WIN. 23236.01
ROUTE 11 (DETECTIVE BENJAMIN CAMPBELL BRIDGE) OVER WEST BRANCH PENOBSCOT RIVER

PENOBSCOT COUNTY, MAINE

FINAL
HYDROLOGIC AND HYDRAULIC REPORT

July 2020

PREPARED FOR

MaineDOT
16 State House Station
Augusta, ME 04333

PREPARED BY

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HNTB

ME 11(DETECTIVE BENJAMIN CAMPBELL BRIDGE) OVER WEST BRANCH PENOBSCOT RIVER
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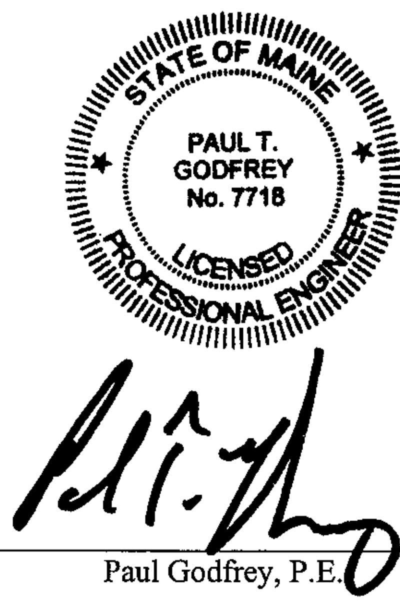

Paul Godfrey, P.E.

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

Prepared By:
HNTB Corporation
4507 North Front Street, Suite 300
Harrisburg, PA 17110

The following is a final report of the hydrologic and hydraulic analysis of the existing and proposed bridges at Detective Benjamin Campbell Bridge (Bridge No. 3666) over West Branch Penobscot River in the Township of Indian Purchase T3 in Penobscot County, Maine.

1.0 Introduction

The Detective Benjamin Campbell Bridge carries Route 11 over the West Branch Penobscot River. The existing bridge is a steel thru-truss bridge with a cast-in-place concrete deck. The existing bridge was built in 1948. The bridge serves approximately 1240 cars per day (2017). The bridge is located approximately 0.40 miles downstream of a dam structure for Elbow Lake and 0.50 miles upstream of the confluence with Quakish Lake.

The bridge spans over the West Branch Penobscot River with a total length of 360 feet from abutment to abutment. The existing structure features two piers with approximately 240 feet between the two piers. The low chord elevation of the existing bridge is 470.91 feet at the north end of the structure. The existing structure has a hydraulic opening of approximately 5653 square feet.

The proposed structure is being constructed on the same alignment as the existing bridge. The proposed structure is a two-span bridge with a total length of 380 feet from abutment to abutment. The proposed structure will feature an out-to-out width of 45.4 feet. The proposed structure will also feature traditional abutments with sloping embankments. The proposed profile of the bridge and approach roadway are proposed to be raised by approximately 4 feet on the northern side of the structure and approximately 3.5 feet on the southern side of the structure with a vertical grade of 1.25%. The low chord elevation is proposed to be raised to 471.34 feet (0.43 feet higher than existing). The proposed bridge provides a hydraulic opening of 5584 square feet. The slight decrease in hydraulic area is due to the placement of the proposed pier within the stream.

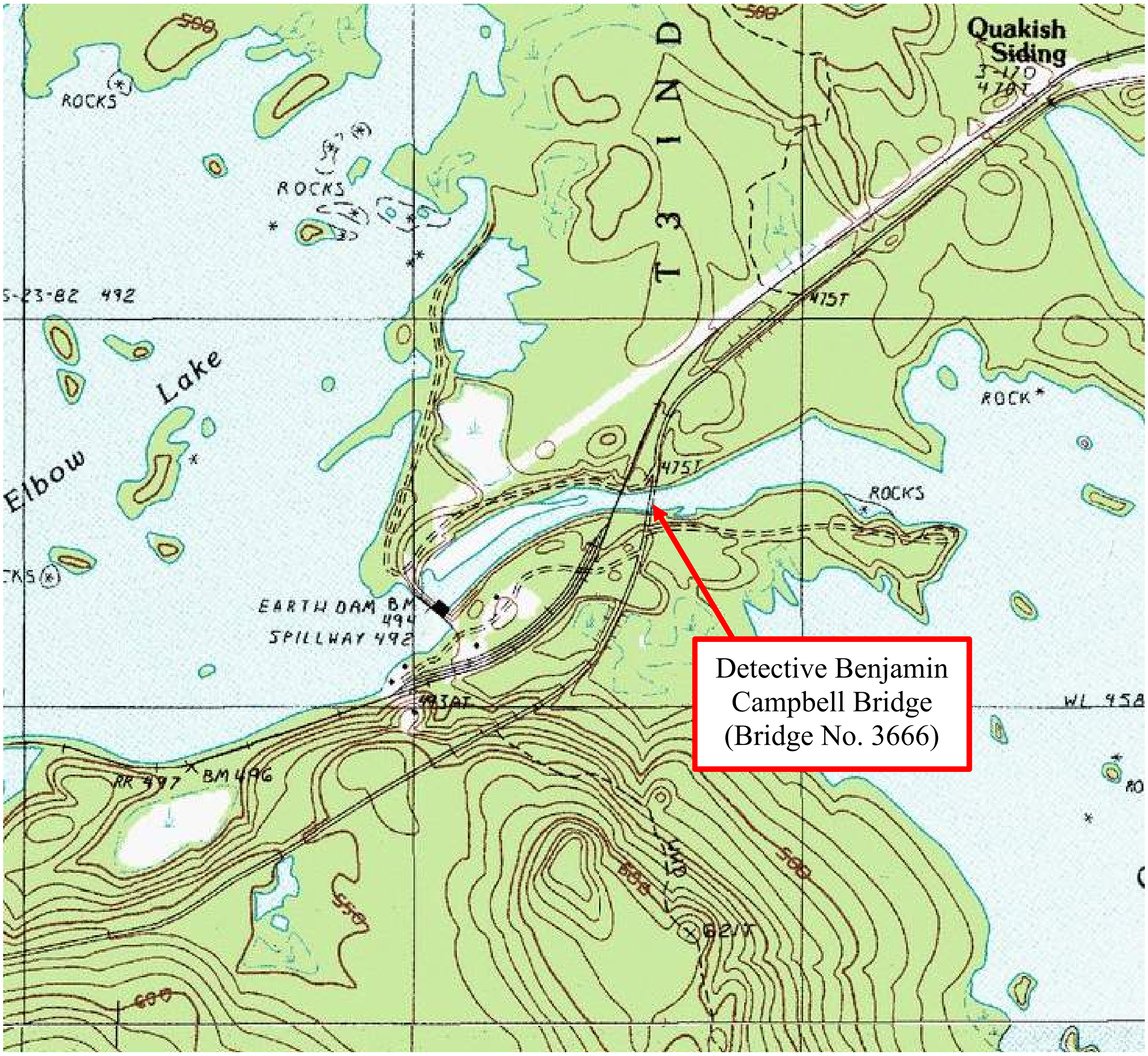

Figure 1 – Project Location Map (USGS Quadrangle – Norcross, ME)

The nearest bridge upstream from Detective Benjamin Campbell Bridge is a small recreational vehicle bridge approximately 90 feet upstream (from centerline to centerline). Approximately 175 feet upstream from the recreational vehicle bridge is an existing rail bridge. The rail bridge was not included in this analysis. Approximately half a mile (2,650 feet) downstream from Detective Benjamin Campbell Bridge is the confluence with Quakish Lake. The project area is not located within a FEMA study area.

Figure 2 – Aerial image showing project site

2.0 Existing Data Review

- Site Photographs are provided in **Appendix A**.
- There is no FEMA data available within the project site or within the vicinity of the structure. The unmapped FEMA map can be found in **Appendix B**.
- There is no USGS stream gage located within the vicinity of the project site.
- West Branch Penobscot River flows were calculated utilizing SIR 2015-4059. These values were used in the analysis and can be found in **Table 1.**

3.0 Hydrology

The peak flows recommended for design for the West Branch Penobscot River at the location of the bridge replacement were based on USGS regression equations. The regression analysis calculates peak flows for small ungaged streams and compares map-based to field-based variables (SIR 2015-4059).

This area does not have FEMA data available. Therefore, the flows calculated using the USGS regression equation were used for the analysis.

The flows found using the USGS regression equations have been provided in **Table 1**. The hydrology report can be found in **Appendix C**.

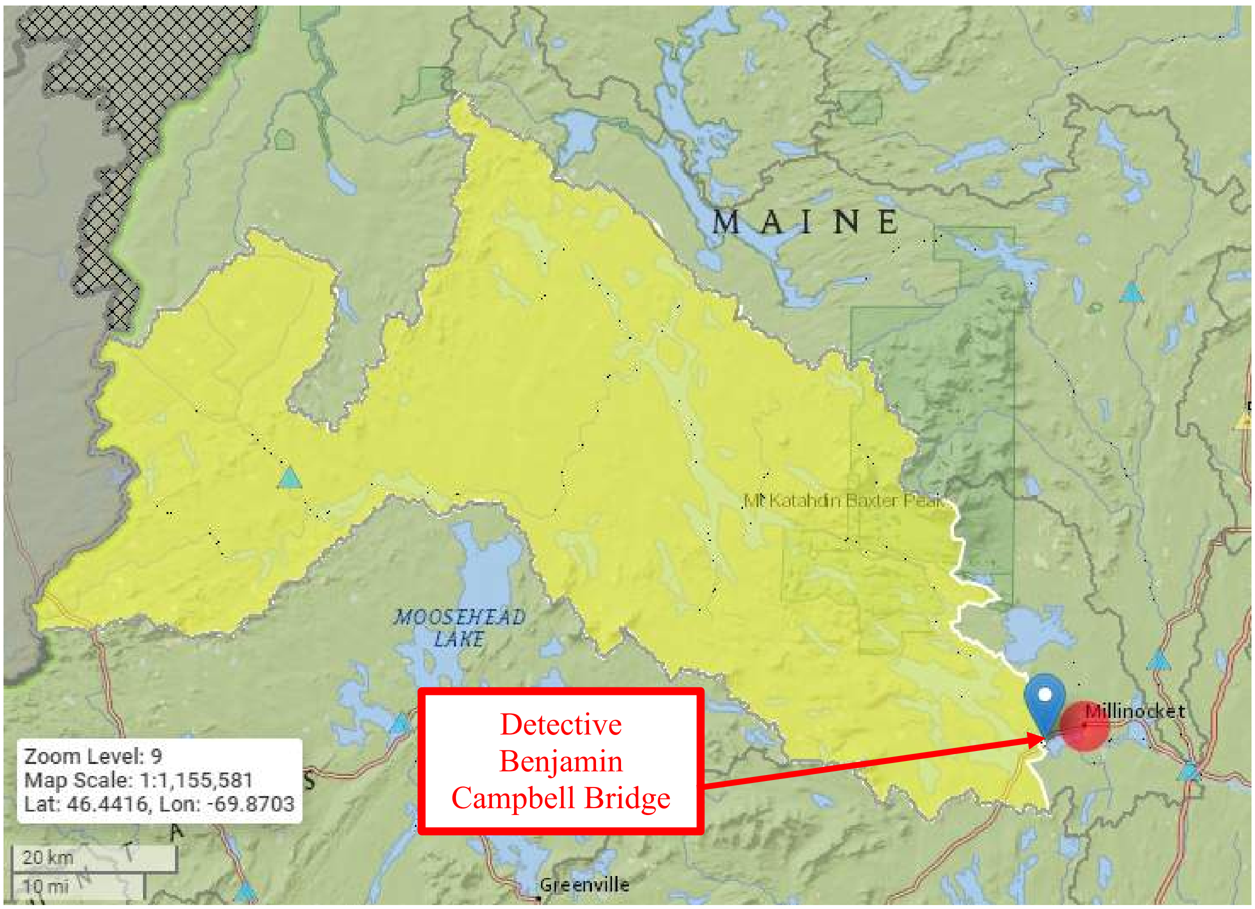

Figure 3 – Watershed above Detective Benjamin Campbell Bridge over West Branch River

Table 1: Flood Information
(For calculations see **Appendix C**)

Year Storm	**USGS SIR 2015-4059 (cfs)**
Drainage Area	**1882.10 sq. mi.**
$Q_{1.1}$	**11,968.1**
Q_2	**18,731.4**
Q_5	**24,687.3**
Q_{10}	**28,703.9**
Q_{25}	**33,501.2**
Q_{50}	**37,024.6**
Q_{100}	**40,710.0**
Q_{500}	**49,194.2**

As mentioned previously, the flows calculated using the USGS regression equation (SIR 2015-4059) were used in the hydraulic analysis of Detective Benjamin Campbell Bridge. The hydrology report can be found in **Appendix C.**

4.0 Hydraulic Analysis

Hydraulic calculations for the existing and proposed conditions along the West Branch Penobscot River were performed using the U.S. Army Corps of Engineers' software HEC-RAS, version 5.0.3 HEC-RAS supports one-dimensional, steady flow, water surface profiles calculations. Cross-sections were cut from survey gathered for this project.

The downstream boundary condition for the HEC-RAS model was set to a normal depth (slope) of 0.0041 ft/ft which is based on the survey of the streambed. The upstream boundary conditions for the HEC-RAS model were also set to a normal depth (slope) of 0.0032 ft/ft which is based on the survey of the streambed.

There is no history of the bridge/roadway being inundated during prior storm events and because the project site is not located in a FEMA studies zone, the boundary conditions were based on field information. A sensitivity analysis showed that utilizing a steeper or shallower normal depth, did not alter results significantly. From this information the boundary conditions based on field survey/observations was deemed appropriate for this analysis.

The model was run using "mixed" flow due to the lack of known water surface elevations and lack of FEMA information. The mixed flow ensures that the model uses both the downstream boundary and upstream boundary conditions discussed above. The model covers approximately 230 feet upstream of the existing structure and 125 feet downstream of the existing structure. The existing and proposed structures are located on the same horizontal alignment, so the cross sections are the same from the existing to proposed analysis.

The Manning's n-values along the West Branch River were estimated based upon aerial images and site photographs. The Manning's n-values were determined to be 0.05 for the channel for both the upstream and downstream extents of the project analysis site. The over bank areas throughout the project were set to 0.08 based upon the heavy forested areas evident in the aerial images.

Ineffective flow areas were set upstream and downstream of the bridge based on contraction and expansion from the existing and proposed bridge in both existing and proposed models. These ineffective flow areas were set to the elevation of the bridge/roadway elevations, but have little effect on the hydraulics of the structure.

The existing three-span structure has a hydraulic opening of 5652.85 square feet. The existing model is run using the momentum equation (coefficient of drag, C_D, =2.00 for square shaped piers) for all storm events (1.1-yr to 500-yr). The momentum flow indicates that the flood is running with some influence by the piers. Because there is no influence by the roadway or bridge superstructure the model does not run utilizing the pressure flow equation.

The proposed two-span structure is being constructed on the same alignment as the existing bridge and has a proposed hydraulic opening of 5583.70 square feet. The bottom chord of the proposed bridge is higher than the bottom chord of the existing structure. Because of the placement and size of the pier, the hydraulic opening decreases from existing to proposed conditions. The proposed model also runs all storm events (1.1-yr to 500-yr) utilizing the momentum equation (coefficient of drag, C_D, =1.39 for triangular shaped nose). This indicates that the structure is running with influence from the proposed pier.

The MaineDOT Bridge Design Guide (BDG) states that bridges that are major riverine bridges must provide four (4) feet over the 50-year event and should be able to pass the 100-year event (ideally with one foot-of freeboard). Based on the BDG, the existing structure does not provide the necessary clearance for the 50-year event (3.66 feet of clearance). Although the proposed structure does raise water surface elevations within the stream (maximum 0.18 feet for Q50), it does provide greater clearance (3.91 feet of clearance) for the 50-year event. Additionally, the clearances to the low chord of the structure increase from existing to proposed for all storm events. Because the area is not located in a FEMA study area, there are no requirements to remap the area. There is no additional risk for any upstream structures (including the rail bridge and pedestrian bridge). These structures have very minimal effect on the hydraulics of the river as the only storm event that is impacted by the pedestrian bridge is the 500-yr event.

The project team conferred regarding the calculated freeboard clearances and concluded the proposed design provides acceptable clearances over projected flood elevations. This conclusion was reached recognizing that while the placement of the pier within the center allowed for a reduction in structure depth that raises the low chord elevation of the bridge, it also slightly decreased the hydraulic opening provided. The resulting upstream water surface elevations are increased for all storm events but the projected increases are minor (0.16 feet for the 100-yr event) and are contained within the streambanks of the project site. This slight increase in water surface elevation does not result in an increased risk of flooding or inundation to adjacent properties and structures upstream of the proposed bridge. Additionally, the floodwater elevation increases only occur on the upstream side of the bridge. Downstream of the structure water elevations match existing conditions. The projected increase in upstream flood elevations is allowed by MaineDOT BDG Section 2.3.10.4 that states "FEMA regulations require that the backwater at Q100 increase no more than 1 foot."

Table 2 provides a summary of the hydraulic analysis of existing and proposed conditions at the Detective Benjamin Campbell Bridge over the West Branch River.

Table 2: Hydraulic Analysis Summary

Summary of Hydraulic Data – Route 11 over West Branch of Penobscot River	Existing Structure	Proposed Structure
Drainage Area (sq. miles)	1882.10	1882.10
Low Chord	470.91	471.34
Floodplain width at Q100, ft	331.18	332.11
Floodplain width at Q500, ft	339.57	340.75
Width at Banks, ft	262.90	262.90
Headwater at Upstream face of bridge, Q10, ft	465.26	465.51
Headwater at Upstream face of bridge, Q25, ft	466.44	466.63
Headwater at Upstream face of bridge, Q50, ft	467.25	467.43
Headwater at Upstream face of bridge, Q100, ft	468.07	468.23
Headwater at Upstream face of bridge, Q500, ft	469.36	469.50
Discharge Velocity at Q10, fps	9.89	9.66
Discharge Velocity at Q25, fps	10.38	10.20
Discharge Velocity at Q50, fps	10.70	10.55
Discharge Velocity at Q100, fps	11.03	10.90
Discharge Velocity at Q500, fps	12.12	11.99
Ordinary High-Water Elevation (Q1.1) (US face), ft	459.69	460.11
Discharge Velocity at Q1.1, fps	7.76	7.36
Clearance at Q10, ft	5.65	5.83
Clearance at Q25, ft	4.47	4.71
Clearance at Q50, ft	3.66	3.91
Clearance at Q100, ft	2.84	3.11
Clearance at Q500, ft	1.55	1.84
Bridge Opening Area, ft^2	5652.85	5583.70
Flow area at Q100, ft^2	3882.86	3934.15
Flow area at Q500, ft^2	4312.88	4362.75

The HEC-RAS model was reviewed for errors, warnings, and notes. There were several notes produced by HEC-RAS for the existing and proposed models about multiple critical depths found at several cross-sections. While there were no errors produced, some notes stated that the critical depth with the lowest, valid, energy was used. After further review these notes were deemed acceptable for this analysis and the answers were deemed valid. HEC-RAS outputs including cross-sections and profiles are provided for existing conditions in **Appendix D** and proposed conditions in **Appendix E**.

5.0 Scour Analysis

A scour analysis was performed based on equations from FHWA publication HEC-18 (Fifth Edition). The 100-year and 500-year events were analyzed for scour at the proposed bridge location. The D_{50} of the streambed material was measured to be approximately 3.68 mm or 0.01207 feet. The D_{50} is provided in **Appendix F** of the report. This D_{50} was used to determine whether clear water or live bed scour analysis was to be performed and concluded the calculation of live bed scour was required. In addition, local scour was calculated per HEC-18 for the near and far abutments.

From the scour analysis it was found that there was some live bed scour at the proposed project site, as well as local scour at the near (Sta 1196+18) and far (Sta 1199+98) abutments. The scour analysis shows that the abutments and slopes should be protected against scour utilizing heavy riprap. During the boring sampling, the bedrock of the stream was determined to be at an elevation of approximately 449 feet. Whereas the proposed pier will be founded on seal concrete placed on intact bedrock significant scour is not expected at the pier location.

The total scour depths can be found in **Table 3** and the scour analysis can be found in **Appendix F**.

Table 3: Scour Depths

	100 - year storm		
	Near Abutment	Pier	Far Abutment
Aggradation/ Degradation (ft)	0.00	0.00	0.00
Contraction/Expansion Scour (ft)	0.67	0.67	0.67
Local Scour (ft)	6.32	11.25	5.45
Pressure Flow Scour (ft)	0.00	0.00	0.00
TOTAL SCOUR (ft)	***6.99***	***11.91***	***6.11***

	500-year storm		
	Near Abutment	Pier	Far Abutment
Aggradation/ Degradation (ft)	0.00	0.00	0.00
Contraction/Expansion Scour (ft)	0.84	0.84	0.84
Local Scour (ft)	7.51	11.86	6.47
Pressure Flow Scour (ft)	0.00	0.00	0.00
TOTAL SCOUR (ft)	***8.35***	***12.70***	***7.32***

Note that local scour is known to be conservative and the calculations do not account for any proposed scour protection such as riprap.

6.0 Summary

In summary, the existing Detective Benjamin Campbell Bridge over West Branch River in Penobscot County is proposed to be replaced. The low chord of the existing structure is at 470.91 feet and no storm events impact the low chord. The existing structure offers approximately 5653 square feet of hydraulic opening. The existing structure does not meet the MaineDOT Bridge Design Guide as it does not provide the required clearance (4 feet) for the 50-yr event.

The proposed bridge is designed to be on the same alignment as the existing structure, while raising the existing low chord elevation and lengthening the span. The span length from abutment to abutment is proposed to be 380 feet. Although the span and low chord are increased, the placement of a pier at the center of the structure decreases the hydraulic opening to 5584 square feet. Although the structure does slightly increase water surface elevations, the structure does provide greater clearance than the existing bridge over the 50-yr event. Additionally, all increases are contained within the streambanks and do not pose a flooding threat to adjacent properties.

Appendix Contents

APPENDIX A

Site Photographs

Photo 1 – Existing Structure– Looking Upstream

Photo 2 – Existing Structure and Pedestrian Bridge – Looking Downstream

Photo 3 – ME-11 – Looking North

Photo 4 – ME-11 – Looking South

Photo 5 – Upstream Structures – Looking West

APPENDIX B

FEMA FIRM


Poplar St
11
North Twin Dam Rd
Elbow Lake
PROJECT
LOCATION
Aroostook
Poplar St
Selected Flood Map Boundary
Digital Data Available
No Digital Data Available
Unmapped
Esri, HERE, Garmin, INCREMENT P, NGA,

APPENDIX C

Hydrology Report

WIN:	23236.00		**Project Name:**	T3 Indian PurchaseWest Branch Bridge
Town:	T3 Indian Purchase		**Stream Name:**	West Branch Penobscot River
Route No.	Rt 11		**Bridge Name:**	West Branch Bridge
Asset ID:	3666		**Analysis by:**	DFB
Lat:	45.6372	**Long:** -68.77349	**Date:**	9/11/2017

Peak Flow Calculations by USGS Regression Equations (Hodgkins, 1999 & Lombard/Hodgkins, 2015)

Enter data in blue cells only!

	km^2	mi^2	ac	*Enter data in [mi^2]*
A	4874.64	1882.10	1204544.0	Watershed Area *DRNAREA*
W	795.54	307.2	196581.6	Wetlands area (by NWI)
P_c	458243	5087040		watershed centroid (E, N; UTM 19N; meters)
County	Penobscot N			*choose county from drop-down menu*
pptA	41.5			mean annual precipitation (inches; by look-up)
SG	0.01			sand & gravel aquifer as decimal fraction of watershed A

Worksheet prepared by:

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Environmental Office
Maine Dept. Transportation
Augusta, ME 04333-0016
207-557-1052
Charles.Hebson@maine.gov

ver. 2017 Jun. 09

A (km^2)	4874.64	**Conf Lvl**	0.67
W (%)	16.32	NWI Wetlands % *STORNWI*	

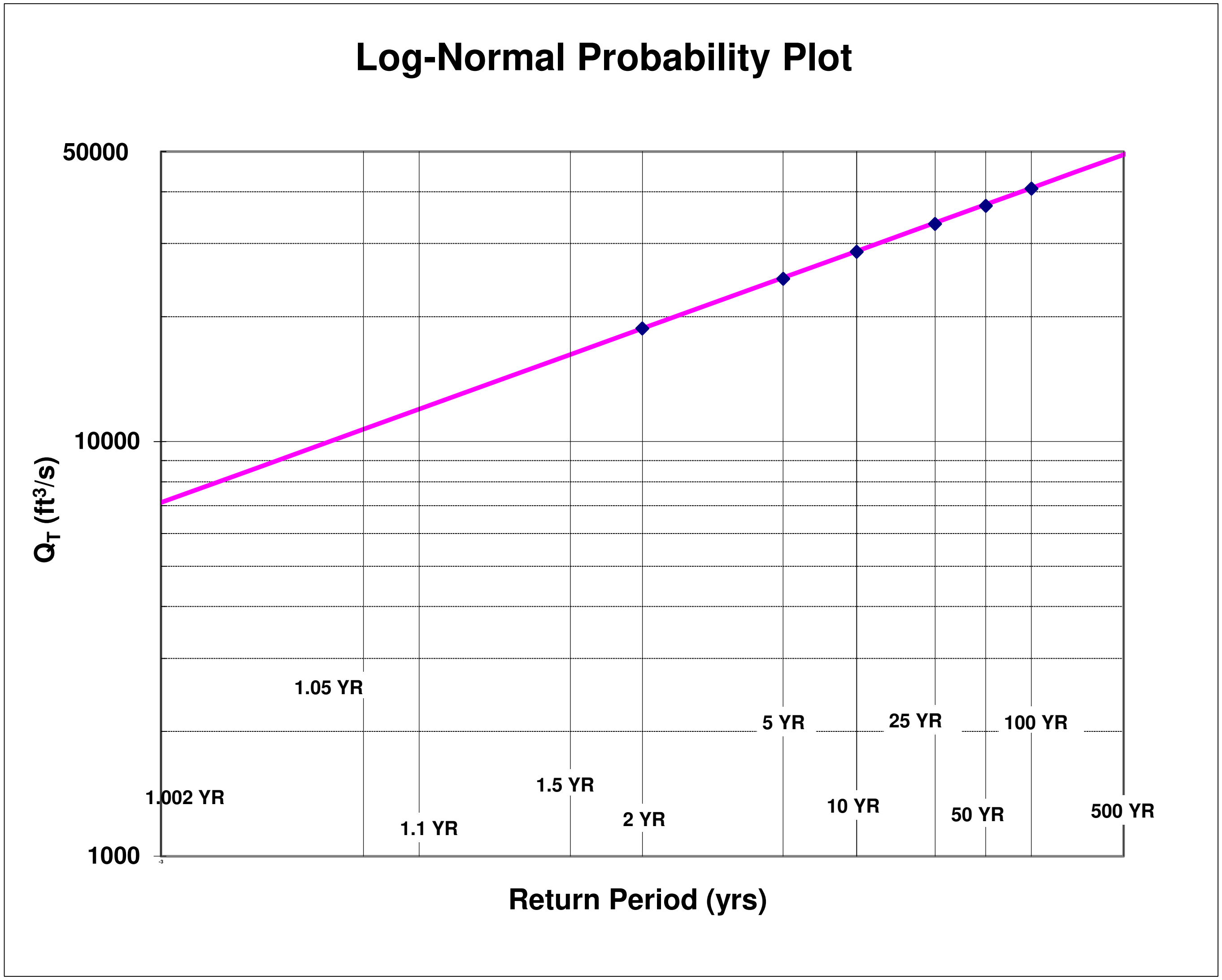
References:

Hodgkins, G.A., 1999.
Estimating the magnitude of peak flows for streams
in Maine for selected recurrence intervals
WRIR 99-4008, USGS Augusta, ME

Lombard, P.J. & G.A. Hodgkins, 2015.
Peak flow regression equations for small, ungaged streams in
Maine - Comparing map-based to field-based variables
SIR 2015-4059, USGS, Augusta, ME

Ret Pd T (yr)	**Peak Flow Estimate Lower**	**Q_T (m^3/s)**	**Upper**	**Q_T (ft^3/s)**
1.1		338.94		11968.1
2		530.48		18731.4
5		699.16		24687.3
10		812.91		28703.9
25		948.77		33501.2
50		1048.56		37024.6
100		1152.93		40710.0
500		1393.21		49194.2

$Q_T = b \times A^a \times 10^{-wW}$



Log-Normal Probability Plot
50000
10000
1000
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)

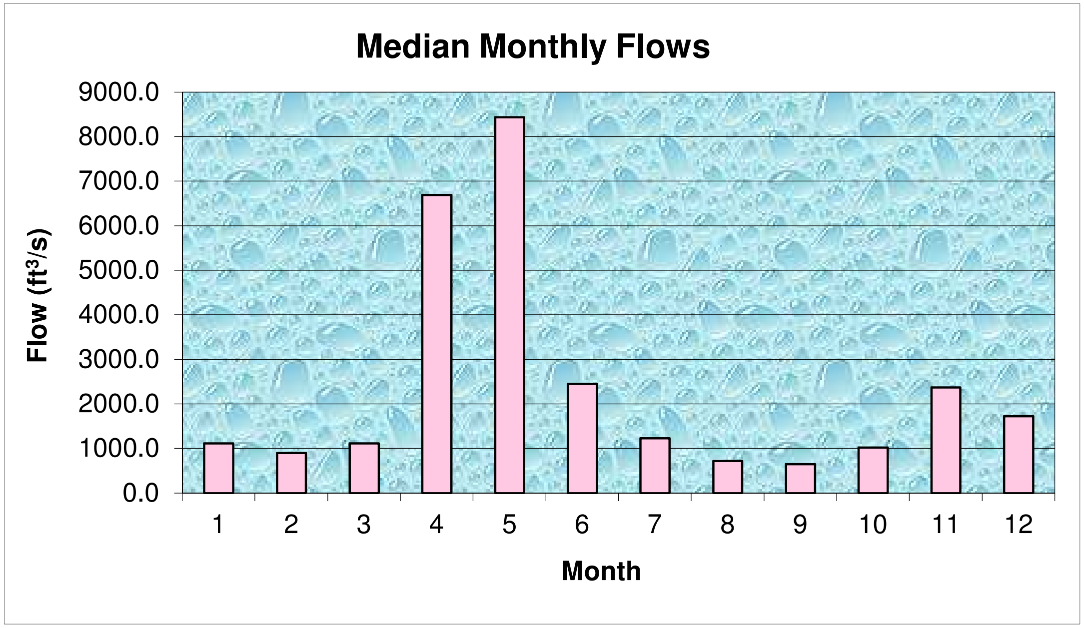
WIN:	23236.00	**Project Name:**	T3 Indian PurchaseWest Branch Bridge
Town:	T3 Indian Purchase	**Stream Name:**	West Branch Penobscot River
Route No.	Rt 11	**Bridge Name:**	West Branch Bridge
Asset ID:	3666	**Analysis by:**	DFB
Lat:	45.63715 **Long:** -68.77349	**Date:**	9/11/2017

DO NOT ENTER ANY DATA ON THIS PAGE; EVERYTHING IS CALCULATED

MAINE MONTHLY MEDIAN FLOWS and HYDRAULIC GEOMETRY BY USGS REGRESSION EQUATIONS (2004, 2013)

	Value	**Variable**	**Explanation**
	1882.10	*A*	Area (mi^2)
458242.9	5087040	P_c	Watershed centroid (E,N; UTM; Zone 19; meters)
	150.52	*DIST*	Distance from Coastal reference line (mi)
	41.5	*pptA*	Mean Annual Precipitation (inches)
	0.01	*SG*	Sand & Gravel Aquifer (decimal fraction of watershed area)

Month	Q_{median} (ft3/s)	(m^3/s)
Jan	**1120.41**	31.7509
Feb	**901.60**	25.5501
Mar	**1118.55**	31.6982
Apr	**6689.83**	189.5804
May	**8434.19**	239.0131
Jun	**2450.26**	69.4369
Jul	**1232.83**	34.9367
Aug	**719.95**	20.4024
Sep	**652.49**	18.4905
Oct	**1025.10**	29.0498
Nov	**2370.35**	67.1724
Dec	**1724.70**	48.8757



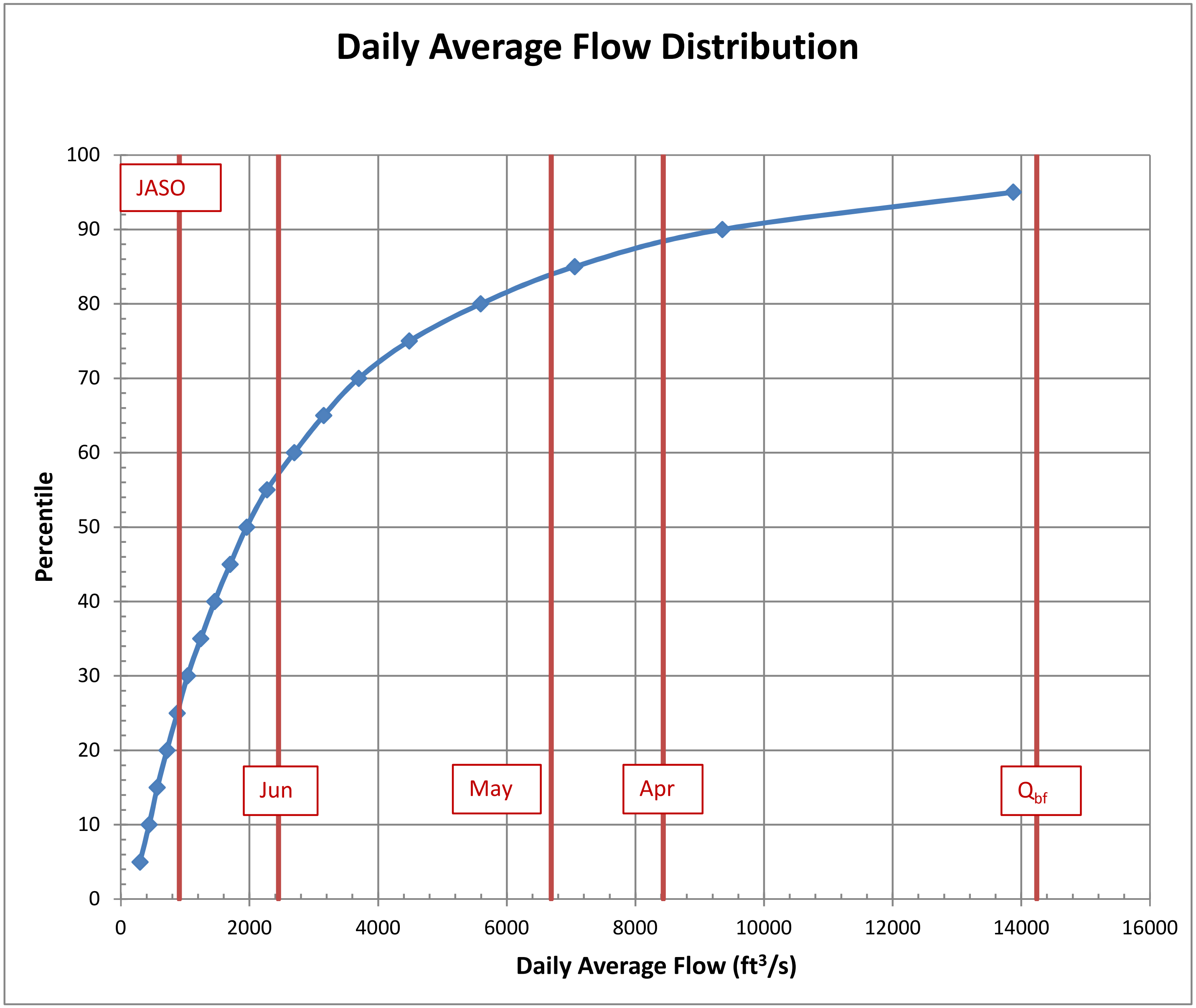
Q_{bf}	**14241.1**	
ann avg	**3506.5**	
ann med	**1836.8**	
$Q_{1.002}$	**7125.8**	
$Q_{1.01}$	**8566.1**	
$Q_{1.05}$	**10695.4**	
Q_{bf}	**8352.3**	assume v = 4ft/s

W_{bf}	**270.8**	estimated bankfull width (ft)
d_{bf}	**7.7**	estimated bankfull depth (ft)
A_{bf}	**2979.9**	estimated bankfull flow area (ft^2)

References

Dudley, R.W., 2013. FY2013 Progress Report - Phase 1 …, USFWS QRP Project

Dudley, R.W., 2004. Estimating Monthly Streamflows … , SIR 2004-5026



Daily Avg Flow Dist

A_{ws} = (mi^2) 1882.1

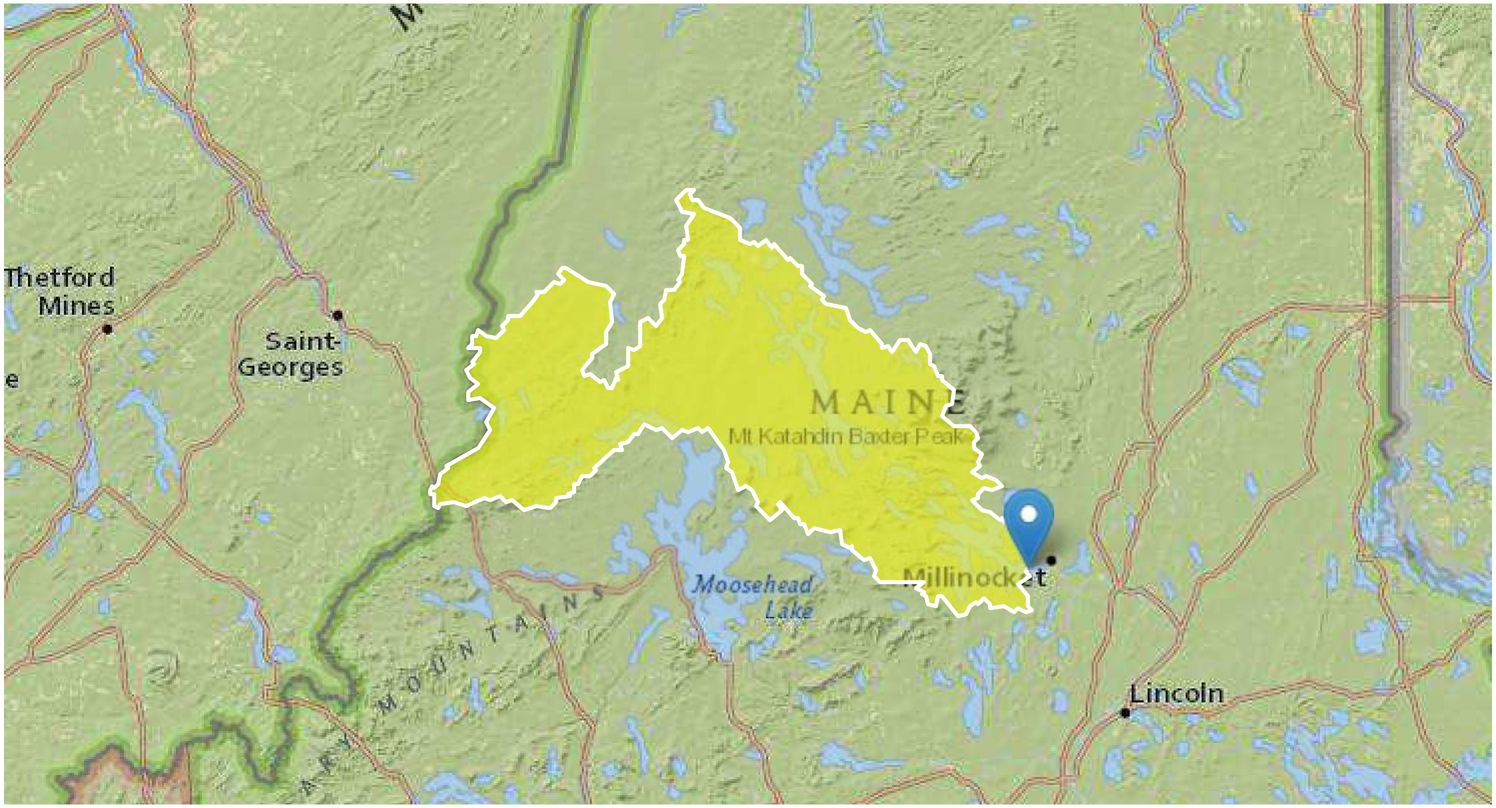
Q (ft^3/s)

Pctl	Median	84th pctl
5	296.27	476.78
10	440.05	661.65
15	565.62	826.18
20	716.31	1001.91
25	876.28	1174.47
30	1036.96	1337.63
35	1242.33	1528.79
40	1456.85	1758.09
45	1698.14	1987.86
50	1955.04	2346.84
55	2270.38	2731.49
60	2696.37	3206.37
65	3154.49	3735.54
70	3700.12	4358.21
75	4485.54	5240.93
80	5593.98	6257.39
85	7058.36	8018.79
90	9349.92	10767.52
95	13876.21	16744.37

Q_{bf}	14241.1
$Q_{1.002}$	7125.8
$Q_{1.1}$	11968.1
Q_2	18731.4

T3 Indian Purchase 23236 W Branch Bridge 3666

Region ID: ME
Workspace ID: ME20170911092317287000
Clicked Point (Latitude, Longitude): 45.63715, -68.77349
Time: 2017-09-11 09:24:22 -0400



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	1882.1	square miles
STORNWI	Percentage of strorage (combined water bodies and wetlands) from the Nationa Wetlands Inventory	16.32	percent

Parameter Code	Parameter Description	Value	Unit
SANDGRAVAF	Fraction of land surface underlain by sand and gravel aquifers	0.006	dimensionless
ELEV	Mean Basin Elevation	1241.1	feet
BSLDEM10M	Mean basin slope computed from 10 m DEM	7.43	percent
CENTROIDX	Basin centroid horizontal (x) location in state plane coordinates	458242.87	
CENTROIDY	Basin centroid vertical (y) location in state plane units	5087039.83	
COASTDIST	Shortest distance from the coastline to the basin centroid	152	miles
ELEVMAX	Maximum basin elevation	5260.5	feet
LC06WATER	Percent of open water, class 11, from NLCD 2006	7.58	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	0.34	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	0.051	percent
PRECIP	Mean Annual Precipitation	41.5	inches
SANDGRAVAP	Percentage of land surface underlain by sand and gravel aquifers	0.57	percent
STATSGOA	Percentage of area of Hydrologic Soil Type A from STATSGO	4.85	percent

General Disclaimers

The delineation point is in an exclusion area.

Peak-Flow Statistics Parameters [100 Percent (1880 square miles) Statewide Peak Flow Full GT 12sqmi WRI 99 4008]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1882.1	square miles	0.93	1653
STORNWI	Percentage of Storage from NWI	16.32	percent	0.7	26.7

Peak-Flow Statistics Disclaimers [100 Percent (1880 square miles) Statewide Peak Flow Full GT 12sqmi WRI 99 4008]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Peak-Flow Statistics Flow Report [100 Percent (1880 square miles) Statewide Peak Flow Full GT 12sqmi WRI 99 4008]

Statistic	Value	Unit
2 Year Peak Flood	18700	ft^3/s
5 Year Peak Flood	24700	ft^3/s
10 Year Peak Flood	28700	ft^3/s
25 Year Peak Flood	33500	ft^3/s
50 Year Peak Flood	37000	ft^3/s
100 Year Peak Flood	40700	ft^3/s
500 Year Peak Flood	49200	ft^3/s

Peak-Flow Statistics Citations

Hodgkins, G. A.,1999, Estimating the Magnitude of Peak Flows for Streams in Maine for Selected Recurrence Intervals: U.S. Geological Survey Water-Resources Investigations Report 99-4008, 45 p. (http://me.water.usgs.gov/99-4008.pdf)

Low-Flow Statistics Parameters [100 Percent (1880 square miles) Statewide LowFlow SIR 2004 5026]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1882.1	square miles	9.79	1418
SANDGRAVAF	Fraction of Sand and Gravel Aquifers	0.006	dimensionless	0	0.455

Low-Flow Statistics Disclaimers [100 Percent (1880 square miles) Statewide LowFlow SIR 2004 5026]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Low-Flow Statistics Flow Report [100 Percent (1880 square miles) Statewide LowFlow SIR 2004 5026]

Statistic	Value	Unit
7 Day 10 Year Low Flow	165	ft^3/s

Low-Flow Statistics Citations

Dudley, R.W.,2004, Estimating Monthly, Annual, and Low 7-Day, 10-Year Streamflows for Ungaged Rivers in Maine: U.S. Geological Survey Scientific Investigations Report 2004-5026, 22 p. (http://water.usgs.gov/pubs/sir/2004/5026/pdf/sir2004-5026.pdf)

Flow-Duration Statistics Parameters [100 Percent (1880 square miles) Statewide Annual SIR 2015 5151]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1882.1	square miles	14.9	1419
SANDGRAVAF	Fraction of Sand and Gravel Aquifers	0.006	dimensionless	0	0.212
ELEV	Mean Basin Elevation	1241.1	feet	239	2120

Flow-Duration Statistics Disclaimers [100 Percent (1880 square miles) Statewide Annual SIR 2015 5151]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Flow-Duration Statistics Flow Report [100 Percent (1880 square miles) Statewide Annual SIR 2015 5151]

Statistic	Value	Unit
1 Percent Duration	373	ft^3/s
5 Percent Duration	579	ft^3/s
10 Percent Duration	716	ft^3/s
25 Percent Duration	1010	ft^3/s
50 Percent Duration	1860	ft^3/s
75 Percent Duration	4310	ft^3/s
90 Percent Duration	9050	ft^3/s
95 Percent Duration	13700	ft^3/s
99 Percent Duration	24000	ft^3/s

Flow-Duration Statistics Citations

Dudley, R.W.,2015, Regression equations for monthly and annual mean and selected percentile streamflows for ungaged rivers in Maine: U.S. Geological Survey Scientific Investigations Report 2015–5151, 35 p. (http://dx.doi.org/10.3133/sir20155151)

Annual Flow Statistics Parameters [100 Percent (1880 square miles) Statewide Annual SIR 2015 5151]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	1882.1	square miles	14.9	1419
SANDGRAVAF	Fraction of Sand and Gravel Aquifers	0.006	dimensionless	0	0.212
ELEV	Mean Basin Elevation	1241.1	feet	239	2120

Annual Flow Statistics Disclaimers [100 Percent (1880 square miles) Statewide Annual SIR 2015 5151]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Annual Flow Statistics Flow Report [100 Percent (1880 square miles) Statewide Annual SIR 2015 5151]

Statistic	Value	Unit
Mean Annual Flow	3710	ft^3/s

Annual Flow Statistics Citations

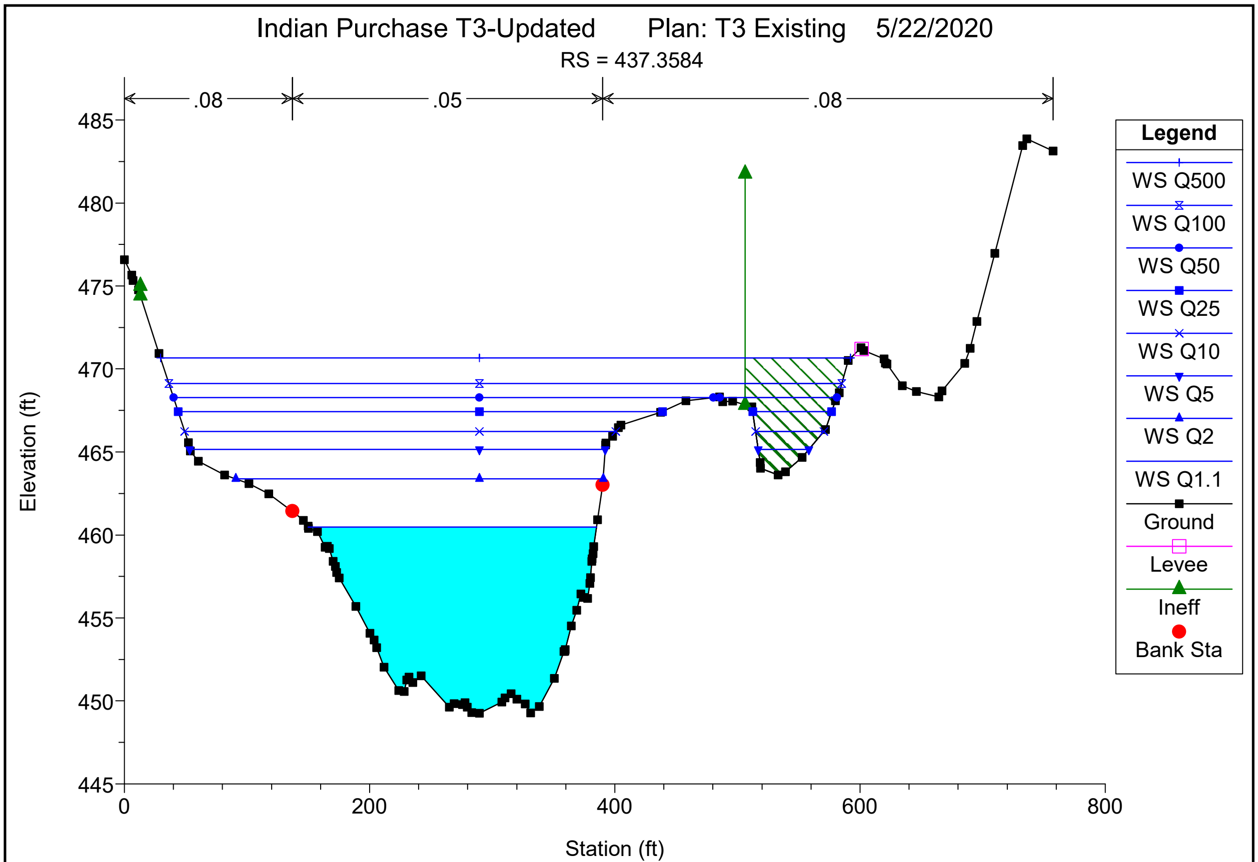
Dudley, R.W.,2015, Regression equations for monthly and annual mean and selected percentile streamflows for ungaged rivers in Maine: U.S. Geological Survey Scientific Investigations Report 2015–5151, 35 p. (http://dx.doi.org/10.3133/sir20155151)

APPENDIX D

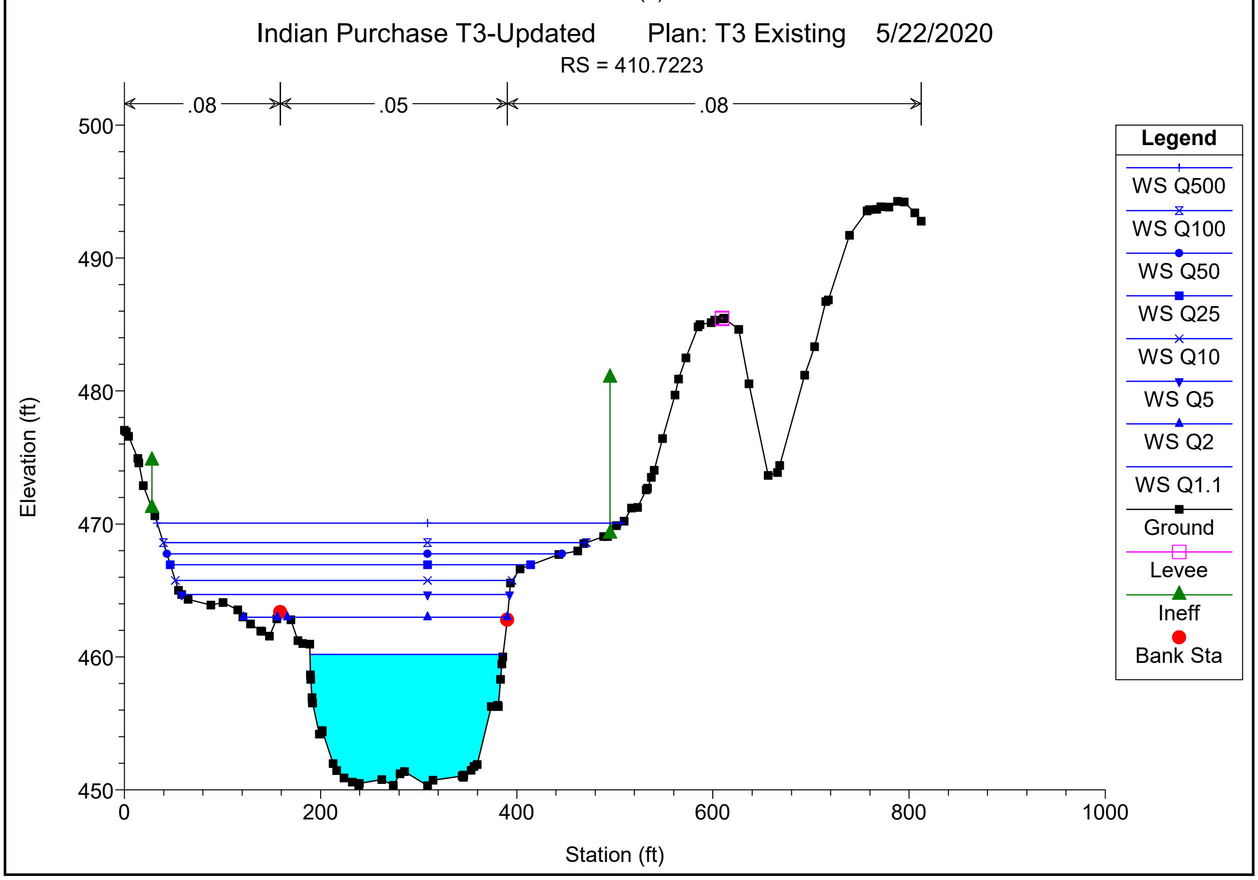
Existing HEC-RAS Analysis

HEC-RAS Plan: Existing River: Stream Reach: Reach

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	437.3584	Q1.1	11968.10	449.26	460.48	456.31	461.14	0.003174	6.53	1833.87	235.15	0.41
Reach	437.3584	Q2	18731.40	449.26	463.37	458.10	464.21	0.002840	7.32	2592.39	299.77	0.41
Reach	437.3584	Q5	24687.30	449.26	465.16	459.49	466.18	0.002814	8.13	3172.49	380.20	0.42
Reach	437.3584	Q10	28703.90	449.26	466.24	460.41	467.37	0.002803	8.59	3543.38	407.56	0.42
Reach	437.3584	Q25	33501.20	449.26	467.44	461.41	468.69	0.002792	9.10	3984.92	459.44	0.43
Reach	437.3584	Q50	37024.60	449.26	468.27	462.01	469.61	0.002776	9.42	4332.90	535.55	0.43
Reach	437.3584	Q100	40710.00	449.26	469.12	462.61	470.52	0.002737	9.71	4730.07	548.72	0.43
Reach	437.3584	Q500	49194.20	449.26	470.66	464.03	472.26	0.002818	10.48	5458.35	562.72	0.44
Reach	410.7223	Q1.1	11968.10	450.31	460.19	456.67	461.03	0.003792	7.36	1627.11	196.68	0.45
Reach	410.7223	Q2	18731.40	450.31	462.98	458.42	464.09	0.003960	8.45	2240.61	258.97	0.47
Reach	410.7223	Q5	24687.30	450.31	464.70	459.79	466.06	0.004093	9.38	2747.41	334.31	0.49
Reach	410.7223	Q10	28703.90	450.31	465.75	460.65	467.24	0.004027	9.88	3105.28	343.56	0.50
Reach	410.7223	Q25	33501.20	450.31	466.93	461.81	468.56	0.003952	10.40	3519.68	367.49	0.50
Reach	410.7223	Q50	37024.60	450.31	467.75	462.55	469.48	0.003890	10.73	3836.35	402.96	0.50
Reach	410.7223	Q100	40710.00	450.31	468.59	463.42	470.40	0.003809	11.03	4189.73	431.41	0.50
Reach	410.7223	Q500	49194.20	450.31	470.07	465.06	472.13	0.003908	11.89	4861.52	472.92	0.51
Reach	385		Bridge									
Reach	358.3758	Q1.1	11968.10	448.74	460.03	456.10	460.81	0.003400	7.06	1695.01	201.32	0.43
Reach	358.3758	Q2	18731.40	448.74	462.81	457.95	463.85	0.003728	8.18	2291.74	237.47	0.46
Reach	358.3758	Q5	24687.30	448.74	464.51	459.35	465.81	0.003839	9.15	2733.82	283.59	0.48
Reach	358.3758	Q10	28703.90	448.74	465.54	460.21	467.00	0.003853	9.71	3046.82	318.91	0.49
Reach	358.3758	Q25	33501.20	448.74	466.70	461.28	468.33	0.003838	10.29	3429.53	339.03	0.49
Reach	358.3758	Q50	37024.60	448.74	467.52	461.99	469.25	0.003811	10.66	3710.75	356.03	0.50
Reach	358.3758	Q100	40710.00	448.74	468.33	462.84	470.18	0.003786	11.03	4005.81	392.15	0.50
Reach	358.3758	Q500	49194.20	448.74	469.67	464.25	471.88	0.004076	12.11	4532.30	461.97	0.53
Reach	333.8266	Q1.1	11968.10	447.37	459.95	456.02	460.72	0.003558	7.04	1700.41	208.35	0.43
Reach	333.8266	Q2	18731.40	447.37	462.74	457.89	463.75	0.003828	8.05	2327.17	247.86	0.46
Reach	333.8266	Q5	24687.30	447.37	464.46	459.32	465.69	0.004177	8.88	2795.73	301.97	0.49
Reach	333.8266	Q10	28703.90	447.37	465.52	460.22	466.87	0.004043	9.33	3134.49	335.48	0.49
Reach	333.8266	Q25	33501.20	447.37	466.71	461.25	468.19	0.003902	9.80	3551.61	361.55	0.49
Reach	333.8266	Q50	37024.60	447.37	467.54	462.01	469.11	0.003798	10.09	3854.99	365.49	0.49
Reach	333.8266	Q100	40710.00	447.37	468.39	462.79	470.03	0.003697	10.37	4163.72	369.59	0.49
Reach	333.8266	Q500	49194.20	447.37	469.76	464.36	471.70	0.003887	11.32	4672.30	379.47	0.51
Reach	314.7174	Q1.1	11968.10	449.73	459.69	456.64	460.63	0.004657	7.76	1541.63	201.96	0.50
Reach	314.7174	Q2	18731.40	449.73	462.49	458.39	463.65	0.004895	8.62	2172.11	254.93	0.52
Reach	314.7174	Q5	24687.30	449.73	464.20	459.81	465.59	0.004714	9.45	2648.00	299.53	0.52
Reach	314.7174	Q10	28703.90	449.73	465.26	460.80	466.77	0.004659	9.89	2974.61	314.28	0.53
Reach	314.7174	Q25	33501.20	449.73	466.44	462.01	468.09	0.004474	10.38	3348.13	321.26	0.52
Reach	314.7174	Q50	37024.60	449.73	467.25	462.64	469.01	0.004365	10.70	3612.78	326.21	0.52
Reach	314.7174	Q100	40710.00	449.73	468.07	463.27	469.93	0.004267	11.03	3882.86	331.18	0.52
Reach	314.7174	Q500	49194.20	449.73	469.36	464.72	471.59	0.004576	12.12	4312.88	339.57	0.55
Reach	295		Bridge									
Reach	256	Q1.1	11968.10	449.44	459.22	456.67	460.28	0.005746	8.27	1447.80	202.67	0.55
Reach	256	Q2	18731.40	449.44	462.01	458.48	463.28	0.005999	9.06	2067.78	261.64	0.57
Reach	256	Q5	24687.30	449.44	463.72	459.82	465.19	0.005622	9.76	2571.35	313.24	0.56
Reach	256	Q10	28703.90	449.44	464.76	460.74	466.35	0.005298	10.17	2902.65	322.50	0.56
Reach	256	Q25	33501.20	449.44	465.91	462.09	467.64	0.005021	10.62	3277.52	327.91	0.55
Reach	256	Q50	37024.60	449.44	466.72	462.74	468.54	0.004857	10.92	3543.06	331.69	0.55
Reach	256	Q100	40710.00	449.44	467.52	463.35	469.44	0.004715	11.23	3811.98	334.75	0.55
Reach	256	Q500	49194.20	449.44	468.71	464.65	471.03	0.005098	12.37	4212.43	339.04	0.58
Reach	236.2108	Q1.1	11968.10	448.57	459.21	456.09	460.09	0.004394	7.53	1588.87	208.62	0.48
Reach	236.2108	Q2	18731.40	448.57	462.01	457.84	463.08	0.004375	8.31	2263.95	276.21	0.49
Reach	236.2108	Q5	24687.30	448.57	463.72	459.17	465.00	0.004247	9.11	2789.14	344.95	0.50
Reach	236.2108	Q10	28703.90	448.57	464.76	460.39	466.17	0.004124	9.57	3135.93	366.32	0.50
Reach	236.2108	Q25	33501.20	448.57	465.91	461.27	467.46	0.004014	10.07	3532.30	387.99	0.50
Reach	236.2108	Q50	37024.60	448.57	466.72	461.87	468.36	0.003941	10.40	3816.78	397.65	0.50
Reach	236.2108	Q100	40710.00	448.57	467.53	462.54	469.26	0.003867	10.71	4103.82	405.44	0.50
Reach	236.2108	Q500	49194.20	448.57	468.78	463.93	470.78	0.004090	11.65	4827.83	449.76	0.52
Reach	184.0766	Q1.1	11968.10	448.77	459.01	455.69	459.86	0.004104	7.39	1620.39	208.73	0.47
Reach	184.0766	Q2	18731.40	448.77	461.80	457.48	462.86	0.004103	8.25	2292.35	284.64	0.48
Reach	184.0766	Q5	24687.30	448.77	463.49	458.83	464.78	0.004101	9.13	2756.01	319.21	0.49
Reach	184.0766	Q10	28703.90	448.77	464.51	459.69	465.95	0.004102	9.67	3042.13	342.92	0.50
Reach	184.0766	Q25	33501.20	448.77	465.62	460.89	467.24	0.004101	10.28	3364.54	409.16	0.51
Reach	184.0766	Q50	37024.60	448.77	466.39	461.55	468.14	0.004100	10.68	3593.41	423.52	0.51
Reach	184.0766	Q100	40710.00	448.77	467.16	462.17	469.04	0.004106	11.09	3825.03	432.11	0.52
Reach	184.0766	Q500	49194.20	448.77	468.53	463.49	470.57	0.004092	11.77	4814.03	461.37	0.52



Indian Purchase T3-Updated Plan: T3 Existing 5/22/2020
RS = 437.3584
.08
.05
.08
Elevation (ft)
Station (ft)
485
480
475
470
465
460
455
450
445
0
200
400
600
800
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Levee
Ineff
Bank Sta



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.05
.08
Elevation (ft)
Station (ft)
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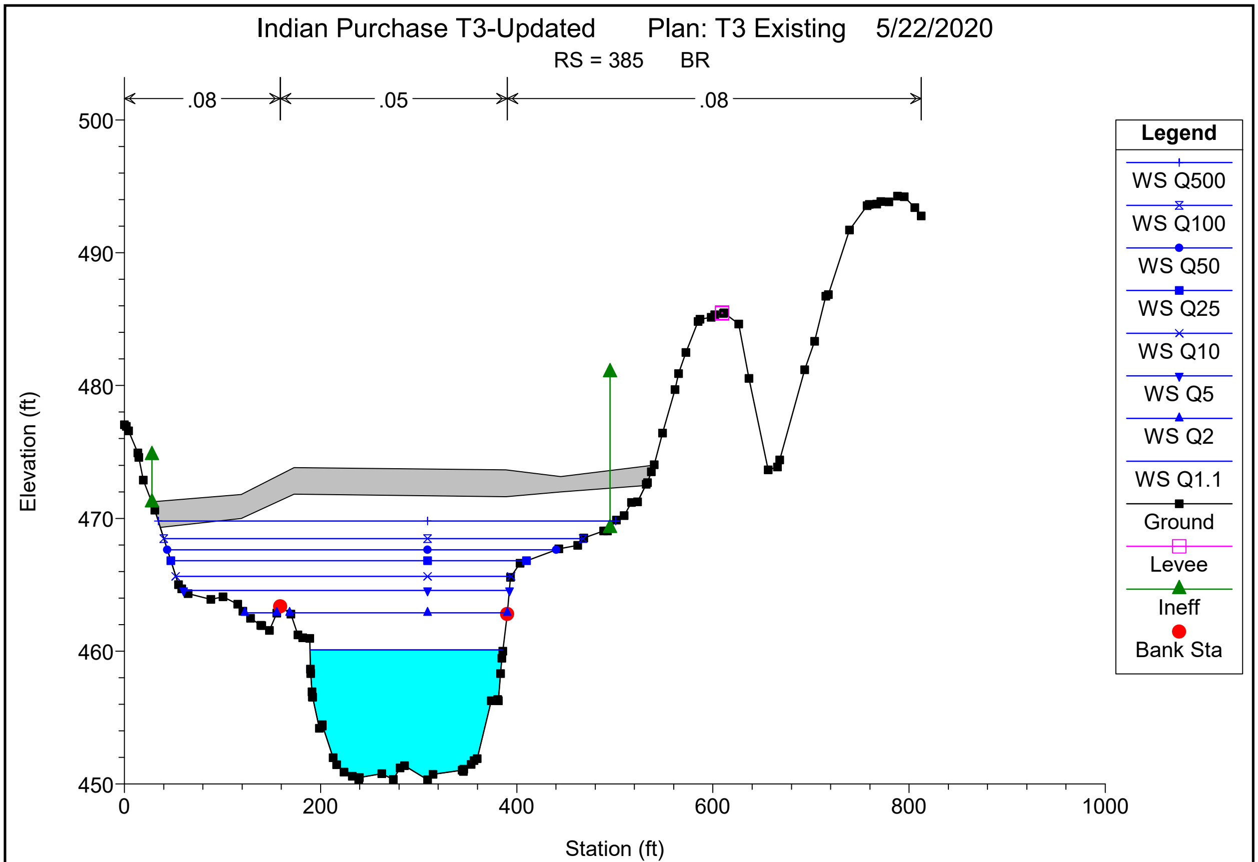
490
480
470
460
450
0
200
400
600
800
1000
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Levee
Ineff
Bank Sta



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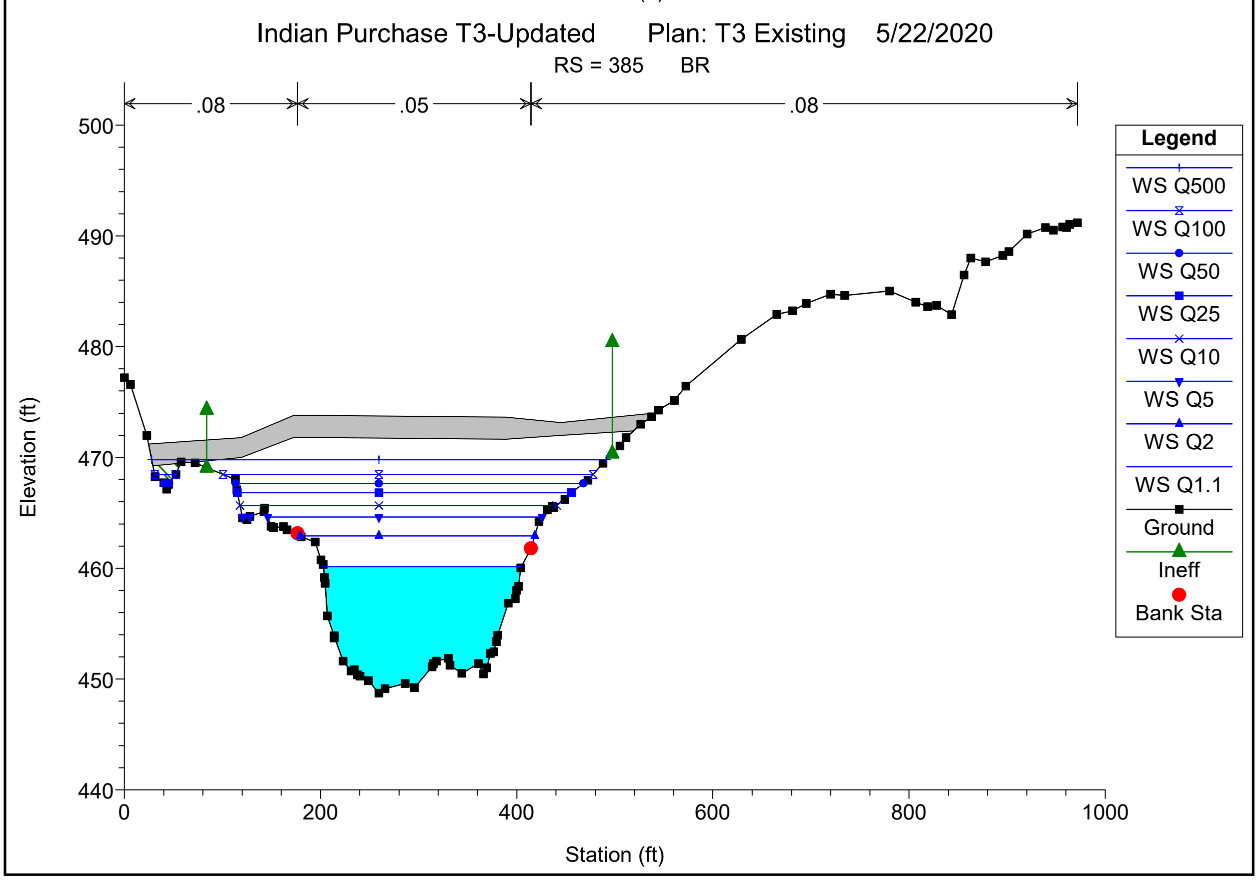
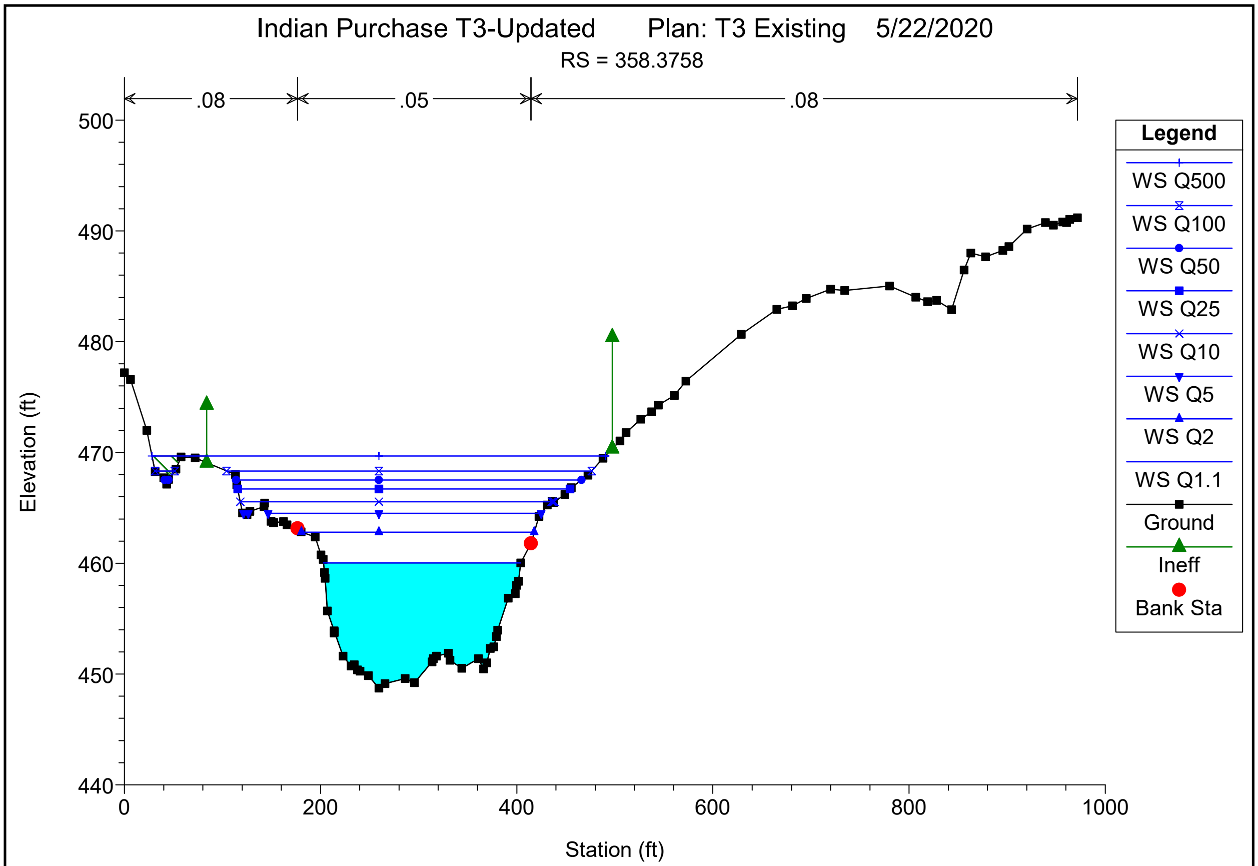
RS = 385 BR
.08
.05
.08
Elevation (ft)
Station (ft)
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Levee
Ineff
Bank Sta



Indian Purchase T3-Updated Plan: T3 Existing 5/22/2020
RS = 385 BR
.08
.05
.08
Elevation (ft)
Station (ft)
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Ineff
Bank Sta



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.05
.08
Elevation (ft)
Station (ft)
Legend
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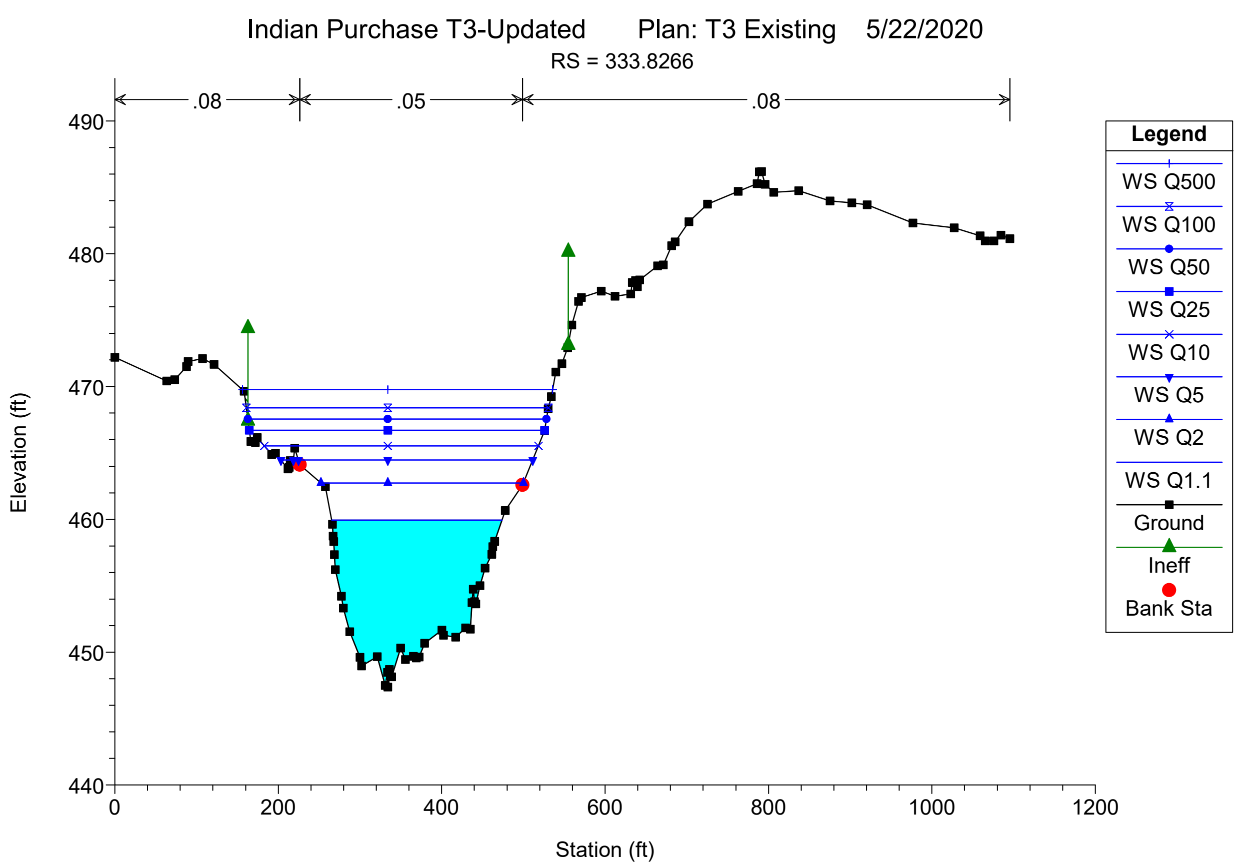
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Ineff
Bank Sta



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.05
.08
Elevation (ft)
Station (ft)
Legend
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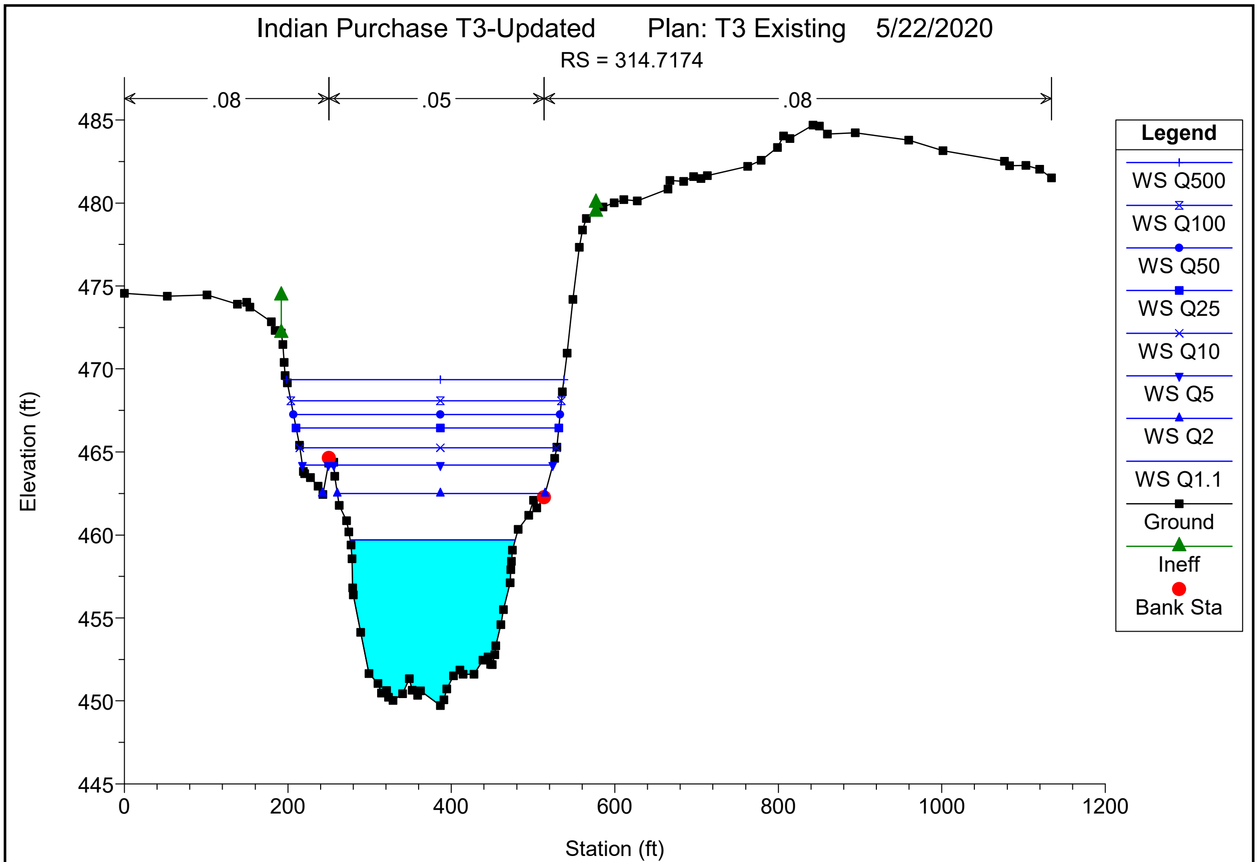
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Ineff
Bank Sta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.05
.08
Elevation (ft)
Station (ft)
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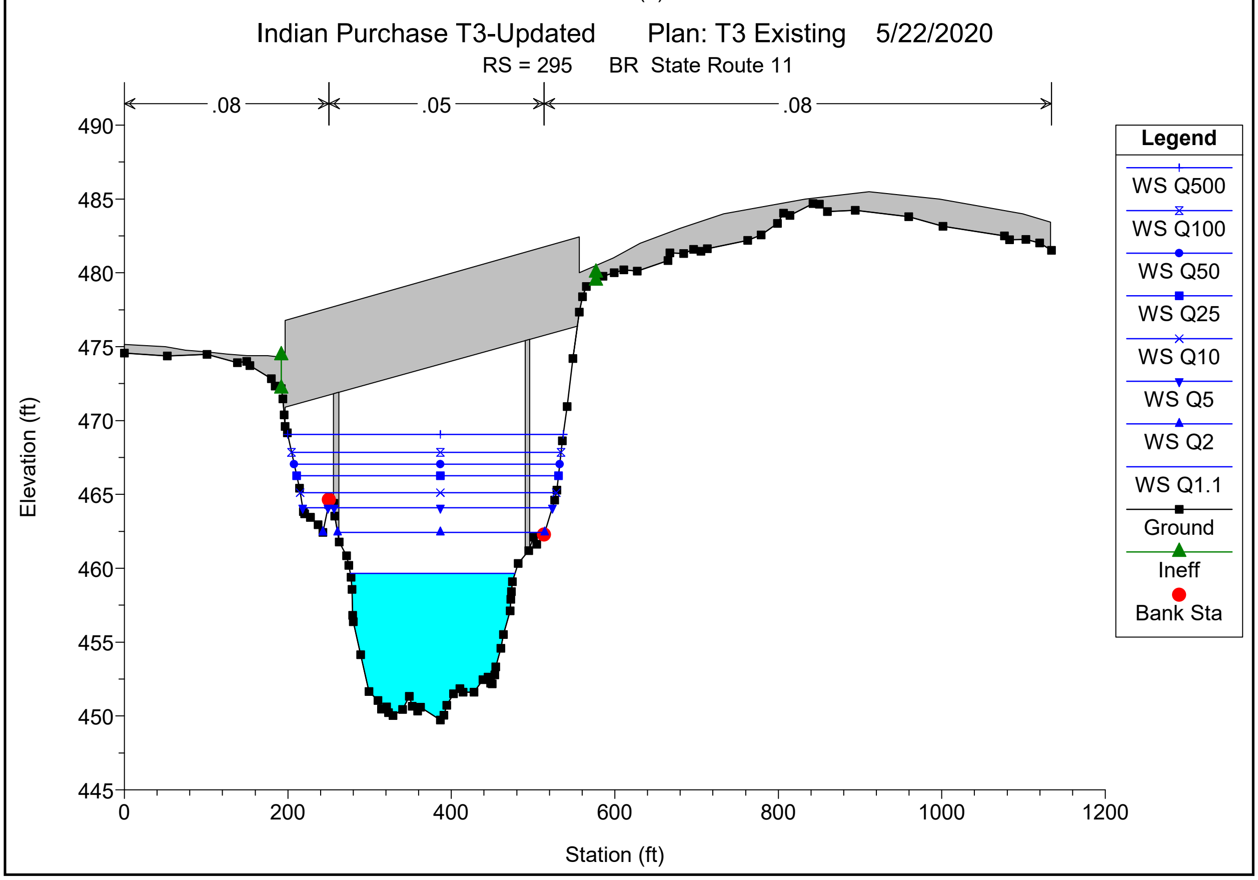
450
455
460
465
470
475
480
485
0
200
400
600
800
1000
1200
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Ineff
Bank Sta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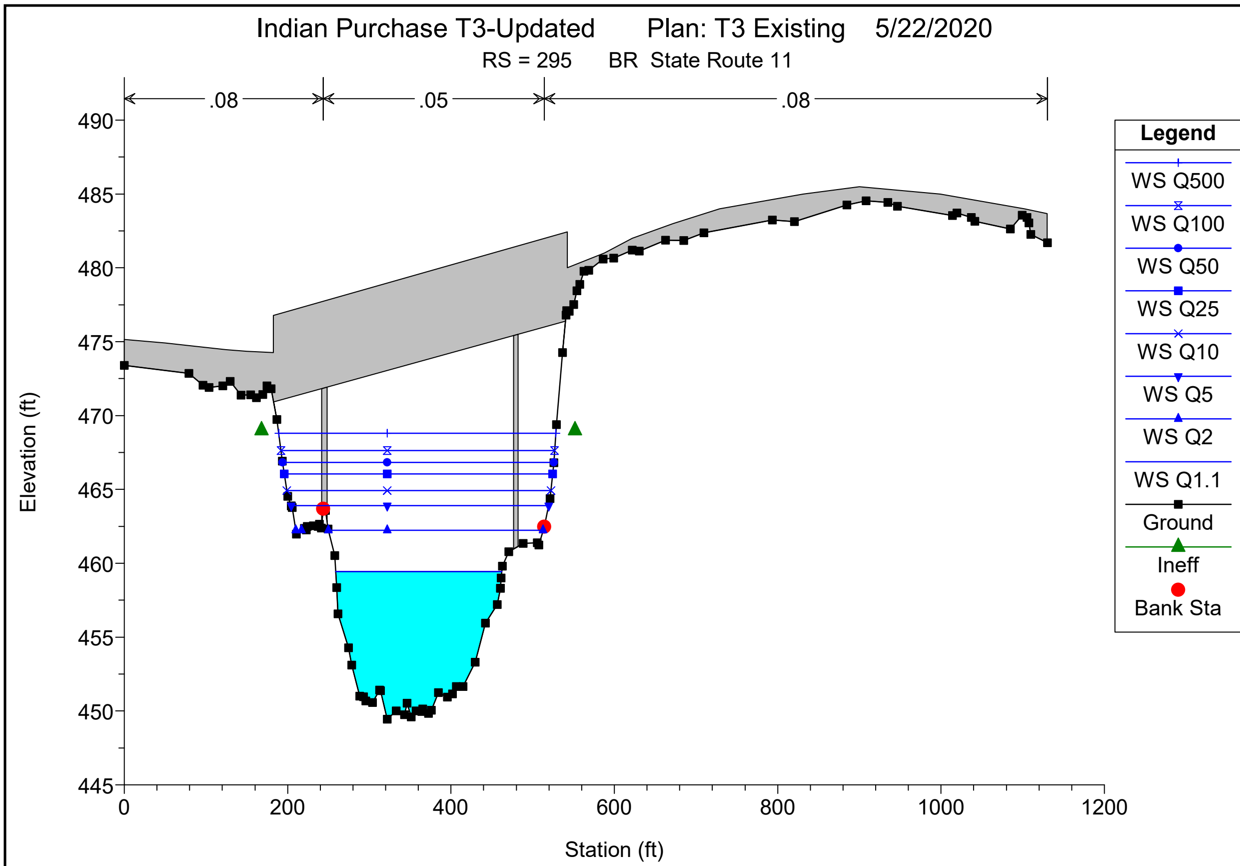
RS = 295 BR State Route 11
.08
.05
.08
Elevation (ft)
Station (ft)
445
450
455
460
465
470
475
480
485
490
0
200
400
600
800
1000
1200
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Ineff
Bank Sta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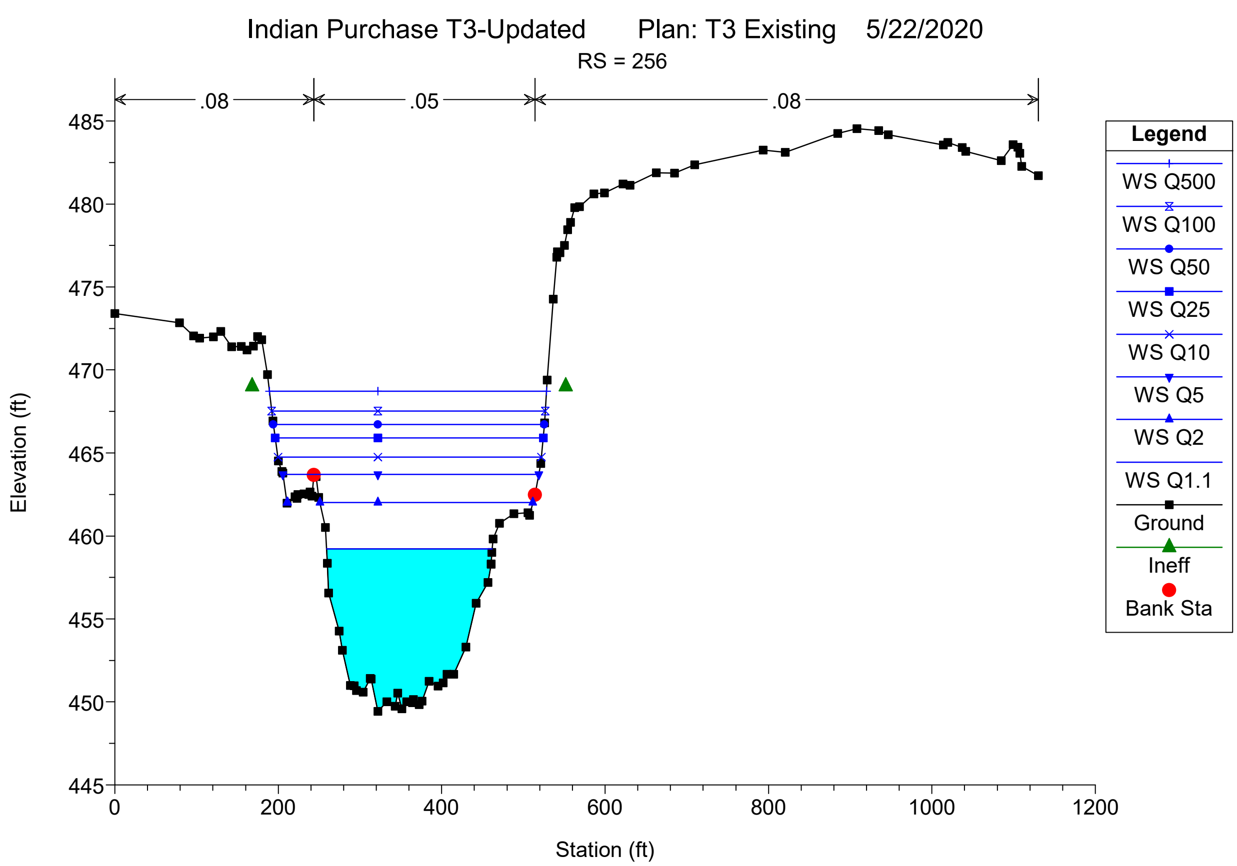
.08
.05
.08
Elevation (ft)
Station (ft)
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Ineff
Bank Sta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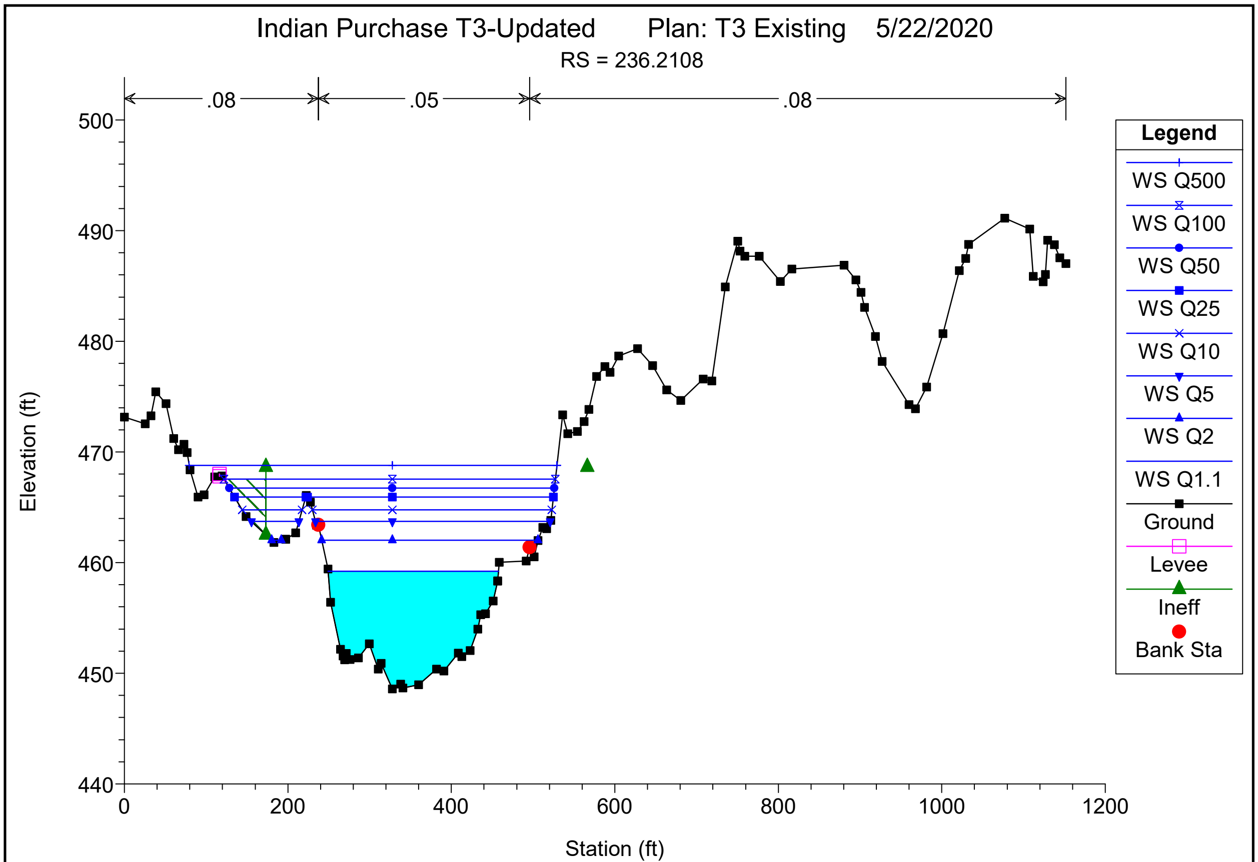
.08
.05
.08
Elevation (ft)
Station (ft)
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Ineff
Bank Sta



Indian Purchase T3-Updated Plan: T3 Existing 5/22/2020
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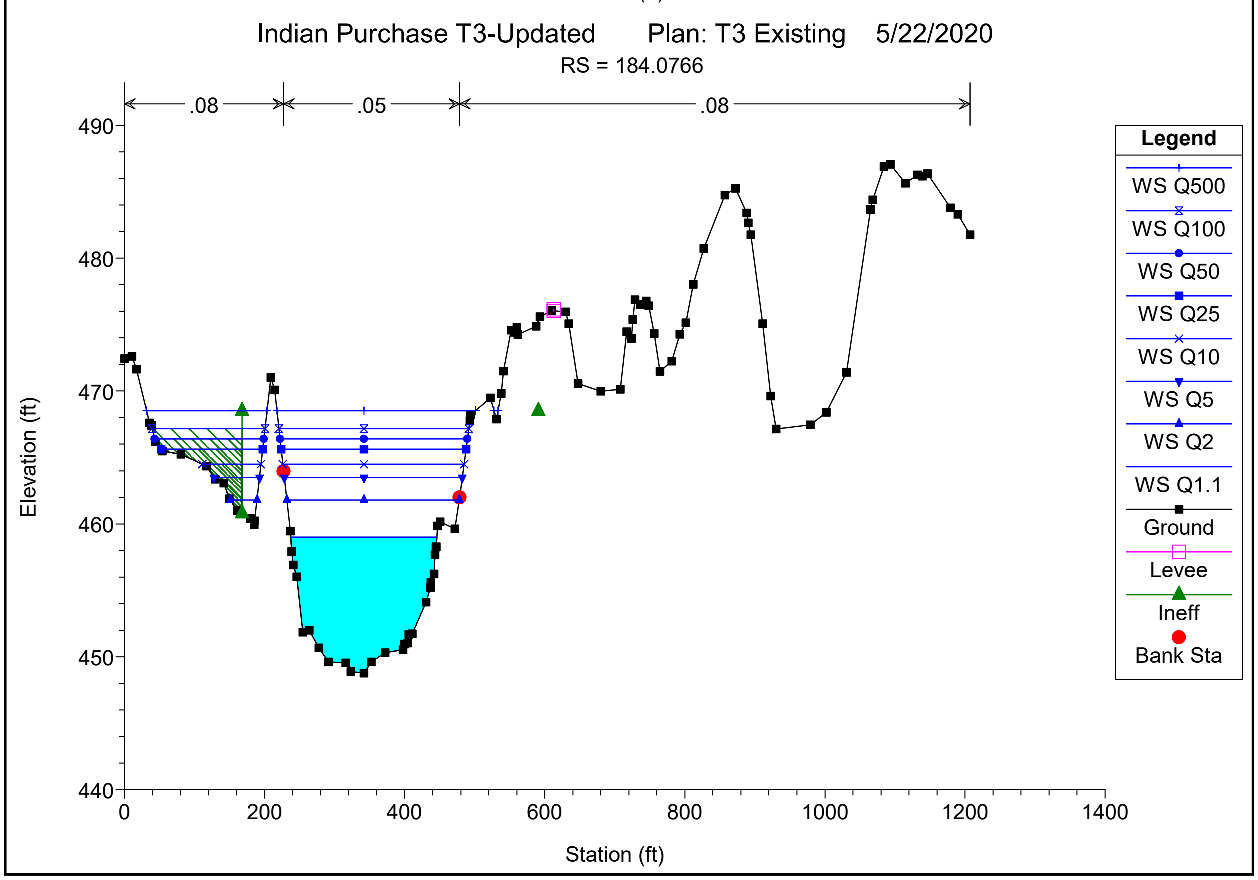
.08
.05
.08
Elevation (ft)
Station (ft)
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Levee
Ineff
Bank Sta



Indian Purchase T3-Updated Plan: T3 Existing 5/22/2020
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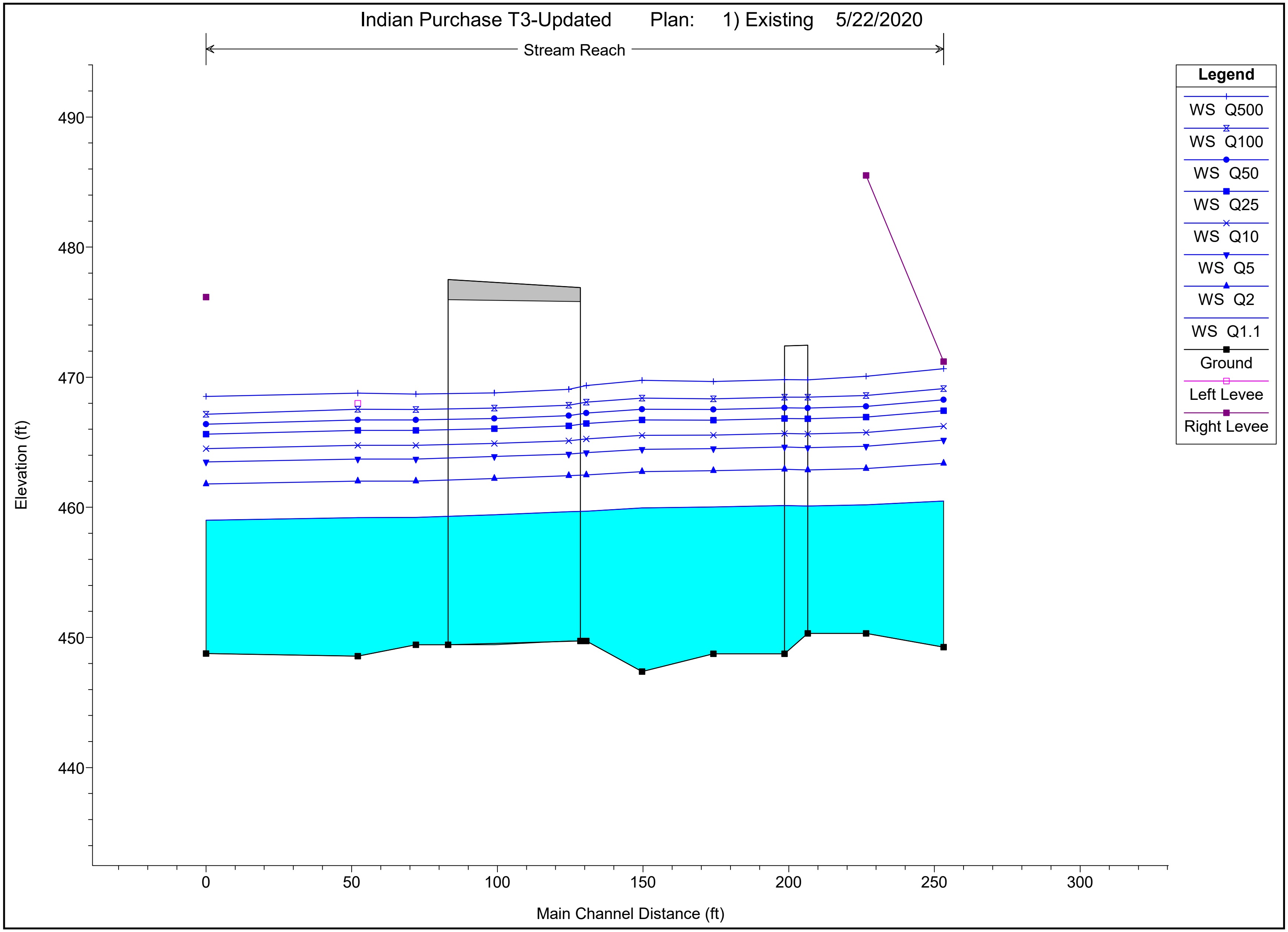
.08
.05
.08
Elevation (ft)
Station (ft)
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Levee
Ineff
Bank Sta



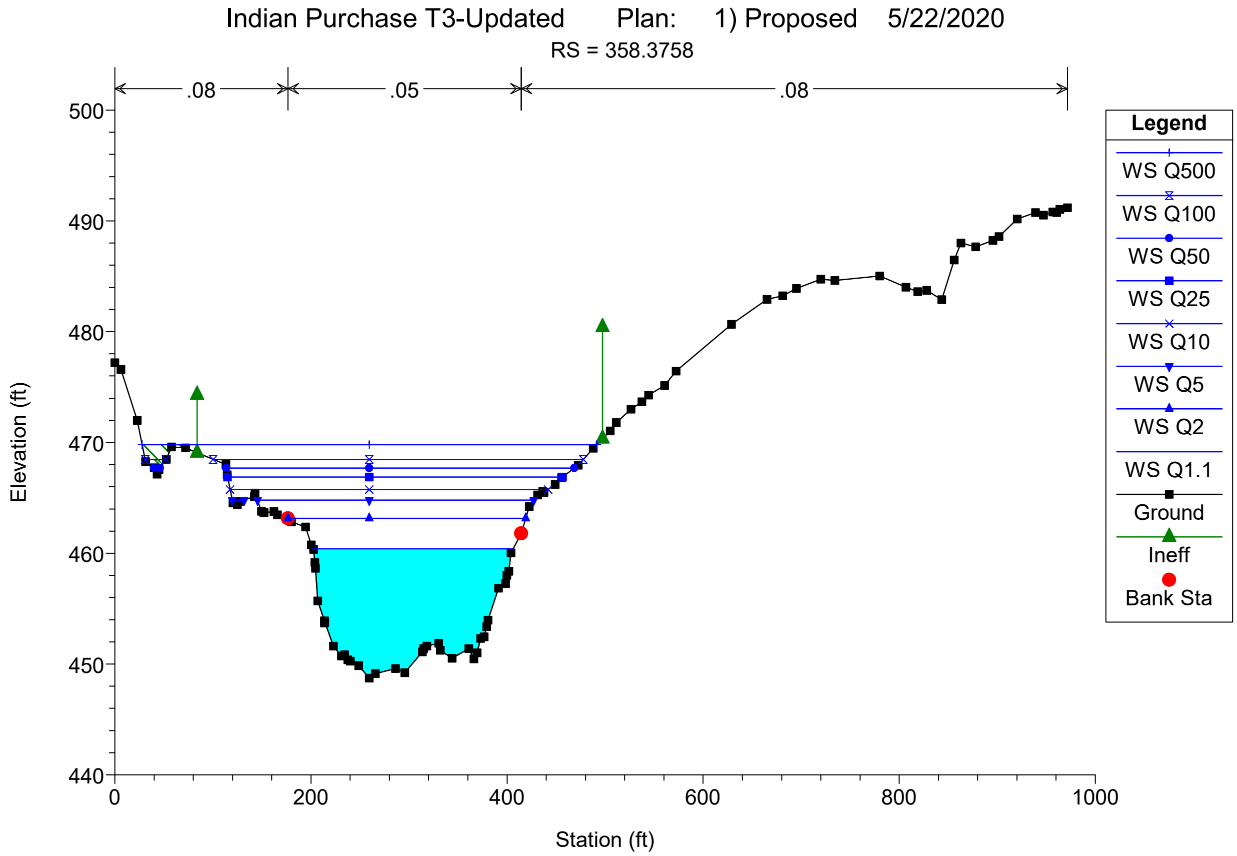
Indian Purchase T3-Updated Plan: 1) Existing 5/22/2020
Stream Reach
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Left Levee
Right Levee
Elevation (ft)
490
480
470
460
450
440
0
50
100
150
200
250
300
Main Channel Distance (ft)

APPENDIX E

Proposed HEC-RAS Analysis

HEC-RAS Plan: Proposed River: Stream Reach: Reach

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach	437.3584	Q1.1	11968.10	449.26	460.79	456.31	461.40	0.002837	6.27	1908.40	238.79	0.39
Reach	437.3584	Q2	18731.40	449.26	463.67	458.10	464.45	0.002576	7.11	2682.26	313.92	0.39
Reach	437.3584	Q5	24687.30	449.26	465.39	459.49	466.36	0.002635	7.96	3248.82	384.06	0.40
Reach	437.3584	Q10	28703.90	449.26	466.42	460.41	467.51	0.002671	8.47	3606.37	411.76	0.41
Reach	437.3584	Q25	33501.20	449.26	467.58	461.41	468.80	0.002694	9.00	4041.33	465.16	0.42
Reach	437.3584	Q50	37024.60	449.26	468.40	462.01	469.71	0.002691	9.33	4392.70	542.37	0.42
Reach	437.3584	Q100	40710.00	449.26	469.23	462.61	470.61	0.002664	9.62	4784.03	549.66	0.42
Reach	437.3584	Q500	49194.20	449.26	470.76	464.03	472.34	0.002753	10.40	5509.38	564.70	0.44
Reach	410.7223	Q1.1	11968.10	450.31	460.53	456.67	461.31	0.003335	7.06	1694.39	197.33	0.42
Reach	410.7223	Q2	18731.40	450.31	463.31	458.42	464.34	0.003666	8.16	2328.14	271.47	0.46
Reach	410.7223	Q5	24687.30	450.31	464.96	459.79	466.25	0.003775	9.15	2835.12	337.45	0.47
Reach	410.7223	Q10	28703.90	450.31	465.96	460.65	467.40	0.003792	9.69	3177.28	346.34	0.48
Reach	410.7223	Q25	33501.20	450.31	467.09	461.81	468.68	0.003781	10.26	3581.09	374.27	0.49
Reach	410.7223	Q50	37024.60	450.31	467.90	462.55	469.58	0.003745	10.60	3897.66	415.15	0.49
Reach	410.7223	Q100	40710.00	450.31	468.72	463.42	470.49	0.003688	10.92	4247.24	437.04	0.49
Reach	410.7223	Q500	49194.20	450.31	470.20	465.06	472.22	0.003795	11.77	4920.40	476.35	0.51
Reach	385		Bridge									
Reach	358.3758	Q1.1	11968.10	448.74	460.40	456.10	461.11	0.003006	6.77	1768.91	204.15	0.41
Reach	358.3758	Q2	18731.40	448.74	463.16	457.95	464.13	0.003385	7.89	2375.90	242.67	0.44
Reach	358.3758	Q5	24687.30	448.74	464.79	459.35	466.02	0.003535	8.92	2814.28	293.87	0.46
Reach	358.3758	Q10	28703.90	448.74	465.77	460.21	467.17	0.003623	9.53	3118.39	324.46	0.47
Reach	358.3758	Q25	33501.20	448.74	466.88	461.28	468.46	0.003665	10.15	3489.89	341.63	0.48
Reach	358.3758	Q50	37024.60	448.74	467.68	461.99	469.37	0.003663	10.53	3767.57	360.64	0.49
Reach	358.3758	Q100	40710.00	448.74	468.48	462.84	470.29	0.003665	10.92	4058.80	398.88	0.49
Reach	358.3758	Q500	49194.20	448.74	469.81	464.25	471.97	0.003953	11.99	4587.97	463.79	0.52
Reach	333.8266	Q1.1	11968.10	447.37	460.33	456.02	461.03	0.003121	6.72	1779.67	211.64	0.41
Reach	333.8266	Q2	18731.40	447.37	463.10	457.89	464.03	0.003492	7.75	2418.37	257.00	0.44
Reach	333.8266	Q5	24687.30	447.37	464.75	459.32	465.91	0.003801	8.63	2884.38	309.54	0.47
Reach	333.8266	Q10	28703.90	447.37	465.75	460.22	467.04	0.003774	9.13	3211.73	340.07	0.48
Reach	333.8266	Q25	33501.20	447.37	466.89	461.25	468.32	0.003710	9.65	3617.25	362.40	0.48
Reach	333.8266	Q50	37024.60	447.37	467.71	462.01	469.23	0.003638	9.96	3914.62	366.26	0.48
Reach	333.8266	Q100	40710.00	447.37	468.53	462.79	470.14	0.003567	10.26	4216.60	370.53	0.48
Reach	333.8266	Q500	49194.20	447.37	469.89	464.36	471.79	0.003770	11.21	4722.51	382.34	0.50
Reach	314.7174	Q1.1	11968.10	449.73	460.11	456.64	460.95	0.003985	7.36	1627.10	205.58	0.46
Reach	314.7174	Q2	18731.40	449.73	462.89	458.39	463.95	0.004233	8.24	2276.05	264.53	0.49
Reach	314.7174	Q5	24687.30	449.73	464.52	459.81	465.82	0.004317	9.15	2744.10	306.42	0.50
Reach	314.7174	Q10	28703.90	449.73	465.51	460.80	466.95	0.004311	9.66	3053.76	315.67	0.51
Reach	314.7174	Q25	33501.20	449.73	466.63	462.01	468.23	0.004235	10.20	3411.13	322.45	0.51
Reach	314.7174	Q50	37024.60	449.73	467.43	462.64	469.13	0.004167	10.55	3670.05	327.27	0.51
Reach	314.7174	Q100	40710.00	449.73	468.23	463.27	470.04	0.004105	10.90	3934.15	332.11	0.51
Reach	314.7174	Q500	49194.20	449.73	469.50	464.72	471.69	0.004425	11.99	4362.75	340.75	0.54
Reach	295		Bridge									
Reach	256	Q1.1	11968.10	449.44	459.22	456.67	460.28	0.005746	8.27	1447.80	202.67	0.55
Reach	256	Q2	18731.40	449.44	462.01	458.48	463.28	0.005999	9.06	2067.78	261.64	0.57
Reach	256	Q5	24687.30	449.44	463.72	459.82	465.19	0.005622	9.76	2571.35	313.24	0.56
Reach	256	Q10	28703.90	449.44	464.76	460.74	466.35	0.005298	10.17	2902.65	322.50	0.56
Reach	256	Q25	33501.20	449.44	465.91	462.09	467.64	0.005021	10.62	3277.53	327.91	0.55
Reach	256	Q50	37024.60	449.44	466.72	462.74	468.54	0.004857	10.92	3543.06	331.69	0.55
Reach	256	Q100	40710.00	449.44	467.52	463.35	469.44	0.004715	11.23	3811.98	334.75	0.55
Reach	256	Q500	49194.20	449.44	468.71	464.65	471.03	0.005098	12.37	4212.43	339.04	0.58
Reach	236.2108	Q1.1	11968.10	448.57	459.21	456.09	460.09	0.004394	7.53	1588.87	208.62	0.48
Reach	236.2108	Q2	18731.40	448.57	462.01	457.84	463.08	0.004375	8.31	2263.95	276.21	0.49
Reach	236.2108	Q5	24687.30	448.57	463.72	459.17	465.00	0.004247	9.11	2789.14	344.95	0.50
Reach	236.2108	Q10	28703.90	448.57	464.76	460.39	466.17	0.004124	9.57	3135.93	366.32	0.50
Reach	236.2108	Q25	33501.20	448.57	465.91	461.27	467.46	0.004014	10.07	3532.31	388.00	0.50
Reach	236.2108	Q50	37024.60	448.57	466.72	461.87	468.36	0.003941	10.40	3816.78	397.65	0.50
Reach	236.2108	Q100	40710.00	448.57	467.53	462.54	469.26	0.003867	10.71	4103.82	405.44	0.50
Reach	236.2108	Q500	49194.20	448.57	468.78	463.93	470.78	0.004090	11.65	4827.85	449.76	0.52
Reach	184.0766	Q1.1	11968.10	448.77	459.01	455.69	459.86	0.004104	7.39	1620.39	208.73	0.47
Reach	184.0766	Q2	18731.40	448.77	461.80	457.48	462.86	0.004103	8.25	2292.35	284.64	0.48
Reach	184.0766	Q5	24687.30	448.77	463.49	458.83	464.78	0.004101	9.13	2756.01	319.21	0.49
Reach	184.0766	Q10	28703.90	448.77	464.51	459.69	465.95	0.004102	9.67	3042.13	342.92	0.50
Reach	184.0766	Q25	33501.20	448.77	465.62	460.89	467.24	0.004101	10.28	3364.54	409.16	0.51
Reach	184.0766	Q50	37024.60	448.77	466.39	461.55	468.14	0.004100	10.68	3593.41	423.52	0.51
Reach	184.0766	Q100	40710.00	448.77	467.16	462.17	469.04	0.004106	11.09	3825.03	432.11	0.52
Reach	184.0766	Q500	49194.20	448.77	468.53	463.49	470.57	0.004092	11.77	4814.03	461.37	0.52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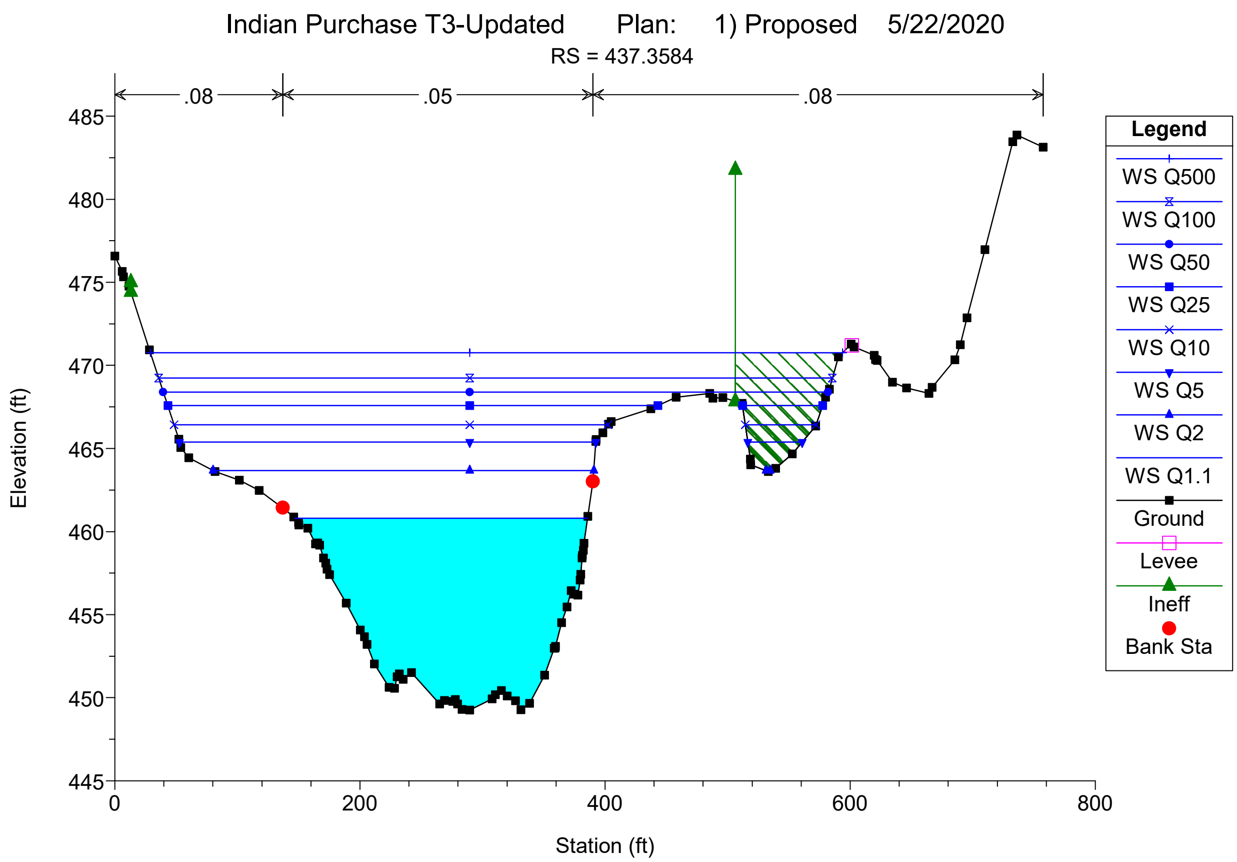
RS = 358.3758
.08
.05
.08
Elevation (ft)
Station (ft)
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Ineff
Bank Sta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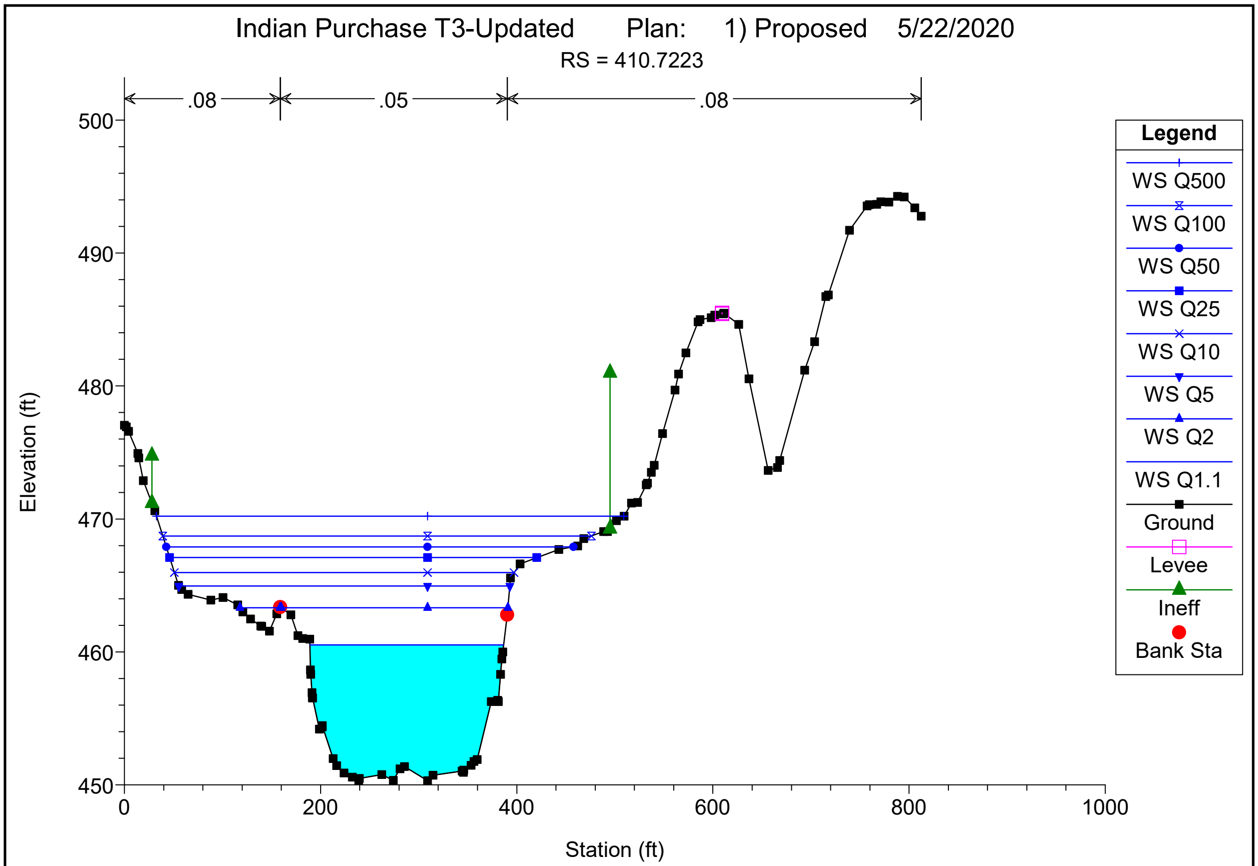
.08
.05
.08
Elevation (ft)
Station (ft)
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Levee
Ineff
Bank Sta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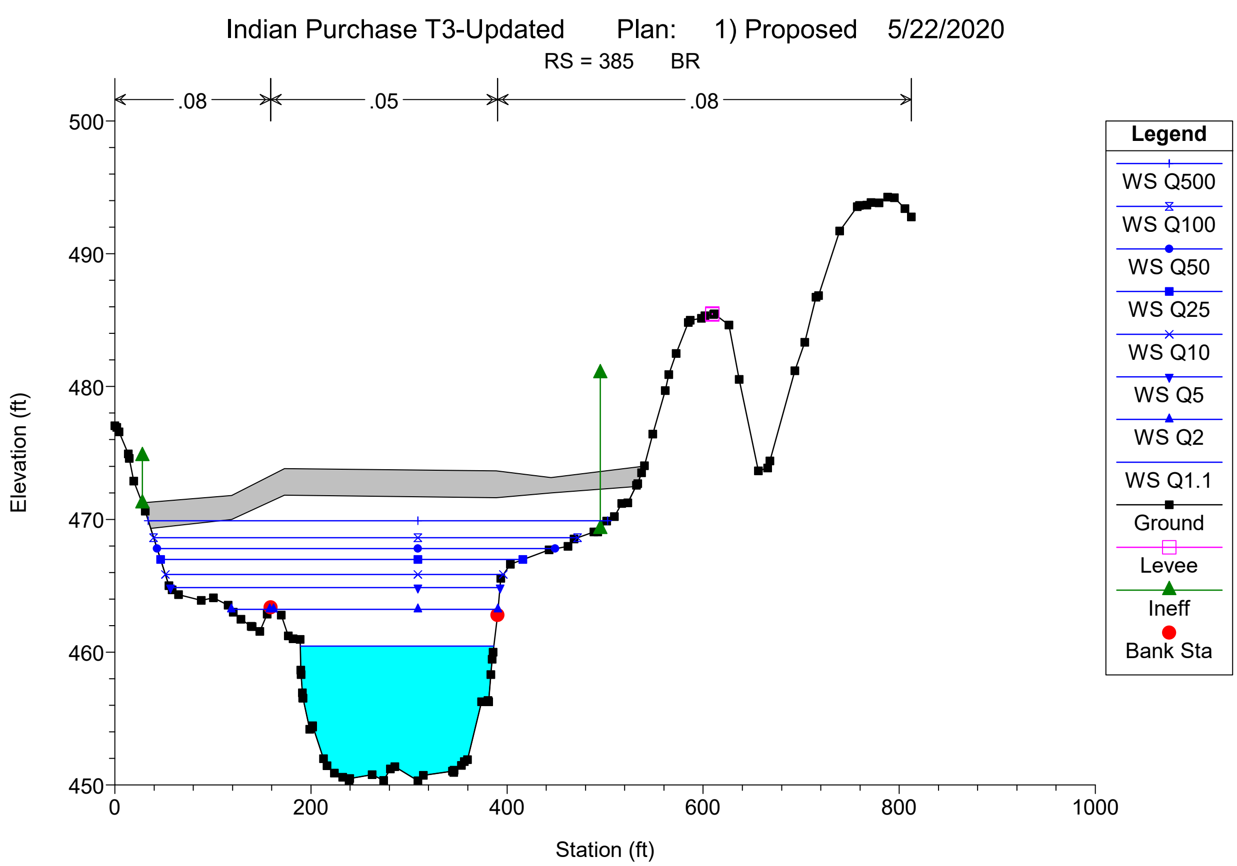
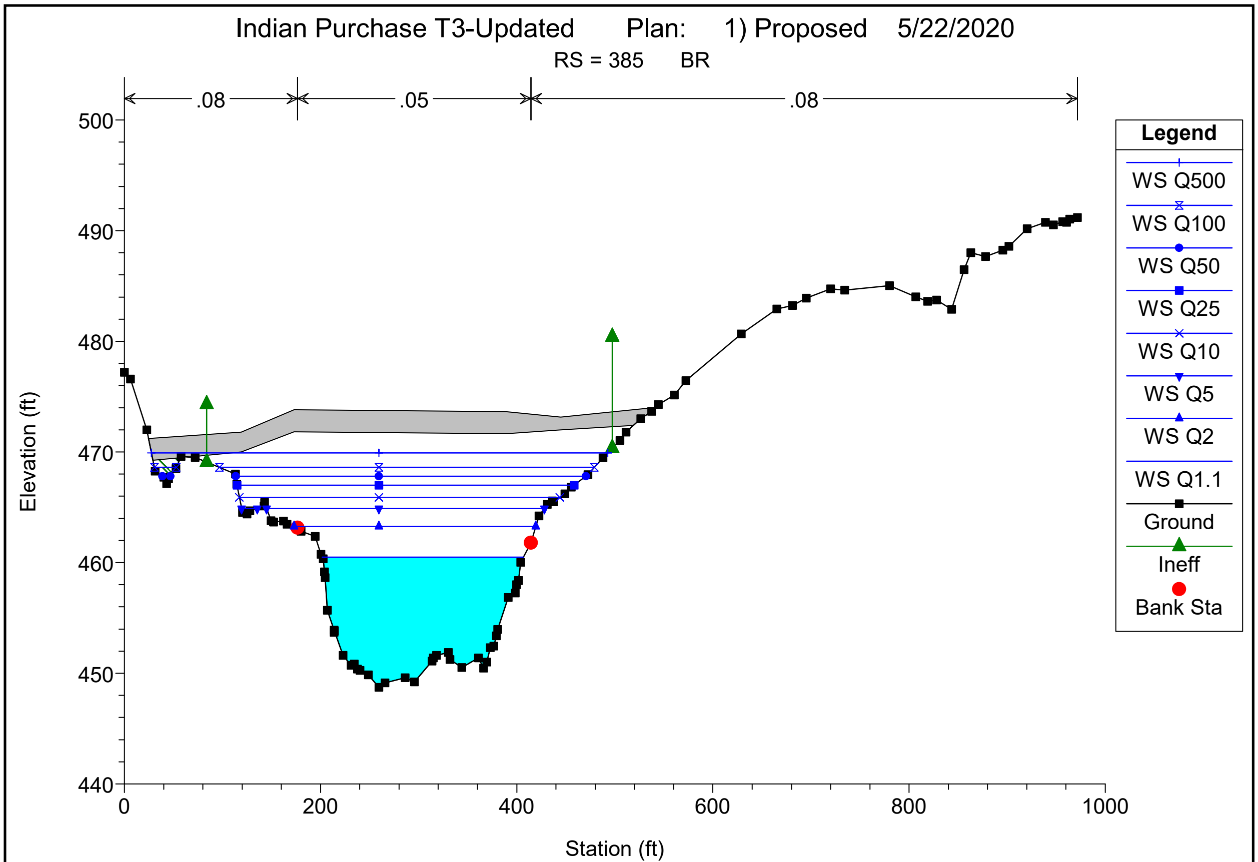
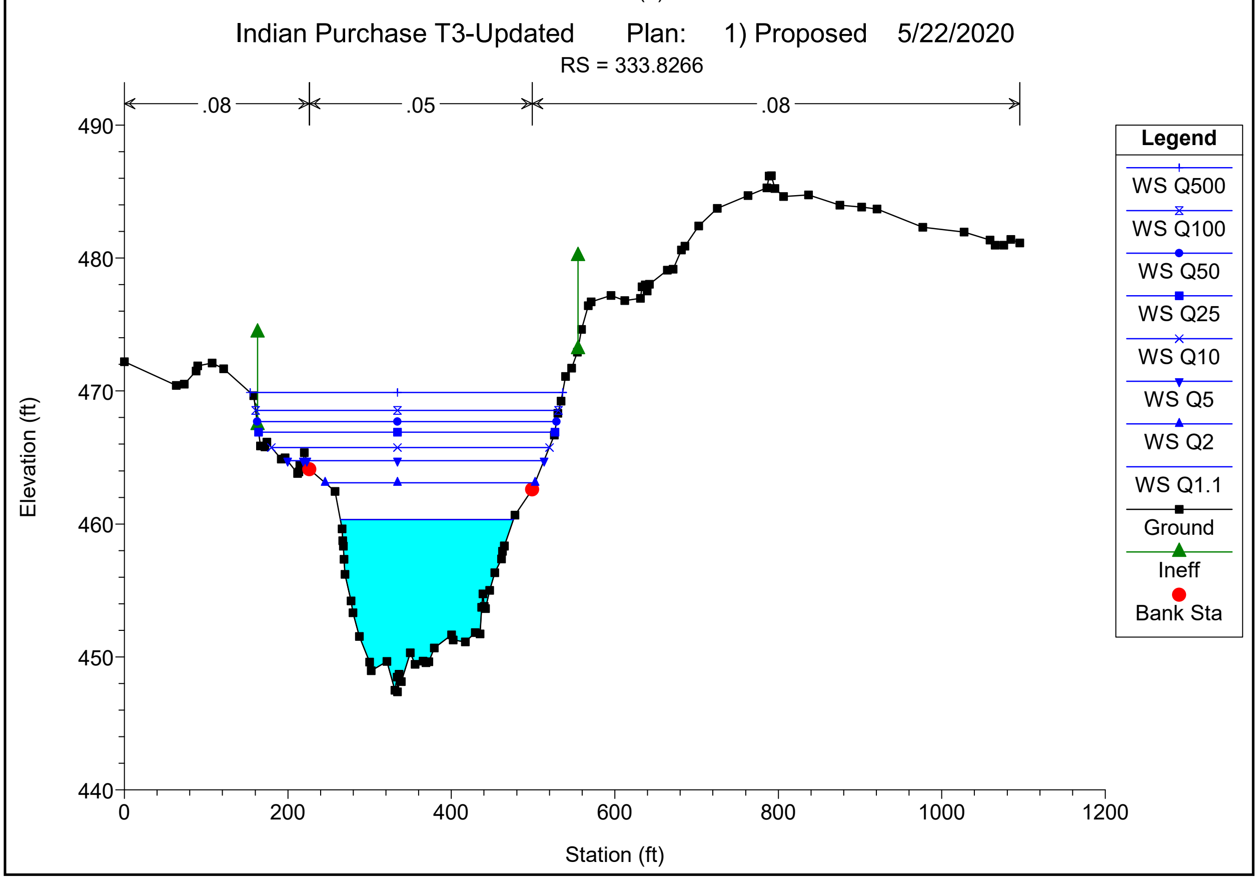
.08
.05
.08
Elevation (ft)
Station (ft)
500
490
480
470
460
450
0
200
400
600
800
1000
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Levee
Ineff
Bank Sta


Indian Purchase T3-Updated Plan: 1) Proposed 5/22/2020
RS = 385 BR
.08
.05
.08
Elevation (ft)
Station (ft)
500
490
480
470
460
450
0
200
400
600
800
1000
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Levee
Ineff
Bank Sta


Indian Purchase T3-Updated Plan: 1) Proposed 5/22/2020
RS = 385 BR
.08
.05
.08
Elevation (ft)
Station (ft)
500
490
480
470
460
450
440
0
200
400
600
800
1000
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Ineff
Bank Sta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RS = 333.8266
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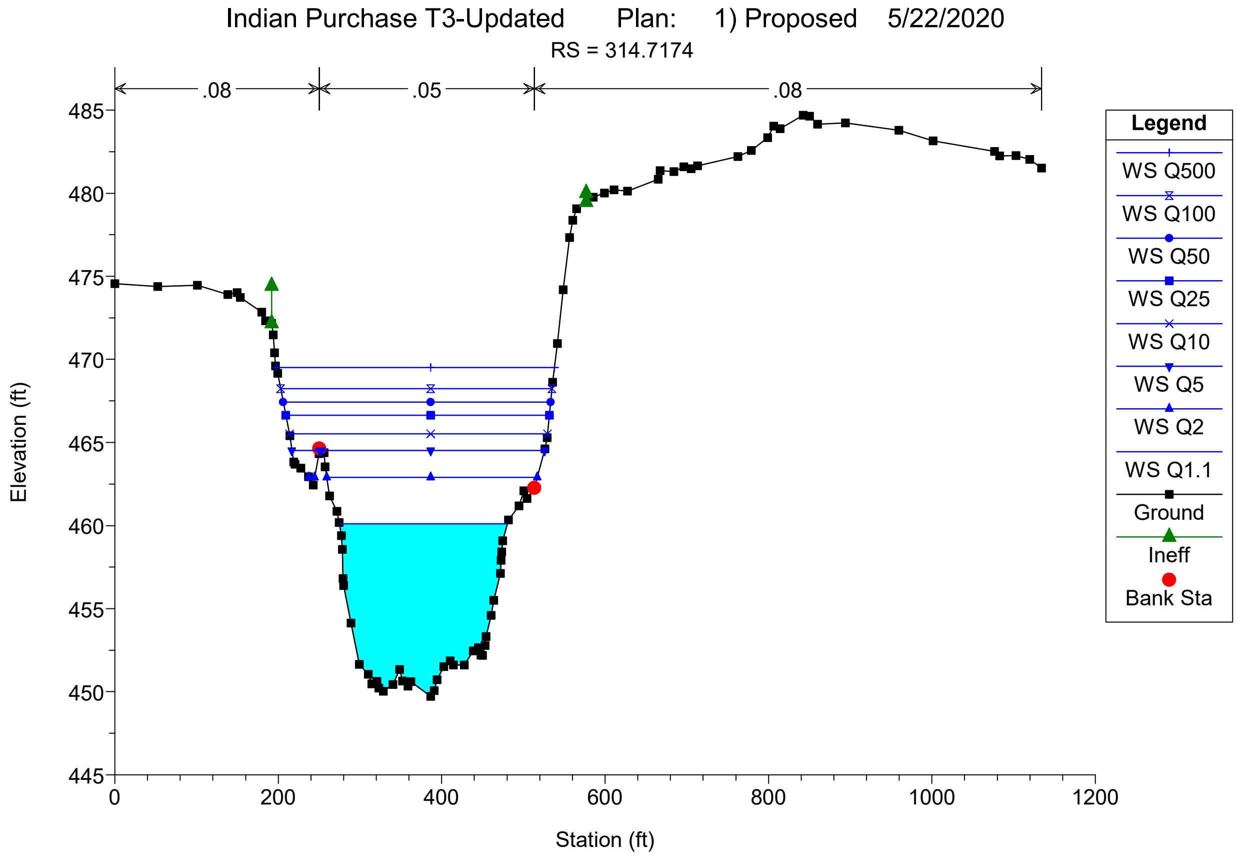
.05
.08
Elevation (ft)
Station (ft)
490
480
470
460
450
440
0
200
400
600
800
1000
1200
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Ineff
Bank Sta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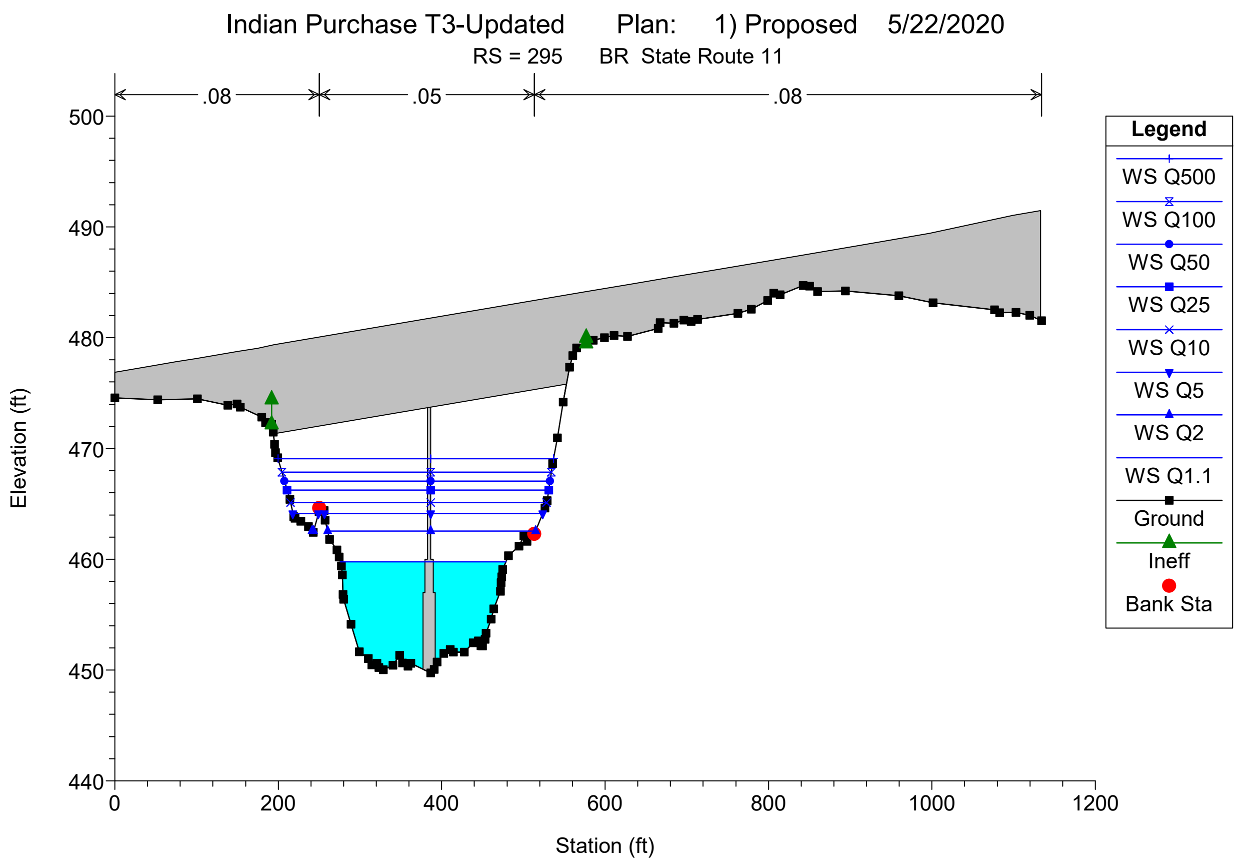
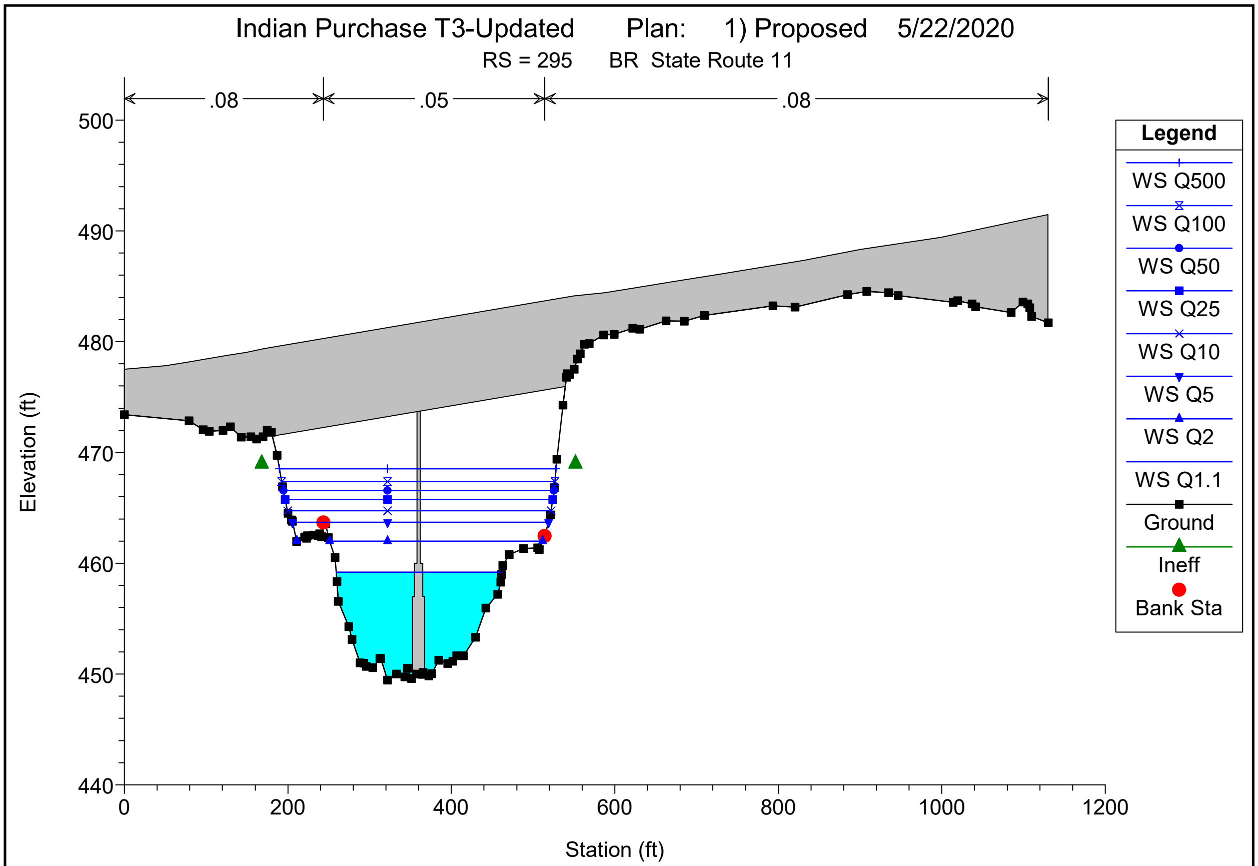
.08
.05
.08
Elevation (ft)
Station (ft)
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Ineff
Bank Sta


Indian Purchase T3-Updated Plan: 1) Proposed 5/22/2020
RS = 295 BR State Route 11
.08
.05
.08
Elevation (ft)
Station (ft)
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Ineff
Bank Sta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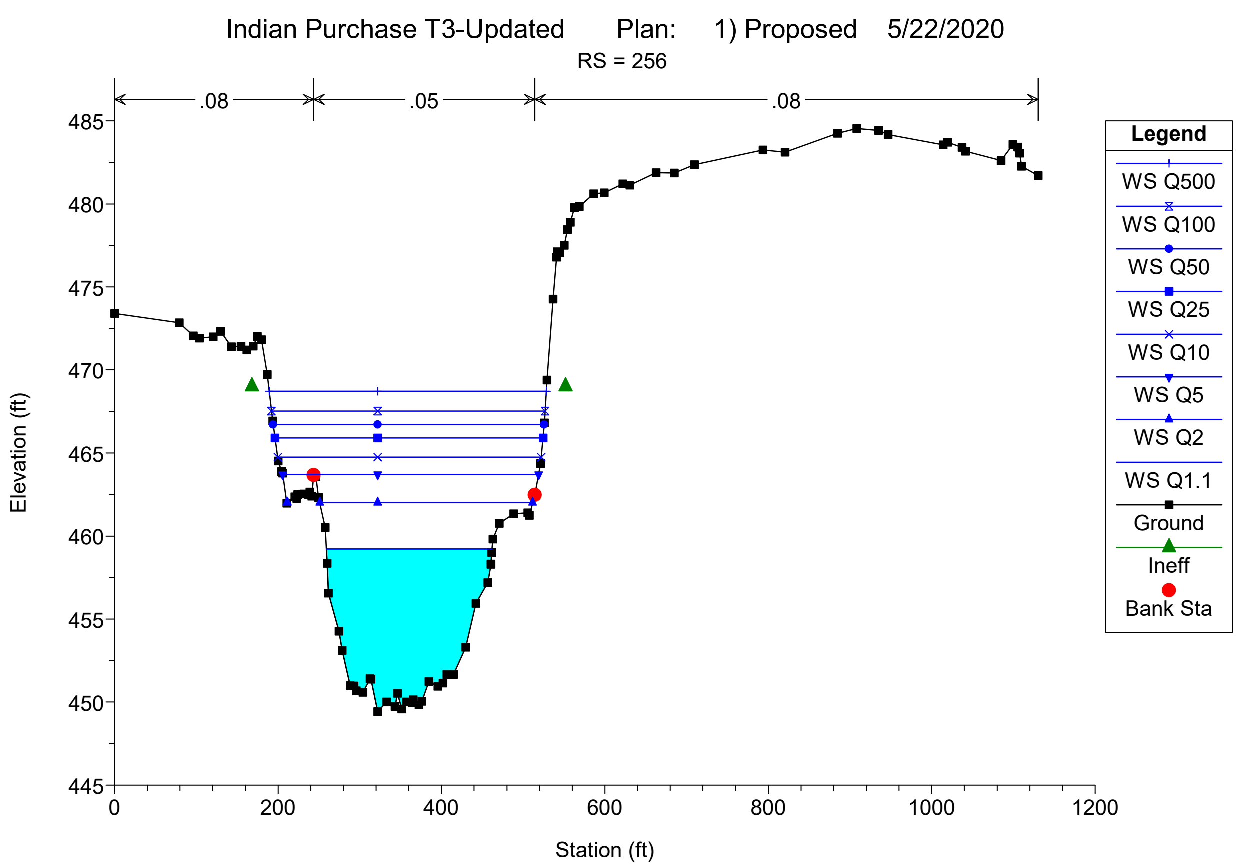
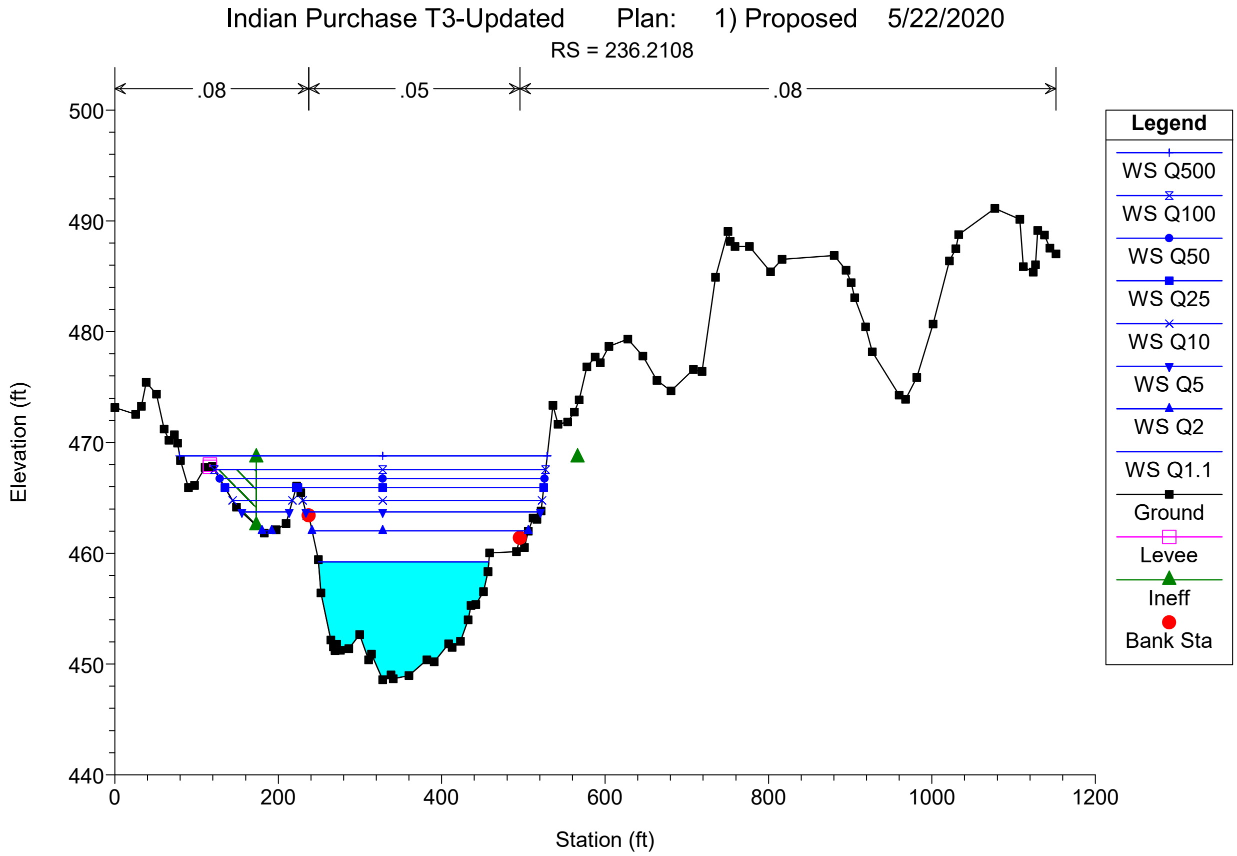
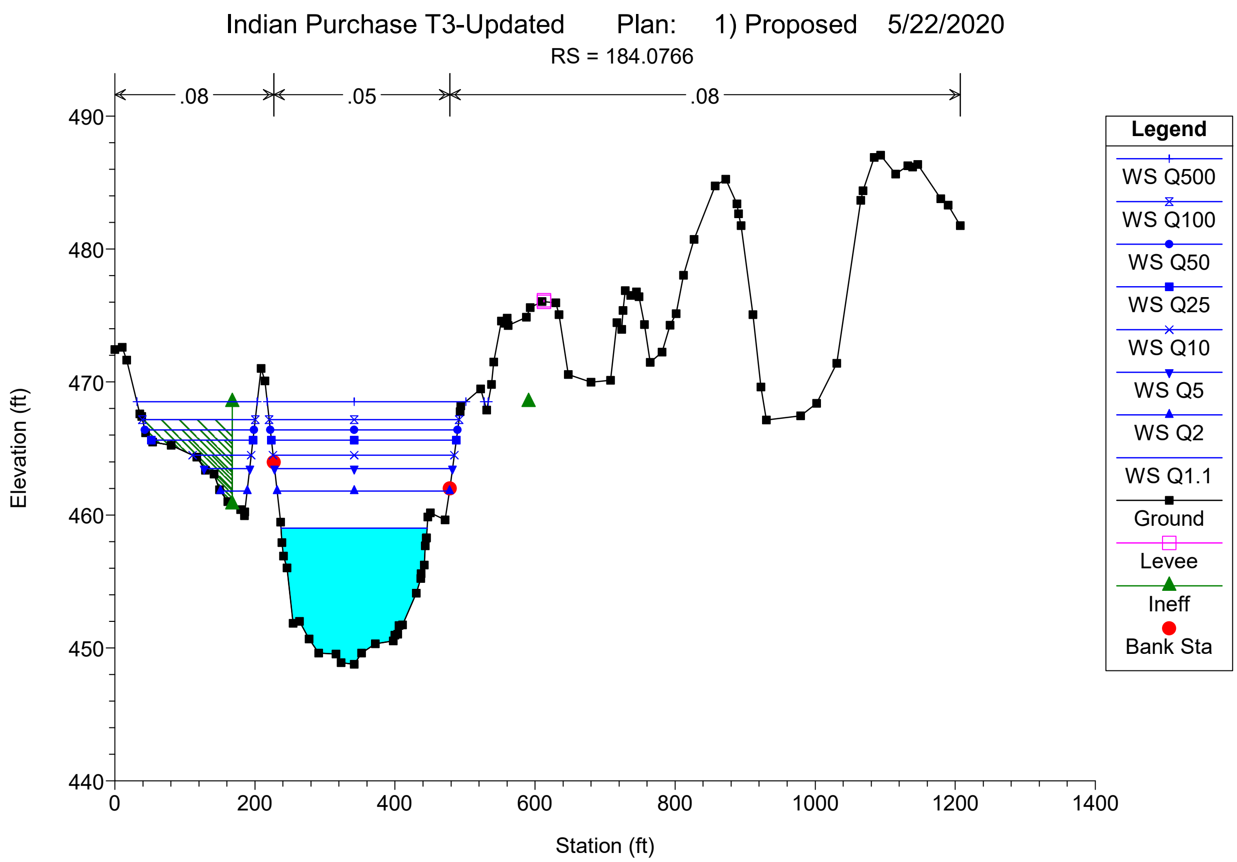
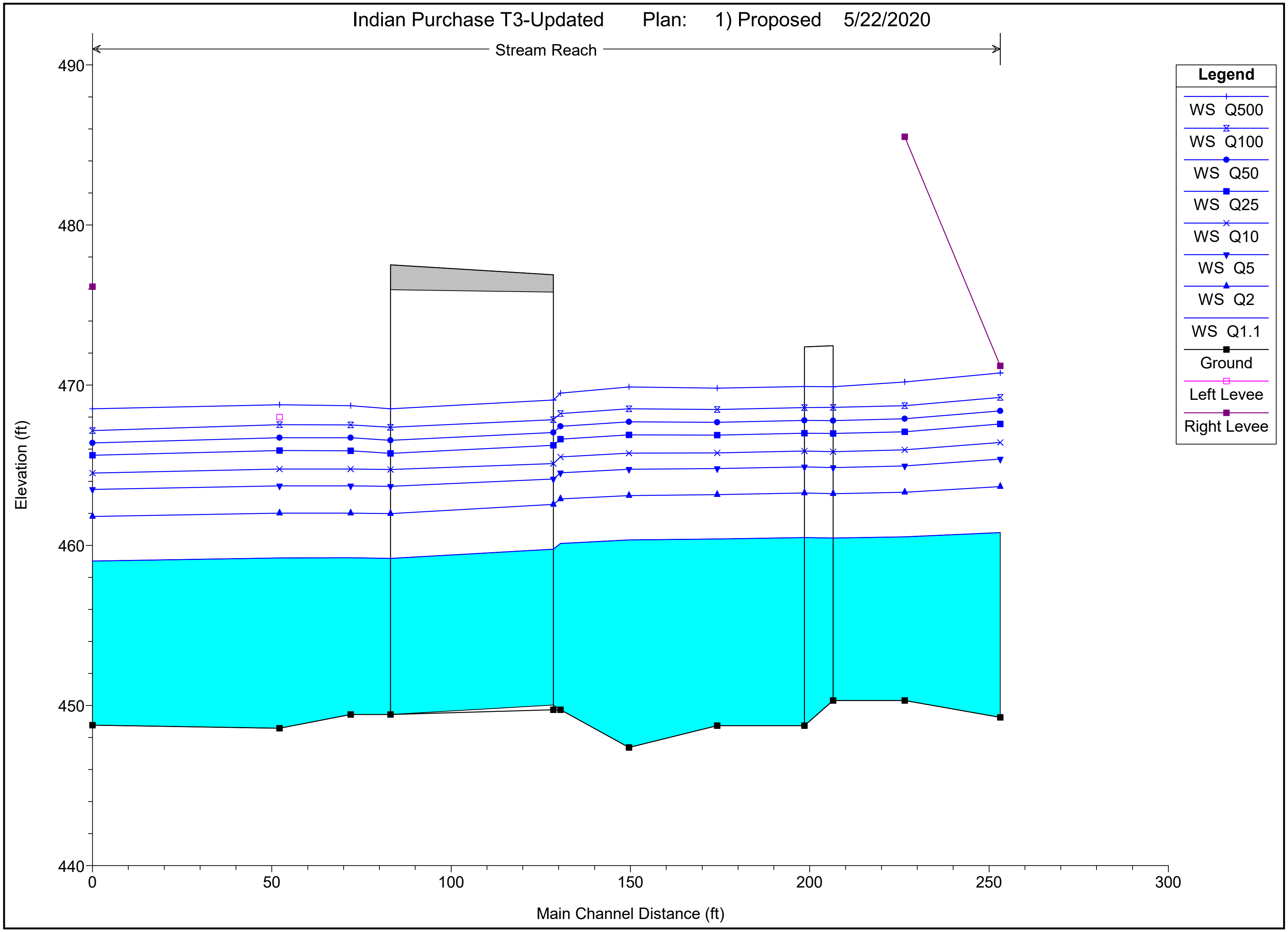
RS = 295 BR State Route 11
.08
.05
.08
Elevation (ft)
Station (ft)
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Ineff
Bank Sta


Indian Purchase T3-Updated Plan: 1) Proposed 5/22/2020
RS = 256
.08
.05
.08
Elevation (ft)
Station (ft)
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Ineff
Bank Sta


Indian Purchase T3-Updated Plan: 1) Proposed 5/22/2020
RS = 236.2108
.08
.05
.08
Elevation (ft)
Station (ft)
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Levee
Ineff
Bank Sta


Indian Purchase T3-Updated Plan: 1) Proposed 5/22/2020
RS = 184.0766
.08
.05
.08
Elevation (ft)
Station (ft)
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Levee
Ineff
Bank Sta



Indian Purchase T3-Updated Plan: 1) Proposed 5/22/2020
Stream Reach
Legend
WS Q500
WS Q100
WS Q50
WS Q25
WS Q10
WS Q5
WS Q2
WS Q1.1
Ground
Left Levee
Right Levee
Elevation (ft)
490
480
470
460
450
440
0
50
100
150
200
250
300
Main Channel Distance (ft)

APPENDIX F

Scour Analysis

Scour Analysis: 100-year storm U/S face of Route 11 over W Branch Penobscot River

Aggradation/Degradation | | ***ft***

Live Bed Vs. Clear Water

Depth of flow, y1	14.26	ft
Particle size in a mix of which 50% are smaller, D50 (m)	0.00368	m
Particle size in a mix of which 50% are smaller, D50 (ft)	0.01207	ft
Velocity of main Channel, V	10.26	ft/s
Critical Velocity, Vc	3.99	ft/s

$$V_c = K_u y^{1/6} D^{1/3}$$

Ku = 11.17

(HEC-18, 5th Edition, April 2012, Equation 6.1)

Live Bed vs. Clear Water Live Bed ←Type of Contraction Scour Analysis to be completed

Live Bed Scour

Avg depth in U/S main channel, y1	14.26	ft
Ex depth in the contracted section before scour, yo	13.94	ft
Flow in the U/S channel transporting sediment Q1	39887.97	ft^3/s
Flow in the contracted channel, Q2	39930.99	ft^3/s
Top width of U/S main channel, W1	272.55	ft
Top width of the main channel in the contracted section, W2	262.9	ft
Fall Velocity, ω	0.95	ft/s
Slope of energy grade line of main channel, S1	0.003567	ft/ft
Shear Velocity, Vα	1.28	
Vα/ω	1.35	
Exponent, k1	0.64	
Avg depth in contracted section, y2	14.61	
****Scour depth, ys***	**0.67**	***ft***

$$V_\alpha = (g y_1 S_1)^{1/2}$$

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{\frac{6}{7}} \left(\frac{W_1}{W_2}\right)^{k_1}$$

$$y_s = y_2 - y_0$$

(HEC-18, 5th Edition, April 2012, Equations 6.2 and 6.3)

**** If calculated y_s returns negative answer, the scour depth equals zero***

Proj. W Branch Bridge	Job No. 63738	Sheet No. 2 OF 7
Made by KAR	Checked by SPA	Backchecked by KAR
Date 9-19-2019	Date 9-23-2019	Date 9-24-2019

HNTB

Scour Analysis: 100-year storm U/S face of Route 11 over W Branch Penobscot River

Local Scour Live Bed Scour - Pier

Flow depth directly upstream of pier, Y1	13.85	ft
Correction factor for pier nose shape, K1	0.90	
Correction factor for angle of attack of flow, K2	1.00	
Correction factor for bed condition, K3	1.10	
Correction factor for armoring by bed material size, K4	1.00	
Pier Width, a	5.42	ft
Length of Pier, L	35.00	ft
Froude Number directly upstream of pier, Fr1	**0.52**	
Mean velocity of flow directly upstream of pier, V1	10.97	ft/s
Acceleration of gravity, g	32.20	
Scour Depth, ys	**11.25**	***ft***

$$\frac{y_s}{a} = 2.0K_1K_2K_3K_4\left(\frac{y_1}{a}\right)^{0.35} {Fr_1}^{0.43}$$

(HEC-18, 5th Edition, April 2012, Equation 7.3)

Proj. W Branch Bridge	Job No. 63738	Sheet No. 3 OF 7
Made by KAR	Checked by SPA	Backchecked by KAR
Date 9-19-2019	Date 9-23-2019	Date 9-24-2019

HNTB

Scour Analysis: 100-year storm U/S face of Route 11 over W Branch Penobscot River

Local Scour at Abutments
Near Abutment

Coefficient for Abutment Shape, K1	0.55	
Coefficient for angle of embankment to flow, K2	1.00	
Length of active flow obstructed by embankment, L'	5.00	ft
Average depth of flow on embankment, ya	3.92	ft
Velocity on embankment, Ve	2.95	ft/s
Froude Number of approach flow = $V_e/(gy_a)^{1/2}$	**0.263**	
Length of embankment projected to normal flow, L		ft

$$\frac{y_s}{y_a} = 2.27K_1K_2\left(\frac{L'}{y_a}\right)^{0.43}(Fr)^{0.61} + 1$$

Near Abutment Scour Depth, ys **6.32** ***ft***

(HEC-18, 5th Edition, April 2012, Equation 8.1)

Far Abutment

Coefficient for Abutment Shape, K1	0.55	
Coefficient for angle of embankment to flow, K2	1.00	
Length of active flow obstructed by embankment, L'	3.00	ft
Average depth of flow on embankment, ya	3.63	ft
Velocity on embankment, Ve	2.76	ft/s
Froude Number of approach flow = $V_e/(gy_a)^{1/2}$	**0.255**	
Length of embankment projected to normal flow, L		ft

$$\frac{y_s}{y_a} = 2.27K_1K_2\left(\frac{L'}{y_a}\right)^{0.43}(Fr)^{0.61} + 1$$

Far Abutment Scour Depth, ys **5.45** ***ft***

(HEC-18, 5th Edition, April 2012, Equation 8.1)

Scour Analysis: 500-year storm U/S face of Route 11 over W Branch Penobscot River

Aggradation/Degradation | | *ft*

Live Bed Vs. Clear Water

Depth of flow, y1	15.53	ft
Particle size in a mix of which 50% are smaller, D50 (m)	0.00368	m
Particle size in a mix of which 50% are smaller, D50 (ft)	0.01207	ft
Velocity of main Channel, V	11.28	ft/s
Critical Velocity, Vc	4.05	ft/s

(HEC-18, 5th Edition, April 2012, Equation 6.1)

Live Bed vs. Clear Water — Live Bed ←Type of Contraction Scour Analysis to be completed

Live Bed Scour

Avg depth in U/S main channel, y1	15.53	ft
Ex depth in the contracted section before scour, yo	15.11	ft
Flow in the U/S channel transporting sediment Q1	47778.61	ft^3/s
Flow in the contracted channel, Q2	47989.06	ft^3/s
Top width of U/S main channel, W1	272.55	ft
Top widthof the main channel in the contracted section, W2	262.9	ft
Fall Velocity, ω	0.95	ft/s
Slope of energy grade line of main channel, S1	0.00377	ft/ft
Shear Velocity, Vα	1.37	
Vα/ω	1.45	
Exponent, k1	0.64	
Avg depth in contracted section, y2	15.95	
Scour depth, ys	**0.84**	***ft***

$$V_\alpha = (g y_1 S_1)^{1/2}$$

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{\frac{6}{7}} \left(\frac{W_1}{W_2}\right)^{k_1}$$

$$y_s = y_2 - y_0$$

(HEC-18, 5th Edition, April 2012, Equations 6.2 and 6.3)

**** If calculated y_s returns negative answer, the scour depth equals zero***

Scour Analysis: 500-year storm U/S face of Route 11 over W Branch Penobscot River

Local Scour Live Bed Scour - Pier

Flow depth directly upstream of pier, Y1	15.11	ft
Correction factor for pier nose shape, K1	0.90	
Correction factor for angle of attack of flow, K2	1.00	
Correction factor for bed condition, K3	1.10	
Correction factor for armoring by bed material size, K4	1.00	
Pier Width, a	5.42	ft
Length of Pier, L	35.00	ft
Froude Number directly upstream of pier, Fr1	**0.55**	
Mean velocity of flow directly upstream of pier, V1	12.08	ft/s
Acceleration of gravity, g	32.20	
Scour Depth, ys	**11.86**	***ft***

$$\frac{y_s}{a} = 2.0 K_1 K_2 K_3 K_4 \left(\frac{y_1}{a}\right)^{0.35} Fr_1^{\ 0.43}$$

(HEC-18, 5th Edition, April 2012, Equation 7.3)

Scour Analysis: 500-year storm U/S face of Route 11 over W Branch Penobscot River

Local Scour at Abutments
Near Abutment

Coefficient for Abutment Shape, K1	0.55	
Coefficient for angle of embankment to flow, K2	1.00	
Length of active flow obstructed by embankment, L'	5.00	ft
Average depth of flow on embankment, ya	4.72	ft
Velocity on embankment, Ve	3.47	ft/s
Froude Number of approach flow = $V_e/(gy_a)^{1/2}$	0.281	
Length of embankment projected to normal flow, L		ft

$$\frac{y_s}{y_a} = 2.27 K_1 K_2 \left(\frac{L'}{y_a}\right)^{0.43} (Fr)^{0.61} + 1$$

(HEC-18, 5th Edition, April 2012, Equation 8.1)

Near Abutment Scour Depth, ys 7.51 ***ft***

Far Abutment

Coefficient for Abutment Shape, K1	0.55	
Coefficient for angle of embankment to flow, K2	1.00	
Length of active flow obstructed by embankment, L'	3.00	ft
Average depth of flow on embankment, ya	4.37	ft
Velocity on embankment, Ve	3.24	ft/s
Froude Number of approach flow = $V_e/(gy_a)^{1/2}$	0.273	
Length of embankment projected to normal flow, L		ft

$$\frac{y_s}{y_a} = 2.27 K_1 K_2 \left(\frac{L'}{y_a}\right)^{0.43} (Fr)^{0.61} + 1$$

(HEC-18, 5th Edition, April 2012, Equation 8.1)

Far Abutment Scour Depth, ys 6.47 ***ft***

Proj. W Branch Bridge	Job No. 63738	Sheet No. 7 OF 7
Made by KAR	Checked by SPA	Backchecked by KAR
Date 9-19-2019	Date 9-23-2019	Date 9-24-2019

HNTB

Scour Summary

	100 - year storm		
	Near Abutment	Pier	Far Abutment
Aggradation/ Degradation (ft)	0.00	0.00	0.00
Contraction/Expansion Scour (ft)	0.67	0.67	0.67
Local Scour (ft)	6.32	11.25	5.45
Pressure Flow Scour (ft)	0.00	0.00	0.00
TOTAL SCOUR (ft)	***6.99***	***11.91***	***6.11***

	500-year storm		
	Near Abutment	Pier	Far Abutment
Aggradation/ Degradation (ft)	0.00	0.00	0.00
Contraction/Expansion Scour (ft)	0.84	0.84	0.84
Local Scour (ft)	7.51	11.86	6.47
Pressure Flow Scour (ft)	0.00	0.00	0.00
TOTAL SCOUR (ft)	***8.35***	***12.70***	***7.32***

Plan: Proposed Stream Reach RS: 333.8266 Profile: Q100

E.G. Elev (ft)	470.14	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.60	Wt. n-Val.	0.080	0.050	0.080
W.S. Elev (ft)	468.53	Reach Len. (ft)	21.59	19.11	15.86
Crit W.S. (ft)	462.79	Flow Area (sq ft)	219.62	3887.74	109.24
E.G. Slope (ft/ft)	0.003567	Area (sq ft)	220.93	3887.74	109.24
Q Total (cfs)	40710.00	Flow (cfs)	550.99	39887.97	271.04
Top Width (ft)	370.53	Top Width (ft)	65.96	272.55	32.01
Vel Total (ft/s)	9.65	Avg. Vel. (ft/s)	2.51	10.26	2.48
Max Chl Dpth (ft)	21.16	Hydr. Depth (ft)	3.46	14.26	3.41
Conv. Total (cfs)	681628.8	Conv. (cfs)	9225.5	667865.0	4538.2
Length Wtd. (ft)	19.12	Wetted Per. (ft)	64.57	279.74	32.66
Min Ch El (ft)	447.37	Shear (lb/sq ft)	0.76	3.09	0.74
Alpha	1.11	Stream Power (lb/ft s)	1.90	31.75	1.85
Frctn Loss (ft)	0.07	Cum Volume (acre-ft)	0.91	12.22	0.27
C & E Loss (ft)	0.02	Cum SA (acres)	0.25	0.90	0.07

UNCONTRACTED SECTION

Plan: Proposed Stream Reach RS: 333.8266 Profile: Q500

E.G. Elev (ft)	471.79	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.90	Wt. n-Val.	0.080	0.050	0.080
W.S. Elev (ft)	469.89	Reach Len. (ft)	21.59	19.11	15.86
Crit W.S. (ft)	464.36	Flow Area (sq ft)	306.32	4259.54	156.65
E.G. Slope (ft/ft)	0.003770	Area (sq ft)	313.41	4259.54	156.65
Q Total (cfs)	49194.20	Flow (cfs)	986.26	47747.44	460.49
Top Width (ft)	382.34	Top Width (ft)	72.77	272.55	37.02
Vel Total (ft/s)	10.42	Avg. Vel. (ft/s)	3.22	11.21	2.94
Max Chl Dpth (ft)	22.52	Hydr. Depth (ft)	4.82	15.63	4.23
Conv. Total (cfs)	801236.6	Conv. (cfs)	16063.5	777672.9	7500.2
Length Wtd. (ft)	19.13	Wetted Per. (ft)	64.57	279.74	37.85
Min Ch El (ft)	447.37	Shear (lb/sq ft)	1.12	3.58	0.97
Alpha	1.13	Stream Power (lb/ft s)	3.59	40.17	2.86
Frctn Loss (ft)	0.08	Cum Volume (acre-ft)	1.28	13.34	0.36
C & E Loss (ft)	0.03	Cum SA (acres)	0.29	0.90	0.09

UNCONTRACTED SECTION

Plan: Proposed Stream Reach RS: 314.7174 Profile: Q100

E.G. Elev (ft)	470.04	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.81	Wt. n-Val.	0.080	0.050	0.080
W.S. Elev (ft)	468.23	Reach Len. (ft)	2.00	2.00	2.00
Crit W.S. (ft)	463.27	Flow Area (sq ft)	188.85	3664.88	80.42
E.G. Slope (ft/ft)	0.004105	Area (sq ft)	188.85	3664.88	80.42
Q Total (cfs)	40710.00	Flow (cfs)	557.10	39930.99	221.90
Top Width (ft)	332.11	Top Width (ft)	47.40	262.90	21.81
Vel Total (ft/s)	10.35	Avg. Vel. (ft/s)	2.95	10.90	2.76
Max Chl Dpth (ft)	18.50	Hydr. Depth (ft)	3.98	13.94	3.69
Conv. Total (cfs)	635402.3	Conv. (cfs)	8695.3	623243.6	3463.4
Length Wtd. (ft)	2.00	Wetted Per. (ft)	48.39	267.73	22.78
Min Ch El (ft)	449.73	Shear (lb/sq ft)	1.00	3.51	0.90
Alpha	1.09	Stream Power (lb/ft s)	2.95	38.22	2.50
Frctn Loss (ft)		Cum Volume (acre-ft)	0.81	10.56	0.23
C & E Loss (ft)		Cum SA (acres)	0.22	0.78	0.06

CONTRACTED SECTION

Plan: Proposed   Stream   Reach RS: 314.7174   Profile: Q500

E.G. Elev (ft)	471.69	Element	Left OB	Channel	Right OB
Vel Head (ft)	2.18	Wt. n-Val.	0.080	0.050	0.080
W.S. Elev (ft)	469.50	Reach Len. (ft)	2.00	2.00	2.00
Crit W.S. (ft)	464.72	Flow Area (sq ft)	252.61	4000.06	110.08
E.G. Slope (ft/ft)	0.004425	Area (sq ft)	252.61	4000.06	110.08
Q Total (cfs)	49194.20	Flow (cfs)	871.60	47967.33	355.27
Top Width (ft)	340.75	Top Width (ft)	53.00	262.90	24.85
Vel Total (ft/s)	11.28	Avg. Vel. (ft/s)	3.45	11.99	3.23
Max Chl Dpth (ft)	19.77	Hydr. Depth (ft)	4.77	15.22	4.43
Conv. Total (cfs)	739555.5	Conv. (cfs)	13103.2	721111.5	5340.9
Length Wtd. (ft)	2.00	Wetted Per. (ft)	54.13	267.73	26.07
Min Ch El (ft)	449.73	Shear (lb/sq ft)	1.29	4.13	1.17
Alpha	1.11	Stream Power (lb/ft s)	4.45	49.49	3.76
Frctn Loss (ft)		Cum Volume (acre-ft)	1.14	11.53	0.31
C & E Loss (ft)		Cum SA (acres)	0.26	0.78	0.08

CONTRACTED SECTION

correctly account for the increase in transport that will occur as the result of the bed planing out (which decreases resistance to flow, increases the velocity and the transport of bed material at the bridge). That is, Laursen's equation indicates a decrease in scour for this case, whereas in reality, there would be an increase in scour depth. In addition, at flood flows, a plane bedform will usually exist upstream and through the bridge waterway, and the values of Manning n will be equal. Consequently, the n value ratio is not recommended or presented in Equation 6.2.

4. W_1 and W_2 are not always easily defined. In some cases, it is acceptable to use the topwidth of the main channel to define these widths. Whether topwidth or bottom width is used, it is important to be consistent so that W_1 and W_2 refer to either bottom widths or top widths.

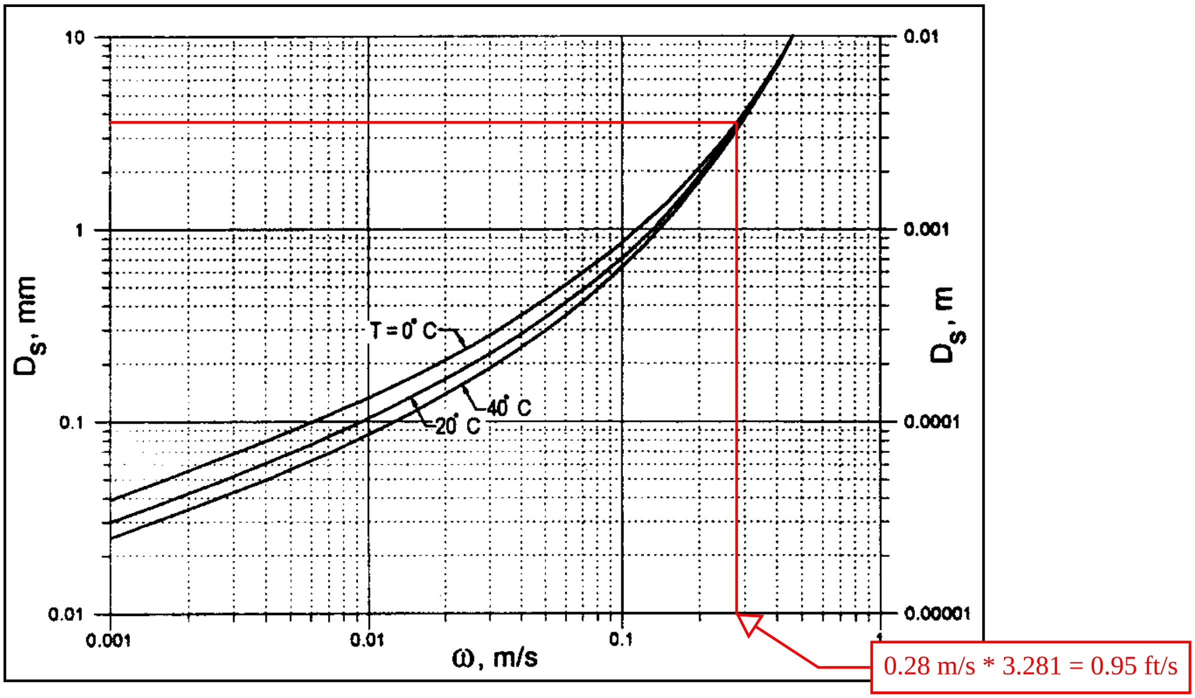


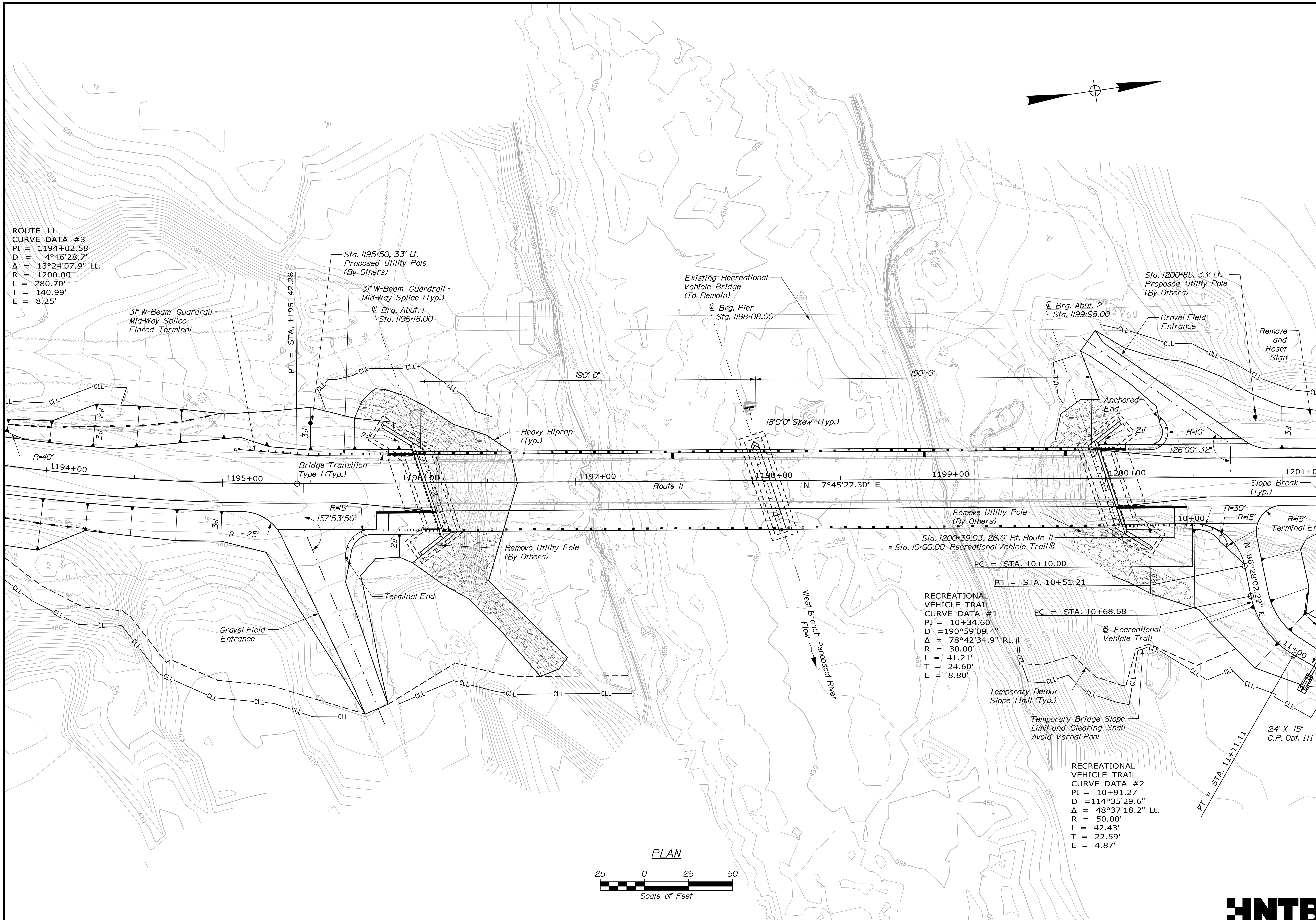
Figure 6.8. Fall velocity of sand-sized particles with specific gravity of 2.65 in metric units.

Boring & Sample ID	Depth (feet)	Elevation (ft NAVD 88)	Water Content (%)	D_{50} (mm)	Classification	
					USCS	AASHTO
BB- IWBP-104, 1D	0-2	461-459	4.7	3.68	SP	A-1-a

Boring Sample to Determine D50

APPENDIX G

Drawings



HNTB

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

2262701

WIN 023236.01

BRIDGE PLANS

Bridge No. 3666

	BY	DATE
PROJ. MANAGER	A. Lathe	
DESIGN-DETAILED	C. Helmick	07/20
CHECKED-REVIEWED	L. Driscoll	07/20
DESIGN2-DETAILED2	R. Harf	07/20
DESIGN3-DETAILED3		
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE

P.E. NUMBER

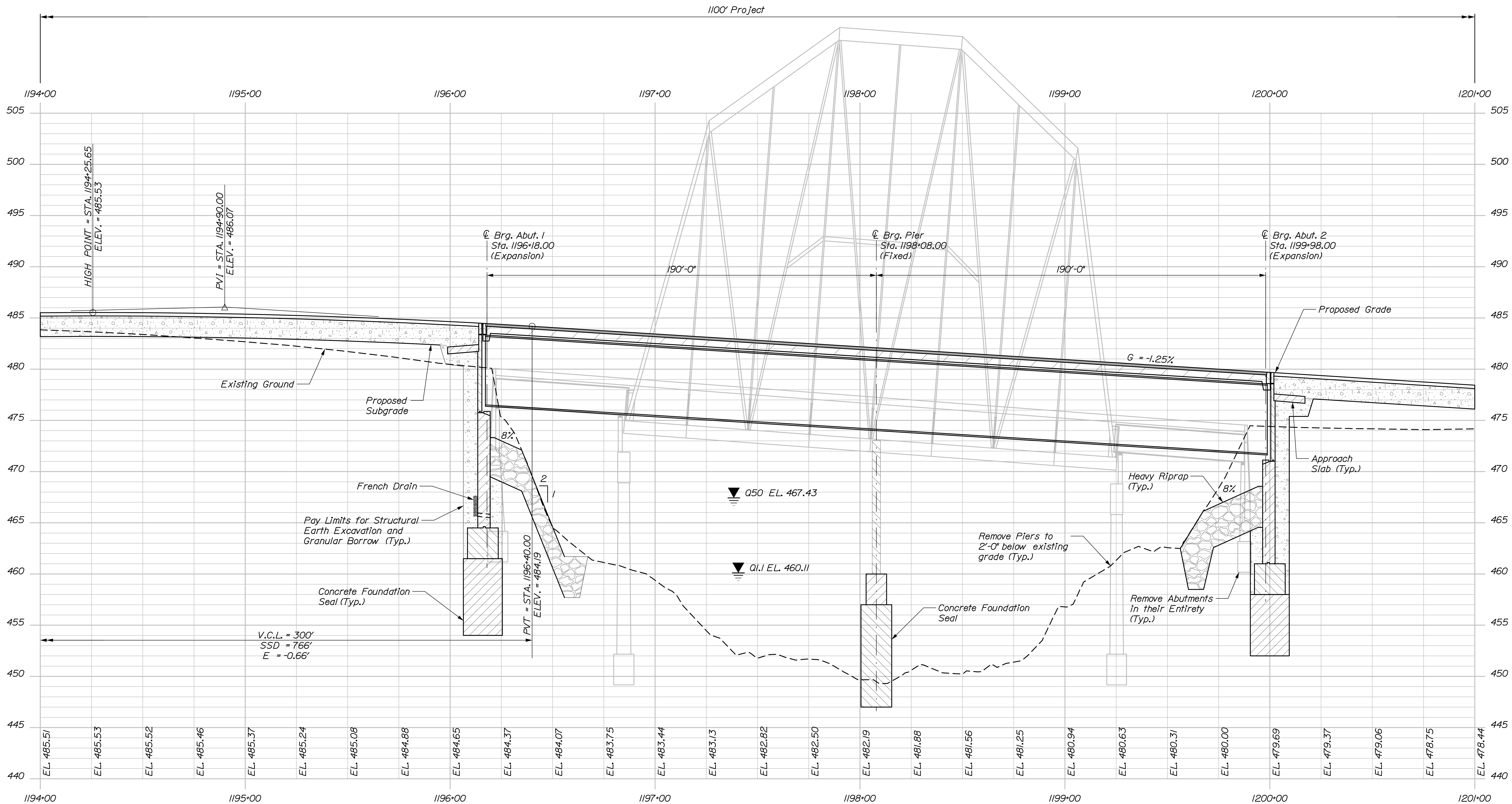
DATE

DETECTIVE BENJAMIN CAMPBELL BRIDGE
WEST BRANCH PENOBSCOT RIVER
T3 INDIAN PUR. TWP PENOBSCOT COUNTY

GENERAL PLAN 2

SHEET NUMBER
5
OF 70

Date:7/30/2020
Username:
Division:
Filename: 005_BDPlan_02.dgn



ROUTE 11
PROFILE

Horiz. 25 0 25 50
Vert. 5 0 5 10
Scale of Feet

HNTB

Date: 7/30/2020
Username:
Division:
Filename: 008_Profile_02.dgn

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

2262701

WIN
023236.01

BRIDGE PLANS

Bridge No. 3666

		BY	DATE
PROJ. MANAGER	A. Lathe		
DESIGN-DETAILED	C. Helmick	P. Bishop	07/20
CHECKED-REVIEWED	L. Driscoll	R. Hanf	07/20
DESIGN2-DETAILED2			
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

SIGNATURE
P.E. NUMBER
DATE

DETECTIVE BENJAMIN CAMPBELL BRIDGE
WEST BRANCH PENOBSCOT RIVER
T3 INDIAN PUR. TWP PENOBSCOT COUNTY

PROFILE 2

SHEET NUMBER
8
OF 70