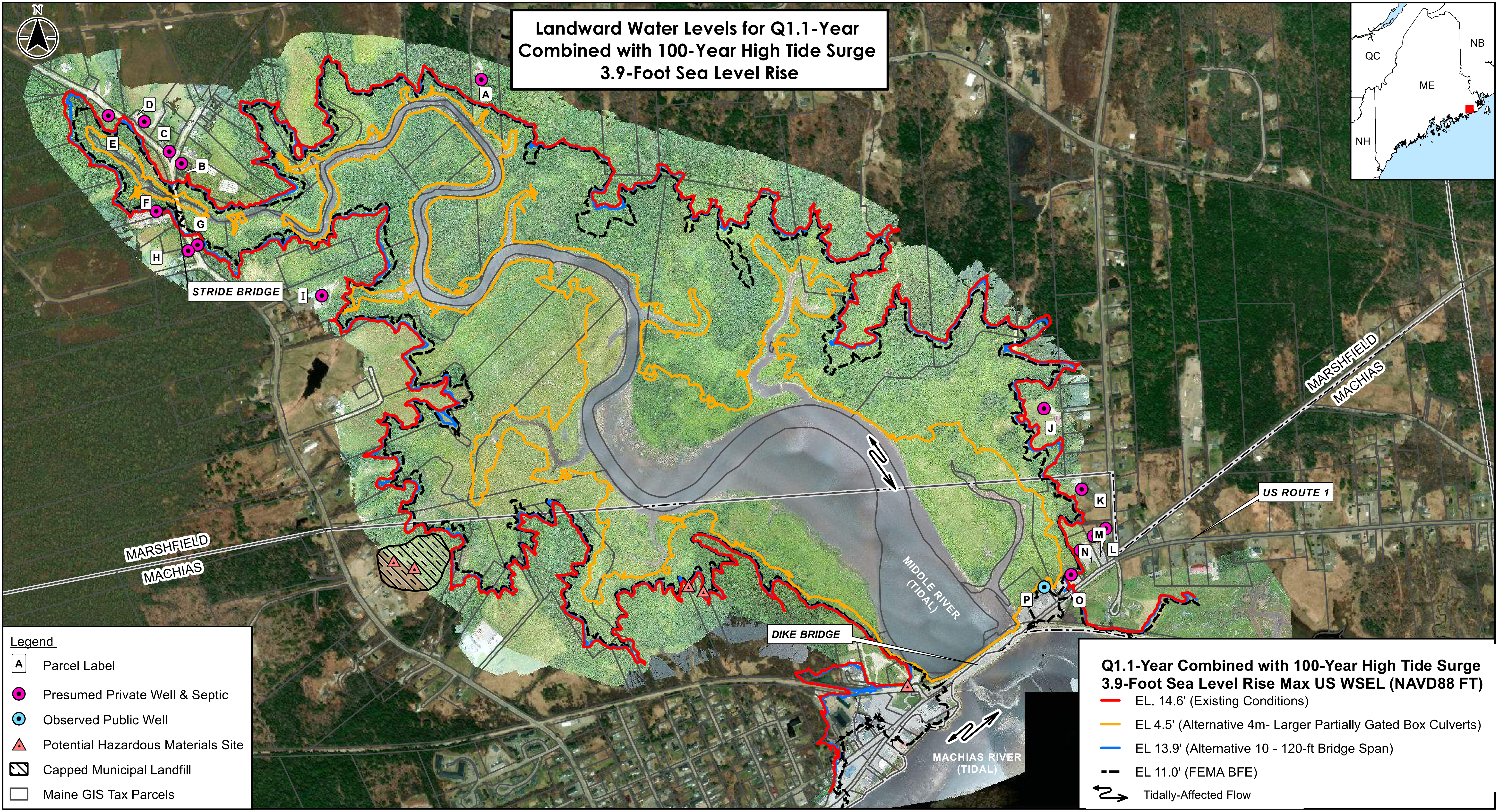
Client/Project
Maine DOT
Dike Bridge
Machias, Maine

Figure No.
B.3

Title
Landward Water Levels for Q1.1-Year Combined with 100-Year High Tide Surge 1.5-Foot Sea Level Rise
12/20/2021

V:\1956\active\0_Task_Ownership\179450347\03_data\gis_cad\gis\MXDs\50347_DykeBridge_100yr_Q1p_SLR.mxd Revised: 2021-12-20 By: ELe

Landward Water Levels for Q1.1-Year Combined with 100-Year High Tide Surge 3.9-Foot Sea Level Rise



Legend

- A Parcel Label
- ● Presumed Private Well & Septic
- ● Observed Public Well
- ▲ Potential Hazardous Materials Site
- ▨ Capped Municipal Landfill
- ☐ Maine GIS Tax Parcels

Q1.1-Year Combined with 100-Year High Tide Surge 3.9-Foot Sea Level Rise Max US WSEL (NAVD88 FT)

- EL. 14.6' (Existing Conditions)
- EL 4.5' (Alternative 4m- Larger Partially Gated Box Culverts)
- EL 13.9' (Alternative 10 - 120-ft Bridge Span)
- EL 11.0' (FEMA BFE)
- ⇄ Tidally-Affected Flow

Stantec
30 Park Drive
Topsham, ME USA 04086
Phone (207) 729-1199

Prepared by EPL on 2021-12-06
Reviewed by TM on 2021-12-06
50347_DykeBridge_100yr_Q1p_SLR.mxd

Notes

1. Existing conditions are based on 2021 tidal stage data that was collected after leaking gates were fixed and 2021 drone imagery collected by MaineDOT before the leaking gates were fixed and represent a range of potential existing conditions.
2. Approximate water surface elevations (WSEL) for proposed alternatives are based on the 2021 Phase 1 and Phase 2 hydraulics analyses using tidal stage data collected by MaineDOT in 2021.
3. Coordinate System: NAD 1983 UTM Zone 19N FT
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6. Aerial imagery surrounding the project area is provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).
7. TIN Surface information is based on survey data provided by the Maine Department of Transportation.

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Client/Project
Maine DOT
Dike Bridge
Machias, Maine

Figure No.
B.4

Title
Landward Water Levels for Q1.1-Year
Combined with 100-Year High Tide Surge
3.9-Foot Sea Level Rise
12/20/2021

APPENDIX C CONCEPTUAL LANDWARD CHANNEL FIGURE

v:\1956\active\0_task_ownership\179450347\03_data\gis_cad\cad\drawing\model\c3d\2021mdot_surf

2021.12.15 12:47:56 PM

Stantec

Stantec Consulting Services Inc.
30 Park Drive
Topsham ME 04086 U.S.A.
Tel: 207.729.1199
www.stantec.com

Notes

N

0 150' 300'

Client/Project
Maine Department of
Transportation
Dike Bridge
Machias, Maine

Project No.
179450347

Title
Conceptual Scour
Channel

Revision

Date
2021.12.15

Reference Sheet

Figure No.
1

Cut/Fill Report

Generated: 2021-12-15 11:47:47
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Volume Summary

Name	Type	Cut Factor	Fill Factor	2d Area (Sq. Ft.)	Cut (Cu. Yd.)	Fill (Cu. Yd.)	Net (Cu. Yd.)
Scour Volume	full	1.000	1.000	138700.07	18516.66	0.00	18516.66<Cut>

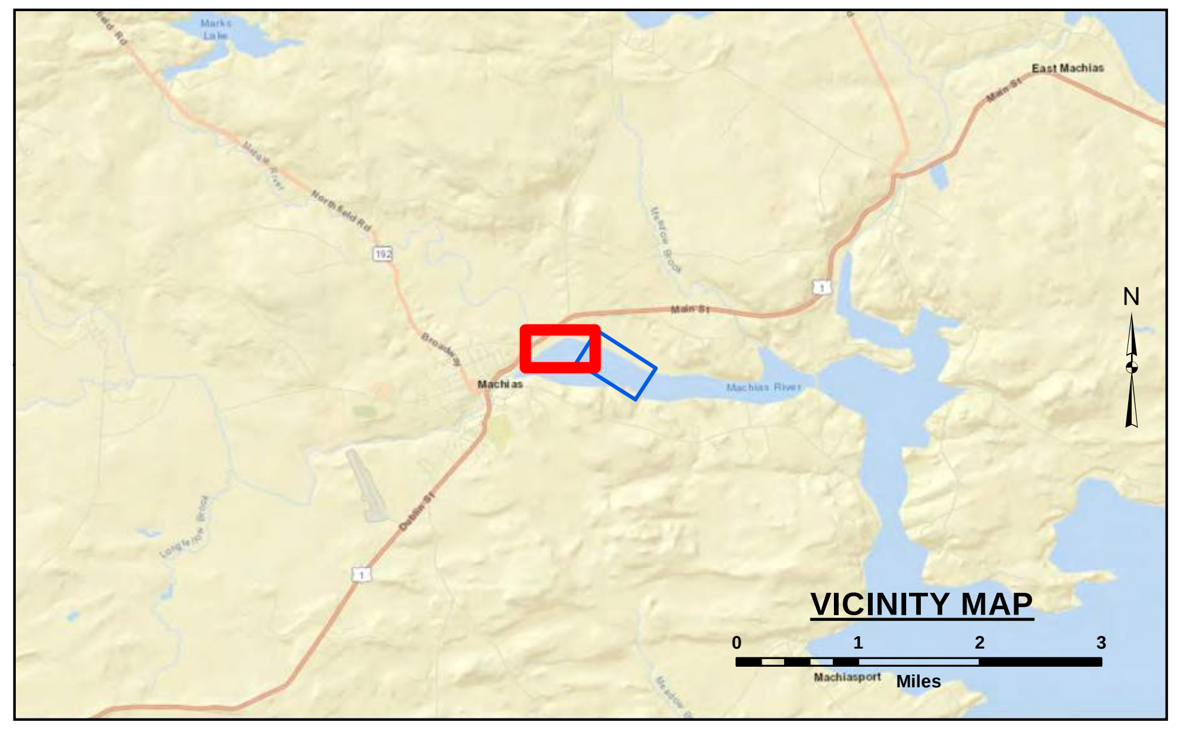
Totals

	2d Area (Sq. Ft.)	Cut (Cu. Yd.)	Fill (Cu. Yd.)	Net (Cu. Yd.)
Total	138700.07	18516.66	0.00	18516.66<Cut>

* Value adjusted by cut or fill factor other than 1.0

APPENDIX D USACE NAVIGATION CHANNEL FIGURES

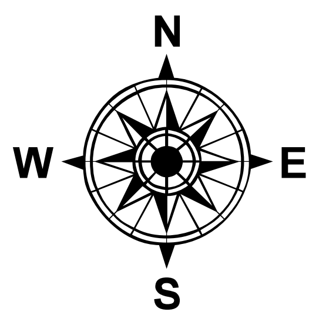
CORPS OF ENGINEERS U.S. ARMY



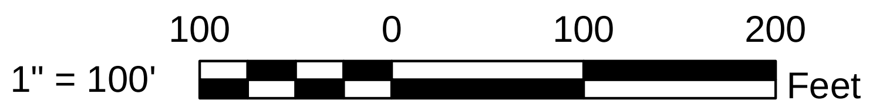
LEGEND

— —	Federal Navigation Channel	✳	Fixed Navigation Aids
- - -	Channel Center Line	▮	Red Navigation Buoy
......	Cable or Pipeline Area	▮	Green Navigation Buoy
——	Contour Line	🟥	Shoaling Area
		●	Shoalest Sounding**

** Shoalest Sounding per Quarter per Reach



GRAPHIC SCALE



Notes:

Horizontal Datum: Maine East, ME-1801 NAD 83
Distance Units: U.S. Survey Feet
Vertical Datum: MLLW
Depth Units: U.S. Survey Feet
Vessel Name: CELESTIAL
Sonar System: ODOM MK 3 (Singlebeam Sonar)
Sounding Frequency: 200 kHz
Survey Method: RTK GPS Tides
GPS_System: Trimble SPS 855 (RTK)
RTK Base Station: BM N 94 (1942)
Software Used: Hypack
Sounding Sort Distance: 20'
Field Books: R&H 3138
Survey No.: ME_04_MAC_20030425_CS_03652
Reference NOAA Chart No.: 13229

The information depicted on these charts represents the results of surveys made on the dates indicated, and can only be considered as indicating the conditions existing at that time.

General Notes

The sounding information shown on this map represents the SHOALEST soundings of those obtained from hydrographic surveys conducted during April 2003. The sounding information depicted on this map represents the results of surveys made on the dates indicated and can only be considered as indicating the conditions existing at that time. The positions of aids to navigation were located during survey operations, are provided for information only and should not be used for navigation. Orthoimagery is from a variety of sources and dates and is intended to portray general characteristics of the shoreline and other features. Temporal changes may have occurred since this dataset was collected and some parts may no longer be an accurate representation of the conditions. The information depicted on this map should NOT be used to determine volumes as volumes are determined from more sounding information than shown.

Project Remarks

None

Water Level Information

Bench Mark BM N94 (NGS Station PID PD0127) is a standard U.S.C & G.S. disk stamped "N 94 1942", located 0.3 miles east along the Maine Central Railroad from the station at Machias, Washington County, about 0.1 miles west of milepost (C44/P266), 13.0 feet north of the north rail, about level with the track and in the top of the southeast corner of an embedded boulder that the exposed portion is 4 x 5 foot and projects 2 feet. Elevation is 18.23 feet above MLLW.

US Army Corps
of Engineers
District: CENAE

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U.S. ARMY CORPS OF ENGINEERS
NEW ENGLAND DISTRICT

SURVEYED BY: RWM
CHECKED BY: ZSM
ISSUE DATE: 4/2/2020
SUBMITTED BY: Zachary McAvoy
APPROVED BY: NAE Survey
SIZE: ANSI D
MAP DOCUMENT: ME_04_MAC_20030425_CS_03652

MACHIAS RIVER
MACHIAS, MAINE
CONDITION SURVEY

4-FOOT CHANNEL

File Name: **ME_04_MAC_20030425_CS_03652**

SHEET IDENTIFICATION
Machias River

Sheet 1 of 1

Revison Number: 4.1-20191105

US Army Corps of Engineers
District: CENAE

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NEW ENGLAND DISTRICT

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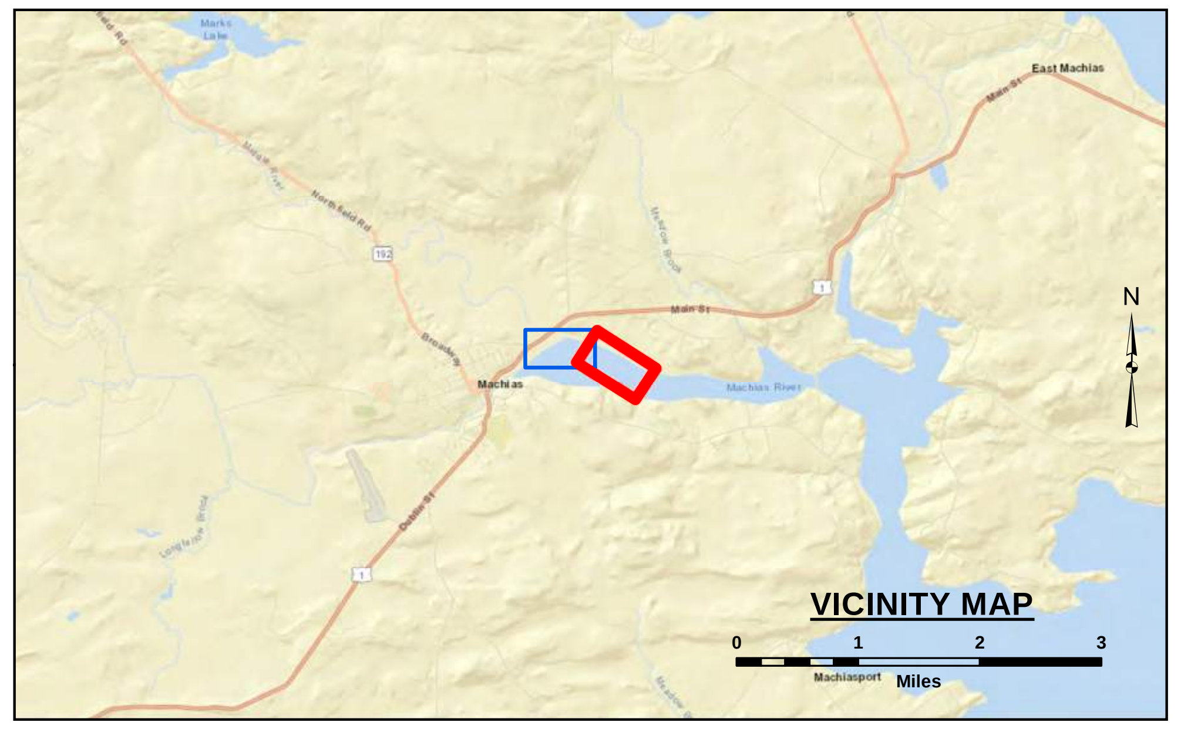
Sheet 1 of 1

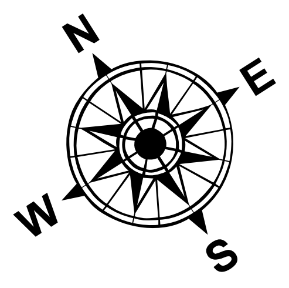


VICINITY MAP

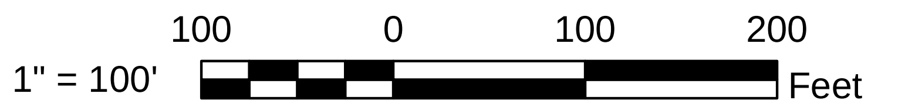
LEGEND

—·—	Federal Navigation Channel	✳	Fixed Navigation Aids
— —	Channel Center Line	▲	Red Navigation Buoy
········	Cable or Pipeline Area	▲	Green Navigation Buoy
——	Contour Line	🟥	Shoaling Area
		●	Shoalest Sounding**

** Shoalest Sounding per Quarter per Reach



GRAPHIC SCALE



Notes:
Horizontal Datum: Maine East, ME-1801 NAD 83
Distance Units: U.S. Survey Feet
Vertical Datum: MLLW
Depth Units: U.S. Survey Feet
Vessel Name: CELESTIAL
Sonar System: ODOM MK 3 (Singlebeam Sonar)
Sounding Frequency: 200 kHz
Survey Method: RTK GPS Tides
GPS_System: Trimble SPS 855 (RTK)
RTK Base Station: BM N 94 (1942)
Software Used: Hypack
Sounding Sort Distance: 20'
Field Books: R&H 3138
Survey No.: ME_04_MAC_20030425_CS_03652
Reference NOAA Chart No.: 13229

The information depicted on these charts represents the results of surveys made on the dates indicated, and can only be considered as indicating the conditions existing at that time.

General Notes

The sounding information shown on this map represents the SHOALEST soundings of those obtained from hydrographic surveys conducted during April 2003. The sounding information depicted on this map represents the results of surveys made on the dates indicated and can only be considered as indicating the conditions existing at that time. The positions of aids to navigation were located during survey operations, are provided for information only and should not be used for navigation. Orthoimagery is from a variety of sources and dates and is intended to portray general characteristics of the shoreline and other features. Temporal changes may have occurred since this dataset was collected and some parts may no longer be an accurate representation of the conditions. The information depicted on this map should NOT be used to determine volumes as volumes are determined from more sounding information than shown.

Project Remarks

None

Water Level Information

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Revison Number: 4.1-20191105

Environmental Office – Hydrology Section
16 State House Station
Augusta ME 04333-0016
207.557.1052
Charles.Hebson@maine.gov

Maine Department of Transportation

Memo

To: Kristen Chamberlain
From: Charles Hebson
CC: Joyce Taylor, David Gardner, Eric Ham
Date: 2023 September 6
Re: 16714 Machias Dyke Bridge #2246 – Flood Control Structure

---

Executive Summary

Dyke Bridge (#2246) in Machias ME carries U.S. Route 1 over the Middle River on an embankment causeway just above its confluence with the Machias River. Based on the local history, as well as the method of construction, it is apparent that Dyke Bridge is not a flood control structure in the modern sense of the term.

A separate memo (MaineDOT, 9/6/23), discusses whether fill associated with raising the Dyke Bridge causeway constitutes a :significant encroachment” on the adjacent mapped flood plains. Our conclusion is that the proposed fill does not rise to the level of a significant encroachment. That memo should be referenced for additional information and complements this discussion.

Discussion

Dyke Bridge (#2246) in Machias ME carries U.S. Route 1 over the Middle River, joining the Machias River at the bridge outlet. The bridge consists of a long causeway embankment structure with four box culverts fitted with flap gates. The embankment has a length of approximately 1,000 feet (ft) and is constructed of timber cribbing with rubble and earthen fill. The four box culverts, constructed of timber and stone masonry, are 5’Sx5’Rx80’L and have top-hinged flap gates installed on the seaward side of each of the four culverts.

A collection of photos follow, providing context for this discussion. The history timeline of the bridge is summarized in Table 1. Hydrology and causeway data are summarized in Tables 2 - 5.

The first crossing was reported to be a private toll bridge bult in 1835, subsequently taken over by the Town in 1845. Images of this bridge have not been found. It is hard to imagine an open trestle of some kind across the entire 1000-ft wide Middle River. A much smaller bridge opening with a flanking causeway seems reasonable but this is only conjecture. In any case, the 1835 bridge was replaced with the current causeway beginning in the mid-1860s and subsequently enlarged over the years.

The primary motivation for building a causeway as opposed to another bridge was undoubtedly agricultural land reclamation. During colonial times and extending well into the 19th century, it was common practice in certain areas to reclaim tidal marsh land by "dyking" and then planting to English hay; see the attached article (Smith and Bridges, 1982). Smith and Bridges specifically identify Machias as a center of hay farming and dyking; the following is especially relevant:

In the Machias area Fenno and his associates dyked and reclaimed over four hundred acres of salt marsh in this first spurt of activity. In the middle 1860s a second and much greater effort was begun in Machias. <u>An immense dyke was constructed on the Middle River between Machias and East Machias.</u> This dyke was built with huge loads of earth brought to the site by tramway. By 1874 the upper portion of the land was producing very large crops of English hay although the process of leaching the areas nearer the water was not as successful. In the 1920s the state erected a road over the dyke (a railway had passed over earlier) and inserted a huge steel flapper valve still in place, although since local dairying disappeared in the 1940s, the hay is no longer harvested. Elsewhere in the area the state has put in place other large steel flapper valves, and in Nova Scotia, on the Tantramar marshes, such valves and dykes are commonplace where public roads are located.

The "immense dyke" is the causeway/culvert structure that eventually became Dyke Bridge. This historical account makes clear that the causeway was not constructed as a flood control structure in the modern sense of managing and protecting against damage from rare (e.g. 0.02 or 0.01 AEP) events, whether riverine or coastal. The original openings in the dyke were probably wooden boxes with flapper "valves"; Smith and Bridges imply that steel flapper gates were installed by the State beginning in the 1920s. Regardless, the intent was to keep out "normal" tides as well as some indeterminate higher tides for the purpose of creating and maintaining conditions suitable for hay farming.

The current roadway elevation (11-ft NAVD88 typical) happens to correspond to recent estimates of the 100-yr annual maximum tide as well as the FEMA 100-yr BFE. More than anything, this is a testament to local knowledge and intuition at the time of construction. As regards the causeway elevation, it was presumably set to provide transit over a range of higher tides, not to function as flood control. The causeway is subject to occasional high water levels, as indicated by the April 2020 event (Figures 13 and 14). The rack line is on the inland side of the causeway, in the swale between the road and the adjacent rail trail. Figure 15 shows high water during the December 2021 event; Figure 16 shows the rack line from the April 2016 event.

Given the purpose of land reclamation, the tidal hydrologic setting, and the materials and technology available to a distant, small 19th century settlement, it followed that construction was by necessity simple. The causeway is a timber crib with rubble, stone and earthen fill. It has held up remarkably well over the past 150 years. Wave action is not particularly intense here and the embankment does not experience high head differentials that might be expected of a flood control structure. Again, this does not fit the picture of a "flood control" structure, particularly in the sense of protecting against physical damage or threats to public safety.

Finally, it is worth noting that the causeway is not and was never meant to permanently impound water. In fact, the intent was quite the opposite – to promote drainage of the upstream marsh and keep tides out.

References

MaineDOT, 6 September 2023. Memo: "16714 Machias Dyke Bridge #2246 - Encroachment", Hebson to Chamberlain et al.

MaineDOT, 21 October 2021. Memo: "16714 Machias – Potential Racetrack Inundation Due to Tidal Restoration", Hebson to Chamberlain et al.

Smith, David C., and Anne E. Bridges. "Salt Marsh Dykes (Dikes) as a Factor in Eastern Maine Agriculture." Maine History 21, 4 (1982): 219-226. https://digitalcommons.library.umaine.edu/mainehistoryjournal/vol21/iss4/4

Smith, David C., 1985. "Salt Marsh Dikes" in Salt Magazine, VII(2):12-15. https://saltstoryarchive.com/articleview.php?id=20474

Stantec, 30 June 2015. Hydrologic Analyses and Alternatives Evaluations, Dyke Bridge and Stride Bridge, Middle River, Machias, Maine. Prepared for MaineDOT.

Table 1. History of Machias Dyke Bridge

Year	Event
1835	Private toll bridge in operation
1845	Private bridge purchased by Town of Machias
1866	State Legislature authorized Town of Machias to build dike across Middle River
1868	causeway completed
1877	Machias Park opened to public
1890s	causeway enlarged for Washington County Railroad (“Calais Branch”)
1930	Current structure built (upstream section)
1944	Structure widened downstream
2008	Repairs made to Dyke Bridge/ Concrete slab built over box culverts
2009	December MaineDOT initial public meeting
2011	MaineDOT completes surveying work
2013	Sewer line extend to east end of causeway
2014	MaineDOT feasibility study begins

Table 2. Middle River @ Causeway Upland Hydrology Summary (Q in ft^3/s; regression)

Aws (mi^2)	Q2	Q10	Q25	Q50	Q100	Q500
13.2	297	565	715	832	958	1,264

Table 3. Machias River - Tidal Datums (ft NAVD88)

MHHW	MHW	MTL	MLW	MLLW
6.9	6.4	-0.3	-7.0	-7.4

Note: datums calculated from September 2021 MaineDOT data as processed by NOAA datum calculator and referenced to Cutler Farris Wharf tide gage

Table 4. Machias River Hydrology - Extreme Tides

Surge		Tidal Annual Max El		
50-yr	100-yr	50-yr	100-yr	Max Tide(obs)
2.2	2.8	10.8	11.0	9.8

Note: Surge from ADCIRC for Machias Bay; max tide (obs) from MaineDOT data collection July – October 2011; Tidal Annual Max from *Updated Tidal Profiles for the New England Coastline*, March 2012, ACOE/STARR.

Table 5. Roadway and Culvert Dimensions and Elevations

Length (ft)	Elev (typ)	Culvert Inverts (typ)	Culvert Dim (nom)
1000+	11	-4.1	5 x 5

Figure 1. Aerial view at lower tide, October 2009 (Google Earth Pro)

Figure 2. Aerial view at higher tide, September 2014 (Google Earth Pro)

Figure 3. Aerial view of Causeway looking upstream (Maine Monitor, 10/09/2022; note leakage through gates)

Figure 4. Dyke Bridge causeway from downstream, south/west to north/east

Figure 5. Looking north/east on upstream side

Figure 6.   Looking north/east on downstream side

Figure 7. View downstream to Machias River from causeway

Figure 8. Panoramic view downstream to Machias River

Figure 9. Panoramic view upstream to Middle River

Figure 10. Outlet at low tide showing flapper gates

Figure 11. Inlet

Figure 12. Looking upstream to Middle River from causeway, August 2020

Figure 13. April 2020 event, rack line landward side looking north

Figure 14. April 2020 event, rack line landward side looking south

Figure 15. December 2021 event, looking south/west along causeway (Machias River to left)

Figure 16. Rack line after April 2016 event, looking south/west

Maine History

Volume 21 | Number 4 Article 4

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Salt Marsh Dykes (Dikes) as a Factor in Eastern Maine Agriculture

David C. Smith

Anne E. Bridges

Recommended Citation

Smith, David C., and Anne E. Bridges. "Salt Marsh Dykes (Dikes) as a Factor in Eastern Maine Agriculture." *Maine History* 21, 4 (1982): 219-226. https://digitalcommons.library.umaine.edu/mainehistoryjournal/vol21/iss4/4

DAVID C. SMITH
ANNE E. BRIDGES

SALT MARSH DYKES (DIKES) AS A FACTOR IN EASTERN MAINE AGRICULTURE

This paper is a summary of work in progress designed ultimately to treat geological and crustal change in eastern Maine, agricultural practices along the Maine coast, and land speculation downeast in the earliest days of settlement.

A few years ago the authors were asked by the Maine Geological Survey to assist them in dating historical structures under geological stress. This dating augments radioactive isotope work conducted on salt marshes in eastern Maine.[1] By site visits, and through close analysis of the topographical maps and aerial photographs of the area, a number of man-made structures were chosen for dating purposes. Among them are dykes[2] built between 1790 and 1870, primarily in Washington County, in order to control and reclaim salt marsh land.

Dykes were constructed along the New England coast as early as 1739. These dykes, built in the Cohasset River area, deteriorated but were eventually rebuilt in 1792. About nine acres of salt marsh were dyked in two separate efforts. When the dykes were reconstructed they were designed to reclaim an area of nearly one hundred acres.[3] Dyking was also fairly well known in Nova Scotia where French settlers along the Bay of Fundy began to reclaim lands late in the seventeenth century.[4] This shore was well known to Massachusetts colonial troops and traders.

In the Massachusetts area an extensive period of dyking began after the Revolution. Two dykes were built in 1789 and 1795, although neither were in use for long. When the Medford Turnpike was constructed in 1803 an area of about fifty acres was dyked in conjunction with that road. Others were constructed in the Chelsea area in 1813. In addition salt marshes were dyked in Dartmouth and Westport.[5]

It seems clear that the technology of building dykes to reclaim coastal salt marshes was reasonably well known in Massachusetts. In 1823, the famous agricultural editor Thomas Fessenden published detailed instructions on building dykes, repairing them, their use, and, generally, provided knowledge to anyone who was interested in the subject. Even earlier Samuel Deane gave instructions on dyking in his agricultural dictionary.[6]

The method of transmission of this knowledge to Maine is unknown, but some informed conjectures can be made. Many of the early Addison and Machias, Maine, settlers came from Salem, Newburyport, and Martha's Vineyard in Massachusetts, as well as Scarborough in Maine. Interest in this downeast area originally centered on the possibility of using the marshes as a source of hay for their cattle in winter and probably as a source of income in the Boston market. The earliest settlements in Scarborough were also founded to procure hay.[7]

Speculators and farmers from the north shore of Massachusetts Bay came to Maine looking for these early sources of hay. Their trips were taken prior to any real efforts at settlement. However, activity in the area stimulated creation of a settlement company. Machias town proprietors now began to plan for settlement and to allot lands in this frontier area. By 1769 some land was surveyed and the allotment began. Settlement was sporadic and troubled until after 1785. Still, the value of the salt marshes was well known. Settlers' land rights always included upland or higher salt marsh, as well as lower salt marsh in relatively equal amounts. In fact, at least once, trespass and resurvey of salt marsh lands resulted in physical conflict and the sheriff was called in to intervene and settle the dispute.[8]

The hay from the marshes was very valuable. Upper salt marsh hay could be fed to cattle in the winter, and it provided a source of nutrients on which cattle might thrive. Lower salt marsh hay produced a coarser hay, called "thatch," which would be used for bedding and rougher purposes and, in emergency, could be fed to cattle.[9] Some hay was also apparently used for fertilizers. A few years after dyking, the salt would be leached from the soil sufficiently to allow the seeding of English hay on upland marshes. Access to the marsh was fairly easy in August and September after regular haying was finished so farmers were prompt to utilize this source. Real estate deeds for the period distinguish between areas producing salt hay, in its various forms, and English hay harvested from upland freshwater meadows.[10]

Dykes were built in Addison in 1792, according to one deed from this area, but the evidence is unclear as to where this dyke was and how long it was in use. Other dykes in the Addison area were constructed by 1795 and a period of reclamation activity ensued. However, this apparently was not an organized effort. More secure materials for dating other sites downeast have been located dating from 1823 to 1835, with the main dykes in Machias being constructed from 1823 to 1826.

Joseph Fenno, originally a resident of Salem, moved part of his mercantile business to the Machias area about 1800. By 1823 he had risen to moderate importance in the area, and he had begun to purchase the original proprietary rights to salt marsh in Machias, Machiasport, and what is now East Machias. His activity in the purchase of land rights and salt marsh was substantial. In the spring of 1824 advertisements appeared in the local press from William Simpson calling to the attention of the public his intention to dyke a salt marsh in East Machias.[11] Throughout the area a dyking spree apparently ensued, probably following the directions published in the *New England Farmer* the previous year.

Dyking involved tedious work over long periods of time by teams of three men. Using a special dyking spade equipped with a long, narrow blade, perhaps fourteen inches long and five inches wide, the first person dug a sod of this length and width, and perhaps four inches deep. The sods were dug about ten feet behind the proposed dyke, thus providing both dyking material and a ditch to drain the water. The digger then passed his sod brick to a second person. He, in turn, gave it to a third person who laid the sods in an interlocking fashion much like bricklaying. The dyke was built wider at the bottom and formed, in profile, a crushed, flat-topped pyramid. Every so often in the dyke, perhaps each fifty to one hundred feet, an area was left open for a clapper or flapper valve to be installed. When the tide is in, the valve closes automatically, thus preventing contamination behind the dyke, while when the tide is low, the valve swings free, allowing drainage of the water from the marsh. In most areas the dykes were eight feet wide and six feet high. However, where the stress was greater, dykes were occasionally constructed as much as thirty feet wide, at bottom, and fifteen feet high. Normally roads, often corduroy roads, were constructed on the dykes for access to the hay. Complete drainage of the salt marsh, and the subsequent creation of an area to seed with English hay took from ten to fifteen years. Dykes needed fairly frequent repair, especially after heavy winter storms, or especially high tides.[12] Tax records from the area attest to the increased value of dyked marsh lands.[13]

In the Machias area Fenno and his associates dyked and reclaimed over four hundred acres of salt marsh in this first spurt of activity. In the middle 1860s a second and much greater effort was begun in Machias. An immense dyke was constructed on the Middle River between Machias and East Machias. This dyke was built with huge loads of earth brought to the site by tramway. By 1874 the upper portion of the land was producing very large crops of English hay, although the process of leaching the areas nearer the water was not as successful. In the 1920s the state erected a road over the dyke (a railway had passed over earlier) and inserted a huge steel flapper valve still in place, although since local dairying disappeared in the 1940s, the hay is no longer harvested.[14] Elsewhere in the area the state has put in place other large steel flapper valves, and in Nova Scotia, on the Tantramar marshes, such valves and dykes are commonplace where public roads are located.

The reclamation of salt marshes continued to interest progressive farmers in Maine. The subject of fencing on the dykes in areas where several owners wished to pasture cattle was discussed.[15] Other areas were dyked, especially in Marshfield, Kennebunk, Old Orchard and elsewhere, as well as in other areas of New England. When the editors of the state's press met in Machias for an excursion, they viewed the dykes and many reported their findings to their readers.[16] Scarborough marshes were always an object of interest for potential dykers and several attempts, none very successful, were begun in that area.[17]

Over and over again the *Maine Farmer* presented articles, queries, and responses with regard to salt marsh reclamation. Usually, however, it was the Nova Scotia marshes that were cited as exemplars for future work.[18]

Dykes in the southern part of Maine tended to go out of use fairly early. The demand for hay increased but cleared land inland supplied that need. Remains of those dykes are noticeable from the road once one is prepared to look for them. Downeast, the dykes remained in good repair until the 1920s. Even in that decade dykes were constructed and repaired on the Pleasant River in Addison. By World War II, however, farming downeast had nearly disappeared. Dykes were no longer repaired routinely each spring. Hay was still cut, but now for use only in burning the blueberry barrens. By 1946 even this use was over, once low cost petroleum derivatives replaced the salt hay. Today the dykes remain. Whether their usefulness is over is unknown, but their history of providing income for downeast farmers suggests that another day may yet see dyking and reclamation of salt marshes both as a topic in the press and on the land.[19]

NOTES

[1] David C. Smith, Anne E. Bridges, and R. Scott Anderson, "Agricultural Dykes and Salt Marshes: Tools for Study and Dating in Recent Geological Time," *Abstract* in Geological Society of America, Sixteenth Annual Meeting, 1981, p. 121; R. S. Anderson, C. D. Race, H. W. Borns, Jr., and D. C. Smith, "A Rising Sea-Level in Maine, as Determined from Salt Marsh Data," in *ibid.*, p. 177.

[2] Dykes were spelled this way until 1920 when the spelling "dikes" began to be normal. There is a transition period from 1870 to 1920 when "dykes" is normal, but the second spelling is occasionally used. However, "dikes" is found very early as well. We choose to use "dykes" as this was the more normal spelling in the time under discussion.

[3] *New England Farmer*, March 2, 1827, letter from "D."

[4] Graeme Wynn, "Late Eighteenth Century Agriculture on the Bay of Fundy Marshlands," *Acadiensis* 18 (Spring 1979): 80-89; A. H. Clark, *Acadia: The Geography of Early Nova Scotia* (Madison, Wisc.: University of Wisconsin Press, 1968); Howard Trueman, *Early Agriculture in the Maritime Provinces* (Moncton, N.B.: Times Printing Co., 1907).

[5] *New England Farmer*, Jan. 26, Feb. 2, March 2, 1827, all salt marshes and dykes in Massachusetts; *ibid.*, March 25, 1826, quoting the *New Bedford Mercury* on "Reclaimed Marshes."

[6] *New England Farmer,* March 1, 1823, Thomas Fessenden, ed., "On Embankment Dikes, Drains, etc. for the Purposes of Reclaiming Lands from the Seas, Rivers, etc." Also see *American Farmer,* 2: 131, 243, 244; Samuel Deane, *The New England Farmer* (Worcester, Mass.: Isaiah Thomas, 1790), pp. 81, 169-70, 218-19.

[7] George W. Drisko, *Narrative of the Town of Machias,* (Machias, Me.: Press of the Republican, 1904).

[8] Town of Machias, Proprietors' Records, County Commissioners' Archives, Machias, Me.

[9] D. B. Scott, and F. S. Medioli, "Vertical Zonations of Marsh Foraminifera as Accurate Indicators of Former Sea Levels" *Nature,* vol. 272, no. 3653, April 6, 1978, pp. 528-31; W. F. Ganong, "The Vegetation of the Bay of Fundy Salt and Dyked Marshes: An Ecological Study" *Botanical Gazette* 36 (1903): 161-86, 280-302, 349-67, 429-55; Anderson *et al.,* "Rising Sea Level in Maine;" *New England Farmer,* Jan. 21, 28, Feb. 4, 9, March 16, 1831. These last are four responses from different persons to a query on salt marsh uses. The *Oxford Dictionary* definition of the words used in the deeds indicates a direct transfer of technology from the fens area of England. On the peat that was a part of these marshes and contemporary views of its use see *New England Farmer,* May 13, 20, 27, 1825. For haying on the salt marsh dykes see Farm Ledger and Day Book, Samuel Waldo, 1796-1803, for a Thomaston dyked marsh. In Maine Historical Society collections. An important book is Douglas Johnson, *The New England-Acadian Shoreline* (New York: J. Wiley and Sons, Inc., 1925; reprint ed., New York: Hafner Press, 1967), chapters 16, 17, especially.

[10] See forthcoming work by the authors on Joseph Fenno and other land speculators in the 1820-45 time period. As an example see Deed, Joseph Fenno to S. and W. Holway, March 26, 1834, Book 27, pp. 108-10, 206-7, Washington County Register of Deeds, Machias, Me.

[11] *Machias Eastern Star,* April, 1824

[12] Personal observations, oral interviews with Fellows Drisko and Earle H. Preble, June 1, 1979; *Maine Farmer,* Sept. 26, 1874, "The Dyked Marshes of Machias River;" *New England Farmer,* March 1, 1823; *Kennebec Journal,* Dec. 7, 1866, on repairs needed after a bad storm and high tide.

[13] Tax records for the 1840s, East Machias, Maine, in possession of E. Jones, who allowed us to use them. Most of the tax records for both Machias and East Machias were lost in fire. The deeds indicate an increased value greater than other land transfers as well.

[14] *Maine Farmer,* July 23, 1863, Sept. 26, 1874; personal observations; *Portland Price-Current,* June 16, 1866, reporting a meeting of the dyking company; June 10, 1868; and the books of the Middle River Dyking Company, located in Special Collections, Fogler Library, University of Maine at Orono.

[15] *Maine Farmer,* April 10, 1869.

[16] *Maine Farmer,* May 27, 1871; *Portland Price-Current,* Aug. 24, 1867; *Kennebec Journal,* July 27, 1866, are examples of press comment. Also see *Fourteenth Annual Report of the Secretary of the Maine Board of Agriculture, for the Year, 1869* (Augusta, Me.: Sprague, Owen and Nash, 1870).

[17] *Portland Price-Current,* April 20, 1867; *Maine Farmer,* June 15, 1872, J. P. M., "Farming in Maine."

[18] *Maine Farmer,* Feb. 21, 1861, letter from Hopewell, N. B. , asking for information on how to use dyked land he had begun to reclaim. Interestingly enough, his experience was as a boy on the south shore of Massachussetts Bay; Dec. 4, 1862, a letter on Nova Scotia agriculture; October 2, 1862, an editorial, "Reclaiming Salt Marshes"; April 11, 1867, "Diking Marshes"; June 14, 1860, Agricola writing on the Minas Basin and why doesn't Maine do more with its salt marshes.

[19] Oral interviews with Fellows Drisko and Earle H. Preble, Addison, Maine, June 7, 1979; *Maine Farmer,* Aug. 16, 1888, describes haying on fresh meadows, then haying for salt hay with horses wearing "bog shoes" in Waldo County.

salt

NUMBER 26, THREE DOLLARS

Hot clouds clamp a lid over the wild blueberry barrens of Maine. A bumper crop ripens too fast, 45 million pounds in a vast oven. Two thousand rakers race the heat. "Beat the sun. Ya gotta beat that sun, cause she'll wear it right outta ya . . ." (page 16)

Lynn Kippax, Jr.

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Cover photograph by Lynn Kippax, Jr.

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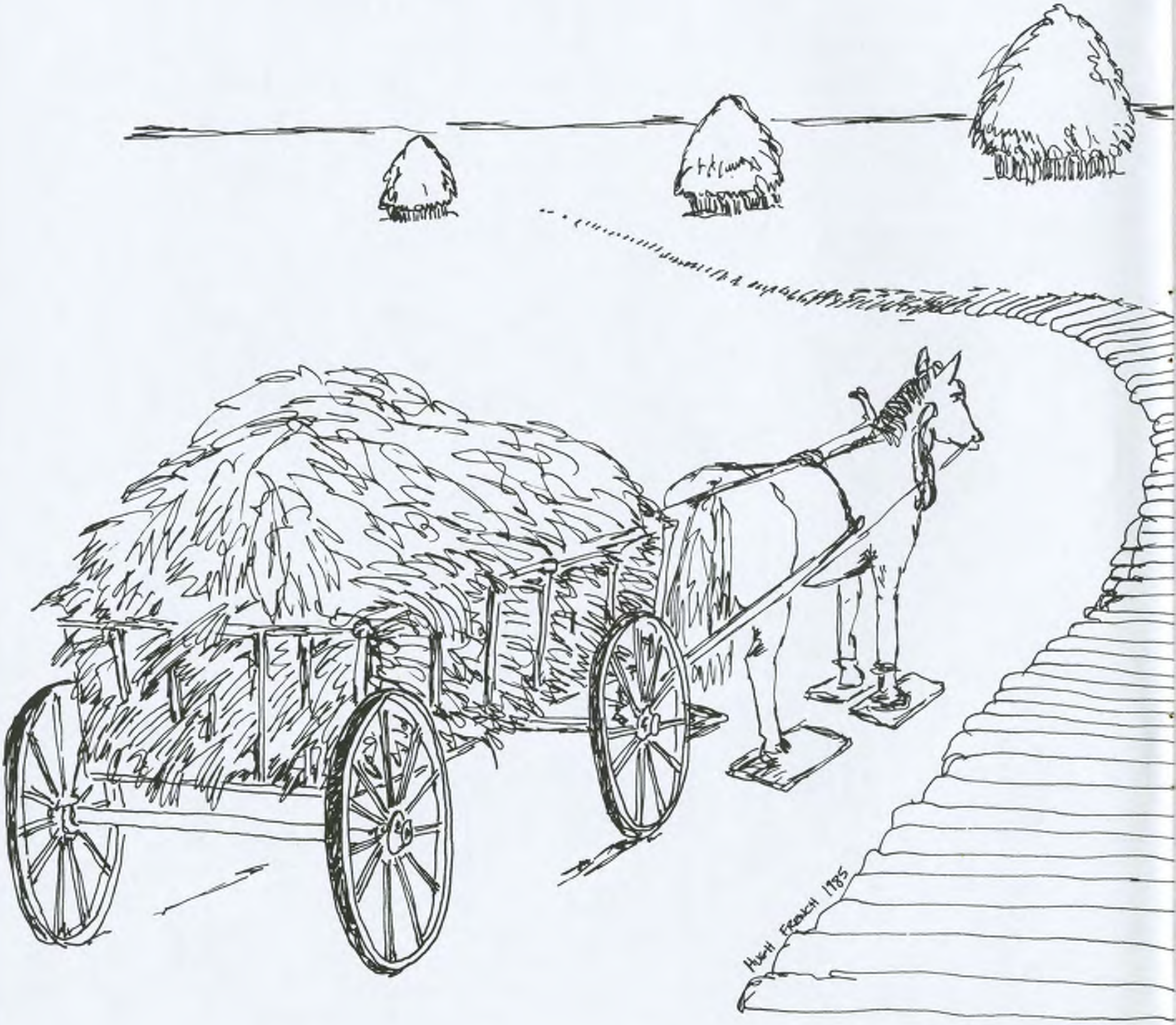
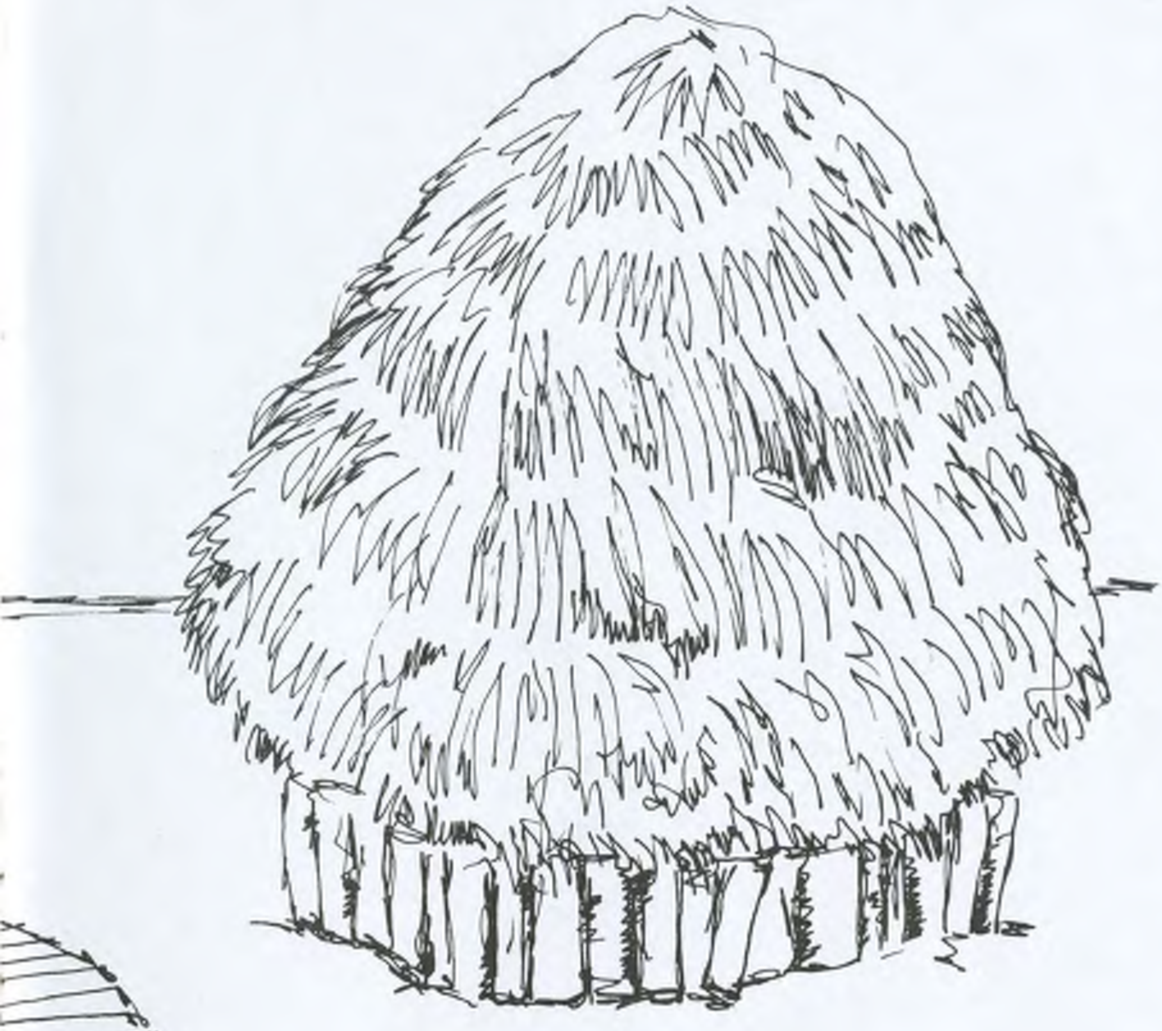
SALT MARSH DIKES

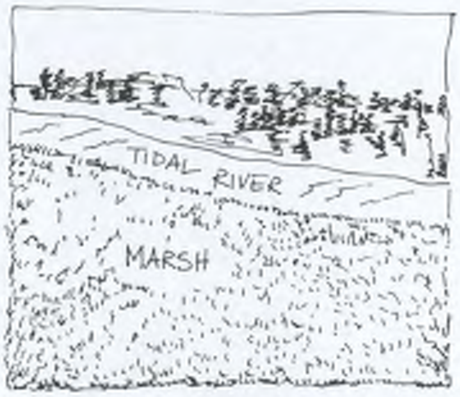




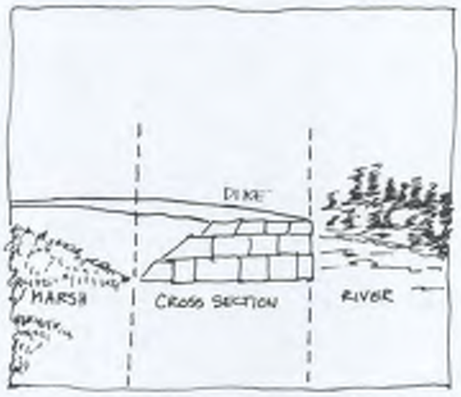
By David C. Smith

David Smith, Professor of History at the University of Maine at Orono and a member of Salt's Academic Board, flew down to Salt weekly during the fall of 1984 to lecture and work with students. His visits were part of Salt's visiting professor and lecturer series funded by the Exxon Education Foundation.

Several of David Smith's talks were about salt marsh dikes that ranged along the coast of Maine from the late eighteenth century into the

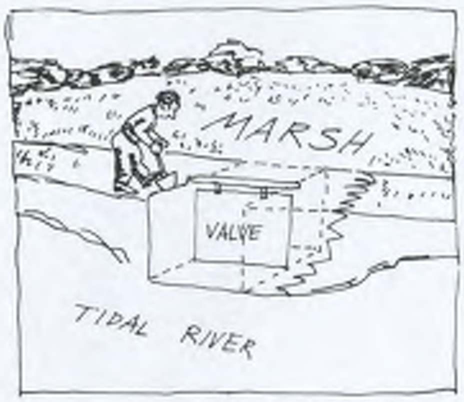


Salt marsh farmer

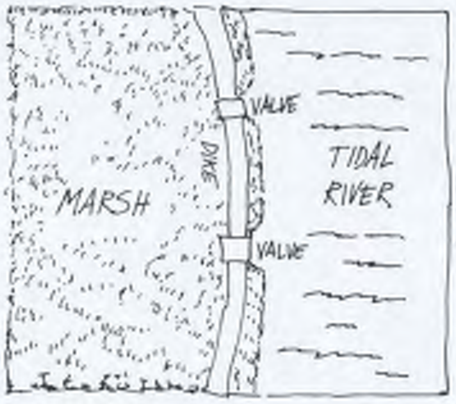


erects a dike

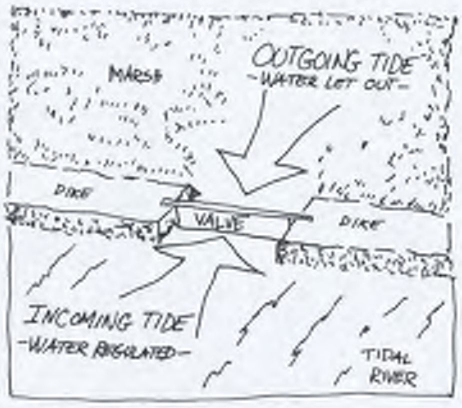
on the marshes' edge.



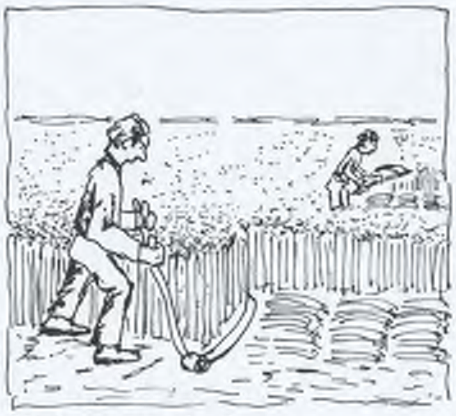
He places valves



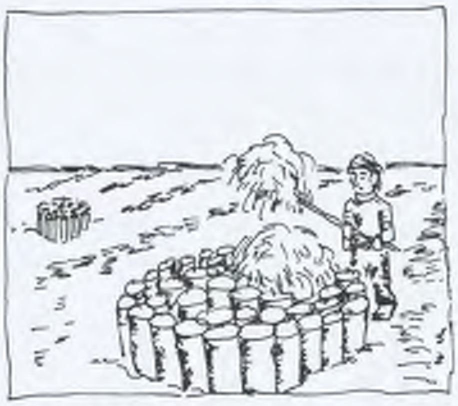
in the dike



to regulate saltwater.



He harvests the hay



onto a circle of posts

nineteenth century. His talks were tape recorded and an edited version of them appears below.

TEN YEARS AGO, I wouldn't have known a dike from a chair probably. I didn't think there were any in North America. No one had ever talked about it. There's nothing in the literature about it. And then suddenly we found one and they asked me to date it and I dated that first one. This was in Machias.

When people came to this area, they were interested in making as much money as they could. These giant salt marshes were a potential source of hay for cattle, especially if you could stabilize it. They developed a technique based on the same technique that was used in Brittany and the Netherlands and the south of England, translated that technique here and salt marsh lands became some of the most valuable lands along the Maine coast.

Before a dike, it's all salt marsh. Once you dike it, you're controlling the salinity, and thus controlling the grasses that grow. They knew this zonation business, and so the deeds talk about thatch grass which is the lowest level because you use it to thatch houses, though they didn't thatch houses in Maine. Then there is browse which is winter feed, very salt hay. And then salt hay. Then English hay.

You can't do anything with those salt marshes until they are consolidated into one or two hands or families' hands. You can take hay off them, but you can't control them or manipulate them. Once that consolidation occurs, we find that within a year or two, you get a dike on the land.

Three men, on a river bank that needs to be diked, organize themselves so that one person cutting sods—usually about 14 inches long and about six inches wide—cuts sods away from the bank, about 20, 30 feet. He cuts those sods and the diking spade is designed to hold one sod. He passes the sod on his diking spade to the middle man who accepts it, turns around and gives it to the person who is laying the sod, brick fashion, building up the dike itself.

The dike usually has a more or less even, perpendicular front side, that is, the side near the water. Whereas the back side slopes away towards the hole where the sods have come. The dike is built up (two or two and a half feet) until it's quite far above any salt water incursion, except a very abnormal tide or a storm.

About every 50 feet, sometimes more, occasionally less, the dike is breached and a square box of wood is laid down in the dike with a swinging door hung from the top. That device is called a flapper valve. It allows the dike to drain itself on an automatic and regular basis whether anyone's there or not.

That works really through a kind of specific gravity. You're dealing with fresh water on one side and salt water on the other. There is a difference in specific gravity between the water coming out and the water going in. As the tide goes out, it hits the flapper valve and it goes open. But as the tide comes back, the valve closes.

If you just let it go, what you've got is salt water coming out, no salt water coming in except underneath, and ultimately you'll get fresh water marsh there.

It allows the persons owning the dikes do one or two things. They either can control the amount of salt water they have which gives you a steady flow of grass. Or if you want to, you can drain it entirely which is the way the Dutch have done to get fresh meadow eventually. The process to create fresh meadow out of salt marsh is about 20 years, until the land is leached.

There is an economic value to both ways. If you're going to be as the Dutch have been, in the dairy business, you may want fresh meadow in order to insure that the taste of the milk is kept constant. On the other hand, if you're using it for a supplementary feed, the amount of the grass rather than the quality is more significant.

If you go out on a salt marsh today in low water, there's a great deal of sponge and give to it. The more you control the drainage—it'll still be spongy, it'll still be on top of peat—but it won't have so much water in it. You could go on the dike and cut it with a scythe, but the problem is to get it back.

So it needs to be firm enough to support a horse or to support a wagon or alternatively to create a place where you can store the hay and then when it freezes come out and get it.

Once you've cut the stuff, you can't let it stay out there in the wet again. So they developed a technique of building a haycock on the marshes, but settled on cedar or oak posts driven into the marsh that stayed there all the time. The hay is laid much as you were putting in a barn with a oval cupola so that it will shed water on top. And it set up in the air probably 18 inches or 2 feet. The hay would be then above the high water mark.

So you've got two methods. One is that the hay is cut, laid in wind rows. Then you put the horses out with your wagons, usually through a corduroy road. But then you've got to collect the hay out here. If it's narrow enough, you can just move the hay to the wagon that stays on the corduroy road.

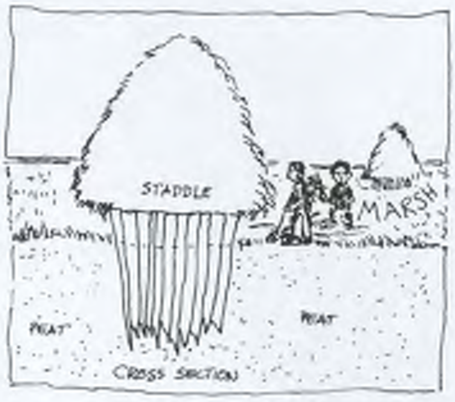
Or you've got to get the horse off the corduroy road, which means you've got to give him something so he won't sink in. They experimented and developed what they called bog shoes which are essentially a snowshoe for horses.

The ones I've seen are about a foot across with a place for the horse shoe in this flat piece of wood, and then strapped up to the horse's leg, up almost to the fetlock so that the horse is walking along with these bog shoes so that he wouldn't sink down. Apparently the horses had no problems with this.

The last working dike in Maine was in Addison. They were still using that as late as 1946 as a source of hay to burn blueberry fields in Northfield and those areas. He stopped doing it because Number 6 fuel became cheaper than to hay it. Obviously in his case, he wasn't repairing it. The last time this had been repaired was 1914.

I talked to two men who had done it. The fascinating thing was to meet these two men, in their nineties, who had actually done some of this work and could describe it for me. This is literally recovering the world we have lost.

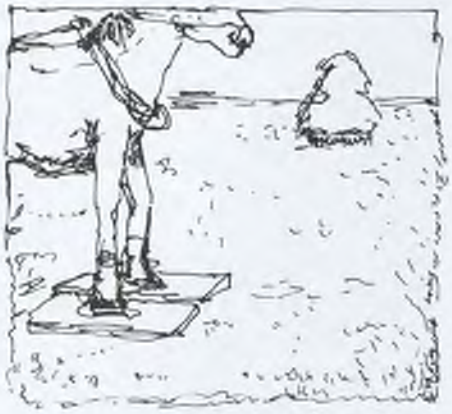
salt



driven into the marsh.

He gathers the hay

in winter with horses



that wear bog shoes.

Technical Report: Middle River Hydrologic and Alternatives Analyses

Hydrologic Analyses and Alternatives Evaluations, Dyke Bridge and Stride Bridge, Middle River, Machias, Maine

Prepared for:
Maine Department of Transportation
Attn.: Nathan Howard
Bureau of Planning
16 State House Station
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Prepared by:
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June 30, 2015

Sign-off Sheet

This document entitled Technical Report: Middle River Hydrologic and Alternatives Analyses was prepared by Stantec Consulting Services Inc. ("Stantec") for the account of the Maine Department of Transportation (the "Client"). Northstar Hydro, Inc. is a subcontractor to Stantec for this study and contributed to the preparation of this report.

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Michael Chelminski, P.E., Principal, Stantec Consulting Services Inc.

Reviewed by ____
(signature)
Ellen O'Brien, P.E., President, Northstar Hydro.

This report was prepared for the MaineDOT Bureau of Planning by Stantec for work as part of State W.I.N. # 016714.00, Federal W.I.N. #BR-1671(400)X, and funded through Appropriation #9095.

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Executive Summary

The Maine Department of Transportation (MaineDOT) contracted with Stantec Consulting Services Inc. (Stantec) to perform hydrologic and hydraulic analyses to evaluate a range of bridge and/or culvert alternatives to replace the Dyke Bridge (#2246) and the Stride Bridge (#3973) over the Middle River in the vicinity of the Town of Machias, Maine. Dyke Bridge crosses the Middle River immediately landward of the confluence of the Middle River with the Machias River in the Town of Machias. Stride Bridge crosses the Middle River in the Town of Marshfield approximately 3 miles upstream from Dyke Bridge.

This study develops and evaluates a range of alternative bridge and/or culvert geometries at Dyke Bridge and Stride Bridge. The primary focus of this study is to evaluate potential replacement structures at the two bridges relative to existing conditions and potential sea-level rise. Seven general alternatives were evaluated at Dyke Bridge, and range from no-action (Alternative 1) and replacement in-kind (Alternative 2), alternative culvert systems with operable gates (e.g., self-regulating tide gates [SRTs]) as presented by Alternatives 3 and 4, to a large bridge and/or group of culverts (Alternatives 5, 6, and 7) that would provide for unhindered tidal exchange in the Middle River upstream (landward) from Dyke Bridge.

Evaluated alternatives at Stride Bridge where limited to retaining the existing culvert and replacement with a single-span bridge.

Factors that are considered in the development and evaluation of alternatives at Dyke Bridge in this report include:

1) Conveyance of tidal flow at Dyke Bridge;
2) Potential inundation of land upstream from Dyke Bridge that would result from increased tidal exchange;
3) Upstream fish passage at Dyke Bridge and impacts to upstream fish passage at Stride Bridge; and
4) The potential for evaluated alternatives to affect inundation of areas along the Middle River landward from Dyke Bridge for the evaluated sea-level rise conditions.

The primary tool for evaluation of alternatives is a numerical hydraulic model of the study reach of the Middle River from its confluence with the Machias River to Stride Bridge. The one-dimensional, unsteady-state numerical hydraulic model was developed using the U.S. Army Corps of Engineers HEC-RAS software system (HEC-RAS model). The model was developed using Lidar terrain data and bathymetric data collected by MaineDOT. Boundary condition and calibration data for the HEC-RAS model included tidal stage data and peak upland flow statistics provided by MaineDOT. The HEC-RAS model was calibrated and validated for existing conditions using tidal stage data provided by MaineDOT.

The preliminary alternative evaluation process was initiated with a review of information on SRTs, which are the basis of two of the general alternatives. Based on this review, it was determined that SRTs (Alternative 3) and "fish-friendly" SRTs (Alternative 4) are not practical technologies for replacement of the existing culvert and flap-gates system at Dyke Bridge and are not expected to improve upstream fish passage relative to other evaluated alternatives.

Three general alternatives were evaluated to provide for unhindered tidal exchange at Dyke Bridge. Based on this review, it was determined that a single-span bridge (Alternative 6) is a feasible alternative for replacement of the existing culverts at Dyke Bridge, but that a group of large culverts (Alternative 5) or a group of culverts along with a single-span bridge (Alternative 7) are not feasible alternatives at Dyke Bridge.

The HEC-RAS model was used to evaluate a set of the evaluated alternatives at Dyke Bridge and Stride Bridge. The HEC-RAS model was used to evaluate a broad range of alternatives; this study presents information and findings for approximately 100 unsteady-state flow scenarios. Based on information obtained from the HEC-RAS model and consideration of the four factors noted previously, it was identified that feasible alternatives at Dyke Bridge include:

- Replacement in-kind (Alternative 2) without flap gates on every culvert; and
- Replacement with a single-span bridge (Alternative 6).

Multiple scenarios were evaluated for replacement in-kind (Alternative 2). These scenarios evaluated four or five box culverts with up to two free-flowing culverts (no flap gate). These scenarios would provide for landward flow through the culverts without flap gates during flood tides and are expected to substantially improve upstream fish passage while limiting inundation of land along the Middle River landward from Dyke Bridge. Depending on the selected variation of Alternative 2, including the total number of culverts and the number of culverts with and without flap gates, this alternative can limit inundation of land upstream from Dyke Bridge while substantially improving upstream fish passage. Information developed as part of this study indicates that increasing typical tidal water surface elevations upstream from Dyke Bridge by more than 2 feet (ft) would result in regular tidal inundation of substantial areas of land.

Replacement with a single-span bridge (Alternative 6) would provide for volitional upstream fish passage and would result in substantial inundation of land along the Middle River landward from Dyke Bridge. Specifically, normal tidal water surface elevations would increase by 8 to 10 ft immediately landward from Dyke Bridge. Based on the results of the HEC-RAS model evaluations, the minimum length of a single-span bridge to provide unhindered tidal flow at Dyke Bridge is 60 ft with vertical abutments and would require dredging of a channel under the bridge and upstream into the Middle River.

Based on factors that are considered in this study and the study evaluations and findings, the primary constraints associated with replacement of the existing Dyke Bridge culvert systems are 1) upstream fish passage, and 2) inundation of land upstream from Dyke Bridge. Replacement in-kind (Alternative 2) with some free-flowing culverts can provide for improved upstream fish passage while limiting flooding of landward areas. Installation of a single-span bridge can provide for free-flowing conditions at Dyke Bridge and volitional upstream fish passage, but would result in substantial inundation of land upstream from Dyke Bridge.

1.0 INTRODUCTION

The Maine Department of Transportation (MaineDOT) contracted with Stantec Consulting Services Inc. (Stantec) to perform hydrologic and hydraulic analyses to evaluate a range of bridge and/or culvert alternatives to replace the Dyke Bridge (#2246) and the Stride Bridge (#3973) over the Middle River in the vicinity of the Town of Machias, Maine. Dyke Bridge crosses the Middle River immediately landward of the confluence of the Middle River with the Machias River in the Town of Machias. Stride Bridge crosses the Middle River in the Town of Marshfield approximately 3 miles upstream from Dyke Bridge. The project location is depicted in Figure 1.

The objective of this study is to develop and evaluate a range of alternative bridge and/or culvert geometries at the two subject bridges, and the primary focus is to evaluate potential alternatives for replacement structures at the two subject bridges. The evaluation of replacement includes consideration of the existing tidal restriction associated with Dyke Bridge, which severely limits tidal flow landward from Dyke Bridge. This study evaluates a range of alternatives at Dyke Bridge and two alternatives at Stride Bridge. The evaluated alternatives at Dyke Bridge include:

- Alternative 1: No Action;
- Alternative 2 (baseline): Replacement In-Kind without restoration of tidal flow;
- Alternative 2 (variations) :Replacement In-Kind with the following variations;
    - Replacement In-Kind with partial restoration of tidal flow;
    - Replacement with partial restoration of tidal flow and provisions for fish passage;
- Alternative 3: Replacement with self-regulating tide gates (SRTs);
- Alternative 4: Replacement with “fish-friendly” SRTs;
- Alternative 5: Replacement with multiple adjacent culverts to restore tidal flow;
- Alternative 6: Replacement with a traditional span bridge; and
- Alternative 7: Replacement with a traditional span bridge with some adjacent culverts.

The evaluated alternatives at Stride Bridge include:

1. Concrete invert lining;
2. Slip-lining; and
3. Other alternatives to be determined.

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Notes
1. Coordinate System: NAD 1983 UTM Zone 19N
2. Data Sources include:USGS Imagery/Topo provided by The National Map Mapping Service (http://basemap.nationalmap.gov/arcgis/services/USGSImageryTopo).

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Prepared by ABC on 2014-00-00
Reviewed by ABC on 2015-00-00

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Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
1

Title
Project Location Map
7/1/2015

2.0 EXISTING CONDITIONS

2.1 DYKE BRIDGE

Dyke Bridge is located on U.S. Route 1 and consists of an embankment structure with four box culverts that are fitted with flap gates. The embankment has a length of over 1,000 feet (ft) and is constructed of timber cribbing with rubble and earthen fill. The four box culverts, constructed of timber and stone masonry, are approximately 80 ft long, 5 ft wide, 5 ft high, and have top-hinged flap gates installed on the seaward side of each of the four culverts. The culverts and flap gates are deteriorated. A combination of factors, including leakage through the flap gates and the causeway, result in landward flow into the Middle River during semi-diurnal flood tides. Dyke Bridge is shown in Figure 2 along with relevant adjacent features.

2.2 STRIDE BRIDGE

Stride Bridge is located on State Route 192 and consists of an earthen embankment with a 12.5-ft-diameter corrugated metal pipe culvert (CMP) with the ends coped to the roadway embankment. Stride Bridge is shown in Figure 3.

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Reviewed by MRC on 2015-02-23

00963_DykeBridge_Aerial.mxd

Notes
1. Coordinate System: NAD 1983 UTM Zone 19N
2. Aerial imagery provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).

Legend

⇄ Dominant Upland Flow

Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
2

Title
Dyke Bridge Aerial
7/1/2015

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Legend

⇄ Dominant Upland Flow

Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
3

Title
Stride Bridge Aerial
7/1/2015

2.3 HYDROLOGY

MaineDOT design guidelines recommend evaluating the following combinations of upland stream flows with selected tidal stages. The following combinations were modeled as part of this study:

a. Everyday Tides with 1.1-year river flow;

b. Everyday Tides with 50-year river flow;

c. 50-year Storm Surge with 1.1 year river flow;

d. Surge to be superimposed at mid-rising, high tide, mid-falling and low tides.

These conditions were modeled with the addition of 100-year upland flow with typical tides.

2.3.1 Upland Hydrology

Boundary condition data for upland flows in the Middle River at Stride Bridge and Dyke Bridge were provided by MaineDOT and are included as Appendix A. A summary of peak flow statistics is provided in Table 1.

Table 1: Peak Flows

	Drainage Area (sq. mi.)	***Return-Interval Event (Years)*/Peak Flow (cfs)**							
Location		***1.1***	***2***	***5***	***10***	***25***	***50***	***100***	***500***
Stride Bridge	9.41	130	265	213	522	670	787	912	1,221
Dyke Bridge	13.22	152	297	452	565	715	832	958	1,264

For model simulations of storm surge, a steady state upland flow of 152 cubic feet per second (cfs) was used to model flow in the Middle River. For model simulations combining typical tide cycles (1.1-year tide) with higher upland flows (50- and 100-year), flow hydrographs were developed for the Middle River. Hydrograph time to peak was assumed to be 12 hours and recession time was assumed to be 24 hours. Peak stream flow was assumed to occur at about 12 hours before the highest tide in the 1.1-year tide hydrograph. Hydrograph shape was assumed to be triangular. These assumptions should be evaluated for appropriateness for final evaluation and design of a selected alternative for replacement of the culverts at Dyke Bridge.

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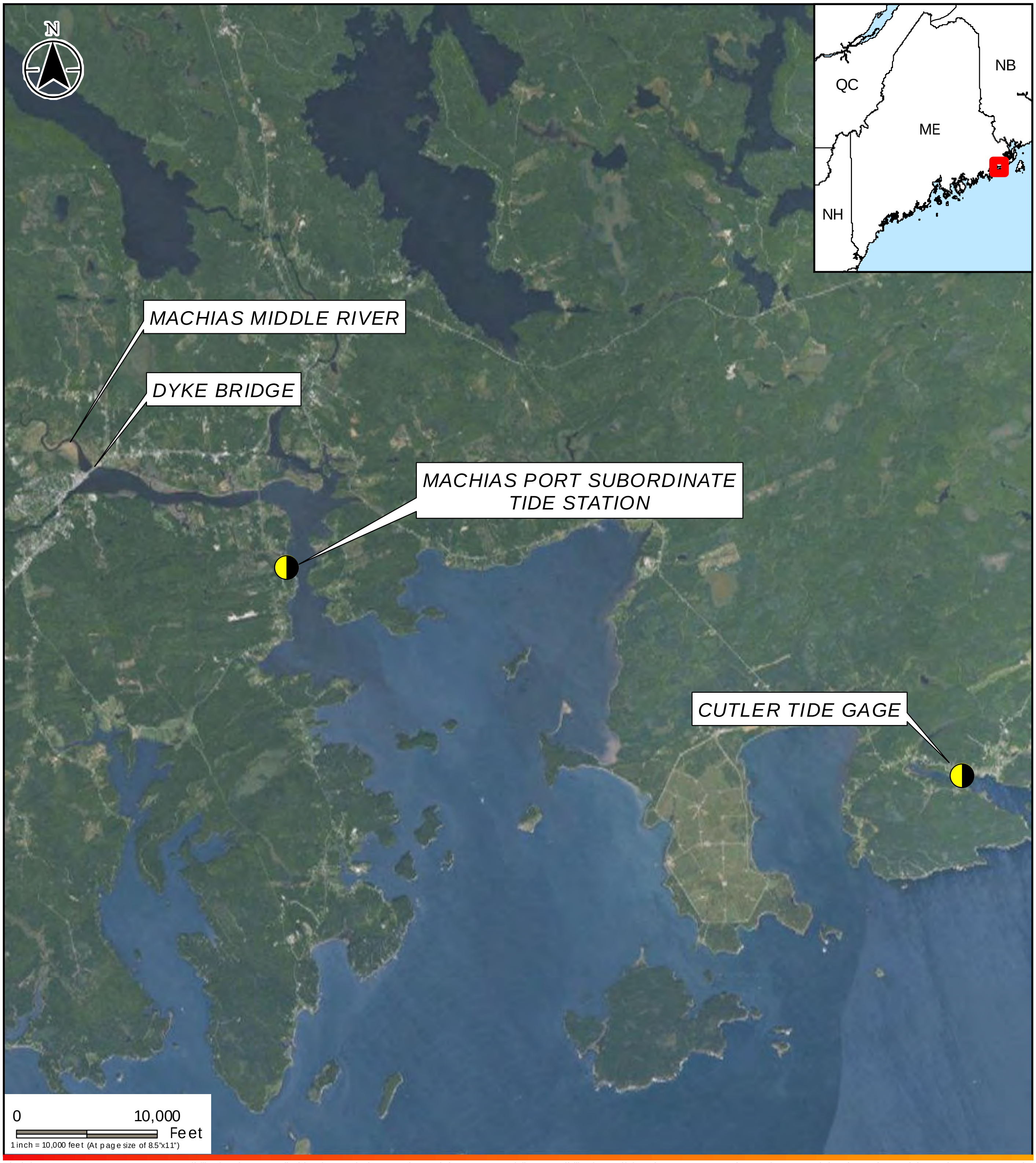

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Legend

◐ Tide Gages

Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
4

Title
NOAA Tide Stations

7/1/2015

2.3.2 Tidal Hydrology at Dyke Bridge

Sources of tide data used for this study include:

a. NOAA Recording tide gage data at Eastport, Cutler;

b. NOAA Predicted tide data at Subordinate Station on Machias River;

c. MaineDOT recorded data downstream of Dyke Bridge and Upstream of Dyke Bridge;

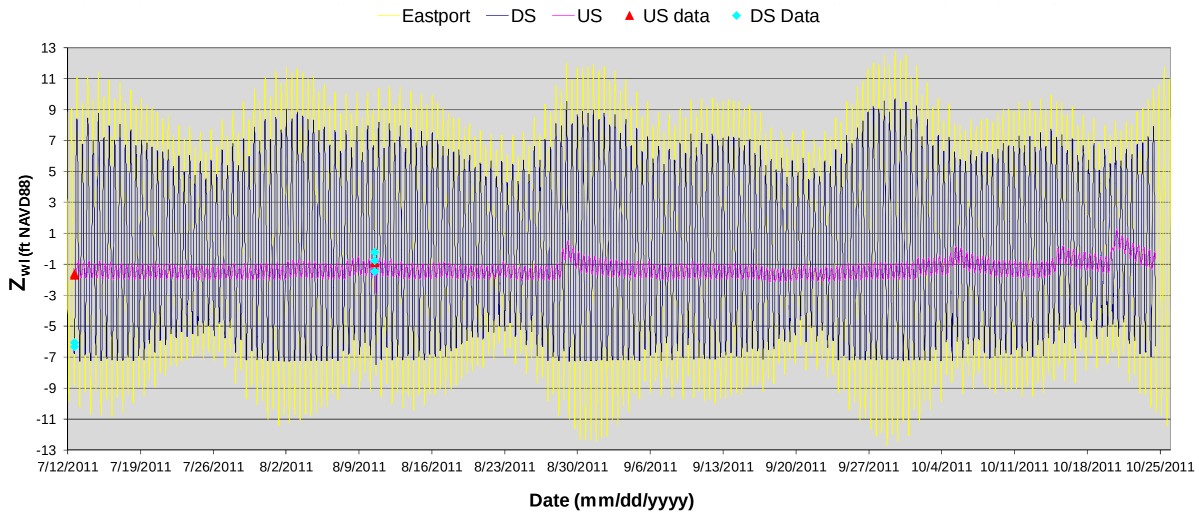
d. U.S. Army Corps of Engineers (USACE) Tidal Flood Profiles for Peak Storm Surge Elevations; and

e. MaineDOT provided guidance on calculation of surge hydrographs.

2.3.2.1 Recorded Tidal Stage Data- Project Data and NOAA Station Data

MaineDOT measured tidal stage data in the vicinity of Dyke Bridge in 2011 as part of this study. The tidal stage data were collected at two locations during the period from July 12, 2011, through October 24, 2011, using datalogging pressure transducers that recorded pressures at 5-minute intervals. The data were collected landward and seaward from Dyke Bridge in the Middle River and Machias River, respectively. These data were rectified by MaineDOT to the NAVD88 vertical datum in electronic file format and are plotted in Figure 5.

Figure 5: MaineDOT Tide Data, Downstream and Upstream of Dyke Bridge, July through October 2011



Tidal statistics were obtained for the tidal stage data collected in the Machias River seaward from Dyke Bridge by parsing-out the higher high tide, lower high tide, higher low tide, and lower low tide for the period from July 12, 2011, through October 24, 2011, using a parsing algorithm subroutine programmed in Visual Basic for Applications. Mean higher high water (MHHW) is calculated as the average of the higher high tide over each 24-hour period, and mean high water (MHW) is calculated as the average of the lower high tide over each 24-hour period. Mean low water (MLW) and mean lower low water (MLLW) area calculated as the average of the higher and lower (lowest) low tide over each 24-hour period. These site-specific calculations are compared to the predicted values of MHHW, MHW, MLW and MLLW at the Machiasport Tide Station and at the Cutler Tide Gage in Table 2, Table 3, and Table 4.

Review of Figure 5 indicates a low-end threshold for the data collected in the Machias River seaward from Dyke Bridge; this suggests that the datalogging pressure transducer was installed above the elevation of the lower low tides.

The parsed data was used to develop tidal statistics that are presented in Table 2, which includes the maximum, minimum, and average water surface elevations from the tidal stage data that was collected in the Machias River seaward from Dyke Bridge.

Table 2: Tidal Statistics from MaineDOT Data Set

Tidal Data (ft, NAVD88)						
Max.	**MHHW**	**MHW**	**Average**	**MLW**	**MLLW**	**Min.**
9.8	7.4	6.5	0.05	-6.4	-6.8	-7.5

Table 3 presents tidal statistics from National Oceanic and Atmospheric Administration tide stations at Eastport, Cutler Naval Base (Cutler), and Bar Harbor (Machias is located between Cutler and Bar Harbor along the coastline).

Table 3: Tidal Statistics from NOAA Stations

Station	Tidal Statistics (Elevation in feet)						
	MHHW	**MHW**	**NAVD88**	**MTL**	**MSL**	**MLW**	**MLLW**
Eastport	9.34’	8.86’	0’	-0.31’	-0.23’	-9.49’	-9.93’
Cutler	6.81’	6.39’	N/A	0.1’	0.0’	-6.37’	-6.75’
Bar Harbor	5.7’	5.28’	N/A	-0.1’	0.0’	-5.29’	-5.67’

Additional tidal data is available for Machias Port. This station is a subordinate tidal station, with predicted tides based on Eastport tides multiplied by 0.69.

Table 4: Tidal Statistics Predicted at Machias Port NOAA Subordinate Station

Station	Tidal Statistics (Elevations in feet)						
	MHHW	**MHW**	**NAVD88**	**MTL**	**MSL**	**MLW**	**MLLW**
Machias Port	6.45	6.11	0’	-0.21	-0.16’	-6.55	-6.85

Because the recorded data provided similar statistics to the NOAA station data at Cutler and Machiasport, the tidal data obtained by MaineDOT was used for stage boundary conditions at the downstream (seaward end) of the project for model runs where high upland flows were combined with normal tides, and where storm surge was added to typical tides.

2.3.2.2 Storm Surge Boundary Condition

A boundary condition representative of a Category 1 hurricane (approximately equivalent to a 50-year storm surge) is required for tidal bridge design and was developed for this study.

For the downstream storm surge boundary condition, an unsteady flow hydrograph representing a 50-year storm surge event was developed by combining typical tide data with predicted surge at Machias.

2.3.2.2.1 Daily Tide

Measured tide data in the Machias River immediately seaward from Dyke Bridge was obtained by MaineDOT from July 2011 through October of 2011. These data are in good agreement with predicted tide data from the referenced seaward locations, and were combined with a storm surge hydrograph to create a synthetic storm surge tide at the project site. Data from September 21 to 25, 2011 was used as a representative set of typical tide data. High tides ranged to a high of 7.3 ft and a low of -6.9 ft, and are in good agreement with the statistical MHHW and MLLW values of 7.4 ft and --6.8 ft computed for the data set (Table 2).

2.3.2.2.2 Storm Surge

The Maine coast experiences storm surge due to hurricanes and Nor'easter storms. MaineDOT recommends using a category 1 hurricane wind field to estimate a storm surge for a 50-year (2-percent annual return-interval) surge. This analysis is based on Phase III of Development of Hydraulic Computer Models to Analyze Tidal and Coastal Storm Hydraulic Conditions at Hydraulic Structures and two appendices – A: National Oceanic and Atmospheric Administration (NOAA) Predictions of Hurricane Properties and B- ADCIRC Station Results (Phase III Report). For this project, MaineDOT provided a spreadsheet for converting peak surge levels to a hurricane-type surge hydrograph.

ADCIRC predicted surge levels for Machias Bay as follows:

- 50-year surge: 2.16 ft. Hydrograph duration 15 hours
- 100-year surge: 2.79 ft. Hydrograph duration 15 hours

Section 2.1 of the Phase III Report predicts a maximum surge of 2.5 ft. This is based on a Radius of Maximum Winds of 51 nm and forward speed of 54 knots for 95% of storms in Downeast Maine. With a D value of 0.94, a resulting maximum surge level of 2.5 is calculated.

The maximum recorded surge at Cutler is 2.466 ft with a surge duration of 17 hours. The maximum recorded surge at Eastport is 2.523 ft.

2.3.2.2.3 Combined Peak Surge Plus Tide Data

The following list summarizes available information on storm tides, combined surge statistics (typical tide plus surge), and recorded high tide events at locations near the project area (Table 5).

- USACE 2012 Tidal Flood Profiles.
    - Eastport: 50-year 14.3 ft NAVD88
    - Machias Port: 50-year (Eastport multiplied by 0.69) 9.9 ft NAVD88
    - Cutler: 50-year 10.8 ft NAVD88
- FEMA Flood Insurance Study of Machias.
    - 100-year: 11.8 ft NAVD88
    - 100-year map, 1988, 12.5 ft NGVD29[1], 11.8 ft NAVD88
    - Based on outdated USACE Tidal Flood Profiles
- USACE Tidal Flood Profiles 2012 at Cutler:
    - 50-year 10.5 ft NAVD88
    - 100-year 10.8 ft NAVD88

Table 5: Recorded Highest Tides at Cutler NOAA Gage and Machias (Data from MaineDOT)

Date	Machias	Cutler
9/28/2011	9.55	9.9
9/29/2011	9.71	10.14
10/28/2011		10.7

---

[1] National Geodetic Vertical Datum of 1929

3.0 HEC-RAS HYDRAULIC MODEL

A one-dimensional, unsteady-state numerical hydraulic model was developed using the USACE HEC-RAS (versions 4.1 and 5.0 [beta]). HEC-RAS version 5.0 (beta) was used for project work beginning in April of 2015 at the suggestion of MaineDOT as this version of HEC-RAS includes automated routines for modeling flap gates. The hydraulic model was developed using information obtained from MaineDOT and other sources.

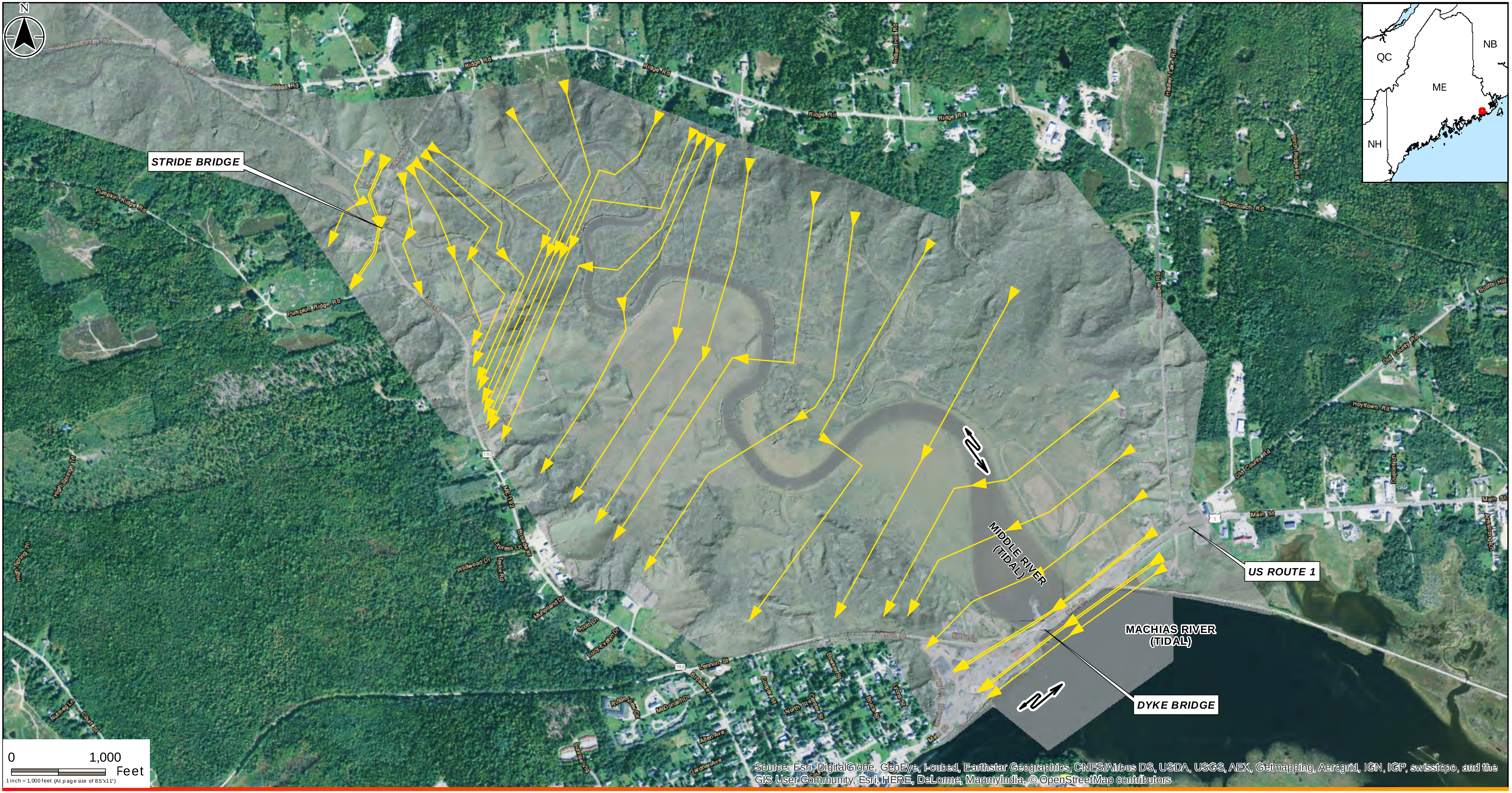
3.1 GEOMETRIC DATA

Geometric data for the revised HEC-RAS model was developed using topographic data provided by MaineDOT along with a limited number of bathymetric transects surveyed by MaineDOT. The layout of the HEC-RAS model domain is depicted in Figure 6, and Figure 7 depicts the geometric domain with color shading and the existing area that is normally wetted based on interpretation of aerial photography.

The HEC-RAS model domain was developed using the HEC-GeoRAS Geographic Information System (GIS) extension in ESRI ARC GIS software. The basis for this model was Lidar data provided by MaineDOT, which is depicted as the gray-shaded area in Figure 6. The Lidar data did not provide elevation coverage in persistently wetted areas landward (upstream) from Dyke Bridge. Bathymetric transects obtained by MaineDOT were therefore used to augment the Lidar data.

The GIS model was also used to develop an area-elevation dataset for the reach of the Middle River between Stride Bridge and Dyke Bridge. This curve is provided in Appendix B.

\\us1241-f01\workgroup\1956\active\195600963\drawing\mxd\00963_DykeBridge11x17.mxd Revised: 2015-07-01 By: ele



Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors

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Prepared by EPL on 2015-02-23
Reviewed by MRC on 2015-02-23

00963_DykeBridge11x17.mxd

Legend

- ➤➤➤ Cross Sections
- ▨ Maine DOT TIN Surface
- ⇄ Dominant Upland Flow

Notes

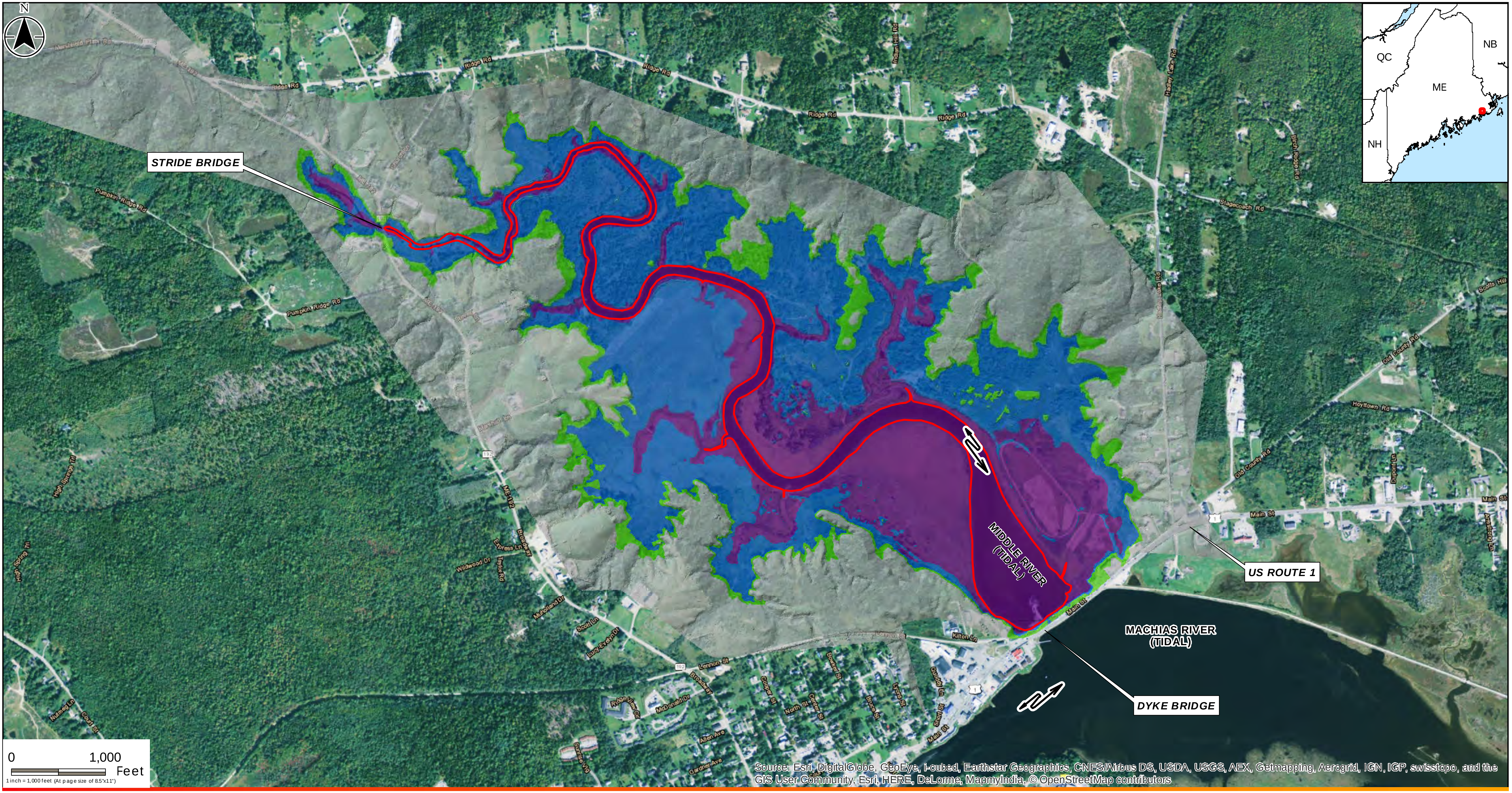
1. Coordinate System: NAD 1983 UTM Zone 19N FT
2. Aerial imagery provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).
3. TIN Surface information is based on survey data provided by the Maine Department of Transporation.

Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
6

Title
HEC-RAS Model Domain

7/1/2015



Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors

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00963_DykeBridge11x17_elev.mxd

Legend

Water Surface Elevation (ft)

🟪	< 4
🟦	4 - 8
🟩	8 - 12
⬜	>12
—	Inundated Area
⇄	Dominant Upland Flow

Notes

1. Coordinate System: NAD 1983 UTM Zone 19N FT
2. Vertical Datum: NAVD88
3. Aerial imagery provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).
4. TIN Surface information is based on survey data provided by the Maine Department of Transporation.

Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
7

Title
Elevation Map

7/1/2015

3.2 BOUNDARY CONDITIONS

The following combinations of upland flow and tidal stage were selected for the hydraulic model at Dyke Bridge and Stride Bridge.

- Typical tides with 1.1-year river flow, upland flow modeled as steady state flow.
- Typical tides with 50-year river return-interval flow with the riverine flow hydrograph modeled as triangular hydrograph with 12 hour time to peak.
- Typical tides with 100-year return-interval flow with the riverine flow hydrograph modeled as triangular hydrograph with 12 hour time to peak.
- 50-year storm surge with 1.1 year river flow.
- Surge to be superimposed at mid-rising, high tide, mid-falling and low tides.

3.2.1 Middle River (Upland Flow)

Riverine peak flows in the Middle River were provided by MaineDOT and are included in Table 6. For this project, and to simplify boundary conditions, only the flows predicted for Dyke Bridge were used in the model, but were used as the boundary condition at the upstream end of the model upstream from Stride Bridge. This assumption and development and use of suitable upland flow hydrographs should be incorporated into final design analyses.

Table 6: Riverine Peak Flows in Middle River

Location	1.1-Year Return-Interval (cfs)	50- Year Return-Interval (cfs)	100- Year Return-Interval (cfs)
Stride Bridge	130	787	912
Dyke Bridge	152	832	958

3.2.2 Tidal Stage

3.2.2.1 Typical Tides

Typical ("everyday") tide hydrographs are based on data recorded by MaineDOT from July 2011 to October of 2011 in the Machias River immediately seaward from Dyke Bridge. The data show a highest recorded tide elevation of 9.7 ft on September 29, 2011. At that time, the Cutler gage recorded an elevation of 10.1 ft.

Table 7: Summary of Tide Stage Information

Tide Stage/Date	Recorded at Machias (ft, NAVD88)	Cutler gage (ft, NAVD88)
MHHW	7.4	6.8
MHW	6.5	6.4
MLW	-6.5	-6.4
MLLW	-6.8	-6.8
lowest	-7.5	not applicable
9/24/2011	7.4	7.3
9/28/2011	9.55	9.9
9/29/2011	9.71	10.14
10/28/2011		10.7

3.2.2.2 Combinations of Riverine Peak Flows and Typical Tides

Riverine peak flows were combined with typical high tides as recorded in the MaineDOT data. An example of this combination is in HEC-RAS Plan No. 24, which models the existing culverts at Dyke Bridge and Stride Bridge, and imposes a 50-year peak flow hydrograph on a high tide. The 50-year return-interval hydrograph peak flow of 832 cfs passes Stride Bridge at 12:35 on 14 July, 2011. Corresponding water levels at Dyke Bridge are presented in Table 8.

Table 8: Combinations of Peak Upland Flows and Typical Tides at Dyke Bridge

Date and Time	High Water Level (ft, NAVD88)	50- Year Return-Interval Peak Flow (cfs)
July 14, 2011 at 22:25	8.4	832
July 14, 2011 at 10:35	7.0	832
July 14, 2011 at 23:05	8.8	832

Tidal and upland flow hydrographs were combined with that same timing. This combination should be reviewed for final design.

3.2.2.3 Combination of 1.1-year Riverine Peak Flow with Storm Surge Tides

For this study, the MHHW value for the MaineDOT recorded normal tide data downstream of Dyke Bridge was combined with a peak surge of 2.5 ft, with the following high and low values associated with timing of peak surge and tides. These tidal conditions were modeled with the 1.1-year return-interval peak flow (152 cfs) as the inflow (upstream) boundary condition. A precise recurrence interval has not been assigned to this surge level, but the difference between a 50-year and 100-year surge in this area is a few tenths of a foot. Based on data outlined in

Section 2.3.2.2.3, this tidal peak elevation should be reviewed for final design. The data suggests a value between 9.8 ft and 10.8 ft when the peak surge coincides with the peak high tide.

Table 9: Combinations of Upland Flow with Storm Surge Tides

Timing of Peak Surge	High Water Level (ft, NAVD88)	Low Water Level Before Peak Surge (ft, NAVD88)
Mid-Rising	8.0	-7.0
High Tide	9.8	-7.0
Mid-Falling	8.0	-7.0
Low-Tide	7.8	-7.0

4.0 MODEL BOUNDARY CONDITIONS

This section presents boundary condition scenarios requested by MaineDOT for evaluation with the study hydraulic model.

4.1 STEADY-STATE BOUNDARY CONDITIONS

Steady-state boundary conditions were modeled with specified inflow (upstream) boundary conditions and specified water surface elevations at the downstream (seaward) boundary condition. Steady-state boundary conditions are presented in Table 10.

Table 10: Steady-State Boundary Conditions

Case	Upland Runoff (Return-Interval Event)	Downstream (fixed stage)	Comments
Case 1	50-Year	MHW	-Gates assumed fully open. (4 ft height). Upstream elevation would be 9.9 ft. Upstream of Stride Bridge, the modeled elevation is 11.0 ft.
Case 2	50-Year	MLW	The applied water surface elevation for MLW is expected to result in very high calculated flow speeds for the span bridge alternatives at Dyke Bridge because the upstream channel elevation is well above the MLW elevation. Upstream of Dyke Bridge, water surface elevation would be 1.4 ft and 7.3 ft upstream of Stride Bridge.

Based on review of information, including the area-elevation curve that was developed as part of this project for the reach of the Middle River between Stride Bridge and Dyke Bridge and the HEC-RAS model results, it was determined that steady-state hydraulic analyses are of little practical utility for this study. The basis for this determination is that there is substantial hydrologic storage in the reach of the Middle River between the two project bridges relative to the volume of upland runoff hydrographs in the Middle River. This finding was validated as part of this study by 1) steady-state model simulations that depict overtopping of Dyke Bridge during moderate upland runoff flow events that predict overtopping of Dyke Bridge, and 2) unsteady-state model simulations with upland runoff hydrographs that do not result in overtopping of Dyke Bridge. The question of whether Dyke Bridge has been overtopped was discussed with MaineDOT during project meetings, and MaineDOT indicated that they are not aware of upland runoff events having resulted in overtopping of Dyke Bridge.

4.2 UNSTEADY-STATE BOUNDARY CONDITIONS

Unsteady-state boundary conditions were used for hydraulic model evaluations using the project HEC-RAS model. Unsteady-state boundary conditions are presented in Table 11. As noted in Section 4.1, trial runs using upland peak flows as a steady state input resulted in unrealistically high water surface elevations that do not account for storage along the reach of the Middle River between the two bridges. For this reason, upland flows were modeled as triangular hydrographs that were developed based on professional judgment.

Table 11: Unsteady-State Boundary Conditions

Case	Upland Runoff (Return-Interval Event)	Tidal Regime	Comments
Q1T1	1.1-Year-steady flow	Recorded Tides +9.0/-7.5	
Q50T1	50-Year-Hydrograph, peak = 824 cfs	Recorded Tides	Peak upland flow occurs at tides in range of 7.0 ft to 8.8 ft.
Q100T1	100-Year-Hydrograph = 958 cfs	Recorded Tides	Peak upland flow occurs at tides in range of 7.0 ft to 8.8 ft.
Q1T50M	1.1-Year	Category 1 Hurricane (2.5 ft peak)_ +9.8 ft /-6.9 ft	Peak of storm surge at mid-rising tide (8.0 ft)
Q1T50H	1.1-Year	Category 1 Hurricane (2.5 ft peak)	Peak of storm surge at high tide (9.8 ft)
Q1T50M	1.1-Year	Category 1 Hurricane – (2.5 ft peak)	Peak of storm surge at mid-falling tide (8.0 ft)
Q1T50L	1.1-Year	Category 1 Hurricane – (2.5 ft peak)	Peak of storm surge at low tide (7.8 ft)

4.3 SEA-LEVEL RISE SCENARIOS

Three sea-level rise (SLR) scenarios were evaluated for selected model simulations, including:

1) Current MHHW conditions;
2) Design Year (current) MHHW with Moderate (0.5 meter [1.64 ft]) SLR; and
3) Design Year (current) MHHW with High (1.0 meter [3.28 ft]) SLR.

5.0 PRELIMINARY EVALUATIONS – TYPICAL TIDES

This section presents information on the evaluation of project alternatives with typical tides and low streamflows in the Middle River as represented by tidal stage data collected by MaineDOT and a flow of 20 cfs in the Middle River, respectively.

5.1 EXISTING CONDITIONS AND REPLACEMENT IN-KIND

Hydraulic conditions at Dyke Bridge were evaluated for existing conditions (Alternative 1) and for replacement in-kind (Alternative 2). The objectives of these evaluations included:

1) Calibration and validation of the hydraulic model for existing conditions; and
2) Evaluation of replacement in-kind (i.e., with four 5 ft by 5 ft flap gates).

These evaluations were performed using tidal stage data collected by MaineDOT and an assumed normal upland flow in the Middle River of 20 cfs.

5.1.1 Alternative 1 - Existing Conditions

Existing conditions at Dyke Bridge were modeled in HEC-RAS using gates and operational rules. The use of gates and operational rules precludes modeling of culverts in combination with gates in HEC-RAS. The modeled approach therefore does not include effects of flow through culverts and gates; it solely evaluates hydraulic parameters (e.g., conveyance, losses) at the gate. This approach is analogous to flow through on overly-large culvert (i.e., losses are minimal and can be discounted) with a controlled gate at one end. This approach was used early in the project because HEC-RAS 4.1 did not include an option for modeling flap gates (Plan No. 87).

The existing Dyke Bridge culverts include four 5 ft by 5 ft wood and masonry box culverts with flap gates. Based on review of survey data provided by MaineDOT, including elevations of the culvert inverts and tidal stage data collected landward and seaward from Dyke Bridge, and preliminary model simulation, the existing culverts were modeled with heights of 4 ft and minimum gate openings of 0.35 ft. The reduced gate heights were used to address apparent blockage in the bottoms of the culverts as determined from bridge inspection reports provided by MaineDOT. The minimum gate opening was used to provide for landward flow during flood tides, which is apparent in visual observations and tidal stage data collected by MaineDOT in the Middle River landward from Dyke Bridge. The culverts and flap gates were modeled as sluice gates in HEC-RAS using operational rules programmed in the HEC-RAS unsteady-flow rules editor.

5.1.1.1 Existing Conditions Without Gate Operations

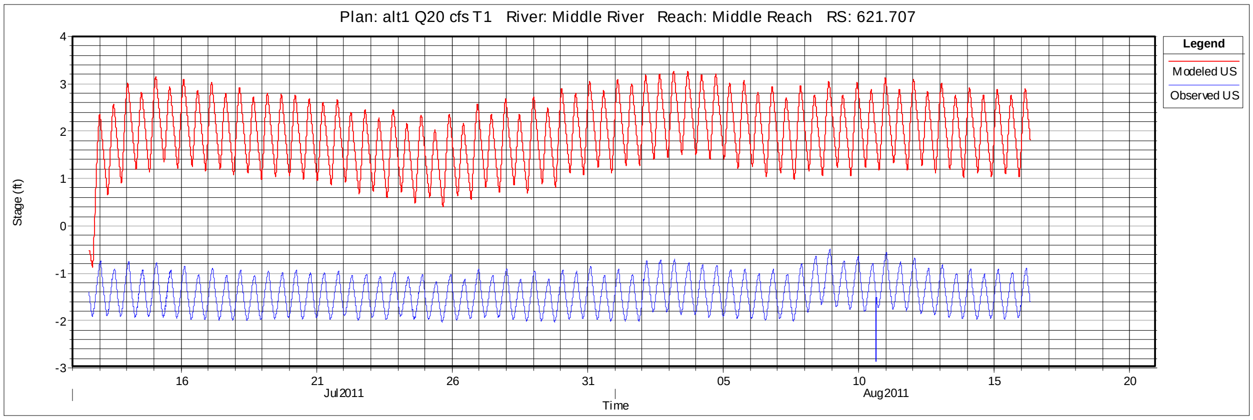
Existing conditions were initially evaluated without operational rules and the four gates set in the “open” position. Under this condition, the equilibrium water level in the landward reach of the

Middle River is simulated as the approximate average of the high and low water conditions (Plan No. 86).

This simulation reflects conditions that would result from removal or failure of the tide gates. Results of this simulation, including measured ("Observed US[2]") and simulated ("Modeled US") water surface elevations in the Middle River landward from Dyke Bridge, are depicted in Figure 8. It is apparent in this figure that removal or failure of the tide gates would increase in daily water surface elevations by up to 5 ft in the Middle River upstream from Dyke Bridge during typical tides with an upland flow in the Middle River of 20 cfs. The increase in water surface elevations by 5 ft reflects the difference between the maximum elevation of typical tides (elevation -1 ft) and the predicted maximum elevation of approximately 4 ft for typical tides.

Figure 9 presents the measured tidal stage data seaward from Dyke Bridge ("Observed DS[3]") and the simulated water surface elevations landward from Dyke Bridge ("Modeled US").

Figure 8: Alternative 1 (Existing Conditions) W/O Gate Operations (Measured and Simulated Water Surface Elevation Landward from Dyke Bridge)



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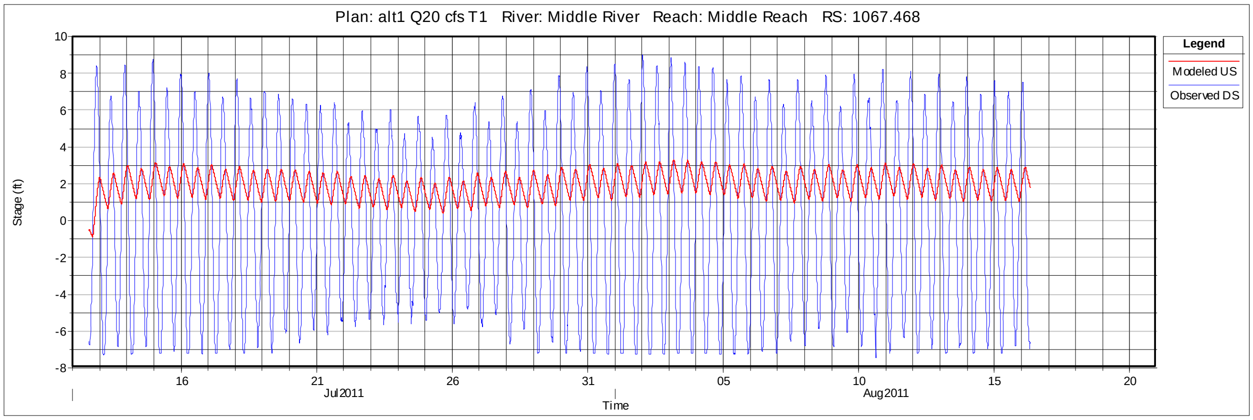
[2] "US" is used as an abbreviation for "upstream" (landward) from Dyke Bridge.
[3] "DS" is used as an abbreviation for "downstream" (seaward) from Dyke Bridge.

Figure 9: Alternative 1 (Existing Conditions) W/O Gate Operations (Simulated Landward and Measured Seaward Water Surface Elevations)



5.1.1.2 Existing Conditions With Gate Operations

Existing conditions were simulated using the HEC-RAS unsteady-flow rules option to reflect operation of the existing flapper gates and represents calibration of this model scenario to existing conditions (Plan No. 87). These rules were programmed as internal boundary conditions in HEC-RAS. The programmed rules were set to operate the four existing flap gates according to the same rules. The analysis for existing conditions with gate operations used a minimum gate opening of 0.35 ft to account for leakage through the existing gates and the causeway.

The rules for the existing conditions evaluation are shown in Figure 10. Figure 11 presents the simulated water surface elevations ("Modeled US") relative to the measured stage ("Observed US") landward from Dyke Bridge as measured by MaineDOT. The predicted water surface elevations range from approximately -2.0 ft to -0.7 ft for a period of time when data obtained by MaineDOT indicates water surface elevations of approximately -2.0 ft to -0.8 ft.

Table 12 presents invert information for the 4 existing box culverts.

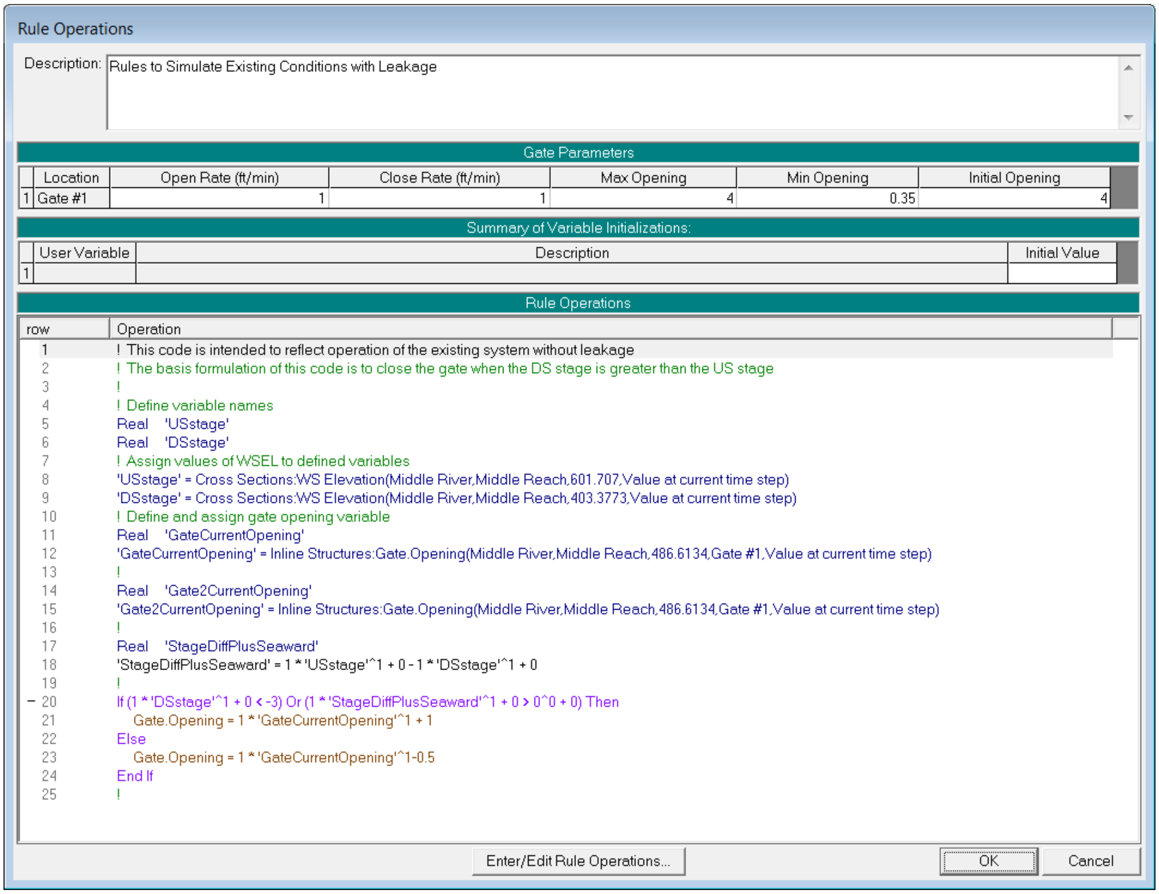
Table 12: Dyke Bridge Culvert Box Inverts

Location	Culvert	DS Invert	DS (Prev)	US (Prev)
east	Culvert #1	-4.0	-0.38	-3.8
center-east	Culvert #2	-4.0	-4.2	-4.2
center-west	Culvert #3	-4.5	-4.7	-4.7
west	Culvert #4	-3.6	-4.4	-4.4
	average	***-4.1***	***-3.4***	***-4.3***

Following review of the tidal stage data collected by MaineDOT and the reported invert elevations, it is apparent that debris likely limits outflow from the landward reach of the Middle

River. To accommodate debris, the modeled invert for existing conditions was set at an elevation of -3.1 ft, which is approximately 1 ft higher than the average invert elevation of the four culverts. The culvert height was reduced to 4 ft for this analysis to accommodate the apparent partial occlusion in the culverts.

Figure 10: Existing Conditions Rules



Description: Rules to Simulate Existing Conditions with Leakage

Gate Parameters

	Location	Open Rate (ft/min)	Close Rate (ft/min)	Max Opening	Min Opening	Initial Opening
1	Gate #1	1	1	4	0.35	4

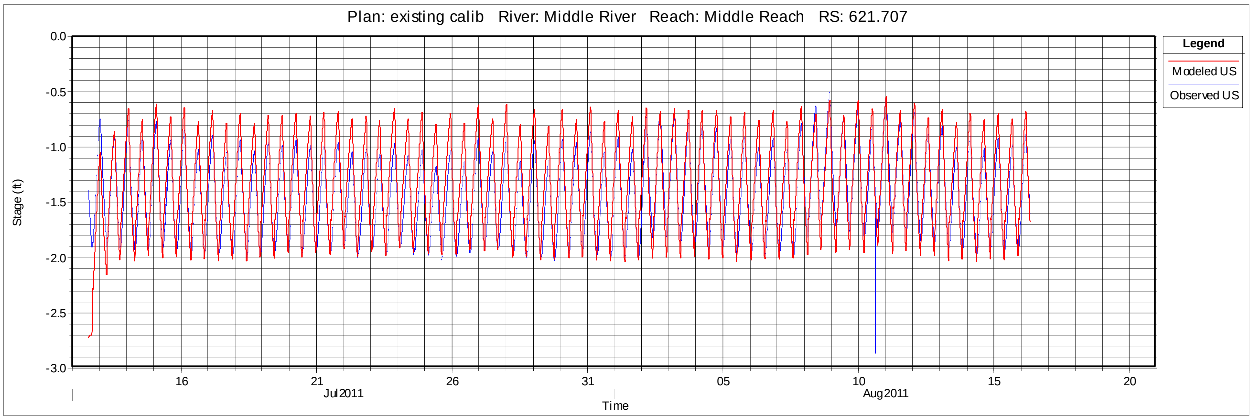
Summary of Variable Initializations:

	User Variable	Description	Initial Value
1			

Rule Operations

```
! This code is intended to reflect operation of the existing system without leakage
! The basis formulation of this code is to close the gate when the DS stage is greater than the US stage
!
! Define variable names
Real   'USstage'
Real   'DSstage'
! Assign values of WSEL to defined variables
'USstage' = Cross Sections:WS Elevation(Middle River,Middle Reach,601.707,Value at current time step)
'DSstage' = Cross Sections:WS Elevation(Middle River,Middle Reach,403.3773,Value at current time step)
! Define and assign gate opening variable
Real   'GateCurrentOpening'
'GateCurrentOpening' = Inline Structures:Gate.Opening(Middle River,Middle Reach,486.6134,Gate #1,Value at current time step)
!
Real   'Gate2CurrentOpening'
'Gate2CurrentOpening' = Inline Structures:Gate.Opening(Middle River,Middle Reach,486.6134,Gate #1,Value at current time step)
!
Real   'StageDiffPlusSeaward'
'StageDiffPlusSeaward' = 1 * 'USstage'^1 + 0 - 1 * 'DSstage'^1 + 0
!
If (1 * 'DSstage'^1 + 0 < -3) Or (1 * 'StageDiffPlusSeaward'^1 + 0 > 0^0 + 0) Then
   Gate.Opening = 1 * 'GateCurrentOpening'^1 + 1
Else
   Gate.Opening = 1 * 'GateCurrentOpening'^1-0.5
End If
!
```

Figure 11: Alternative 1 (Existing Conditions) with Gate Operations (Simulated and Observed)



5.1.2 Alternative 2 – Replacement In-Kind

Replacement in-kind with flap gates on four culverts was evaluated along with variations of replacement in-kind that evaluated eliminating flap gates on some of the culverts.

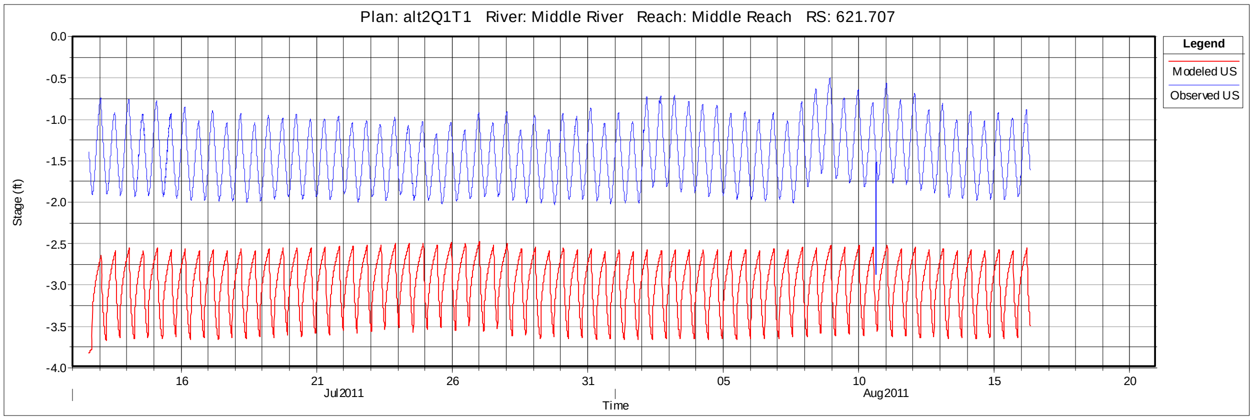
5.1.2.1 Replacement In-Kind (Plan No. 13[4])

Alternative 2 reflects in-kind replacement of the existing culvert and gate system. The model setup for this alternative did not include a minimum gate setting to account for leakage through the gates or the causeway. A pronounced effect of this simulation results from the lack of landward tidal flow, which results in very small semi-diurnal variation in stage that results from riverine inflows into the “impoundment” when the tide gates are “closed.” These conditions were simulated with upland flow of 20 cfs and typical tides represented using tidal stage data collected by MaineDOT seaward from Dyke Bridge in the Machias River.

---

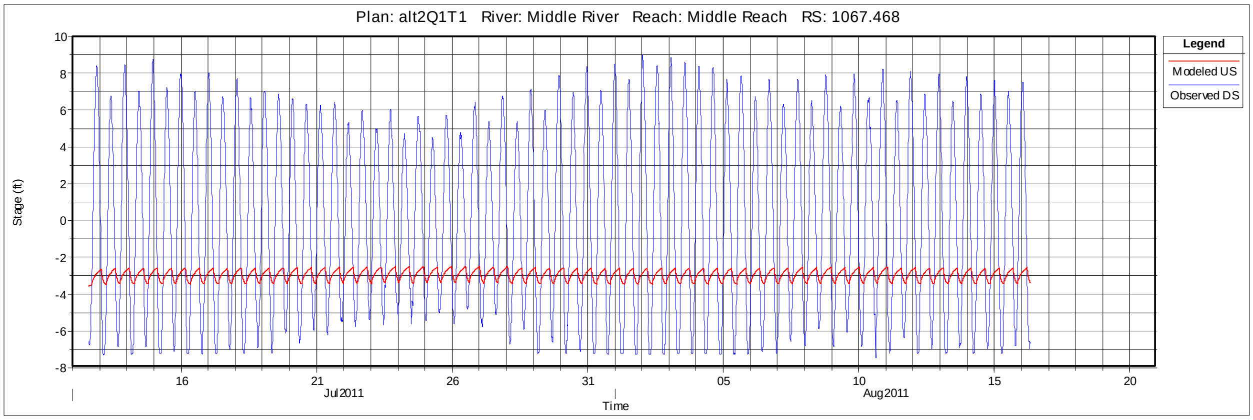
[4] This HEC-RAS model simulation was performed using Plan No. 13, which is setup to model the 1.1-year, return-interval flow with the inflow boundary condition changed from 151.6 cfs to 20 cfs for this simulation only.

Figure 12: Alternative 2 (Replacement In-Kind) (Simulated [Landward] and Observed [Landward])



Modeling of this alternative was performed using the invert elevations provided by MaineDOT with gate heights of 5 ft. For the MaineDOT recorded tide data, downstream of Dyke Bridge elevations vary from 9.0 ft to -7.5 ft. Upstream of Dyke Bridge, the simulated tidal elevations in the Middle River landward from Dyke Bridge range from -3.3 ft to -2.5 ft. The lower water surface elevations immediately landward from Dyke Bridge eliminate tidally-influenced changes in water surface elevations at Stride Bridge.

Figure 13: Alternative 2 (Replacement In-Kind) (Simulated and Observed, Landward and Seaward)



5.1.3 Replacement In-Kind With Variations for Flap Gate Operations

Replacement in-kind with variations for operations of flap gates were evaluated as a means to provide for improved upstream fish passage at Dyke Bridge. The objective of the modeled variations on Alternative 2 is to evaluate the potential to provide for landward flow at Dyke Bridge during the flood tide through culverts without gates. The modeled Alternative 2 variations include:

a. Five 5 ft x 5 ft culverts with flap gates on four of the culverts (Plan No. 82). Results of this simulation that include the observed upstream tide data are presented in Figure 14;

b. Four 5 ft x 5 ft culverts with flap gates on three of the culverts (Plan No. 83). Results of this simulation that include the observed upstream tide data are presented in Figure 15; and

c. Four 5 ft x 5 ft culverts with flap gates on two of the culverts (Plan No. 27). Results of this simulation that include the observed upstream tide data are presented in Figure 16.

Summary tables with the results of these simulations are included in Section 6.0.

The model simulation results with five box culverts with four flap gates (Figure 14) and four box culverts with three flap gates (Figure 15) are similar, and would result in maximum typical water surface elevations landward from Dyke Bridge that are approximately 1.5 ft to 2 ft higher (typical high tide elevations are approximately 0.5 ft and 1 ft, respectively) than current conditions (existing typical high tide elevation is approximately -1 ft). The low tide simulation results indicate that the alternative with five box culverts would result in low tide water surface elevations that are similar to existing conditions, whereas the simulation results with four box culverts indicate that low tide water surface elevations would be approximately 1 ft higher. The lower low tide elevations result from the increased capacity of the five culverts to discharge flow seaward during the ebb tide relative to the capacity of the single open culvert to provide for landward flow. A criteria for evaluating these alternatives is the ratio of culverts with landward conveyance and seaward conveyance, which is 0.2 for the alternative with five box culverts and four flap gates and 0.25 for the alternative with four box culverts and three flap gates.

The model simulation results with four box culverts and two flap gates (Figure 16), and has a ratio of culverts with landward conveyance and seaward conveyance of 0.5. The maximum typical high tide elevations for this alternative are approximately 3 ft higher (typical high tide elevation is approximately 2 ft) than existing conditions (existing typical high tide elevation is approximately -1 ft) and the low tide elevations are marginally higher than the maximum typical high tide elevations.

Figure 17 depicts approximate contour lines and shading associated with the maximum typical tidal water surface elevations in the Middle River landward from Dyke Bridge for these three variations of Alternative 2, including contour lines at elevations of 1 ft and 2 ft and a change in shading at an elevation of 4 ft. For reference, this figure also includes the area that is currently wetted during typical tidal conditions (approximate elevation of -1 ft). Note that the terrain data used to develop this figure (Lidar data provided by MaineDOT) did not include bathymetric data, and contour lines that extend across the channel of the Middle River are not accurate.

Figure 14: Five 5 ft x 5 ft Culverts with Flap Gates on Four Culverts (One Open)

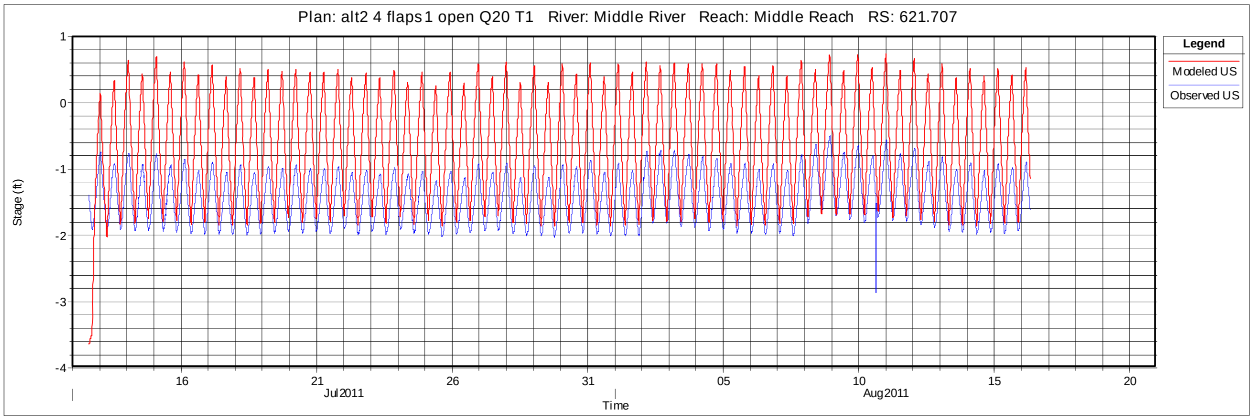


Figure 15: Four 5 ft x 5 ft Culverts with Flap Gates on Three Culverts (One Open)

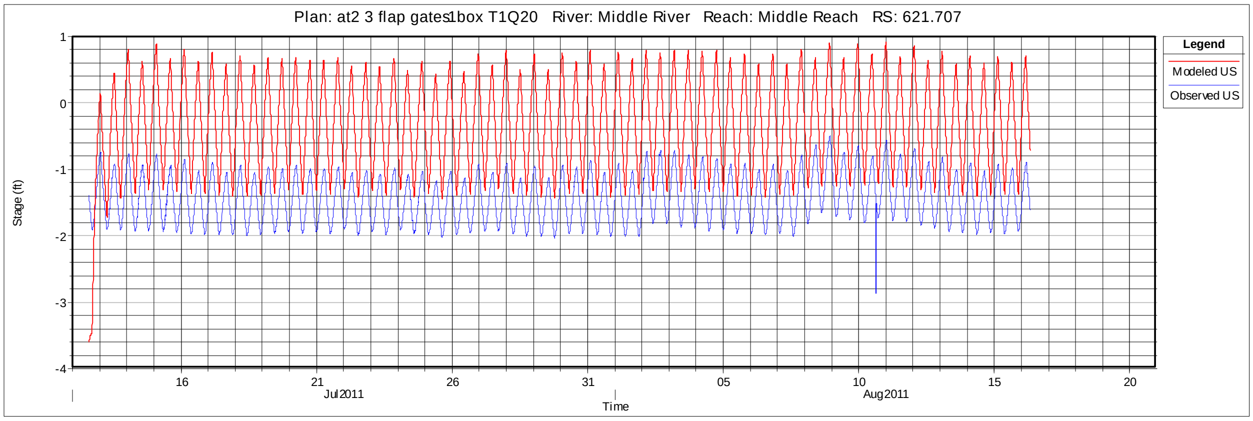
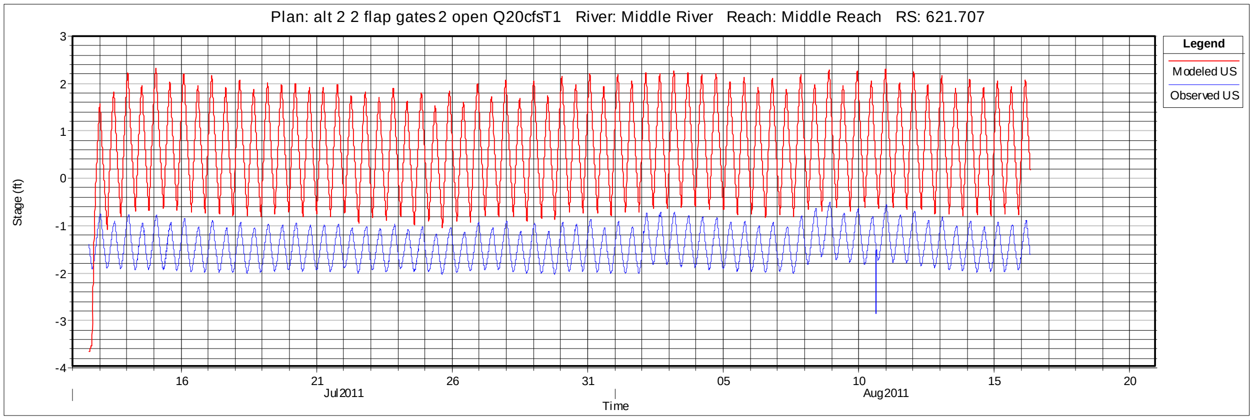
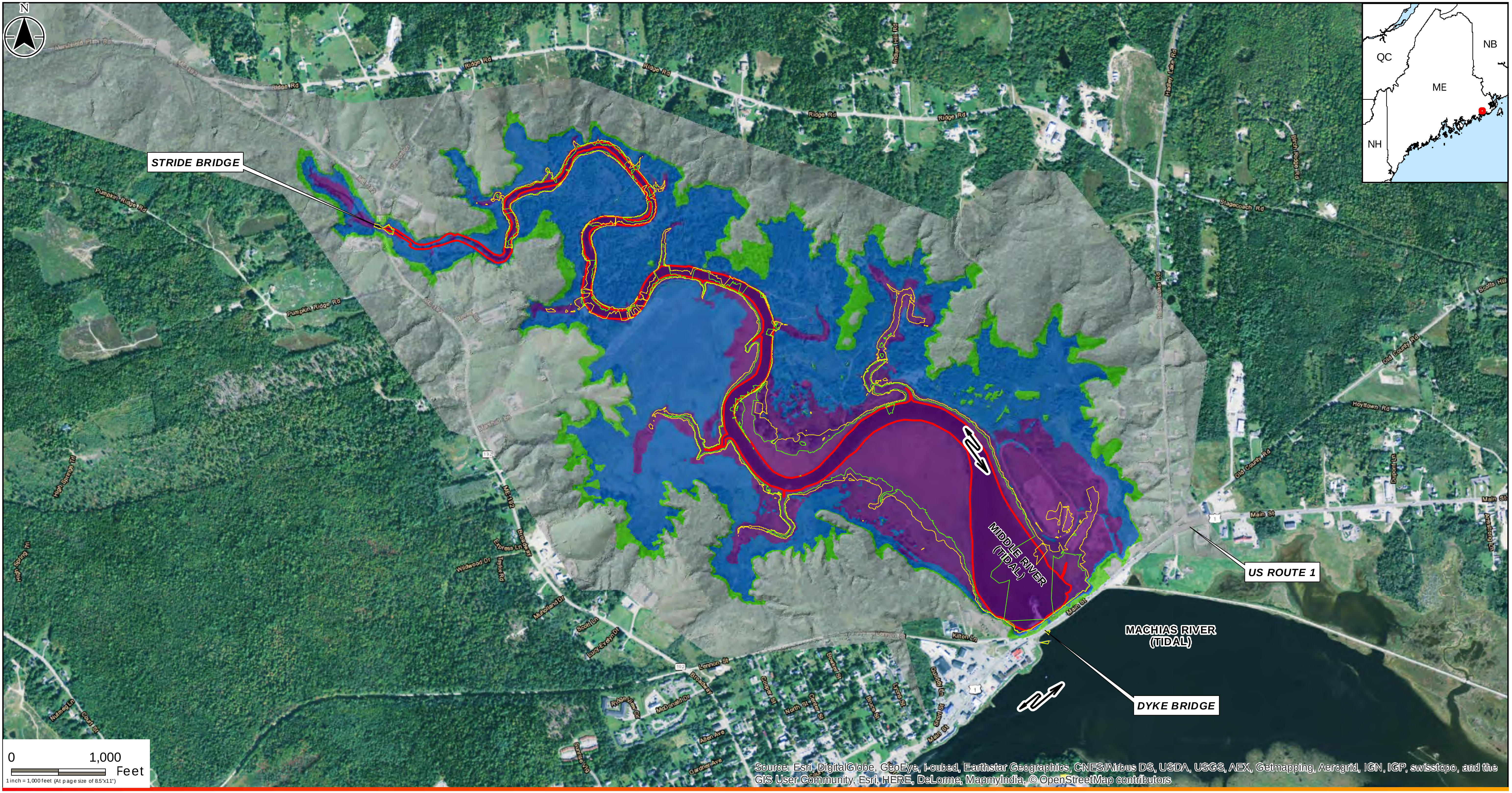


Figure 16: Four 5 ft x 5 ft Culverts with Flap Gates on Two the Culverts (Two Open)



\\us1241-f01\workgroup\1956\active\195600963\drawing\mxd\00963_DykeBridge11x17_cont.mxd Revised: 2015-07-01 By: ele



Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors

195600963

Stantec

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Prepared by EPL on 2015-02-23
Reviewed by MRC on 2015-02-23

00963_DykeBridge11x17_cont.mxd

Legend

Water Surface Elevation (ft)

🟪	< 4
🟦	4 - 8
🟩	8 - 12
⬜	>12
⇄	Dominant Upland Flow
—	Inundated Area
—	1' Contour
—	2' Contour

Notes

1. Coordinate System: NAD 1983 UTM Zone 19N FT
2. Vertical Datum: NAVD88
3. Aerial imagery provided by ArcGIS Online World Imagery Mapping Service (http://server.arcgisonline.com/arcgis/services/World_Imagery/MapServer).
4. TIN Surface information is based on survey data provided by the Maine Department of Transporation.

Client/Project
Maine DOT
Dyke Bridge
Machias, Maine

Figure No.
17

Title
Contour Map

7/1/2015

5.2 SELF-REGULATING TIDE GATES

This section presents information on potential alternatives with self-regulating tide gates (SRTs).

5.2.1 Alternative 3 – SRT without Fish Passage

Alternative 3 reflects SRTs without provisions for upstream fish passage. This alternative could be implemented with a single large SRT or with multiple smaller SRTs. This alternative was not evaluated with the hydraulic model following review of SRT technologies as part of this alternative (reference Appendix C).

5.2.2 Alternative 4 – SRT with Fish Passage

Alternative 4 reflects SRTs with provisions for upstream fish passage. This alternative could be implemented with a single large SRT that would be operated to allow for upstream fish passage, multiple smaller SRTs that could be operated individually or collectively to provide for upstream fish passage, or single or multiple SRTs along with an ungated (free-flowing) culvert that would be intended to provide for upstream fish passage. This alternative was not evaluated with the hydraulic model following review of SRT technologies as part of this alternative (reference Appendix C).

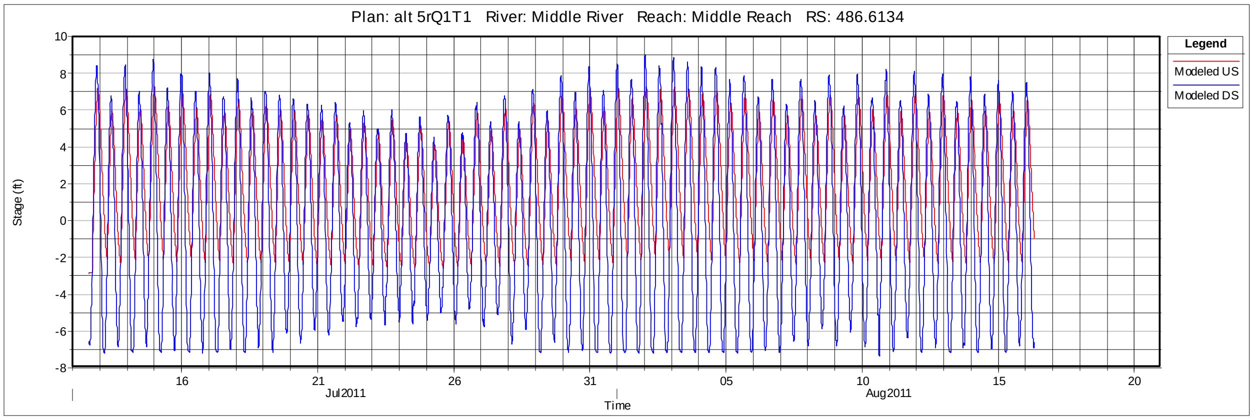
5.3 FREE-FLOWING ALTERNATIVES

This section presents alternatives that are intended to provide for restoration of tidal flow in the Middle River landward from Dyke Bridge to within 3 to 6 inches of conditions in the Machias River immediately seaward from Dyke Bridge.

5.3.1 Alternative 5 – Multiple Adjacent Culverts

Multiple geometries were evaluated for Alternative 5, which reflects multiple adjacent culverts that are intended to provide for tidal restoration. Model simulations were performed for an alternative comprised of five 12 ft (height) by 15 ft (width) box culverts with the inverts set at an elevation of -4.0 ft. Simulated water surface elevations (Figure 18) seaward (“Modeled DS”) and landward (“Modeled US”) from Dyke Bridge for this geometry and the 1.1-year return-interval upland flow simulations indicate that multiple adjacent culverts would not restore tidal stages to within 3 inches to 6 inches landward from Dyke Bridge. (Plan No. 17)

Figure 18: Alternative 5 – (4) 12’ (h) x 15’ (w) Box Culverts

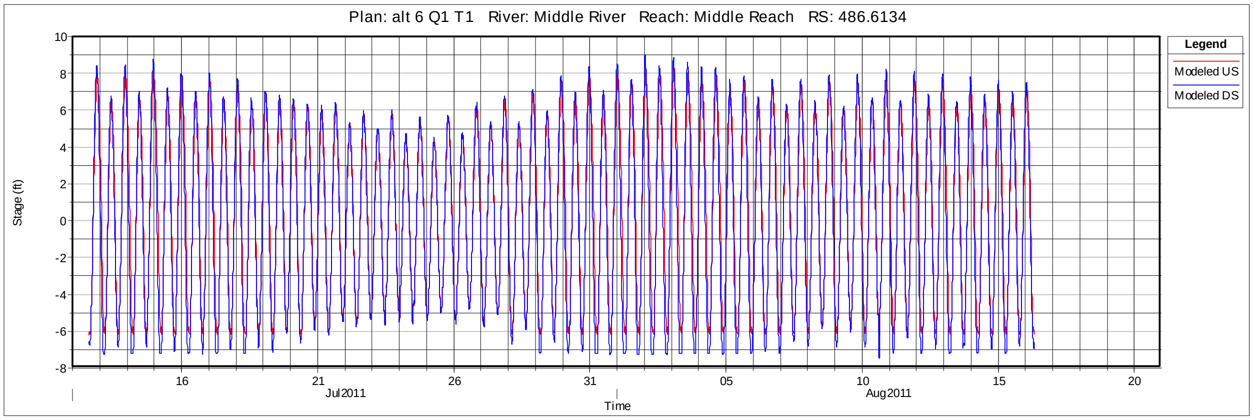


5.3.2 Alternative 6 – Span Bridge

Alternative 6 reflects a span bridge intended to provide for tidal restoration. This alternative was the first of the “free-flowing” alternatives to be evaluated as this alternative provides a means to bound the other free-flowing alternatives (Alternatives 5 and 7).

Based on the preliminary simulation results, a traditional span bridge would require a minimum span of 60 ft with vertical abutments to achieve close to the objectives of this alternative (Figure 19 - 1.1-year flow and tide is simulated in Plan No. 20 for this alternative). Based on the model results, a single-span bridge with a clear span of 60 ft would provide for landward tidal water surface elevations within 0.5 of the seaward tidal stage except during higher high tides, during which the landward tidal stage would be up to 1 ft below the seaward tidal stage.

Figure 19: Alternative 6 – 60-ft Clear Span Bridge



5.3.3 Alternative 7 – Span Bridge with Culverts

Alternative 7 as requested by MaineDOT reflects a span bridge with adjacent culverts intended to provide for tidal restoration. The suggested basis for this alternative is use of a smaller span (relative to Alternative 6) along with relief culverts in the causeway adjacent to the bridge.

An identified consideration for this alternative is whether to install the relief culvert inverts low enough to remain wetted at low tide or whether to install relief culverts that would convey flow during the peak tidal flow only.

Based on the preliminary model analyses and subsequent discussions with MaineDOT, it was determined that this alternative is not feasible relative to the single span bridge alternative (Alternative 6). This alternative was not modeled.

6.0 HYDRAULIC MODEL EVALUATION RESULTS

This section presents results of the hydraulic model evaluation performed as part of this study.

High upland flows and high tides were modeled for each bridge alternative as described in Section 5.0. Tide and flow combinations are as discussed in Sections 3.0 and 4.0.

Table 13 presents model results for existing conditions (Alternative 1). Table 14 presents model results for Alternative 2 (replacement in-kind with four 5 ft x 5 ft box culverts with flap gates) along with a variation on this alternative that is comprised of five 5 ft x 5 ft box culverts with four culverts have flap gates and one ungated, free-flowing culvert. Table 15 presents a summary of three variations on Alternative 2, including:

1) Five 5 ft x 5 ft culverts with flap gates on four culverts and one free-flow culvert;

2) Four 5 ft x 5 ft culverts with flap gates on three culverts and one free-flow culvert; and

3) Four 5 ft x 5 ft culverts with flap gates on two culverts and two free-flow culverts.

Table 16 presents model results for Alternative 5. This alternative is comprised of five 12 ft (h) x 15 ft (w) box culverts, and evaluated the potential to provide for full tidal restoration using culverts in lieu of a bridge.

Table 17 and Table 18 present model results for Alternative 6, which is represented by a 60-ft, single-span bridge, and include evaluation of higher roadway elevations as part of analyses that evaluated sea-level rise and slip-lining at Stride Bridge.

Table 19 presents a summary of results from the HEC-RAS model evaluations and result. Information on the HEC-RAS model setup, including identification of the HEC-RAS geometry, flow, and plan files, is provided in Appendix D.

Table 13: Summary of Model Results for Alternative 1 - Existing Conditions

Riverine Flow (cfs)	Tides (high/low)	Sea Level Rise (m)	Surge (ft)	Tide + Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
					High	Low	DS	US
1.1-year	**Recorded**							
152 - steady	+9.0/-7.5	none	none	9.0/-7.5	1	-0.9	1.4	1.8
		0.5 m		10.7/-5.6	1.4	-0.6	1.7	2.1
		1m		12.3/-4.22	4.5		4.6	4.7
50-year	**Recorded**							
824 steady	+9.0/-7.5	none	none	9.0/-7.5	6.7	4.4	6.9	8.3
Hydrograph	+9.0/-7.5	none	none	9.0/-7.5	3.7	-0.1	4.6	7.3
Hydrograph		0.5 m		10.7/-5.6	4.3	-0.6	4.7	7.3
Hydrograph		1m		12.3/-4.22	5.5	-0.05	5.5	7.3
100-year	**Recorded**							
958 -steady	+9.0/-7.5	none	none	9.0/-7.5	7.6	5.4	5.4	9.4
958 hydrograph	+9.0/-7.5	.5 m		10.7/-5.6	4.2	-1	4.2	8.1
hydrograph		1 m		12.3/-4.22	4.6	-0.7	5.1	8.1
Hydrograph		1m		12.3/-4.22	5.7	-0.5	5.7	8.1
1.1year	**Spring tides**		**2.5' surge**	**Surge at High Tide**				
1.1-year	7.3/-6.9	none	2.5	9.8/-7.0	0.6	-1.1	1.1	1.7
steady		0.5 m		11.4/-5.7	1.2	-0.7	1.5	2
		1m		13.1/-5.4	5.8	-1.9	5.9	5.9
1.1-year	**Spring tides**		**Surge timing**					
1.1-year	7.3/-6.9	none	MR	8/-7	0.6	-1	1.1	1.8
steady		none	MF	8/-7	0.6	-1.1	1.1	1.8
		none	L	7.8/-7	0.6	-1	1.1	1.8

Table 14: Summary of Model Results for Alternative 2 with One Variation on Alternative 2

Riverine Flow (cfs)	Tides (ft) (high/low)	Sea Level Rise (m)	Surge (ft)	Tide + Surge Downstream from Dyke Bridge (ft)	Four 5 ft x 5 ft Box Culverts				Five 5 ft x 5 ft Box Culverts with One Open			
					Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)		Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
					High	Low	DS	US	High	Low	DS	US
1.1-year	Recorded											
152 - steady	+9.0/-7.5	none	none	9.0/-7.5	0.08	-2.3	0.8	1.6	1.8	-0.7	2	2.3
		0.5 m		10.7/-5.6	0.5	-2	1	0.7	2.4	-0.24	2.6	
		1m		12.3/-4.22	3.6	-1.2	3.6	3.7	5	0.3	5	
50-year	Recorded											
Hydrograph	+9.0/-7.5	none	none	9.0/-7.5	3.2	-2.2	4.3	7.3	4	-1	4.8	7.3
		0.5 m		10.7/-5.6	3.5	-2	4.5	7.3				
		1m		12.3/-4.22	4.5	-1.3	5	7.3				
100-year	Recorded											
hydrograph	+9.0/-7.5	none	none	9.0/-7.5	3.5	-2.3	4.7	8.1	4.3	-0.9	5.1	8.1
		0.5 m		10.7/-5.6	3.8	-2	4.9	8.1				
		1m		12.3/-4.22	4.8	-1.5	5.4	8.1				
1.1year	Spring tides		2.5' surge	Surge at High Tide								
152 cfs steady flow	7.3/-6.9	none	2.5	9.8/-7.0	-0.17	-2.3	0.7	1.6	1.8	-1	2	2.3
		0.5 m		11.4/-5.4	0.4	-2	1	1.7	2.5	-0.4	2.8	2.9
		1m		13.1/-3.8	5.6	-1.1	5.7	5.7	6.3	0.5	6.3	6.3
1.1-year	Spring tides		Surge timing									
152 cfs - steady	7.3/-6.9	none	MR	8/-7	-0.1	-2.3	0.8	1.6				
		none	MF	8/-7								
		none	L	7.8/-7								

Table 15: Summary of Model Results for Alternative 2 Variations

Alternative 2 Variations	Riverine Flow (cfs)	Tides (ft) (high/low)	Sea Level Rise (m)	Surge (ft)	Tide + Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
						DS	US	DS	US
Five 5 ft x 5 ft box culverts with four flap gates and one open culvert Invert Elev.: -4.05 ft; Top of Road Elev.: 11 ft									
	20	9.0/-7.5	none	0	9.0/-7.5	9	0.7	0.8	0.8
	152			0		9	1.8	2	2.3
	152	7.3/-6.9	none	2.5	9.8/-7.0	9.8	1.8	2	2.3
Four 5 ft x 5 ft box culverts with three flap gates and one open culvert Invert Elev.: -4.05 ft; Top of Road Elev. 11 ft									
	20	9.0/-7.5	none	0	9.0/-7.5	9	0.9	0.9	1
	152			0		9	2.1	2.2	2.5
	152	7.3/-6.9	none	2.5	9.8/-7.0	9.8	2	2.2	2.5
Four 5 ft x 5 ft box culverts with two flap gates and two open culverts Invert Elev.: -4.05; Top of Road Elev.: 11 ft									
	20	9.0/-7.5	none	0	9.0/-7.5	9	2	2.3	2.3
	152			0		9	3.1	3.2	3.4
	152	7.3/-6.9	none	2.5	9.8/-7.0	9.8	3	3.1	3.3

Table 16: Summary of Model Results for Alternative 5 - Replacement with Five 12 ft x 15 ft Box Culverts with Top of Road at 17 ft

Riverine Flow (cfs)	Tides (ft) (high/low)	Sea Level Rise (m)	Surge (ft)	Tide + Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
					High	Low	DS	US
1.1-year	**Recorded**							
152 - steady	+9.0/-7.5	none	none	9.0/-7.5	7.3	-2.5	7.4	7.4
		0.5 m		10.7/-5.6	8.6	-2	8.6	8.7
		1m		12.3/-4.22	10.2	-0.6	10.2	10.3
50-year	**Recorded**							
Hydrograph	+9.0/-7.5	none	none	9.0/-7.5	7.5	-2.3	7.6	8.8
		0.5 m		10.7/-5.6	8.7	-2	8.7	9.8
		1m		12.3/-4.22	10.2	-0.6	10.2	11.1
100-year	**Recorded**							
hydrograph	+9.0/-7.5	none	none	9.0/-7.5	7.5	-2.3	7.7	9.3
		0.5 m		10.7/-5.6	8.8	-1.9	8.9	10.2
		1m		12.3/-4.22	10.2	-0.6	10.3	11.5
1.1year	**Spring tides**		**2.5' surge**	**Surge at High Tide**				
152 - steady	7.3/-6.9	none	2.5	9.8/-7.0	7.5	-2.6	7.5	7.6
		0.5 m		11.4/-5.4	8.8	-1.9	8.8	8.8
		1m		13.1/-4.0	10.6	-0.6	10.6	10.6
1.1-year	**Spring tides**		Surge timing					
152 - steady	7.3/-6.9	none	Mid-Flood	8/-7	6.9	-2.5	7	7
		none	Mid-Ebb	8/-7				
		none	L	7.8/-7				

Table 17: Summary of Model Results for Alternative 6 -60 ft Span at Dyke Bridge (Low Chord at 9 ft, Top of Road at Elev. 11 ft) with Multiple Alternatives at Stride Bridge (as noted) with Top of Road at Elev. 17 ft

Riverine Flow (cfs)	Tides (ft) (high/low)	Sea Level Rise (m)	Surge (ft)	Tide + Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
					High	Low	DS	US
1.1-year	**Recorded**							
152 - steady	+9.0/-7.5	none	none	9.0/-7.5	8.3	-6.1	8.5	8.5
		0.5 m		10.7/-5.6	9.8	-5.6	9.8	9.9
		1m		12.3/-4.22	11.2	-3.8	11.2	11.3
50-year	**Recorded**							
Hydrograph	+9.0/-7.5	none	none	9.0/-7.5	8.3	-6.1	8.3	9.5
		0.5 m		10.7/-5.6	9.8	-5.6	9.8	10.8
		1m		12.3/-4.22	11.2	-3.8	11.2	12.2
100-year	**Recorded**							
hydrograph	+9.0/-7.5	none	none	9.0/-7.5	8.4	-5.9	8.4	9.9
hydrograph		0.5 m		10.7/-5.6	9.9	-5.6	9.9	11.1
hydrograph		1m		12.3/-4.22	11.3	-3.7	11.3	12.6
1.1year	**Spring tides**		**2.5' surge**	**Surge at High Tide**				
1.1-year	7.3/-6.9	none	2.5	9.8/-7.0	8.9	-6.1	8.9	8.9
		0.5 m		11.4/-5.4	10.1	-5.3	10.1	10.2
		1 m		13.1/-3.7	11.5	-3.6	11.6	11.6
1.1-year	**Spring tides**		**Surge timing**					
1.1-year	7.3/-6.9	none	Mid-Flood	8/-7	7.7	-1.1	7.7	7.8
		0.5 m	Mid-Ebb	9.64/-5.4				
		1m	L	11.28/-3.7				

Table 18: Summary of Model Results for Alternative 6 - 60 ft Span at Dyke Bridge (Low Chord at 9 ft, Top of Road at Elev. 14.7 ft) with Multiple Alternatives at Stride Bridge (as noted) with Top of Road at Elev. 17 ft

Riverine Flow (cfs)	Stride Bridge Alternative	Tides (ft) (high/low)	Sea Level Rise (m)	Surge (ft)	Tide + Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
						High	Low	DS	US
1.1-year		Recorded							
	no change	9/-7.5	1m	none	12.3/-4.2	11.3	-3.8	11.3	11.4
	slip lined	9/-7.5	1m		12.3/-4.2	11.3	-3.8	11.3	11.4
50-year	no change	9/-7.5	none	none	9/-7.5				
Hydrograph			0.5 m		10.7/-5.9				
			1m		12.3/-4.2	11.2	-3.8	11.3	12.2
100-year	no change	9/-7.5	none	none	9/-7.5				
Hydrograph			0.5 m		10.7/-5.9				
			1m		12.3/-4.2	11.3	-3.8	11.3	12.6
50-year	slip lined	9/-7.5	none	none	9/-7.5	8.4	-6.1	8.4	9.8
Hydrograph			0.5 m		10.7/-5.9	9.8	-5.6	9.9	11.2
			1m		12.3/-4.2	11.3	-3.7	11.4	12.7
100-year	slip lined	9/-7.5	none	none	9/-7.5	8.3	-6.1	8.4	10.3
Hydrograph			0.5 m		10.7/-5.9	9.8	-5.6	9.9	11.7
			1m		12.3/-4.2	11.3	-3.8	11.4	13.2
		Spring			Surge=2.5 ft				
1.1-year	no change	7.3/-6.9	none	2.5	9.8/-6.9	8.7	-6.1	8.8	8.8
			0.5 m		11.4/-5.3	10.1	-5.2	10.2	10.2
			1m		13.1/-3.6	11.5	-3.6	11.7	11.7
					Mid Tide Surge				
1.1-year	no change	7.3/-6.9	none	2.5	8.0/-6.9				
			0.5 m		9.6/-5.3				
			1m		11.3/-3.6				
					High tide surge				
1.1-year	slip lined	7.3/-6.9	none	2.5	9.8/-6.9	8.9	-6.2	8.8	8.8
			0.5 m		11.4/-5.3	10.1	-5.1	10.1	10.2
			1 m		13.1/-3.6	11.7	-3.6	11.7	11.7
					Mid Tide Surge				
1.1-year	slip lined	7.3/-6.9	none	2.5	8.0/-6.9				
			0.5 m		9.6/-5.3				
			1 m		11.3/-3.6				

Table 19: Summary of Model Evaluations and Results

Bridge Geometry	Top of Roadway at Dyke Bridge (ft)	Dyke Bridge Geometry	Stride Bridge Geometry	Riverine Flow (cfs)	Tides (ft) (high/low)	SLR (m)	Surge (ft)	Tide+ Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
									High	Low	DS	US
Typical Tides, 1.1-year flow, SLR				**1.1-year**	**Recorded**			**DS of Dyke BR**				
1-Existing	elev 11	Existing	TR=12	152 - steady	+9.0/-7.5	none	none	+9.0/-7.5	1	-0.9	1.4	1.8
		4-4X5' boxes	inv -2.8/-2.5			0.5 m		+10.7/-5.6	1.4	-0.6	1.7	2.1
		w/ gates, inv -3.1	12.5' cmp			1m		+12.3/-4.22	4.5		4.6	4.7
2-replace	elev 11	replace ex, gates	TR=12	152 - steady	+9.0/-7.5	none	none	+9.0/-7.5	0.08	-2.3	0.8	1.6
		4-5X5 boxes,	inv -2.8/-2.5			0.5 m		+10.7/-5.6	0.5	-2	1	0.7
		inv -4.05	12.5' cmp			1m		+12.3/-4.22	3.6	-1.2	3.6	3.7
2 REV	elev 11	replace ex, gates	same	152 - steady	+9.0/-7.5	none	none	+9.0/-7.5	1.8	-0.7	2	2.4
		4 flap gates, 1 open box				0.5 m		+10.7/-5.6	2.4	-0.24	2.6	2.8
		inv -4.05				1m		+12.3/-4.22	5	0.3	5	5.1
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	152 - steady	+9.0/-7.5	none	none	+9.0/-7.5	7.3	-2.5	7.4	7.4
		bridge	invs -2.6/-2.5			0.5 m		+10.7/-5.6	8.6	-2	8.6	8.7
		inv = -5, n=.03	n=.015			1m		+12.3/-4.22	10.2	-0.6	10.2	10.3
6 - 60' span	elev 11	1- 60' span	TR=17	152 - steady	+9.0/-7.5	none	none	+9.0/-7.5	8.3	-6.1	8.5	8.5
		LC=9, TR=11	n=.028			0.5 m		+10.7/-5.6	9.8	-5.6	9.8	9.9
		invs -7.2/-8.0	invs -2.6/-2.5			1m		+12.3/-4.22	11.2	-3.8	11.2	11.3
Typical Tides, 50-year flow, SLR				**50-year**	**Recorded**							
1-Existing	elev 11	Existing	TR=12	824 steady	+9.0/-7.5	none	none	+9.0/-7.5	6.7	4.4	6.9	8.3
		4-4X5' boxes	inv -2.8/-2.5	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	3.7	-0.1	4.6	7.3
		w/ gates, inv -3.1	12.5' cmp	Hydrograph		0.5 m		+10.7/-5.6	4.3	-0.6	4.7	7.3
				Hydrograph		1m		+12.3/-4.22	5.5	-0.05	5.5	7.3
2-replace	elev 11	replace ex, gates	TR=12	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	3.2	-2.2	4.3	7.3
		4-5X5 boxes,	inv -2.8/-2.5	Hydrograph		0.5 m		+10.7/-5.6	3.5	-2	4.5	7.3
		inv -4.05	12.5' cmp	Hydrograph		1m		+12.3/-4.22	4.5	-1.3	5	7.3
2 REV	elev 11	replace ex, gates	same	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	4	-1	4.8	7.3
		4 flap gates, 1 open box		Hydrograph		0.5 m		+10.7/-5.6				
		inv -4.05		Hydrograph		1m		+12.3/-4.22				
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	7.5	-2.3	7.6	8.8
		bridge	invs -2.6/-2.5	Hydrograph		0.5 m		+10.7/-5.6	8.7	-2	8.7	9.8
		inv = -5, n=.03	n=.015	Hydrograph		1m		+12.3/-4.22	10.2	-0.6	10.2	11.1
6 - 60' span	elev 11	1- 60' span	TR=17	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	8.3	-6.1	8.3	9.5
		LC=9, TR=11	n=.028	Hydrograph		0.5 m		+10.7/-5.6	9.8	-5.6	9.8	10.8
		invs -7.2/-8.0	invs -2.6/-2.5	Hydrograph		1m		+12.3/-4.22	11.2	-3.8	11.2	12.2
Typical Tides, 100-year flows, plus SLR				**100-year**	**Recorded**							
1-Existing	elev 11	Existing	TR=12	958 -steady	+9.0/-7.5	none	none	+9.0/-7.5	7.6	5.4	5.4	9.4
		4-4X5' boxes	inv -2.8/-2.5	958 hydrograph	+9.0/-7.5	.5 m		+10.7/-5.6	4.2	-1	4.2	8.1
		w/ gates, inv -3.1	12.5' cmp	Hydrograph		1 m		+12.3/-4.22	4.6	-0.7	5.1	8.1
				Hydrograph		1m		+12.3/-4.22	5.7	-0.5	5.7	8.1
2-replace	elev 11	replace ex, gates	TR=12	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	3.5	-2.3	4.7	8.1
		4-5X5 boxes,	inv -2.8/-2.5	Hydrograph		0.5 m		+10.7/-5.6	3.8	-2	4.9	8.1
		inv -4.05	12.5' cmp	Hydrograph		1m		+12.3/-4.22	4.8	-1.5	5.4	8.1
2 REV	elev 11	replace ex, gates	same	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	4.3	-0.9	5.1	8.1
		4 flap gates, 1 open box		Hydrograph		0.5 m		+10.7/-5.6				
		inv -4.05		Hydrograph		1m		+12.3/-4.22				
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	7.5	-2.3	7.7	9.3
		bridge	invs -2.6/-2.5	Hydrograph		0.5 m		+10.7/-5.6	8.8	-1.9	8.9	10.2
		inv = -5, n=.03	n=.015	Hydrograph		1m		+12.3/-4.22	10.2	-0.6	10.3	11.5
6 - 60' span	elev 11	1- 60' span	TR=17	Hydrograph	+9.0/-7.5	none	none	+9.0/-7.5	8.4	-5.9	8.4	9.9
		LC=9, TR=11	n=.028	Hydrograph		0.5 m		+10.7/-5.6	9.9	-5.6	9.9	11.1
		invs -7.2/-8.0	invs -2.6/-2.5	Hydrograph		1m		+12.3/-4.22	11.3	-3.7	11.3	12.6

Table 19: Summary of Model Evaluations and Results

Bridge Geometry	Top of Roadway at Dyke Bridge (ft)	Dyke Bridge Geometry	Stride Bridge Geometry	Riverine Flow (cfs)	Tides (ft) (high/low)	SLR (m)	Surge (ft)	Tide+ Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
									High	Low	DS	US
High Spring Tide plus Surge, 1.1-year flow, plus SLR				**1.1year**	**Spring tides**		**2.5' surge**					
1-Existing	elev 11	Existing	TR=12	1.1-year	7.3/-6.9	none	2.5	9.8/-7.0	0.6	-1.1	1.1	1.7
		4-4X5' boxes	inv -2.8/-2.5	steady		0.5 m		11.4/-5.7	1.2	-0.7	1.5	2
		w/ gates, inv -3.1	12.5' cmp			1m		13.1/-5.4	5.8	-1.9	5.9	5.9
2-replace	elev 11	replace ex, gates	TR=12	1.1-year	7.3/-6.9	none	2.5	9.8/-7.0	-0.17	-2.3	0.7	1.6
		4-5X5 boxes,	inv -2.8/-2.5			0.5 m		11.4/-5.4	0.4	-2	1	1.7
		inv -4.05	12.5' cmp			1m		13.1/-3.8	5.6	-1.1	5.7	5.7
2 REV	elev 11	replace ex, gates	same	1.1-year	7.3/-6.9	none	2.5	9.8/-7.0	1.8	-1	2	2.3
		4 flap gates, 1 open box				0.5 m		11.4/-5.4	2.5	-0.4	2.8	2.9
		inv -4.05				1m		13.1/-3.8	6.3	0.5	6.3	6.3
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	1.1-year	7.3/-6.9	none	2.5	9.8/-7.0	7.5	-2.6	7.5	7.6
		bridge	invs -2.6/-2.5			0.5 m		11.4/-5.4	8.8	-1.9	8.8	8.8
		inv = -5, n=.03	n=.015			1m		13.1/-4.0	10.6	-0.6	10.6	10.6
6 - 60' span	elev 11	1- 60' span	TR=17	1.1-year	7.3/-6.9	none	2.5	9.8/-7.0	8.9	-6.1	8.9	8.9
		LC=9, TR=11	n=.028			0.5 m		11.4/-5.4	10.1	-5.3	10.1	10.2
		invs -7.2/-8.0	invs -2.6/-2.5			1 m		13.1/-3.7	11.5	-3.6	11.6	11.6
1-Existing	Existing	Existing	Existing	1.1-year	7.3/-6.9	none	MR	8/-7	0.6	-1	1.1	1.8
				steady		none	MF	8/-7	0.6	-1.1	1.1	1.8
						none	L	7.8/-7	0.6	-1	1.1	1.8
2-replace	Same as Exist.	Same as Exist.	no change	1.1-year	7.3/-6.9	none	MR	8/-7	-0.1	-2.3	0.8	1.6
						none	MF	8/-7				
						none	L	7.8/-7				
5- 5 boxes	Same as Exist.	5- 15' boxes	no change	1.1-year	7.3/-6.9	none	MR	8/-7	6.9	-2.5	7	7
						none	MF	8/-7				
						none	L	7.8/-7				
6 - 60' span	Same as Exist.	1- 60' span	no change	1.1-year	7.3/-6.9	none	MR	8/-7	7.7	-1.1	7.7	7.8
						0.5 m	MF	9.64/-5.4				
						1m	L	11.28/-3.7				
Typical Tides, Flows Vary, Dyke BR and Stride BR Alternatives				**1.1-year**	**Recorded**							
6 - 60' span	**14.7'**	1- 60' span	no change	1.1-year	9/-7.5	1m	none	12.3/-4.2	11.3	-3.8	11.3	11.4
6 - 60' span	**14.7'**	1- 60' span	**slip lined**	1.1-year	9/-7.5	1m		12.3/-4.2	11.3	-3.8	11.3	11.4
6 - 60' span	**14.7'**	1- 60' span	no change	**50-year**	9/-7.5	none	none	9/-7.5				
				Hydrograph		0.5 m		10.7/-5.9				
						1m		12.3/-4.2	11.2	-3.8	11.3	12.2
6 - 60' span	**14.7'**	1- 60' span	no change	**100-year**	9/-7.5	none	none	9/-7.5				
				Hydrograph		0.5 m		10.7/-5.9				
						1m		12.3/-4.2	11.3	-3.8	11.3	12.6
6 - 60' span	**14.7'**	1- 60' span	**slip lined**	**50-year**	9/-7.5	none	none	9/-7.5	8.4	-6.1	8.4	9.8
				Hydrograph		0.5 m		10.7/-5.9	9.8	-5.6	9.9	11.2
						1m		12.3/-4.2	11.3	-3.7	11.4	12.7
6 - 60' span	**14.7'**	1- 60' span	**slip lined**	**100-year**	9/-7.5	none	none	9/-7.5	8.3	-6.1	8.4	10.3
				Hydrograph		0.5 m		10.7/-5.9	9.8	-5.6	9.9	11.7
						1m		12.3/-4.2	11.3	-3.8	11.4	13.2

Table 19: Summary of Model Evaluations, Results, and HEC-RAS Model Setup (Continued)

Bridge Geometry	Top of Roadway at Dyke Bridge (ft)	Dyke Bridge Geometry	Stride Bridge Geometry	Riverine Flow (cfs)	Tides (ft) (high/low)	SLR (m)	Surge (ft)	Tide+ Surge Downstream from Dyke Bridge (ft)	Elevations Upstream from Dyke Bridge (ft)		Peak Elevations at Stride Bridge (ft)	
									High	Low	DS	US
Storm Surge Tides, 1.1-year flows, plus SLR, Dyke/Stride options					**Spring**			**Surge=2.5'**				
6 - 60' span	**14.7'**	1- 60' span	no change	**1.1-year**	7.3/-6.9	none	2.5	9.8/-6.9	8.7	-6.1	8.8	8.8
						0.5 m		11.4/-5.3	10.1	-5.2	10.2	10.2
						1m		13.1/-3.6	11.5	-3.6	11.7	11.7
								Mid Tide Surge				
Case 6 - 60' span	**14.7'**	1- 60' span	no change	**1.1-year**	7.3/-6.9	none	2.5	8.0/-6.9				
						0.5 m		9.6/-5.3				
						1m		11.3/-3.6				
								High tide surge				
Case 6 - 60' span	**14.7'**	1- 60' span	**slip lined**	1.1-year	7.3/-6.9	none	2.5	9.8/-6.9	8.9	-6.2	8.8	8.8
						0.5 m		11.4/-5.3	10.1	-5.1	10.1	10.2
						1 m		13.1/-3.6	11.7	-3.6	11.7	11.7
								Mid Tide Surge				
Case 6 - 60' span	**14.7'**	1- 60' span	**slip lined**	1.1-year	7.3/-6.9	none	2.5	8.0/-6.9				
						0.5 m		9.6/-5.3				
						1 m		11.3/-3.6				
Calibration Model Runs				**20 cfs**	**Recorded**							
Case 1	11	Existing	TR=12		+9.0/-7.5	none	none	9.0/-7.5	-0.55	-2	-0.49	-0.41
		4-4X5' boxes	inv -2.8/-2.5									
		w/ gates, inv -3.1	12.5' cmp									
Case 1	11	Existing	TR=12		+9.0/-7.5	none	none	9.0/-7.5	3.3	3.3	3.3	0.7
		4-4X5' boxes	inv -2.8/-2.5									
		NO gates, inv -3.1	12.5' cmp									
Alt 2 Replacement in kind options												
Alt 2 4 flap gates, 1 open box		4 5X5 flap gates	TR=12	20	+9.0/-7.5	none	none	9.0/-7.5	9	0.7	0.8	0.8
	11	one open 5X5	inv -2.8/-2.5	152					9	1.8	2	2.3
		inv -4.05	12.5' cmp									
alt 2 3 flaps 1 open		3 5X5 flap gates	TR=12	20	+9.0/-7.5	none	none	9.0/-7.5	9	0.9	0.9	1
		one open 5X5	inv -2.8/-2.5	152					9	2.1	2.2	2.5
		inv -4.05	12.5' cmp									
alt 2 2 flaps 1 open		2 5X5 flap gates	TR=12	20	+9.0/-7.5	none	none	9.0/-7.5	9	2	2.3	2.3
		two open 5X5	inv -2.8/-2.5	152					9	3.1	3.2	3.4

7.0 TECHNOLOGY REVIEW: SELF-REGULATION TIDE GATES

Stantec performed a technology review of SRTs as part of this study. This review included obtaining and reviewing information on SRTs and evaluating the potential suitability of SRTs as elements of Alternative 3 and "fish-friendly" SRTs as elements of Alternative 4. The compiled SRT technology review is provided in Appendix B.

7.1 SELF-REGULATING TIDE GATES

Review of information and discussions with SRT manufacturers indicated that SRTs can be constructed in virtually any size based on site-specific needs. Scaling-up of SRT designs would necessitate appropriate care of structural elements and consideration of hydraulic performance. In addition, mechanical components of scale-up SRTs would need to be appropriately designed.

SRT costs vary between manufacturers and specific designs. A rule-of-thumb provided by a designer and manufacturer of tide gates who was contacted as part of this study is $450 per square-foot of gate area for manufacturing smaller SRTs. Application of this rule to a 4 ft by 4 ft SRT would result in a cost of $7,200. Similarly, application of this rule to a 10 ft by 10 ft SRT would result in a cost of $45,000, which appears to be low and reflect that the rule-of-thumb is not linearly scalable to larger gates. Note that these costs do not include installation of SRTs or modifications to associated culvert systems, which may include construction of additional structural elements and design features intended to prevent movement of the culvert elements when there is differential hydraulic head at closed tide gates.

Maintenance requirements for SRTs will vary based on selected designs and size; it is expected that larger SRTs will require increased maintenance. Expected primary maintenance requirements include 1) maintaining the SRT mechanical systems, and 2) debris management. Potential failure of mechanical systems can result from wear resulting from regular operation of tide gates and damage from debris, such as flotsam (e.g., logs) and ice during winter months. Based on discussions with a manufacturer of tide gates, operation of tide gates at flow speeds of greater than 5 to 6 feet-per-second (fps) during closure of the tide gates can result in damage to the tide gate systems. Based on modeled conditions for this study, it is expected that flow speeds in excess of 6 fps could be encountered during gate closure if operation of tide gates requires gate closure when the hydraulic head between the seaward and landward sides of the tide gate is greater than approximately 0.6 ft.

Evaluation of hydraulic model simulation data for Alternative 5 indicates that the hydraulic head through culverts as part of that alternative would exceed 1 ft within 1 hour after the start of the flood tide and would exceed 2 ft later during each flood tide. These conditions would result in flow speeds in the range of 8 fps and 10 fps, respectively, through a tide gate installed on the seaward face of a culvert system. Note that additional hydraulic losses through the tide gates in addition to those that were calculated for the culverts would result in increased hydraulic head and flow speeds.

Consequences of failure of SRTs are relevant to this project. Because the Dyke Bridge and associated causeway are located on a waterway with a relatively large tributary watershed and the existing tidal regime landward from the bridge is suppressed, there are potential impacts that could result from failure of SRT gate systems in the "open" or "closed" positions. Failure of tides gates in the "open" position could result in increased tidal inundation landward from Dyke Bridge (this scenario is similar to what would result if the existing flap gates failed or were removed). Failure of tide gates in the "closed" position could result in accumulation of freshwater landward from the bridge. Given the relatively large volume of available hydrologic storage between Dyke Bridge and Stride Bridge, it is expected that failure of tide gates in the "open" position and resulting tidal inundation would result in increased impacts relative to failure of tide gates in "closed" positions.

Factors related to public safety include entrainment in the tide gates (including SRTs) and/or culverts. Culverts with widths that are less than small recreational watercraft pose impingement hazards, as small boats could become impinged across the culvert inlets; installation and operation of tide gates would increase the impingement hazard by reducing opening widths. The associated hazard increases at higher flow speeds through the tide gate or culvert. An additional factor related to public safety is that larger culvert and gate systems will have capacity for increased flow and a larger area of influence that could result in entrainment of boats and swimmers. While a bridge opening could have greater capacity, the reduced potential for impingement associated with a bridge would result in a decrease in potential hazards. These concerns are relevant to this project given the proximity of the state-owned boat launch that is located immediately seaward from the existing Dyke Bridge culverts.

The potential for sea level rise should be evaluated in the context of SLRs and resiliency of the Dyke Bridge causeway to limit landward inundation. This concern is particularly relevant to overtopping of the causeway during storm events, which could result in inundation of areas that are currently "protected" by the causeway. Even short-term inundation of the landward area with salt water could have pronounced effects on existing flora and fauna, such as die-off of salt-intolerant vegetation.

7.2 "FISH-FRIENDLY" SRTS

Some manufacturers of SRTs describe "fish-friendly" SRTs; information obtained as part of the SRT technology review indicates that some SRTs may be better suited than others for fish passage, and that these may be termed "fish-friendlier" but not necessarily fish-friendly.

Site-specific constraints appear to substantially limit the use of fish-friendlier SRTs at Dyke Bridge; these constraints largely follow on the factors that are identified for typical SRTs, and include functional limitations on the operational capabilities of SRTs related to hydraulic head and flow speeds.

The primary identified constraints to installation of fish-friendly SRTs at Dyke Bridge are associated with:

1) Operation of tide gates in a high-velocity environment; and

2) Relatively high-speed flow through the culvert and tide gate system during the ebb tide.

As discussed in the preceding section, operation of SRTs in high-velocity environments can result in damage to the tide gates. The applicability of fish-friendly SRTs at Dyke Bridge to provide for improved upstream fish passage is therefore substantially constrained by the large difference in water surface elevations seaward and landward from Dyke Bridge during the flood tide.

Based on the evaluation of culverts for Alternative 5, flow speeds through the evaluated culverts during the ebb tide would largely preclude upstream movement of slower-swimming fish, such as rainbow smelt (*Osmerus mordax*). In addition, the culvert inverts would need to be set at an elevation of approximately -8 ft (4 ft lower than the existing culverts) to have the culvert and tide gate invert below low tide elevations seaward from Dyke Bridge as a baseline requirement for upstream passage low tide. An expected consequence of lower culvert inverts is lowering of the low tide pool landward of Dyke Bridge by approximately 7 ft relative to existing conditions.

8.0 FISH PASSAGE

This study includes preliminary evaluation of fish passage at Dyke Bridge and Stride Bridge, including evaluation of “fish friendly” self-regulating tide gates (Alternative 4) at Dyke Bridge. This section presents information on and an evaluation of fish passage through SRTs and general and site-specific constraints to use of SRTs technologies at Dyke Bridge.

Identified effects on fish passage are addressed separately for Dyke Bridge and Stride Bridge. While there is interaction between the two sites, including effects of tidal stage associated with the evaluated alternatives at Dyke Bridge, the number of alternatives and scenarios evaluated as part of this study did not include direct evaluation of all of the potential combinations of alternatives at Dyke Bridge and Stride Bridge that may affect upstream fish passage at both sites.

Discussion of fish passage is focused on Dyke Bridge, where existing conditions for upstream fish passage are currently marginal, and is followed by a discussion of fish passage at Stride Bridge.

8.1 DYKE BRIDGE

8.1.1 Alternative 1: No Action

The existing flap gates at Dyke Bridge are deteriorated, and leakage through the flap gates and embankment results in some landward tidal flow. Landward flow through gaps in the flap gaps and/or unseated closure is possible but is expected to be limited except for very small-bodied fish that will pass through gaps. Analysis of the tidal stage data provided by MaineDOT for the period from July 11 through October 24, 2011 indicates that the temporal during of landward and seaward flow is evenly split (i.e., 50% landward and 50% seaward) during normal tides. The HEC-RAS model analysis of existing conditions for the period from July 12, 2011 through August 12, 2011, yielded the same percentages of landward and seaward flow.

As previously noted, landward flow at Dyke Bridge during flood tide results from leakage of the flap gates and leakage through the adjacent embankment, and therefore provides for very limited upstream fish passage. Based on observed conditions at Dyke Bridge, upstream fish passage during periods of seaward flow is expected to be limited to short duration periods when the tidal stage landward from Dyke Bridge is marginally higher than the seaward stage and the seaward stage is higher than the culvert barrel outlet inverts. When the seaward stage is below the culvert barrel outlet inverts, it is expected that flow over the riprap apron seaward from the Dyke Bridge culverts prevents upstream passage for fish due to high-speed flow and a leaping barrier associated with flow over the riprap apron.

8.1.2 Stride Bridge

The existing Stride Bridge culvert is persistently backwatered and the invert (elevation -2.5 ft) is below the lowest recorded water surface elevation upstream from Dyke Bridge, and is therefore expected to provide for good upstream fish passage during lower flow conditions. During high-flow conditions, this culvert may be a short-term barrier to upstream fish passage depending on backwater conditions (e.g., water surface elevations in the downstream reach of the river) and total flow.

8.2 ALTERNATIVE 2: REPLACEMENT IN-KIND WITHOUT RESTORATION OF TIDAL FLOW

8.2.1 Dyke Bridge

In-kind replacement of the culverts and flap gates at Dyke Bridge is expected to eliminate landward flow through the culverts and therefore eliminate landward movement of fish during the flood tide or the ebb tide when water surface elevations landward from Dyke Bridge are lower than the seaward water surface elevations. It is not expected that there would be more than incidental landward passage of fish through the flap gates when flow is seaward due to high-speed flow through the gates and flow over riprap apron seaward from the culvert.

8.2.2 Stride Bridge

This alternative could reduce daily variations in flow landward from Dyke Bridge and would therefore result in lower water surface elevations at Stride Bridge. These potential changes could result in increased downstream flow speeds at Stride Bridge. Lower tailwater elevations and increased flow speeds at Stride Bridge would decrease the potential for upstream fish passage relative to existing conditions. Note that reductions in tailwater surface elevations at Stride Bridge would be persistent at low flows for this alternative because of the loss of tidal affects.

8.3 ALTERNATIVE 2: REPLACEMENT IN-KIND WITH VARIATIONS FOR FLAP GATE OPERATIONS

This modified concept for Alternative 2 includes evaluation of box culverts at Dyke Bridge with flap gates on a subset of the culverts and at least one free-flowing culvert. The objective of having a persistently-open culvert(s) is to provide for unhindered landward flow when the flood tide is higher than the elevation of the culvert invert and the water surface elevation landward from Dyke Bridge.

8.3.1 Dyke Bridge

Three variations on Alternative 2 were evaluated:

a. Five 5 ft x 5 ft culverts with flap gates on four of the culverts (Plan No. 82). Results of this simulation that include the observed upstream tide data are presented in Figure 14;

b. Four 5 ft x 5 ft culverts with flap gates on three of the culverts (Plan No. 83). Results of this simulation that include the observed upstream tide data are presented in Figure 15; and

c. Four 5 ft x 5 ft culverts with flap gates on two of the culverts (Plan No. 27). Results of this simulation that include the observed upstream tide data are presented in Figure 16.

Table 20 presents information on the three evaluated variations of Alternative 2 and, for comparison, simulation results for existing conditions.

Table 20: Evaluation of Landward and Seaward Flow

Simulation	Typical High Tide (ft NAVD88)	Seaward Flow (%)	Landward Flow (%)
Existing Conditions	-1 ft	50%	50%
Five Culverts with one free-flowing (Plan No. 82)	0.5 ft	53%	47%
Four culverts with one free-flowing (Plan No. 83)	1 ft	55%	45%
Four culverts with two free-flowing (Plan No. 27)	2 ft	55%	45%

The three evaluated Alternative 2 variations result in higher water surface elevations landward from Dyke Bridge relative to existing conditions and small (3% to 5%) decreases in the duration of landward flow relative to existing conditions. While the duration of landward flow is decreased relative to existing conditions, the Alternative 2 variations provide for landward flow through an open box culvert. Note that existing landward flow results from the deteriorated condition of the existing culverts and flap gates, and that reconstruction of the culverts would result in no landward flow. The Alternative 2 variations are therefore expected to provide for substantial improvements to upstream fish passage at Dyke Bridge relative to existing conditions and in-kind replacement of the existing culvert system.

8.3.2 Stride Bridge

The Alternative 2 variations would result in higher typical tidal elevations landward from Dyke Bridge and could result in increased depths of water at Stride Bridge, which would result in lower flow speeds through the Stride Bridge stream crossing.

8.4 ALTERNATIVE 3: REPLACEMENT WITH PARTIAL RESTORATION OF TIDAL FLOW

8.4.1 Dyke Bridge

Installation of tide gates at Dyke Bridge that would allow for higher normal tides elevations landward from the bridge would result in increased landward flow during the flood tide through the bridge and could result in some improvement to upstream fish passage. The potential to improve upstream fish passage with tide gates would be heavily influence by the type of tide gate and operational regime.

8.4.2 Stride Bridge

Potential impacts to upstream fish passage at Stride Bridge could result from partial restoration of tidal flow at Dyke Bridge. Higher tidally-affected water surface elevations at Stride Bridge would result in lower flow speeds through the existing culvert and could result in flow reversal (i.e., landward flow), which would tend to improve upstream fish passage. If a tide gate was operated to provide lower water surface elevations landward from Dyke Bridge, this condition would result in higher flow speeds and reduced potential for upstream fish passage at Stride Bridge.

Note that the geometry of the HEC-RAS model was developed without detailed bathymetric information along some of the reach of the Middle River downstream from Stride Bridge, and it is therefore uncertain whether there are natural hydraulic controls (e.g., riffles) that would limit reductions in water surface elevations at Stride Bridge if a replacement culvert at Dyke Bridge resulted in lower low tide elevations landward from Dyke Bridge.

8.5 ALTERNATIVE 4: REPLACEMENT WITH PARTIAL RESTORATION OF TIDAL FLOW AND PROVISIONS FOR FISH PASSAGE

8.5.1 Dyke Bridge

Installation of tide gates with dedicated provisions for upstream fish passage at Dyke Bridge would allow for management of typical tidal water surface elevations landward from the bridge. Depending on the operational regime of tide gates and landward flow during flood tide, this alternative could improve upstream fish passage relative to existing conditions.

8.5.2 Stride Bridge

Potential impacts to upstream fish passage at Stride Bridge could result from partial restoration of tidal flow at Dyke Bridge and would largely depend on the tidal regime landward from Dyke Bridge. Higher tidally-affected water surface elevations at Stride Bridge would result in lower flow speeds through the existing culvert and could result in flow reversal (i.e., landward flow), which would tend to improve upstream fish passage. Lower water surface elevations could also result, which would result in high flow speeds through the culvert and reduced potential for upstream fish passage.

Note that the geometry of the HEC-RAS model was developed without detailed bathymetric information along some of the reach of the Middle River downstream from Stride Bridge. It is therefore uncertain whether there are natural hydraulic controls (e.g., riffles) downstream from Stride Bridge that would limit reductions in water surface elevations downstream from Stride Bridge if a replacement culvert at Dyke Bridge resulted in lower landward low tide elevations.

8.6 ALTERNATIVES 5, 6, AND 7: FULL TIDAL RESTORATION

Full restoration of tidal flow as part of Alternatives 5, 6, and 7 would result in improved upstream fish passage at Dyke Bridge. Achieving upstream fish passage for slower-swimming fish would, however, require construction of a new, lower channel through the footprint of the existing Dyke Bridge causeway and upstream along the Middle River. The need for a new channel is based on bathymetric data collected by MaineDOT landward from Dyke Bridge, which indicates that the bottom of the existing channel higher than low tide elevations downstream (seaward) from Dyke Bridge.

8.6.1 Dyke Bridge

Full tidal restoration at Dyke Bridge would improve upstream fish passage, but the extent of improvements would be substantially affected by the bottom elevation of the channel through the bridge opening and into the upstream reach of the Middle River. Based on the hydraulic model results and observed conditions, it is expected that full tidal restoration could result in high flow speeds through a full-restoration alternative unless a lower channel is constructed (e.g., dredge) within the footprint of the existing Dyke Bridge causeway and further upstream in the Middle River.

8.6.2 Stride Bridge

Potential impacts to upstream fish passage at Stride Bridge would result from full tidal restoration of tidal flow at Dyke Bridge. Higher tidally-affected water surface elevations at Stride Bridge would result in lower flow speeds through the existing culvert and, at higher tides, flow reversal (i.e., landward flow) at Stride Bridge. Higher water surface elevation and/or flow reversal would improve upstream fish passage, but lower water surface elevations, which could also result from a larger tidal range, would result in high flow speeds through the culvert.

Note that the geometry of the HEC-RAS model was developed without detailed bathymetric information along some of the reach of the Middle River downstream from Stride Bridge, and it is therefore uncertain whether there are natural hydraulic controls (e.g., riffles) that would limit reductions in water surface elevations at Stride Bridge if a replacement structure at Dyke Bridge resulted in lower low tide elevations landward from the Dyke Bridge causeway.

9.0 STRIDE BRIDGE REPLACEMENT OPPORTUNITIES

A preliminary evaluation for replacement of Stride Bridge was developed as part of this study. This evaluation was developed based on a minimum span of 37 ft as defined by 1.2-times the bankfull width of the Middle River at Stride Bridge of 31 ft as identified by MaineDOT.

The preliminary evaluation included review of geologic map data obtained from the Maine Geological Survey to assess potential subsurface conditions (e.g., potential presence of shallow bedrock) and hydrologic information that was used as part of this study.

Three potential, single-span options were evaluated:

1) A single, 1.2-times bankfull-width span with vertical abutments and a shallow foundation;

2) A single, 1.2-times bankfull-width span with sloped abutments and a deep foundation; and

3) A single, 1.0-time bankfull-width span with sloped abutments and a deep foundation.

A summary memo that presents information on potential replacement bridge geometries at Stride Bridge is included in Appendix E.

10.0 REFERENCES

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NOAA, Tides and Water Levels. Cutler, http://tidesandcurrents.noaa.gov/waterlevels.html?id=8411060

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APPENDICES

Appendix C : SRT TECHNOLOGY REVIEW

Project Name:	Machias Causeway	**PIN:**	16714
Stream Name:	Middle River	**Town:**	Marshfield
Bridge Name:	Stride Bridge	**Bridge No.**	3973
Route No.	US 1	**USGS Quad:**	
Analysis by:	CSH	**Date:**	5/13/2014

Peak Flow Calculations by USGS Regression Equations (Hodgkins, 1999)

Enter data in blue cells only!

	km^2	**mi^2**	**ac**	***Enter data in [mi^2]***
A	24.38	9.41	6024.4	Watershed Area
W	3.05	1.18	753.7	Wetlands area (by NWI)

P_c	618573	4957554	watershed centroid (E, N; UTM 19N; meters)
County	Washington		*choose county from drop-down menu*
pptA	44.2		mean annual precipitation (inches; by look-up)
SG	0.00		sand & gravel aquifer as decimal fraction of watershed A

A (km^2)	24.38	**Conf Lvl**	0.67
W (%)	12.51		

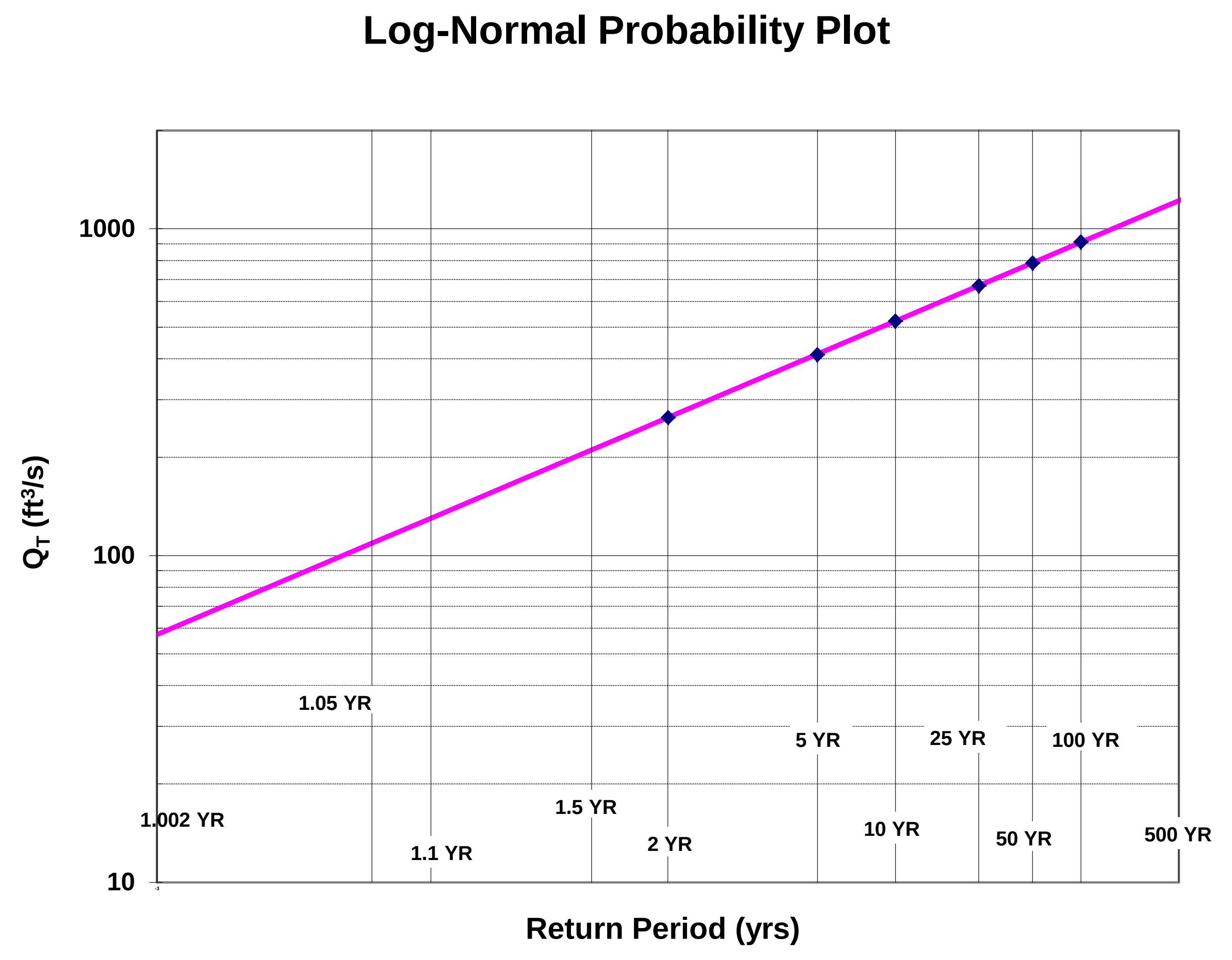
Worksheet prepared by:
Charles S. Hebson, PE
Environmental Office
Maine Dept. Transportation
Augusta, ME 04333-0016
207-557-1052
Charles.Hebson@maine.gov

Ret Pd	**Peak Flow Estimate**			
T (yr)	**Lower**	**Q_T (m^3/s)**	**Upper**	**Q_T (ft^3/s)**
1.1		3.69		130.2
2	5.36	7.50	10.49	264.7
5	8.32	11.68	16.41	412.5
10	10.42	14.78	20.99	522.0
25	13.18	18.98	27.33	670.2
50	15.28	22.27	32.46	786.5
100	17.50	25.82	38.11	911.8
500	22.68	34.57	52.70	1220.6

Reference:

Hodgkins, G., 1999.
Estimating the magnitude of peak flows for streams
in Maine for selected recurrence intervals
Water-Resources Investigations Report 99-4008
US Geological Survey, Augusta, Maine

$Q_T = b \times A^a \times 10^{-wW}$


Log-Normal Probability Plot
1000
100
10
Q_T (ft³/s)
1.002 YR
1.05 YR
1.1 YR
1.5 YR
2 YR
5 YR
10 YR
25 YR
50 YR
100 YR
500 YR
Return Period (yrs)

Project Name:	Machias Causeway	**PIN:**	16714
Stream Name:	Middle River	**Town:**	Marshfield
Bridge Name:	Stride Bridge	**Bridge No.**	3973
Route No.	US 1	**USGS Quad:**	
Analysis by:	CSH	**Date:**	5/13/2014

DO NOT ENTER ANY DATA ON THIS PAGE; EVERYTHING IS CALCULATED

MAINE MONTHLY MEDIAN FLOWS BY USGS REGRESSION EQUATIONS (2004)

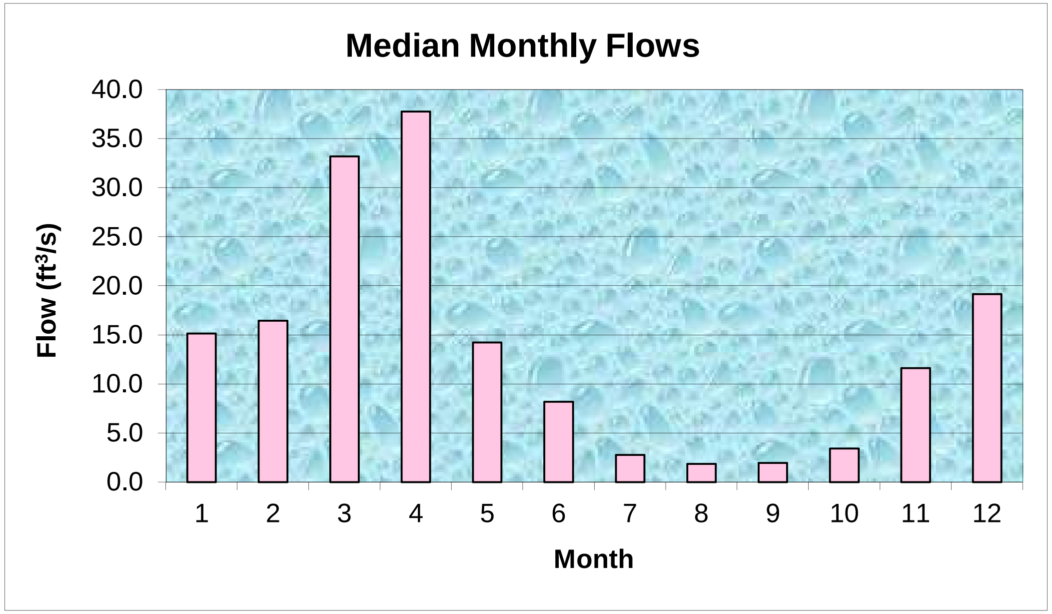
Worksheet prepared by:
Charles S. Hebson, PE
Chief Hydrologist
Maine Dept. Transportation
Augusta, ME 04333-0016
207-624-3073
Charles.Hebson@maine.gov

	Value	**Variable**	**Explanation**
	9.413	*A*	Area (mi^2)
618573	4957554	*P$_c$*	Watershed centroid (E,N; UTM; Zone 19; meters)
	31.80	*DIST*	Distance from Coastal reference line (mi)
	44.2	*pptA*	Mean Annual Precipitation (inches)
	0.00	*SG*	Sand & Gravel Aquifer (decimal fraction of watershed area)

Month	**Q$_{median}$** (ft3/s)	(m^3/s)
Jan	**15.14**	0.4290
Feb	**16.44**	0.4658
Mar	**33.19**	0.9406
Apr	**37.77**	1.0702
May	**14.22**	0.4029
Jun	**8.19**	0.2322
Jul	**2.76**	0.0782
Aug	**1.87**	0.0531
Sep	**1.96**	0.0555
Oct	**3.41**	0.0967
Nov	**11.61**	0.3289
Dec	**19.15**	0.5426

Q_{bf}	**54.6**
ann avg	**19.1**
ann med	**9.7**
$Q_{1.002}$	**57.3**
$Q_{1.01}$	76.7
$Q_{1.05}$	109.1

W_{bf}	24.5	estimated bankfull width
d_{bf}	1.9	
Q_{bf}	186.4	assume v = 4ft/s




MARSHFIELD

Project Name: Machias Causeway
Stream Name: Middle River
Bridge Name: Dyke Bridge
Route No. US 1
Analysis by: CSH

PIN: 16714
Town: Machias
Bridge No. 2246
USGS Quad:
Date: 11/29/2011

Peak Flow Calculations by USGS Regression Equations (Hodgkins, 1999)

Enter data in blue cells only!

	km^2	mi^2	ac	*Enter data in [mi^2]*
A	34.24	13.22	8459.9	Watershed Area
W	5.25	2.03	1297.3	Wetlands area (by NWI)
P_c	620020	4956225		watershed centroid (E, N; UTM 19N; meters)
County	Washington			*choose county from drop-down menu*
pptA	44.2			mean annual precipitation (inches; by look-up)
SG	0.00			sand & gravel aquifer as decimal fraction of watershed A

A (km^2)	34.24	**Conf Lvl**	0.67
W (%)	15.33		

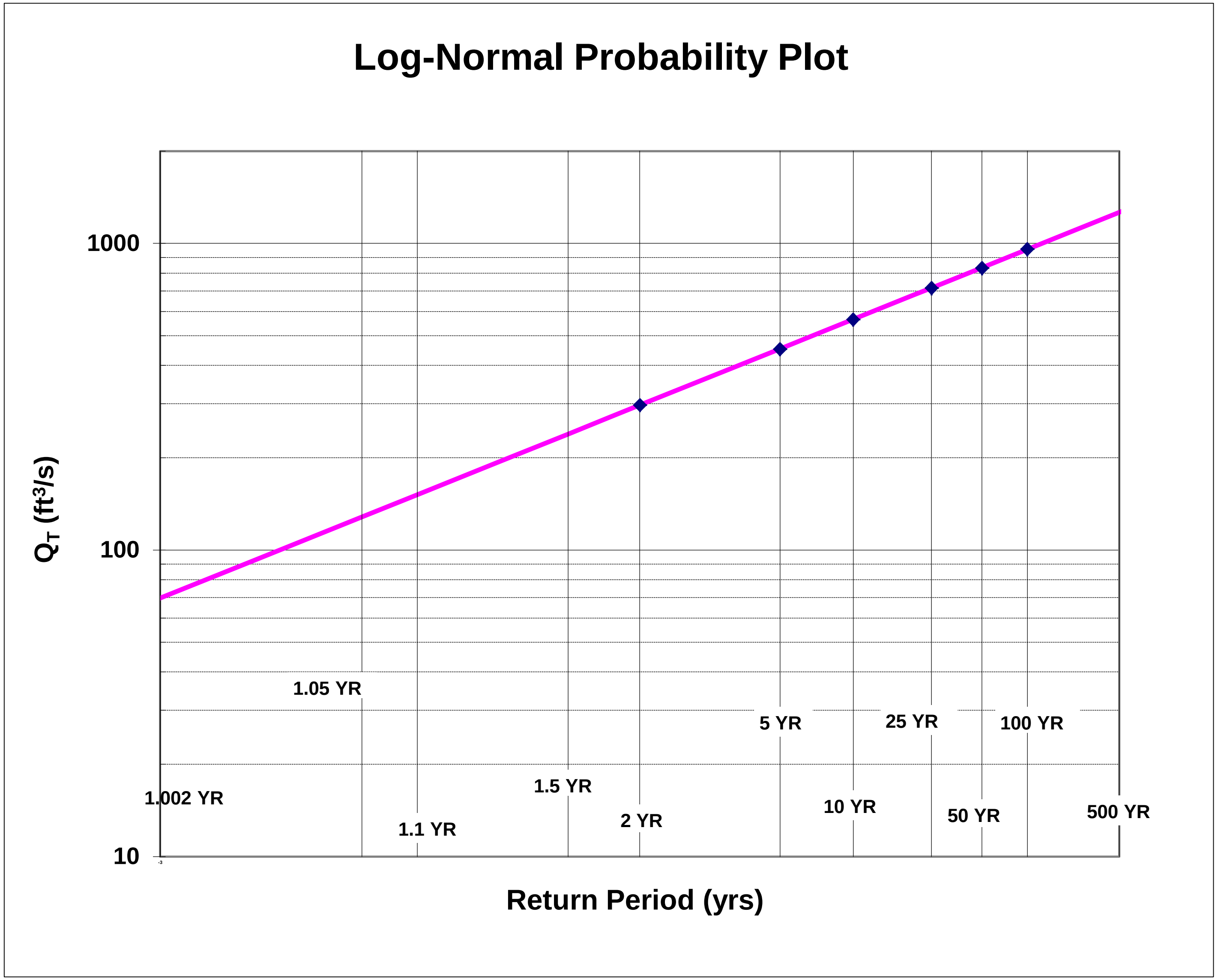
Worksheet prepared by:
Charles S. Hebson, PE
Environmental Office
Maine Dept. Transportation
Augusta, ME 04333-0016
207-557-1052
Charles.Hebson@maine.gov

Ret Pd	**Peak Flow Estimate**			
T (yr)	**Lower**	**Q_T (m^3/s)**	**Upper**	**Q_T (ft^3/s)**
1.1		4.29		151.6
2	6.01	8.41	11.76	296.9
5	9.12	12.80	17.95	451.9
10	11.28	15.99	22.68	564.7
25	14.09	20.26	29.14	715.4
50	16.20	23.57	34.31	832.4
100	18.42	27.14	39.98	958.3
500	23.53	35.79	54.45	1263.9

Reference:

Hodgkins, G., 1999.
Estimating the magnitude of peak flows for streams
in Maine for selected recurrence intervals
Water-Resources Investigations Report 99-4008
US Geological Survey, Augusta, Maine

$Q_T = b \times A^a \times 10^{-wW}$


Log-Normal Probability Plot
Q_T (ft³/s)
1000
100
10
Return Period (yrs)
1.002 YR
1.05 YR
1.1 YR
1.5 YR
2 YR
5 YR
10 YR
25 YR
50 YR
100 YR
500 YR

Project Name: Machias Causeway
Stream Name: Middle River
Bridge Name: Dyke Bridge
Route No. US 1
Analysis by: CSH

PIN: 16714
Town: Machias
Bridge No. 2246
USGS Quad:
Date: 11/29/2011

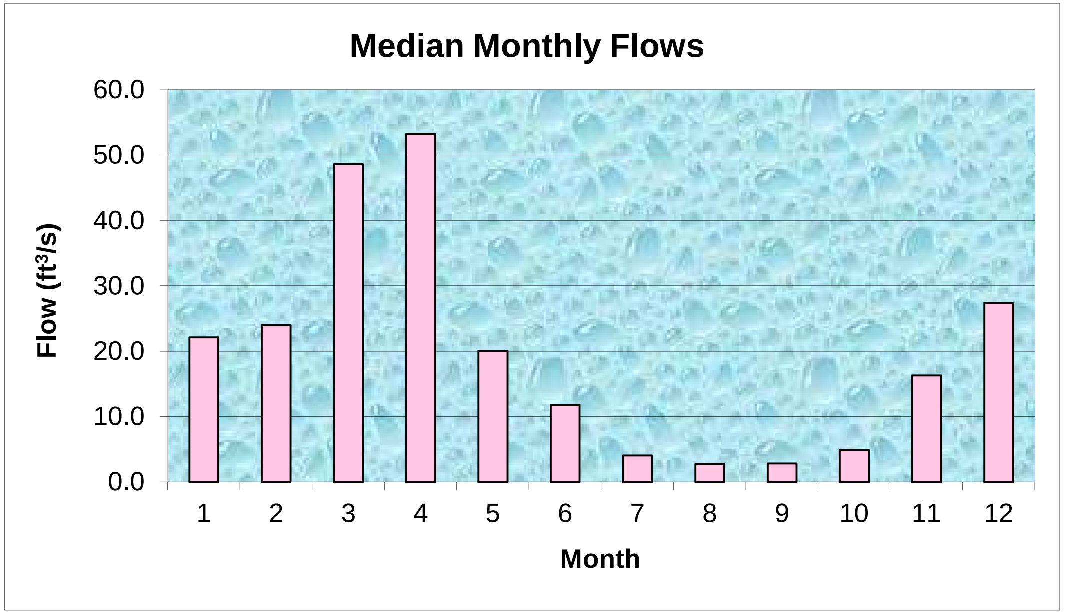
DO NOT ENTER ANY DATA ON THIS PAGE; EVERYTHING IS CALCULATED

MAINE MONTHLY MEDIAN FLOWS BY USGS REGRESSION EQUATIONS (2004)

	Value	**Variable**	**Explanation**
	13.219	*A*	Area (mi^2)
620020	4956225	P_c	Watershed centroid (E,N; UTM; Zone 19; meters)
	30.65	*DIST*	Distance from Coastal reference line (mi)
	44.2	*pptA*	Mean Annual Precipitation (inches)
	0.00	*SG*	Sand & Gravel Aquifer (decimal fraction of watershed area)

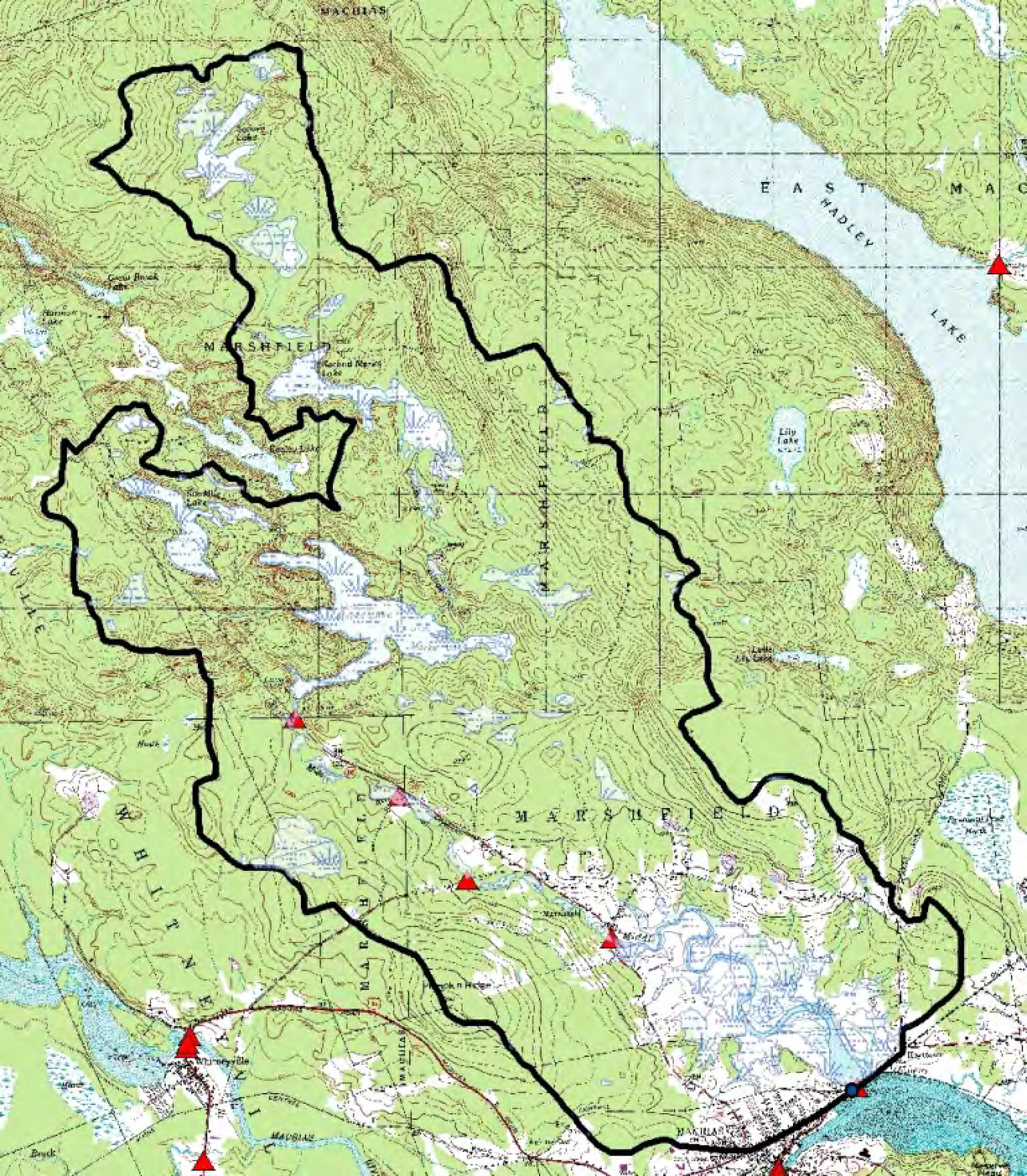
Worksheet prepared by:
Charles S. Hebson, PE
Chief Hydrologist
Maine Dept. Transportation
Augusta, ME 04333-0016
207-624-3073
Charles.Hebson@maine.gov

Month	**Q_{median}** (ft3/s)	(m^3/s)
Jan	**22.14**	0.6273
Feb	**23.99**	0.6800
Mar	**48.61**	1.3775
Apr	**53.21**	1.5080
May	**20.10**	0.5696
Jun	**11.81**	0.3346
Jul	**4.08**	0.1156
Aug	**2.74**	0.0776
Sep	**2.84**	0.0805
Oct	**4.91**	0.1392
Nov	**16.32**	0.4625
Dec	**27.41**	0.7766



Q_{bf}	**78.1**
ann avg	**26.7**
ann med	**13.7**
$Q_{1.002}$	**69.7**
$Q_{1.01}$	91.8
$Q_{1.05}$	128.1

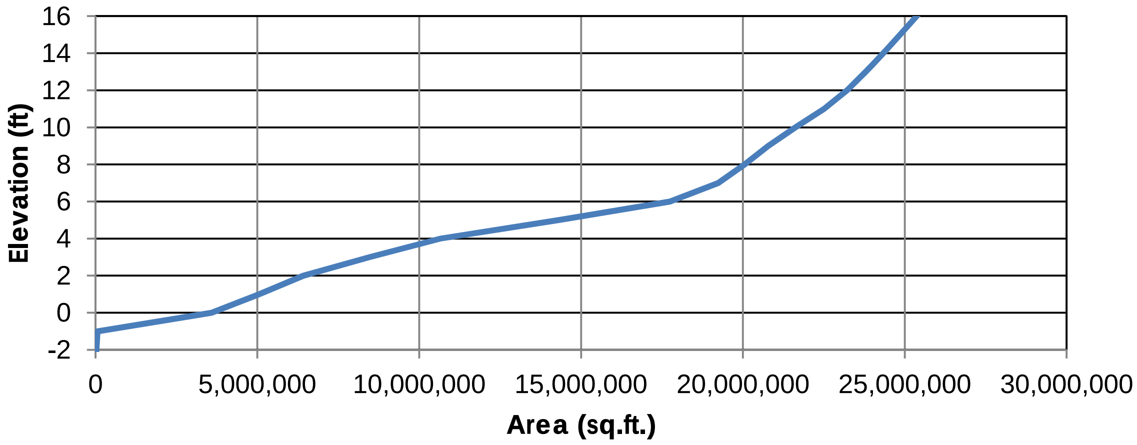
W_{bf}	29.2	estimated bankfull width
d_{bf}	2.3	
Q_{bf}	265.4	assume v = 4ft/s


MACHIAS
EAST MAC
HADLEY
LAKE
Lily Lake
MARSHFIELD
MARSHFIELD
MARSHFIELD
MARSHFIELD
Little Lily Lake
WHITNEYVILLE
Whitneyville
MACHIAS

Appendix A :UPLAND HYDROLOGY

Appendix B: ELEVATION-AREA INFORMATION, MIDDLE RIVER LANDWARD FROM DYKE BRIDGE

Plot of Elevation-Area Data

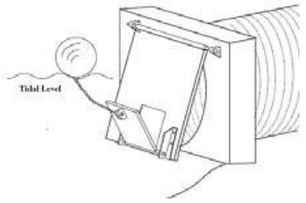
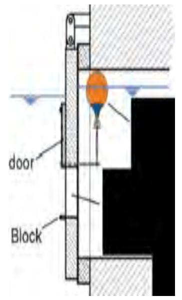
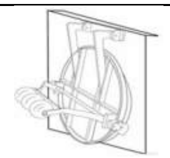


Tabular Elevation-Area Data

Elevation (ft NAVD88)	Area (sq. ft)	Area (acres)
-1	62,361	1.43
0	3,584,172	82.3
1	5,052,564	116
2	6,426,034	148
3	8,469,801	194
4	10,661,151	245
5	14,323,379	329
6	17,742,072	407
7	19,237,352	442
8	20,052,345	460
9	20,780,224	477
10	21,623,345	496
11	22,513,513	517
12	23,220,294	533
13	23,796,594	546
14	24,328,877	559
15	24,853,485	571
16	25,366,834	582

TYPE	MANUFACTURER	OPERATIONS	PASSIVE / ACTIVE	ALLOWS TIDAL FLUSHING?	ALLOWS US FISH PASSAGE?	GATE MATERIALS	PROS	CONS	NOTES	**IMAGES** (from manufacturers' websites)
TRADITIONAL TIDE GATES (most restrictive)										
Top-Hinged Tide Gate (THTG): cast iron and wood	Armtec (Hydro Gate), Golden Harvest, Waterman, Rodney Hunt	Round or square lid hinged at upper edge of pipe. Attached by single- or double-hinge system. Hydraulic head differential causes gate to open/close.	Passive (change in hydraulic head differential)	No (unless leaking or propped open)	Under limited range of flow conditions during ebb tide	Cast iron, wood (materials with higher restorative force)	Relatively simple, durable and reliable. Long lifespan. Efficient in preventing backflushing if sized, installed and maintained properly.	Landward impacts associated with impacts on tidal flushing, WSELs, AOP, water quality. Can trap floating debris (requiring maintenance). Conveyance reduced as weight to size ratio increases. Limited conveyance capacity and increased velocities at lower flows associated with reduced opening. THTGs expected to remain closed at least 50% of time. Heavier gates have higher restorative force resulting in 1) large hydraulic head differential required to open gate (resulting in opening only during brief period of ebb tide) and 2) increased velocity and turbulence through opening.	Traditionally, round THTGs are cast iron and rectangular THTGs are wood. Variable criteria in top-hinge flap gates include: opening size (e.g., radius), opening shape (e.g., round, rectangular), pivot radius (measured from top hinge), and duty (e.g., light/medium/heavy-duty).	
FISH-FRIENDLIER TIDE GATES (less restrictive)										
THTG: lighter materials	Golden Harvest, Nehalem Marine Manufacturing, Waterman, Rodney Hunt	Same as above.	Same as above	No (unless leaking or propped open)	Same as above	Aluminum, plastic, FRP, fiberglass (materials with lower restorative force)	Lighter materials may require significantly less hydraulic head differential to open in relation to THTGs made from traditional materials (e.g., cast iron, wood). Open for greater amount of time and with wider opening than heavier THTGs. Plastic and fiberglass gate may be less expensive than metal gates.	Lighter materials may not be as strong or durable, may include increased maintenance and repairs, are more easily damaged, and may have decreased lifespan. Landward impacts related to tidal flushing remain similar to THTGs constructed of heavier materials.		
THTG: radial	Unable to find current manufacturer.	Same as above.	Same as above	No (unless leaking or propped open)	Same as above	Spun aluminum	Lightweight and relatively inexpensive. Low restorative force.	Thin material can be vulnerable to damage from debris. Concave shape of gate may constrain passage of larger fish. Landward impacts related to tidal flushing remain similar to THTGs constructed of heavier materials.	Unable to find a current manufacturer of this style.	
THTG: flexible	Armtec (Hydro Gate), Plasti-Fab Inc.	Same as above.	Same as above	No (unless leaking or propped open)	Same as above	1"-thick neoprene cover mounted to steel frame	Quiet operations, low maintenance, low head loss, debris easily removed/flushed, no hinge pin wear points, no painting or lubrication required.	Flexible materials may be less durable. Landward impacts related to tidal flushing remain similar to THTGs constructed of heavier materials.	60" max width (per Hydro Gate).	
Duckbill	RedValve (Tideflex)	Opening is vertical slot (check valve) in stiff, yet deformable material mounted at DS end of pipe; default position of check valve is closed; deforms to open when hydraulic head differential is high enough.	Passive (change in hydraulic head differential)	No (unless leaking or propped open)	Thought to prevent US migration of some adult fish.	Flexible synthetic material	Simple, can be durable and reliable. Requires low hydraulic head differential to open valve. Can be self-cleaning (of debris). Flexible material may allow for formation of seal even around debris, allowing only minor leakage even when clogged with debris. Relative to DS flow, studies suggest performs equal to or better than THTGs.	Landward impacts associated with impacts on tidal flushing, WSELs, AOP, water quality. Small opening does not pass large debris; difficult to keep free from debris and debris removal can be difficult to remove. Potential for excessive head loss. Thought to allow downstream migration of juveniles but to prevent US migration of some adult fish.		

TYPE	MANUFACTURER	OPERATIONS	PASSIVE / ACTIVE	ALLOWS TIDAL FLUSHING?	ALLOWS US FISH PASSAGE?	GATE MATERIALS	PROS	CONS	NOTES	**IMAGES** (from manufacturers' websites)
FISH-FRIENDLIER TIDE GATES (less restrictive - *continued*)										
Motorized Slide Gate	Armtec (Hydro Gate), Waterman	Motorized vertical lift slide gate. Water levels monitored by sensors. Gate raises/lowers according to programmed parameters (e.g., water level elevations).	Active (Motorized vertical lift	Yes (depending on management)	Dependent on operations parameters	Metal	Allows for tidal flushing within desired parameters; allows for modification of parameters.	Requires electrical services at tide gate. Maintenance of motor, electrical supply and programming. Relatively complicated and expensive. Power outage can result in loss of control of gate.		
Manually Actuated Gate	Armtec (Hydro Gate), Plasti-Fab Inc., Rodney Hunt	Manually opened & closed. Approach can be applied to entire gate or to "trap door" within gate (see below).	Active (gate manually operated)	Yes (depending on management)	Dependent on operations parameters		Low cost	Requires manual operation / implementation of operational protocol.		
Side-Hinged Tide Gate (SHTG)	Armtec (Hydro Gate), Golden Harvest, Plasti-Fab Inc.	Top hinge installed closer to culvert opening than bottom hinge to create downward tilt which provides restorative force to enable gate to close at end of ebb tide.	Passive (change in hydraulic head differential)	No (unless leaking or propped open)	Under limited range of flow conditions during ebb tide	Wood, aluminum, stainless steel	Simple, can be durable and reliable, wide opening under lower flows (relative to THTGs), less likely to trap debris (compared to THTGs, duckbill style), reduced impingement hazard. Very small restorative force. Opens with smaller hydraulic head differential and stays open longer and wider than THTGs. Water velocities and turbulence through SHTGs are typically lower than through THTGs of similar size and weight. Increased opening duration and size (during ebb tide) reduces certain impacts associated with AOP, water quality and connectivity impacts relative to THTGs. Nehalem states SHTG capable of providing up to 30-40% more conveyance than THTG.	Landward impacts associated with impacts on tidal flushing, WSELs, AOP, water quality. Potential for increased wear on hinge mechanisms relative to THTGs. Support structure for gate is more difficult and costly to install. Angle of tilt must be set precisely and in such a way that it will not change over time.		 

TYPE	MANUFACTURER	OPERATIONS	PASSIVE / ACTIVE	ALLOWS TIDAL FLUSHING?	ALLOWS US FISH PASSAGE?	GATE MATERIALS	PROS	CONS	NOTES	**IMAGES** (from manufacturers' websites)
FISH FRIENDLIER GATE MODIFICATIONS (less restrictive)										
Pet Door / Trap Door (top-hinge, bottom-hinge, and side-hinge)	Nehalem Marine Manufacturing, Golden Harvest	Smaller gate placed within field of the tide gate. Smaller gate constructed to open with very low hydraulic head differential (lower than tide gate). Hinge may be mounted on top, bottom or side.	Passive (change in hydraulic head differential)	No (unless leaking or propped open); except Bottom-Hinged Trap Door which remains open for part of the flood tide.	Under limited range of flow conditions during ebb tide (and flood tide in case of bottom-hinged trap door)	Aluminum, plastic (materials with low restorative force)	Trap door requires lower hydraulic head differential to open (than tide gate on which it is mounted); may remain open for longer duration than gate; may improve flow and fish passage.	Trap door may clog with debris and may increase susceptibility of gate to debris jams.		 
Mitigator Fish Passage Device	Nehalem Marine Manufacturing	Floats mounted on gate rotate a block (cam) that props gate partially open during portion of rising tide. Can be mounted on THTG or on smaller aperture within larger gate (e.g., Pet Door).	Passive (change in hydraulic head differential)	Yes. Limited.	Under limited range of flow conditions during ebb tide and portion of flood tide.		Inexpensive and reliable.	Limited adjustability (opening limited to range of cam). Debris can foul float mount.	Size of cams determines size of opening during flood tide. Can be sized based on passage criteria of fish.	 
Permanent Hole		Permanent opening placed within field of larger tide gate. Allows for limited amount of bi-directional flow.	n/a	Yes. Limited.	Under appropriate flow conditions during ebb and flood tide.		Allows for limited tidal flushing, saltwater intrusion; may provide US and DS AOP through ebb and flood tides. May improve water quality, connectivity, AOP.	Uncontrolled opening.	Opening must be sized and located correctly to avoid/minimize high velocities and turbulence relative to fish passage criteria.	
Variable Backflow Flap Gate (VBFG)	Juel Tide Gates	Control mechanism retrofitted to SHTG or THTG. Gate closes on rising tide when "draft force" through culvert exceeds tension exerted by VBFG rigging device.	Passive (change in flow through culvert and hydraulic head differential)	Yes (within set parameters)	Under appropriate flow conditions during ebb and flood tide.		Appears to be a simple and relatively inexpensive retrofit.	Minimal information available for review (except promotional piece by the designer labeling the VBFG "ingenious").	Gate opens 80-90 degrees to headwall when WSEL at DS side of gate is ≤ WSEL at US side.	 

TYPE	MANUFACTURER	OPERATIONS	PASSIVE / ACTIVE	ALLOWS TIDAL FLUSHING?	ALLOWS US FISH PASSAGE?	GATE MATERIALS	PROS	CONS	NOTES	**IMAGES** (from manufacturers' websites)
SELF REGULATING TIDE GATES & SIMILAR (least restrictive)										
Buoyancy-Compensated THTG (SRT)	Waterman Industries, Golden Harvest	Gate is buoyant; rises with water level. Floats mounted to counterbalancing arm of gate frame are more buoyant than gate lid. Default position is open (gate floating on water). Position of floats controls WSEL "trip elevation" - WSEL at which gate closes on rising tide.	Passive (change in hydraulic head differential and WSEL)	Yes (within set parameters)	Under appropriate flow conditions during ebb and flood tides.		Relatively simple. Designed to remain open except when flood tide exceeds set elevation; allows tidal flushing within desired parameters. Relatively low maintenance. Because default position is open, may interfere least with fish passage.	Frame / floats can collect debris, affect operation and requiring maintenance. Float adjustment may be difficult and/or have limited range. During high flow events, submerged vent tubes may pass floodwater US. Gates may slam shut. Culvert may require vertical vents to prevent water hammer when gate closes. Cannot respond to FW elevs at US side (as compared to MTR [see below]).		
Muted Tidal Regulator (MTR)	Nehalem Marine Manufacturing	MTR unit mounts on US side of pipe in SHTG or THTG. Gate is closed by float located at US side of pipe. Control mechanism extends from float at US end to gate at DS end of pipe. During flood tide, gate remains open until target WSEL is reached at US side of pipe. Requires related infrastructure on both US and DS sides of pipe Closing is regulated by the WSEL at US side of the pipe - so can respond to conditions related to both tidal and FW flows/elevs.	Passive (change in WSEL at US side of pipe)	Yes (within set parameters)	Under appropriate flow conditions during ebb and flood tides.		Placement of MTR at US side of pipe allows for opening/closing of structure to respond to both landward and seaward WSELs (tidal & FW conditions); trip elevation is related to max elevation of backwater pool, not tidal elev., resulting in greater opportunity for connectivity, mixing, and passage. SHTG with MTR provides >50% more fish passage "time" relative to conventional THTG and SHTG applications (per Leo Kuntz). Kuntz states that failed SRTs are replaced with SHTG/MTR combos. Easily adjustable trip elevation.	Expensive. Includes many moving components.		

Appendix D : SUMMARY OF HEC-RAS MODEL SETUP

Appendix D: Summary of HEC-RAS Model Setup

Bridge Geometry	Top of Roadway at Dyke Bridge (ft)	Dyke Bridge Geometry	Stride Bridge Geometry	Riverine Flow (cfs)	Tides (ft) (high/low)	SLR (m)	Surge (ft)	HEC-RAS Model Files		
								Geometry File	Flow file	Plan
Typical Tides, 1.1-year flow, SLR				**1.1-year**	**Recorded**			**Q1.1 Recorded Tides SLR varies**		
1-Existing	elev 11	Existing	TR=12	152 - steady	+9.0/-7.5	none	none	Alternative 1r rev.g21	Alternative 1 US Rules Q1p1 .u5	alt1rq1Tide1.p10
		4-4X5' boxes	inv -2.8/-2.5			0.5 m		Alternative 1r rev.g21	Alternative 1 US Rules Q1p1HSLR .u11	alt1rq1Tide1Hslr.p11
		w/ gates, inv -3.1	12.5' cmp			1m		Alternative 1r rev.g21	Alternative 1 US Rules Q1p1FSLR .u12	alt1rq1Tide1Fslr.p12
2-replace	elev 11	replace ex, gates	TR=12	152 - steady	+9.0/-7.5	none	none	Alternative 2r.g12	Alternative 2 US Rules Q1p1 .u13	Alt2 R1 Q1p13
		4-5X5 boxes,	inv -2.8/-2.5			0.5 m		Alternative 2r.g12	Alt 2 US Rules Q1p1HSLR .u14	Alt2 R1 Q1p1 HSLR.p14
		inv -4.05	12.5' cmp			1m		Alternative 2r.g12	Alt 2 US Rules Q1p1FSLR .u15	Alt2 R1 Q1p1 FSLR.p15
2 REV	elev 11	replace ex, gates	same	152 - steady	+9.0/-7.5	none	none	Alternative 2 REV 4 gates 1box.g22	.u51	alt 2 REV Q1 T1.p84
		4 flap gates, 1 open box				0.5 m		Alternative 2 REV 4 gates 1box.g22	.u53	alt 2 REV Q1 T1 HSLR.p79
		inv -4.05				1m		Alternative 2 REV 4 gates 1box.g22	.u54	alt 2 REV Q1 T1 FSLR.p85
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	152 - steady	+9.0/-7.5	none	none	Alternative 5r.g13	Alternatives5-6-7 Free FlowingQ1p1.u16	alt 5rQ1T1.p17
		bridge	invs -2.6/-2.5			0.5 m		Alternative 5r.g13	Alternatives5-6-7 Free FlowingQ1p1 HSLR.u1	alt5r Q1 T1 HSLR.p18
		inv = -5, n=.03	n=.015			1m		Alternative 5r.g13	Alternatives5-6-7 Free FlowingQ1p1 FSLR.u1	alt5r Q1 T1 FSLR.p19
6 - 60' span	elev 11	1- 60' span	TR=17	152 - steady	+9.0/-7.5	none	none	Alternative 6.g09	Alternatives5-6-7 Free FlowingQ1p1.u16	alt 6 Q1 T1.p20
		LC=9, TR=11	n=.028			0.5 m		Alternative 6.g09	Alternatives5-6-7 Free FlowingQ1p1 HSLR.u1	alt 6 Q1 T1 HSLR.p21
		invs -7.2/-8.0	invs -2.6/-2.5			1m		Alternative 6.g09	Alternatives5-6-7 Free FlowingQ1p1 FSLR.u1	alt 6 Q1 T1 FSLT.p22
Typical Tides, 50-year flow, SLR				**50-year**	**Recorded**			**Q50**		
1-Existing	elev 11	Existing	TR=12	824 steady	+9.0/-7.5	none	none	Alternative 1r rev.g21	Alternative 1 US rules R Q50.u9	atr1r Q50 T1.p23
		4-4X5' boxes	inv -2.8/-2.5	Hydrograph	+9.0/-7.5	none	none	Alternative 1r rev.g21	Alternative 1 US rules R Q50Hydrograph.u1	alt1r q50HYD-T1.p24
		w/ gates, inv -3.1	12.5' cmp	Hydrograph		0.5 m		Alternative 1r rev.g21	Alternative 1 US rules R Q50Hyd- HSLR.u19	alt 1r q50HYD-T1HSLR.p25
				Hydrograph		1m		Alternative 1r.g11	Alternative 1 US rules R Q50Hyd-FSLR.u20	1r q50HYD-T1FSLR.p26
2-replace	elev 11	replace ex, gates	TR=12	Hydrograph	+9.0/-7.5	none	none	Alternative 2r.g12	Alternative 2 US Rules R Q50HYD p1 .u21	Alt2 R1 Q50HYD T1.p28
		4-5X5 boxes,	inv -2.8/-2.5	Hydrograph		0.5 m		Alternative 2r.g12	Alternative 2 R q50HYD T1 HSLR.u22	alt2 q50 HYD T1 HLSR.p29
		inv -4.05	12.5' cmp	Hydrograph		1m		Alternative 2r.g12	alt2R Q50HYD T1 FSLR.u23	alt2 q50 HYD T1 FLSR.p30
2 REV	elev 11	replace ex, gates	same	Hydrograph	+9.0/-7.5	none	none	Alternative 2 REV 4 gates 1box.g22	alt 2REV T50 Q1. u55	alt 2 rev T50 Q1.p89
		4 flap gates, 1 open box		Hydrograph		0.5 m		Alternative 2 REV 4 gates 1box.g22		
		inv -4.05		Hydrograph		1m		Alternative 2 REV 4 gates 1box.g22		
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	Hydrograph	+9.0/-7.5	none	none	Alternative 5r.g13	Alternatives 5-6-7 Q50HYD T1.u24	alt5 Q50HYD T1.p31
		bridge	invs -2.6/-2.5	Hydrograph		0.5 m		Alternative 5r.g13	Alternatives 5-6-7 Q50HYD T1 HSLR.u25	alt5 Q50HYD T1 HSLR.p32
		inv = -5, n=.03	n=.015	Hydrograph		1m		Alternative 5r.g13	Alternatives 5-6-7 Q50HYD T1 FSLR.u26	alt5 Q50HYD T1 FSLR.p33
6 - 60' span	elev 11	1- 60' span	TR=17	Hydrograph	+9.0/-7.5	none	none	Alternative 6.g09	Alternatives 5-6-7 Q50HYD T1.u24	alt6 Q50HYD T1.p34
		LC=9, TR=11	n=.028	Hydrograph		0.5 m		Alternative 6.g09	Alternatives 5-6-7 Q50HYD T1 HSLR.u25	alt6 Q50HYD T1 HSLR.p35
		invs -7.2/-8.0	invs -2.6/-2.5	Hydrograph		1m		Alternative 6.g09	Alternatives 5-6-7 Q50HYD T1 FSLR.u26	alt6 Q50HYD T1 FSLR.p36
Typical Tides, 100-year flows, plus SLR				**100-year**	**Recorded**			**Q100**		
1-Existing	elev 11	Existing	TR=12	958 -steady	+9.0/-7.5	none	none	Alternative 1r rev.g21	Alternative 1 US rules R Q100.u27	atr1r Q100 T1.p37
		4-4X5' boxes	inv -2.8/-2.5	958 hydrograph	+9.0/-7.5	.5 m		Alternative 1r rev.g21	Alternative 1 R Q100Hyd T1.u28	alt1r q100HYD-T1.p38
		w/ gates, inv -3.1	12.5' cmp	Hydrograph		1 m		Alternative 1r rev.g21	Alternative 1 R Q100Hyd T1HSLR.u36	alt1r q100HYD-T1HSLR.p52
				Hydrograph		1m		Alternative 1r rev.g21	Alternative 1 R Q100Hyd T1FSLR.u37	alt1r q100HYD-T1FSLR.p53
2-replace	elev 11	replace ex, gates	TR=12	Hydrograph	+9.0/-7.5	none	none	Alternative 2r.g12	Alternative 2 US Rules R Q100HYD p1 .u29	Alt2 R1 Q100HYD T1.p39
		4-5X5 boxes,	inv -2.8/-2.5	Hydrograph		0.5 m		Alternative 2r.g12	Alternative 2 US Rules R Q100HYD t1 HSLR .u3	Alt2 R1 Q100HYD T1 HSLR.p54
		inv -4.05	12.5' cmp	Hydrograph		1m		Alternative 2r.g12	Alternative 2 US Rules R Q100HYD T1 FSLR .u3	Alt2 R1 Q100HYD T1 FSLR.p55
2 REV	elev 11	replace ex, gates	same	Hydrograph	+9.0/-7.5	none	none	Alternative 2 REV 4 gates 1box.g22	Alt 2 REV q100 T1.u56	Alt 2 REV Q100 T1. p81
		4 flap gates, 1 open box		Hydrograph		0.5 m		Alternative 2 REV 4 gates 1box.g22		
		inv -4.05		Hydrograph		1m		Alternative 2 REV 4 gates 1box.g22		
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	Hydrograph	+9.0/-7.5	none	none	Alternative 5r.g13	Alternatives 5-6-7 Q100HYD T1.u30	alt5 Q100HYD T1.p40
		bridge	invs -2.6/-2.5	Hydrograph		0.5 m		Alternative 5r.g13	" HSLR.u40	" HSLR.p01
		inv = -5, n=.03	n=.015	Hydrograph		1m		Alternative 5r.g13	" FSLR.u41	" FSLR.p57
6 - 60' span	elev 11	1- 60' span	TR=17	Hydrograph	+9.0/-7.5	none	none	Alternative 6.g09	Alternatives 5-6-7 Q100HYD T1.u30	alt5 Q100HYD T1 FSLR.p41
		LC=9, TR=11	n=.028	Hydrograph		0.5 m		Alternative 6.g09	"HSLR.u40	" HSLR.p58
		invs -7.2/-8.0	invs -2.6/-2.5	Hydrograph		1m		Alternative 6.g09	" FSLR.u41	" FSLR.p59

Appendix D: Summary of HEC-RAS Model Setup (Continued)

Bridge Geometry	Top of Roadway at Dyke Bridge (ft)	Dyke Bridge Geometry	Stride Bridge Geometry	Riverine Flow (cfs)	Tides (ft) (high/low)	SLR (m)	Surge (ft)	HEC-RAS Model Files		
								Geometry File	Flow file	Plan
High Spring Tide plus Surge, 1.1-year flow, plus SLR				**1.1year**	**Spring tides**		**2.5' surge**	**Q1.1 50-year SURGE at HIGH TIDE SLR varies**		
1-Existing	elev 11	Existing	TR=12	1.1-year	7.3/-6.9	none	2.5	Alternative 1r rev.g21	Alternative1_Cat50yr_Q1H.u04	Alt 1r 50Tide Q1H.p42
		4-4X5' boxes	inv -2.8/-2.5	steady		0.5 m		Alternative 1r rev.g21	" HSLR.u44	" HSLR.p88
		w/ gates, inv -3.1	12.5' cmp			1m		Alternative 1r rev.g21	" FSLR.u45	" FSLR.p78
2-replace	elev 11	replace ex, gates	TR=12	1.1-year	7.3/-6.9	none	2.5	Alternative 2r.g12	Alternatives2r_Cat50yr_Q1p1_H.u06	alt2r 50yrtide q1 surgeathigh.p43
		4-5X5 boxes,	inv -2.8/-2.5			0.5 m		Alternative 2r.g12	" HSLR.u46	" HSLR.p16
		inv -4.05	12.5' cmp			1m		Alternative 2r.g12	" FSLR.u47	" FSLR.p56
2 REV	elev 11	replace ex, gates	same	1.1-year	7.3/-6.9	none	2.5	Alternative 2 REV 4 gates 1box.g22	Alt 2 REV q1 T50.u57	alt2REV q1 T50.p90
		4 flap gates, 1 open box				0.5 m		Alternative 2 REV 4 gates 1box.g22	Alt 2 REV q1 T50 HSLR.u58	alt 2 REV q1 T50 HSLR.p91
		inv -4.05				1m		Alternative 2 REV 4 gates 1box.g22	Alt 2 REV q1 T50 FSLR.u59	alt 2 REV q1 T50 FSLR.p92
5- 5 boxes	elev 11	5- 15HX12W' boxes	TR 17	1.1-year	7.3/-6.9	none	2.5	Alternative 5r.g13	Alternatives5r_Cat50yr_Q1p1_H.u03	alt5r 50yrtide q1 surgeathigh.p44
		bridge	invs -2.6/-2.5			0.5 m		Alternative 5r.g13	" HSLR.u43	" HSLR.p03
		inv = -5, n=.03	n=.015			1m		Alternative 5r.g13	"FSLR.u42	" FSLR.p02
6 - 60' span	elev 11	1- 60' span	TR=17	1.1-year	7.3/-6.9	none	2.5	Aternative 6.g09	Alternatives6_Cat50yr_Q1p1_H.u03	alt6 50yrtide q1 surgeathigh.p45
		LC=9, TR=11	n=.028			0.5 m		Aternative 6.g09	" HSLR.u43	" HSLR.p60
		invs -7.2/-8.0	invs -2.6/-2.5			1 m		Aternative 6.g09	" FSLR.u42	" FSLR.p61
1-Existing	Existing	Existing	Existing	1.1-year	7.3/-6.9	none	MR	Alternative 1r rev.g21	alternative1_Cat50yr_Q1MF.u031	alt 1r 50Tide Q1 surgeatMFT.p46
				steady		none	MF	Alternative 1r rev.g21	alternative1_Cat50yr_Q1ME.u032	alt 1r 50Tide Q1 surgeatME.p47
						none	L	Alternative 1r rev.g21	alternative1_Cat50yr_Q1L.u033	alt 1r 50Tide Q1 surgeatL.p48
2-replace	Same as Exist.	Same as Exist.	no change	1.1-year	7.3/-6.9	none	MR	Alternative 2r.g12	Alternatives2r_Cat50yr_Q1p1_MF.u34	alt2r 50T Q1 surge at MF tide.p49
						none	MF	Alternative 2r.g12	ME	ME
						none	L	Alternative 2r.g12	L	L
5- 5 boxes	Same as Exist.	5- 15' boxes	no change	1.1-year	7.3/-6.9	none	MR	Alternative 5r.g13	Alternatives5-6-7_Cat50yr_Q1p1_MF.u34	alt5r 50T Q1 surge at MF tide.p50
						none	MF	Alternative 5r.g13	ME	ME
						none	L	Alternative 5r.g13	L	L
6 - 60' span	Same as Exist.	1- 60' span	no change	1.1-year	7.3/-6.9	none	MR	Aternative 6.g09	Alternatives5-6-7_Cat50yr_Q1p1_MF.u35	alt6 50T Q1 surge at MF tide.p51
						0.5 m	MF	Aternative 6.g09	HSLR	HSLR
						1m	L	Aternative 6.g09	FSLR	FSLR
Typical Tides, Flows Vary, Dyke BR and Stride BR Alternatives				**1.1-year**	**Recorded**			**High Causeway at Route 1 plus check slip lined Stridge Bridge Q1.1, Q50, Q100 with Recorded Tide and SLR**		
6 - 60' span	**14.7'**	1- 60' span	no change	1.1-year	9/-7.5	1m	none	Alternative 6 elev14p7.g08	Alternatives 5-6-7FreeflowingQ1p1FSLR.u18	alt6 14p7 Q1T1FSLR.p62
6 - 60' span	**14.7'**	1- 60' span	**slip lined**	1.1-year	9/-7.5	1m		Alternative 6 elev14p7 slipline stride.g1	Alternatives 5-6-7FreeflowingQ1p1FSLR.u18	alt6 14p7 SL Q1T1FSLR.p63
6 - 60' span	**14.7'**	1- 60' span	no change	**50-year**	9/-7.5	none	none	Alternative 6 elev14p7.g08	Alternatives 5-6-7 Q50 T1.u24	
				Hydrograph		0.5 m		Alternative 6 elev14p7.g08	Alternatives 5-6-7 Q50 T1 HSLR.u25	
						1m		Alternative 6 elev14p7.g08	alt 5-6-7 Q50HYD T1 FSLR.u26	alt6 14p7 Q50 T1 FSLR.p64
6 - 60' span	**14.7'**	1- 60' span	no change	**100-year**	9/-7.5	none	none	Alternative 6 elev14p7.g08	alternatives 5-6-7 100HYD T1.u30	
				Hydrograph		0.5 m		Alternative 6 elev14p7.g08	"HSLR.u40	
						1m		Alternative 6 elev14p7.g08	" FSLR.u41	alt 6 14p7 Q100 T1 FSLR.p65
6 - 60' span	**14.7'**	1- 60' span	**slip lined**	**50-year**	9/-7.5	none	none	Alternative 6 elev14p7 slipline stride.g1	Alternatives 5-6-7 Q50 T1.u24	alt 6 14p7 SL Q50 T1.p66
				Hydrograph		0.5 m		Alternative 6 elev14p7 slipline stride.g1	Alternatives 5-6-7 Q50 T1 HSLR.u25	" HSLR.p67
						1m		Alternative 6 elev14p7 slipline stride.g1	alt 5-6-7 Q50HYD T1 FSLR.u26	" FSLR.p68
6 - 60' span	**14.7'**	1- 60' span	**slip lined**	**100-year**	9/-7.5	none	none	Alternative 6 elev14p7 slipline stride.g1	alternatives 5-6-7 100HYD T1.u30	alt6 14p7 SL Q100 T1.p69
				Hydrograph		0.5 m		Alternative 6 elev14p7 slipline stride.g1	"HSLR.u40	" HSLR.p70
						1m		Alternative 6 elev14p7 slipline stride.g1	" FSLR.u41	" FSLR.p71

Appendix D: Summary of HEC-RAS Model Setup (Continued)

Bridge Geometry	Top of Roadway at Dyke Bridge (ft)	Dyke Bridge Geometry	Stride Bridge Geometry	Riverine Flow (cfs)	Tides (ft) (high/low)	SLR (m)	Surge (ft)	HEC-RAS Model Files		
								Geometry File	Flow file	Plan
Storm Surge Tides, 1.1-year flows, plus SLR, Dyke/Stride options					**Spring**			**High Causeway at Route 1 plus check slip lined Stridge Bridge 50-year SURGE at High Spring Tide plus SLR**		
6 - 60' span	**14.7'**	1- 60' span	no change	**1.1-year**	7.3/-6.9	none	2.5	Alternative 6 elev14p7.g08	Alternatives6_Cat50yr_Q1p1_H.u03	alt 6 14p7 Q1 T50.p72
						0.5 m		Alternative 6 elev14p7.g08	" HSLR.u43	alt 6 14p7 Q1 T50 HSLR.p73
						1m		Alternative 6 elev14p7.g08	" FSLR.u42	alt 6 14p7 Q1 T50 FSLR.p74
Case 6 - 60' span	**14.7'**	1- 60' span	no change	**1.1-year**	7.3/-6.9	none	2.5	Alternative 6 elev14p7.g08		
						0.5 m		Alternative 6 elev14p7.g08		
						1m		Alternative 6 elev14p7.g08		
Case 6 - 60' span	**14.7'**	1- 60' span	**slip lined**	1.1-year	7.3/-6.9	none	2.5	Alternative 6 elev14p7 slipline stride.g18	Alternatives6_Cat50yr_Q1p1_H.u03	alt6 14p7 SL Q1 T50H.p76
						0.5 m		Alternative 6 elev14p7 slipline stride.g18	" HSLR.u43	alt6 14p7 SL Q1 T50H HSLR.p75
						1 m		Alternative 6 elev14p7 slipline stride.g18	" FSLR.u42	alt6 14p7 SL Q1 T50H FSLR.p77
Case 6 - 60' span	**14.7'**	1- 60' span	**slip lined**	1.1-year	7.3/-6.9	none	2.5	Alternative 6 elev14p7 slipline stride.g18		
						0.5 m		Alternative 6 elev14p7 slipline stride.g18		
						1 m		Alternative 6 elev14p7 slipline stride.g18		
Calibration Model Runs				**20 cfs**	**Recorded**					
Case 1	11	Existing	TR=12		+9.0/-7.5	none	none	Alternative 1r-rev.g21	Alt 1 rules rev.u52	Alt 1r gates 20 cfs T1.p87
		4-4X5' boxes	inv -2.8/-2.5							
		w/ gates, inv -3.1	12.5' cmp							
Case 1	11	Existing	TR=12		+9.0/-7.5	none	none	Alt 1 no gates.g20	Alternative 1 no gates 20 cfs T1.u50	alt 1 q20 T1 no gates.p86
		4-4X5' boxes	inv -2.8/-2.5							
		NO gates, inv -3.1	12.5' cmp							
Alt 2 Replacement in kind options										
Alt 2 4 flap gates, 1 open box		4 5X5 flap gates	TR=12	20	+9.0/-7.5	none	none	Alternative 2 REV 4 gates 1box.g22	alternative 2 REV no rules Q20T1.u61	alt2 4 flapgates 1 open box Q20cfsT1.p82
	11	one open 5X5	inv -2.8/-2.5	152				Alternative 2 REV 4 gates 1box.g22	alternative 2 REV no rules Q1T1.u51	alt2 4 flapgates 1 open box Q1cfsT1.p80
		inv -4.05	12.5' cmp							
alt 2 3 flaps 1 open		3 5X5 flap gates	TR=12	20	+9.0/-7.5	none	none	Alternative 2 3 flap gates 1 open.g02	alternative 2 REV no rules Q20T1.u61	alt2 3 flapgates 1 open box Q20cfsT1.p04
		one open 5X5	inv -2.8/-2.5	152				Alternative 2 3 flap gates 1 open.g02	alternative 2 REV no rules Q1T1.u51	alt2 3 flapgates 1 open box Q1cfsT1.p83
		inv -4.05	12.5' cmp							
alt 2 2 flaps 1 open		2 5X5 flap gates	TR=12	20	+9.0/-7.5	none	none	alternative 2 2 flap gates 2 open.g03	alternative 2 REV no rules Q20T1.u61	alt2 2 flapgates 2 open box Q20cfsT1.p27
		two open 5X5	inv -2.8/-2.5	152					alternative 2 REV no rules Q1T1.u51	alt2 2 flapgates 2 open box Q1T1.p06

Appendix E: MEMO ON STRIDE BRIDGE REHABILITATION AND REPLACEMENT OPTIONS

Memo

To: Michael Chelminski
Topsham ME Office
From: Tim Merritt
Scarborough ME Office
File: 195600963, Task 208
Date: January 22, 2015

Reference: MaineDOT Stride Bridge – Rehab & Replacement Options

The following is a memo describing the rehab and replacement options for the Stride Bridge for your review/use:

STRIDE BRIDGE

Stride Bridge is located on the Middle River in Marshfield, Maine, and is comprised of a corrugated metal pipe (CMP) with a diameter of 12.5 feet (ft) that is approximately 40 ft long and mitered to the upstream and downstream slopes of the roadway embankment. The upstream and downstream invert elevations[1] of the culvert are -2.58 ft and -2.48 ft, respectively.

Hydraulic Conditions In the Middle River

Hydraulic conditions at Stride Bridge are affected by upland (riverine) flow and backwater conditions that propagate upstream from the downstream reach of the Middle River, including effects associated with regulation of landward tidal flow at Dyke Bridge. Peak riverine flows in the Middle River at Stride Bridge and Dyke Bridge were provided by MaineDOT and are provided in Table 1.

Table 1: Peak Flows

Location	***Return-Interval Event (Years)*/**Peak Flow (cfs)							
	1.1	***2***	***5***	***10***	***25***	***50***	***100***	***500***
Stride Bridge	130	265	213	522	670	787	912	1,221
Dyke Bridge	152	297	452	565	715	832	958	1,264

Dyke Bridge is approximately 15,000 ft downstream (seaward) from Stride Bridge, and is comprised of a causeway with four box culverts that crosses the Middle River immediately upstream (landward[2]) from its confluence with the Machias River. Hydraulic conveyance at the Dyke Bridge is provided by four 5 ft x 5 ft box culverts with invert elevations of approximately -4 ft that have flap gates installed on the downstream (seaward) side of the culverts. The flap gates restrict landward tidal flow while allowing for downstream (seaward) flow of upland runoff from the Middle River.

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[1] Elevations provided by Maine DOT and referenced to the North American Vertical Datum of 1988 (NAVD88).

[2] "Landward" and "seaward" are used in addition to "upstream" and "downstream", respectively, to reflect bi-directional flow associated with tidal conditions in the Machias River.