APPENDIX F

Laboratory Test Results

State of Maine - Department of Transportation

Laboratory Testing Summary Sheet

Town(s): Allagash Work Number: 17236.00

Boring & Sample	Station	Offset	Depth	Reference	G.S.D.C.	W.C.	L.L.	P.I.	Classification		
Identification Number	(Feet)	(Feet)	(Feet)	Number	Sheet	%			Unified	AASHTO	Frost
HB-ALLA-101, 1D	5+86	7.0 Rt.	5.0-6.0	243132	1	3.8			SM	A-1-b	II
HB-ALLA-101, 1D/A	5+86	7.0 Rt.	6.0-7.0	243133	1	22.4			CL-ML	A-4	IV
HB-ALLA-101, 2D	5+86	7.0 Rt.	10.0-12.0	243134	1	6.7			SM	A-1-b	II
HB-ALLA-101, 3D	5+86	7.0 Rt.	14.0-16.0	243135	1	16.1			SM	A-2-4	II
HB-ALLA-101, 4D	5+86	7.0 Rt.	19.0-21.0	243136	1	10.0			GM	A-1-b	I
HB-ALLA-101, 5D	5+86	7.0 Rt.	24.0-26.0	243137	1	10.8			SM	A-1-b	II
HB-ALLA-101, 6D	5+86	7.0 Rt.	29.0-31.0	243138	2	8.7			GM	A-1-a	I
HB-ALLA-101, 7D	5+86	7.0 Rt.	34.0-36.0	243139	2	8.1			GM	A-1-a	I
HB-ALLA-101, 8D	5+86	7.0 Rt.	39.0-41.0	243140	2	12.0			SM	A-1-b	II
HB-ALLA-101, 9D	5+86	7.0 Rt.	44.0-46.0	243141	2	9.2			SM	A-1-a	II
HB-ALLA-101, 10D	5+86	7.0 Rt.	49.0-51.0	243142	2	9.8			GC	A-1-b	II
HB-ALLA-101, 11D	5+86	7.0 Rt.	55.0-57.0	243143	2	11.7			GW-GM	A-1-a	0
HB-ALLA-201, 3D	4+60	7.4 Rt.	9.0-11.0	304151	3	9.7			SW-SM	A-1-a	0
HB-ALLA-201, 5D/A	4+60	7.4 Rt.	20.0-21.0	304152	3	24.1			CL	A-4	IV
HB-ALLA-201, 6D	4+60	7.4 Rt.	24.0-26.0	304169	3	21.3	21	3	ML	A-4	IV
HB-ALLA-201, 8D	4+60	7.4 Rt.	34.0-36.0	304153	3	7.8			GW-GM	A-1-a	0
HB-ALLA-202, 3D	7+17	8.1 Rt.	10.0-12.0	304154	4	13.8			SM	A-1-b	II
HB-ALLA-202, 5D	7+17	8.1 Rt.	20.0-22.0	304155	4	5.6			GW-GM	A-1-a	0
HB-ALLA-202, 7D	7+17	8.1 Rt.	30.0-32.0	304156	4	20.8			GW-GM	A-1-a	0
HB-ALLA-202, 9D	7+17	8.1 Rt.	40.0-42.0	304157	4	17.3			SM	A-2-4	II
HB-ALLA-202, 11D	7+17	8.1 Rt.	50.0-52.0	304158	5	10.4			SC-SM	A-1-b	II
HB-ALLA-202, 12D/B	7+17	8.1 Rt.	56.0-57.0	304160	5	11.6			SC-SM	A-4	III
HB-ALLA-202, 14D	7+17	8.1 Rt.	65.0-66.1	304159	5	15.7	-N	P-	ML	A-4	IV
HB-ALLA-203, 2D	9+59	17.2 Rt.	5.0-7.0	304161	6	8.6			SC-SM	A-1-b	II
HB-ALLA-203, 5D	9+59	17.2 Rt.	19.0-21.0	304162	6	9.5			SW-SM	A-1-a	0
HB-ALLA-203, 9D	9+59	17.2 Rt.	39.0-41.0	304163	6	10.1			SC-SM	A-1-b	II
HB-ALLA-204, 2D	9+33	16.5 Lt.	5.0-7.0	304164	6	4.6			SW-SM	A-1-b	0
HB-ALLA-204, 5D	9+33	16.5 Lt.	19.0-21.0	304165	6	10.5			SW-SM	A-1-a	0
HB-ALLA-204, 8D	9+33	16.5 Lt.	34.0-36.0	304166	6	7.6			SC-SM	A-4	III

Classification of these soil samples is in accordance with AASHTO Classification System M-145-40. This classification is followed by the "Frost Susceptibility Rating" from zero (non-frost susceptible) to Class IV (highly frost susceptible). The "Frost Susceptibility Rating" is based upon the MaineDOT and Corps of Engineers Classification Systems.

GSDC = Grain Size Distribution Curve as determined by AASHTO T 88-93 (1996) and/or ASTM D 422-63 (Reapproved 1998)

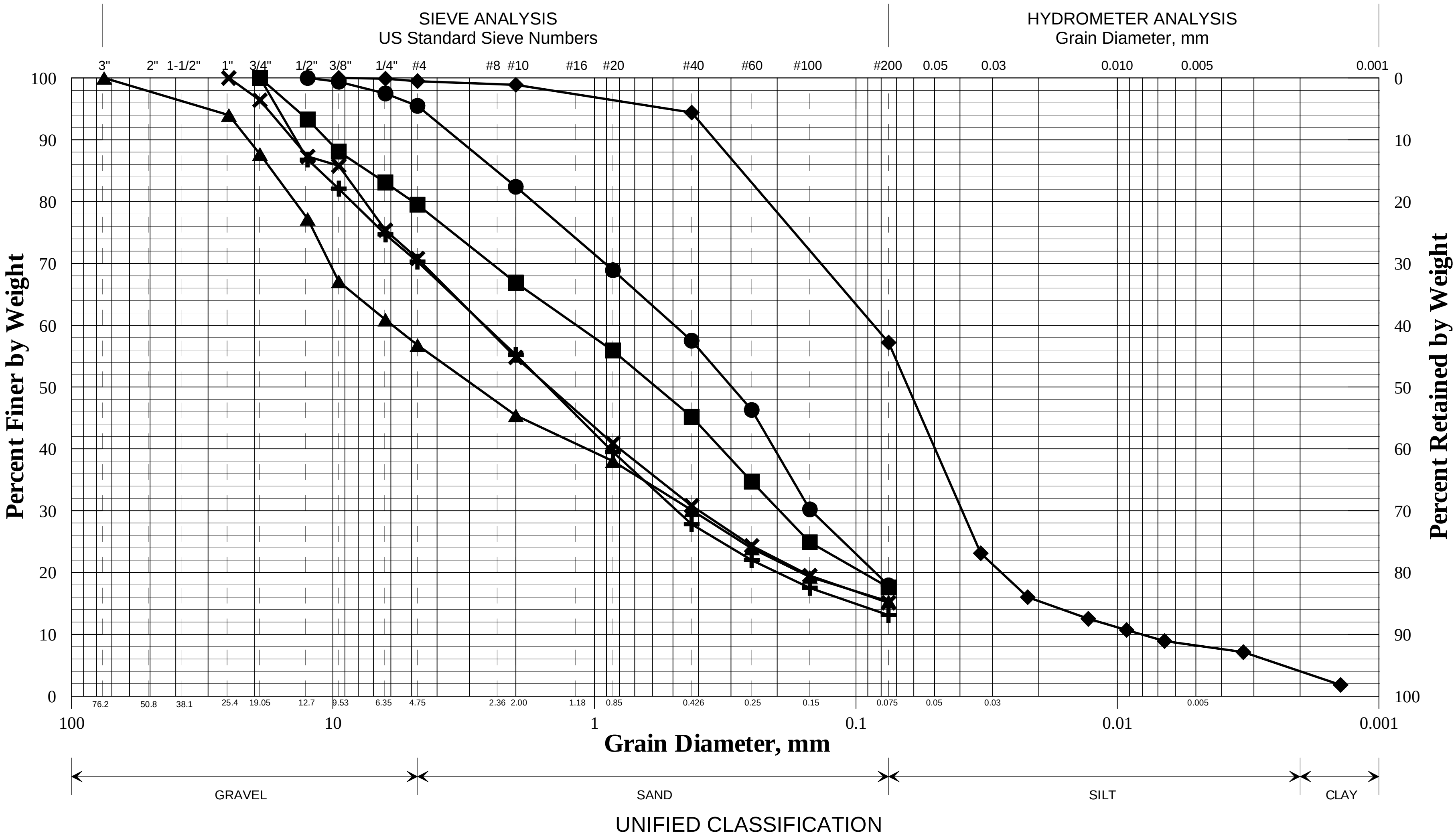
WC = water content as determined by AASHTO T 265-93 and/or ASTM D 2216-98

LL = Liquid limit as determined by AASHTO T 89-96 and/or ASTM D 4318-98 NP = Non Plastic

PI = Plasticity Index as determined by AASHTO 90-96 and/or ASTM D4318-98

State of Maine Department of Transportation

GRAIN SIZE DISTRIBUTION CURVE

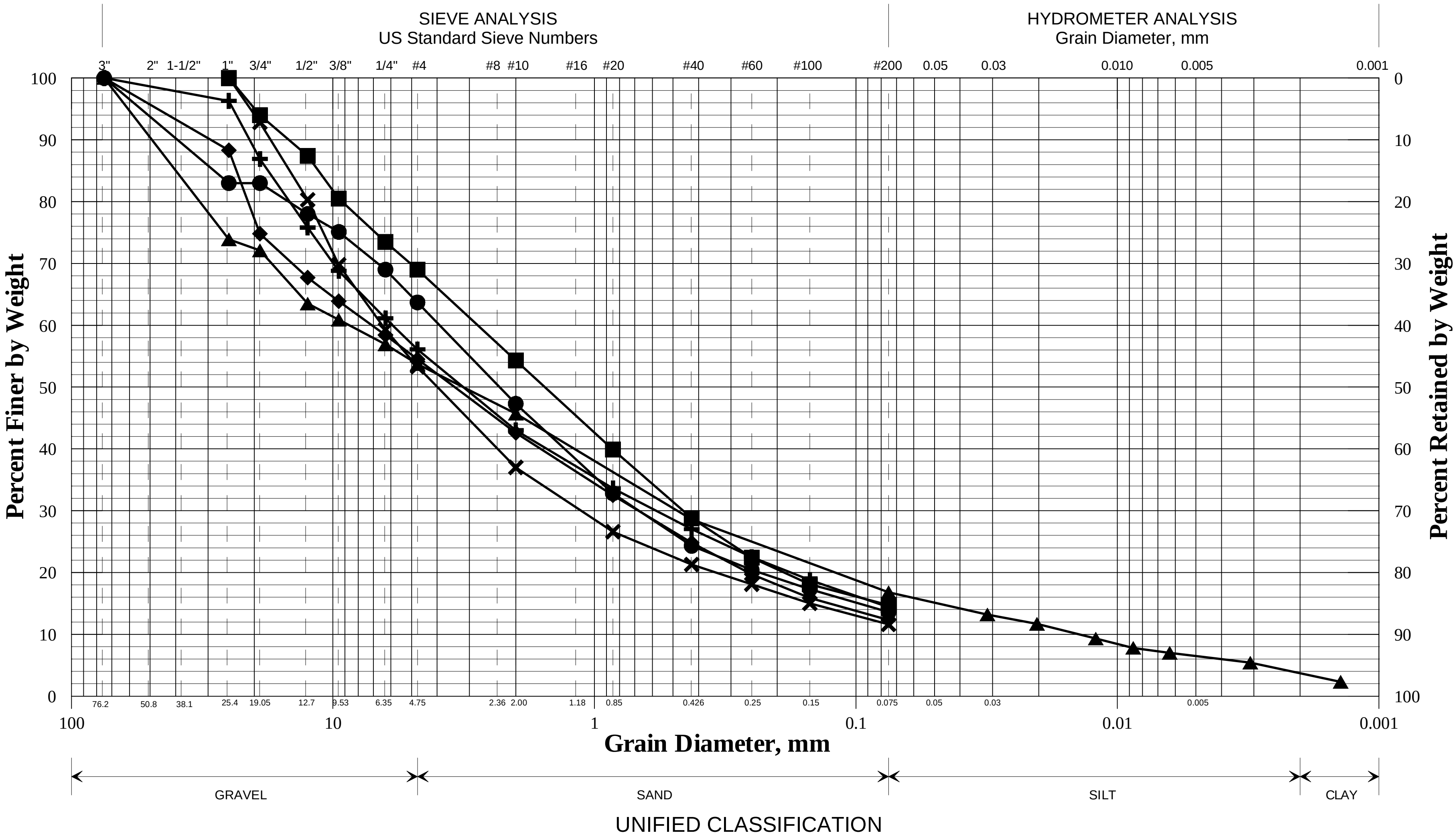


	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
✚	HB-ALLA-101/1D	5+86	7.0 RT	5.0-6.0	SAND, some gravel, little silt.	3.8			
◆	HB-ALLA-101/1DA	5+86	7.0 RT	6.0-7.0	Sandy SILT, trace clay, trace gravel.	22.4			
■	HB-ALLA-101/2D	5+86	7.0 RT	10.0-12.0	SAND, some gravel, little silt.	6.7			
●	HB-ALLA-101/3D	5+86	7.0 RT	14.0-16.0	SAND, little silt, trace gravel.	16.1			
▲	HB-ALLA-101/4D	5+86	7.0 RT	19.0-21.0	Sandy GRAVEL, little silt.	10.0			
✖	HB-ALLA-101/5D	5+86	7.0 RT	24.0-26.0	SAND, some gravel, little silt.	10.8			

WIN
017236.00
Town
Allagash, Saint Francis
Reported by/Date
WHITE, TERRY A 11/17/2016

SHEET 1

State of Maine Department of Transportation
GRAIN SIZE DISTRIBUTION CURVE



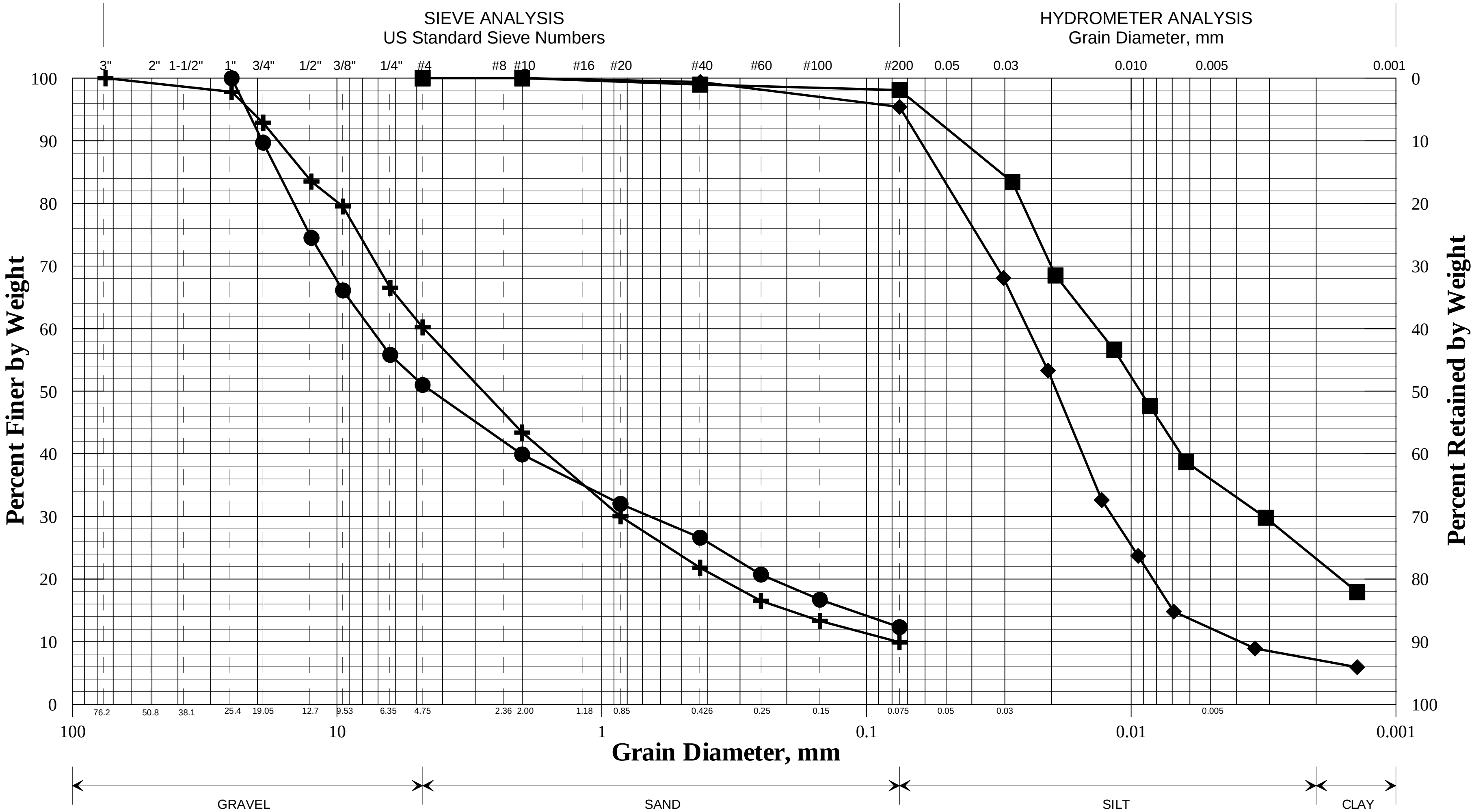
	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
✚	HB-ALLA-101/6D	5+86	7.0 RT	29.0-31.0	Sandy GRAVEL, little silt.	8.7			
◆	HB-ALLA-101/7D	5+86	7.0 RT	34.0-36.0	Sandy GRAVEL, little silt.	8.1			
■	HB-ALLA-101/8D	5+86	7.0 RT	39.0-41.0	SAND, some gravel, little silt.	12.0			
●	HB-ALLA-101/9D	5+86	7.0 RT	44.0-46.0	Gravelly SAND, little silt.	9.2			
▲	HB-ALLA-101/10D	5+86	7.0 RT	49.0-51.0	Sandy GRAVEL, little silt, trace clay.	9.8			
✖	HB-ALLA-101/11D	5+86	7.0 RT	55.0-57.0	Sandy GRAVEL, little silt.	11.7			

WIN
017236.00
Town
Allagash, Saint Francis
Reported by/Date
WHITE, TERRY A 11/17/2016

SHEET 2

State of Maine Department of Transportation

GRAIN SIZE DISTRIBUTION CURVE



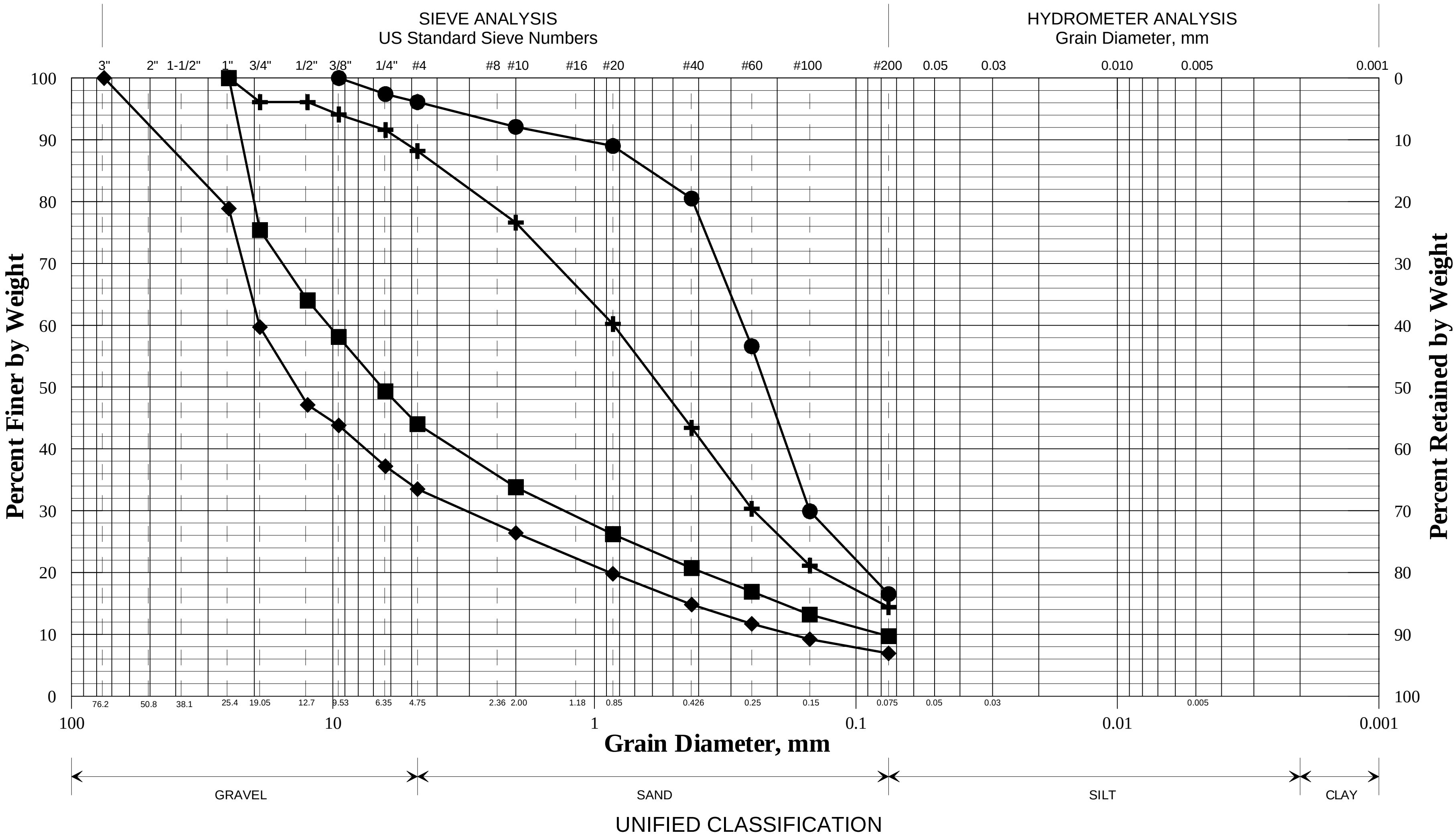
UNIFIED CLASSIFICATION

	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
✚	HB-ALLA-201/3D	4+60	7.4 RT	9.0-11.0	Gravelly SAND, trace silt.	9.7			
◆	HB-ALLA-201/5DA	4+60	7.4 RT	19.0-21.0	SILT, trace clay, trace sand.	24.1			
■	HB-ALLA-201/6D	4+60	7.4 RT	24.0-26.0	SILT, some clay, trace sand.	21.3	21	18	3
●	HB-ALLA-201/8D	4+60	7.4 RT	34.0-36.0	Sandy GRAVEL, little silt.	7.8			
▲									
✖									

WIN
017236.00
Town
Allagash, Saint Francis
Reported by/Date
WHITE, TERRY A 11/17/2016

SHEET 3

State of Maine Department of Transportation
GRAIN SIZE DISTRIBUTION CURVE

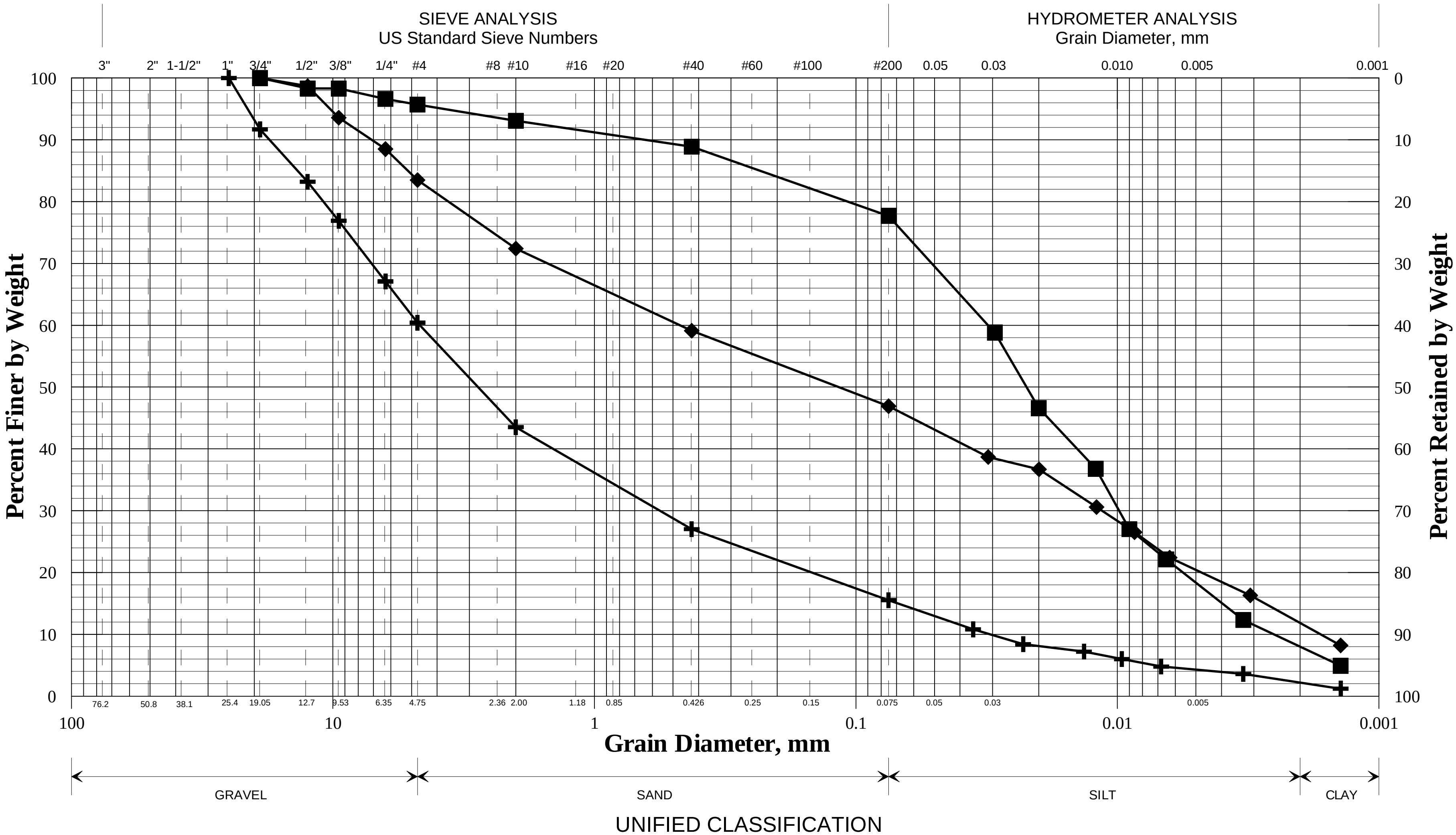


	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
✚	HB-ALLA-202/3D	7+17	8.1 RT	10.0-12.0	SAND, little silt, little gravel.	13.8			
◆	HB-ALLA-202/5D	7+17	8.1 RT	20.0-22.0	GRAVEL, some sand, trace silt.	5.6			
■	HB-ALLA-202/7D	7+17	8.1 RT	30.0-32.0	GRAVEL, some sand, trace silt.	20.8			
●	HB-ALLA-202/9D	7+17	8.1 RT	40.0-42.0	SAND, little silt, trace gravel.	17.3			
▲									
✖									

WIN
017236.00
Town
Allagash, Saint Francis
Reported by/Date
WHITE, TERRY A 11/18/2016

SHEET 4

State of Maine Department of Transportation
GRAIN SIZE DISTRIBUTION CURVE

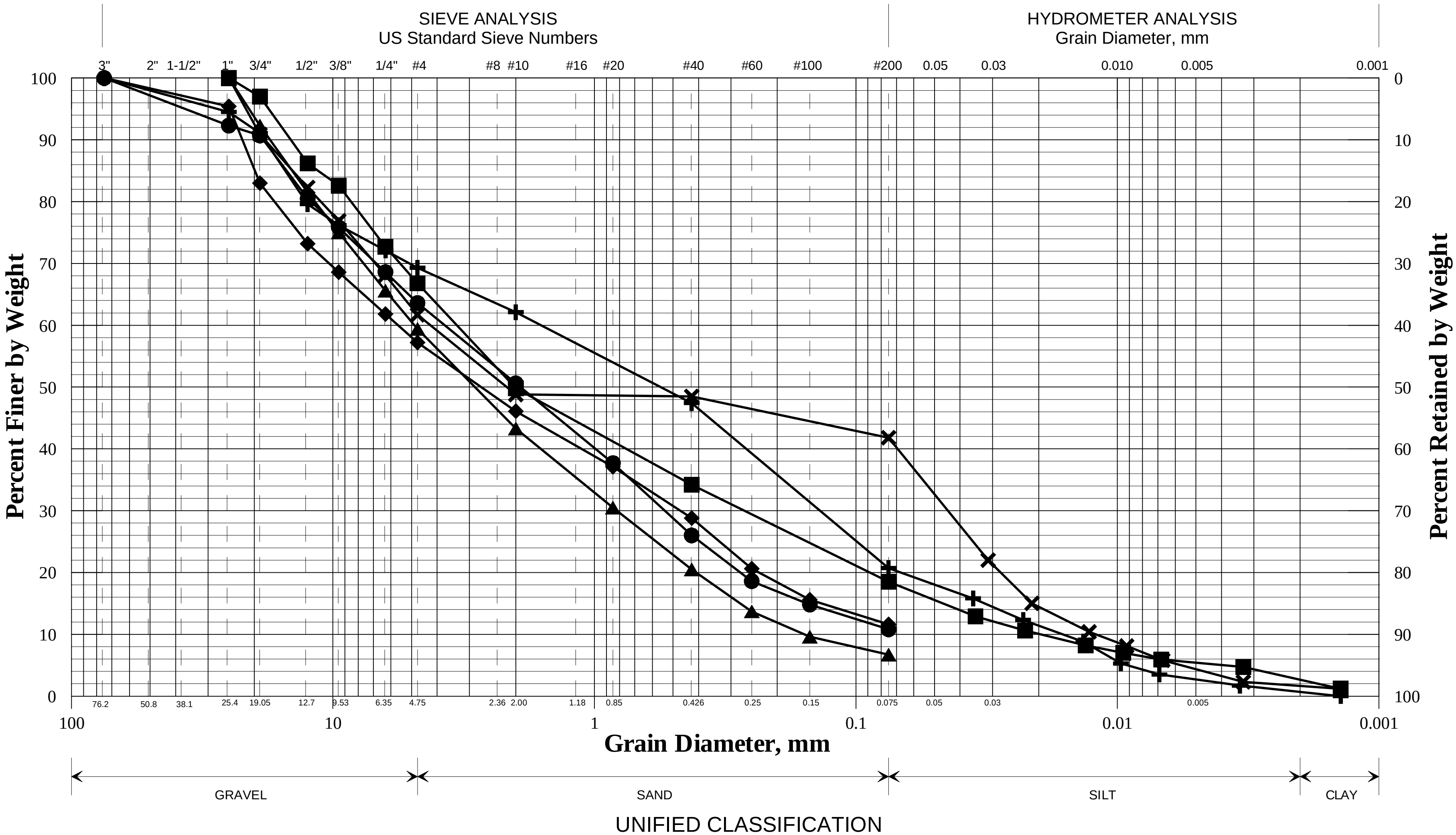


	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
✚	HB-ALLA-202/11D	7+17	8.1 RT	50.0-52.0	Gravelly SAND, little silt, trace clay.	10.4			
◆	HB-ALLA-202/12DB	7+17	8.1 RT	55.0-57.0	SILT, some sand, little gravel, little clay.	11.6			
■	HB-ALLA-202/14D	7+17	8.1 RT	65.0-67.0	SILT, little sand, little clay, trace gravel.	15.7			NP
●									
▲									
✖									

WIN
017236.00
Town
Allagash, Saint Francis
Reported by/Date
WHITE, TERRY A 11/18/2016

SHEET 5

State of Maine Department of Transportation
GRAIN SIZE DISTRIBUTION CURVE

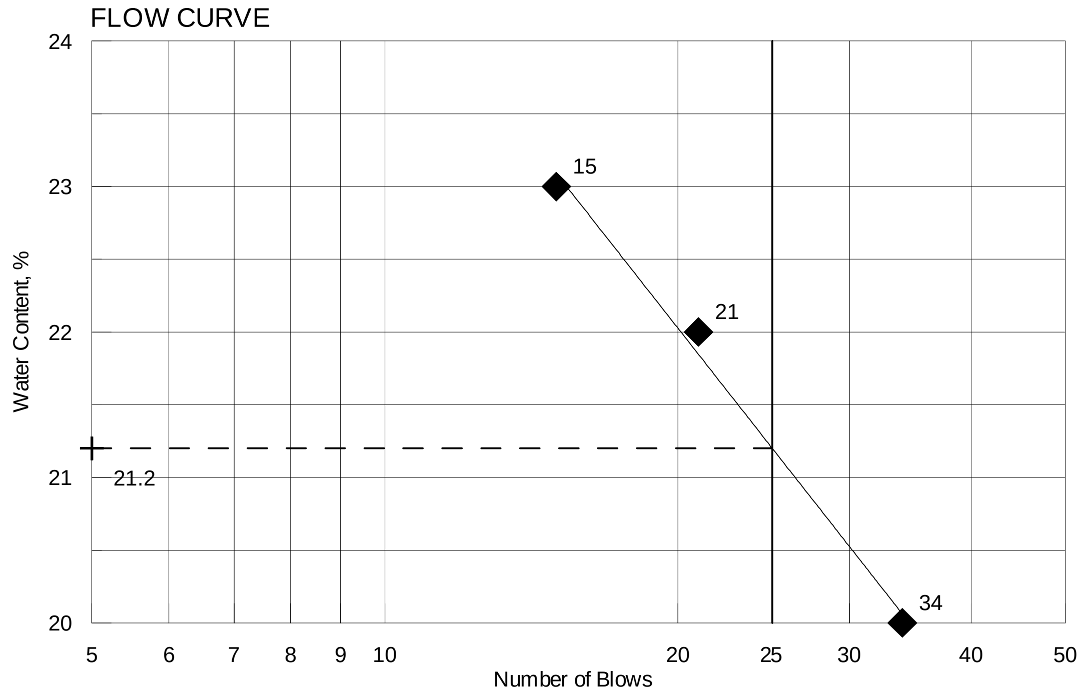


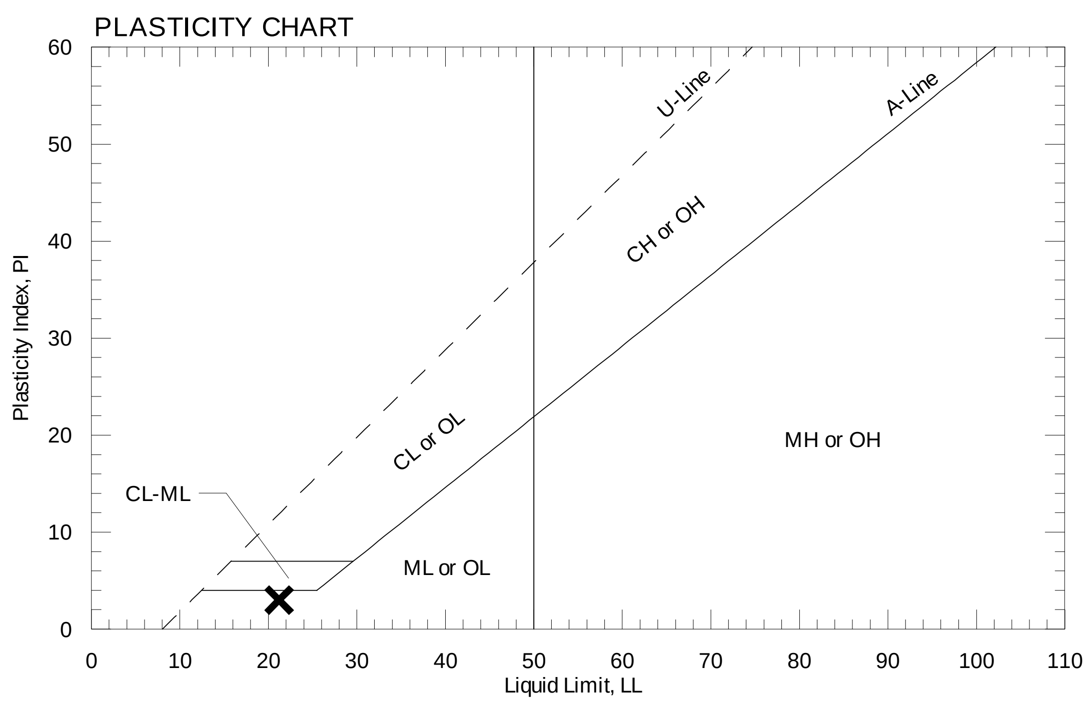
	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
✚	HB-ALLA-203/2D	9+59	17.2 RT	5.0-7.0	SAND, some gravel, little silt, trace clay.	8.6			
◆	HB-ALLA-203/5D	9+59	17.2 RT	19.0-21.0	Gravelly SAND, little silt.	9.5			
■	HB-ALLA-203/9D	9+59	17.2 RT	39.0-41.0	SAND, some gravel, little silt, trace clay.	10.1			
●	HB-ALLA-204/2D	9+33	16.5 LT	5.0-7.0	Gravelly SAND, trace silt.	4.6			
▲	HB-ALLA-204/5D	9+33	16.5 LT	19.0-21.0	Gravelly SAND, trace silt.	10.5			
✖	HB-ALLA-204/8D	9+33	16.5 LT	34.0-36.0	Gravelly SILT, little sand, trace clay.	7.6			

WIN	
017236.00	
Town	
Allagash, Saint Francis	
Reported by/Date	
WHITE, TERRY A	11/18/2016

SHEET 6

TOWN	Allagash, Saint Francis	Reference No.	304169
WIN	017236.00	Water Content, %	21.3
Sampled	9/23/2016	Liquid Limit @ 25 blows (T 89), %	21
Boring No./Sample No.	HB-ALLA-201/6D	Plastic Limit (T 90), %	18
Station	4+60	Plasticity Index (T 90), %	3
Depth	24.0-26.0	Tested By	BBURR





State of Maine - Department of Transportation

Laboratory Testing Summary Sheet

Town(s): St. Francis   Work Number: 17236.10

Boring & Sample Identification Number	Station (Feet)	Offset (Feet)	Depth (Feet)	Reference Number	G.S.D.C. Sheet	W.C. %	L.L.	P.I.	Classification Unified	AASHTO	Frost
HB-STFR-101, 1D	7+19.3	10.1 Rt.	5.0-7.0	243144	1	3.8			SW-SM	A-1-b	0
HB-STFR-101, 2D	7+19.3	10.1 Rt.	10.0-12.0	243145	1	9.0			SW-SM	A-1-b	0
HB-STFR-101, 3D	7+19.3	10.1 Rt.	14.0-16.0	243146	1	11.0			GW-GM	A-1-a	0
HB-STFR-101, 4D	7+19.3	10.1 Rt.	19.0-21.0	243147	1	10.6			SM	A-2-4	II
HB-STFR-101, 5D	7+19.3	10.1 Rt.	24.0-26.0	243148	2	11.3			SW-SM	A-1-b	0
HB-STFR-101, 6D	7+19.3	10.1 Rt.	29.0-31.0	243149	2	11.8			SW-SM	A-1-a	0
HB-STFR-101, 7D	7+19.3	10.1 Rt.	34.0-36.0	243150	2	13.2			SW-SM	A-1-a	0
HB-STFR-201, 2D	4+61	5.8 Rt.	5.0-7.0	304167	3	8.9			SM	A-2-4	II
HB-STFR-201, 4D	4+61	5.8 Rt.	15.0-17.0	304168	3	16.7			CL	A-4	IV
HB-STFR-201, 8D	4+61	5.8 Rt.	34.0-36.0	304170	3	13.3			SW-SM	A-1-b	0
HB-STFR-201, 13D	4+61	5.8 Rt.	59.0-61.0	304171	3	11.8			SW-SM	A-1-b	0
HB-STFR-202, 2D	9+04	13.2 Lt.	5.0-7.0	304172	4	1.9			SW-SM	A-1-a	0
HB-STFR-202, 6D	9+04	13.2 Lt.	24.0-26.0	304173	4	18.9	21	2	ML	A-4	IV
HB-STFR-202, 8D	9+04	13.2 Lt.	34.0-36.0	304174	4	20.4			ML	A-4	IV
HB-STFR-202, 10D	9+04	13.2 Lt.	45.0-47.0	304175	4	10.8			SW-SM	A-1-a	0
HB-STFR-202, 13D	9+04	13.2 Lt.	59.0-61.0	304201	4	8.9			SC-SM	A-2-4	III
HB-STFR-202, 15D	9+04	13.2 Lt.	69.0-71.0	304202	4	7.5			SM	A-2-4	II
HB-STFR-203, 2D	12+09	11.0 Rt.	5.0-7.0	304203	5	1.9			SM	A-1-b	II
HB-STFR-203, 4D	12+09	11.0 Rt.	15.0-17.0	304204	5	6.0			SC-SM	A-1-b	II
HB-STFR-203, 6D/B	12+09	11.0 Rt.	26.0-27.0	304205	5	21.7	23	1	ML	A-4	IV
HB-STFR-203, 7D	12+09	11.0 Rt.	30.0-32.0	304206	5	9.3			SC-SM	A-2-4	III
HB-STFR-203, 10D	12+09	11.0 Rt.	45.0-47.0	304207	5	8.2			SC-SM	A-4	III
HB-STFR-203, 12D	12+09	11.0 Rt.	55.0-56.5	304208	5	6.9			SM	A-4	III
HB-STFR-204, 4D	10+43	8.2 Rt.	15.0-17.0	304209	6	8.6			SW-SC	A-1-a	0
HB-STFR-204, 6D	10+43	8.2 Rt.	25.0-27.0	304210	6	20.5			SC-SM	A-2-4	III
HB-STFR-204, 7D/B	10+43	8.2 Rt.	27.5-29.0	304211	6	25.6	26	6	CL-ML	A-4	IV
HB-STFR-204, MV1	10+43	8.2 Rt.	32.0-34.0	304212	6	14.6	26	3	ML	A-4	IV
HB-STFR-204, 9D	10+43	8.2 Rt.	40.0-41.7	304213	6	8.0			SC-SM	A-2-4	III
HB-STFR-204, 10D	10+43	8.2 Rt.	45.0-47.0	304214	6	8.7			SM	A-4	III

Classification of these soil samples is in accordance with AASHTO Classification System M-145-40. This classification is followed by the "Frost Susceptibility Rating" from zero (non-frost susceptible) to Class IV (highly frost susceptible). The "Frost Susceptibility Rating" is based upon the MaineDOT and Corps of Engineers Classification Systems.

GSDC = Grain Size Distribution Curve as determined by AASHTO T 88-93 (1996) and/or ASTM D 422-63 (Reapproved 1998)

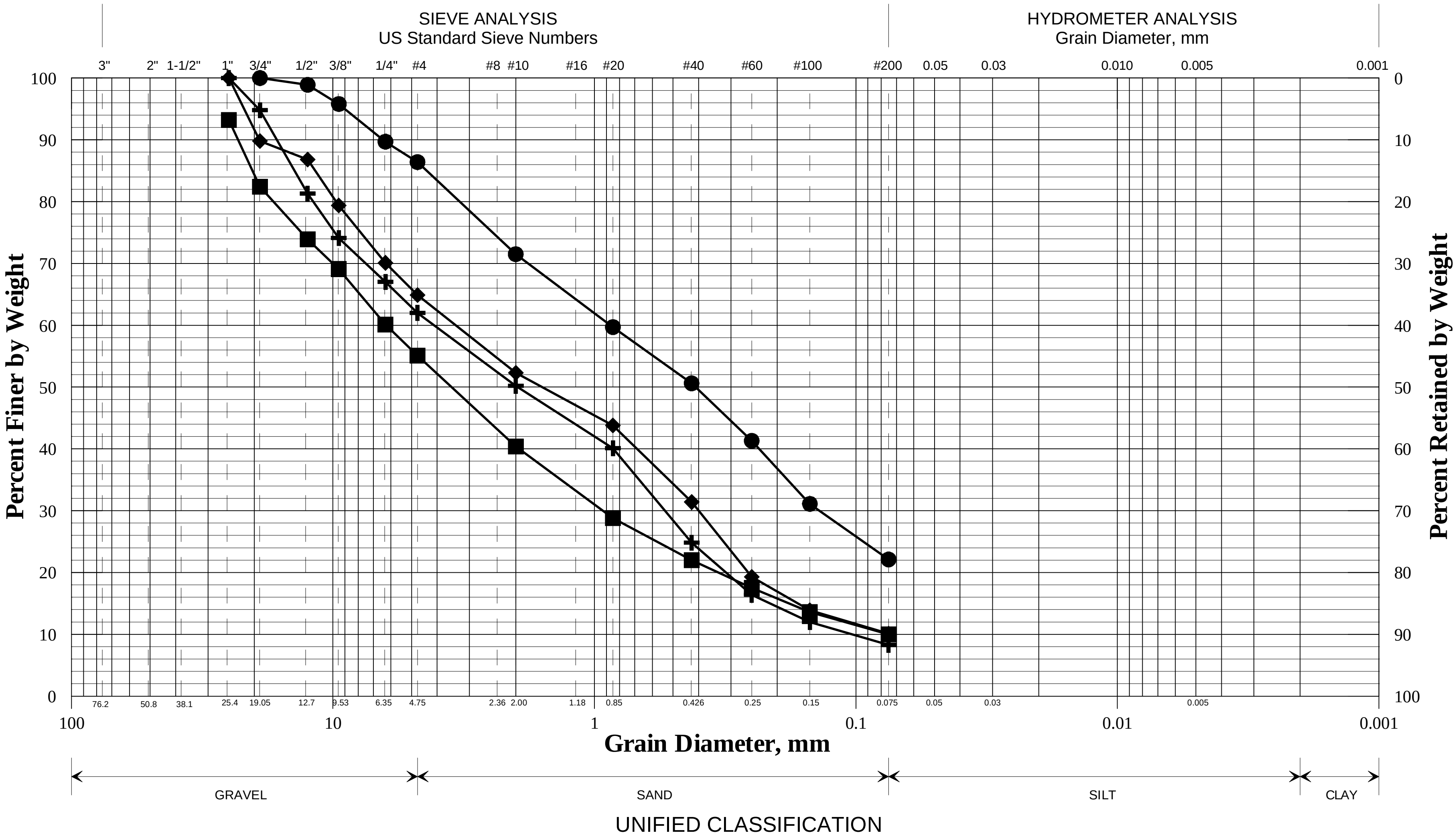
WC = water content as determined by AASHTO T 265-93 and/or ASTM D 2216-98

LL = Liquid limit as determined by AASHTO T 89-96 and/or ASTM D 4318-98   NP = Non Plastic

PI = Plasticity Index as determined by AASHTO 90-96 and/or ASTM D4318-98

State of Maine Department of Transportation

GRAIN SIZE DISTRIBUTION CURVE

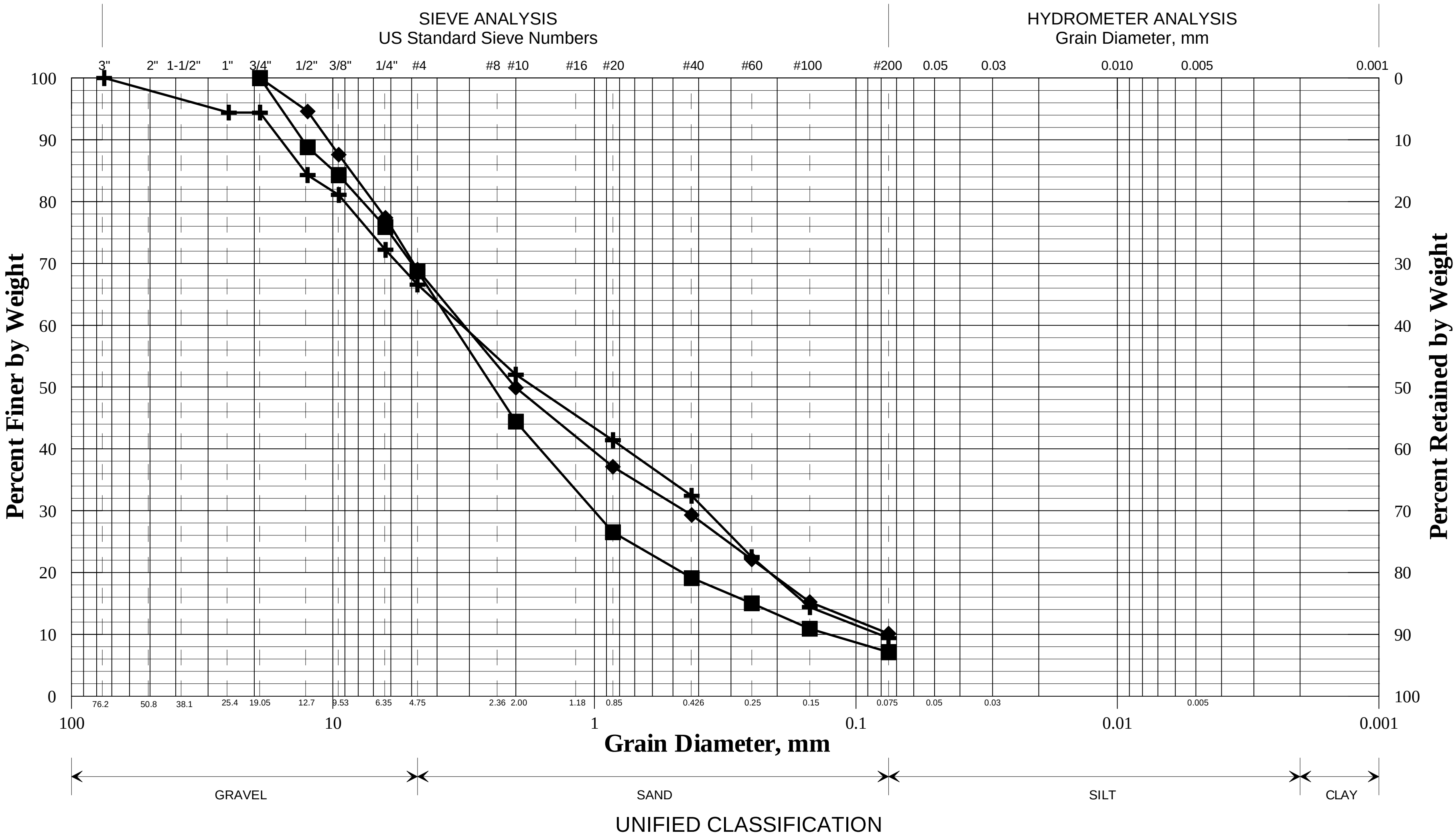


	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
✚	HB-STFR-101/1D	7+19.3	10.1 RT	5.0-7.0	Gravelly SAND, trace silt.	3.8			
◆	HB-STFR-101/2D	7+19.3	10.1 RT	10.0-12.0	SAND, some gravel, trace silt.	9.0			
■	HB-STFR-101/3D	7+19.3	10.1 RT	14.0-16.0	Sandy GRAVEL, trace silt.	11.0			
●	HB-STFR-101/4D	7+19.3	10.1 RT	19.0-21.0	SAND, some silt, little gravel.	10.6			
▲									
✖									

WIN
017236.10
Town
Allagash, Saint Francis
Reported by/Date
WHITE, TERRY A 11/21/2016

SHEET 1

State of Maine Department of Transportation
GRAIN SIZE DISTRIBUTION CURVE



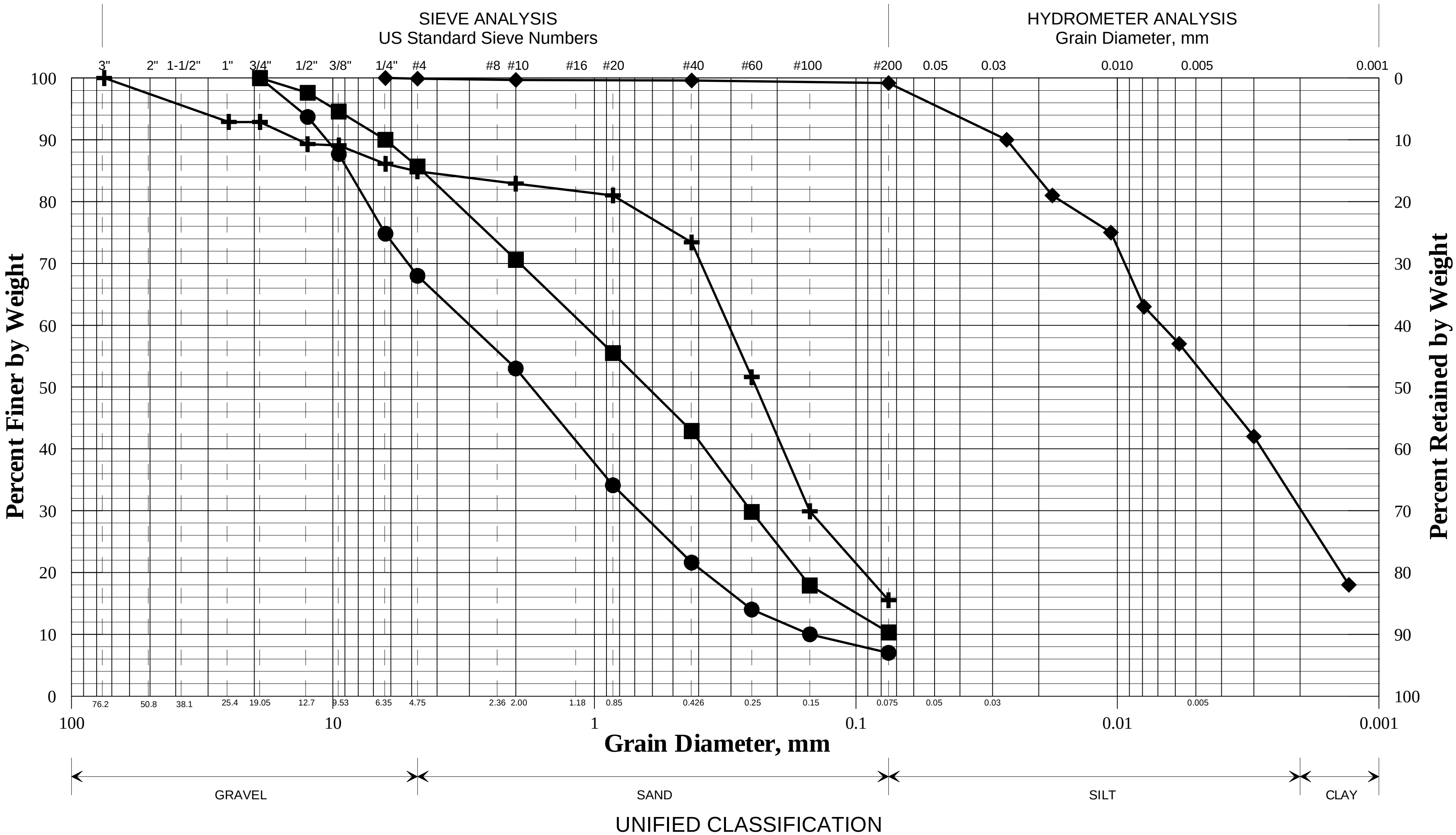
	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
✚	HB-STFR-101/5D	7+19.3	10.1 RT	24.0-26.0	SAND, some gravel, trace silt.	11.3			
◆	HB-STFR-101/6D	7+19.3	10.1 RT	29.0-31.0	SAND, some gravel, trace silt.	11.8			
■	HB-STFR-101/7D	7+19.3	10.1 RT	34.0-36.0	SAND, some gravel, trace silt.	13.2			
●									
▲									
✖									

WIN
017236.10
Town
Allagash, Saint Francis
Reported by/Date
WHITE, TERRY A 11/21/2016

SHEET 2

State of Maine Department of Transportation

GRAIN SIZE DISTRIBUTION CURVE

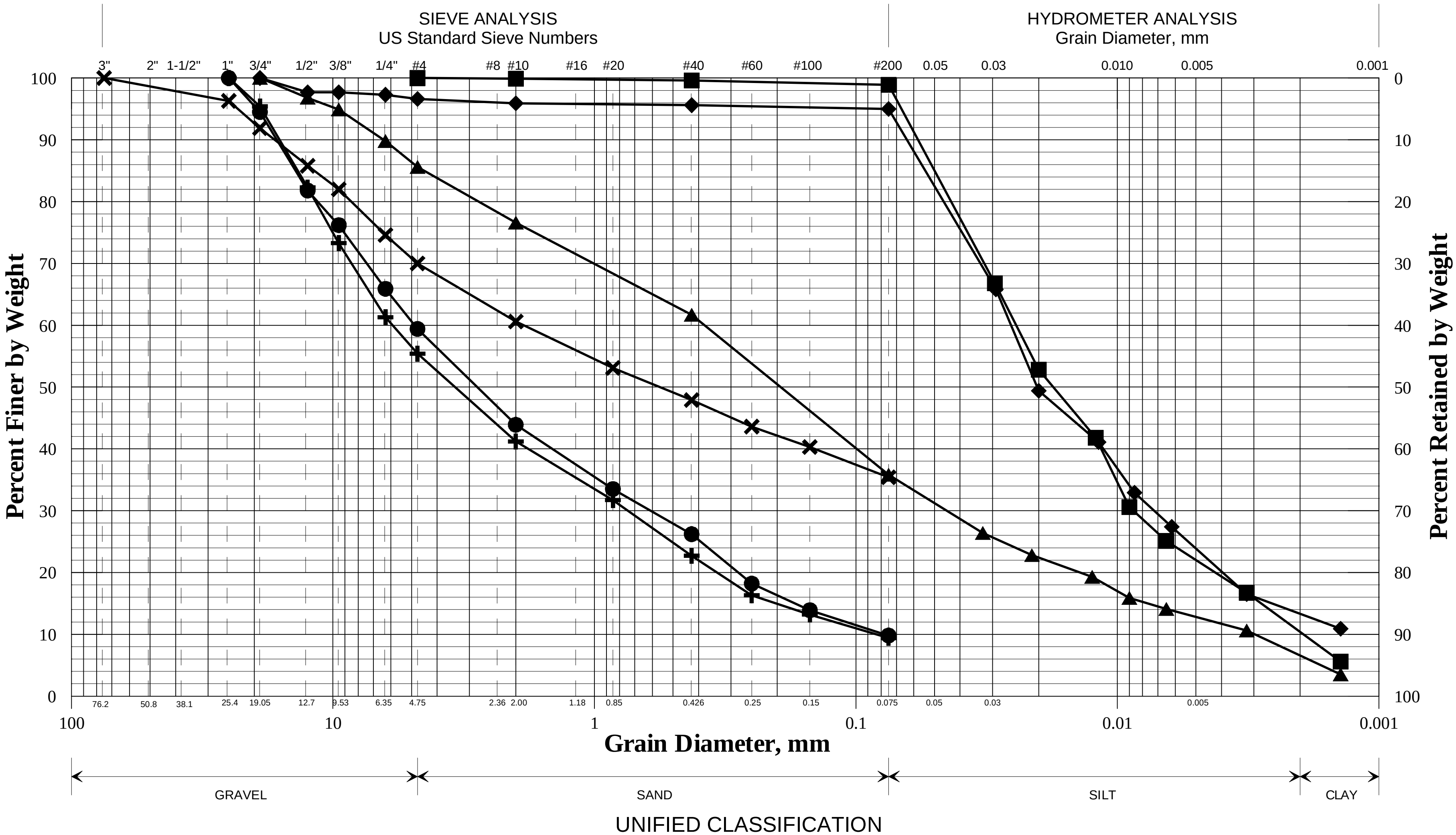


	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
✚	HB-STFR-201/2D	4+61	5.8 RT	5.0-7.0	SAND, little silt, little gravel.	8.9			
◆	HB-STFR-201/4D	4+61	5.8 RT	15.0-17.0	SILT, some clay, trace sand, trace gravel.	16.7			
■	HB-STFR-201/8D	4+61	5.8 RT	34.0-36.0	SAND, little gravel, trace silt.	13.3			
●	HB-STFR-201/13D	4+61	5.8 RT	59.0-61.0	SAND, some gravel, trace silt.	11.8			
▲									
✖									

WIN
017236.10
Town
Allagash, Saint Francis
Reported by/Date
WHITE, TERRY A 11/21/2016

SHEET 3

State of Maine Department of Transportation
GRAIN SIZE DISTRIBUTION CURVE

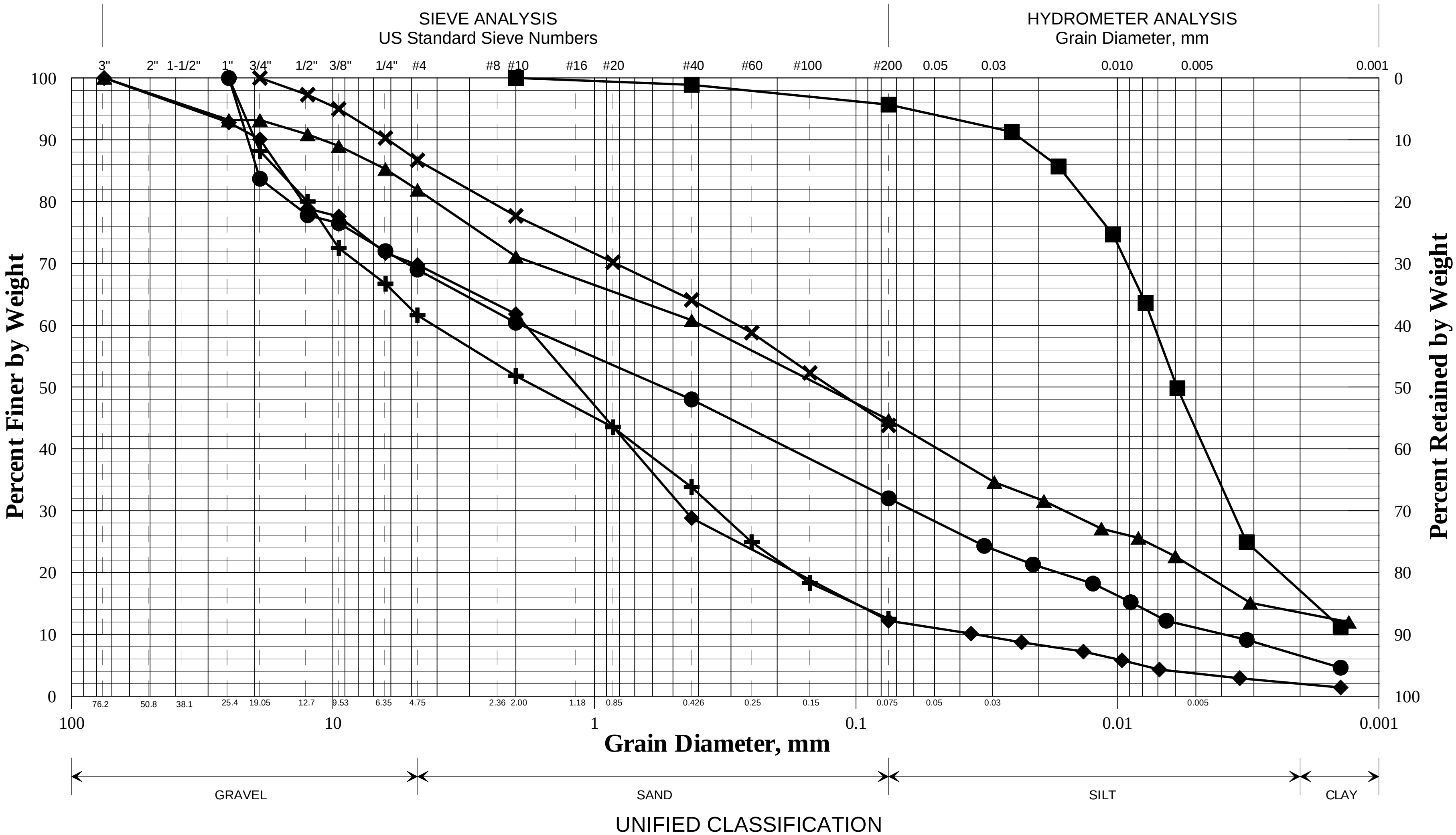


	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
✚	HB-STFR-202/2D	9+04	13.2 LT	5.0-7.0	Gravelly SAND, trace silt.	1.9			
◆	HB-STFR-202/6D	9+04	13.2 LT	24.0-26.0	SILT, little clay, trace gravel, trace sand.	18.9	21	19	2
■	HB-STFR-202/8D	9+04	13.2 LT	34.0-36.0	SILT, trace clay, trace sand.	20.4			
●	HB-STFR-202/10D	9+04	13.2 LT	45.0-47.0	Gravelly SAND, trace silt.	10.8			
▲	HB-STFR-202/13D	9+04	13.2 LT	59.0-61.0	SAND, some silt, little gravel, trace clay.	8.9			
✖	HB-STFR-202/15D	9+04	13.2 LT	69.0-71.0	SILT, some sand, some gravel.	7.5			

WIN
017236.10
Town
Allagash, Saint Francis
Reported by/Date
WHITE, TERRY A 11/21/2016

State of Maine Department of Transportation

GRAIN SIZE DISTRIBUTION CURVE

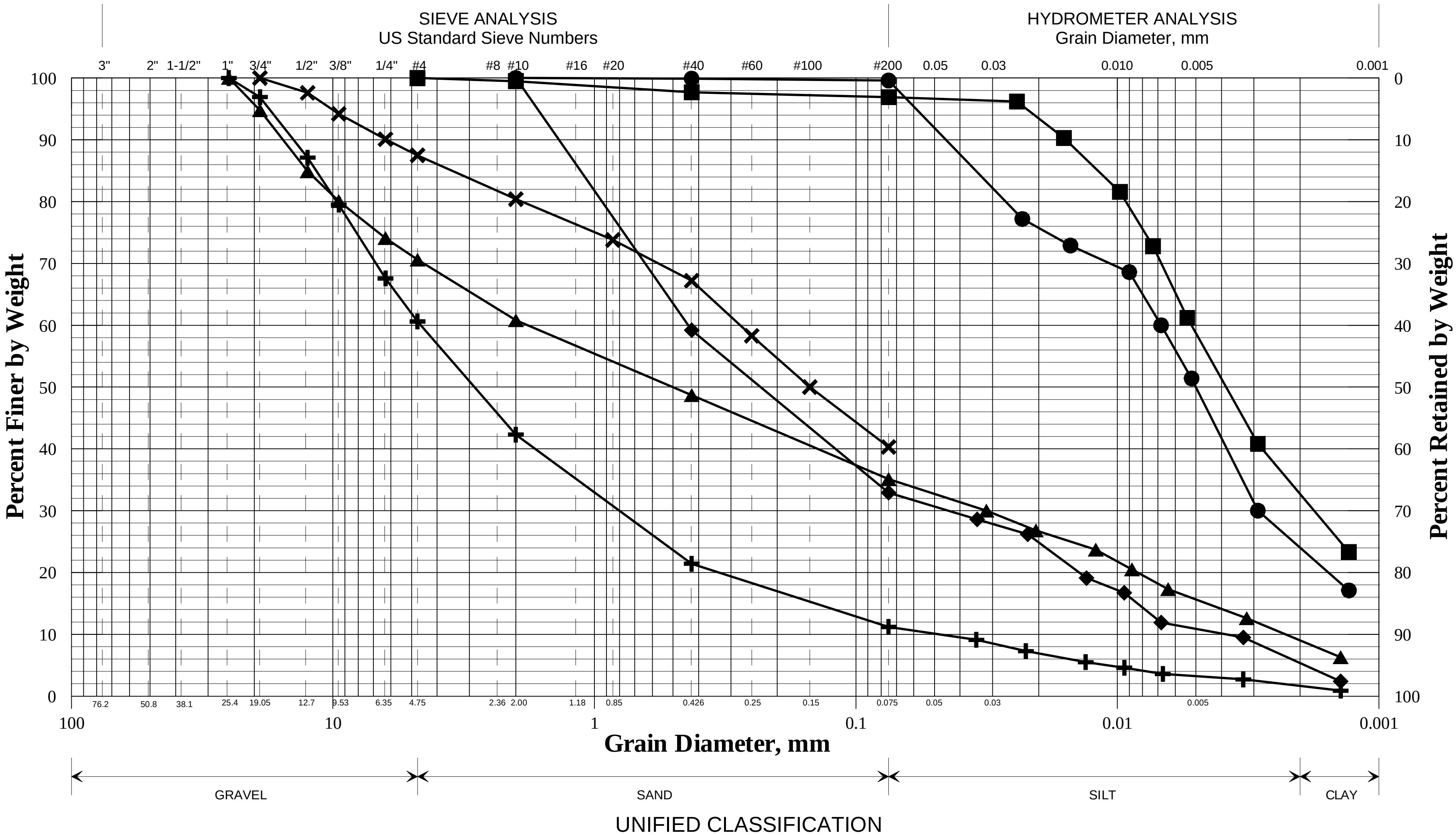


	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
✚	HB-STFR-203/2D	12+09	11.0 RT	5.0-7.0	Gravelly SAND, little silt.	1.9			
◆	HB-STFR-203/4D	12+09	11.0 RT	15.0-17.0	SAND, some gravel, trace silt, trace clay.	6.0			
■	HB-STFR-203/6DB	12+09	11.0 RT	26.0-27.0	SILT, little clay, trace sand.	21.7	23	22	1
●	HB-STFR-203/7D	12+09	11.0 RT	30.0-32.0	SAND, some gravel, some silt, trace clay.	9.3			
▲	HB-STFR-203/10D	12+09	11.0 RT	45.0-47.0	SAND, some silt, little gravel, little clay.	8.2			
✖	HB-STFR-203/12D	12+09	11.0 RT	55.0-56.5	Sandy SILT, little gravel.	6.9			

WIN
017236.10
Town
Allagash, Saint Francis
Reported by/Date
WHITE, TERRY A 11/21/2016

SHEET 5

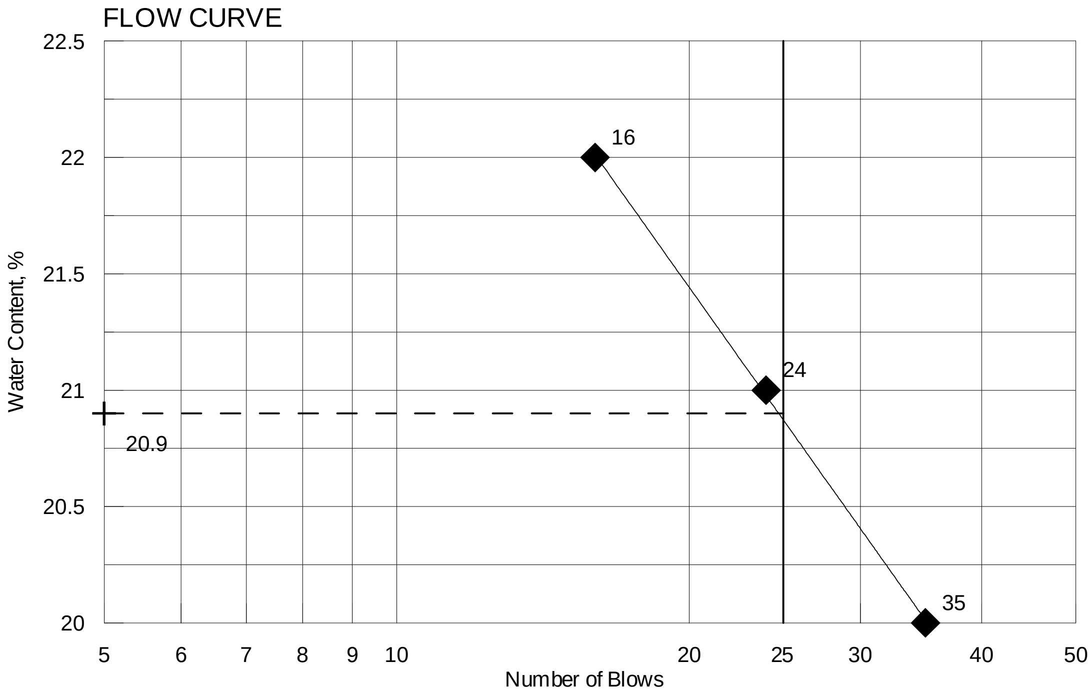
State of Maine Department of Transportation
GRAIN SIZE DISTRIBUTION CURVE

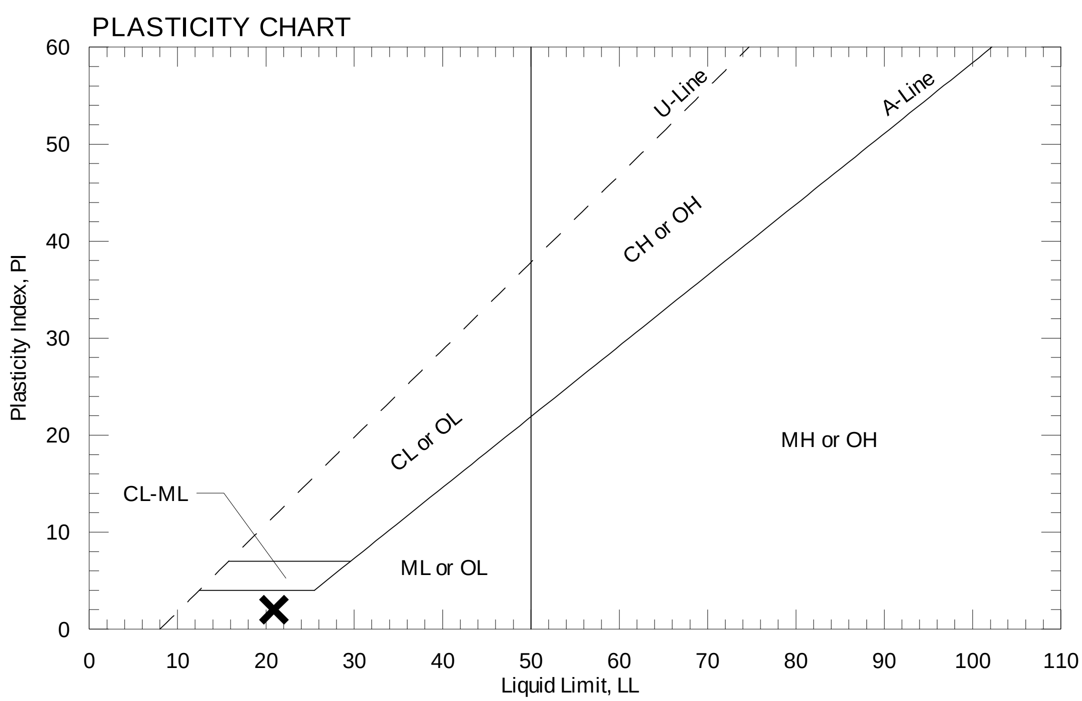


	Boring/Sample No.	Station	Offset, ft	Depth, ft	Description	W, %	LL	PL	PI
✚	HB-STFR-204/4D	10+43	8.2 RT	15.0-17.0	Gravelly SAND, trace silt, trace clay.	8.6			
◆	HB-STFR-204/6D	10+43	8.2 RT	25.0-27.0	SAND, some silt, trace clay.	20.5			
■	HB-STFR-204/7DB	10+43	8.2 RT	27.5-29.0	SILT, some clay, trace sand.	25.6	26	20	6
●	HB-STFR-204/MV1	10+43	8.2 RT	32.0-34.0	SILT, some clay, trace sand.	14.6	26	23	3
▲	HB-STFR-204/9D	10+43	8.2 RT	40.0-41.7	SAND, some gravel, some silt, trace clay.	8.0			
✖	HB-STFR-204/10D	10+43	8.2 RT	45.0-47.0	Silty SAND, little gravel.	8.7			

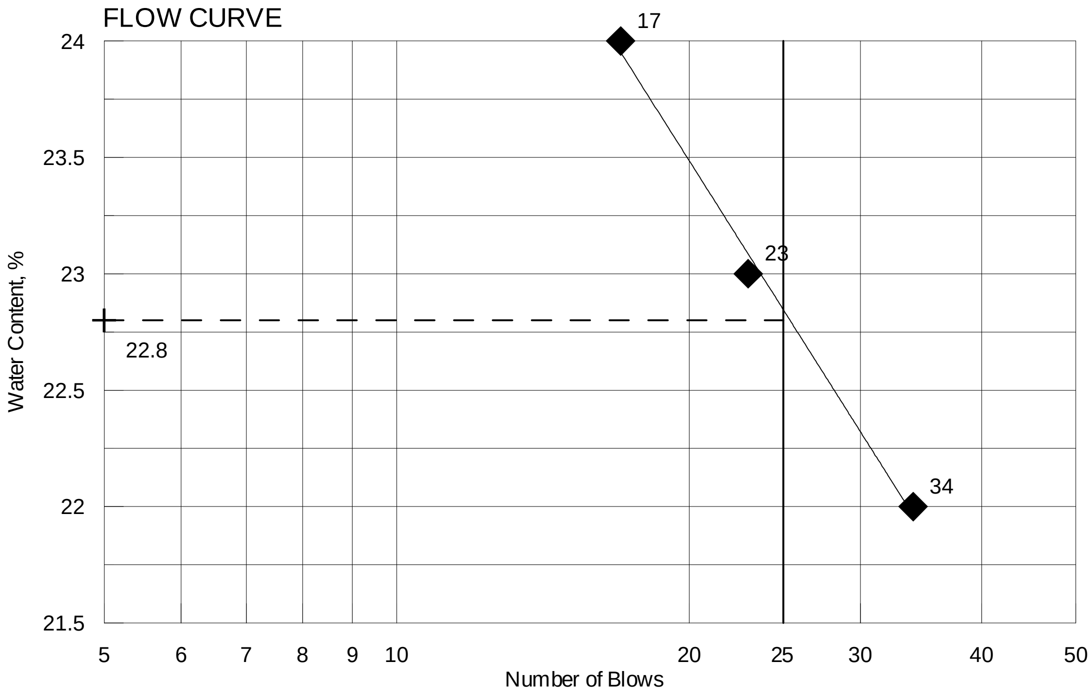
WIN
017236.10
Town
Allagash, Saint Francis
Reported by/Date
WHITE, TERRY A 11/21/2016

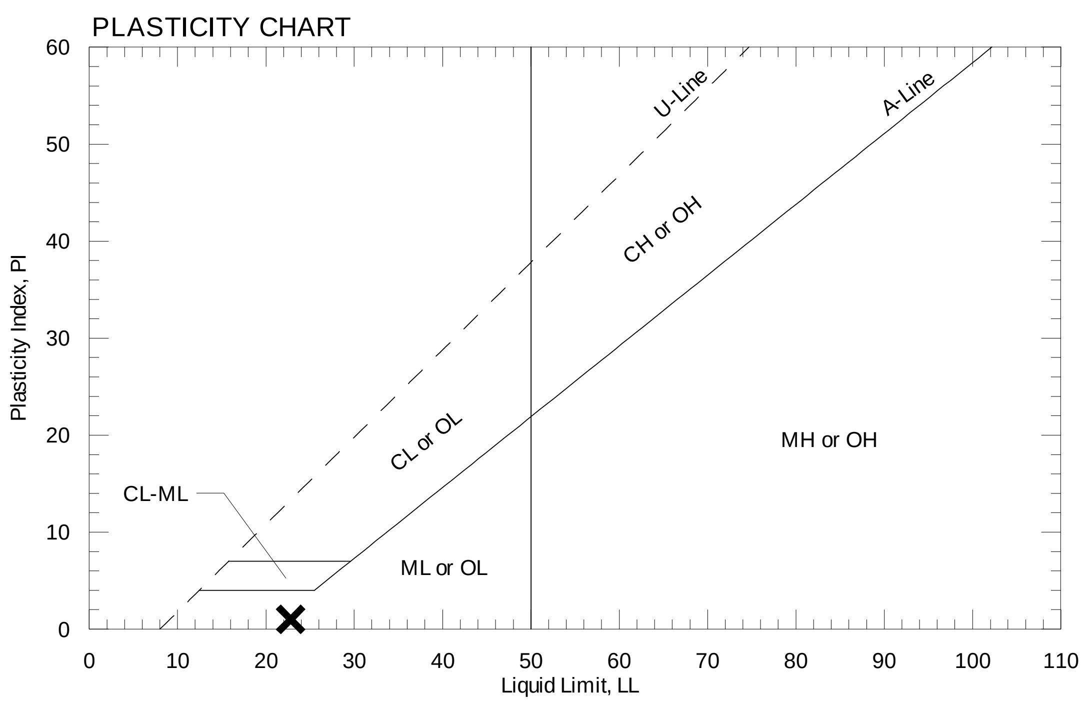
TOWN	Allagash, Saint Francis	Reference No.	304173
WIN	017236.00	Water Content, %	18.9
Sampled	9/26/2016	Liquid Limit @ 25 blows (T 89), %	21
Boring No./Sample No.	HB-STFR-202/6D	Plastic Limit (T 90), %	19
Station	9+04	Plasticity Index (T 90), %	2
Depth	24.0-26.0	Tested By	BBURR



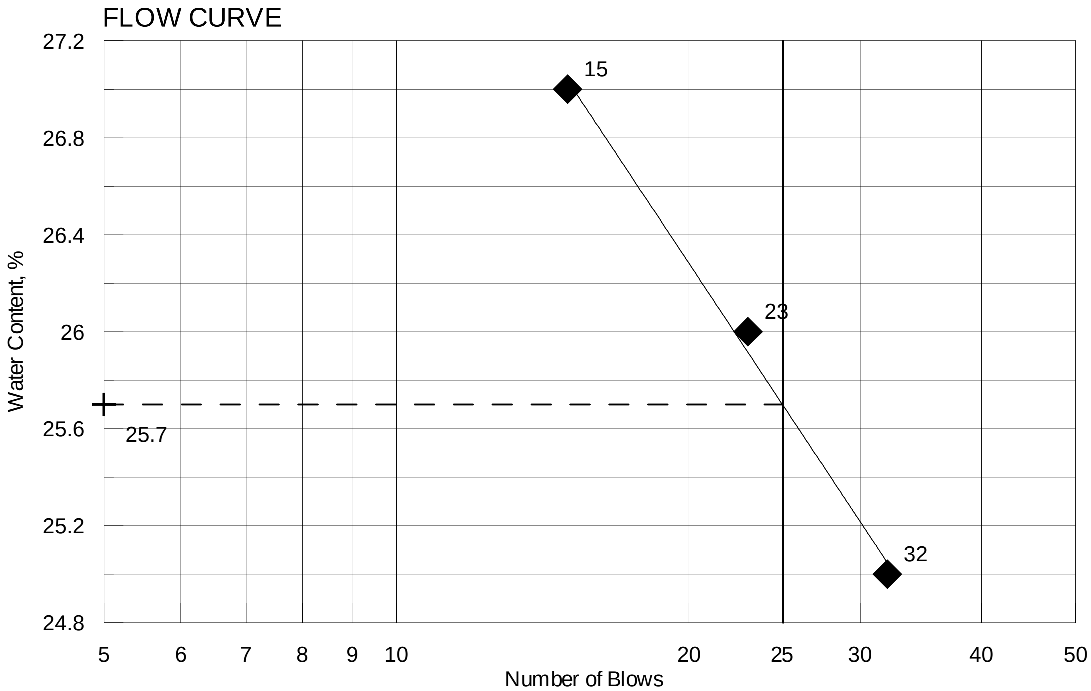


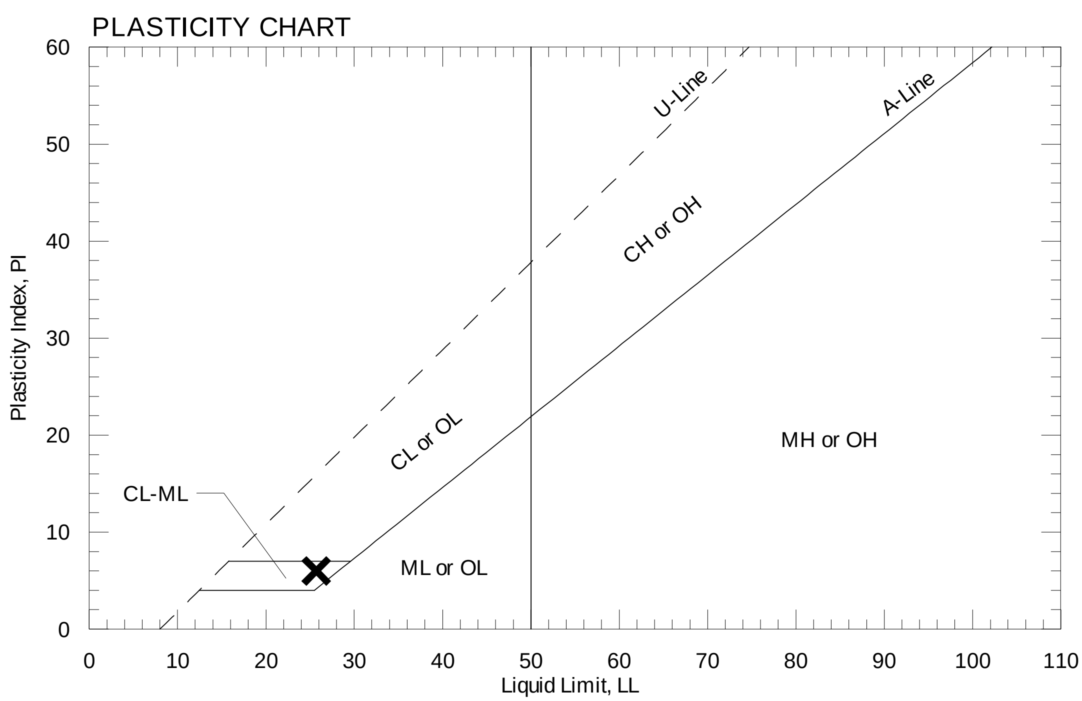
TOWN	Allagash, Saint Francis	Reference No.	304205
WIN	017236.00	Water Content, %	21.7
Sampled	9/26/2016	Liquid Limit @ 25 blows (T 89), %	23
Boring No./Sample No.	HB-STFR-203/6DB	Plastic Limit (T 90), %	22
Station	12+09	Plasticity Index (T 90), %	1
Depth	26.0-27.0	Tested By	BBURR



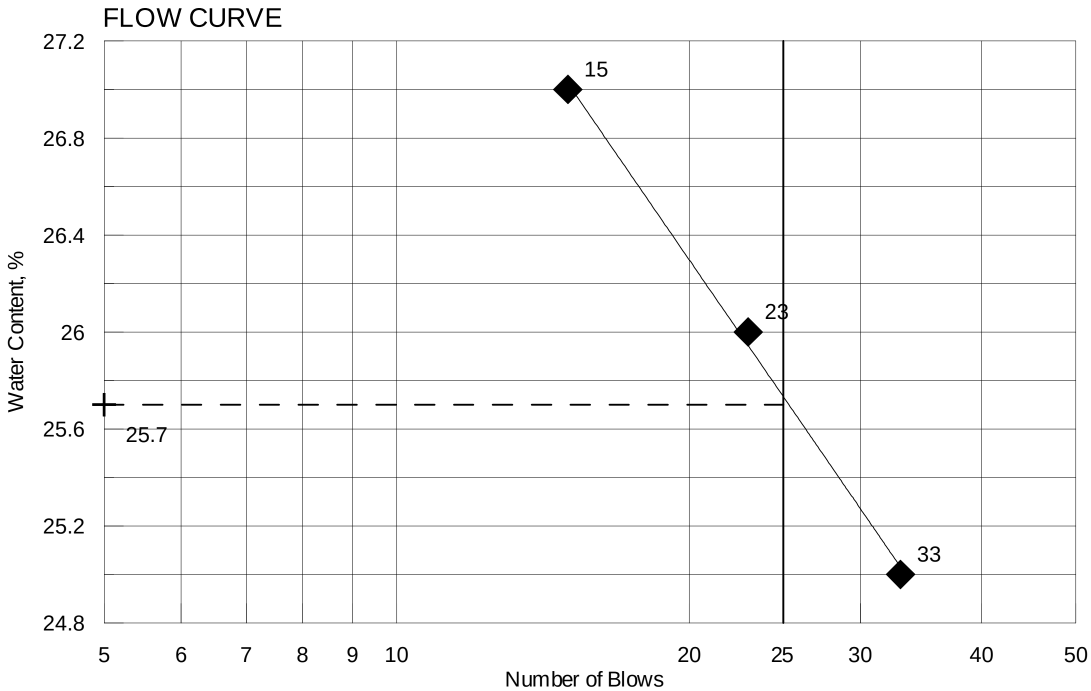


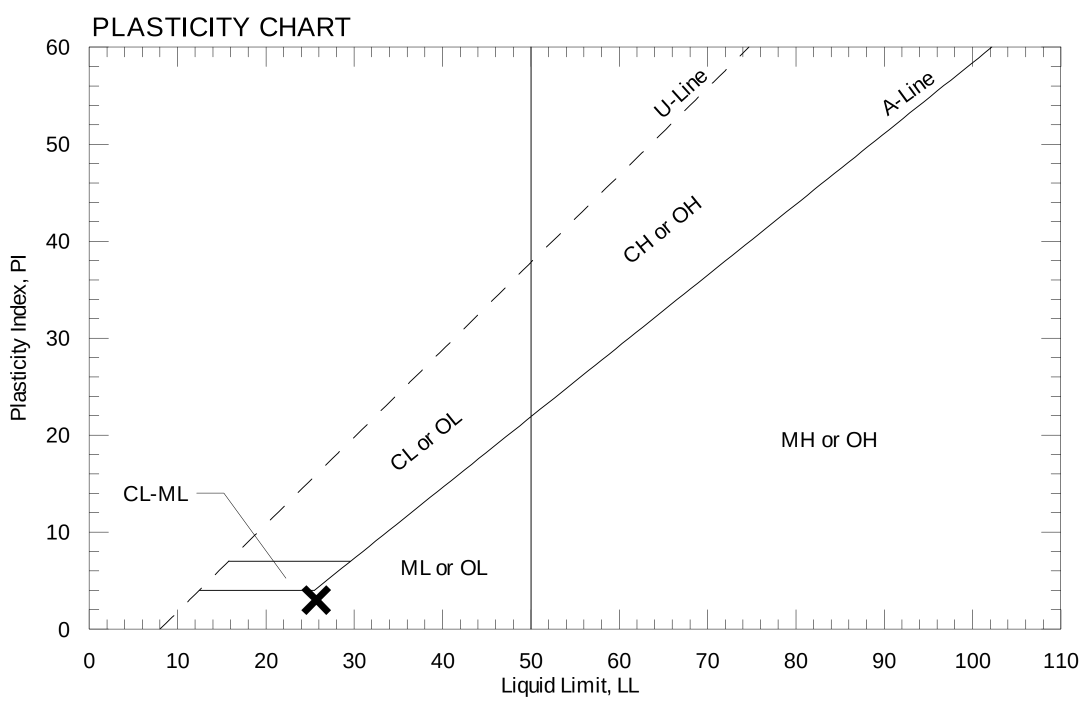
TOWN	Allagash, Saint Francis	Reference No.	304211
WIN	017236.00	Water Content, %	25.6
Sampled	9/22/2016	Liquid Limit @ 25 blows (T 89), %	26
Boring No./Sample No.	HB-STFR-204/7DB	Plastic Limit (T 90), %	20
Station	10+43	Plasticity Index (T 90), %	6
Depth	27.5-29.0	Tested By	BBURR





TOWN	Allagash, Saint Francis	Reference No.	304212
WIN	017236.00	Water Content, %	14.6
Sampled	9/22/2016	Liquid Limit @ 25 blows (T 89), %	26
Boring No./Sample No.	HB-STFR-204/MV1	Plastic Limit (T 90), %	23
Station	10+43	Plasticity Index (T 90), %	3
Depth	32.0-34.0	Tested By	BBURR



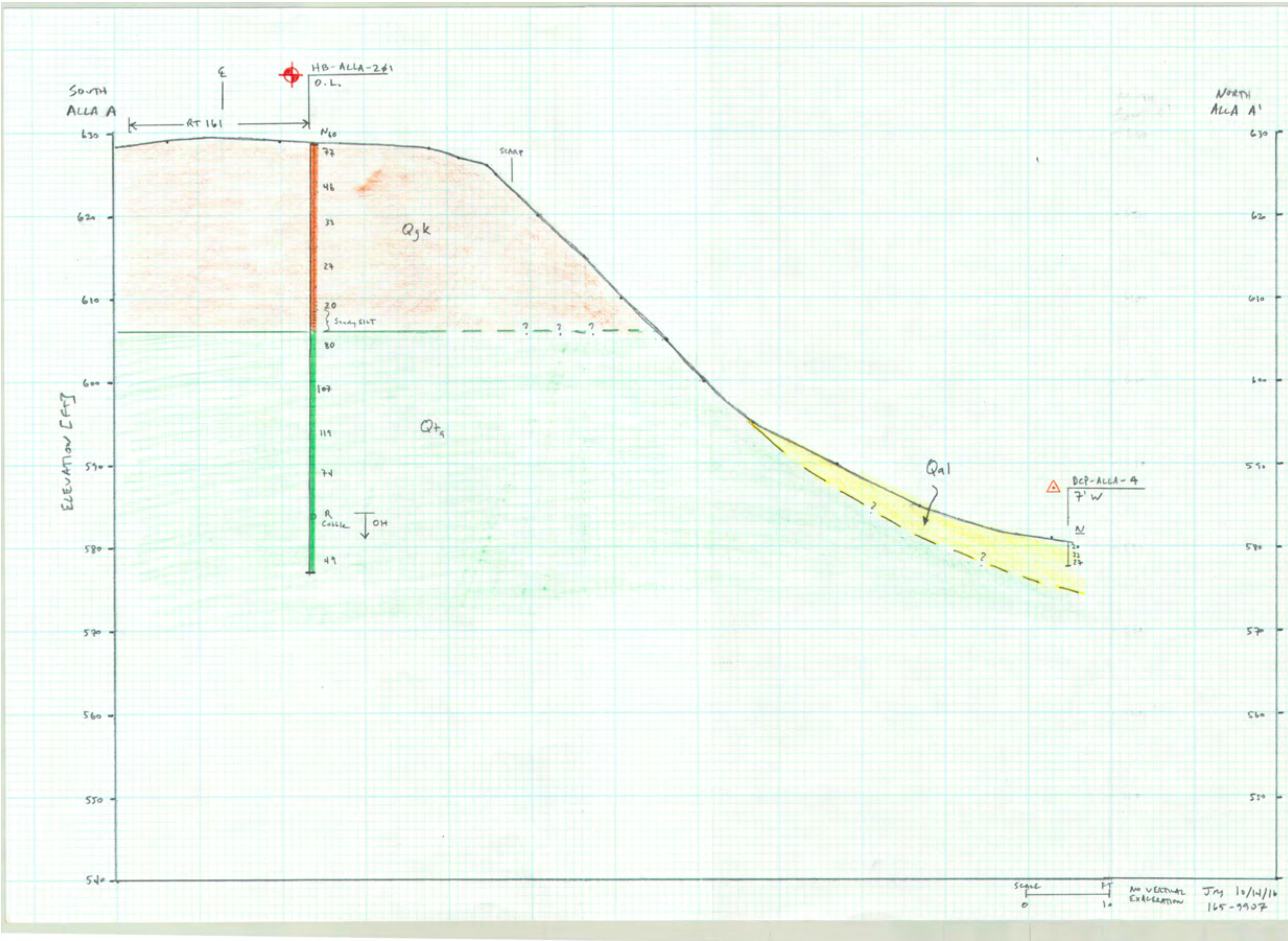


APPENDIX G

Subsurface Profiles

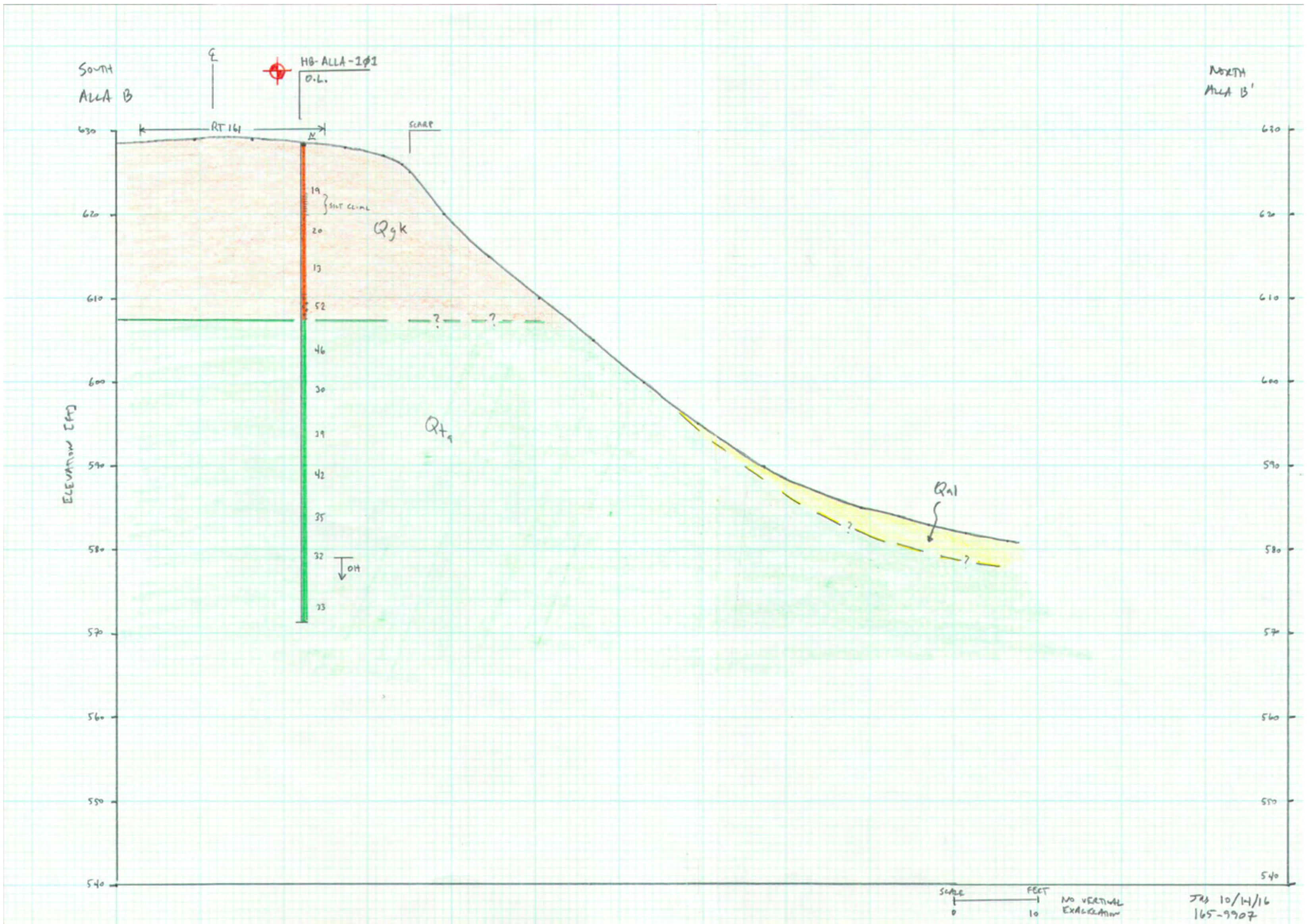
APPENDIX G.1

Allagash Subsurface Profiles



CLIENT	MAINE DEPARTMENT OF TRANSPORTATION 16 STATE HOUSE STATION AUGUSTA, MAINE 04333-0016
PROJECT	GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00
CONSULTANT	GOLDER
YYYY-MM-DD	2019-03-18
DESIGNED	JRS
PREPARED	SKB
REVIEWED	JDL
APPROVED	MSP
TITLE	Allagash Profile A-A'
PROJECT NO.	165-9907
PHASE	
FIGURE	G.1.1

Note:
The location of the profile is indicated on the geologic map plan in Appendix C.1



Note:
The location of the profile is indicated on the geologic map plan in Appendix C.1

CLIENT
MAINE DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

PROJECT
GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION
STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER
ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00

CONSULTANT

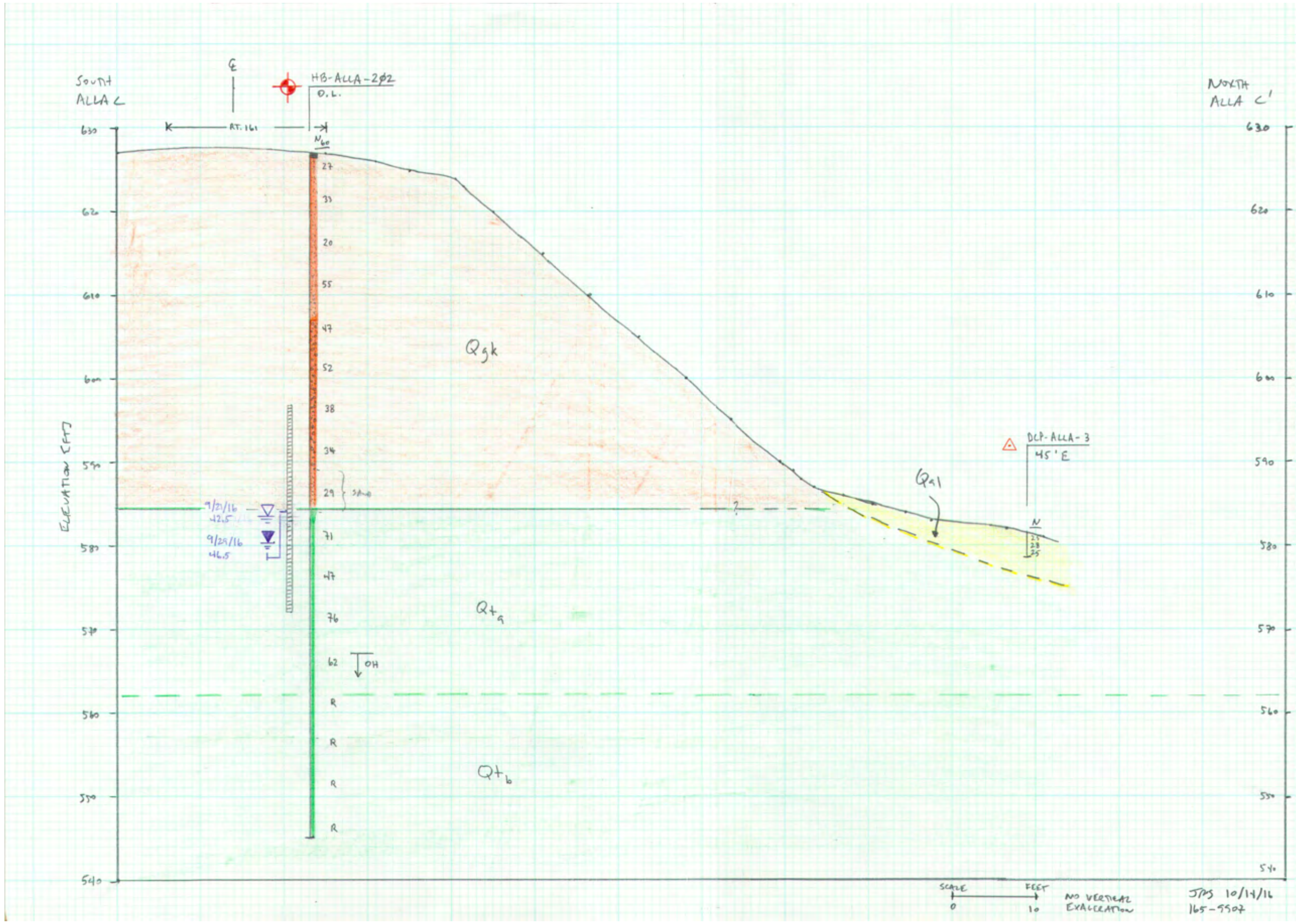
GOLDER

YYYY-MM-DD	**2019-03-18**
DESIGNED	**JRS**
PREPARED	**SKB**
REVIEWED	**JDL**
APPROVED	**MSP**

TITLE

Allagash Profile B-B'

PROJECT NO. 165-9907
PHASE
FIGURE **G.1.2**



Note:
The location of the profile is indicated on the geologic map plan in Appendix C.1

CLIENT
MAINE DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

CONSULTANT

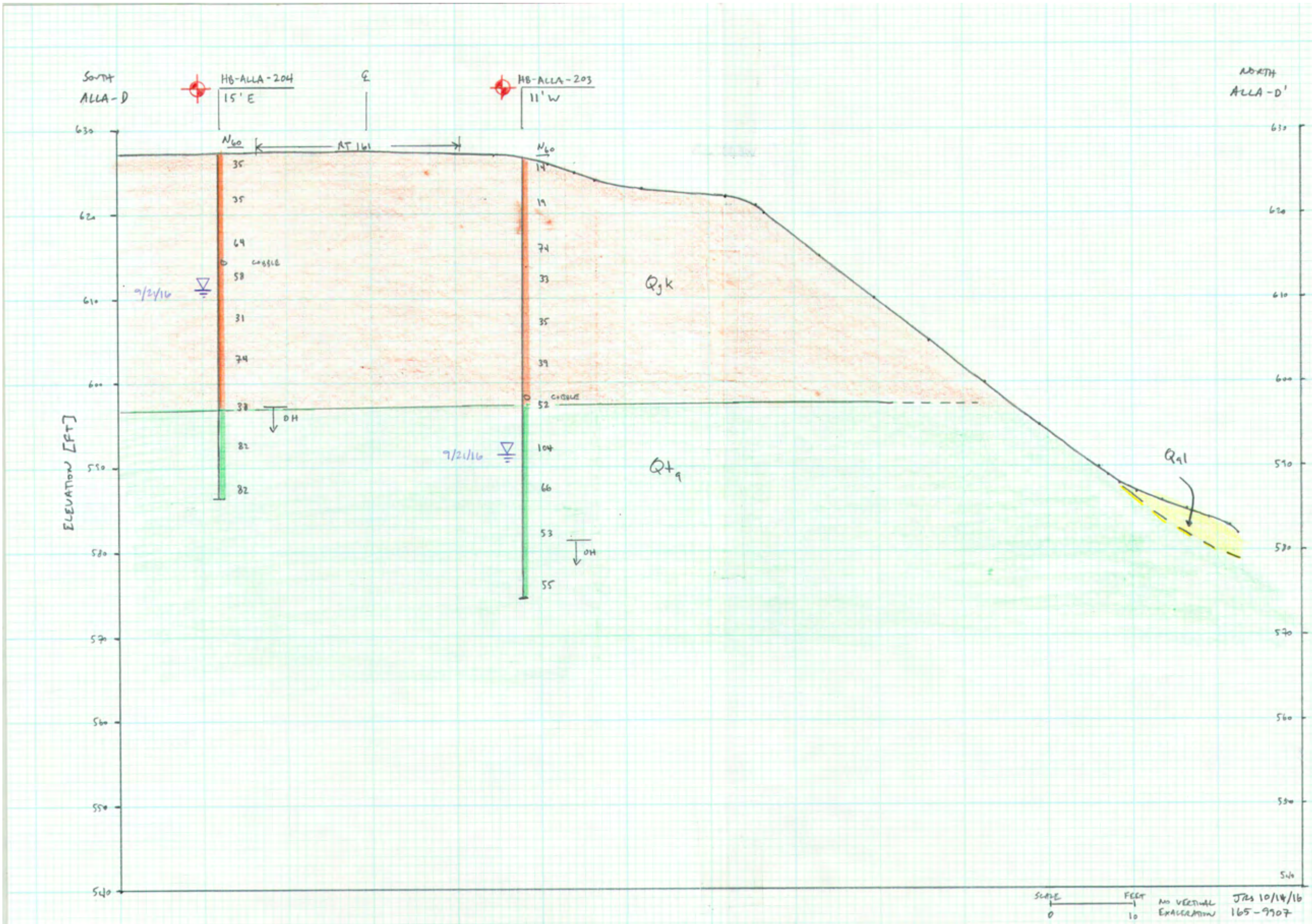
GOLDER

YYYY-MM-DD	**2019-03-18**
DESIGNED	**JRS**
PREPARED	**SKB**
REVIEWED	**JDL**
APPROVED	**MSP**

PROJECT
GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION
STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER
ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00

TITLE
Allagash Profile C-C'

PROJECT NO.	PHASE	FIGURE
165-9907		**G.1.3**



Note:
The location of the profile is indicated on the geologic map plan in Appendix C.1

CLIENT
MAINE DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

PROJECT
GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION
STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER
ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00

CONSULTANT

GOLDER

YYYY-MM-DD	**2019-03-18**
DESIGNED	**JRS**
PREPARED	**SKB**
REVIEWED	**JDL**
APPROVED	**MSP**

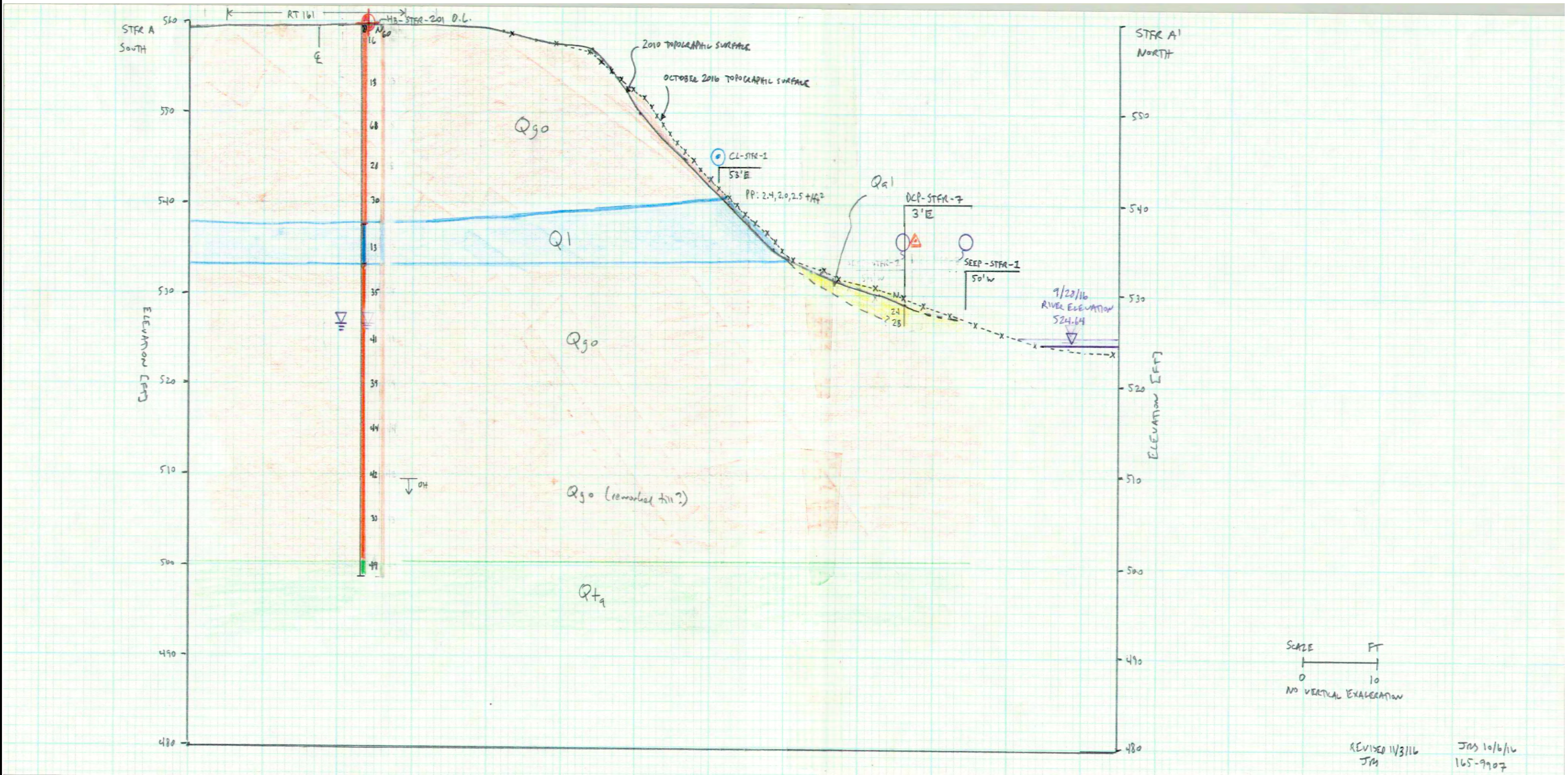
TITLE

Allagash Profile D-D'

PROJECT NO. 165-9907
PHASE
FIGURE **G.1.4**

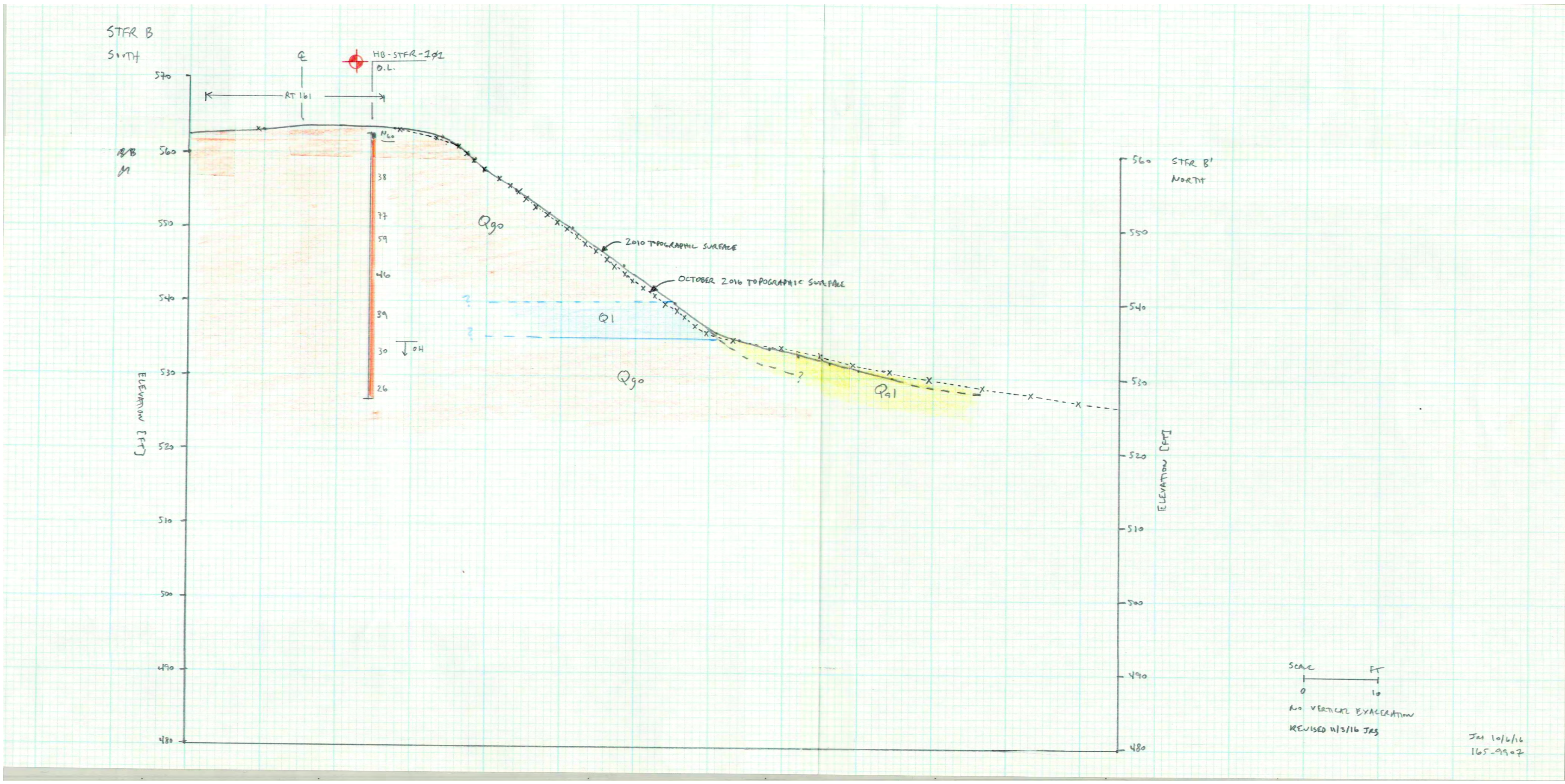
APPENDIX G.2

St. Francis Subsurface Profiles



Note:
The location of the profile is indicated on the geologic map plan in Appendix C.2

CLIENT	MAINE DEPARTMENT OF TRANSPORTATION 16 STATE HOUSE STATION AUGUSTA, MAINE 04333-0016
PROJECT	GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00
CONSULTANT	GOLDER
YYYY-MM-DD	2019-03-18
DESIGNED	JRS
PREPARED	SKB
REVIEWED	JDL
APPROVED	MSP
TITLE	St. Francis Profile A-A'
PROJECT NO.	165-9907
PHASE	
FIGURE	G.2.1



Note:
The location of the profile is indicated on the geologic map plan in Appendix C.2

CLIENT
MAINE DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

CONSULTANT

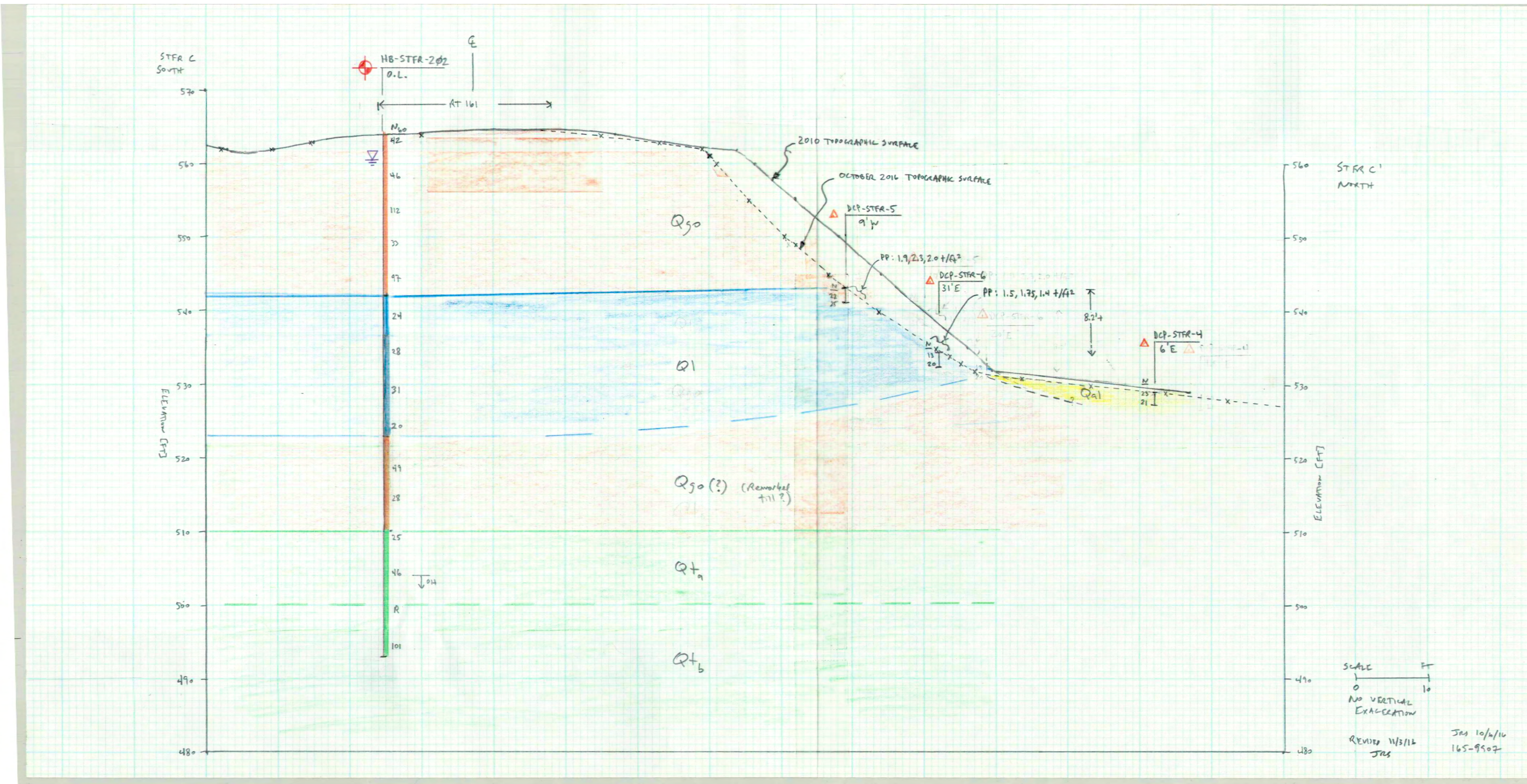
GOLDER

YYYY-MM-DD	**2019-03-18**
DESIGNED	**JRS**
PREPARED	**SKB**
REVIEWED	**JDL**
APPROVED	**MSP**

PROJECT
GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION
STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER
ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00

TITLE
St. Francis Profile B-B'

PROJECT NO. 165-9907
PHASE
FIGURE **G.2.2**



IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

Note:
The location of the profile is indicated on the geologic map plan in Appendix C.2

CLIENT
MAINE DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

PROJECT
GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION
STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER
ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00

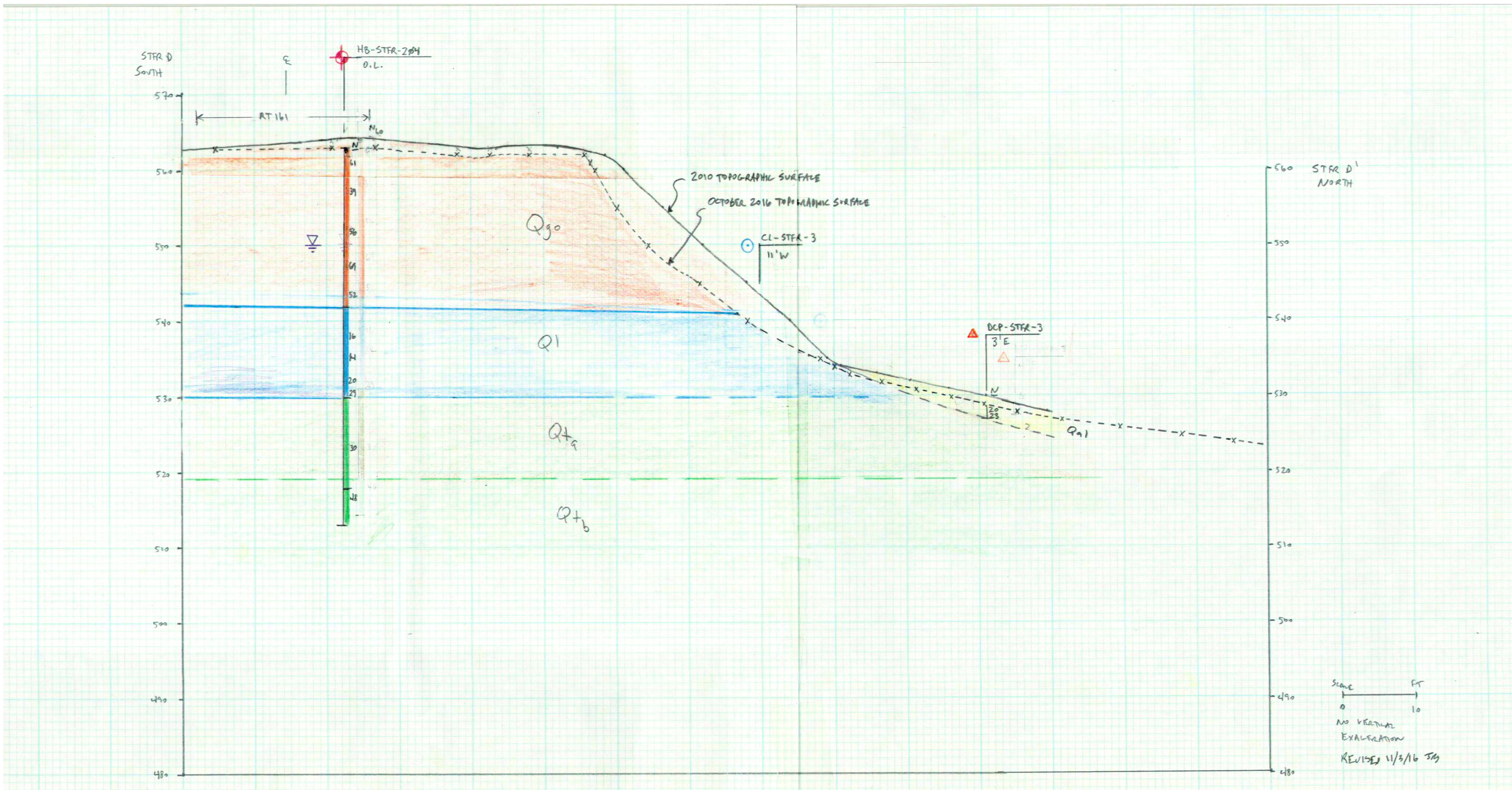
CONSULTANT

GOLDER

YYYY-MM-DD	2019-03-18
DESIGNED	JRS
PREPARED	SKB
REVIEWED	JDL
APPROVED	MSP

TITLE
St. Francis Profile C-C'

PROJECT NO. 165-9907
PHASE
FIGURE G.2.3



Note:
The location of the profile is indicated on the geologic map plan in Appendix C.2

CLIENT
MAINE DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

CONSULTANT

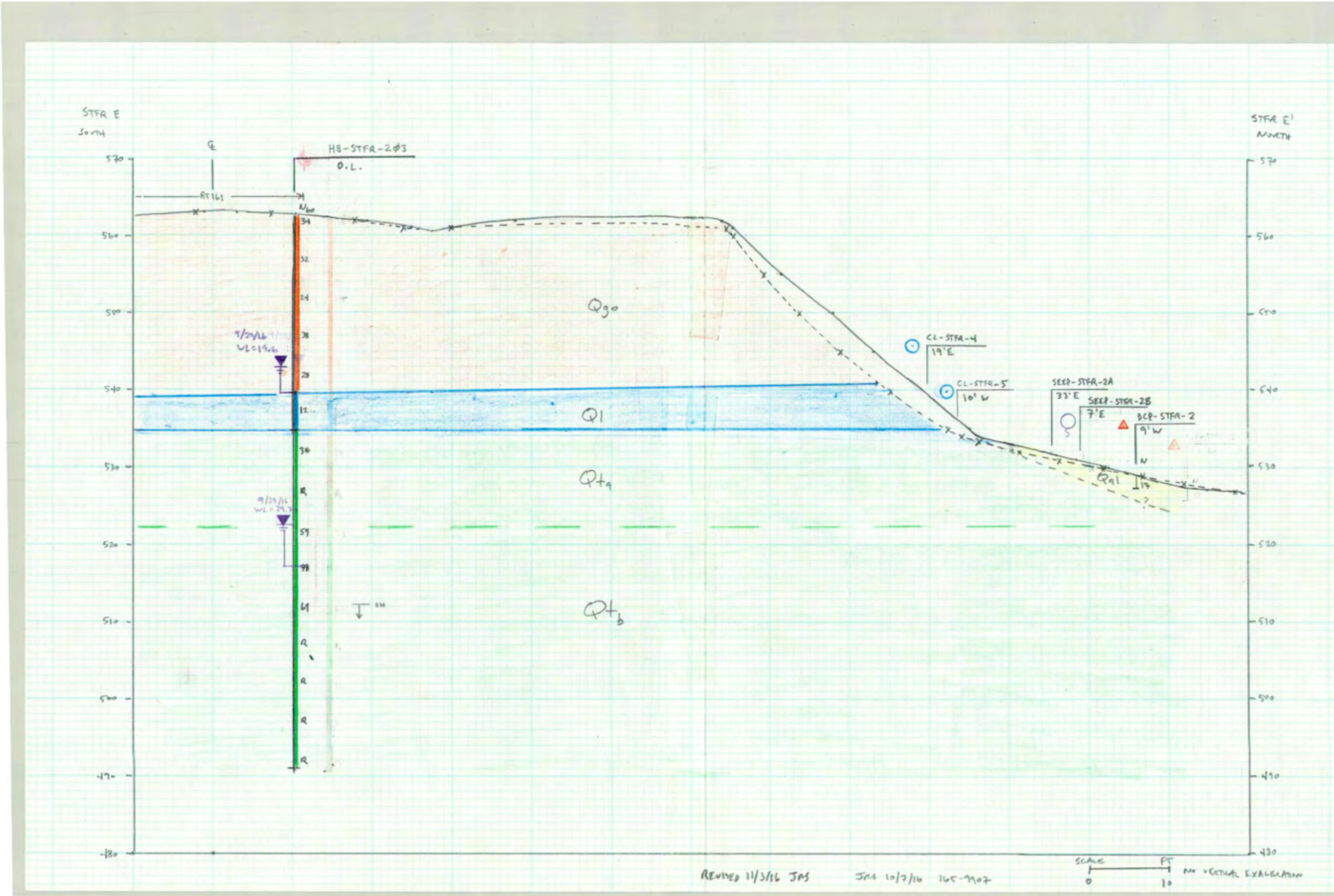
GOLDER

YYYY-MM-DD	**2019-03-18**
DESIGNED	**JRS**
PREPARED	**SKB**
REVIEWED	**JDL**
APPROVED	**MSP**

PROJECT
GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION
STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER
ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00

TITLE
St. Francis Profile D-D'

PROJECT NO.	PHASE	FIGURE
165-9907		**G.2.4**



CLIENT
MAINE DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

PROJECT
GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION
STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER
ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00

CONSULTANT

GOLDER

YYYY-MM-DD	**2019-03-18**
DESIGNED	**JRS**
PREPARED	**SKB**
REVIEWED	**JDL**
APPROVED	**MSP**

TITLE

St. Francis Profile E-E'

PROJECT NO. 165-9907

PHASE

FIGURE **G.2.5**

Note:
The location of the profile is indicated on the geologic map plan in Appendix C.2

0 1 in IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

APPENDIX H

Hydrologic and Hydraulic Evaluation of Existing Conditions

TECHNICAL MEMORANDUM

DATE March 15, 2017 **Project No.** 1659907

TO Project File
MainDOT

CC Mark Peterson, PE, Golder Associates Inc., Freeport, ME

FROM Scott Stoneman, PE (WA), Andreas Kammereck, PE (WA) **EMAIL** sstoneman@golder.com

HYDROLOGIC AND HYDRAULIC EVALUATION OF EXISTING CONDITIONS – SLOPE STABILIZATION OF STATE ROUTE 161 AT ST. FRANCIS AND ALLAGASH, MAINE

1.0 INTRODUCTION

Golder Associates Inc (Golder) was requested by the Maine Department of Transportation (MaineDOT) to provide hydraulic engineering services for assessment and design support for slope stabilization for two sites adjacent to State Route 161between the roadway and the St. John River. One site is along roughly an 800-foot segment of State Route 161 in St. Francis and the second site is about a 550-foot portion of the roadway in the town of Allagash. The Allagash slope segment is positioned at the confluence of the Allagash River and the St. John River. The St. Francis slope segment is located on the St. John River approximately 12 miles downstream of Allagash site and directly downstream of a valley constriction that occurs just downstream of the confluence of the St. Francis River and the St. John River.

This memorandum presents a hydrologic and hydraulic evaluation of existing conditions for the two sites. The hydrologic analysis provides peak discharge estimates for average recurrence intervals for the 2- through 500-year events. The hydraulic evaluation includes modelling the sites using both Hydrologic Engineering Center River Analysis System (HEC-RAS) (USACE 2018) and TUFLOW (BMT 2017). The results of these models are later to be used for the assessment of the scour potential and design of the riverbank stabilization.

2.0 HYDROLOGY

Peak discharge at the two sites were estimated using the United States Geological Survey (USGS) application entitled StreamStats. StreamStats is a web-based Geographic Information Systems (GIS) application that provides users with access to an assortment of analytical tools that are useful for a variety of water-resources planning, management, and engineering purposes (USGS 2017). StreamStats is regression techniques based on USGS gage station data. The closest United States Geological Survey (USGS) gage to the Allagash site, USGS Gage 01010500 – St. John River at Dickey, is located on the St. John River about 3 miles upstream of the confluence with the Allagash River. The closest USGS gage to the St. Francis site, USGS Gage 01014000 – St. John below Fish River, at Fort Kent, Maine, is located on the St. John directly downstream from the St. John's confluence with the Fish River. Table 1 presents the estimated peak discharge on the St. John River at the Allagash and St. Francis sites.

Table 1: Estimated Peak Discharge

Recurrence Interval	St. John River at Allagash	St. John River at St. Francis
2-yr	58,000	68,000
5-yr	78,000	92,000
10-yr	92,000	108,000
25-yr	108,000	127,000
50-yr	120,000	141,000
100-yr	133,000	156,000
500-yr	163,000	191,000

As a comparison and check of the StreamStats flows, peak discharge was also estimated utilizing a regression method found in *Estimating the Magnitude of Peak Flows for Streams in Maine for Selected Recurrence Intervals* (Hodgkins 1999). Additionally, peak discharge at the Allagash site was compared with published values found in the 2003 Flood Insurance Study (FIS) Number 230440V000A for the Town of Allagash, Maine, Aroostook County (FEMA 2003). Comparison of all flow data showed similar results, and the StreamStats results were utilized for this evaluation. All hydrologic data, calculations and comparisons can be found in Attachment A.

3.0 HYDRAULICS

A hydraulic analysis was completed for both the Allagash and St. Francis sites using one-dimensional (1D) steady-flow HEC-RAS models. The models were developed using survey data collected in 2016 by MaineDOT. The site survey included three river cross-sections taken at each site; one cross-section at the slope failure location and two cross-sections directly downstream.

A Manning's roughness was estimated at 0.027 and 0.03 for the channel and 0.04 and 0.05 for the surrounding floodplain for the St. Francis model and the Allagash model, respectively.

The downstream boundary conditions for the St. Francis and Allagash sites were set as normal depth with slopes of 0.10% and 0.15%, respectively.

Additionally, a layer of ice thickness was taken into account in the 1D HEC-RAS models through the 'ice cover' tool option. An ice cover thickness of 3 feet for the banks and 2.5 feet for the channel was selected for both sites based on guidance from the FEMA FIS (FEMA 2003). For both sites, the results of the 1D HEC-RAS model with ice cover for the 100-year recurrence interval event yielded much slower velocities, higher water surface elevations and greater channel depths. Table 2 presents the results of the HEC-RAS for the 100-year event.

Table 2: HEC-RAS Results for the 100-year Event at Site Surveyed Cross-Section

Site	Condition	Water Surface Elevation (feet NAVD 88)	Maximum Channel Depth (feet)	Channel Velocity (feet per second)
Allagash	Without Ice	594.77	18.90	6.85
	With Ice	605.49	29.62	3.89
St. Francis	Without Ice	541.66	21.13	9.21
	With Ice	554.34	33.81	5.41

The resulting water surface elevation at the Allagash site (with ice) was more conservative than the FEMA FIS study. The FEMA study shows the 100-year water surface elevation (base flood elevation [BFE]) at the Allagash site at approximately 604.1 feet NAVD 88 (604.5 feet NGVD 29). The HEC-RAS model developed by Golder resulted in a water surface elevation of 605.49 feet, which is approximately 1.4 feet higher than the FEMA study. Attachment B includes HECRAS printouts.

In addition to the 1D HEC-RAS models, two-dimensional (2D) models were created for the same reaches as the HEC-RAS model, with the exception they were a little longer. The 2D Allagash model extended far enough upstream to include the effects of the confluence of the Allagash and St. John Rivers; therefore, two inflow boundary conditions were required for the Allagash Model. The 2D models included the following elements:

- Topography – The digital elevation model (DEM) was generated from combining the 2016 MaineDOT survey data with a Light Detection and Ranging (LiDAR) survey (FEMA 2009). The LiDAR data was obtained during the high flow season of the spring freshet and as such did not capture much of the channel bathymetry. The bathymetry was estimated through extrapolation of the surveyed cross-sections.
- Manning's Roughness – The 2D models incorporated a Manning's roughness of 0.027 for the channel and 0.040 for the overbank. Two small areas within the Allagash model were slightly unstable and higher n-values were assigned.
- Inflow Boundary – Inflow hydrographs were set to the inflow boundaries. The inflow ramped up to the peak discharge at 0.25 hours and held steady for the remainder of the run. The Allagash model included two inflow boundaries, which were the Allagash River and St. John Rivers. The total estimated flow at the site was proportioned by contributing drainage area to each of the inflow boundary locations. The Allagash River accounts for 31% of the contributing drainage area received 31% of the total peak discharge. The St. John River upstream of the confluence of the Allagash River received 69% of the total peak discharge.
- Outlet Boundary – The outlet boundaries were setup as a head versus time boundary, with the water surface elevation to approximately match the results of the HEC-RAS model.
- 2D Grid Cell Size – The model was set up with a cell size of 10 feet.
- Time step – A time step of 2 seconds was used.

- Simulation time – The model was run for a total of 2.5 hours, with results obtained at the end of the run.

Figures 1 through 6 present the results of the 2D hydraulic model results including velocity, water surface elevation and depth for the both the Allagash and St. Francis sites for the 100-year peak discharge event. Table 3 summarizes the resulting maximum velocity, water surface elevation and maximum depth at the location of the surveyed cross-section at each site.

Table 3: TUFLOW Results for the 100-year Event at Site Surveyed Cross-Section

Site	Water Surface Elevation (feet NAVD 88)	Maximum Channel Depth (feet)	Maximum Channel Velocity (feet per second)
Allagash	595.9	16.8	7.5
St. Francis	542.6	22.3	10.4

*Modeled without ice.

Attachments

Figures

Figure 1: 2D Modeling Results – Velocity, 100-year Event (No Ice), St. Francis Site
Figure 2: 2D Modeling Results – WSE, 100-year Event (No Ice), St. Francis Site
Figure 3: 2D Modeling Results – Depth, 100-year Event (No Ice), St. Francis Site
Figure 4: 2D Modeling Results – Velocity, 100-year Event (No Ice), Allagash Site
Figure 5: 2D Modeling Results – WSE, 100-year Event (No Ice), Allagash Site
Figure 6: 2D Modeling Results – Depth, 100-year Event (No Ice), Allagash Site

Appendices

Attachment A: Hydrologic Analysis
Attachment B: HEC-RAS Printouts

4.0 REFERENCES

BMT Group Ltd. 2017. TUFLOW Release 2017-09-AC.

Federal Emergency Management Administration (FEMA). 2003. *Town of Allagash, Maine, Aroostook County, Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS)*, Number 230440V000A, Revised April 2, 2003.

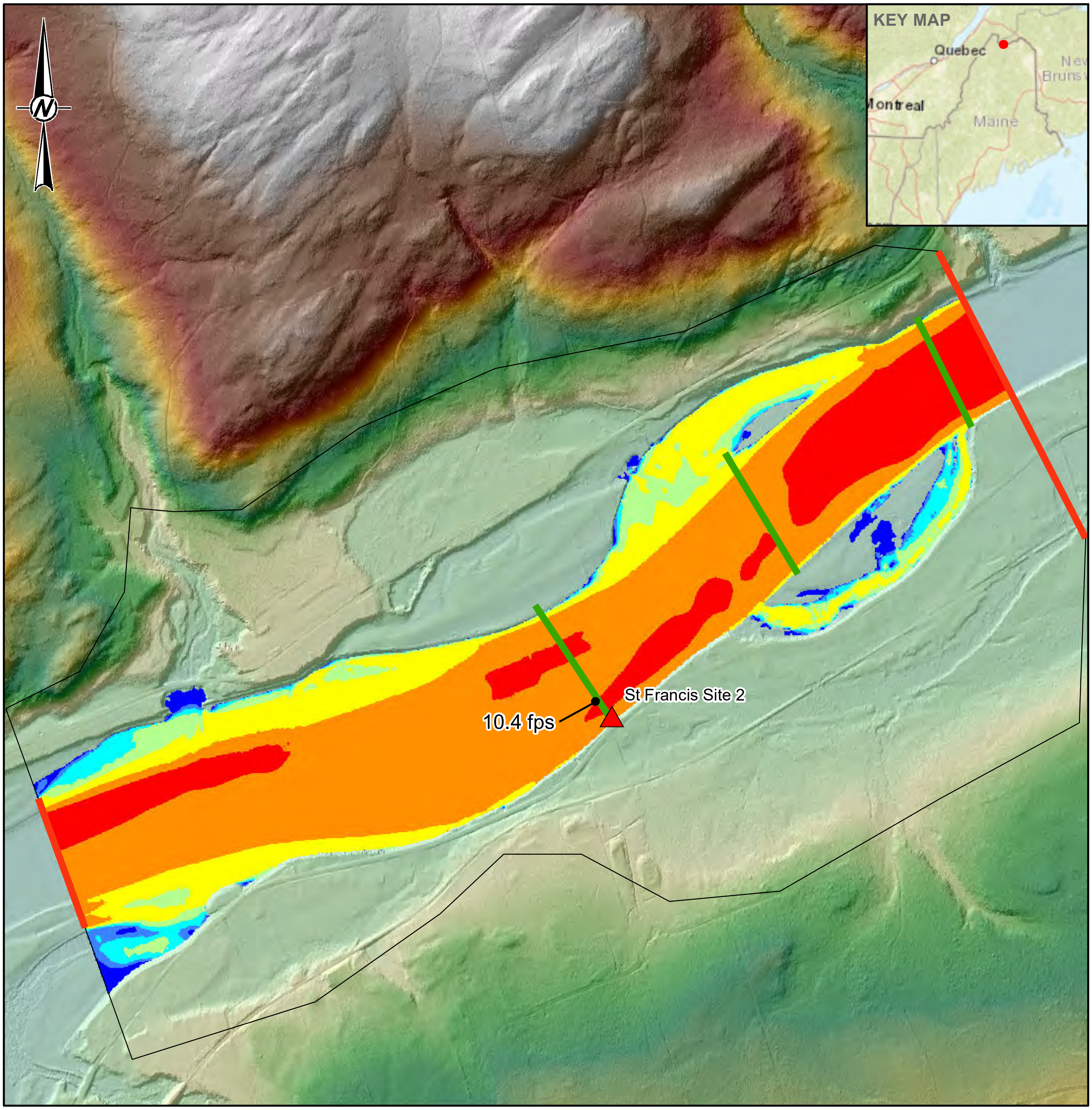
FEMA. 2009. Fort Kent LiDAR Survey.

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.

US Army Corps of Engineers (USACE). 2018. HEC-RAS River Analysis System 5.0.5 June 2018.

US Geological Survey (USGS). 2017. StreamStats website, http://water.usgs.gov/osw/streamstats/.

Figures



LEGEND

- Boundary Condition
- Surveyed cross-sections
- Model Domain

Velocity (fps)

- 0.00 to 0.20
- 0.20 to 0.50
- 0.50 to 1.00
- 1.00 to 2.00
- 2.00 to 5.00
- 5.00 to 10.00
- 10.00 to 20.00

0 375 750 1,500
Feet

REFERENCE(S)

1. HYDRAULIC MODEL SETUP AND RESULTS IS FROM GOLDER BASED ON TUFLOW.
2. DIGITAL ELEVATION MODEL (DEM) IS FROM 2009 FEDERAL EMERGENCY MANAGEMENT AGENCY TOPOGRAPHIC LIDAR: FORT KENT, MAINE.
3. SUPPLEMENTAL BATHYMETRY IS BASED ON FROM MAINE DEPARTMENT OF TRANSPORTATION SURVEY OF THREE CROSS-SECTION, 10/2016.
4. COORDINATE SYSTEM: NAD 1983 MAINE 2000 CENTRAL ZONE FOOT US
5. SERVICE LAYER CREDITS: SOURCES: ESRI, DELORME, NAVTEQ, USGS, INTERMAP, IPC, NRCAN, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), ESRI (THAILAND), TOMTOM, 2013

CLIENT
MAINE DOT

PROJECT
EVALUATION AND STABILIZATION OF UNSTABLE SLOPES
STATE ROUTE 161, ST. FRANCIS AND ALLAGASH, MAINE

TITLE
2D MODELING RESULTS - VELOCITY
100-YEAR EVENT (NO ICE)
ST FRANCES SITE

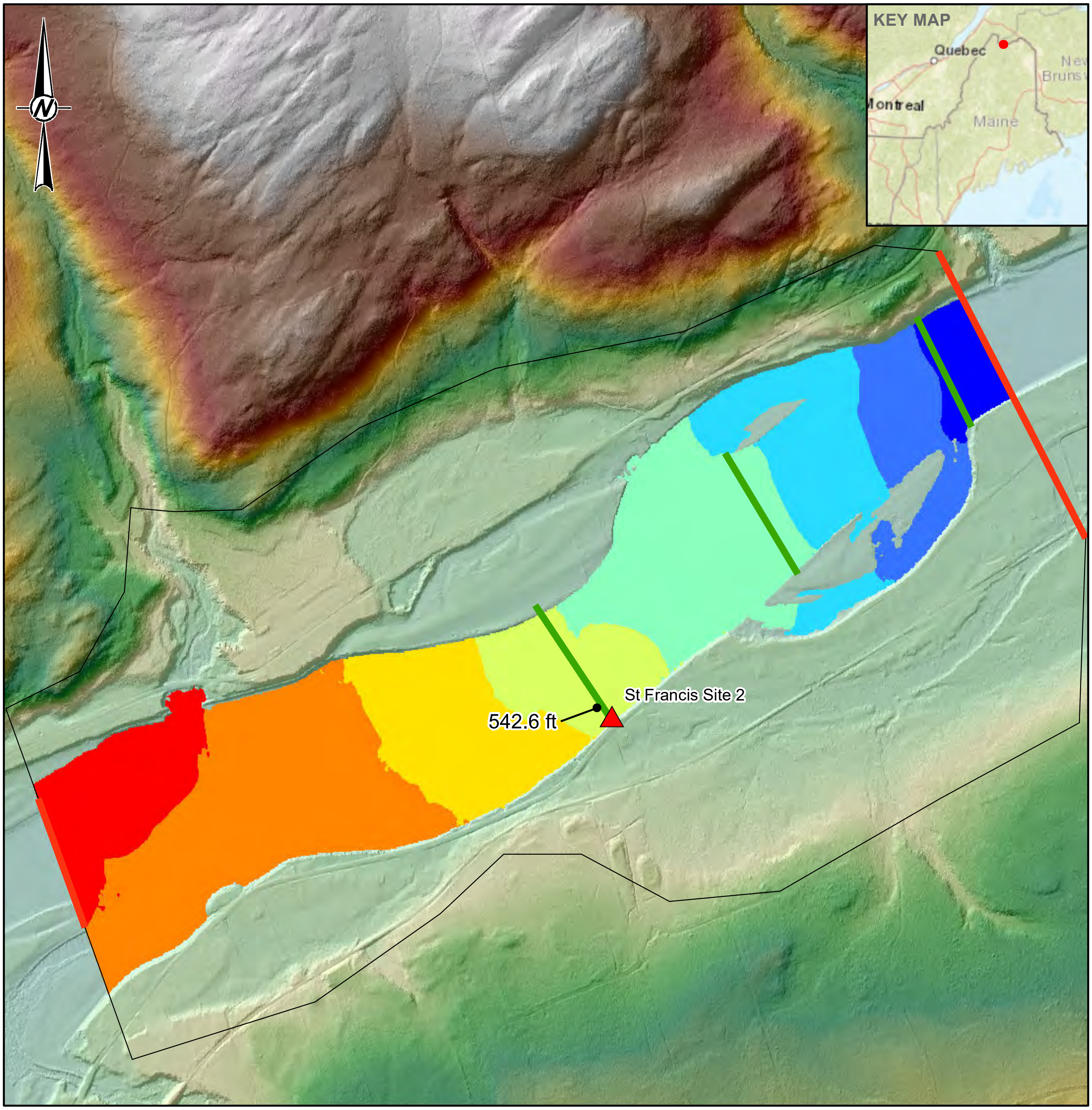
CONSULTANT
GOLDER

YYYY-MM-DD	2019-03-12
DESIGNED	SJS
PREPARED	SJS
REVIEWED	AQK
APPROVED	AQK

PROJECT NO.	PHASE	REV.	FIGURE
1659907	004	0	1

PATH: G:\MaineDOT\Allagash\99_PROJECTS\1659907_Allagash\02_PRODUCTION\MXD\FIGURES\Rev0\1659907_001_TUFLOW_StFrancis.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A



LEGEND

- Boundary Condition
- Surveyed cross-sections
- Model Domain

WSE (ft) - NAVD88

- 538 to 539
- 539 to 540
- 540 to 541
- 541 to 542
- 542 to 543
- 543 to 544
- 544 to 545
- 545 to 546

0 375 750 1,500 Feet

REFERENCE(S)

1. HYDRAULIC MODEL SETUP AND RESULTS IS FROM GOLDER BASED ON TUFLOW.
2. DIGITAL ELEVATION MODEL (DEM) IS FROM 2009 FEDERAL EMERGENCY MANAGEMENT AGENCY TOPOGRAPHIC LIDAR: FORT KENT, MAINE.
3. SUPPLEMENTAL BATHYMETRY IS BASED ON FROM MAINE DEPARTMENT OF TRANSPORTATION SURVEY OF THREE CROSS-SECTION, 10/2016.
4. COORDINATE SYSTEM: NAD 1983 MAINE 2000 CENTRAL ZONE FOOT US
5. SERVICE LAYER CREDITS: SOURCES: ESRI, DELORME, NAVTEQ, USGS, INTERMAP, IPC, NRCAN, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), ESRI (THAILAND), TOMTOM, 2013

CLIENT
MAINE DOT

PROJECT
EVALUATION AND STABILIZATION OF UNSTABLE SLOPES
STATE ROUTE 161, ST. FRANCIS AND ALLAGASH, MAINE

TITLE
2D MODELING RESULTS - WSE
100-YEAR EVENT (NO ICE)
ST FRANCES SITE

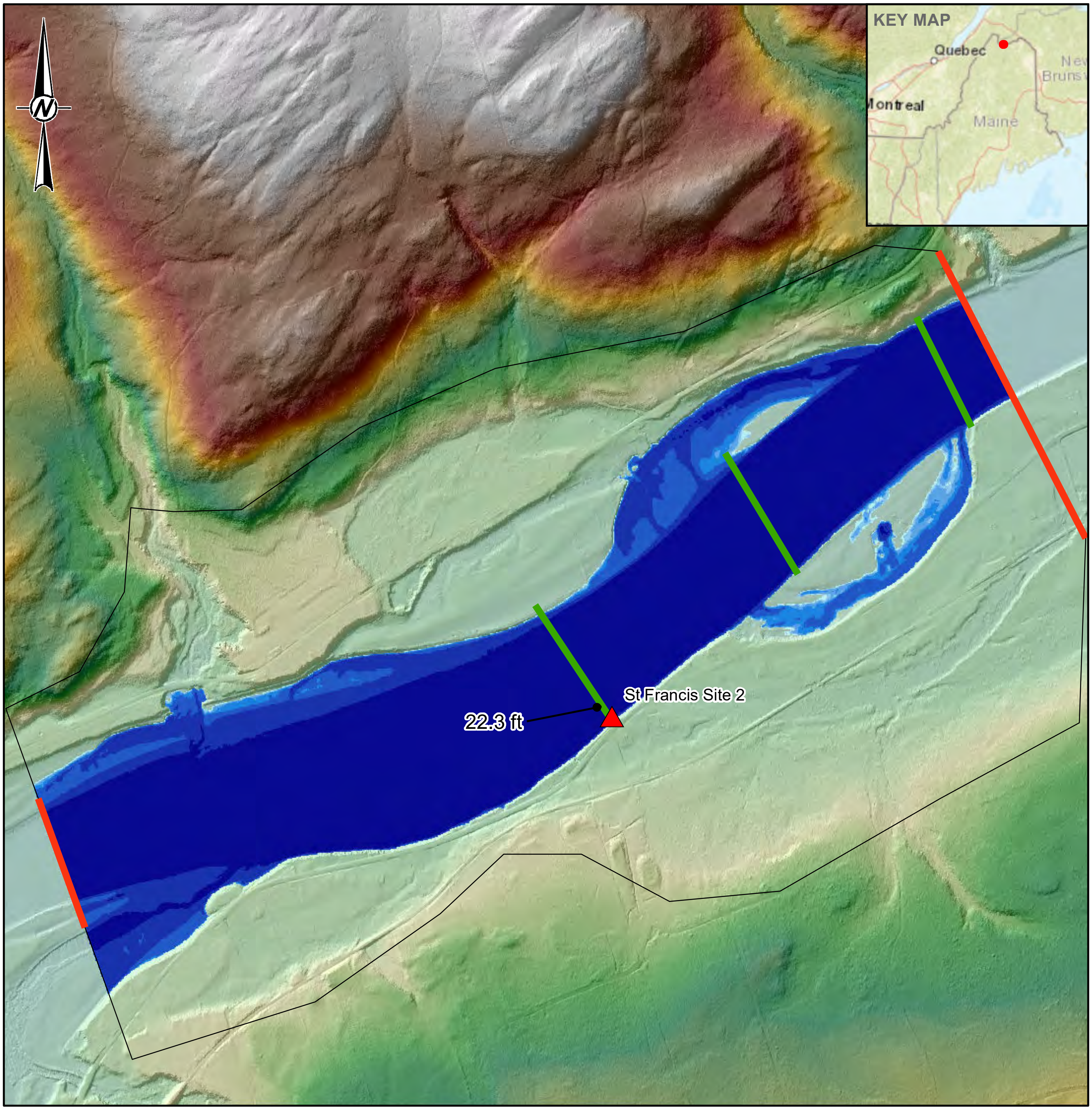
CONSULTANT
GOLDER

YYYY-MM-DD	2019-03-12
DESIGNED	SJS
PREPARED	SJS
REVIEWED	AQK
APPROVED	AQK

PROJECT NO.	PHASE	REV.	FIGURE
1659907	004	0	2

PATH: G:\MaineDOT\Allagash\99_PROJECTS\1659907_Allagash\02_PRODUCTION\MXD\FIGURES\Rev0\1659907_002_TUFLOW_StFrancis.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A



LEGEND

- Boundary Condition
- Surveyed cross-sections
- Model Domain

Depth (ft)

- 0.00 to 0.20
- 0.20 to 0.50
- 0.50 to 1.00
- 1.00 to 2.00
- 2.00 to 5.00
- 5.00 to 10.00
- 10.00 to 20.00

REFERENCE(S)
1. HYDRAULIC MODEL SETUP AND RESULTS IS FROM GOLDER BASED ON TUFLOW.
2. DIGITAL ELEVATION MODEL (DEM) IS FROM 2009 FEDERAL EMERGENCY MANAGEMENT AGENCY TOPOGRAPHIC LIDAR: FORT KENT, MAINE.
3. SUPPLEMENTAL BATHYMETRY IS BASED ON FROM MAINE DEPARTMENT OF TRANSPORTATION SURVEY OF THREE CROSS-SECTION, 10/2016.
4. COORDINATE SYSTEM: NAD 1983 MAINE 2000 CENTRAL ZONE FOOT US
5. SERVICE LAYER CREDITS: SOURCES: ESRI, DELORME, NAVTEQ, USGS, INTERMAP, IPC, NRCAN, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), ESRI (THAILAND), TOMTOM, 2013

CLIENT
MAINE DOT

PROJECT
EVALUATION AND STABILIZATION OF UNSTABLE SLOPES
STATE ROUTE 161, ST. FRANCIS AND ALLAGASH, MAINE

TITLE
2D MODELING RESULTS - DEPTH
100-YEAR EVENT (NO ICE)
ST FRANCES SITE

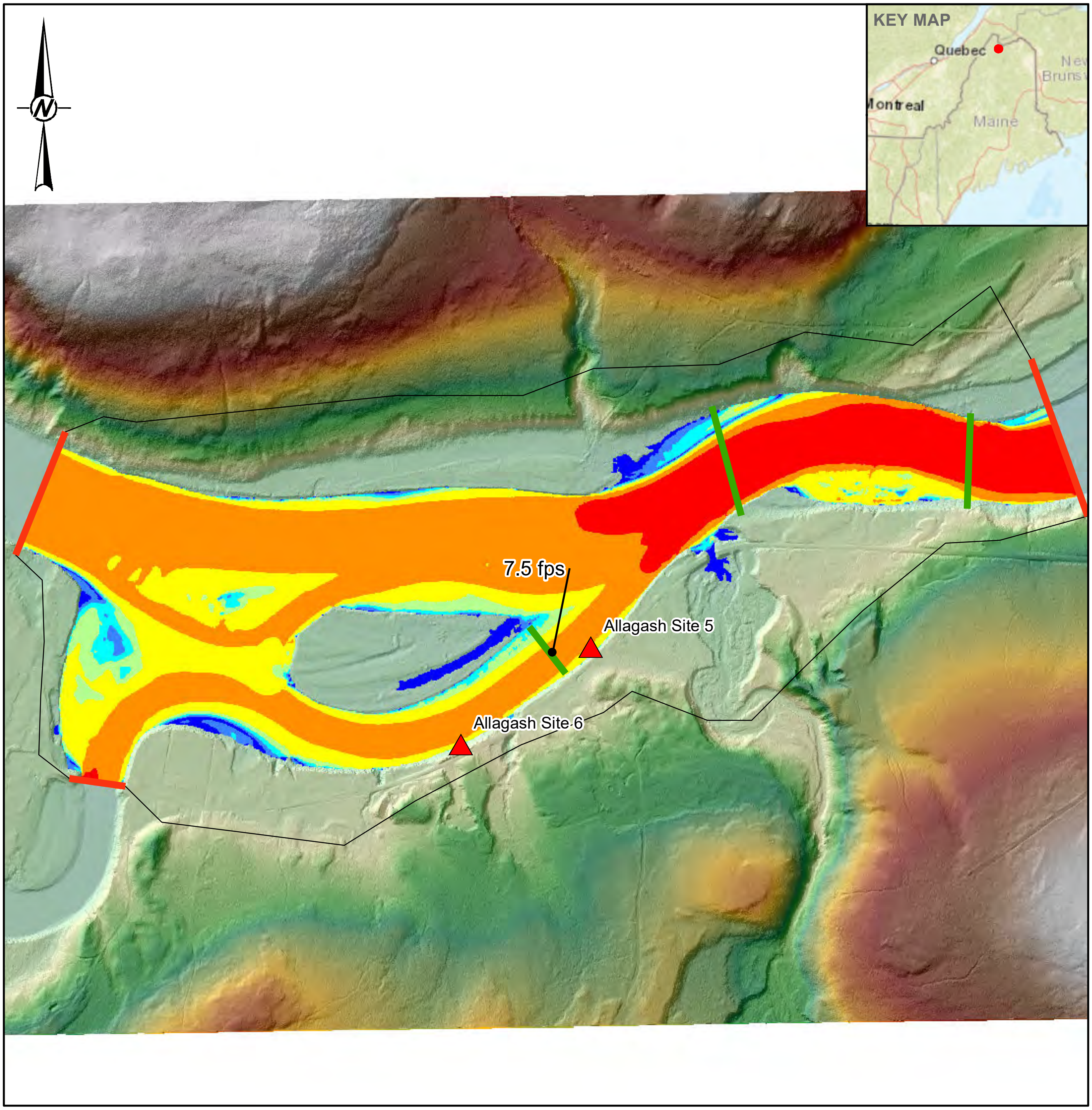
CONSULTANT
GOLDER

YYYY-MM-DD	2019-03-12
DESIGNED	SJS
PREPARED	SJS
REVIEWED	AQK
APPROVED	AQK

PROJECT NO.	PHASE	REV.	FIGURE
1659907	004	0	3

PATH: G:\MaineDOT\Allagash\99_PROJECTS\1659907_Allagash\02_PRODUCTION\MXD\FIGURES\Rev0\1659907_003_TUFLOW_StFrancis.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A



LEGEND

- Boundary Condition
- Surveyed cross-sections
- Model Domain

Velocity (fps)

- 0.00 to 0.20
- 0.20 to 0.50
- 0.50 to 1.00
- 1.00 to 2.00
- 2.00 to 5.00
- 5.00 to 10.00
- 10.00 to 20.00

0 400 800 1,600
Feet

REFERENCE(S)
1. HYDRAULIC MODEL SETUP AND RESULTS IS FROM GOLDER BASED ON TUFLOW.
2. DIGITAL ELEVATION MODEL (DEM) IS FROM 2009 FEDERAL EMERGENCY MANAGEMENT AGENCY TOPOGRAPHIC LIDAR: FORT KENT, MAINE.
3. SUPPLEMENTAL BATHYMETRY IS BASED ON FROM MAINE DEPARTMENT OF TRANSPORTATION SURVEY OF THREE CROSS-SECTION, 10/2016.
4. COORDINATE SYSTEM: NAD 1983 MAINE 2000 CENTRAL ZONE FOOT US
5. SERVICE LAYER CREDITS: SOURCES: ESRI, DELORME, NAVTEQ, USGS, INTERMAP, IPC, NRCAN, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), ESRI (THAILAND), TOMTOM, 2013

CLIENT
MAINE DOT

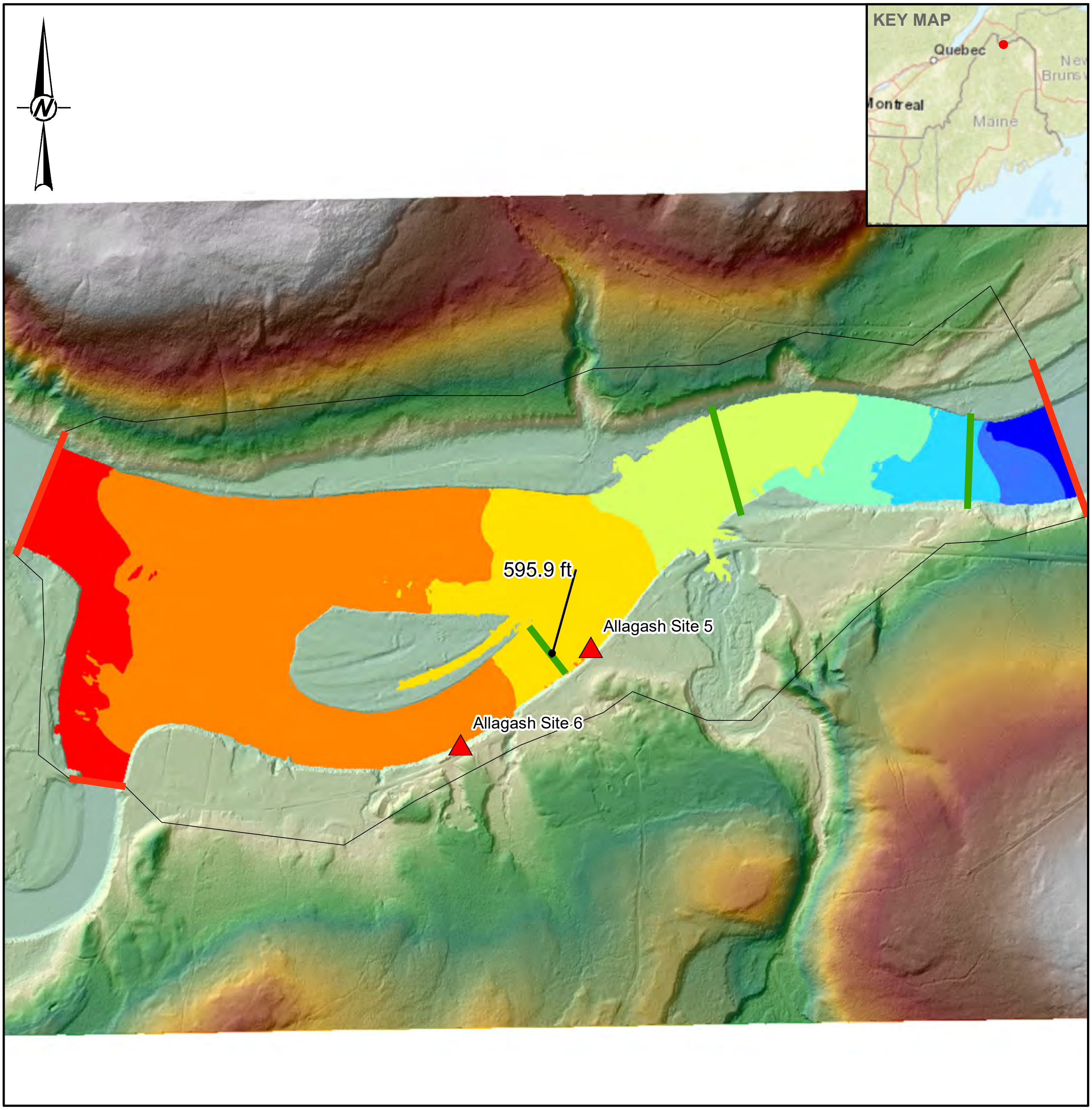
PROJECT
EVALUATION AND STABILIZATION OF UNSTABLE SLOPES
STATE ROUTE 161, ST. FRANCIS AND ALLAGASH, MAINE

TITLE
2D MODELING RESULTS - VELOCITY
100-YEAR EVENT (NO ICE)
ALLAGASH SITE

CONSULTANT
GOLDER

YYYY-MM-DD	2019-03-12
DESIGNED	SJS
PREPARED	SJS
REVIEWED	AQK
APPROVED	AQK

PROJECT NO.	PHASE	REV.	FIGURE
1659907	004	0	4



LEGEND

- Boundary Condition
- Surveyed cross-sections
- Model Domain

WSE (ft) - NAVD88

- 584 to 586
- 586 to 588
- 588 to 590
- 590 to 592
- 592 to 594
- 594 to 596
- 596 to 598
- 598 to 600

0 400 800 1,600
Feet

REFERENCE(S)

1. HYDRAULIC MODEL SETUP AND RESULTS IS FROM GOLDER BASED ON TUFLOW.
2. DIGITAL ELEVATION MODEL (DEM) IS FROM 2009 FEDERAL EMERGENCY MANAGEMENT AGENCY TOPOGRAPHIC LIDAR: FORT KENT, MAINE.
3. SUPPLEMENTAL BATHYMETRY IS BASED ON FROM MAINE DEPARTMENT OF TRANSPORTATION SURVEY OF THREE CROSS-SECTION, 10/2016.
4. COORDINATE SYSTEM: NAD 1983 MAINE 2000 CENTRAL ZONE FOOT US
5. SERVICE LAYER CREDITS: SOURCES: ESRI, HERE, DELORME, USGS, INTERMAP, INCREMENT P, NRCAN, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), ESRI KOREA, ESRI (THAILAND),

CLIENT
MAINE DOT

PROJECT
EVALUATION AND STABILIZATION OF UNSTABLE SLOPES
STATE ROUTE 161, ST. FRANCIS AND ALLAGASH, MAINE

TITLE
2D MODELING RESULTS - WSE
100-YEAR EVENT (NO ICE)
ALLAGASH SITE

CONSULTANT
GOLDER

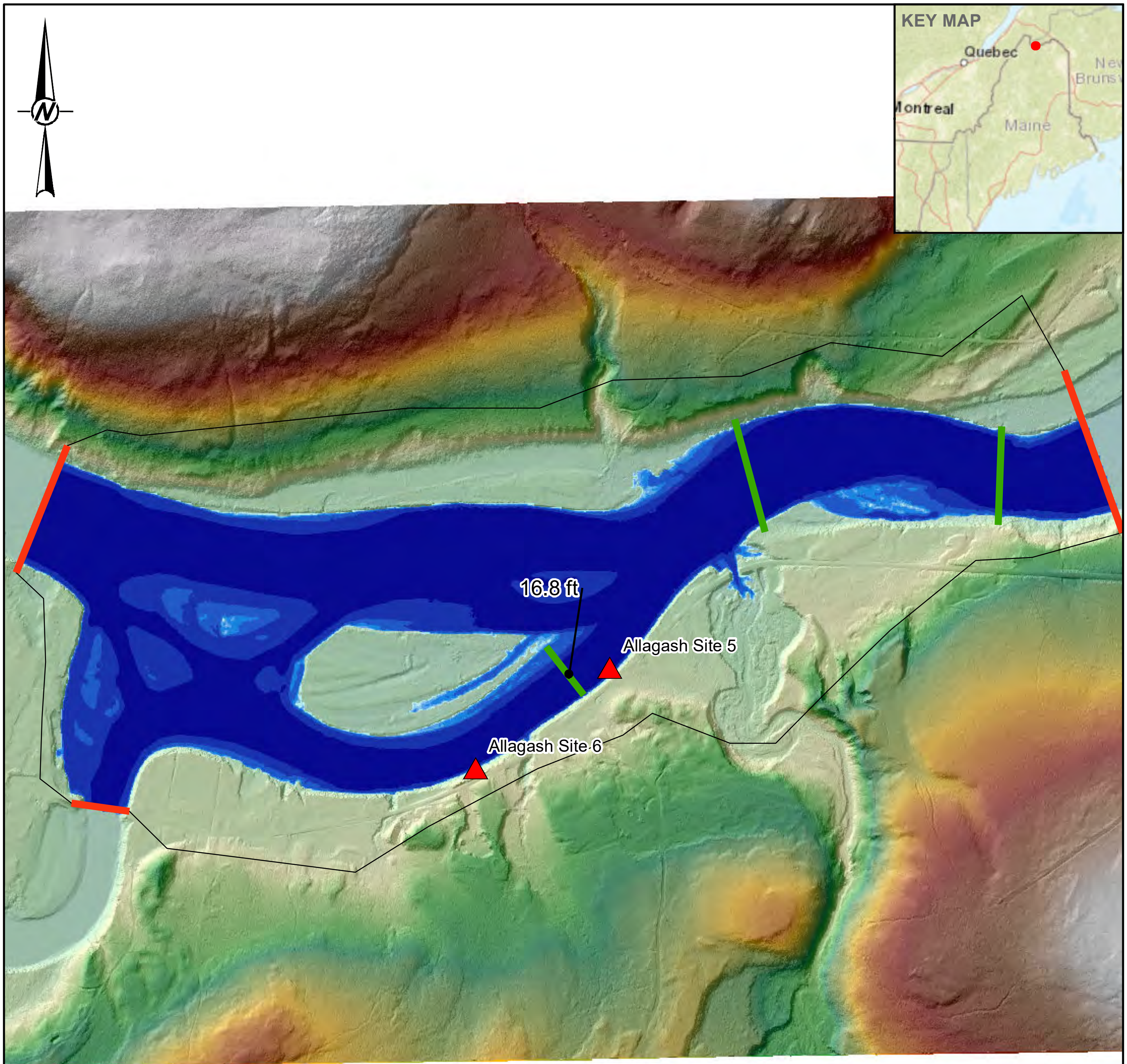
YYYY-MM-DD	2019-03-12
DESIGNED	SJS
PREPARED	SJS
REVIEWED	AQK
APPROVED	AQK

PROJECT NO.	PHASE	REV.	FIGURE
1659907	004	0	**5**

PATH: G:\MaineDOT\Allagash\99_PROJECTS\1659907_Allagash\02_PRODUCTION\MXD\FIGURES\Rev0\1659907_005_TUFLOW_Allagash.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

0 1 in



LEGEND

- Boundary Condition
- Surveyed cross-sections
- Model Domain

Depth (ft)

- 0.00 to 0.20
- 0.20 to 0.50
- 0.50 to 1.00
- 1.00 to 2.00
- 2.00 to 5.00
- 5.00 to 10.00
- 10.00 to 20.00

0 400 800 1,600
Feet

REFERENCE(S)

1. HYDRAULIC MODEL SETUP AND RESULTS IS FROM GOLDER BASED ON TUFLOW.
2. DIGITAL ELEVATION MODEL (DEM) IS FROM 2009 FEDERAL EMERGENCY MANAGEMENT AGENCY TOPOGRAPHIC LIDAR: FORT KENT, MAINE.
3. SUPPLEMENTAL BATHYMETRY IS BASED ON FROM MAINE DEPARTMENT OF TRANSPORTATION SURVEY OF THREE CROSS-SECTION, 10/2016.
4. COORDINATE SYSTEM: NAD 1983 MAINE 2000 CENTRAL ZONE FOOT US
5. SERVICE LAYER CREDITS: SOURCES: ESRI, DELORME, NAVTEQ, USGS, INTERMAP, IPC, NRCAN, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), ESRI (THAILAND), TOMTOM, 2013

CLIENT
MAINE DOT

PROJECT
EVALUATION AND STABILIZATION OF UNSTABLE SLOPES
STATE ROUTE 161, ST. FRANCIS AND ALLAGASH, MAINE

TITLE
2D MODELING RESULTS - DEPTH
100-YEAR EVENT (NO ICE)
ALLAGASH SITE

CONSULTANT
GOLDER

YYYY-MM-DD	2019-03-12
DESIGNED	SJS
PREPARED	SJS
REVIEWED	AQK
APPROVED	AQK

PROJECT NO.	PHASE	REV.	FIGURE
1659907	004	0	**6**

ATTACHMENT A

Hydrologic Data

Hydrology - Summary
Maine DOT / Highway 161 Slope Stabilization at Allagash and St Francis
Created by: GK 11/8/2016
Checked by: SJS 11/16/2016

Method: StreamStats (USGS website, http://water.usgs.gov/osw/streamstats/) was used to estimate drainage area, basin characteristics and peak discharge at the Allagash and the St. Francis project sites. As a comparison , peak flows were also estimated utilizing the method in the case of an ungaged site near a streamgage (USGS. 1999. *Estimating the Magnitude of Peak Flows for Streams in Maine for Selected Recurrence Intervals*). The StreamStats results were utilized for further calculations and are presented below.

Recurrence Interval	Allagash	St Francis
2-yr	57,800	68,300
5-yr	77,800	91,600
10-yr	91,600	107,700
25-yr	108,000	126,900
50-yr	120,300	141,200
100-yr	132,900	155,800
500-yr	162,800	190,600

Hydrology - Allagash Site

Maine DOT / Highway 161 Slope Stabilization at Allagash and St Francis
Created by: GK 11/8/2016
Checked by: SJS 11/16/2016

StreamStats Method

Peak-Flow Estimates

Recurrence Interval	Peak Flow (cfs)
2-yr	58,000
5-yr	78,000
10-yr	92,000
25-yr	108,000
50-yr	120,000
100-yr	133,000
500-yr	163,000

Gauged Discharge - Weighted Area Method

$$Q_{uf} = Q_w (A_u / A_g)^b,$$

Ag, USGS Gauge 01010500 - St John River at Dickey (sq. mi.)	2,680
Au, Allagash Project Site - St John River (sq.mi.)	3,940
Percent area difference	147%

Recurrence Interval	Discharge at USGS Gauge 01010500 - St John River at Dickey - Qw (cfs)	Coefficient from USGS Publication	Peak Flow - Quf (cfs)
2-yr	44,100	0.825	60,600
5-yr	60,200	0.797	81,837
10-yr	71,400	0.783	96,540
25-yr	84,900	0.767	114,088
50-yr	95,000	0.757	127,169
100-yr	105,000	0.748	140,069
500-yr	130,000	0.729	172,154

FEMA Peak Discharges

Recurrence Interval	St. John River - Downstream of the mouth of the Allagash River and approx. 500 ft upstream of the mouth of Pelletier Brook
100-yr	131,700

Raw Data - Allagash Site
Maine DOT / Highway 161 Slope Stabilization at Allagash and St Francis
Created by: GK 11/8/2016
Checked by: SJS 11/18/2016

StreamStats Output Report

State/Region ID	ME
Workspace ID	ME20161018172639017000
Latitude	47.08994
Longitude	-69.0256

Parameters

Name	Value	Unit
DRNAREA	3939.6	square miles
STORNWI	8.15	percent
PRECIP	39.7	inches

Peak-Flow Statistics Parameters 100 Percent Statewide Peak Flow Full WRI 99 4008

Name	Value	Min Limit	Max Limit
Drainage Area	3939.6	0.93	1653
Percentage of Storage from NWI	8.15	0.7	26.7

Peak-Flow Statistics Flow Report 100 Percent Statewide Peak Flow Full WRI 99 4008

Name	Value (cfs)
2 Year Peak Flood	57801
5 Year Peak Flood	77774
10 Year Peak Flood	91540
25 Year Peak Flood	107995
50 Year Peak Flood	120271
100 Year Peak Flood	132858
500 Year Peak Flood	162774

Peak-Flow Statistics Flow Report Area-Averaged

Name	Value (cfs)
2 Year Peak Flood	57796
5 Year Peak Flood	77766
10 Year Peak Flood	91531
25 Year Peak Flood	107984
50 Year Peak Flood	120259
100 Year Peak Flood	132845
500 Year Peak Flood	162758

StreamStats Output Report - for Drainage Area Split by Confluence Rivers

Saint John River - Upstream of Allagash River

Drainage Area	2701.4	sq mi
Percent of Total Drainage Area	69%	

Statistic	Value (cfs)
2 Year Peak Flood	44100
5 Year Peak Flood	60200
10 Year Peak Flood	71400
25 Year Peak Flood	85000
50 Year Peak Flood	95100
100 Year Peak Flood	106000
500 Year Peak Flood	130000

Allagash River

Drainage Area	1234.6	sq mi
Percent of Total Drainage Area	31%	

Statistic	Value (cfs)
2 Year Peak Flood	19400
5 Year Peak Flood	26700
10 Year Peak Flood	31800
25 Year Peak Flood	38000
50 Year Peak Flood	42700
100 Year Peak Flood	47500
500 Year Peak Flood	59000

USGS Gage Information

USGS Station Number	1010500
Station Name	St. John River at Dickey
Statistic	Value (cfs)
2 Year Peak Flood	44100
5 Year Peak Flood	60200
10 Year Peak Flood	71400
25 Year Peak Flood	84900
50 Year Peak Flood	95000
100 Year Peak Flood	105000
500 Year Peak Flood	130000

Hydrology - St Francis Site

Maine DOT / Highway 161 Slope Stabilization at Allagash and St Francis
Created by: GK 11/8/2016
Checked by: SJS 11/18/2016

StreamStats Method

Peak-Flow Estimates

Recurrence Interval	Peak Flow (cfs)
2-yr	69,000
5-yr	92,000
10-yr	108,000
25-yr	127,000
50-yr	142,000
100-yr	156,000
500-yr	191,000

Gauged Discharge - Weighted Area Method

$$Q_{uf} = Q_w (A_u / A_g)^b,$$

Ag, USGS Gauge 01014000 - St John River below Fish R, at Fort Kent, Maine (sq. mi.)	5,665
Au, Allagash Project Site - St John River (sq.mi.)	4,639
Percent area difference	82%

Recurrence Interval	Discharge at USGS Gauge 01014000 - St John River below Fish R, at Fort Kent, Maine (cfs)	Coefficient from USGS Publication	Peak Flow - Quf (cfs)
2-yr	68,212	0.825	57,850
5-yr	104,000	0.797	88,696
10-yr	118,000	0.783	100,917
25-yr	135,000	0.767	115,826
50-yr	148,000	0.757	127,233
100-yr	159,000	0.748	136,936
500-yr	186,000	0.729	160,798

FEMA Peak Discharges

N/A

Raw Data - St Francis Site
Maine DOT / Highway 161 Slope Stabilization at Allagash and St Francis
Created by: GK 11/8/2016
Checked by: SJS 11/18/2016

StreamStats Output Report

State/Region ID	ME
Workspace ID	ME20161018174541891000
Latitude	47.19334
Longitude	-68.85413

Parameters

Name	Value	Unit
DRNAREA	4639.4	square miles
STORNWI	7.71	percent
PRECIP	39.8	inches

Peak-Flow Statistics Parameters — 100 Percent Statewide Peak Flow Full WRI 99 4008

Name	Value	Min Limit	Max Limit
Drainage Area	4639.4	0.93	1653
Percentage of Storage from NWI	7.71	0.7	26.7

Peak-Flow Statistics Flow Report — 100 Percent Statewide Peak Flow Full WRI 99 4008

Name	Value (cfs)
2 Year Peak Flood	68212
5 Year Peak Flood	91566
10 Year Peak Flood	107658
25 Year Peak Flood	126832
50 Year Peak Flood	141133
100 Year Peak Flood	155768
500 Year Peak Flood	190584

Peak-Flow Statistics Flow Report — Area-Averaged

Name	Value (cfs)
2 Year Peak Flood	68204
5 Year Peak Flood	91555
10 Year Peak Flood	107646
25 Year Peak Flood	126817
50 Year Peak Flood	141117
100 Year Peak Flood	155750
500 Year Peak Flood	190562

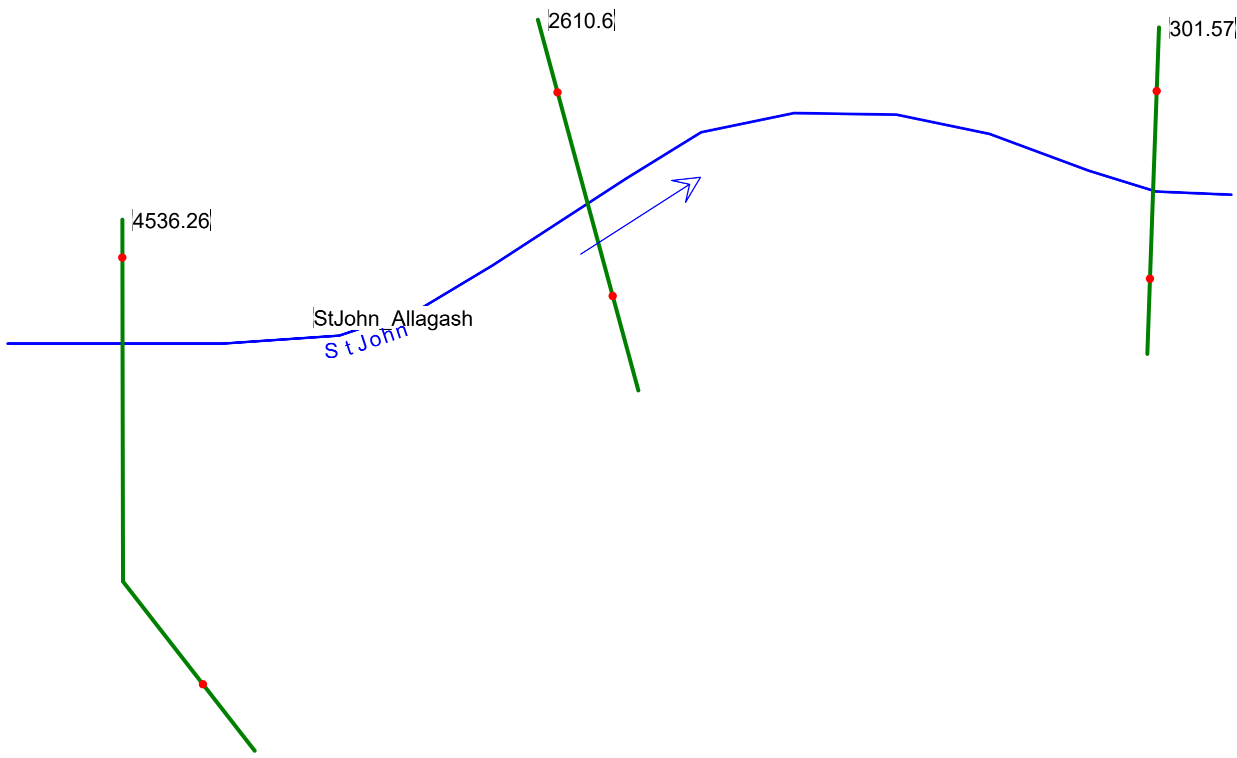
USGS Gage Information

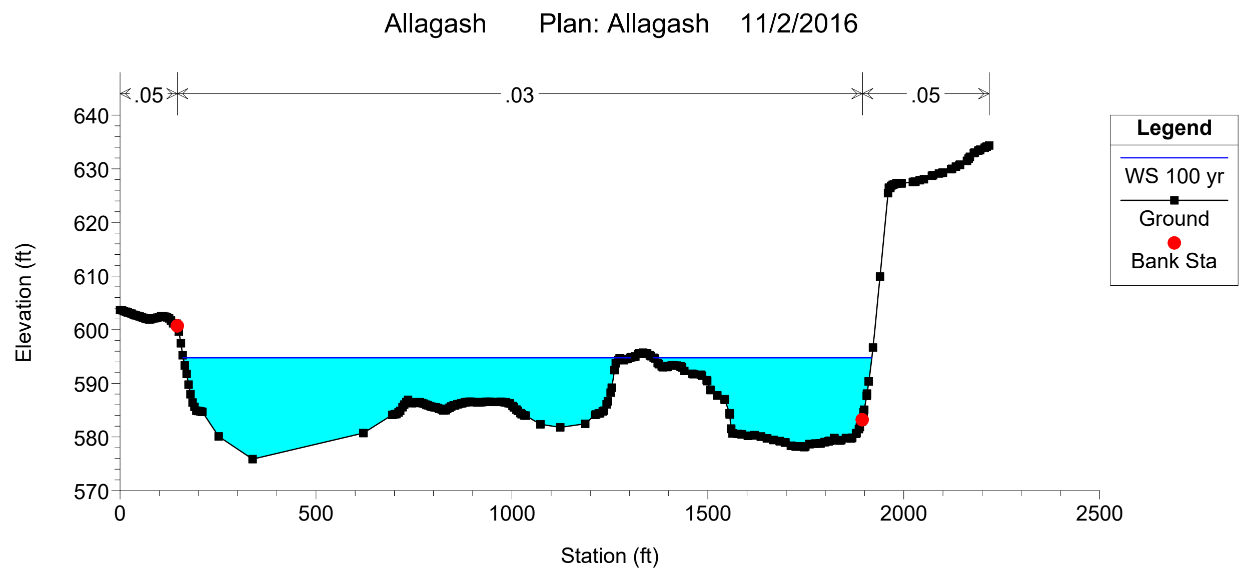
USGS Station Number	1014000
Station Name	St. John River below Fish R, at Fort Kent, Maine
Peak-Flow Statistics	Value (cfs)
2_Year_Peak_Flood	81600
5_Year_Peak_Flood	104000
10_Year_Peak_Flood	118000
25_Year_Peak_Flood	135000
50_Year_Peak_Flood	148000
100_Year_Peak_Flood	159000
500_Year_Peak_Flood	186000

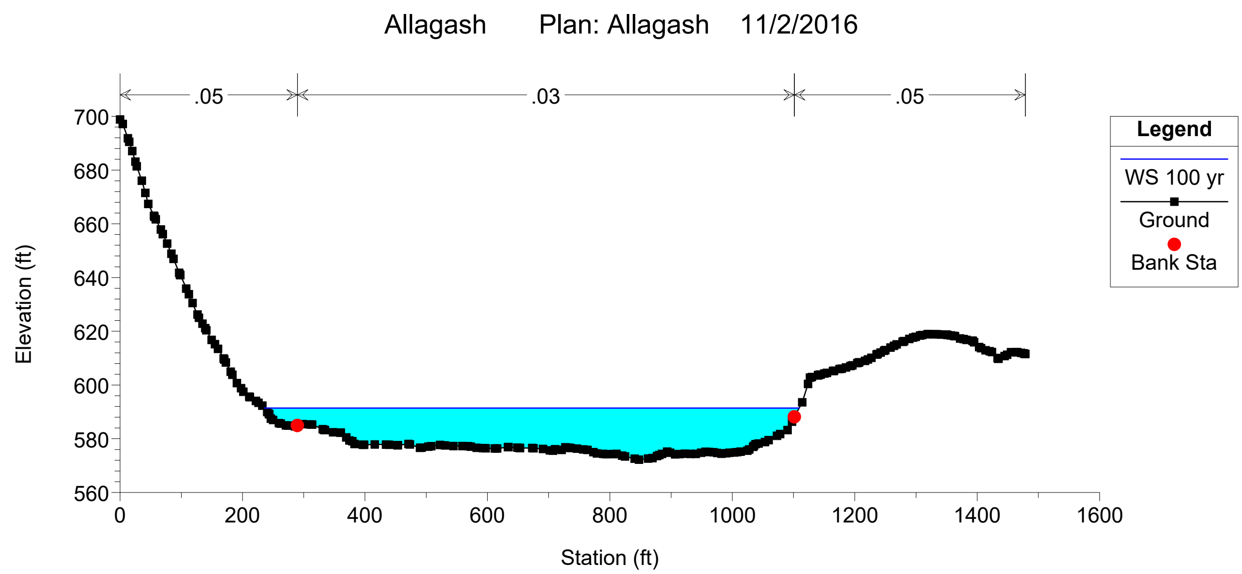
ATTACHMENT B

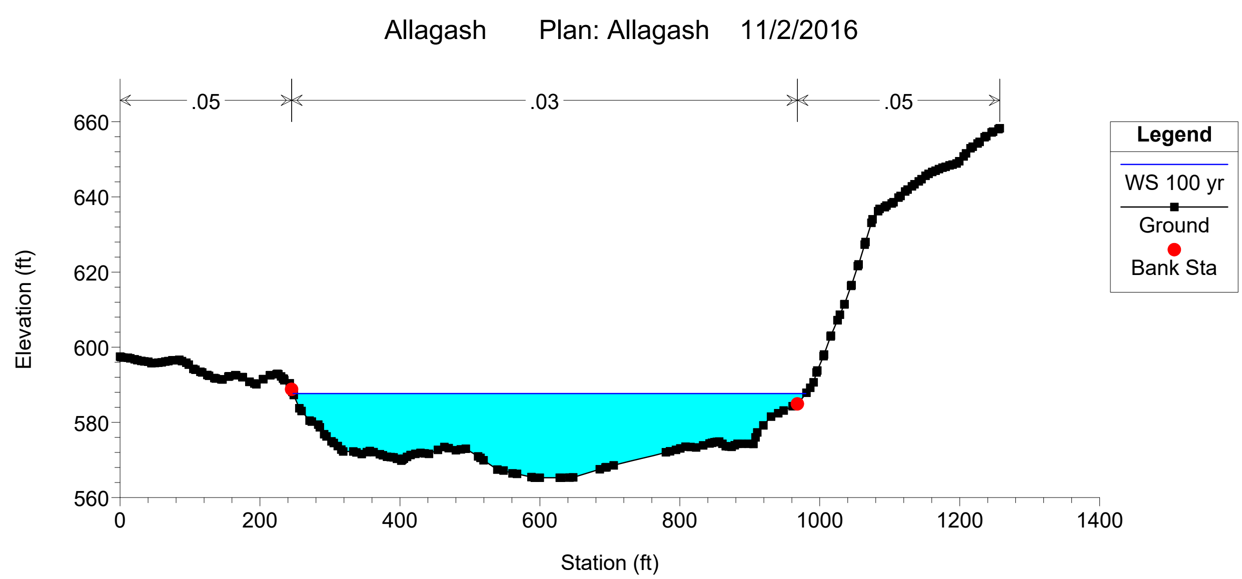
HEC-RAS Printouts

Allagash Model Geometry Layout




Allagash Plan: Allagash 11/2/2016
.05
.03
.05
Elevation (ft)
Station (ft)
Legend
WS 100 yr
Ground
Bank Sta


Allagash Plan: Allagash 11/2/2016
.05
.03
.05
Elevation (ft)
Station (ft)
Legend
WS 100 yr
Ground
Bank Sta


Allagash Plan: Allagash 11/2/2016
.05
.03
.05
Elevation (ft)
Station (ft)
Legend
WS 100 yr
Ground
Bank Sta

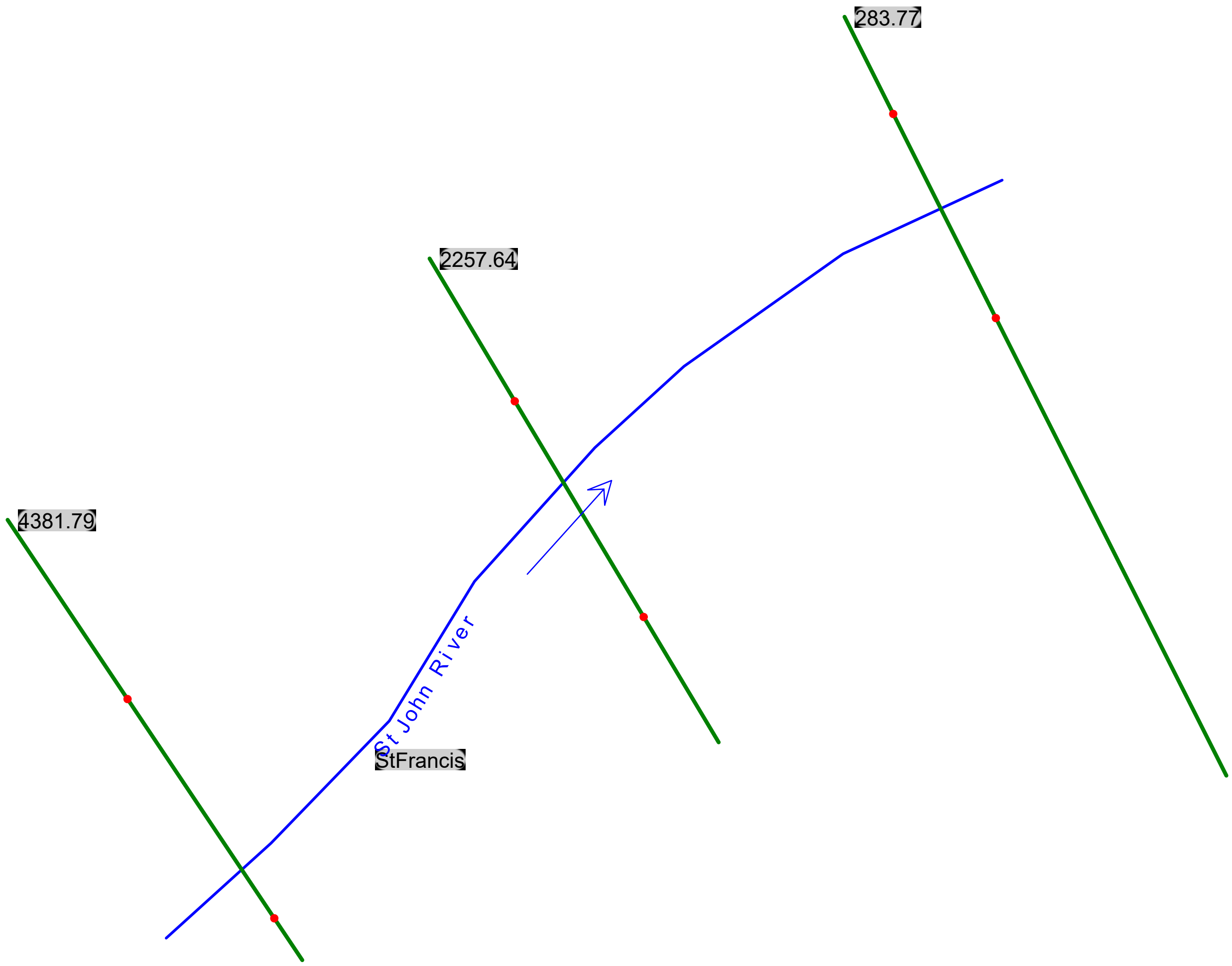
HEC-RAS Plan: Allagash River: StJohn Reach: StJohn_Allagash

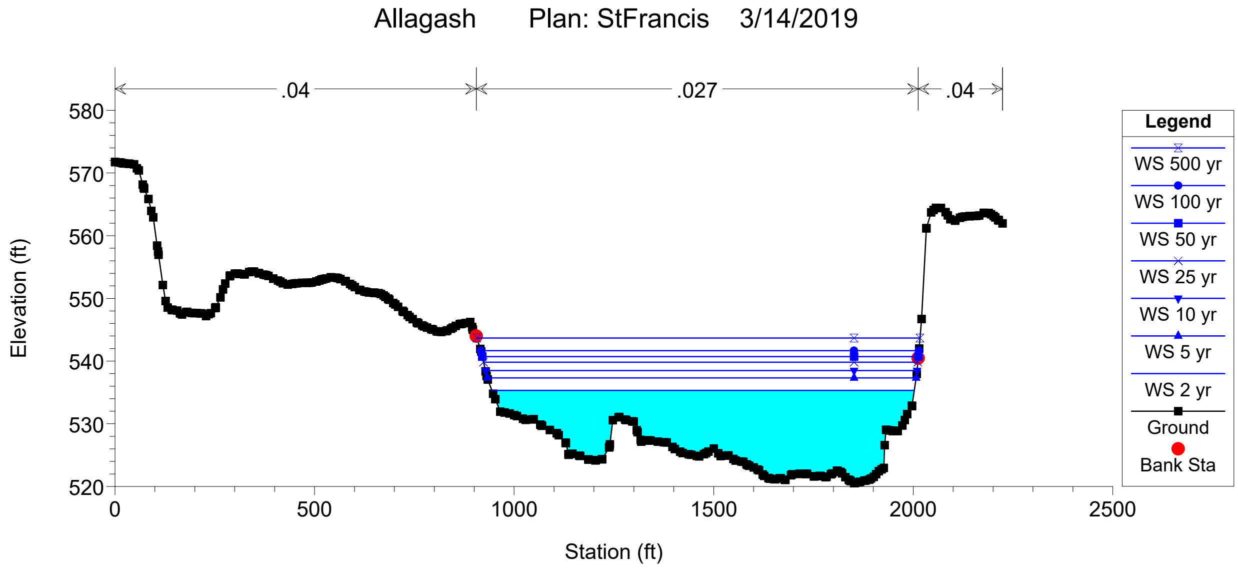
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
StJohn_Allagash	4536.26	2 yr	58000.00	575.87	588.60	584.69	589.13	0.001092	5.85	9933.08	1472.82	0.40
StJohn_Allagash	4536.26	5 yr	78000.00	575.87	590.37	585.81	590.97	0.000926	6.23	12553.03	1496.34	0.38
StJohn_Allagash	4536.26	10 yr	92000.00	575.87	591.54	586.67	592.18	0.000848	6.45	14317.54	1518.78	0.37
StJohn_Allagash	4536.26	25 yr	108000.00	575.87	592.83	587.28	593.51	0.000792	6.64	16331.41	1575.79	0.36
StJohn_Allagash	4536.26	50 yr	120000.00	575.87	593.79	587.71	594.49	0.000768	6.74	17873.79	1646.14	0.36
StJohn_Allagash	4536.26	100 yr	133000.00	575.87	594.77	588.15	595.50	0.000734	6.85	19517.51	1697.39	0.35
StJohn_Allagash	4536.26	500 yr	163000.00	575.87	596.91	589.11	597.68	0.000648	7.05	23261.74	1765.57	0.34
StJohn_Allagash	2610.6	2 yr	58000.00	572.23	585.01		586.27	0.002003	9.03	6427.35	798.71	0.55
StJohn_Allagash	2610.6	5 yr	78000.00	572.23	586.99		588.46	0.001814	9.71	8083.42	848.75	0.54
StJohn_Allagash	2610.6	10 yr	92000.00	572.23	588.25		589.84	0.001699	10.15	9153.25	856.86	0.54
StJohn_Allagash	2610.6	25 yr	108000.00	572.23	589.53		591.29	0.001620	10.67	10259.44	862.83	0.53
StJohn_Allagash	2610.6	50 yr	120000.00	572.23	590.44		592.32	0.001577	11.03	11044.97	868.19	0.53
StJohn_Allagash	2610.6	100 yr	133000.00	572.23	591.39		593.39	0.001536	11.40	11871.47	873.57	0.53
StJohn_Allagash	2610.6	500 yr	163000.00	572.23	593.45		595.73	0.001466	12.18	13683.25	888.14	0.53
StJohn_Allagash	301.57	2 yr	58000.00	565.27	581.06	577.03	582.28	0.001501	8.84	6558.78	659.83	0.49
StJohn_Allagash	301.57	5 yr	78000.00	565.27	583.17	578.49	584.65	0.001500	9.78	7977.21	689.76	0.51
StJohn_Allagash	301.57	10 yr	92000.00	565.27	584.49	579.45	586.15	0.001501	10.33	8902.89	708.77	0.51
StJohn_Allagash	301.57	25 yr	108000.00	565.27	585.81	580.47	587.68	0.001502	10.97	9847.44	720.91	0.52
StJohn_Allagash	301.57	50 yr	120000.00	565.27	586.72	581.22	588.75	0.001502	11.43	10507.67	726.70	0.53
StJohn_Allagash	301.57	100 yr	133000.00	565.27	587.67	581.99	589.87	0.001502	11.89	11200.32	732.73	0.53
StJohn_Allagash	301.57	500 yr	163000.00	565.27	589.70	583.65	592.28	0.001501	12.88	12701.82	744.40	0.54

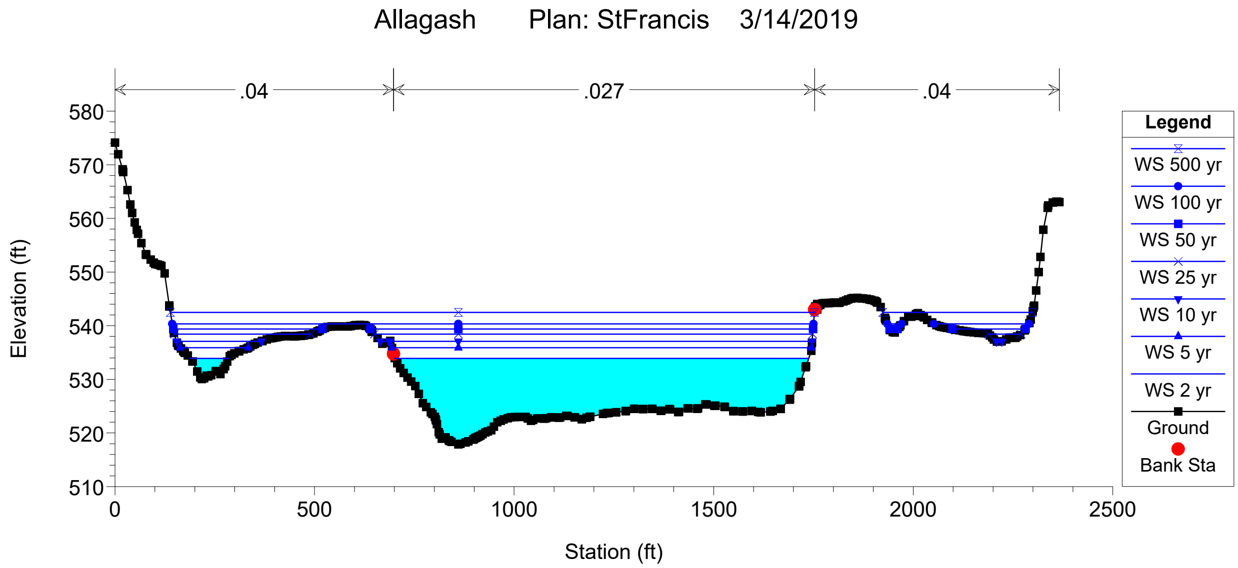
HEC-RAS Plan: Allagash_ice River: StJohn Reach: StJohn_Allagash

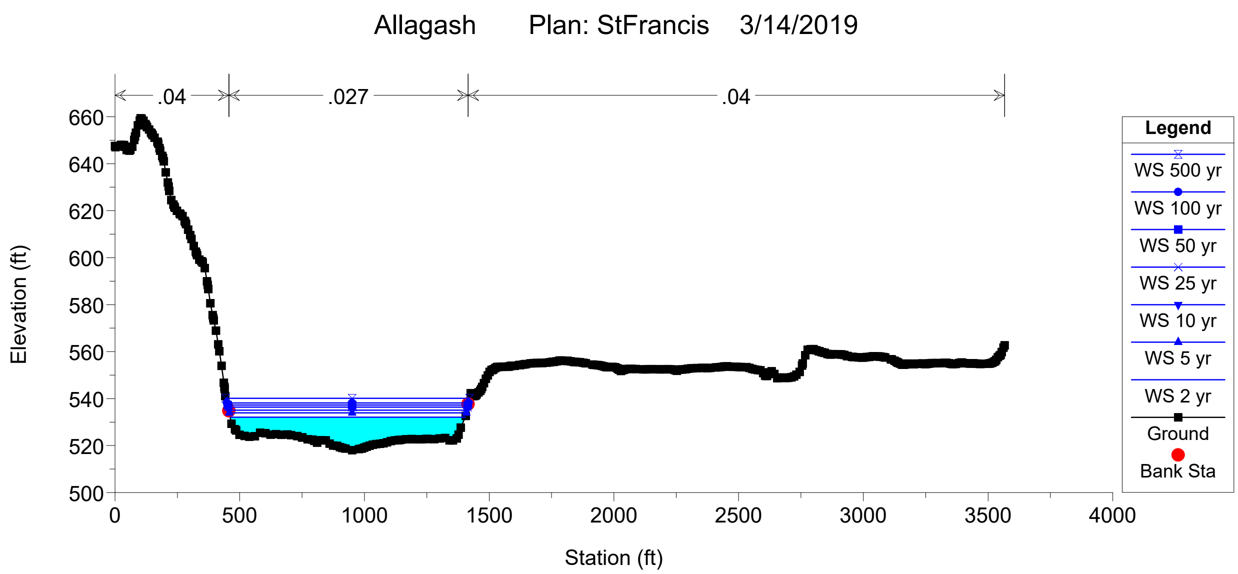
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
StJohn_Allagash	4536.26	2 yr	58000.00	575.87	596.11	586.98	596.27	0.000936	3.25	17915.41	1646.11	0.17
StJohn_Allagash	4536.26	5 yr	78000.00	575.87	598.95	588.10	599.13	0.000832	3.44	22794.75	1763.88	0.17
StJohn_Allagash	4536.26	10 yr	92000.00	575.87	600.74	588.95	600.94	0.000754	3.56	25970.14	1770.58	0.16
StJohn_Allagash	4536.26	25 yr	108000.00	575.87	602.68	589.57	602.89	0.000691	3.69	29398.81	1778.50	0.16
StJohn_Allagash	4536.26	50 yr	120000.00	575.87	604.05	590.02	604.27	0.000655	3.79	31850.53	1793.83	0.16
StJohn_Allagash	4536.26	100 yr	133000.00	575.87	605.49	590.44	605.73	0.000622	3.89	34485.81	1893.04	0.16
StJohn_Allagash	4536.26	500 yr	163000.00	575.87	608.55	591.41	608.81	0.000571	4.10	40369.83	1933.95	0.15
StJohn_Allagash	2610.6	2 yr	58000.00	572.23	593.55		593.94	0.001583	5.01	11734.78	870.26	0.23
StJohn_Allagash	2610.6	5 yr	78000.00	572.23	596.52		596.99	0.001506	5.55	14341.51	890.51	0.24
StJohn_Allagash	2610.6	10 yr	92000.00	572.23	598.40		598.93	0.001470	5.88	16036.03	906.24	0.24
StJohn_Allagash	2610.6	25 yr	108000.00	572.23	600.40		600.99	0.001443	6.22	17854.53	918.99	0.24
StJohn_Allagash	2610.6	50 yr	120000.00	572.23	601.80		602.44	0.001427	6.46	19149.42	925.03	0.24
StJohn_Allagash	2610.6	100 yr	133000.00	572.23	603.26		603.95	0.001412	6.71	20507.86	932.11	0.24
StJohn_Allagash	2610.6	500 yr	163000.00	572.23	606.31		607.11	0.001406	7.25	23374.72	954.04	0.25
StJohn_Allagash	301.57	2 yr	58000.00	565.27	589.96	579.32	590.38	0.001502	5.19	11194.61	730.86	0.23
StJohn_Allagash	301.57	5 yr	78000.00	565.27	592.99	580.78	593.51	0.001502	5.83	13430.96	748.72	0.24
StJohn_Allagash	301.57	10 yr	92000.00	565.27	594.90	581.72	595.50	0.001501	6.22	14923.30	824.54	0.24
StJohn_Allagash	301.57	25 yr	108000.00	565.27	596.90	582.78	597.58	0.001503	6.63	16668.36	891.49	0.25
StJohn_Allagash	301.57	50 yr	120000.00	565.27	598.32	583.49	599.05	0.001501	6.90	17938.01	903.80	0.25
StJohn_Allagash	301.57	100 yr	133000.00	565.27	599.78	584.27	600.58	0.001501	7.18	19331.50	988.95	0.25
StJohn_Allagash	301.57	500 yr	163000.00	565.27	602.83	585.94	603.74	0.001501	7.75	22399.55	1010.03	0.26

St Francis Model Geometry Layout




Allagash Plan: StFrancis 3/14/2019
.04
.027
.04
Elevation (ft)
Station (ft)
Legend
WS 500 yr
WS 100 yr
WS 50 yr
WS 25 yr
WS 10 yr
WS 5 yr
WS 2 yr
Ground
Bank Sta


Allagash Plan: StFrancis 3/14/2019
.04
.027
.04
Elevation (ft)
Station (ft)
Legend
WS 500 yr
WS 100 yr
WS 50 yr
WS 25 yr
WS 10 yr
WS 5 yr
WS 2 yr
Ground
Bank Sta


Allagash Plan: StFrancis 3/14/2019
.04
.027
.04
Elevation (ft)
Station (ft)
Legend
WS 500 yr
WS 100 yr
WS 50 yr
WS 25 yr
WS 10 yr
WS 5 yr
WS 2 yr
Ground
Bank Sta

HEC-RAS Plan: StFrancis River: StJohn River Reach: StFrancis

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)	
StFrancis	4381.79	2 yr	68000.00	520.53	535.33	530.25	536.04	0.000744	6.73	10103.56	1058.40	0.38
StFrancis	4381.79	5 yr	92000.00	520.53	537.31	531.77	538.19	0.000740	7.53	12210.24	1074.49	0.39
StFrancis	4381.79	10 yr	108000.00	520.53	538.50	532.51	539.49	0.000738	8.00	13492.76	1081.75	0.40
StFrancis	4381.79	25 yr	127000.00	520.53	539.81	533.38	540.94	0.000735	8.51	14924.06	1088.28	0.41
StFrancis	4381.79	50 yr	141000.00	520.53	540.73	533.92	541.95	0.000735	8.86	15917.28	1092.79	0.41
StFrancis	4381.79	100 yr	156000.00	520.53	541.66	534.53	542.98	0.000734	9.21	16942.29	1097.65	0.41
StFrancis	4381.79	500 yr	191000.00	520.53	543.68	535.79	545.22	0.000739	9.97	19167.48	1110.42	0.42
StFrancis	2257.64	2 yr	68000.00	517.87	533.91		534.56	0.000635	6.46	10691.97	1134.01	0.36
StFrancis	2257.64	5 yr	92000.00	517.87	535.89		536.71	0.000641	7.27	13014.44	1221.86	0.37
StFrancis	2257.64	10 yr	108000.00	517.87	537.10		538.01	0.000637	7.72	14518.32	1305.25	0.38
StFrancis	2257.64	25 yr	127000.00	517.87	538.43		539.46	0.000635	8.21	16390.13	1521.71	0.38
StFrancis	2257.64	50 yr	141000.00	517.87	539.37		540.47	0.000626	8.50	17902.86	1685.66	0.38
StFrancis	2257.64	100 yr	156000.00	517.87	540.34		541.51	0.000619	8.79	19626.74	1880.02	0.38
StFrancis	2257.64	500 yr	191000.00	517.87	542.49		543.75	0.000581	9.24	23794.41	1989.06	0.38
StFrancis	283.77	2 yr	68000.00	518.06	532.05	528.01	532.98	0.001000	7.71	8816.81	942.42	0.44
StFrancis	283.77	5 yr	92000.00	518.06	533.94	529.27	535.11	0.001002	8.68	10605.15	950.61	0.46
StFrancis	283.77	10 yr	108000.00	518.06	535.09	530.05	536.42	0.001001	9.23	11700.53	954.87	0.46
StFrancis	283.77	25 yr	127000.00	518.06	536.36	530.91	537.86	0.001000	9.84	12913.17	959.66	0.47
StFrancis	283.77	50 yr	141000.00	518.06	537.24	531.53	538.87	0.001000	10.25	13763.79	963.55	0.48
StFrancis	283.77	100 yr	156000.00	518.06	538.15	532.16	539.91	0.001000	10.67	14636.38	967.79	0.48
StFrancis	283.77	500 yr	191000.00	518.06	540.11	533.51	542.19	0.001001	11.57	16543.85	977.06	0.49

HEC-RAS Plan: StFrancis_ice River: StJohn River Reach: StFrancis

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)	
StFrancis	4381.79	2 yr	68000.00	520.53	544.41	532.58	544.64	0.000778	3.90	17440.75	1099.94	0.17
StFrancis	4381.79	5 yr	92000.00	520.53	547.50	534.09	547.80	0.000793	4.41	20874.87	1139.55	0.18
StFrancis	4381.79	10 yr	108000.00	520.53	549.37	534.83	549.72	0.000795	4.70	23150.16	1274.16	0.18
StFrancis	4381.79	25 yr	127000.00	520.53	551.43	535.65	551.82	0.000795	5.01	25919.47	1435.90	0.19
StFrancis	4381.79	50 yr	141000.00	520.53	552.86	536.22	553.28	0.000793	5.21	28007.32	1481.38	0.19
StFrancis	4381.79	100 yr	156000.00	520.53	554.34	536.82	554.79	0.000789	5.41	30254.50	1568.77	0.19
StFrancis	4381.79	500 yr	191000.00	520.53	557.57	538.12	558.08	0.000773	5.79	35936.91	1913.93	0.19
StFrancis	2257.64	2 yr	68000.00	517.87	542.87		543.09	0.000685	3.77	19706.02	1857.17	0.16
StFrancis	2257.64	5 yr	92000.00	517.87	546.04		546.28	0.000638	4.08	25866.21	1999.68	0.16
StFrancis	2257.64	10 yr	108000.00	517.87	547.96		548.22	0.000612	4.25	29833.93	2172.52	0.16
StFrancis	2257.64	25 yr	127000.00	517.87	550.09		550.35	0.000577	4.39	34459.36	2180.51	0.16
StFrancis	2257.64	50 yr	141000.00	517.87	551.57		551.84	0.000556	4.49	37686.00	2186.18	0.16
StFrancis	2257.64	100 yr	156000.00	517.87	553.09		553.37	0.000536	4.59	41020.65	2194.15	0.16
StFrancis	2257.64	500 yr	191000.00	517.87	556.41		556.71	0.000504	4.81	48398.91	2244.60	0.15
StFrancis	283.77	2 yr	68000.00	518.06	541.15	530.30	541.46	0.001001	4.44	15323.72	969.00	0.20
StFrancis	283.77	5 yr	92000.00	518.06	544.32	531.57	544.71	0.001001	5.01	18420.03	997.27	0.20
StFrancis	283.77	10 yr	108000.00	518.06	546.24	532.34	546.68	0.001000	5.34	20368.86	1025.55	0.21
StFrancis	283.77	25 yr	127000.00	518.06	548.36	533.21	548.86	0.001000	5.69	22556.59	1037.26	0.21
StFrancis	283.77	50 yr	141000.00	518.06	549.83	533.82	550.37	0.001001	5.93	24087.07	1045.46	0.21
StFrancis	283.77	100 yr	156000.00	518.06	551.34	534.45	551.93	0.001002	6.18	25674.50	1053.71	0.21
StFrancis	283.77	500 yr	191000.00	518.06	554.63	535.85	555.31	0.001001	6.68	29493.81	1240.12	0.22

APPENDIX I

2D River Hydraulic Modeling

TECHNICAL MEMORANDUM

DATE September 15, 2017 **Project No.** 1659907.4

TO Project File
MaineDOT

CC Scott Stoneman, PE, Golder-Redmond, Mark Peterson, Golder-Maine, Jeff Lloyd, Golder-Maine

FROM Andreas Kammereck, PE, Golder-Redmond **EMAIL akammereck@golder.com**

2D RIVER HYDRAULIC MODELING – SLOPE STABILIZATION OF STATE ROUTE 161 AT ST. FRANCIS AND ALLAGASH, MAINE

1.0 INTRODUCTION

This technical memorandum summarizes modeling analyses completed for the Maine Department of Transportation (MaineDOT) to provide hydraulic engineering services for the assessment and design support of slope stabilization requirements for two unstable slopes segments adjacent to State Route 161 between the roadway and the St. John River. The unstable slope areas are of concern to the MaineDOT due to the close proximity of slide head-scarps to the edge of roadway. This memorandum provides the hydraulic modeling results for a potential scour mitigation measures using placement of bendway weirs; and installed in conjunction with installation of riprap armoring on the banks to mitigate for floods and ice.

One site is along roughly an 800 foot segment of State Route 161 in St. Francis and the second site is about a 550 foot portion of the roadway in the town of Allagash. The Allagash slope segment is positioned at the confluence of the Allagash River and the St. John River. The St. Francis slope segment is located on the St. John River approximately 12 miles downstream of Allagash site and directly downstream of a valley constriction that occurs just downstream of the confluence of the St. Francis River and the St. John River (Figure 1-1).

Figure 1-1: Aerial Image of Project Area

The following sections of this technical memorandum present the methodology and results of the 2D hydraulic modelling of multiple alternatives of bendway weirs placed along the path of identified unstable slope areas. This memorandum is organized into the following sections: model description, model extents and inputs, modelling results and conclusions.

2.0 MODEL DESCRIPTION

The two dimensional (2D) models created for existing conditions, as presented in the Hydrologic and Hydraulic Evaluation of Existing Conditions Technical Memorandum (Golder 2019), were modified to include the proposed conditions of multiple bendway weir configurations. The 2D model was developed using TUFLOW (BMT 2017), a hydrodynamic numerical model, in ESRI's geographical information system software, ArcGIS.

2.1 Surface Topography and Survey Data

The model utilized a combination of topographic and survey data. As previously described Hydrologic and Hydraulic Evaluation of Existing Conditions Technical Memorandum, the digital elevation model (DEM) was generated from combining the 2016 MaineDOT survey data with a Light Detection and Ranging (LiDAR) survey (FEMA 2009). The LiDAR data was obtained during the high flow season of the spring freshet and as such did not capture much of the channel bathymetry. The bathymetry was estimated through extrapolation of the surveyed cross-sections. Figures 2-2 and 2-3 present a hill-shade of the existing conditions channel geometries (clipped to an area beyond the model extents).

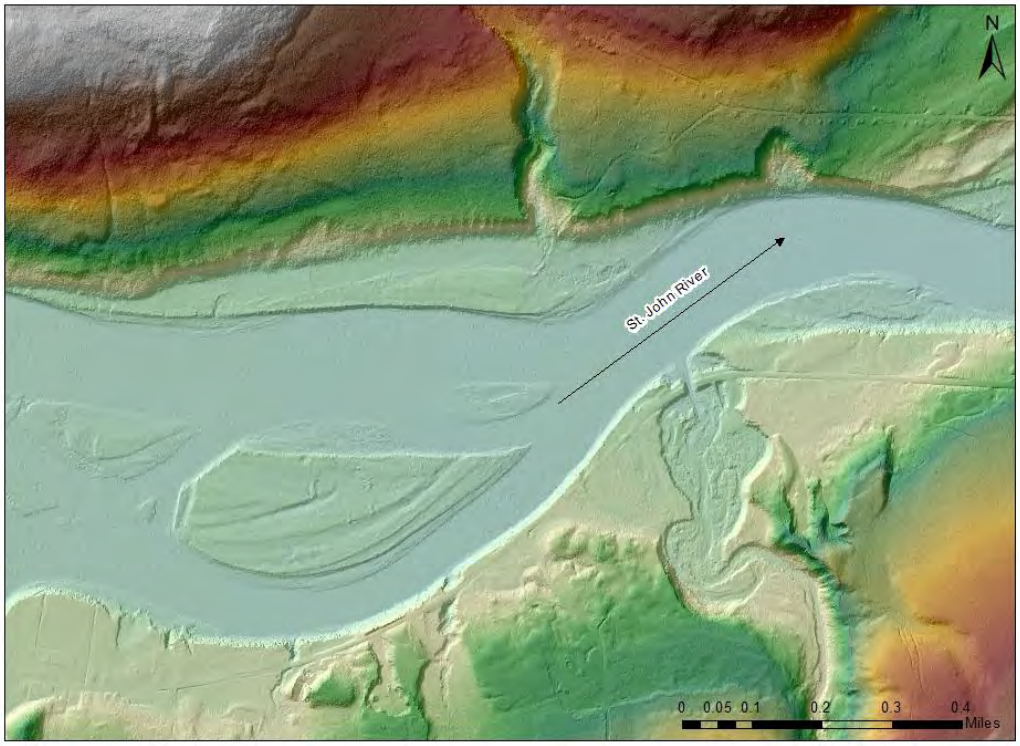


Figure 2-2: Allagash Site: Existing Conditions Model Surface Hill-Shade

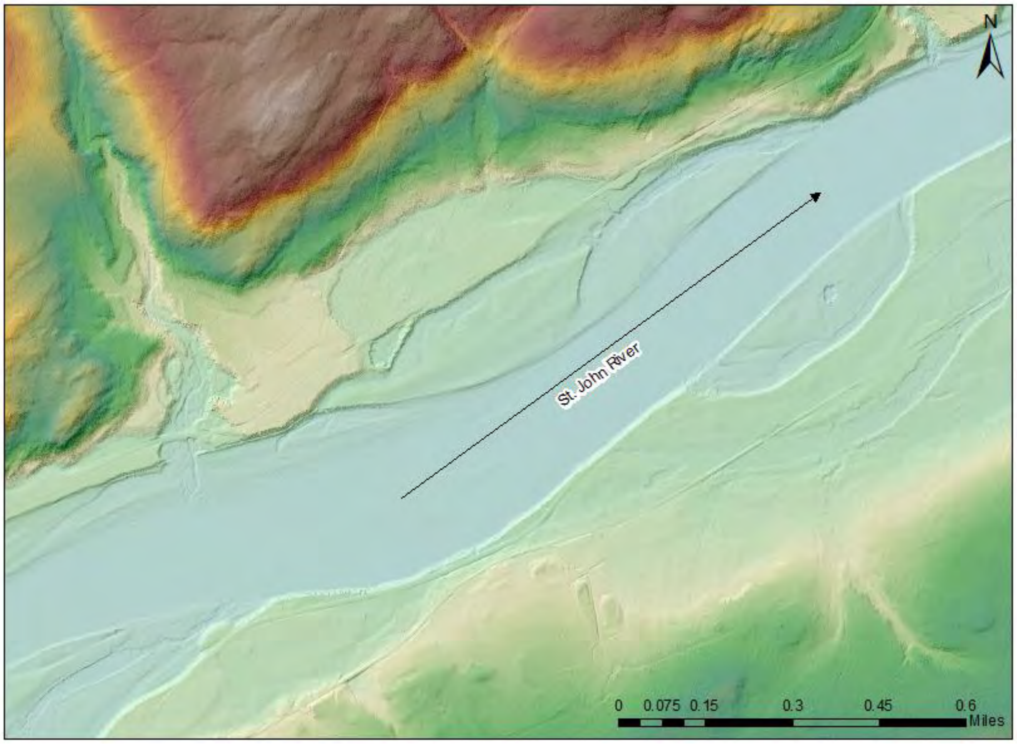


Figure 2-3: St. Francis Site: Existing Conditions Model Surface Hill-Shade

2.2 Model Extents and Inputs

Modelling extents cover approximately a fifteen mile stretch of the St. John River with the Allagash reach covering 1.9 miles and the St. Francis reach covering 1.7 miles. The two modeled reach extents were selected to encompass the proposed channel modifications and anticipated area of influence as presented in Figures 2-4 and 2-5.

The 2D models incorporated a Manning's roughness of 0.027 for the channel and 0.040 for the overbank. Two small areas within the Allagash model were slightly unstable and higher n-values were assigned.

Models were analyzed for the 2- and 100-year annual exceedance probability events of 58,000 and 168,000 cubic feet per second (cfs) for the Allagash site, and 68,000 and 156,000 cfs for the St. Francis site (Golder 2019).

2D TUFLOW models were developed in order to resolve hydraulic conditions at a more granular scale throughout the project areas, to better represent the anticipated complex flow dynamics. 2D models are grid-based and report results for each cell within the grid, allowing for review of hydraulic conditions laterally as well as longitudinally within and between section locations. The 2D TUFLOW models were developed for a variety of proposed bendway weir conditions. The models were run with a grid cell size of 10 feet by 10 feet. A time step of 2 seconds for both the Allagash St. Francis sites. The downstream water surface elevation (WSE) boundary condition determined from a previous 1D HEC-RAS model of the sites (Golder 2019). For the models, the bendway weirs were incorporated as variable 2D Z-lines.

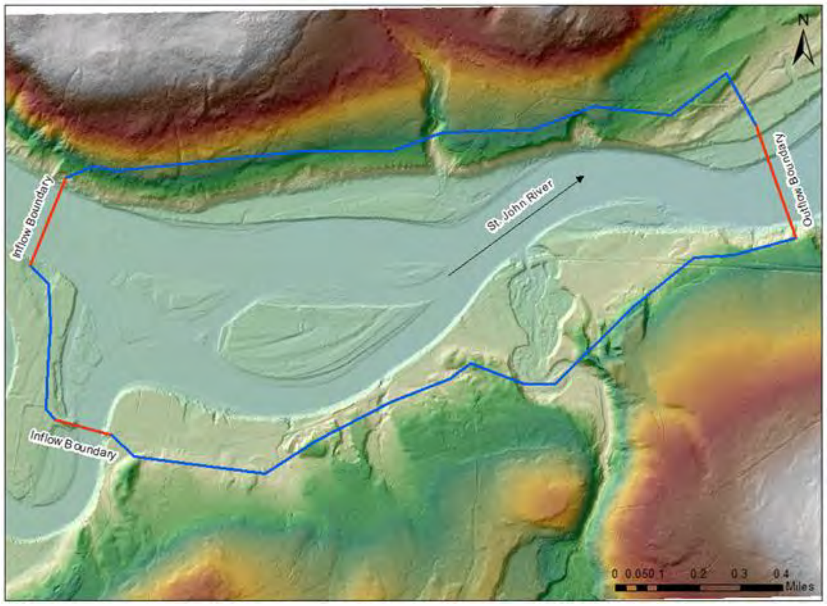


Figure 2-4: Allagash Site TUFLOW Model Extents

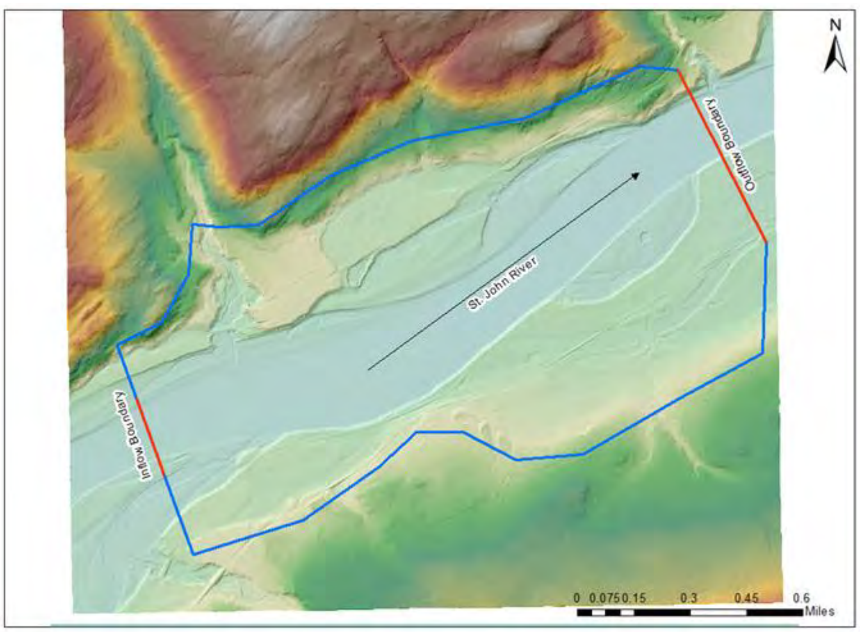


Figure 2-5: St. Francis Site TUFLOW Model Extents

2.3 Model Iterations

A variety of bendway weir structure iterations were run at each unstable slope project site for a variety of weir numbers, placements, widths, heights, and orientations. Refer to Attachment B for a summary of the modeling iterations.

3.0 CONCLUSIONS

This technical memorandum summarizes the development of two-dimensional models that incorporate the proposed in-channel structures, bendway weirs, and evaluate the effects of these additions; these results were used to support development of preliminary design recommendations. The results presented herein provide a representative understanding for the performance of the proposed structures, and comparison of the existing versus proposed conditions for the MaineDOT's project along two unstable slope areas on the St. John River.

Note that reported results from the modeling are absolute values, representing direct output from the analyses, and demonstrate trends in the targeted hydraulic conditions that were evaluated. While absolute values listed for elevations (for example) of 1 foot or less are determined by these models, there may be some varying range in the results that is inherent to this type of analysis (i.e. the typical range of error that comes with modeling) that is likely less than or on par with these absolute values. The intent of this analysis was to identify trends in the existing and proposed conditions relative to the proposed in-channel work, and thereby highlight where possible issues may need to be further assessed or investigated; and to confirm that results and outputs of the modeling makes sense and present logical conclusions that fit expected site hydrologic, hydraulic, and geomorphic conditions.

Attachments

Attachment A: Baseline Flow and Velocity Modeling Results
Attachment B: Modeling Iterations

https://golderassociates.sharepoint.com/sites/106608/project files/6 deliverables/final report/appendix/appendix i techmemo_2dhydraulicmodeling/1659907-tm-rev0-app i_allagash_st. francis_modeling-032519.docx

4.0 REFERENCES

BMT Group Ltd. 2017. TUFLOW Release 2017-09-AC.

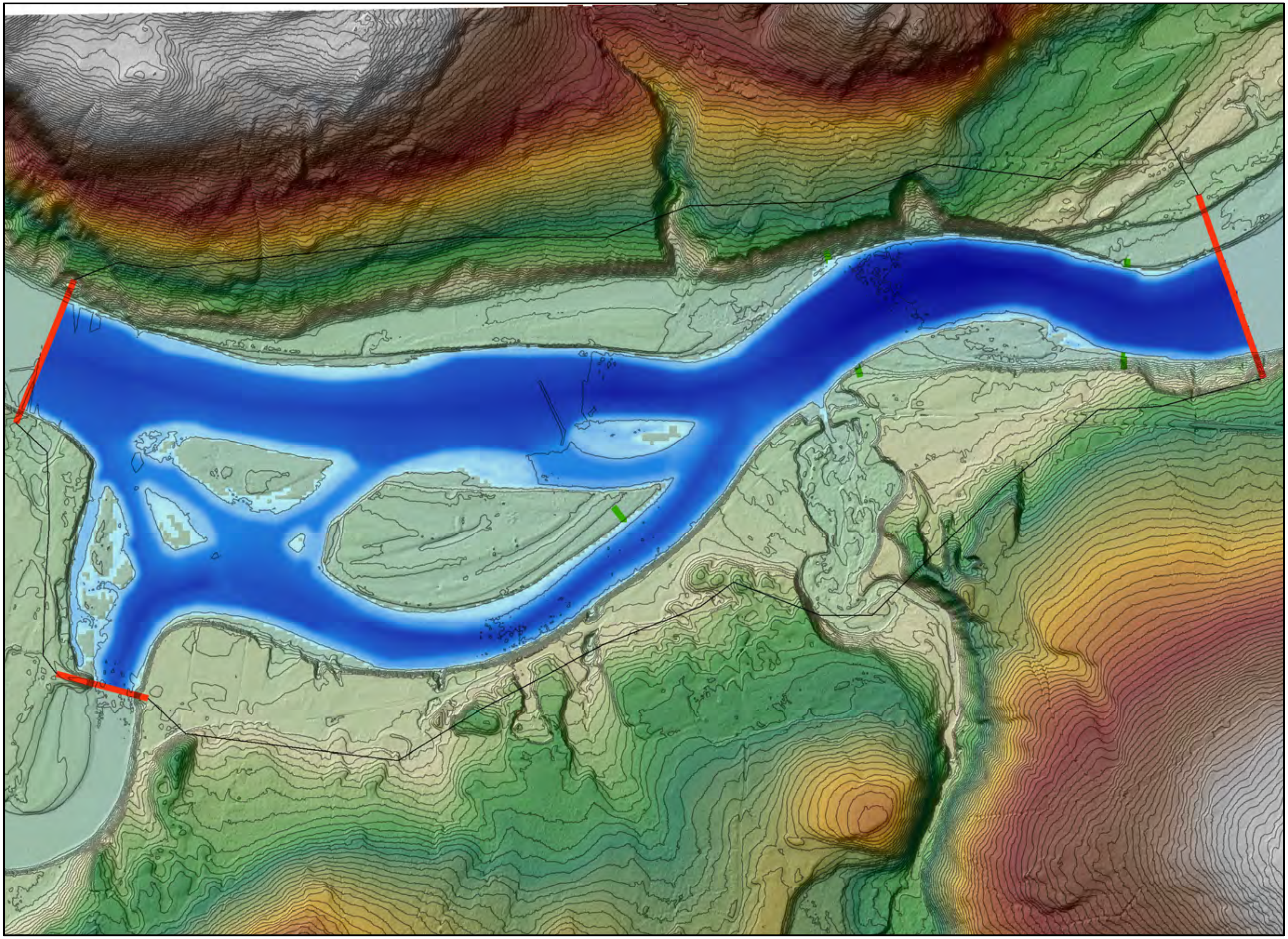
Federal Emergency Management Administration (FEMA). 2009. Fort Kent LiDAR Survey.

Golder Associates Inc. (Golder). 2019. Technical Memorandum. Hydrologic and Hydraulic Evaluation of Existing Conditions – Slope Stabilization of State Route 161 at Francis and Allagash, Maine.

ATTACHMENT A

Baseline Flow And Velocity Modeling Results

1. TUFLOW Allagash 2-yr Flow Depth
2. TUFLOW Allagash 2-yr Flow Velocity
3. TUFLOW Allagash 100-yr Flow Depth
4. TUFLOW Allagash 100-yr Flow Velocity
5. TUFLOW St. Francis 2-yr Flow Depth
6. TUFLOW St. Francis 2-yr Flow Velocity
7. TUFLOW St. Francis 100-yr Flow Depth
8. TUFLOW St. Francis 100-yr Flow Velocity



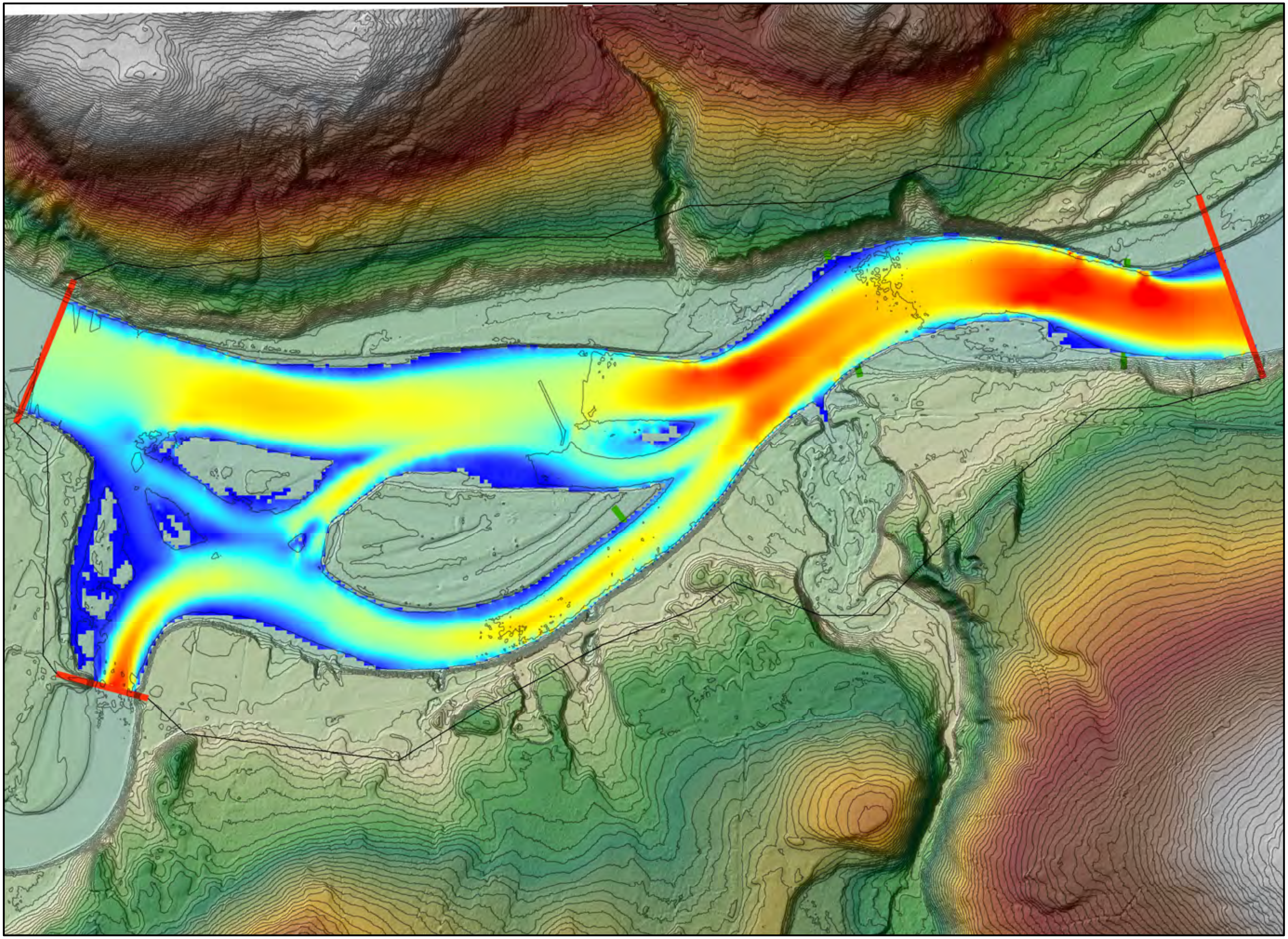
Legend

Allagash 2yr Depth

Value

High : 14.2

Low : 0



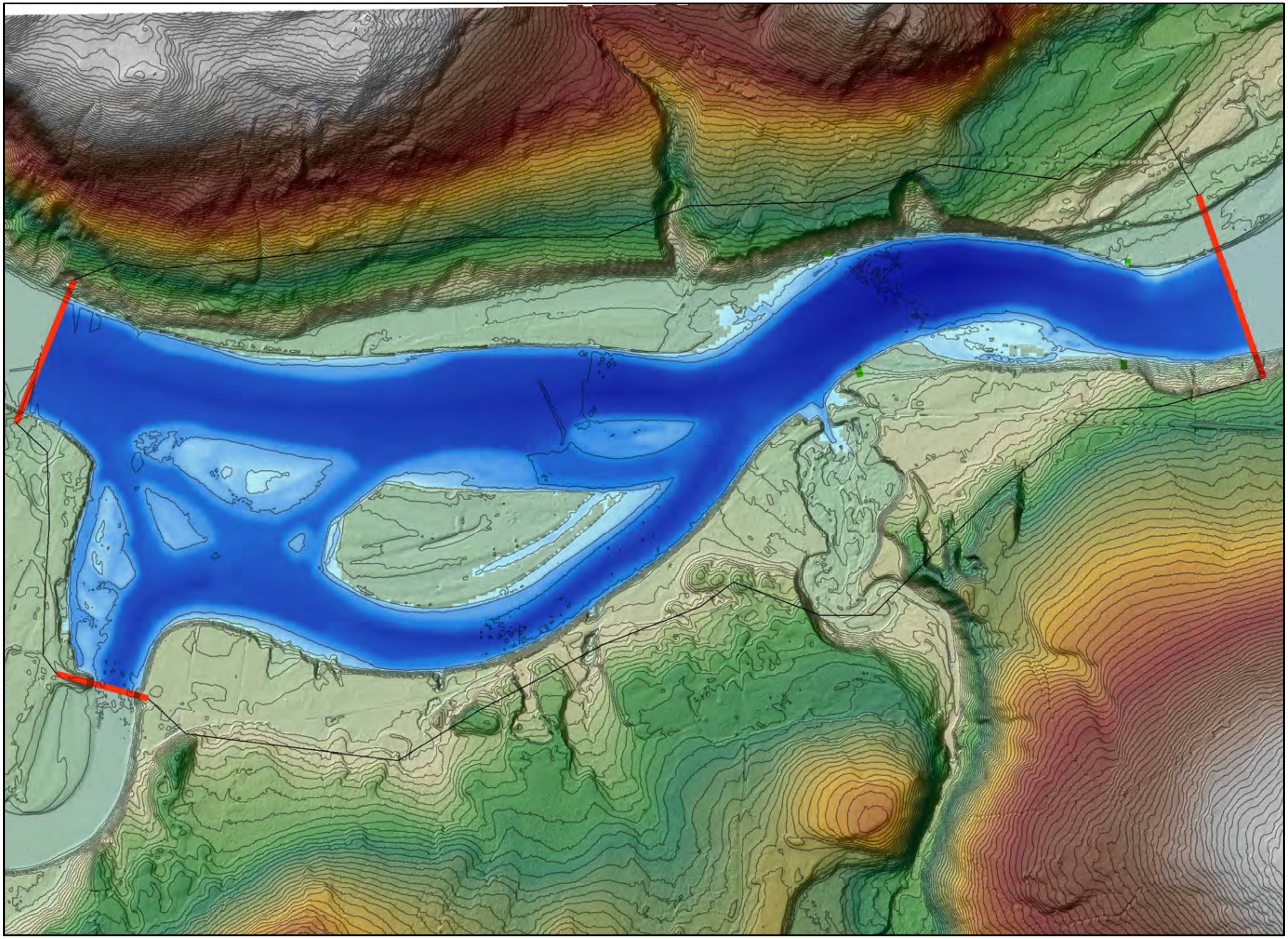
Legend

Allagash 2yr Velocity

Value

High : 11.6

Low : 0



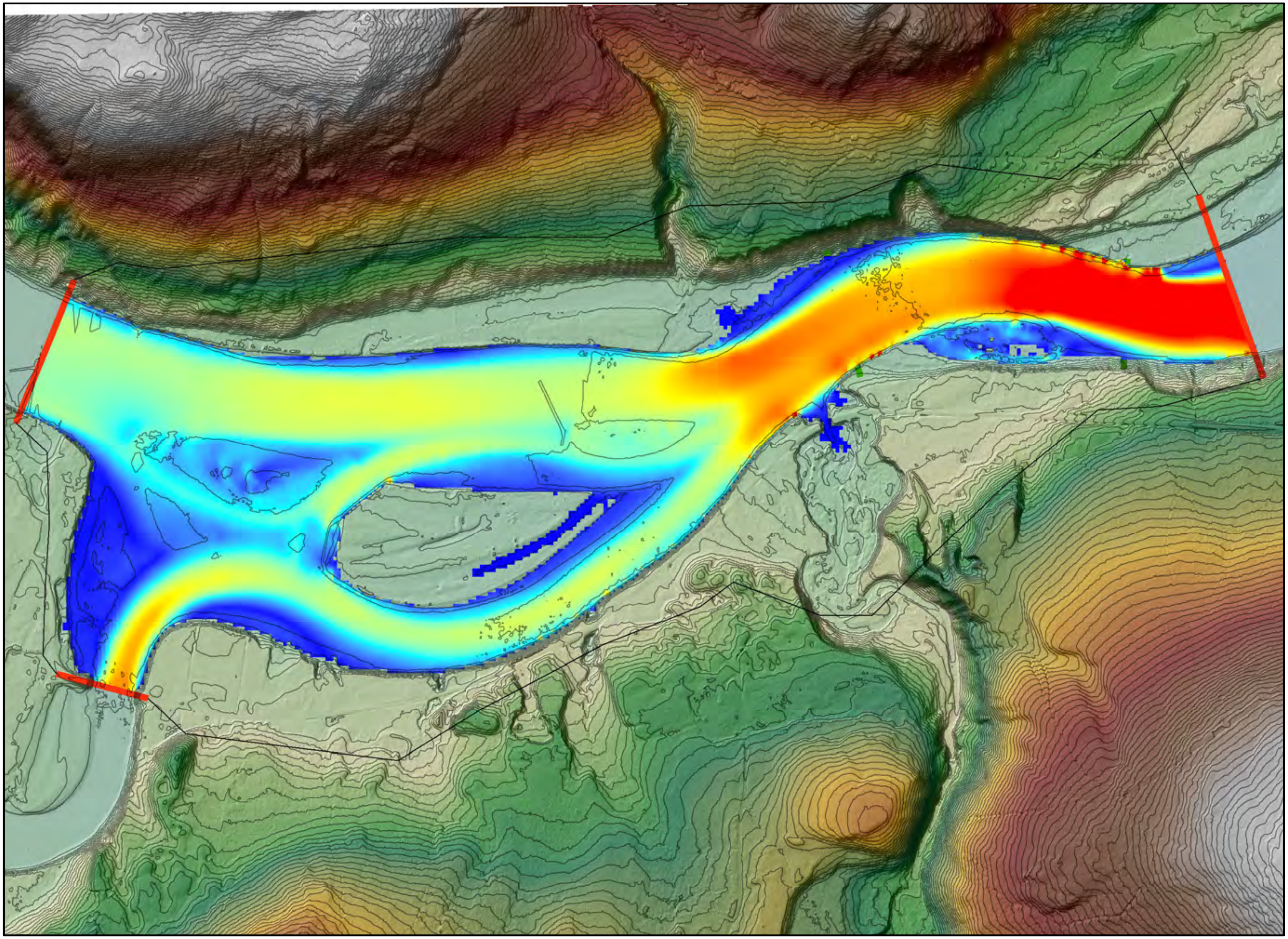
Legend

Allagash 100yr Depth

Value

High : 21.9

Low : 0



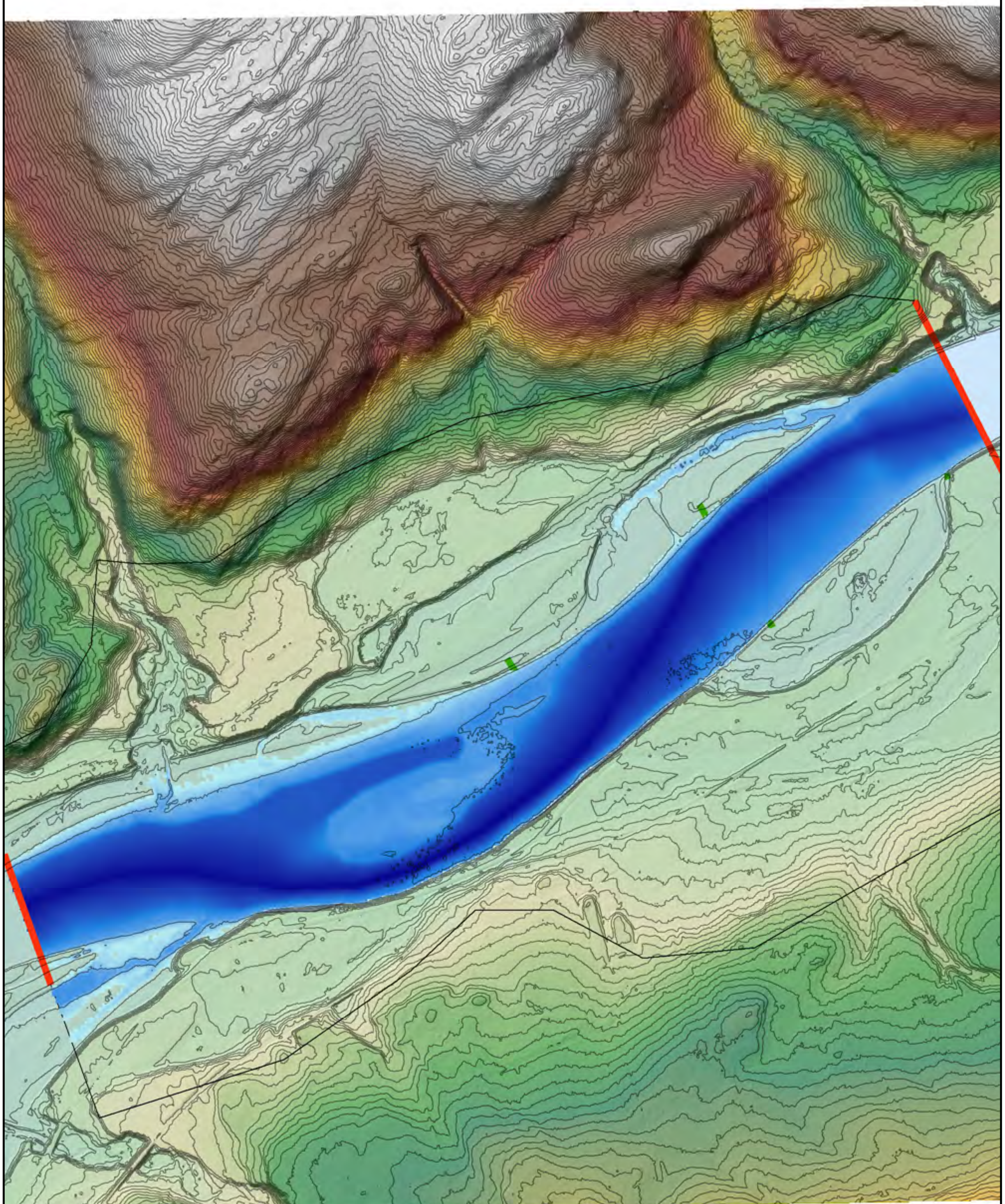
Legend

Allagash 100yr Velocity

Value

High : 16.5

Low : 0



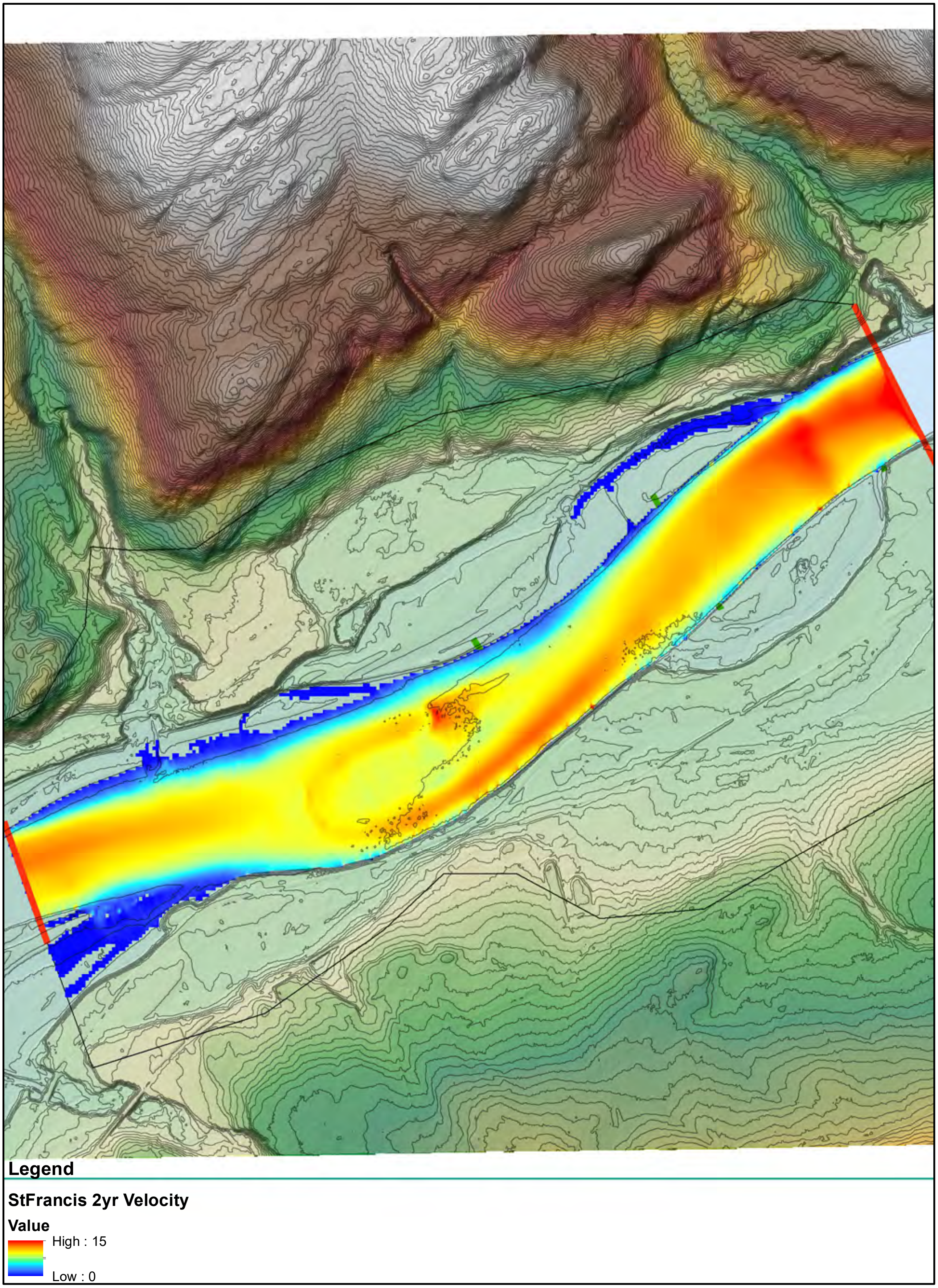
Legend

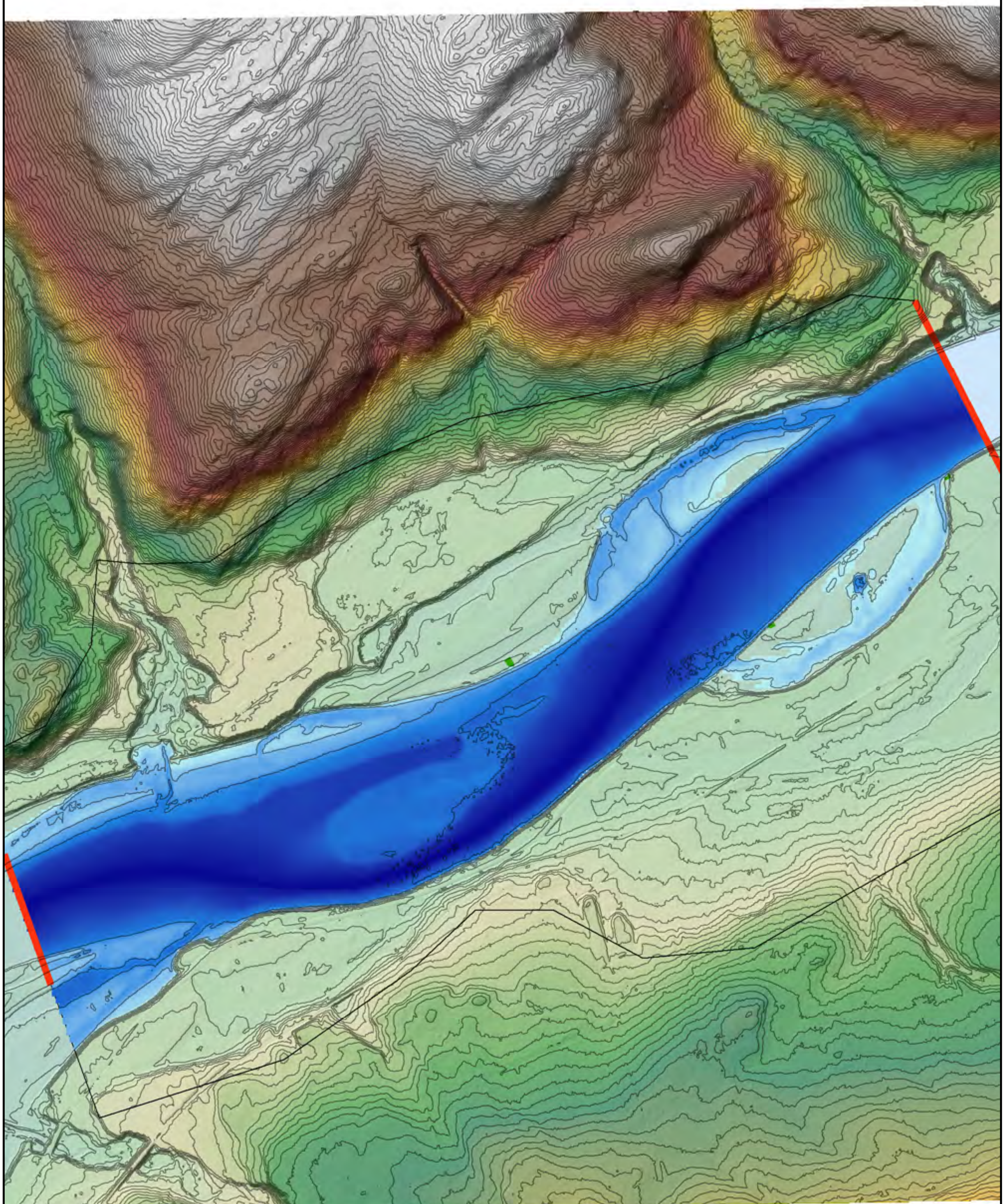
StFrancis 2yr Depth

Value

High : 16.1

Low : 0


Legend
StFrancis 2yr Velocity
Value
High : 15
Low : 0



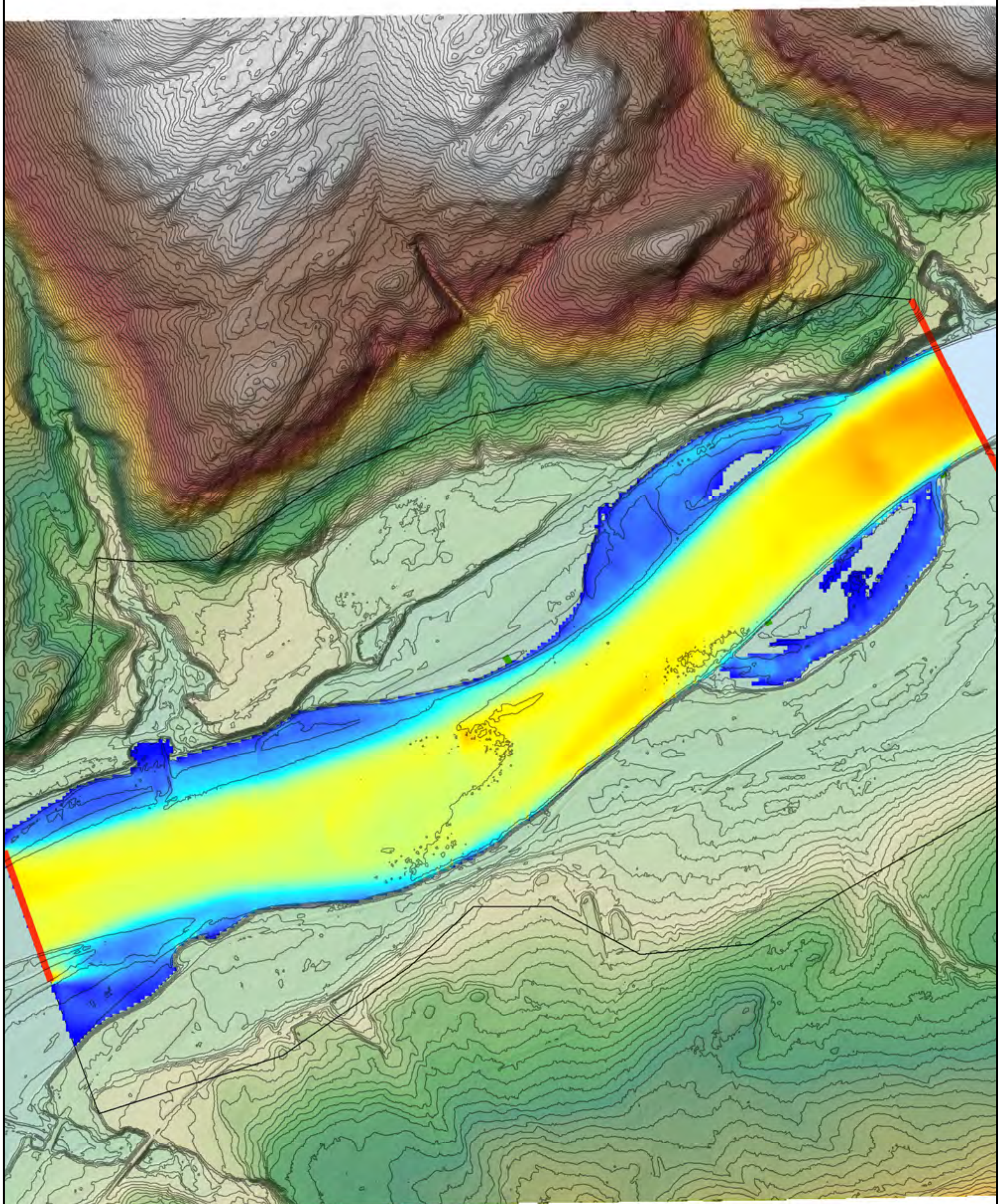
Legend

StFrancis 100yr Depth

Value

High : 22.4

Low : 0



Legend

StFrancis 100yr Velocity

Value

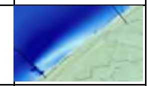
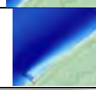
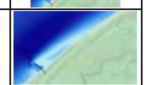
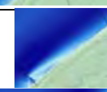
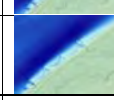
High : 15

Low : 0

ATTACHMENT B

Modeling Iterations

Allagash TUFLOW Models

Name	# of Structures	Length Perpendicular to Bank (ft)	Final EL (ft)	Width (ft)	Orientation Angle (degree)	Structure Spacing (ft)	D/S Influence of Structure(s)	Additional Notes	Picture
StFrancis_1st_20	1	100	536	40	20	N/A	~500ft		
StFrancis_1st_20_50ft	1	50	536	40	20	N/A	~175ft	Almost exact same d/s influence as 90 degree option	
StFrancis_1st_90_50ft	1	50	536	40	90	N/A	~175ft		
StFrancis_1st_90	1	100	536	40	90	N/A	450ft		
StFrancis_1st_30	1	100	536	40	30	N/A	475ft, very similar to 20 degree option		
StFrancis_1st_30_50ft	1	50	536	40	30	N/A	~225ft	Slightly longer influence than 20 degree option	
StFrancis_1st_90_75ft	1	75	536	40	90	N/A	300ft		
StFrancis_1st_30_75ft	1	75	536	40	30	N/A	~315ft		
StFrancis_1st_20_75ft	1	75	536	40	20	N/A	~325ft		
StFrancis_3st_90	3	100	536 to 535.5	40	90	~380	~380ft, a bit less of influence after the second structure		
StFrancis_3st_20	3	100	536 to 535.5	40	20	~380	~380, second structure has a bit less of influence (kind of close to bank)		
StFrancis_3st_20_v2	5	Varies (50-100)	536 to 535.5	40	20	Varies	Influence of each structure is off banks		
StFrancis_3st_90_v2	5	Varies (50-100)	536 to 535.5	40	90	Varies	Influence of each structure is off banks (influence very similar to 20 degree option)		
StFrancis_5st_90_50ft	5	50	536 to 535.5	40	90	200	~200ft for the first structure and a little less than 200ft for the last few structures	I think the 90 degree more effective for this version	
StFrancis_5st_20_50ft	5	50	536 to 535.5	40	20	200	~200ft for the first few structures and a little less than 200ft for the last few structures		
StFrancis_1st_90_75ft_25w	1	75	536	25	90	N/A	325	longer d/s influence compared to 40 ft width option	
StFrancis_1st_30_75ft_25w	1	75	536	25	30	N/A	275	shorter d/s influence compared to 40 ft width option	
StFrancis_1st_20_75ft_25w	1	75	536	25	20	N/A	275	shorter d/s influence compared to 40 ft width option	
St_Francis_6st_90_75ft	6	75 to 35	536 to 535.5	40	90	100 to 250	~1250	Similar d/s influence as 30 degree option	
St_Francis_6st_30_75ft	6	75 to 35	536 to 535.5	40	30	100 to 250	~1250		

Allagash_1st_90_50ft	1	50	589	40	90	N/A	~175ft		
Allagash_1st_90_100ft	1	100	589	40	90	N/A	~550ft		
Allagash_1st_20_50ft	1	50	589	40	20	N/A	200ft		
Allagash_1st_20_100ft	1	100	589	40	20	N/A	~550ft		
Allagash_4st_90_100ft	4	100	588 to 589	40	90	400	Hits next structure, not bank ~400ft	Better alternative compared to 20 degree option	
Allagash_4st_20_100ft	4	100	588 to 589	40	20	400	~400ft, a bit close to bank off second to last structure		
Allagash_6st_90_50ft	7	50	589 to 588	40	90	200	~200ft for the first 2 structures, less than that for the last 5 structures (close to banks)		
Allagash_6st_20_50ft	7	50	589 to 588	40	20	200	~200ft for the first 2 structures, less than that for the last 5 structures (close to banks)	A bit better bank protection than the 90 degree option	

***Note 2yr recurrence flood WSE is just below the final EL of the bendway weirs (~less than 0.5 ft)**

APPENDIX J

Ice Jam Information

APPENDIX J.1

Ice Jam and Flooding Inventory

See Figure J1.1.2 for ice jams in Dickey

CLIENT
MAINE DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

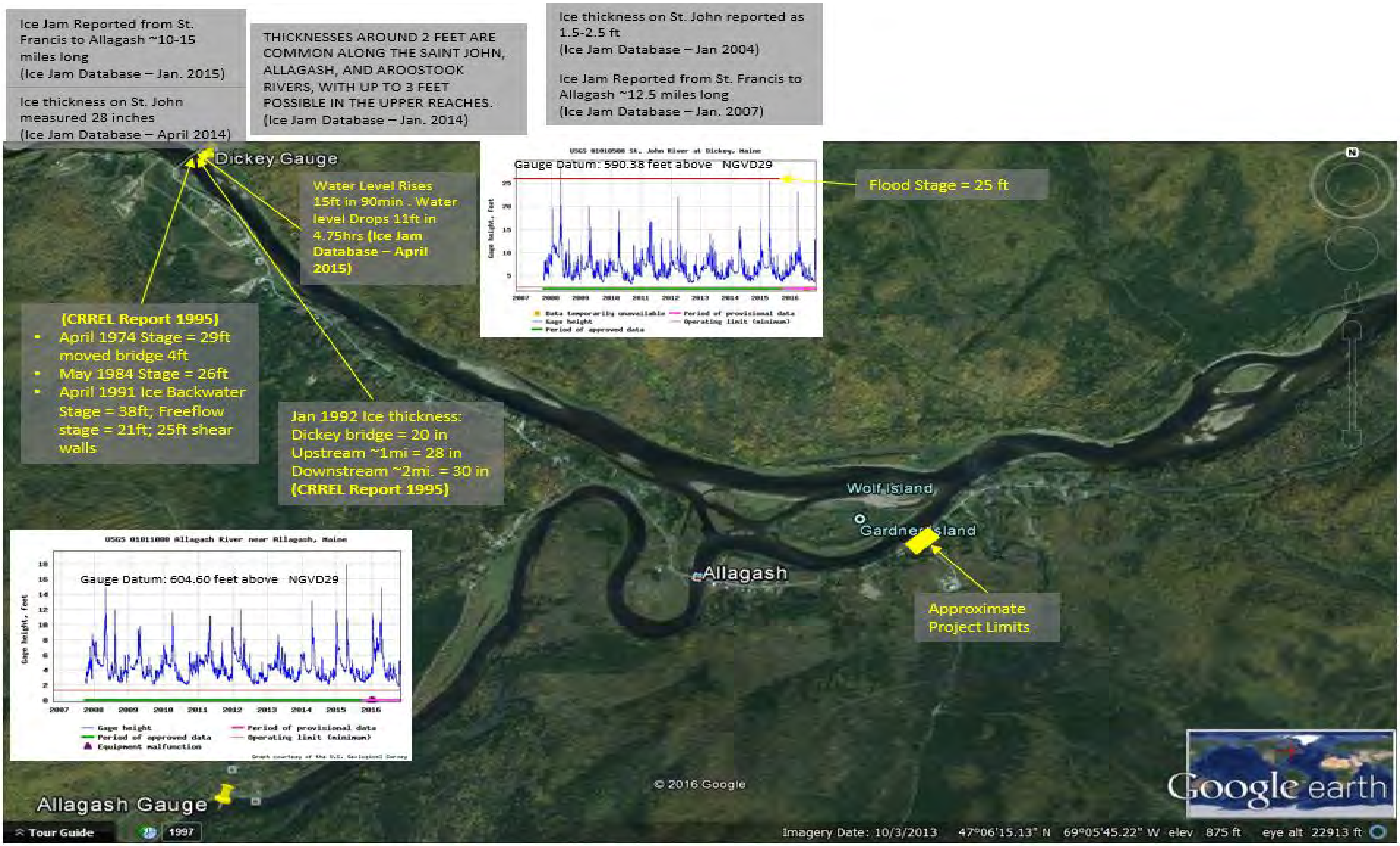
PROJECT
GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION
STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER
ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00

CONSULTANT
GOLDER

YYYY-MM-DD	2019-03-18
DESIGNED	CJS
PREPARED	SKB
REVIEWED	JDL
APPROVED	MSP

TITLE
St. Francis to Allagash Ice Jam Overview

PROJECT NO. 165-9907
PHASE
FIGURE J.1.1



CLIENT
MAINE DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

PROJECT
GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION
STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER
ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00

CONSULTANT

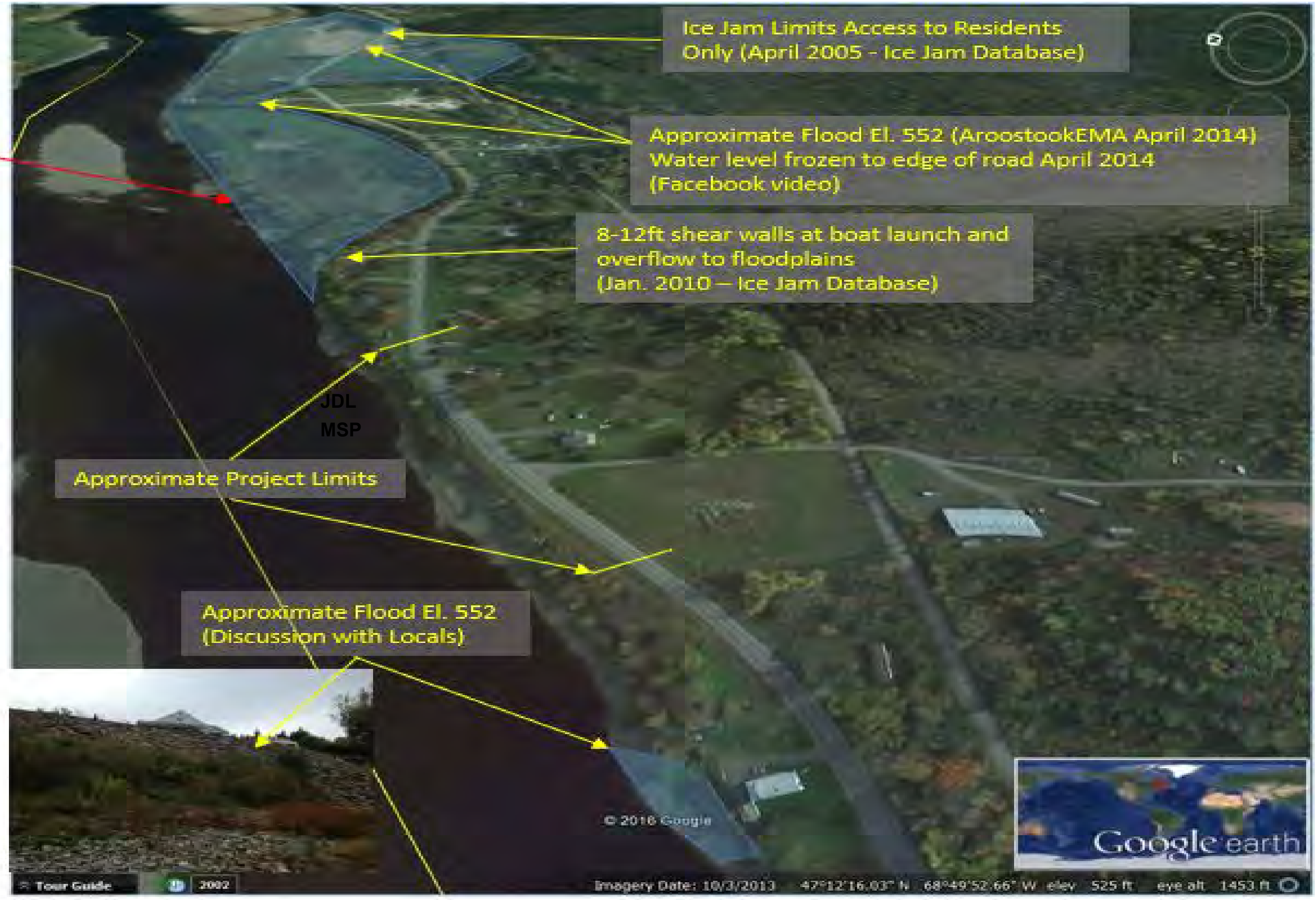
GOLDER

YYYY-MM-DD	2019-03-18
DESIGNED	CJS
PREPARED	SKB
REVIEWED	JDL
APPROVED	MSP

TITLE
Allagash Ice Jam and Flooding Overview

PROJECT NO. 165-9907 PHASE FIGURE J.1.2

Ice Jams Seem To Form at Hunnewell Island



Ice thickness on St. John measured 28 inches (Ice Jam Database – April 2014)

THICKNESSES AROUND 2 FEET ARE COMMON ALONG THE SAINT JOHN, ALLAGASH, AND AROOSTOOK RIVERS, WITH UP TO 3 FEET POSSIBLE IN THE UPPER REACHES. (Ice Jam Database – Jan. 2014)

CLIENT
MAINE DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

PROJECT
GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION
STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER
ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00

CONSULTANT

GOLDER

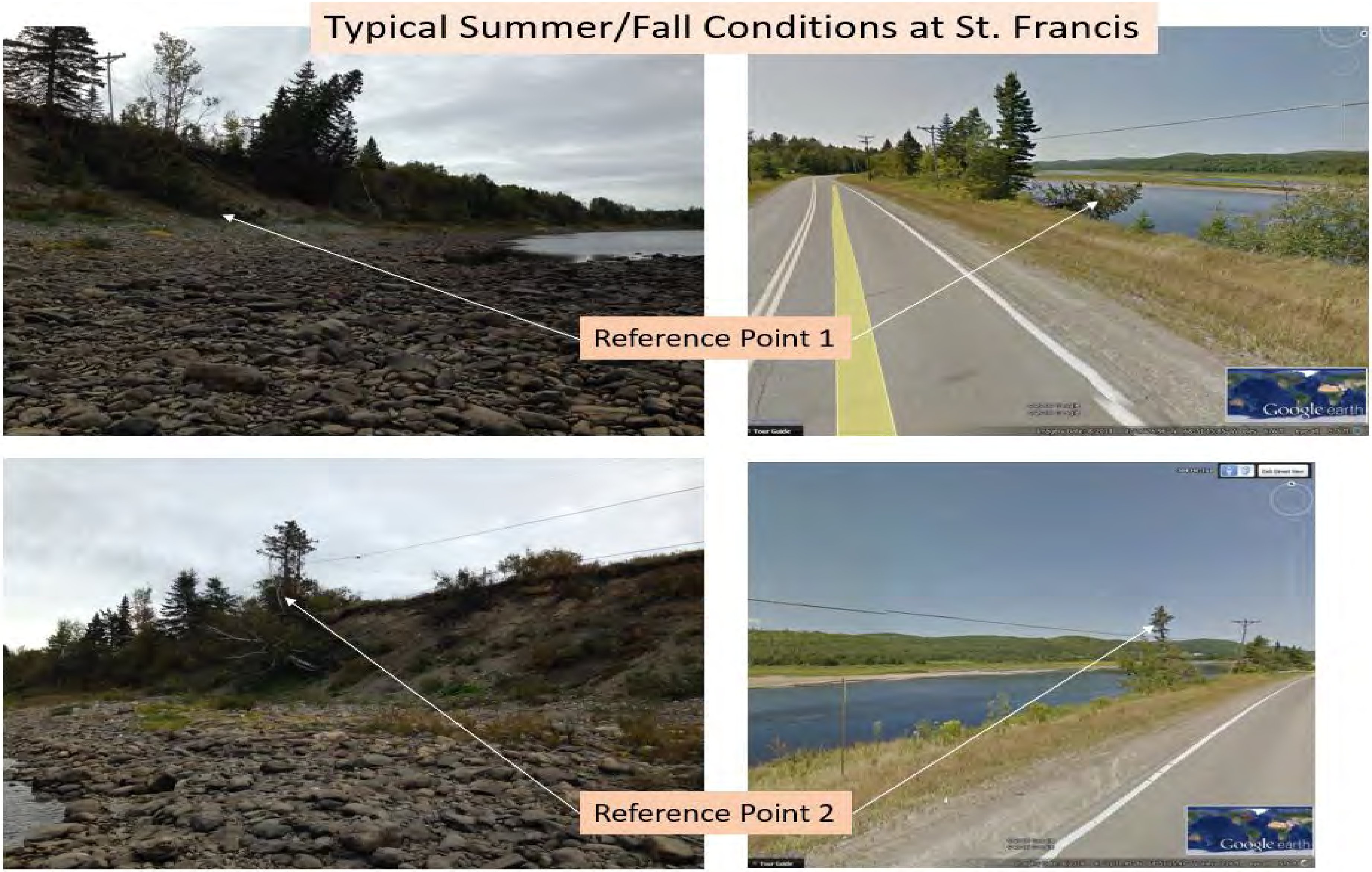
YYYY-MM-DD	2019-03-18
DESIGNED	CJS
PREPARED	SKB
REVIEWED	JDL
APPROVED	MSP

TITLE
St. Francis Ice Jam and Flooding Overview

PROJECT NO. 165-9907
PHASE
FIGURE J.1.3

APPENDIX J.2

St. Francis April 2014 Ice Jam



CLIENT
MAINE DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

PROJECT
GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION
STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER
ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00

CONSULTANT

GOLDER

YYYY-MM-DD	2019-03-18
DESIGNED	CJS
PREPARED	SKB
REVIEWED	JDL
APPROVED	MSP

TITLE

Typical Summer/Fall Conditions

PROJECT NO.	PHASE	FIGURE
165-9907		J.2.1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

1 in

0

CLIENT
MAINE DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

PROJECT
GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION
STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER
ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00

CONSULTANT

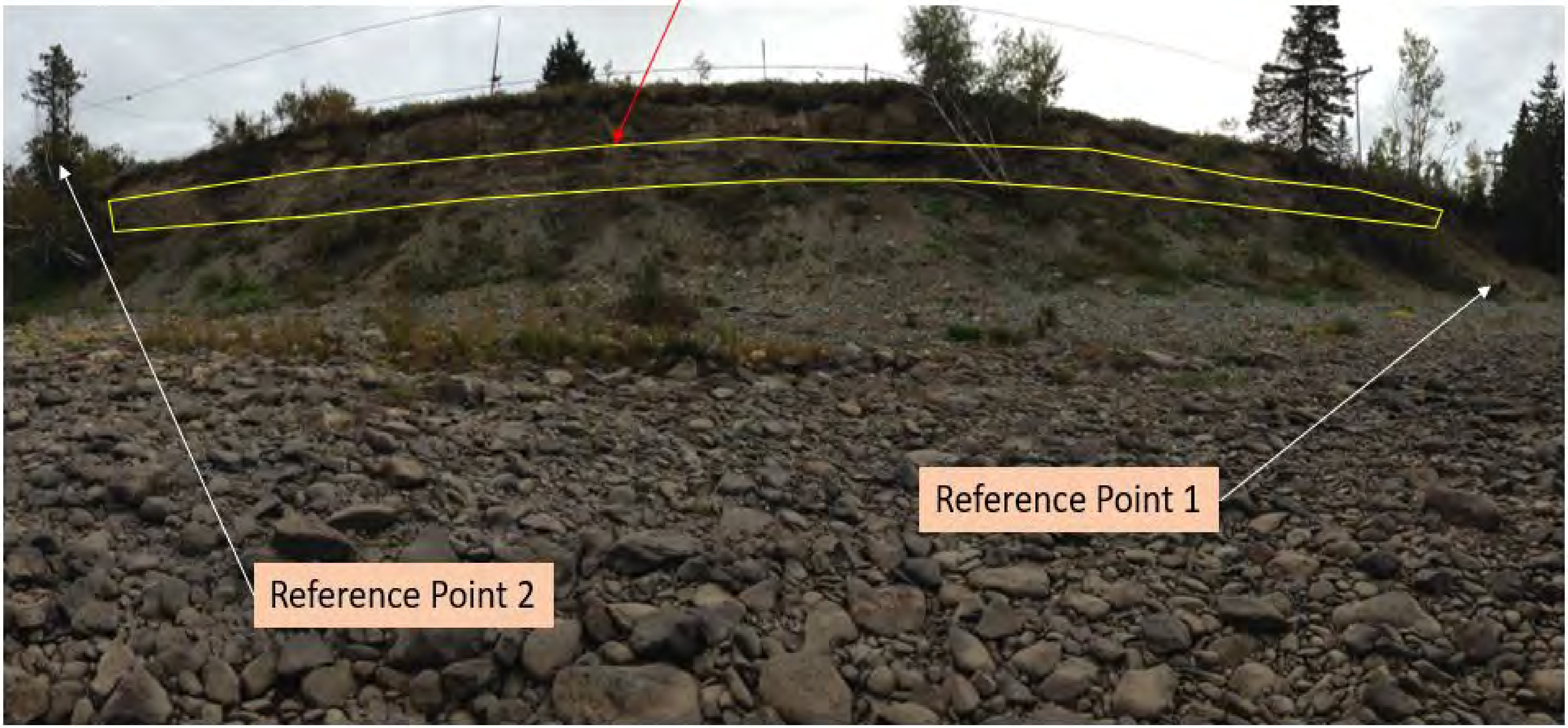
GOLDER

YYYY-MM-DD	**2019-03-18**
DESIGNED	**CJS**
PREPARED	**SKB**
REVIEWED	**JDL**
APPROVED	**MSP**

TITLE

April 2014 Ice Jam Conditions

PROJECT NO.	PHASE	FIGURE
165-9907		**J.2.2**



CLIENT
MAINE DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

PROJECT
GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION
STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER
ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00

CONSULTANT

GOLDER

YYYY-MM-DD	2019-03-18
DESIGNED	CJS
PREPARED	SKB
REVIEWED	JDL
APPROVED	MSP

TITLE
Possible Erosion Zone from Ice Jam

PROJECT NO. 165-9907
PHASE
FIGURE J.2.3

1 in
0

APPENDIX K

Basis of Design Summary for Hydrotechnical Engineering

TECHNICAL MEMORANDUM

DATE September 5, 2017 **Project No.** 1659907.4

TO Project File
MaineDOT

CC Scott Stoneman, PE, Golder-Redmond, Mark Peterson, Golder-Maine, Jeff Lloyd, Golder-Maine

FROM Andreas Kammereck, PE, Golder-Redmond **EMAIL akammereck@golder.com**

BASIS OF DESIGN (BOD) SUMMARY FOR HYDROTECHNICAL ENGINEERING – SLOPE STABILIZATION OF STATE ROUTE 161 AT ST. FRANCIS AND ALLAGASH, MAINE

ATTACHMENTS:
Attachment A: Site Geology
Attachment B: Site Erosion Trends
Attachment C: Riprap Inventory
Attachment D: Example Bank Armoring Projects using Riprap
Attachment E: Example MaineDOT Riprap Specifications

1.0 INTRODUCTION

This technical memorandum summarizes the basis of design (BOD) to support hydrotechnical engineering for the design of bendway weirs for the Maine Department of Transportation (MaineDOT) for two unstable slopes segments adjacent to State Route 161 between the roadway and the St. John River. The proposed bendway weirs will be installed in conjunction with riprap armoring on the banks to mitigate for floods and ice. The first site is along roughly an 800-foot segment of State Route 161 in St. Francis, and the second site is approximately 550-foot in length along the roadway in the town of Allagash. The Allagash slope segment is positioned at the confluence of the Allagash River and the St. John River. The St. Francis slope segment is located on the St. John River approximately 12 miles downstream of Allagash site and directly downstream of a valley constriction that occurs just downstream of the confluence of the St. Francis River and the St. John River.

The following sections of this technical memorandum outline the key components for the BOD, in order to inform and support continued planning and technical work for preliminary and detailed design work. This memorandum is organized into the following sections: site geology, definition of site specific erosion and scour hazards, design overview, general layouts, typical dimensions, local riprap materials, local bank armoring examples, scour trends/estimates, conclusions.

1.1 Site Geology

Refer to Attachment A for preliminary mapping of the site geology, and development of preliminary geologic cross-sections for the Allagash and St. Francis project sites. Site geologic mapping and characterizations were developed by Golder-Maine staff based on review of available geologic information, site investigations, and site reconnaissance.

1.2 Site Erosion Trends

Refer to Attachment B for a preliminary assessment of erosion trends in the area along and adjacent to the toe of the banks at the two project sites. The assessment as completed by comparing successive elevation data sets. The results show preliminary trends as follows:

- Allagash: some areas of deposition, and a general trend of erosion ranging from 0 to 4 feet of degradation along the toe of the bank, and some areas of approximately 4 to 7 feet of degradation within approximately 30 to 50 feet of the toe of the banks.
- St. Francis: some areas of deposition, and a general trend of erosion ranging from 0 to 4 feet of degradation along the toe of the bank, and some areas of approximately 4 to 7 feet of degradation within approximately 5 to 10 feet of the toe of the banks, with localized areas showing upwards of 15 feet of degradation within the same limits.

1.3 Definition of the Hazard

Initial planning and review work looked at available information to define the site specific erosion and scour hazards, and thereby develop conceptual scenarios that for bank failure processes. Figure 1-1 provides a conceptual schematic of the identified erosion and scour processes that may exist at the site, summarized as follows (refer to the numbered bubbles 1 through 5 in the schematic):

1) Bank Erosion – Hydraulic Forces: defined as erosion along the upper portion of the banks resulting from elevated river water levels and corresponding high velocity flows occurring during defined floods (whereby the design peak event is the 100-year flood).
2) Bank Erosion – Ice Forces: defined as erosion along the upper portion of the banks, or extending down to the toe of the bank, resulting from ice coming in direct contact with the bank.
3) Slope Instability (i.e. from over steepening, unstable soil units, etc.): defined as geotechnical slope instability processes defined by the geometry of the slope and the corresponding soil units and/or groundwater conditions of the slope.
4) Slope Instability (i.e. from Rapid draw-down): defined as instability resulting when the soil units in the slope are inundated by flood events and then subjected to a rapid decrease in river levels.
5) Bank Toe Erosion: defined as erosion that is generally limited to the area around toe of the bank during flood events, thereby undercutting the upper portion of the bank and resulting in instability extending father up the bank (i.e. upper bank areas slough down into the toe).
6) River Toe Scour: defined as scour that occurs in the river channel during peak events, either as a function of general or local scour, or from a meandering thalweg alignment, and results in a lowering to the bed in the area around the toe of the bank, undercutting it and causing instability farther up the bank.

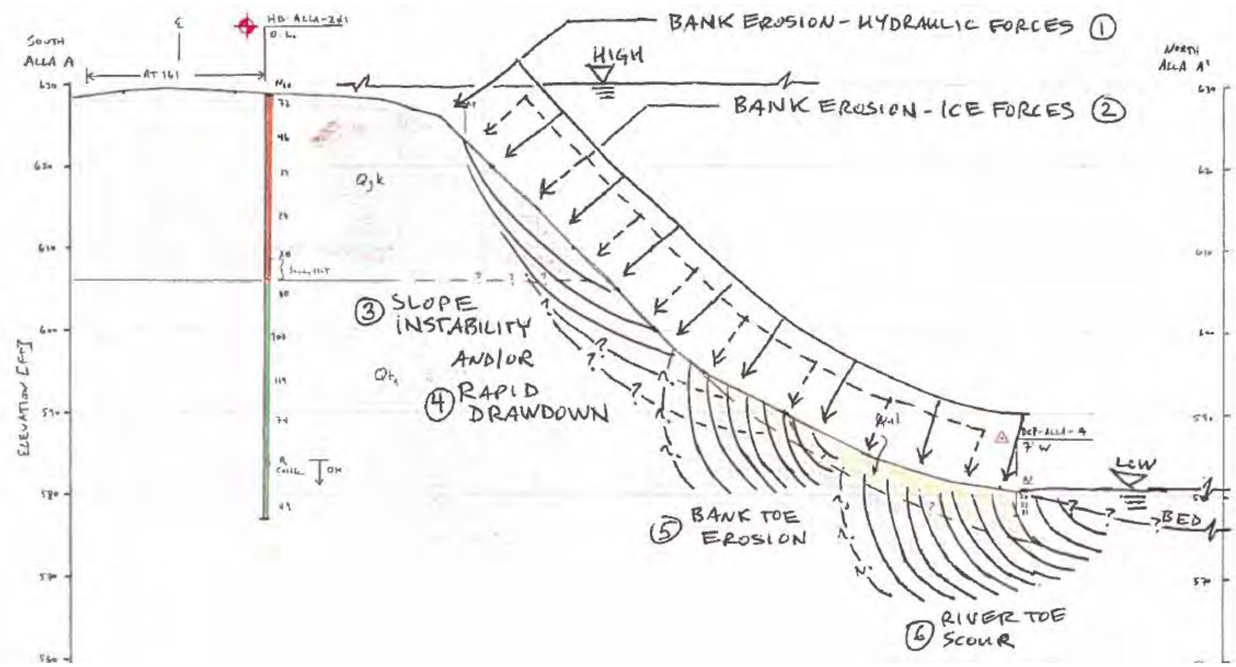


Figure 1-1: Conceptual Erosion and Scour Processes

The following sections of this technical memorandum specifically address the bank toe erosion (number 5) and the river toe scour (number 6) hazards; proposed mitigation for these hazards include the use of bendway weirs.

2.0 DESIGN OVERVIEW

Bendway weirs have been used for decades as an effective method for mitigating erosion and scour hazards and to address bank stabilization issues (Thornton et al 2007). The design of bendway weirs addressed herein is based on a combination of technical engineering criteria, field experience, and engineering judgement. Bendway weirs are typically designed and installed in series, with multiple structures configured in defined layouts, spacing, lengths, heights, widths, and shapes. These design components combine to address the following three primary performance conditions:

- Move the thalweg of the river channel away from the toe off the bank(s) – the thalweg is defined at the lowest and highest velocity zone running along the bottom of the channel and typically following the flow line formed during any defined event. The thalweg trends to the center of straight channels, and trends to the outside of the channel in bends; and the thalweg can change position in low versus high flow conditions, for example moving from the center of the channel during low flows to the side of the channel during high flows as a wider extent of the floodplain becomes inundated (i.e. governing flow directions originate from changed orientations during high versus low flows). When the thalweg moves against the bank, it increases flow velocities along the toe and can result in increased potential for erosion and scour, which evacuates bed and bank materials at the toe and results in bank failures. Bendway weirs move the thalweg away from the toe of the bank by establishing a new effective toe of bank along the tips of the installed structures, thereby moving the erosion and scour away from the bank. The erosion and scour processes still occur, but act on the structure, not the toe of the bank.

- Re-direct flows running along the toe of the bank away from the bank(s) – river flows may have variable flow vectors and geometries throughout the river channel and floodplain areas, governed by bathymetric conditions, debris, vegetated areas, etc. When flows interact with the bank, they tend to follow the bank line, focusing flow energy at the deepest areas along the toe of the bank. Bendway weirs can re-direct flows away from the bank by modifying the orientation, elevation, shape, and dimensions of the structures. In general, flows along the bank are re-directed along vectors that run perpendicular off the centerline alignment of individual structure(s). Therefore, upstream oriented (relative to the bank) structures tend to re-direct flows away from the banks, perpendicular oriented structures tend to maintain flows vectors along the bank, and downstream oriented structure tend to re-direct flows into the bank. Variable bank alignments may require variable orientation and layout of structures. The ultimate orientation on any given structure is selected to perform to meet the project needs. Site specific flow dynamics for varying orientation scenarios can be assessed using 2-dimensional (2D) modeling tools (note, 1D models do not provide the results necessary to evaluate flow dynamics).
- Stabilize the bed materials along the toe of the bank(s) – the placement of bendway weirs along the toe of the bank act to stabilize bed and bank materials. The locally lower velocity zone created by the structures, and relative elevation of the top of the structures act as a series of local grade-controls that maintain sediment elevations. Local scour may occur aground individual structures, and local sediments may accumulate or evacuate, but the net change in sediment elevations generally remains stable at elevations related to the dimensions (length, width, height, etc.) of the installed structures. This increased stability of sediments in and around installed bendway weirs is the result of moving the thalweg away from the area, re-direction of erosion and scour potential flows away from the area, the development of lower velocity zones between and around the installed structures, the tendency for each installed structure to retain sediments on the upstream side; the net effort is to stabilize the targeted project area.

The materials used to construct the bendway weirs can vary, including (but not limited to): concrete pre-cast units, large wood materials, rounded to sub-rounded rock materials, and angular riprap materials. The use of angular riprap materials is most common, and assumed to be used for this project.

The following sections of this technical memorandum provide more information on the above topics.

2.1 Typical Layouts/Configurations

Bendway weirs are typically installed in series, with multiple structures at coordinated orientations and dimensions. Figure 2-1 shows an example of a series of bendway weir structures.

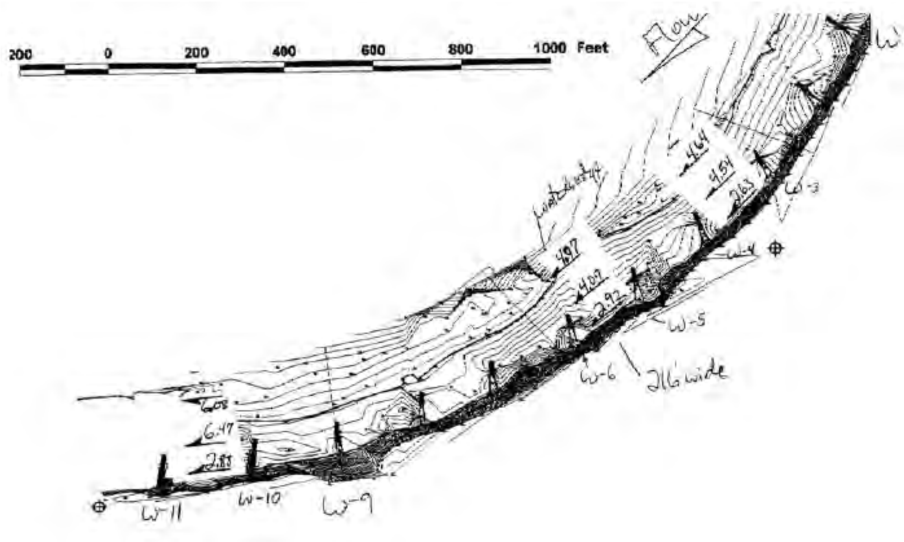


Figure 2-1: Example layout for series of bendway weir structure (NEH 2007)

Flow conditions around individual structures are shown in Figure 2-2 for a typical structure layout, and in Figure 2-3 for an example project site; whereby approaching flows at variable orientations to the structure fall away from the structure perpendicular to the centerline alignment of that structure (see flow vector arrows).

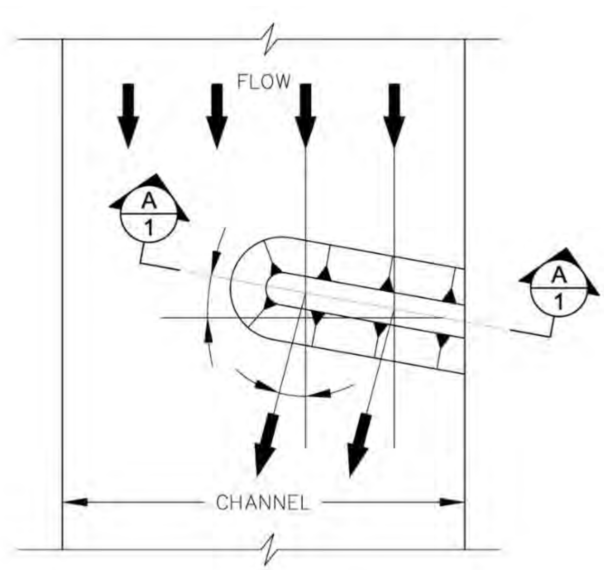


Figure 2-2: Example of flows over upstream oriented bendway weir

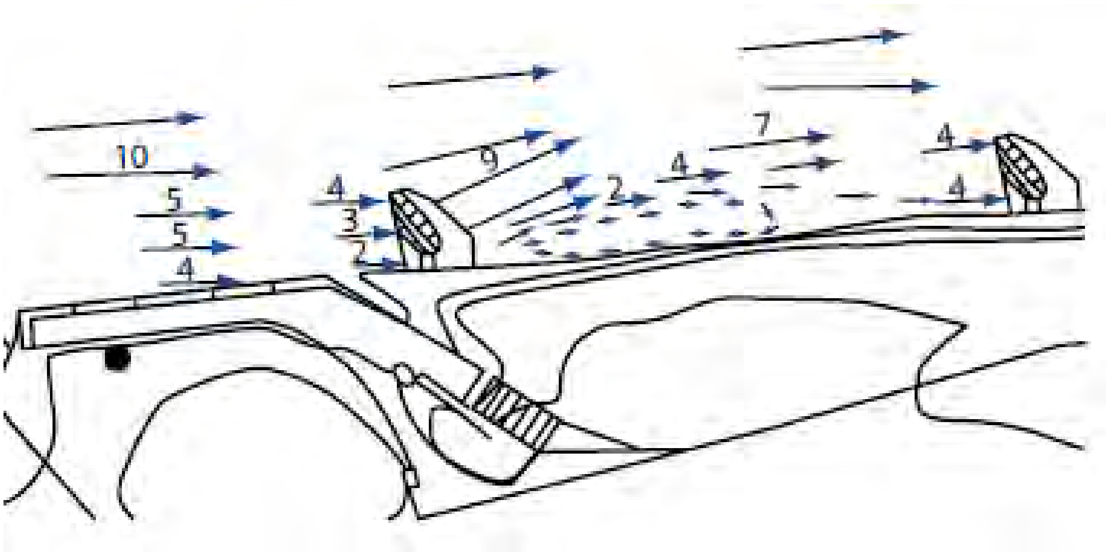


Figure 2-3: Example of flows over upstream oriented bendway weir (NEH 2007)

The installation of the bendway structures moves the thalweg away from the toe of the bank, to an alignment that generally follows along the tips of the structures (Figure 2-4). Erosion and scour occurs at the tips of the structures, rather than along the toe of the bank.

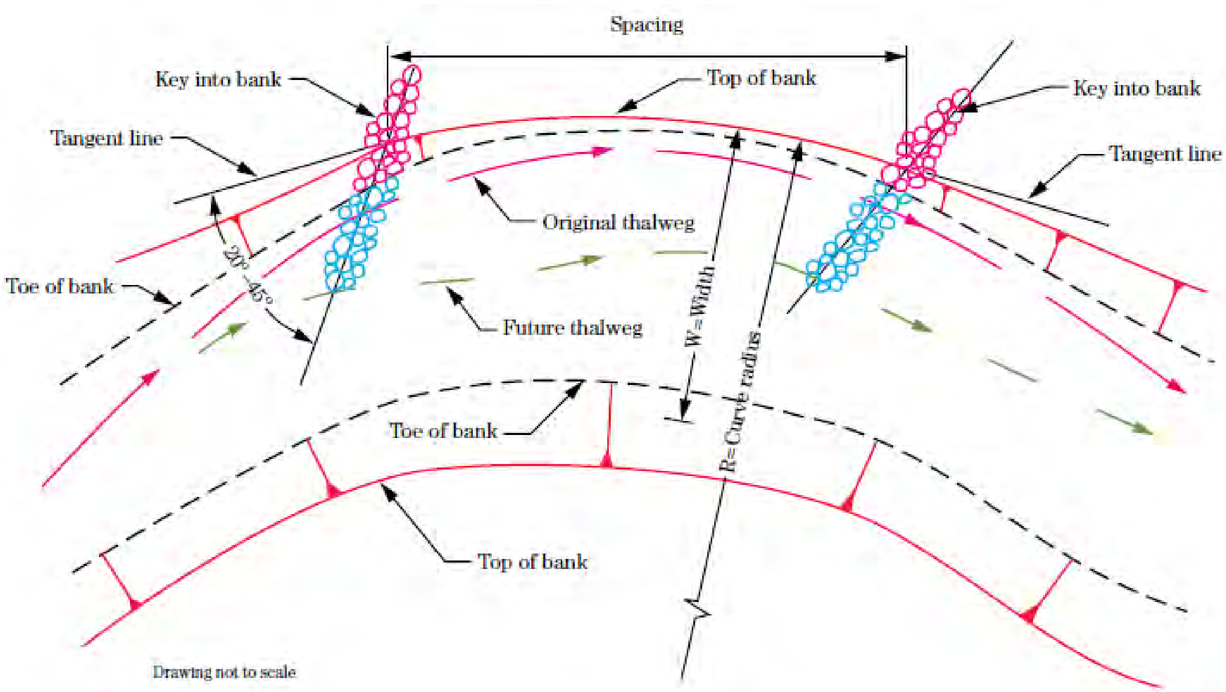


Figure 2-4: Example of flows over upstream oriented bendway weir (NEH 2007)

Typical individual structure profile (along the structure longitudinal alignment) and section views are shown in Figure 2-5. Note that some provision for keying the structure into the bed of the channel is needed to address local scour and erosion around the structure, and the top elevation of the structure can be sloping as shown in Figure 2-5) or more horizontal. A sloping top surface of the structure requires increased flows to overtop the full structure and therby influence flows; whereas a horizontal top of structure can influence flows at a broader range of low to high flows.

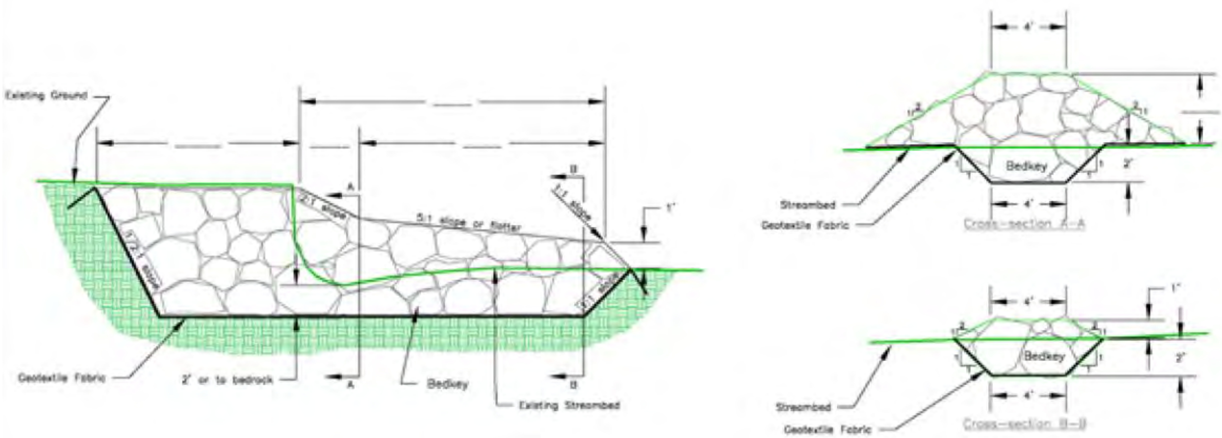


Figure 2-5: Typical Bendway Weir profile and sections (NEH 2007)

2.2 Typical Dimensions

Typical design dimensions for structures include defining the spacing, length, orientation angle, height, width (i.e. generally refers to top and bottom width), and cross-section shape (i.e. up- and downstream slopes), addressed in the following sections.

2.2.1 Spacing

Technical reference information addressing spacing of bendway weir structures can vary widely, as shown in the summary in Figure 2-6 (Colorado State 2017).

Author	Recommended Spacing Ratio	Type of Bank	Remarks
United Nations (1953)	1	Concave	General Practice
	2-2.5	Convex	General Practice
Ahmad (1951)	4.29	Straight	
	~5	Curves	
Joglekar (1971)	2-2.5		Upstream Groynes
US Army (1984a)	2		Mississippi River
Mathes (1956)	1.5		
Strom (1962)	3-5		
Acheson (1968)	3-4		Varies depending on curvature and stream slope
Richardson et al. (1975)	2-6		For bank protection
	3-4		T-head groynes for navigation channels
Mamak (1956)	1.5-2		Deep channel for navigation
Blench et al. (1976)	3.5		
Copeland (1983)	>3	Concave	
Kovacs el al. (1983)	1-2		Danube River
Mohan and Agraval (1979)	5		Submerged groynes of height one-third the depth
Maza Alvarez (1989)	5.1-6.3	Straight	Sloping crested weirs for bank protection
	2.5-4	Curves	

Figure 2-6: Typical Bendway Weir Structure Spacing (Colorado State 2017)

2.2.2 Length

Length of bendway weir structures is a critical component of the design, and as shown in Figure 2-7, the range of literature suggested lengths leans towards site specific considerations, has not specific guidance on numbers, and highlights that in the absence of experience and/or expertise designing and building bendway weir structures that site specific hydro-dynamic modeling is needed to provide a better understanding of local conditions.

Author	Suggested Length
United Nations (1953)	"Start with a shorter length and extend the groynes after space between them has been silted up"
ICBIP (1971):	No rules apply, build models to determine appropriated length
Richardson (1975)	50 feet or less
USACE (1980)	Should be set at the desired constriction width of channel for navigation purposes
Brown (1985)	Less Than 15% of bankfull channel width for impermeable structures
Maza Alvarez (1989)	Less than 25% of bankfull channel width
Lagasse (1997)	Less than 33% of bankfull channel width
Derrick (1998)	Site-Specific Basis, engineering judgment
LaGrone (1998)	16.67%, not a design guideline but a site specific design

Figure 2-7: Typical Bendway Weir Structure Length (Colorado State 2017)

The design length of the structures should address expected loss of material starting at the tips, resulting from erosion and scour. Design should look at installed length versus expected changes (i.e. loss of length) over time, which is should be expected and assumed to be a common performance condition in response to floods (i.e. note the purpose of the bendway weir structure is to take on the wear and tear from attacking thalweg and local erosion and scour, which was previously attacking the bank itself).

2.2.3 Orientation angle

Orientation angles can range widely depending on the site conditions (Figure 2-8). In general, upstream oriented angles result in re-directing flows away from the banks, but actual orientation depend on the bank alignment geometry relative to overall anticipated flow paths.

Author	Range of Angles	Suggested Angle
Brown (1985)	30-150	150 decreasing to 90
Copeland (1983)	60-120	90
Derrick (1994)	45-80	60
Indian Central Board of Irrigation and Power (1965):		60-80
Lagasse (1997)	50-85	60
Mamak (1964): (Copeland Literature Review)		70-80
Maza Alvarez (1989)		110
Richardson (1975)	60-150	70-80
Smith (1998)		60-75
United Nations (1953)		60-80
USACE (1980)		100-105

Figure 2-8: Typical Bendway Weir Structure Orientation Angle (Colorado State 2017)

Hydrodynamic modeling can be a useful tool for reviewing and assessing flow conditions and supporting determination of individual and grouped bendway weir orientations. Where modeling tools are not available, experience and hydrotechnical expertise with how rivers perform in low and high flow conditions should be used to develop recommended orientation angles. In general, and for the purpose of continued design planning on this project, structure orientations are expected to be perpendicular and/or upstream oriented, depending on bank and flow alignments.

2.2.4 Height

The height of the structures needs to take into account keying the structure into the bed of the channel and setting a top elevation of the structure. Key-in depths depend on expected erosion and scour conditions (i.e. may require a targeted study of erosion and scour potential), and experience on previous similar projects. Top elevations are best determined using hydro-dynamic modeling to simulate flow conditions and evaluate options. In general, top elevations for structures may be at or below the bed elevation if they are intended to perform only when scour potential increases, and elevated above the bed elevations when they are intended to perform at defined flow levels.

2.2.5 Width

The width is depended on shape and configuration of the structure section. The top width of the structure typically ranges from a minimum of 5 to 10 feet to upwards of 20 to 30 feet. The structure may change dimensions in response to long-term erosion and scour along the downstream edge, which would tend to reduce the overall width of the structure over time. Additional width can be incorporated into the design at installation, or added as a maintenance activity later on.

2.2.6 Cross-section shape

Cross-section shape varies, see discussion on width; and can be designed to incorporate rounded to sub-rounded local sediments, large woody debris, and riprap materials to better perform to fit the purpose of the project. Engineering judgement should be incorporated into the section geometry, and additional hydrodynamic modeling can be used to simulate variable designs geometries. Typical section shapes use a generally trapezoidal shaped with sloping fore- and backslopes, whereby backslopes are typically flatter; in this configuration the top width is less than the bottom width. This requires additional excavation in order to accommodate the bottom width; as the temporary excavation slopes reach out and beyond the structure footprint creating a volume of material that needs to be backfilled. In some situations, the trapezoid shape can be inverted for the full structure or in order to establish a keyway. In this situation, the top width is wider than the bottom width, which then reduces or even eliminates additional excavation and backfill because the temporary excavation slope and limits (for the structure or the keyway) essentially matches the structure (or keyway) dimensions and the corresponding total volume of the excavation is filled with the primary structure material. The final structure cross-section geometry needs to be determined to best fit the site conditions and project requirements.

2.3 Riprap Materials

A range of materials can be used to construct bendway weir structures, but we expect that some combination of local oversized rounded to sub-rounded and/or angular riprap will be used. Review of other existing bank protection projects near the project sites was completed by Golder, see Attachment C for a summary of the results and more details on the observed riprap materials. Example designs corresponding to Maine DOT projects are provided in Attachment D, along with riprap specifications provided in Attachment E. These references and specifications will be incorporated into the design, where applicable.

3.0 CONCLUSIONS

Layout, configuration, and dimensions for typical bendway weir structures varies widely and is dependent on the site specific conditions. While technical references provide examples for various structure dimensions and layout configurations, previous experience designing and building bendway weir structures combined with applicable and engineering expertise judgment is critical to developing a plan that is fit for purpose. Technical reference information should not be used as absolute conditions for design, and referenced only as guidance; and engineering judgment used to select final design parameters. Additionally, new hydrodynamic modeling tools that incorporate 2-dimensional analytical methods can be very useful in developing simulations of proposed design concepts, to further support final detailed design.

4.0 REFERENCES

Colorado State University. (2017). www.engr.colostate.edu, Colorado State University, on-line content, accessed September.

Julien and Duncan. (2003). “Optimal Design Criteria of Bendway Weirs from Numerical Simulations and Physical Model Studies”, Colorado State University, Civil Engineering, March 17.

NEH. (2007). “Flow Changing Techniques”, National Engineering Handbook (NEH), Technical Supplement 14H, Part 684, August.

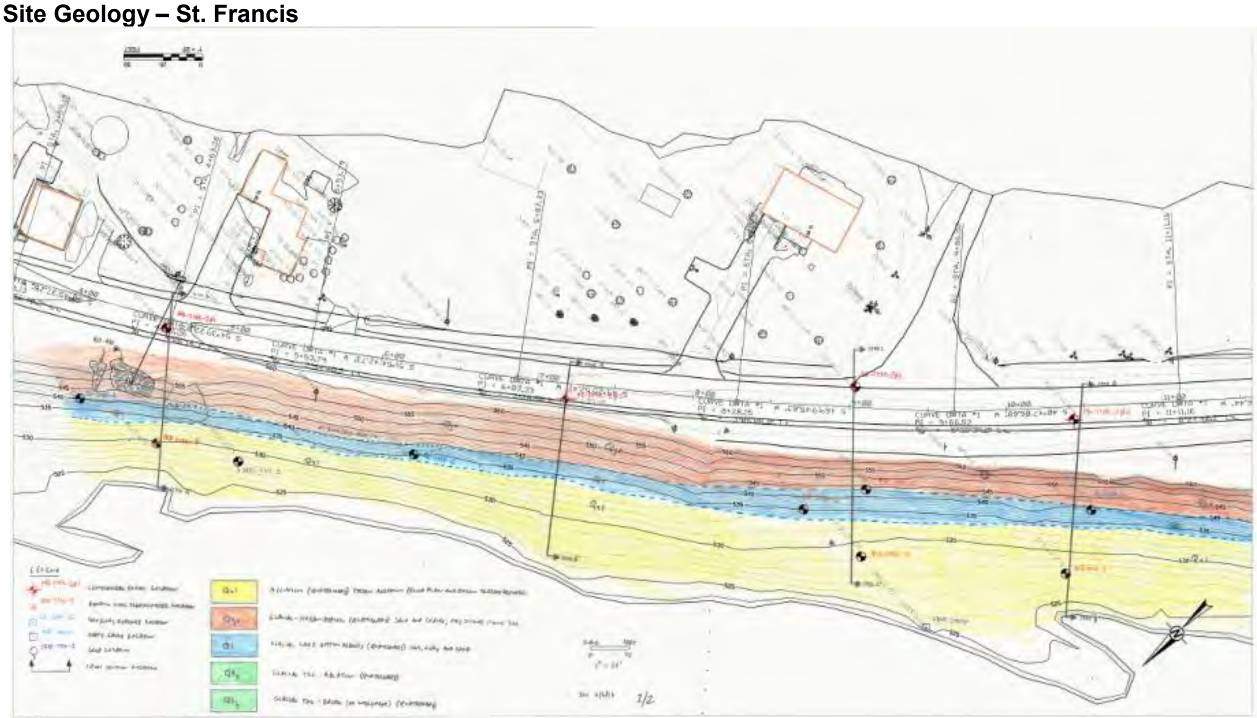
Thornton, C, S. Abt, D. Baird, and R. Padilla (2007) “Hydraulic of Bendway Weirs”, River Basin Management, WIT Transactions on Ecology and the Environment, Vol 104.

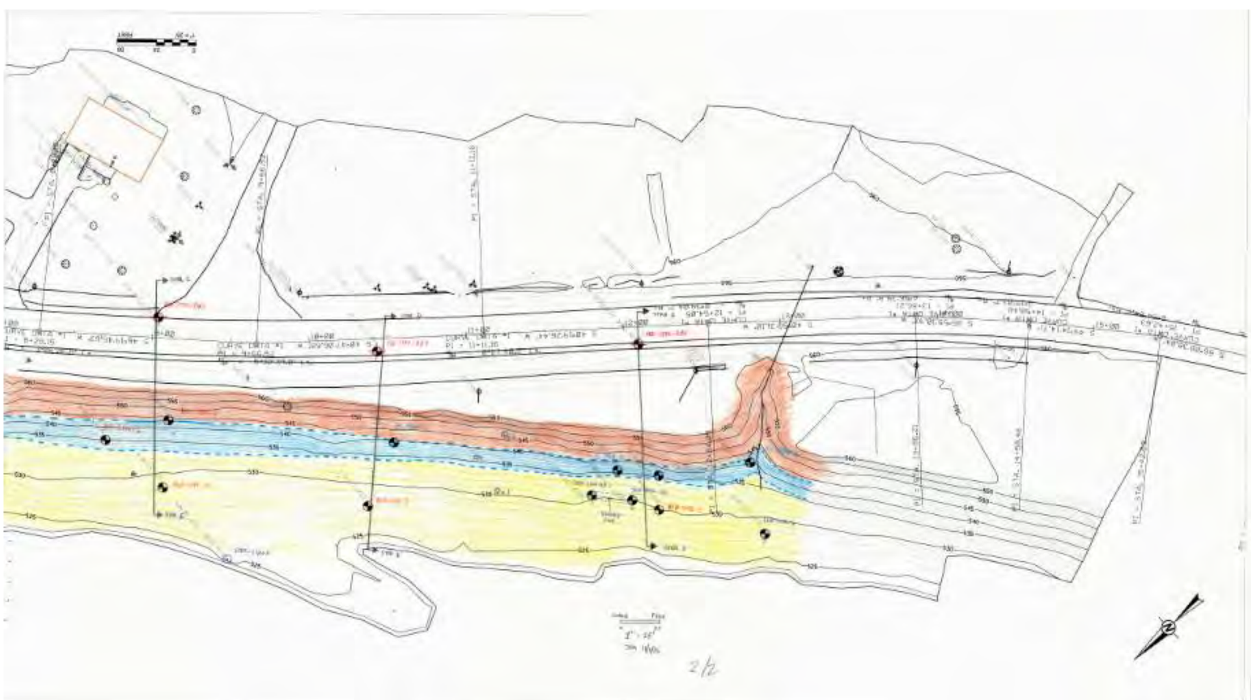
https://golderassociates.sharepoint.com/sites/106608/project files/6 deliverables/final report/appendix/appendix k techmemo_basisofdesign/1659907-tm-rev0-allagash_st.francis_bod-032219.docx

ATTACHMENT A

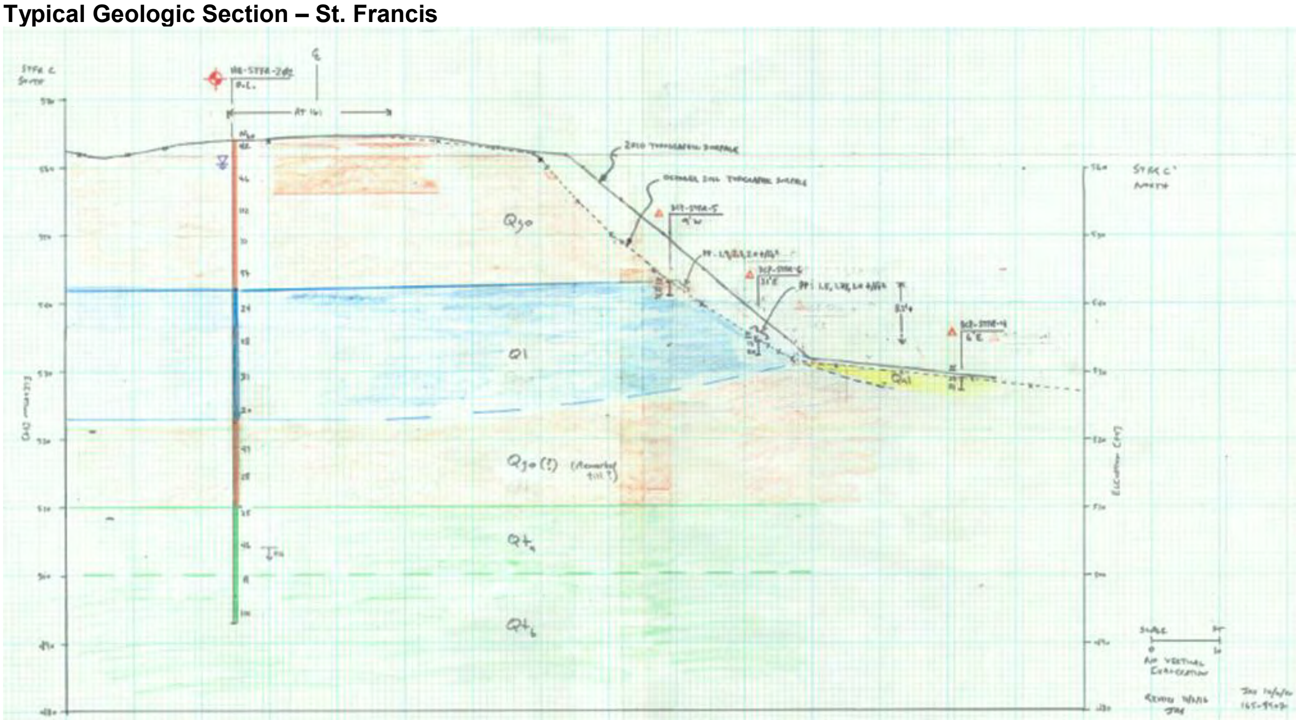
Site Geology

Site Geology – St. Francis

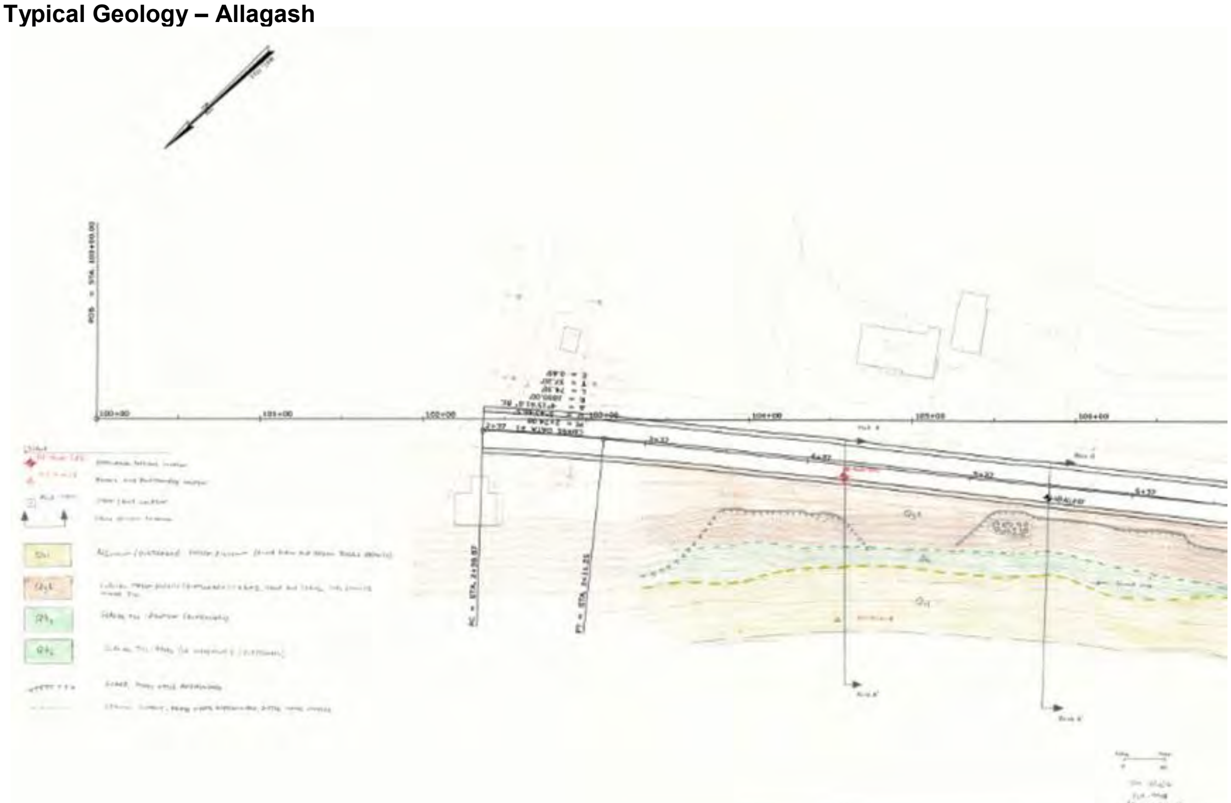


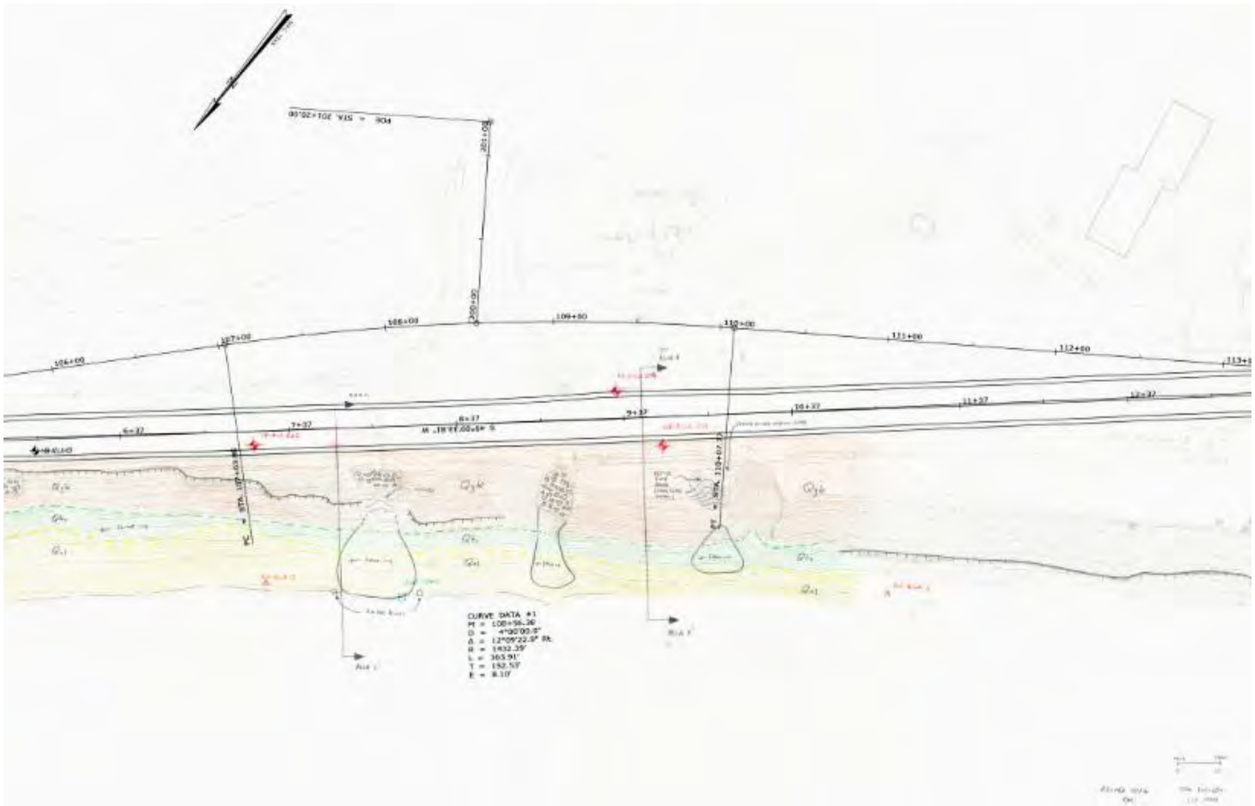


Typical Geologic Section – St. Francis

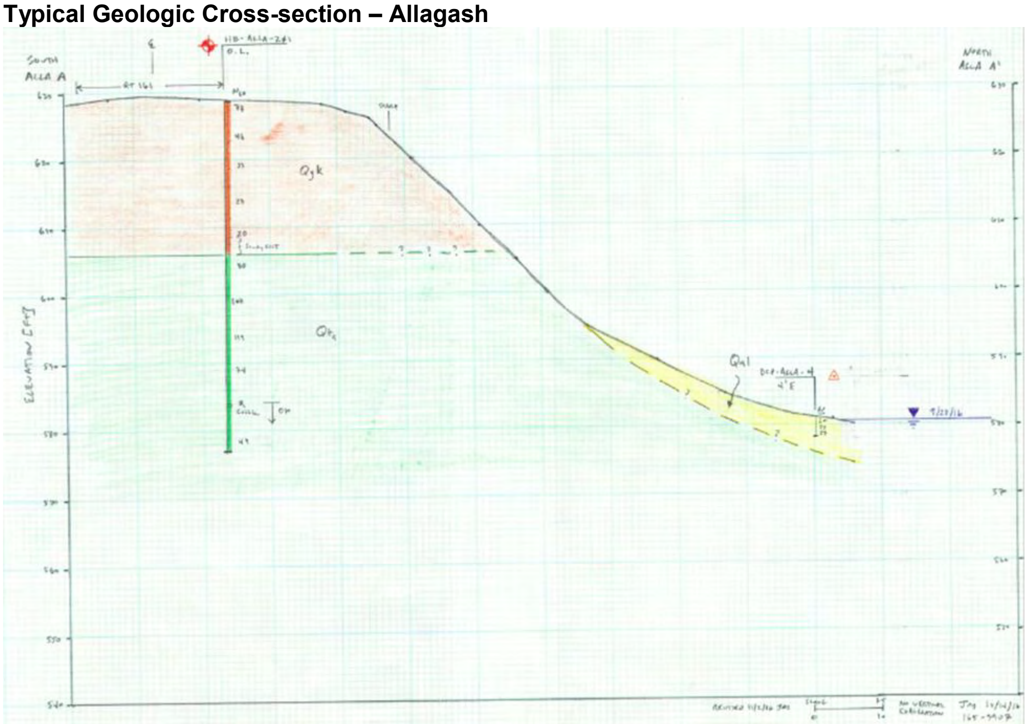


Typical Geology – Allagash



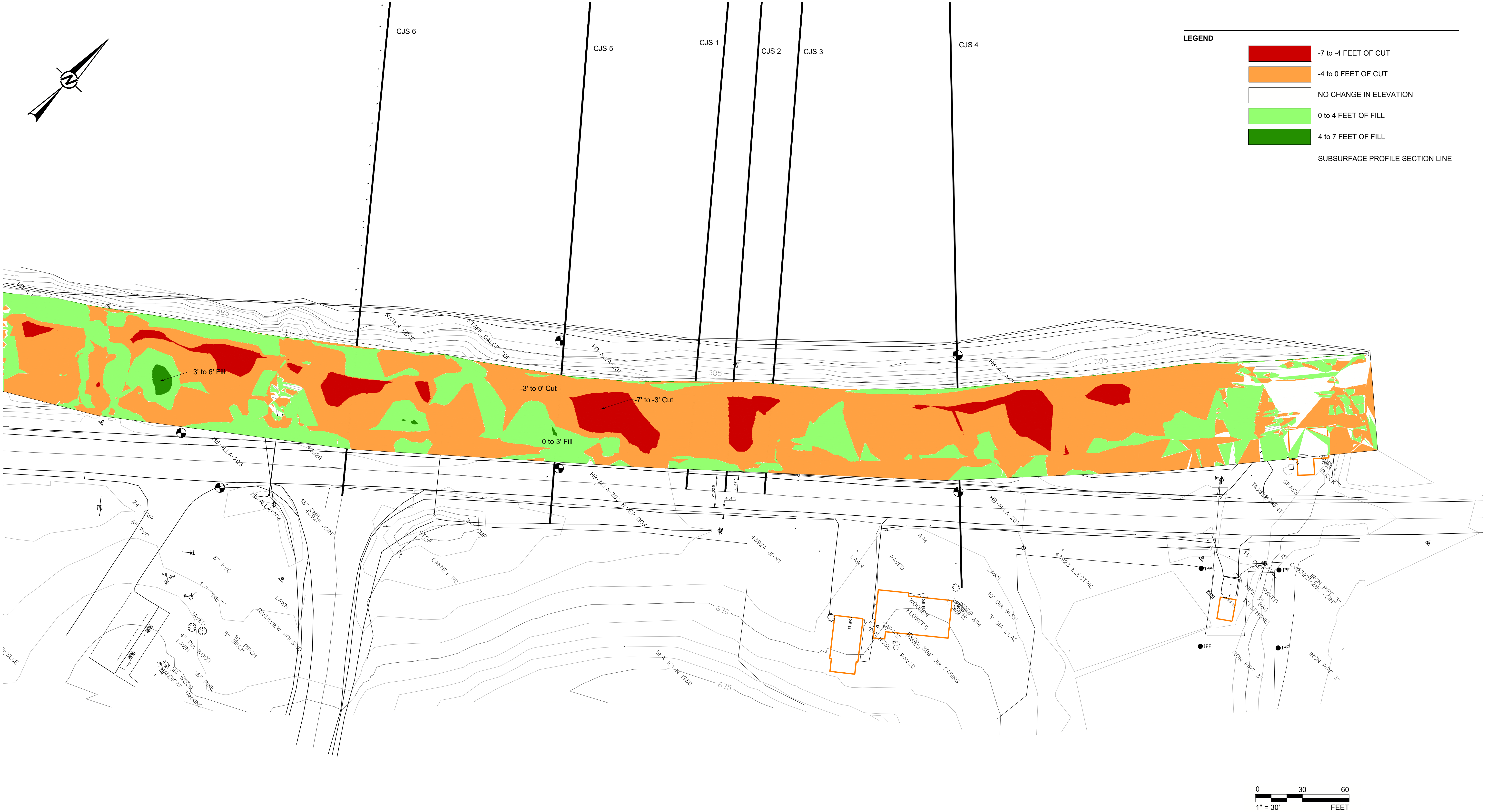


Typical Geologic Cross-section – Allagash



ATTACHMENT B

Site Erosion Trends



LEGEND

- -7 to -4 FEET OF CUT
- -4 to 0 FEET OF CUT
- NO CHANGE IN ELEVATION
- 0 to 4 FEET OF FILL
- 4 to 7 FEET OF FILL
- SUBSURFACE PROFILE SECTION LINE

CLIENT	PROJECT
MaineDOT	Allagash, Maine

CONSULTANT

Golder Associates

YYYY-MM-DD	####
DESIGNED	####
PREPARED	####
REVIEWED	####
APPROVED	####

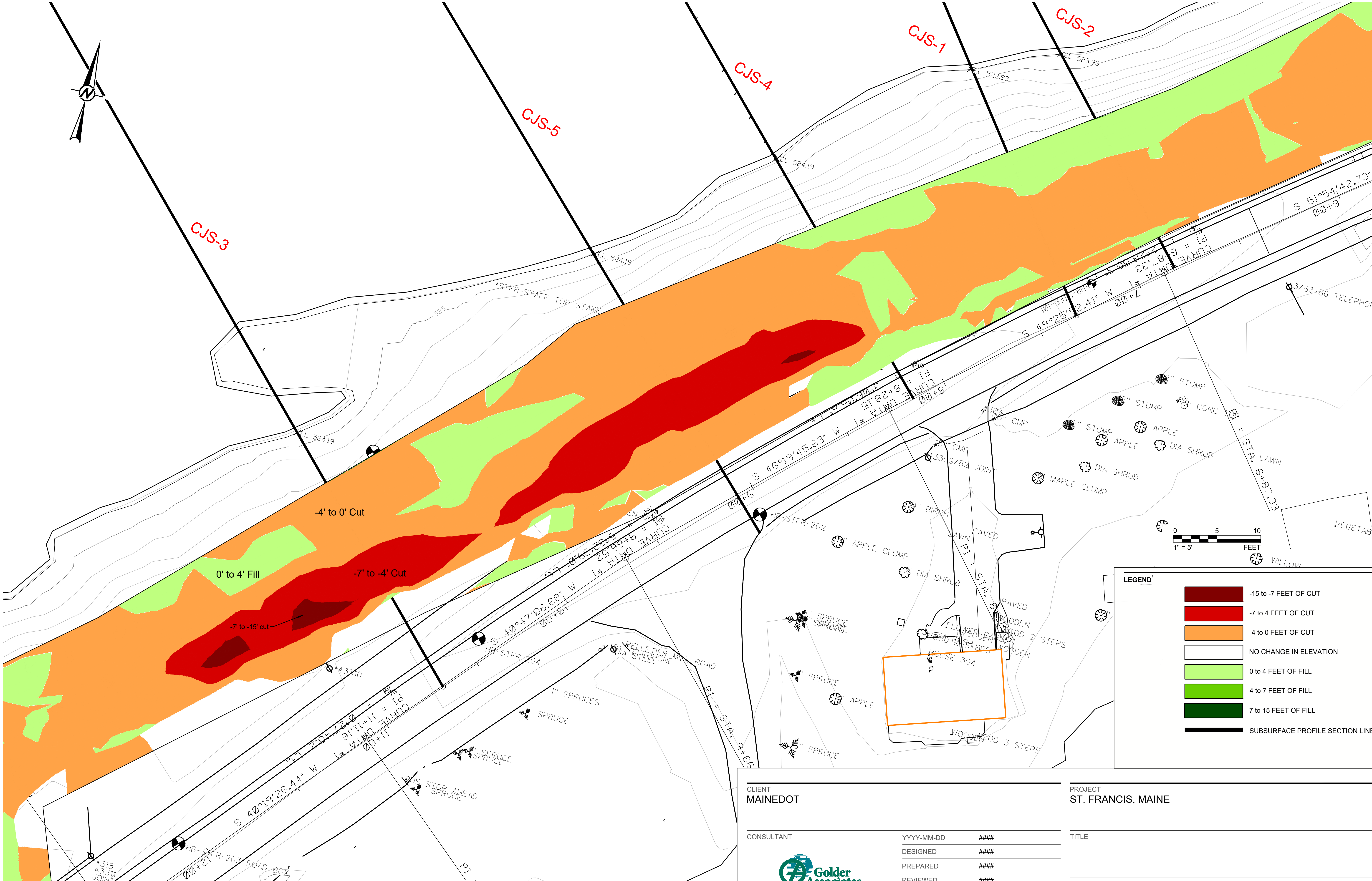
TITLE

PROJECT NO.	####	REV.	####
####	####	####	####

Path: \\manchester\cadd\Drawings\2016\1659907 MaineDOT\St A_Allagash, ME\Source\ | File Name: 3DContours_2016.dwg

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

1 in



CLIENT
MAINEDOT

PROJECT
ST. FRANCIS, MAINE

CONSULTANT

YYYY-MM-DD	####
DESIGNED	####
PREPARED	####
REVIEWED	####
APPROVED	####

Golder Associates

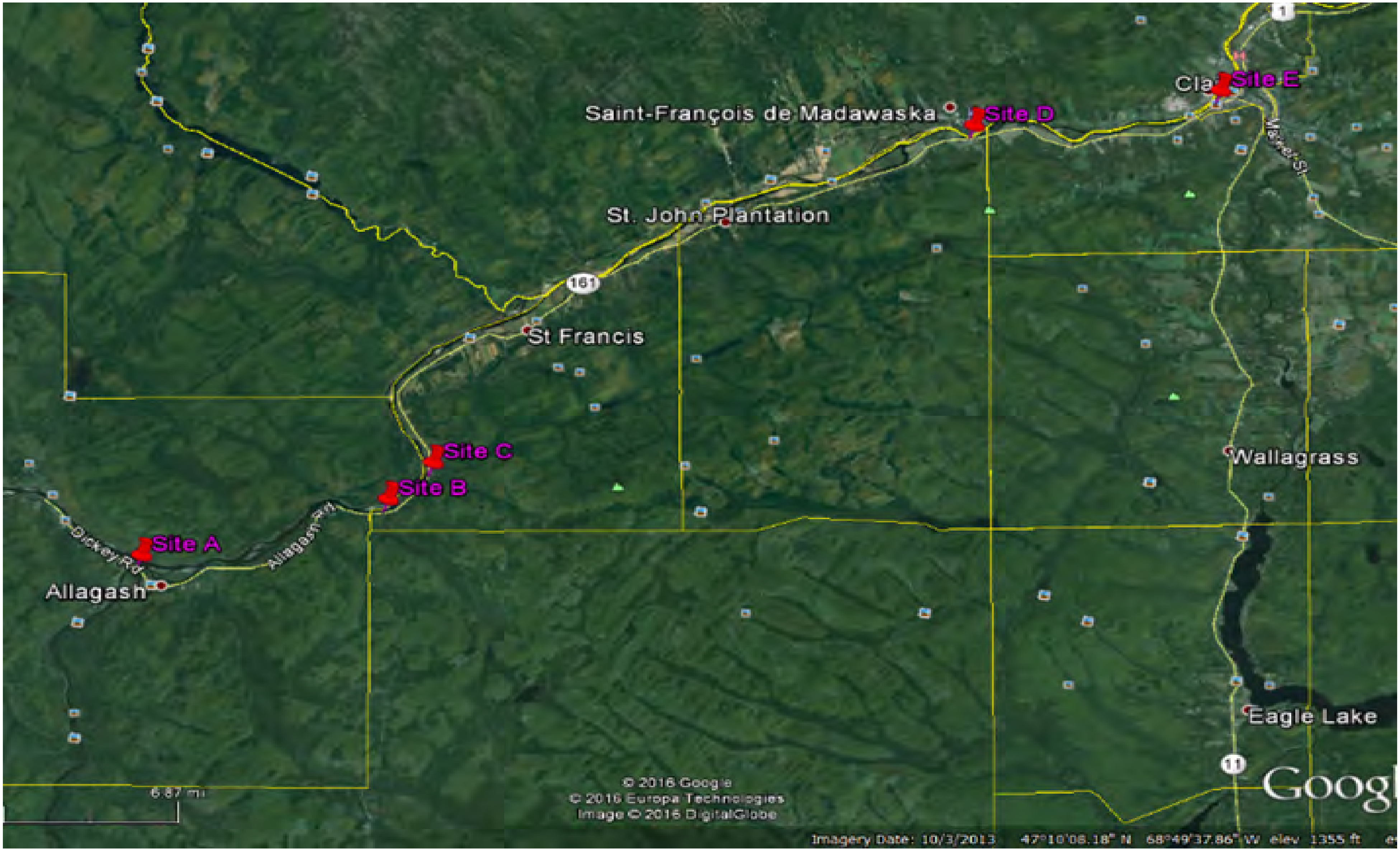
TITLE

PROJECT NO.	####	REV.	####
####	####	####	####

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI D

ATTACHMENT C

Review of Riprap in Project Areas



CLIENT
MAINE DEPARTMENT OF TRANSPORTATION
16 STATE HOUSE STATION
AUGUSTA, MAINE 04333-0016

PROJECT
GEOTECHNICAL AND HYDROTECHNICAL SLOPE STABILIZATION EVALUATION
STATE ROUTE 161 UNSTABLE SLOPES ADJACENT TO THE ST. JOHN RIVER
ALLAGASH AND ST FRANCIS, MAINE WIN 17236.00

CONSULTANT

GOLDER

YYYY-MM-DD	2019-03-06
DESIGNED	CJS
PREPARED	SKB
REVIEWED	JDL
APPROVED	MSP

TITLE
Nearby Riprap Slope Locations

PROJECT NO. 165-9907
PHASE
FIGURE B.1

Appendix B – Riprap Slope Photographs

SITE A – PHOTO A1

Description:

Existing rip rap slope placed between Rt. 161 and Allagash River, Allagash. Observations:

- Slope Height 20-25 ft (vertical)
- Slope Angle: ~35° (~1V:1.5H)
- Rip-Rap: Heavy, 3'x1'x1' typical, and smaller (phyllite/slate/metagraywacke)

Photo Orientation:

View to east from N47° 05' 21.89"/W069° 03' 13.80" (intersection of Rt. 161 and Inn Road).

Photo Date:

9/27/2016

SITE A – PHOTO A2

Description:

View downslope showing rip-rap. Note alluvial sediments between slope toe and edge of river, and driftwood at toe.

Photo Orientation:

View to south at N47° 05' 19.17"/W069° 03' 03.88".

Photo Date:

9/16/2016

Appendix B – Riprap Slope Photographs

SITE A – PHOTO A1 **Description:** View to east showing rip-rap. Note horizontal grass covered crest of slope. **Photo Orientation:** View to east at N47° 05’ 19.28”/W069° 03’ 03.64”. **Photo Date:** 9/27/2016	
SITE B – PHOTO B1 **Description:** Existing rip rap slope placed between Rt. 161 and St. John River, St. Francis. Observations: • Slope Height 16.5 ft (vertical) • Slope Angle: ~27° (~1V:2H) • Rip-Rap: Heavy, up to 5’x3’x1’, most light 2’x1.5’x0.75’ and smaller (phyllite/slate/metagraywacke) • Rip-Rap Thickness: 4’+ **Photo Orientation:** View to west from N47° 06’ 29.92”/W068° 56’ 59.82”. **Photo Date:** 9/27/2016	

Appendix B – Riprap Slope Photographs

Site B – PHOTO B2 **Description:** View of rip-rap slope. Note driftwood located within 5’ from crest of slope, and suspected light rip-rap that has migrated downslope. **Photo Orientation:** View to northwest from N47° 06’ 29.92”/W068° 56’ 59.82”. **Photo Date:** 9/27/2016	
Site B – PHOTO B3 **Description:** View of rip-rap slope conditions. **Photo Orientation:** View to west from N47° 06’ 29.92”/W068° 56’ 59.82”. **Photo Date:** 9/27/2016	

Appendix B – Riprap Slope Photographs

<table>
<tr><td>

SITE C – PHOTO C1

Description:

Existing rip rap slope placed between Rt. 161 and St. John River, St. Francis. Observations:

- Slope Height 25-30 ft (vertical)
- Slope Angle: ~33° (~1V:1.5H)
- Rip-Rap: Heavy, up to 2.5’x2’x1’, most light 1.5’x1’x0.75’ and smaller (mostly metagraywacke)
- Rip-Rap Thickness: 4’+
- 100ft+ to from toe of slope to edge of river

Photo Orientation:

View to west from N47° 07’ 15.11”/W068° 55’ 51.21”.

Photo Date:

9/27/2016

</td><td></td></tr>
<tr><td>

SITE C – PHOTO C2

Description:

Rip rap slope conditions. Estimated age of trees ~10 years. Note driftwood located at about midslope.

Photo Orientation:

View to west from N47° 07’ 15.07”/W068° 55’ 52.29”.

Photo Date:

9/27/2016

</td><td></td></tr>
</table>

Appendix B – Riprap Slope Photographs

SITE C – PHOTO C3

Description:

Close up view of rip rap. Note less platy nature of this rip rap compared with Site A and B rip rap. Field book for scale.

Photo Orientation:

View to west from N47° 07’ 15.58”/W068° 55’ 51.52”.

Photo Date:

9/27/2016

SITE D – PHOTO D1

Description:

Existing rip rap slope placed between Rt. 161 and St. John River, St. John.
Observations:

- Slope Height 35-40 ft (vertical)
- Slope Angle: ~27° (~1V:1.75H)
- Rip-Rap: Heavy, up to 3’x2’x1’, most light 1’x1’x0.5’ and smaller (phyllite/slate/metagraywacke)
- Rip-Rap Thickness: 3.5-4’
- Slope toe at river edge

Photo Orientation:

View to west from N47° 14’ 13.24”/W068° 42’ 19.02”.

Photo Date:

9/27/2016

Appendix B – Riprap Slope Photographs

<table>
<tr>
<td>

SITE D – PHOTO D2

Description:

View downslope at east end. Note rip-rap blocks sitting just upstream of exposed bedrock at river edge.

Photo Orientation:

View to north from N47° 14’ 13.24”/W068° 42’ 19.02”.

Photo Date:

9/27/2016

</td>
<td></td>
</tr>
<tr>
<td>

SITE D – PHOTO D3

Description:

Disintegrated rip-rap block (slate/phyllite). Field book for scale.

Photo Orientation:

Upper end of slope at N47° 14’ 13.24”/W068° 42’ 19.02”.

Photo Date:

9/27/2016

</td>
<td></td>
</tr>
</table>

Appendix B – Riprap Slope Photographs

SITE D – PHOTO D4

Description:

View of midslope conditions. Driftwood/ debris noted at midslope elevation.

Photo Orientation:

View to west from N47° 14’ 13.24”/W068° 42’ 19.02”.

Photo Date:

9/27/2016

SITE E – PHOTO E1

Description:

Existing rip rap slope placed at new Ft. Kent, ME - Clair, NB international bridge over St. John River. Observations:

- Slope Height ~15-20 ft (vertical)
- Slope Angle: ~27° (~1V:1.75H)
- Rip-Rap: Light, mostly 1.5’x1.5’x1’ and smaller (metalimestone)
- Rip-Rap Thickness: unknown
- Slope toe at river edge

Photo Orientation:

View to northeast from N47° 14’ 55.83”/W068° 36’ 08.29”.

Photo Date:

9/27/2016

Appendix B – Riprap Slope Photographs

SITE E – PHOTO E2

Description:

View to southwest of rip rap placed at northeast corner of southeast bridge abutment.

Photo Orientation:

View to southwest from N47° 14’ 55.83”/W068° 36’ 08.29.

Photo Date:

9/16/2016

SITE E – PHOTO E3

Description:

Close up of metalimestone rip rap blocks. Note general equigranular nature of rip rap blocks and coarseness of broken rock surfaces. Motel keys for scale.

Photo Orientation:

Crest of slope at N47° 14’ 55.83”/W068° 36’ 08.29.

Photo Date:

9/27/2016

ATTACHMENT D

Example MaineDot Bank Armoring Project

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

ST. FRANCIS

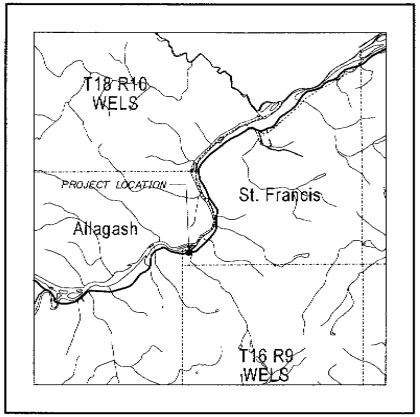
AROOSTOOK

ROUTE 161

PROJECT NO. 016476.30

PROJECT LENGTH : 0.035 mi.

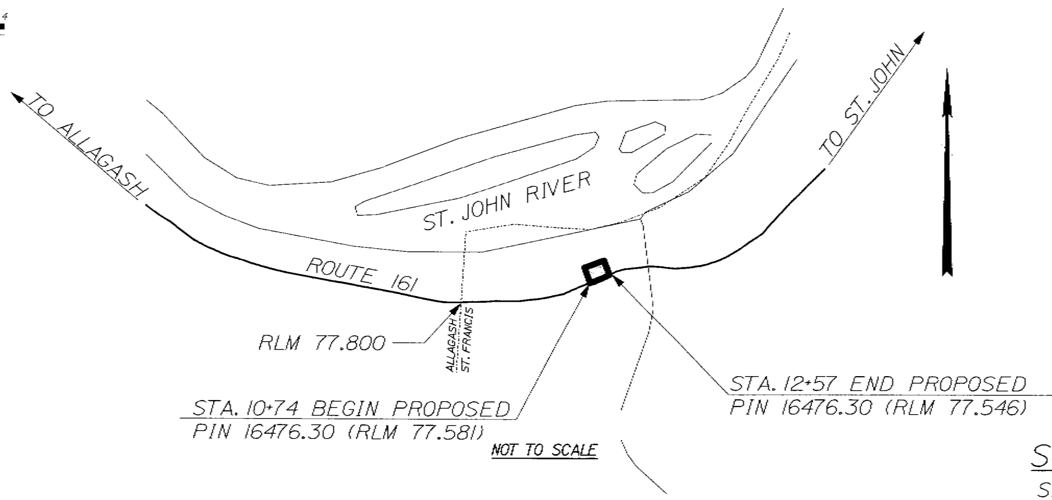
COLLECTOR IMPROVEMENT PROGRAM



LOCATION MAP

Scale in Miles

INDEX OF SHEETS



NOT TO SCALE

SCOPE OF WORK

SLOPE STABILIZATION

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

APPROVED | DATE
COMMISSIONER: | 7/20/07
CHIEF ENGINEER: | 09/19/07

SIGNATURE
P.E. NUMBER 6640
DATE Sept. 17, 2007

PROJECT INFORMATION

PROGRAM	HIGHWAY
PROJECT MANAGER	JON WHITE
DESIGNER	RAY DEMERCHANT
CONSULTANT	
PROJECT RESIDENT	
CONTRACTOR	
PROJECT COMPLETION DATE	

PIN 16476.30

016476.30

ST. FRANCIS
ROUTE 161

TITLE SHEET

SHEET NUMBER
1
OF 10

Filename: ...\30\HIGHWAY\MSTA\D01_Title.dgn Division: HIGHWAY Username: raymond.demerchant Date:9/17/2007

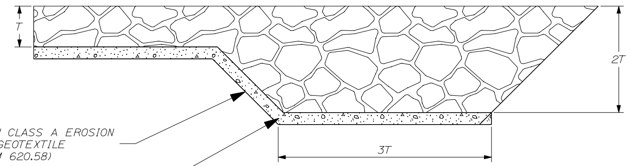
EXCAVATION NOTE

ANY EXCAVATION REQUIRED FOR THE PLACEMENT OF RIPRAP IS TO BE INCIDENTAL TO THE RIPRAP ITEM. THIS INCLUDES EXCAVATION FOR THE ESTABLISHMENT OF THE TOE OR ANY OTHER EXCAVATION REQUIRED TO INSTALL TO GRADE.

GRANULAR BORROW NOTE

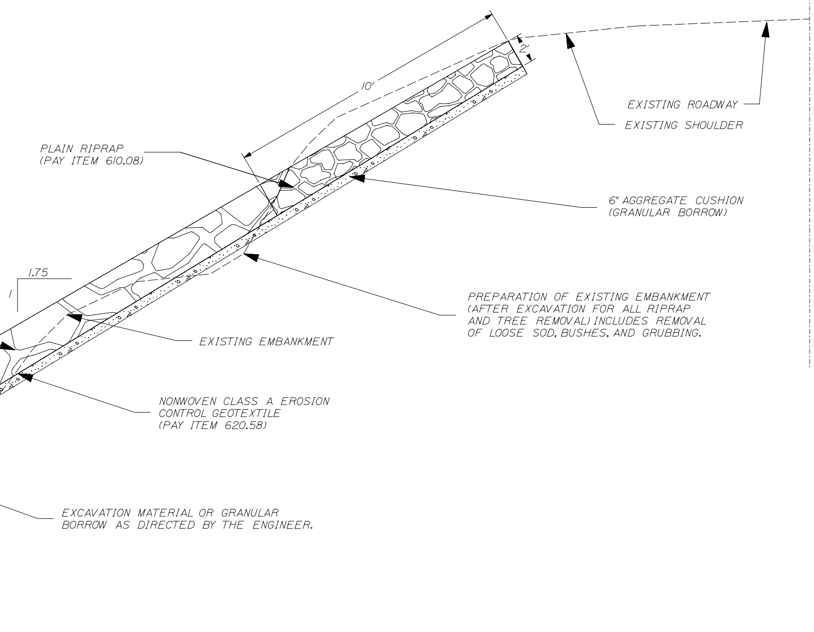
CONTRACTOR HAS OPTION TO REPLACE GRANULAR BORROW WITH ROCK FILL (ANY SIZE) UNDERNEATH THE HEAVY RIPRAP. THE CUSHION AND FABRIC ARE TO BE PLACED UNDER THE ROCK.

STA. 10+74 AND STA. 12+57



FLANK DETAIL

NOT TO SCALE



TYPICAL SECTION

NOT TO SCALE

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
016476.30
PIN 16476.30
HIGHWAY PLANS

	BY	DATE
PROJ. MANAGER	JON BITHER	
DESIGN-DETAILED	RED	8-20-07
CHECKED-REVIEWED		
DESIGN2-DETAILED2		
DESIGN3-DETAILED3		
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE
P.E. NUMBER
DATE

ST. FRANCIS
ROUTE 161

TYPICAL SECTIONS

SHEET NUMBER
2
OF 10

Filename: ...\HIGHWAY\MSTA\002_DETAILS.dgn Division: HIGHWAY Username: brian.mousseau Date:9/18/2007

21

CONSTRUCTION NOTES

203.25 GRANULAR BORROW
SELECTED BACKFILL TO BE USED BENEATH RIPRAP AS BEDDING

610.08 PLAIN RIPRAP
TO BE PLACED AS SLOPE STABILIZATION MEASURE TO LIMITS AND GRADE SHOWN ON TYPICALS AND SECTIONS

610.16 HEAVY RIPRAP
TO BE PLACED AS SLOPE STABILIZATION MEASURE TO LIMITS AND GRADE SHOWN ON TYPICALS AND SECTIONS

613.319 EROSION CONTROL BLANKET
PLACED ON SLOPE AND IN DITCH, AS DIRECTED BY RESIDENT

615.07 LOAM
PLACED IN ALL AREAS TO BE SEEDED, AS DIRECTED BY RESIDENT

618.1401 SEEDING METHOD NO. 2 (PLAN QTY)
USED TO SEED ALL AREAS WHERE LOAM IS PLACED

619.1201 MULCH (PLAN QTY)
TO BE PLACED OVER ALL SEEDED AREAS

619.1401 EROSION CONTROL MIX
TO BE PLACED ON VARIOUS AREAS OF THE SLOPE, AS DIRECTED BY RESIDENT

620.58 EROSION CONTROL GEOTEXTILE
TO BE PLACED BENEATH ALL RIPRAP

ESTIMATED QUANTITIES

ITEM NO.	DESCRIPTION	QUANTITY	UNIT
203.25	GRANULAR BORROW	200	CY
610.08	PLAIN RIPRAP	220	CY
610.16	HEAVY RIPRAP	930	CY
613.319	EROSION CONTROL BLANKET	200	SY
615.07	LOAM	60	CY
618.1401	SEEDING METHOD NO. 2 - PLAN QUANTITY	4	UN
619.1201	MULCH - PLAN QUANTITY	4	UN
619.1401	EROSION CONTROL MIX	100	CY
620.58	EROSION CONTROL GEOTEXTILE	1160	SY
629.05	HAND LABOR, STRAIGHT TIME	5	HR
631.10	AIR COMPRESSOR (INCLUDING OPERATOR)	5	HR
631.11	AIR TOOL (INCLUDING OPERATOR)	5	HR
631.12	ALL-PURPOSE EXCAVATOR (INCLUDING OPERATOR)	5	HR
631.172	TRUCK-LARGE (INCLUDING OPERATOR)	5	HR
631.18	CHAIN SAW RENTAL (INCLUDING OPERATOR)	5	HR
652.31	TYPE I BARRICADE	5	EA
652.33	DRUM	5	EA
652.34	CONE	20	EA
652.35	CONSTRUCTION SIGNS	220	SF
652.36	MAINTENANCE OF TRAFFIC CONTROL DEVICES	30	CD
652.38	FLAGGER	120	MH
656.75	TEMP. SOIL EROSION AND WATER POLLUTION CONTROL PLAN	1	LS
659.10	MOBILIZATION	1	LS

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

016476.30

PIN 16476.30

HIGHWAY PLANS

	BY	DATE
PROJ. MANAGER	JON BITHER	
DESIGN-DETAILED	RED	8-20-07
CHECKED-REVIEWED		
DESIGN2-DETAILED2		
DESIGN3-DETAILED3		
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE

P.E. NUMBER

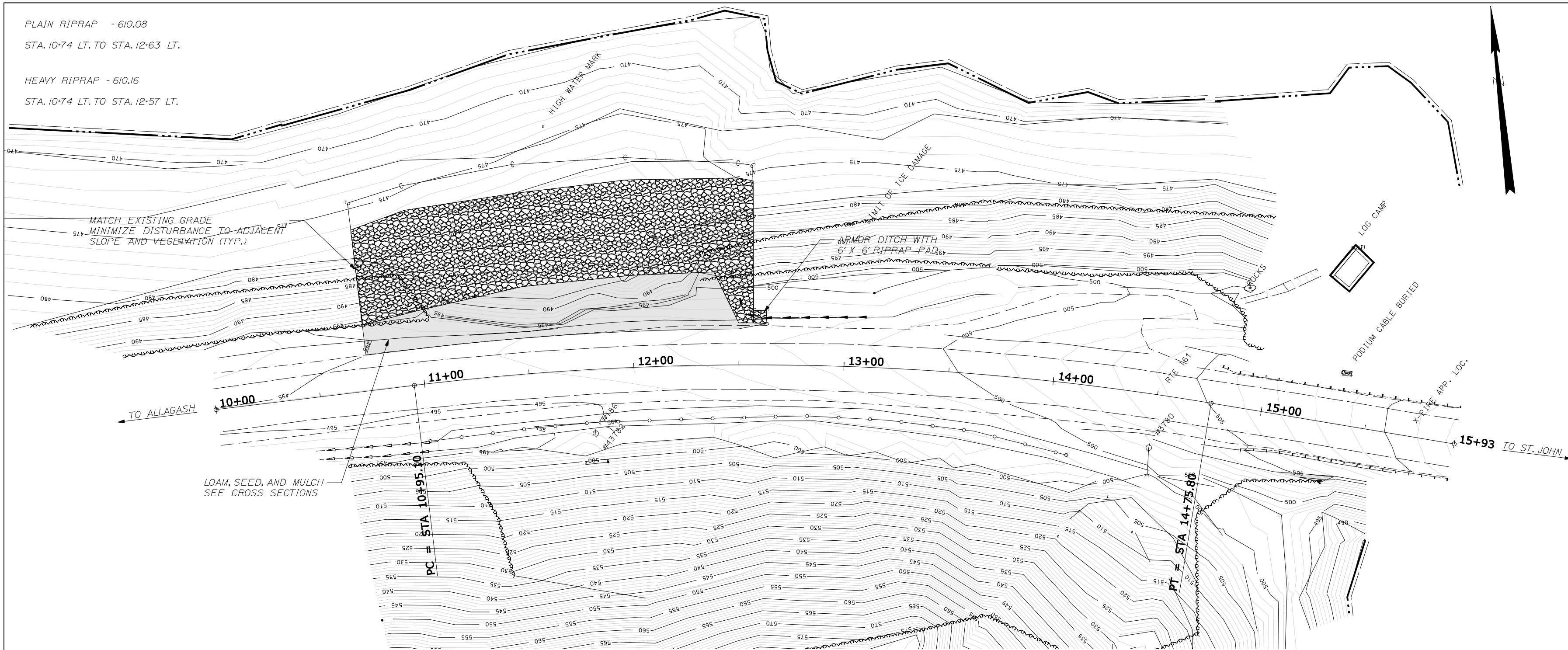
DATE

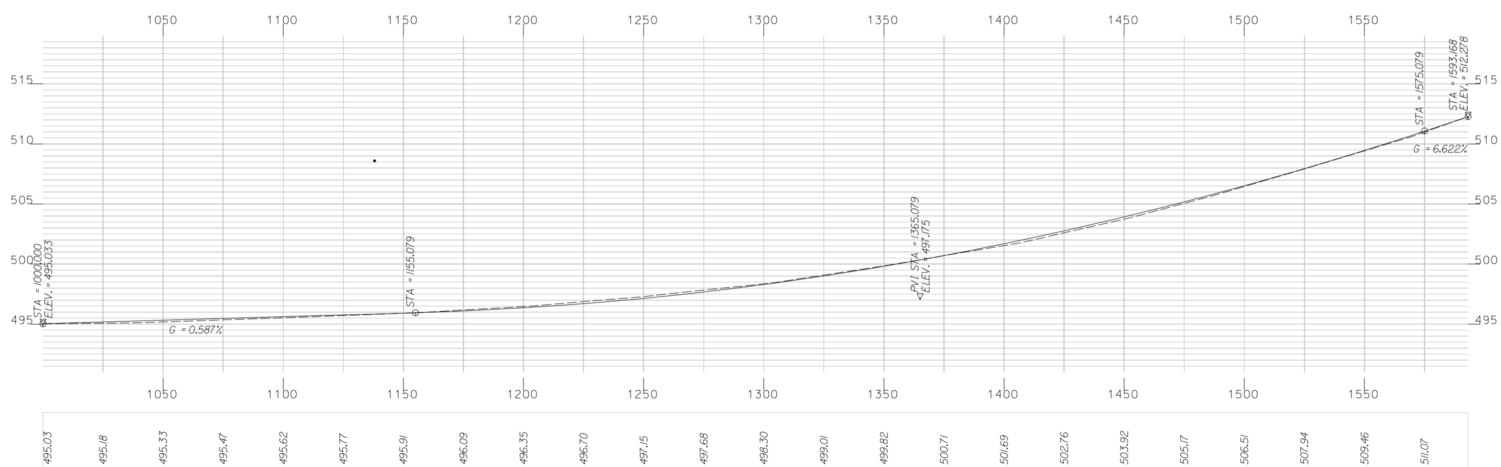
ST. FRANCIS
ROUTE 161

CONSTRUCTION NOTES & ESTIMATED QUANTITIES

SHEET NUMBER
3
OF 10

Filename: ...\HIGHWAY\MSTA\004_HDPlan1.dgn   Division: HIGHWAY   Username: brian.mousseau   Date:9/18/2007





23

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

016476.30

PIN
16476.30

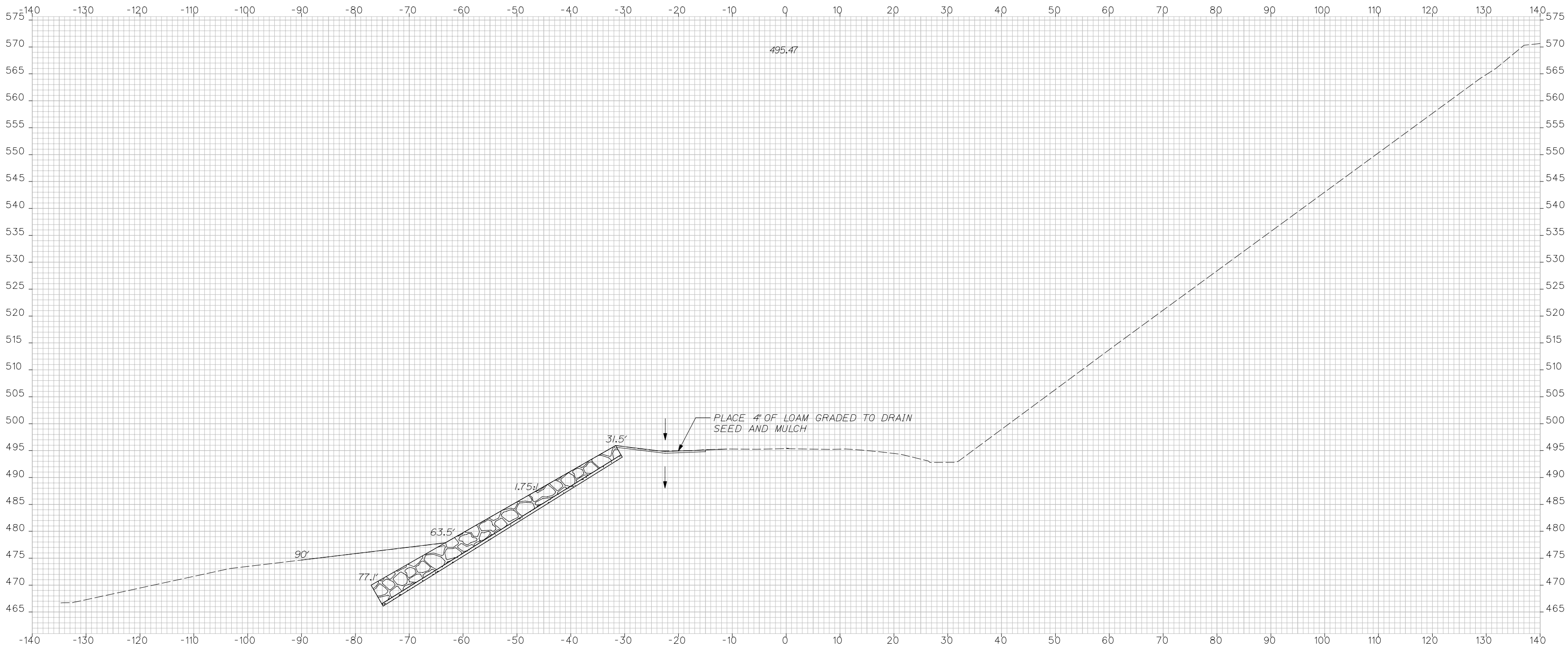
HIGHWAY PLANS

		SIGNATURE	
		P.E. NUMBER	
		DATE	
PROJ. MANAGER	JON BITHER		
DESIGN-DETAILED	RED	8-20-07	
CHECKED-REVIEWED			
DESIGN2-DETAILED2			
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

ST. FRANCIS
ROUTE 161

PLANS

SHEET NUMBER
4
OF 10



10+74.00
BEGIN PROJECT

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

016476.30

PIN
16476.30

HIGHWAY PLANS

PROJ. MANAGER	JON BITHER	BY	DATE
DESIGN-DETAILED		RED	8-20-07
CHECKED-REVIEWED			
DESIGN2-DETAILED2			
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

SIGNATURE

P.E. NUMBER

DATE

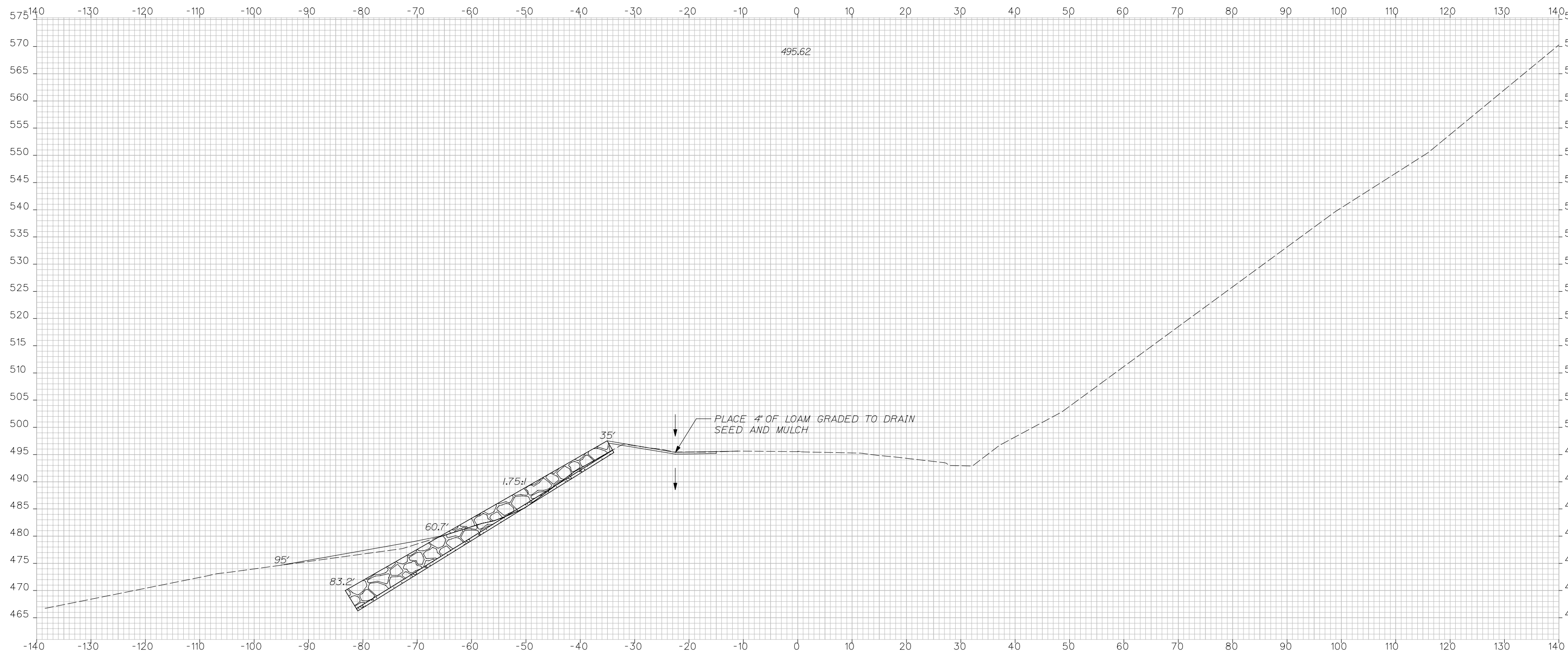
ST. FRANCIS
ROUTE 161

10+74.00 CROSS SECTIONS

SHEET NUMBER
5
OF 10

Filename: ...\MSTA\005_XSMC10_dr_002.dgn Division: HIGHWAY Username: brian.mousseau Date:9/18/2007

Filename: ...\MSTA\006_XSMC10_dr_003.dgn Division: HIGHWAY Username: brian.mousseau Date:9/18/2007



11+00.00

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

016476.30

PIN
16476.30

HIGHWAY PLANS

PROJ. MANAGER	JON BITHER	
	BY	DATE
DESIGN-DETAILED	RED	8-20-07
CHECKED-REVIEWED		
DESIGN2-DETAILED2		
DESIGN3-DETAILED3		
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE

P.E. NUMBER

DATE

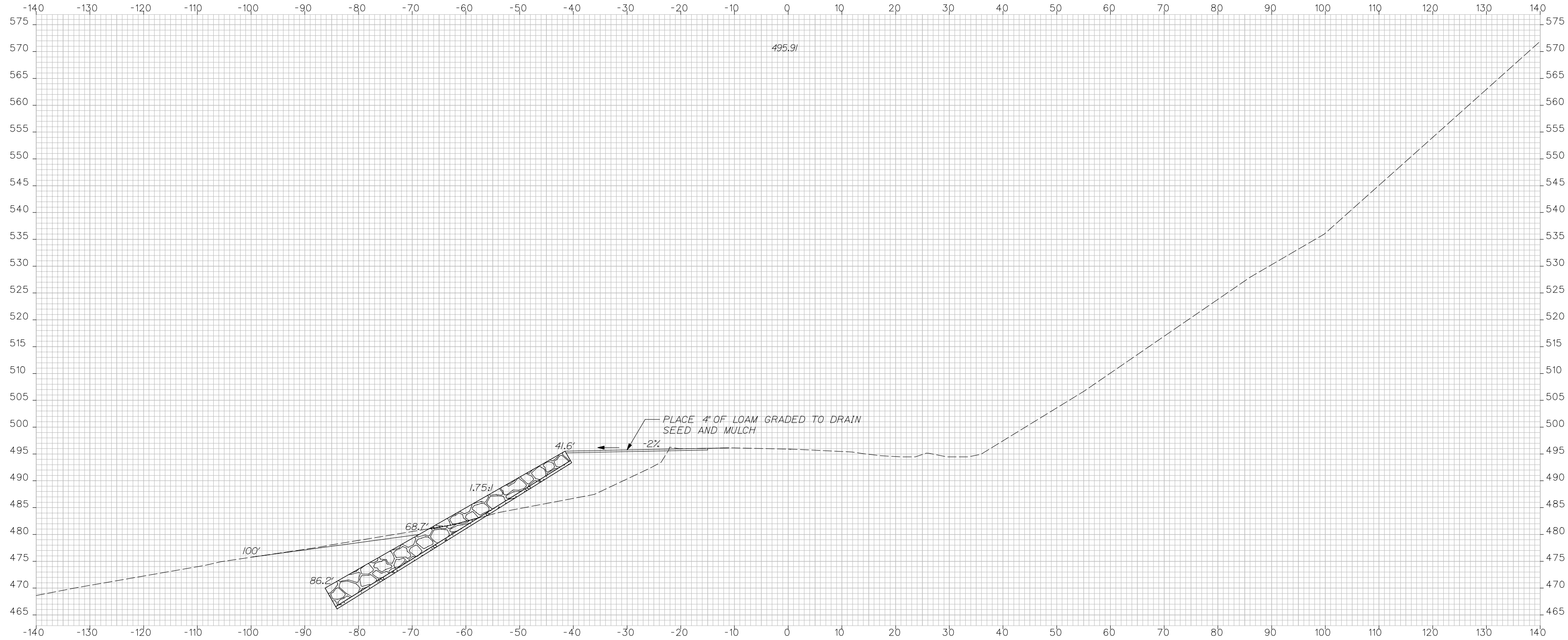
ST. FRANCIS
ROUTE 161

11+00.00 CROSS SECTIONS

SHEET NUMBER

6

OF 10



11+50.00

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

016476.30

PIN
16476.30

HIGHWAY PLANS

PROJ. MANAGER	JON BITHER		
	BY	DATE	
DESIGN-DETAILED	RED	8-20-07	SIGNATURE
CHECKED-REVIEWED			
DESIGN2-DETAILED2			P.E. NUMBER
DESIGN3-DETAILED3			
REVISIONS 1			DATE
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

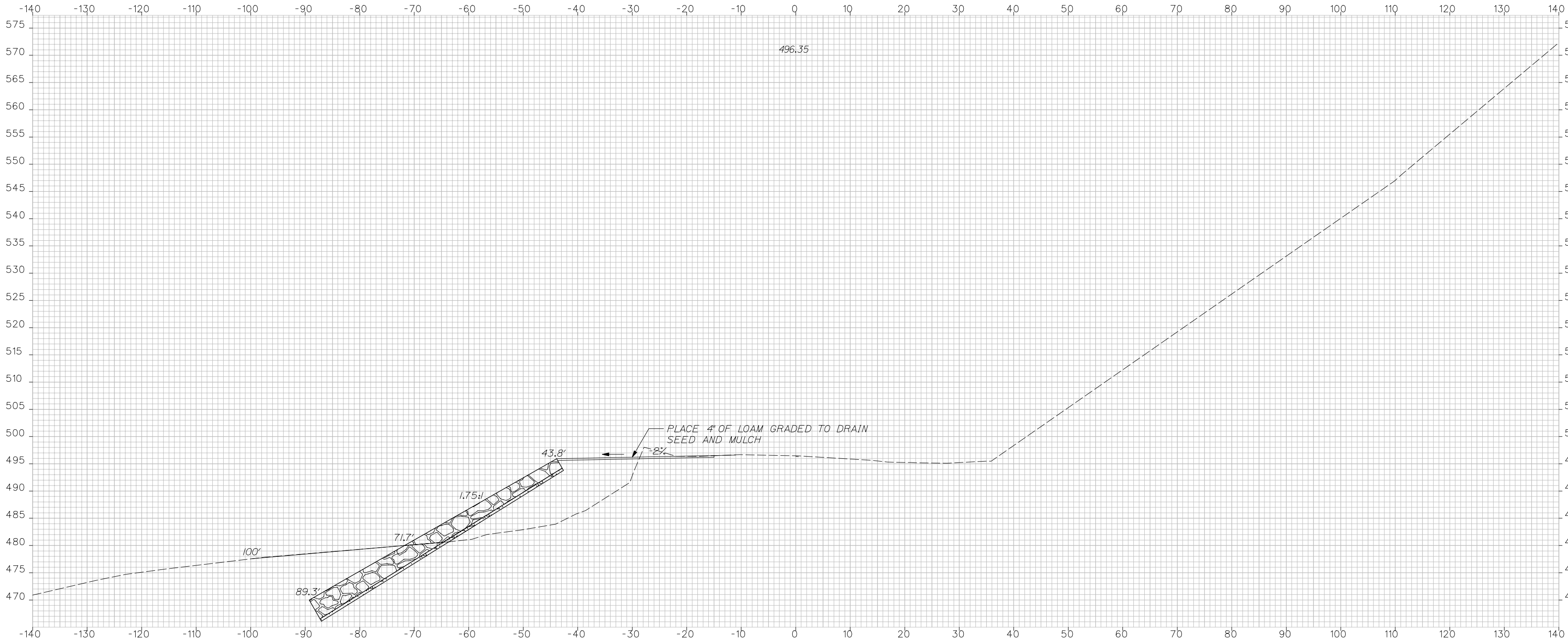
ST. FRANCIS
ROUTE 161

CROSS SECTIONS

11+50.00

SHEET NUMBER
7
OF 10

Filename: ...\MSTA\007_XSMC10_dr_004.dgn Division: HIGHWAY Username: brian.mousseau Date:9/18/2007



12+00.00

Filename: ...\MSTA\008_XSMC10_dr_005.dgn Division: HIGHWAY Username: brian.mousseau Date:9/18/2007

27

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

016476.30

PIN 16476.30

HIGHWAY PLANS

	BY	DATE
PROJ. MANAGER	JON BITHER	
DESIGN-DETAILED	RED	8-20-07
CHECKED-REVIEWED		
DESIGN2-DETAILED2		
DESIGN3-DETAILED3		
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE

P.E. NUMBER

DATE

ST. FRANCIS
ROUTE 161

CROSS SECTIONS

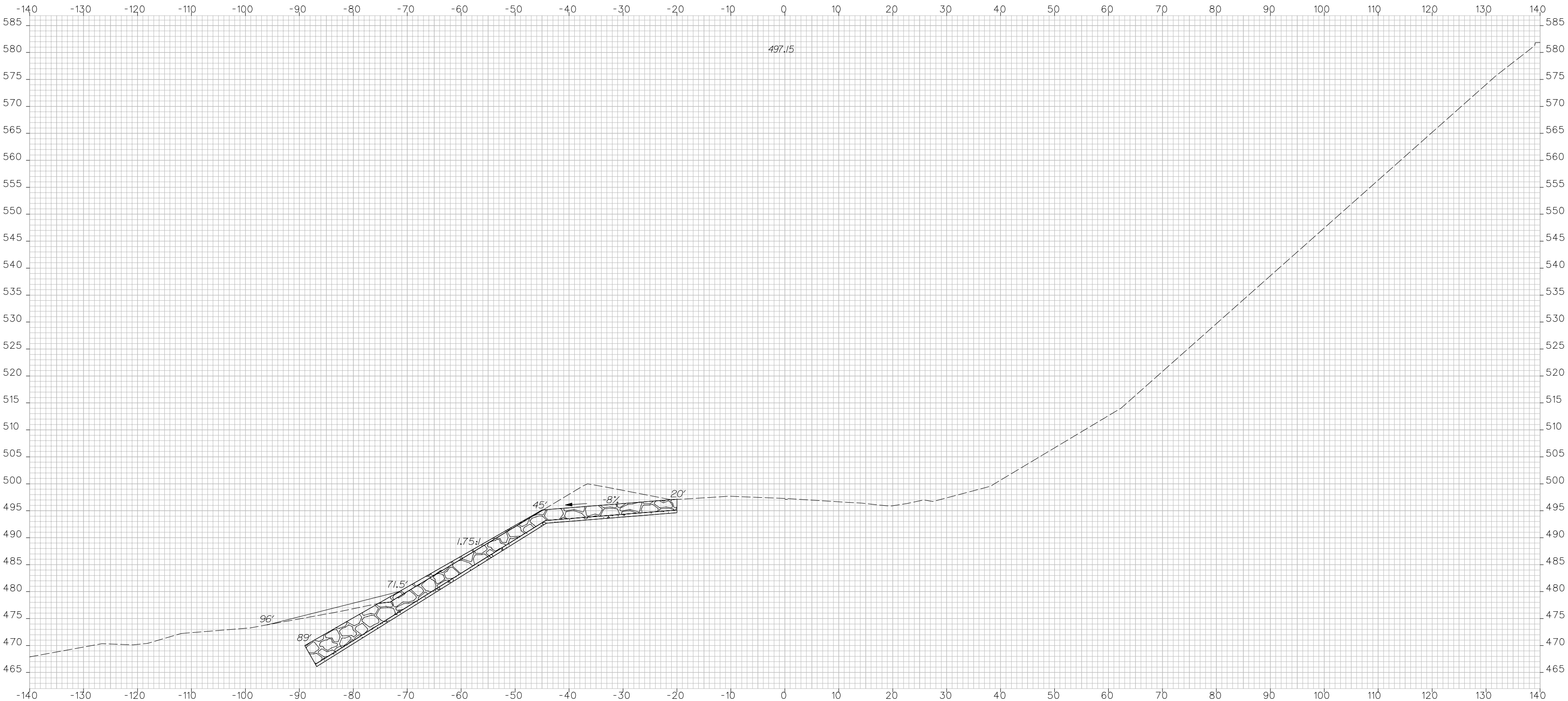
12+00.00

SHEET NUMBER

8

OF 10

Filename: ...\MSTA\009_XSMC10_dr_006.dgn Division: HIGHWAY Username: brian.mousseau Date:9/18/2007



12+50.00

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

016476.30

PIN
16476.30

HIGHWAY PLANS

PROJ. MANAGER	JON BITHER		
DESIGN-DETAILED		RED	8-20-07
CHECKED-REVIEWED			
DESIGN2-DETAILED2			
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

SIGNATURE

P.E. NUMBER

DATE

ST. FRANCIS
ROUTE 161

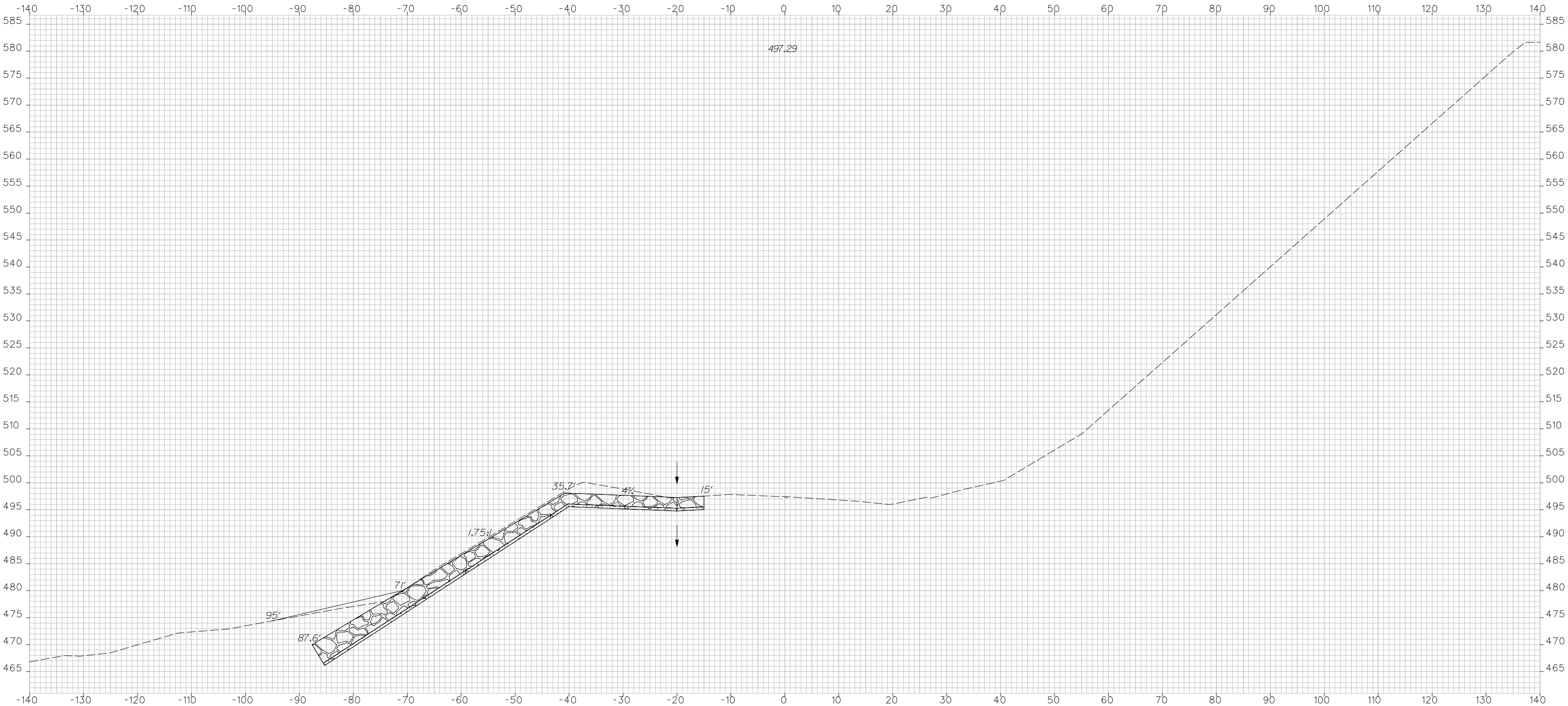
CROSS SECTIONS

12+50.00

SHEET NUMBER

9

OF 10



12+57.00
END PROJECT

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

016476.30

PIN
16476.30

HIGHWAY PLANS

PROJ. MANAGER	JON BITHER	BY	DATE
DESIGN-DETAILED		RED	8-20-07
CHECKED-REVIEWED			
DESIGN2-DETAILED2			
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

SIGNATURE

P.E. NUMBER

DATE

ST. FRANCIS
ROUTE 161

12+57.00 CROSS SECTIONS

SHEET NUMBER
10
OF 10

Filename: ...\MSTA\010_XSMC10_dr_007.dgn Division: HIGHWAY Username: brian.mousseau Date:9/18/2007

ATTACHMENT E

MaineDOT Riprap Specifications

609.38	Reset Curb Type 1	Linear Foot
609.39	Reset Curb Type 2	Linear Foot
609.40	Reset Curb Type 5	Linear Foot

SECTION 610 - STONE FILL, RIPRAP, STONE BLANKET, AND STONE DITCH PROTECTION

610.01 Description This work shall consist of excavating for and constructing a protective covering of stone. The types of protective covering of stone are designated as follows:

a. Stone fill Machine placed embankment for fill slope
b. Plain Riprap Machine placed stones on earth bedding
c. Hand Laid Riprap Hand placed stones on earth bedding
d. Stone Blanket Machine placed stones around piers and Abutments
e. Heavy Riprap Machine placed stones on earth bedding
f. Stone Ditch Protection Machine placed ditch protection of rock

610.02 Materials Materials shall meet the requirements of the following Sections of Division 700 - Materials:

Stone Fill	703.25
Plain and Hand Laid Riprap	703.26
Stone Blanket	703.27
Heavy Riprap	703.28

610.031 General Suitable material removed when excavating for the placing of riprap, stone fill, stone blanket or stone ditch protection shall be used in the formation of embankments, subgrade and for backfilling as shown on the plans or as directed.

610.032 Placing Stones

a. Stone Fill and Stone Blanket Material for stone fill shall be deposited to provide a compact mass. The exposed slope shall be finished to the line and grade required without special handling or handwork. Material for stone blanket shall be deposited for protection around piers or abutments as shown on the plans. The stones shall be placed individually to form a reasonably compact mass. Spaces between the larger stones shall be filled with stone or spall of suitable size to leave an even surface conforming to the contour required. Stone fill and stone blanket shall be placed on the slope in a well-knit, compact and uniform layer. The surface stones shall be chinked with smaller stone from the same source.

b. Riprap Stones for riprap shall be placed upon a slope properly graded and compacted as called for. When required, the bottom of the riprap shall be placed in a trench at the toe of the slope. Plain riprap shall be placed full depth in one operation without special handwork and shall be placed approximately true to the required slope line and grade and be uniform in appearance. Hand laid riprap shall be random rubble, hand laid stones for the full depth placed in one operation to secure interlocking of all face stones and stones placed as backing. Larger stones shall be laid at the base of the slope. The stones shall be laid in close contact with the longer axis perpendicular to the plane of the slope to stagger joints. Except when required to be grouted the openings between the stones in all riprap shall be filled with spall, or rocks securely rammed into place. Riprap shall be placed on the slope in a well-knit, compact and uniform layer. The surface stones shall be chinked with smaller stone from the same source.

Stones for heavy riprap shall be placed to the full depth in one operation without special handwork or machine work upon a properly graded and compacted slope. Above the low water elevation, stones shall be placed to form an approximate uniform surface, free from humps or depressions, with no excessively large stones projecting from the general surface. Loose stones or excessively large stones tending to extend above the average general surface shall be embedded, reoriented, or discarded. The openings between stones on the face of heavy riprap shall be filled with spall or small rocks, securely rammed into place.

c. Stone Ditch Protection The ditch shall be excavated below the flow line to allow placement of the rock material to the specified depth. The stone ditch protection shall be placed, full depth, in one operation without special handwork, shall be approximately true to line and grade and shall be uniform in appearance.

d. Inspection The grading of riprap, stone fill, stone blanket and stone ditch protection shall be determined by the Resident by visual inspection of the load before it is dumped into place, or, if ordered by the Resident, by dumping individual loads on a flat surface and sorting and measuring the individual rocks contained in the load. A separate, reference pile of stone with the required gradation will be placed by the Contractor at a convenient location where the Resident can see and judge by eye the suitability of the rock being placed during the duration of the project. The Resident reserves the right to reject stone at the job site or stockpile, and in place. Stone rejected at the job site or in place shall be removed from the site at no additional cost to the Department.

610.05 Method of Measurement Stone fill, plain riprap, hand laid riprap, stone blanket, heavy riprap and stone ditch protection will be measured by the cubic yard, complete in place, except that when placed under water the quantity may be measured by truck load count with no reduction in volume.

610.06 Basis of Payment The accepted quantities of stone fill, plain riprap, hand laid riprap, stone blanket, heavy riprap and stone ditch protection and materials to fill the voids will be paid for at the contract unit price per cubic yard complete in place.

Costs of all required excavation below the slope line for the placement of bedding, riprap, stone fill, stone blanket, stone ditch protection and for furnishing and placing the bedding material itself, will be considered incidental to the contract items and no separate payment will be made.

Payment will be made under:

Pay Item		Pay Unit
610.07	Stone Fill	Cubic Yard
610.08	Plain Riprap	Cubic Yard
610.09	Hand Laid Riprap	Cubic Yard
610.11	Stone Blanket	Cubic Yard
610.16	Heavy Riprap	Cubic Yard
610.18	Stone Ditch Protection	Cubic Yard

SECTION 611- Reserved

SECTION 612 - BITUMINOUS SEALING

612.01 Description This work shall consist of sealing bituminous mix surfaces with emulsified bituminous sealing compound of the specified color, applied at locations shown on the plans or designated.

612.02 Materials Bituminous material for sealing shall conform to the requirements of Emulsified Bituminous Sealing Compound, Section 702.12.

612.03 General The sealing compound shall be applied in two coats. The first coat shall be diluted by the addition of up to 50% water to a liquid consistency and applied with brooms or other approved methods at a rate of 0.25 gal to 0.50 gal of diluted sealer per square yard. The second coat shall be diluted only to the extent necessary to obtain workability and applied at a rate of 0.25 gal to 0.50 gal of diluted sealer per square yard.

612.04 Method of Measurement Bituminous sealing will be measured by the square yard of surface sealed measured parallel to the surface.

612.05 Basis of Payment The accepted quantities of bituminous sealing will be paid for at the contract unit price per square yard complete in place.

Pay Item		Pay Unit
612.06	Bituminous Sealing-Black	Square Yard

Fifty percent of the stones by volume shall have an average dimension greater than 12 inches (200 lbs).

703.26 Plain and Hand Laid Riprap Stone for riprap shall consist of hard, sound durable rock that will not disintegrate by exposure to water or weather. Stone for riprap shall be angular and rough. Rounded, subrounded or long thin stones will not be allowed. The maximum allowable length to width ratio will be 3:1. Stone for riprap may be obtained from quarries or by screening oversized rock from earth borrow pits. The minimum stone size (10 lbs) shall have an average dimension of 5 inches. The maximum stone size (200 lbs) shall have an average dimension of approximately 12 inches. Larger stones may be used if approved by the Resident. Fifty percent of the stones by volume shall have an average dimension greater than 9 inches (50 lbs).

703.27 Stone Blanket Stones for stone blanket shall consist of sound durable rock that will not disintegrate by exposure to water or weather. Stone for stone blanket shall be angular and rough. Rounded or subrounded stones will not be allowed. Stones may be obtained from quarries or by screening oversized rock from earth borrow pits. The minimum stone size (300 lbs) shall have minimum dimension of 14 inches, and the maximum stone size (3000 lbs) shall have a maximum dimension of approximately 66 inches. Fifty percent of the stones by volume shall have average dimension greater than 24 inches (1000 lbs).

703.28 Heavy Riprap Stone for heavy riprap shall consist of hard, sound, durable rock that will not disintegrate by exposure to water or weather. Stone for heavy riprap shall be angular and rough. Rounded, subrounded, or thin, flat stones will not be allowed. The maximum allowable length to width ratio will be 3:1. Stone for heavy riprap may be obtained from quarries or by screening oversized rock from earth borrow pits. The minimum stone size (500 lbs) shall have minimum dimension of 15 inches, and at least fifty percent of the stones by volume shall have an average dimension greater than 24 inches (1000 lbs)

703.29 Stone Ditch Protection Rock used for ditch protection shall consist of sound, durable rock that will not disintegrate by exposure to water or weather. Fieldstone, rough quarry stone, blasted ledge rock or tailings may be used. The rock shall be graded within the following limits or as otherwise approved

Sieve Designation	Percentage by Weight Passing Square Mesh Sieves
12 inch	90-100
4 inch	0-15

The size of any stone shall not exceed 18 inches when measured along its longest axis.

703.31 Crushed Stone 2-Inch Crushed stone shall be obtained from rock of uniform quality and shall consist of clean, angular fragments of quarried rock, free from soft disintegrated pieces or other objectionable matter.

APPENDIX L

Summary of Bendway Weir Design

TECHNICAL MEMORANDUM

DATE January 22, 2018 **Project No.** 1659907.4

TO Project File
MaineDOT

CC Mark Peterson, Golder-Maine, Jeff Lloyd, Golder-Maine

FROM Andreas Kammereck, PE, and Scott Stoneman, Golder-Redmond

EMAIL **akammereck@golder.com; sstoneman@golder.com**

SUMMARY OF BENDWAY WEIR DESIGN – SLOPE STABILIZATION OF STATE ROUTE 161 AT ST. FRANCIS AND ALLAGASH, MAINE

1.0 INTRODUCTION

Golder Associates Inc (Golder) was requested by the Maine Department of Transportation (MaineDOT) to provide hydraulic engineering services for assessment and design support for slope stabilization for two sites adjacent to State Route 161 between the roadway and the St. John River. One site is along roughly an 800-foot segment of State Route 161 in St. Francis and the second site is about a 550-foot portion of the roadway in the town of Allagash. The Allagash slope segment is positioned at the confluence of the Allagash River and the St. John River. The St. Francis slope segment is located on the St. John River approximately 12 miles downstream of Allagash site and directly downstream of a valley constriction that occurs just downstream of the confluence of the St. Francis River and the St. John River.

This memorandum builds on previous technical work defining the existing conditions hydrologic (Golder 2019a) and hydraulic modelling, Basis of Design (BOD) (Golder 2019b) and 2-dimensional (2D) hydrodynamic modeling of alternative configurations at the sites (Golder 2019c) and provides a brief summary of the proposed mitigation measures using installation of bendway weirs. This memorandum is organized into the following sections: preliminary modeling results, typical hydraulic sections, prelim riprap estimates, prelim scour estimates, 2D modeling to support structure designs, typical profiles/sections, and conclusions.

2.0 PRELIMINARY MODEL RESULTS

A 1-dimensionional (1D) Hydrological Engineering Center River Analysis System (HEC-RAS) model was developed to look at expected hydraulic conditions (i.e. velocity, flow depth, flow width, water surface elevations, etc) for the two sites, the results are summarized in Table 2-1.

Table 2-1: HEC-RAS Results for the 100-year Event at Site Surveyed Cross-Section

Site	Condition	Water Surface Elevation (feet NAVD 88)	Maximum Channel Depth (feet)	Channel Velocity (feet per second)
Allagash	Without Ice	594.77	18.90	6.85
	With Ice	605.49	29.62	3.89
St. Francis	Without Ice	541.66	21.13	9.21
	With Ice	554.34	33.81	5.41

The two dimensional (2D) TUFLOW (BMT 2017) model results (Attachment A) previously developed were compared with the 1D results; the velocities were slightly higher, likely because the maximum velocity is reported instead of the velocity in the channel area (as defined in HEC-RAS), and the 2D modeling showed water levels approximately 1-foot higher, likely due to variations in bathymetric data. In general, the results compared well, and within expected range of variation.

2.1.1 Typical Hydraulic Sections

Using the results from the modeling, typical sections were developed that provide guidance on key river and flood levels. Refer to Attachment B for schematics showing the 2-year and 100-year (with and without ice cover) elevations.

2.2 Preliminary Riprap Calculations

Based on the modeling results discussed in the previous section, preliminary riprap sizing calculations were developed using methods developed for bank protection designs. These preliminary calculations can be used for proposed bank armoring at the two sites, and as an analog for riprap material sizing for the bendway weir structures. Final determination of riprap material sizing for the bendway weirs will be completed later in final design. With considering ice (factor of safety set to 2.0), the rock size for Allagash results in a median diameter (D50) = 14 inches and St Francis the D50 = 33 inches. Refer to Attachment C for calculation details.

2.3 Scour

Scour estimated were developed using the modeling information. Refer to Attachment D for calculation summaries. The results are presented in Table 2-2.

Table 2-2: Summary of Scour Results

Method	100-year Bend Scour Depth (ft)	
	Allagash	St Francis
FHWA Method	5.7	13.1
USBR Method	6.6	6.5
Average Scour Depth	6.2	9.8

3.0 2D MODELING TO SIMULATE BENDWAY WEIR STRUCTURES

A more detailed summary of modeling of proposed bendway weir structures is addressed under a separate technical memorandum (Golder 2019a and 2019b). The following provides a brief summary, supporting development of the preliminary design work. Modelling extents cover approximately a fifteen mile stretch of the St. John River with the Allagash reach covering 1.9 miles and the St. Francis reach covering 1.7 miles (Figures 3-1 and 3-2, respectively). A Manning's n-value of 0.027 was selected for the main and side channels and an overbank value of 0.040 was selected for the floodplain. These roughness values were determined from aerial and site visit photographs. Models were analyzed for the 2- and 100-year annual exceedance probability events of 58,000 and 68,000 cubic feet per second (cfs) for the Allagash site and 68,000 and 156,000 cfs for the St. Francis site.

2D TUFLOW models were developed in order to resolve hydraulic conditions at a more granular scale throughout the project areas, to better represent the anticipated complex flow dynamics. 2D models are grid-based and report results for each cell within the grid, allowing for review of hydraulic conditions laterally as well as longitudinally within and between section locations. The 2D TUFLOW models were developed for a variety of proposed bendway weir conditions. The models were run with a grid cell size of 10 feet by 10 feet. A time step of 2 seconds was used for both the Allagash St. Francis sites. The downstream water surface elevation (WSE) boundary condition determined from a previous 1D HEC-RAS model of the sites. For the models, the bendway weirs were incorporated as variable 2D Z-lines.

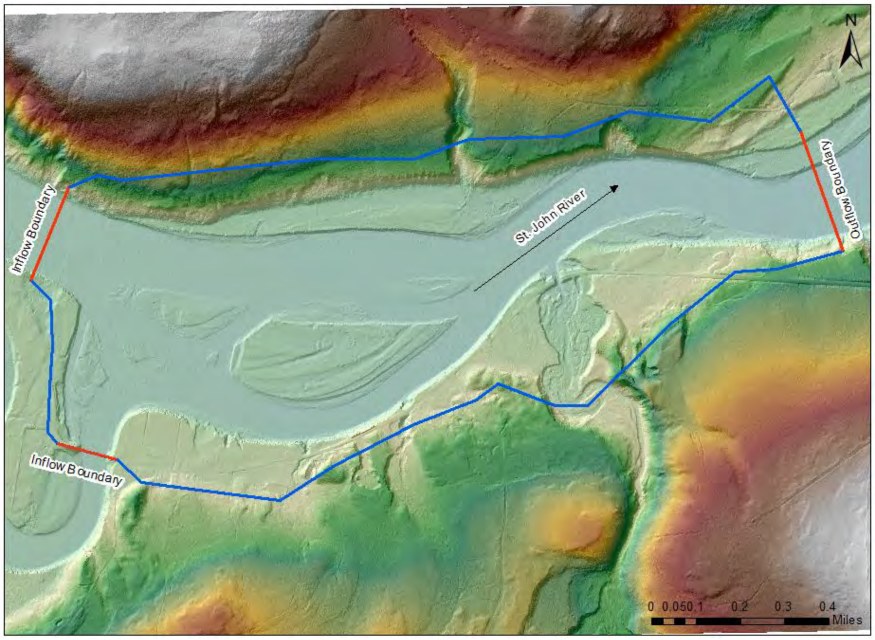


Figure 3-1: Allagash Site TUFLOW Model Extents

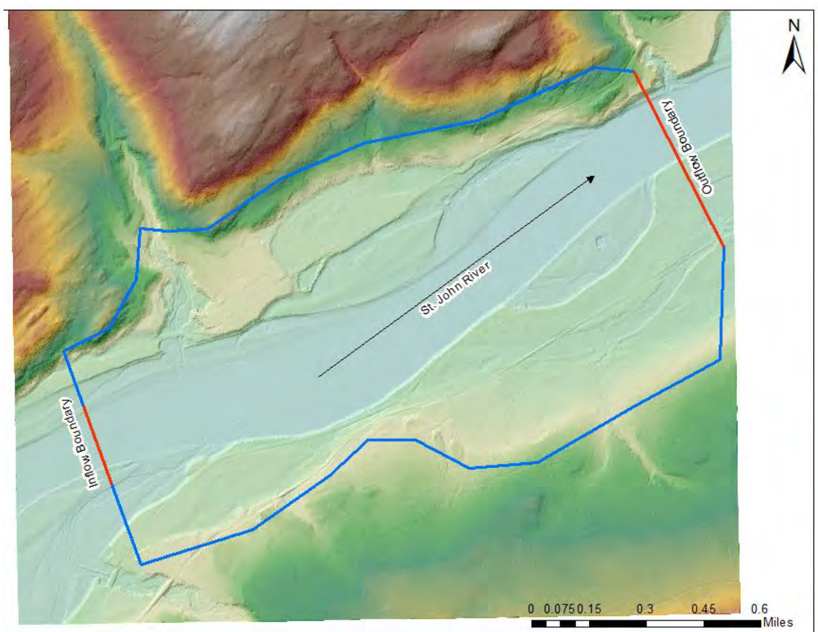


Figure 3-2: St. Francis Site TUFLOW Model Extents

3.1 Model Iterations

A variety of bendway weir structure iterations were run at each unstable slope project site for a variety of weir numbers, placements, widths, heights, and orientations. The general layout details are summarized in Table 3-1, and the details for each structure are shown on the sections sheet in Attachment G.

Table 3-1: Summary of Typical Bendway Weir Dimensions

Length (ft)	Upstream Slope (XH:1V)	Downstream Slope (XH:1V)	Top Width (ft)	Oprientation (degrees away from upstream bank line)	Spacing (ft)
40-90 (1)	1	2	10	60	100-200 (2)
Notes:					
1) ~40 ft at up- and downstream ends of project sites as transitions to longer primary structures, and primary structures are approximately 80-90 feet in length.					
2) Sapcing for up- and downstream transition structures is approxiamtely 100 ft, spacing of primary structures ranges from approximately 100-200 ft.					

Refer to detailed layouts (Attachments E, F and G), as referenced below for each site, for the proposed preliminary design configuration of the bendway weirs. In general, the leading upstream end of the structures includes a shorter length bendway weir that acts as a transition to the following structures, which are longer in length. There is also a shorter length structure at the downstream end, again to act as a transition back to the native bank line downstream of the project. The primary structures placed along the bank are uniform length and orientation (angle measured off the upstream bank line). Spacing between structures ranges from approximately 100-200 feet apart, depending on the simulated performance off the structures. The top elevation of structures was established around the 2-year flood level. Note that the top elevation may vary, depending on bathymetric elevations as they may vary, or in order to target defined scour conditions and/or up- or downstream impacts. The typical sections shown in Attachment G show examples where the bendway weirs are set at or above the bed elevations, where the structures are set lower in elevation due to changes in bathymetry, or where they are set lower in order to only engage if subjected to targeted scour conditions. Refer to the following sections for more detailed discussion of dimensions at each site.

3.1.1 Allagash

Based on review of the results, a preliminary design layout for each site was developed for the Allagash site consisting of 10 bendway weirs; the middle eight bendway weirs were set at a length of approximately 86 feet and offset from the upstream river bank by approximately 60 degrees; the most upstream and most downstream structures were set at a length of approximately 40 feet with the same orientation angle. The top elevation varies between 588 to 589 feet in elevation (approximately the WSE for the 2-year flood event). Bendway weirs were spaced 100 feet apart on the most downstream and upstream weirs, with the second through fourth structures (upstream to downstream) being spaced approximately 200 feet apart, and the remainder being spaced approximately 150 feet apart. Refer to Attachment E for typical plan view layouts for the bendway weirs at the Allagash site, and Attachment G for typical profile and sections (e.g. below, at, or above bed elevations) for the structures.

3.1.2 St. Francis

The final iteration for the St. Francis site consisted of 6 bendway weirs. The middle four bendway weirs were set at a length of 80 to 90 feet at a 60-degree angle off the upstream bank line. The most upstream and most downstream structures were set at a length of approximately 40 feet and also maintained a 60-degree upstream orientation from the bank line. All structures were set to a width of 40 feet and varied between 535.5 to 536.0 feet in elevation (approximately the WSE for the 2-year flood event). Bendway weirs were spaced 100 feet apart on the most downstream and upstream weirs, with the remainder being spaced 250 feet apart. Refer to Attachment

F for typical plan view layouts for the bendway weirs at the St. Francis site, and Attachment G for typical profile and sections (e.g. below, at, or above bed elevations) for the structures.

4.0 PRELIMINARY EXISTING VERSUS PROPOSED COMPARISON

The 2D TUFLOW model was used to assess potential changes in hydraulic conditions for the existing versus proposed bendway weir layouts. Figure 4-1 and 4-2 show the change in velocity and water surface elevations (respectively) from existing to prosed conditions for the Allagash site. Figure 4-3 and 4-4 show the change in velocity and water surface elevations (respectively) from existing to prosed conditions for the St. Francis site.

The results show that some changes in hydraulic parameters may occur, but the changes are within expected values. Changes in velocities increase in a range of approximately 0.2 to 1 feet per second (fps) in the main channel for both sites, and decrease to backwater conditions in between the bendway weirs (as expected). Changes in water surface elevations increase by a range of 0.02 and 0.2 feet upstream and decrease by a range of approximately 0.01 to 0.19 feet downstream of the installed structures for both sites. In general, the changes are very small relative to overall 100-year flood depth of 16.8 feet and 22.3 feet for the Allagash and St. Francis sites, respectively.

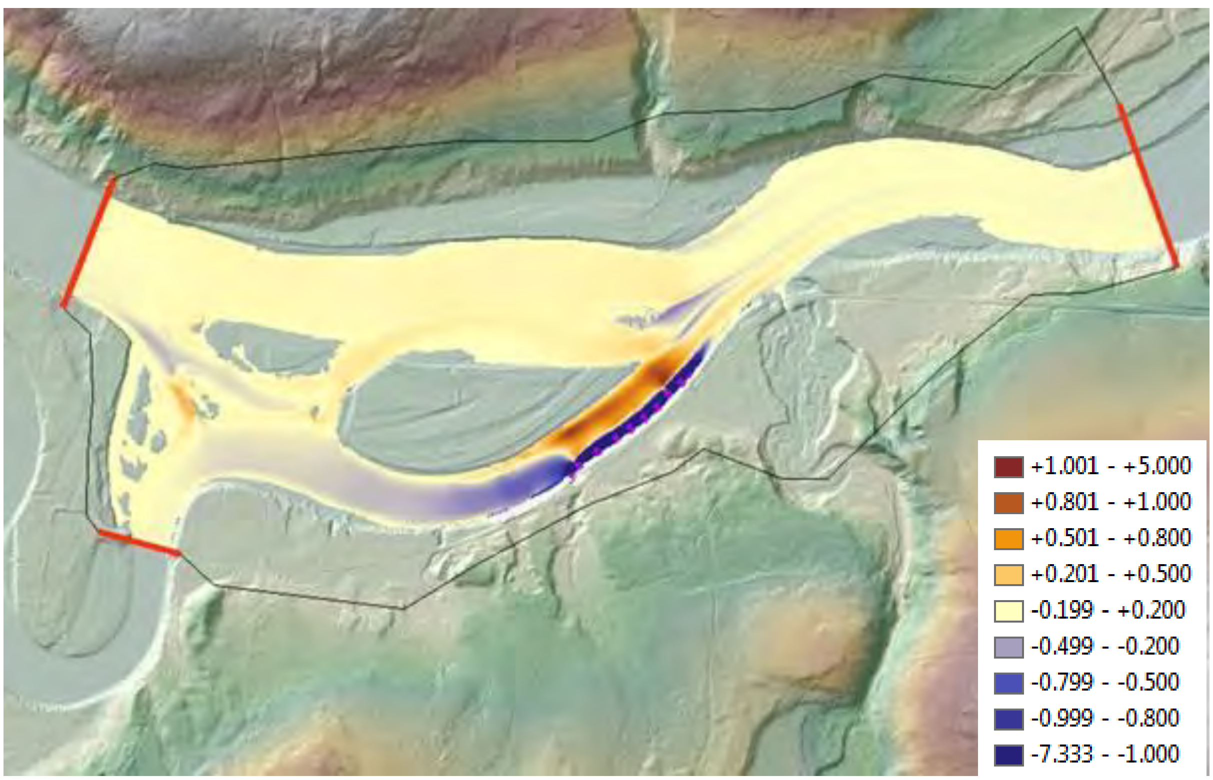


Figure 4-1: Allagash - Change in velocity from base conditions (fps)

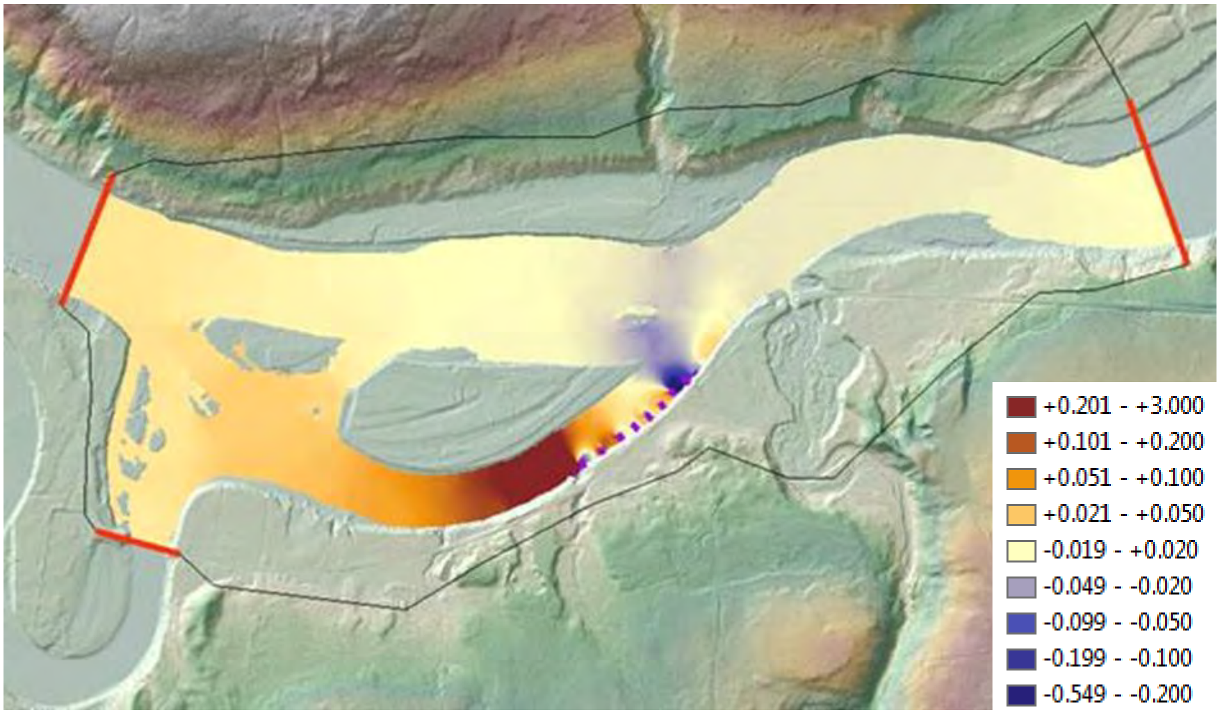


Figure 4-2: Allagash - Change in water surface elevation from base conditions (feet)

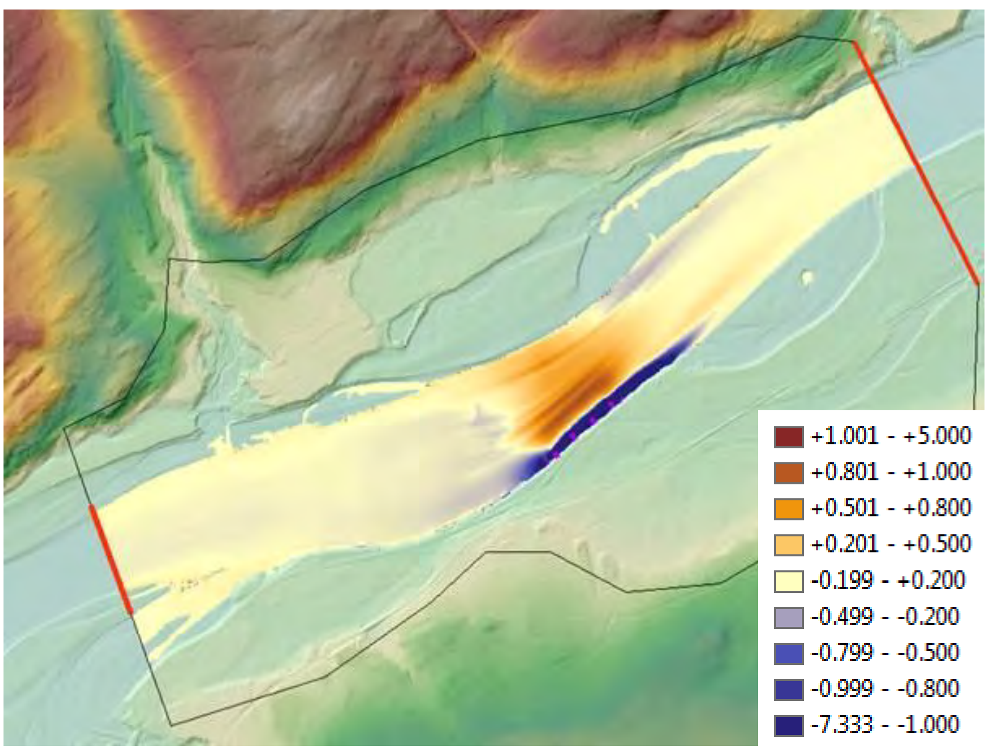


Figure 4-3: Francis - Change in velocity from base conditions (fps)

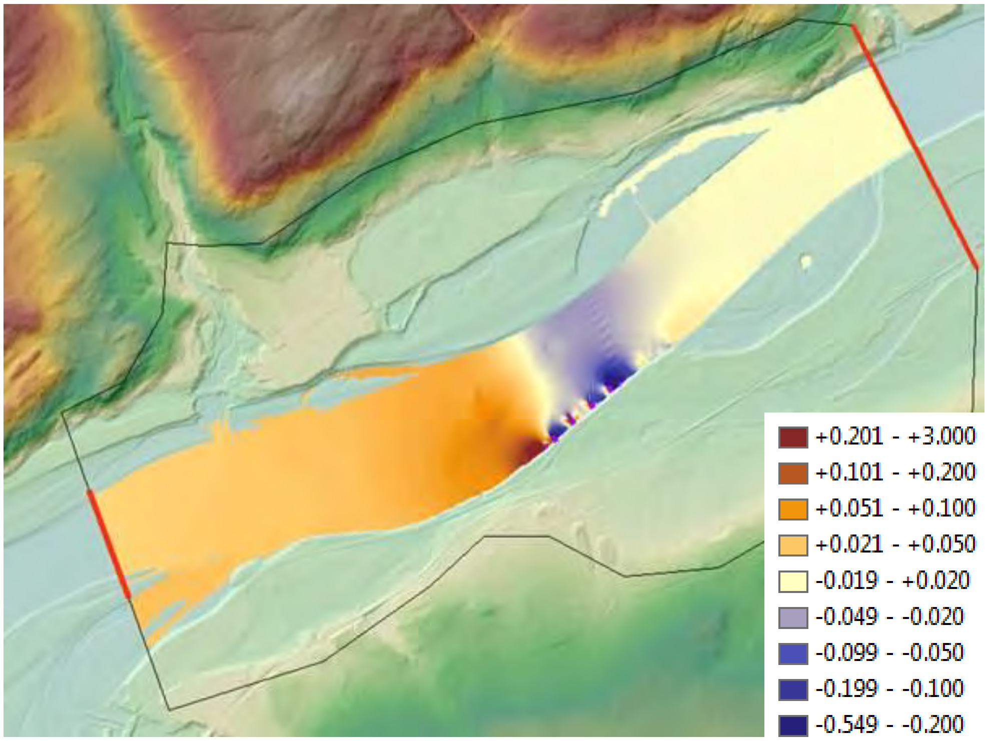


Figure 4-4: Francis - Change in water surface elevation from base conditions (feet)

Note that modeling results reported in this Section 4, and in other supporting technical memorandums, reported results from the modeling that are absolute values, representing direct output from the analyses and demonstrating trends in the targeted hydraulic conditions. While absolute values listed for elevations (for example) of 1 foot or less are determined by these models, there may be some varying range in the results that is inherent to this type of analyses (i.e. the typical range of error that comes with modeling) that is likely less than or on par with these absolute values. The intent of this analysis was to identify trends in the existing and proposed conditions relative to the proposed in-channel work, to support the overall design, to highlight where possible issues may need to be further assessed or investigated, and to confirm that results and outputs of the modeling makes sense and present logical conclusions that fit expected site hydrologic, hydraulic, and geomorphic conditions. These results may change or be modified based on new information, data, or assumptions.

5.0 CONCLUSIONS

This technical memorandum summarized the preliminary design layouts for proposed bendway weir structures. These results will be incorporated with other on-going slope stability and bank armoring work being addressed under separate efforts, and a final and detailed engineering design development that best fit the purpose and needs of the project. Further analysis, modeling, and detailed hydrotechnical engineering may change, update, modify the preliminary designs as presented herein.

https://golderassociates.sharepoint.com/sites/106608/project files/6 deliverables/final report/appendix/appendix l techmemo_bendwayweirdesign/1659907-tm-rev0-allagash_st. francis_prelim design-032219.docx

Attachments:
Attachment A: Preliminary TUFLOW Modeling Results
Attachment B: Preliminary Flood Sections
Attachment C: Preliminary Riprap Calculations
Attachment D: Scour Calculations
Attachment E: Preliminary Allagash Typical Bendway Weir Plan View Layouts
Attachment F: Preliminary St. Francis Typical Bendway Weir Plan View Layouts
Attachment G: Preliminary Typical Bendway Weir Profile/Section Views

6.0 REFERENCES

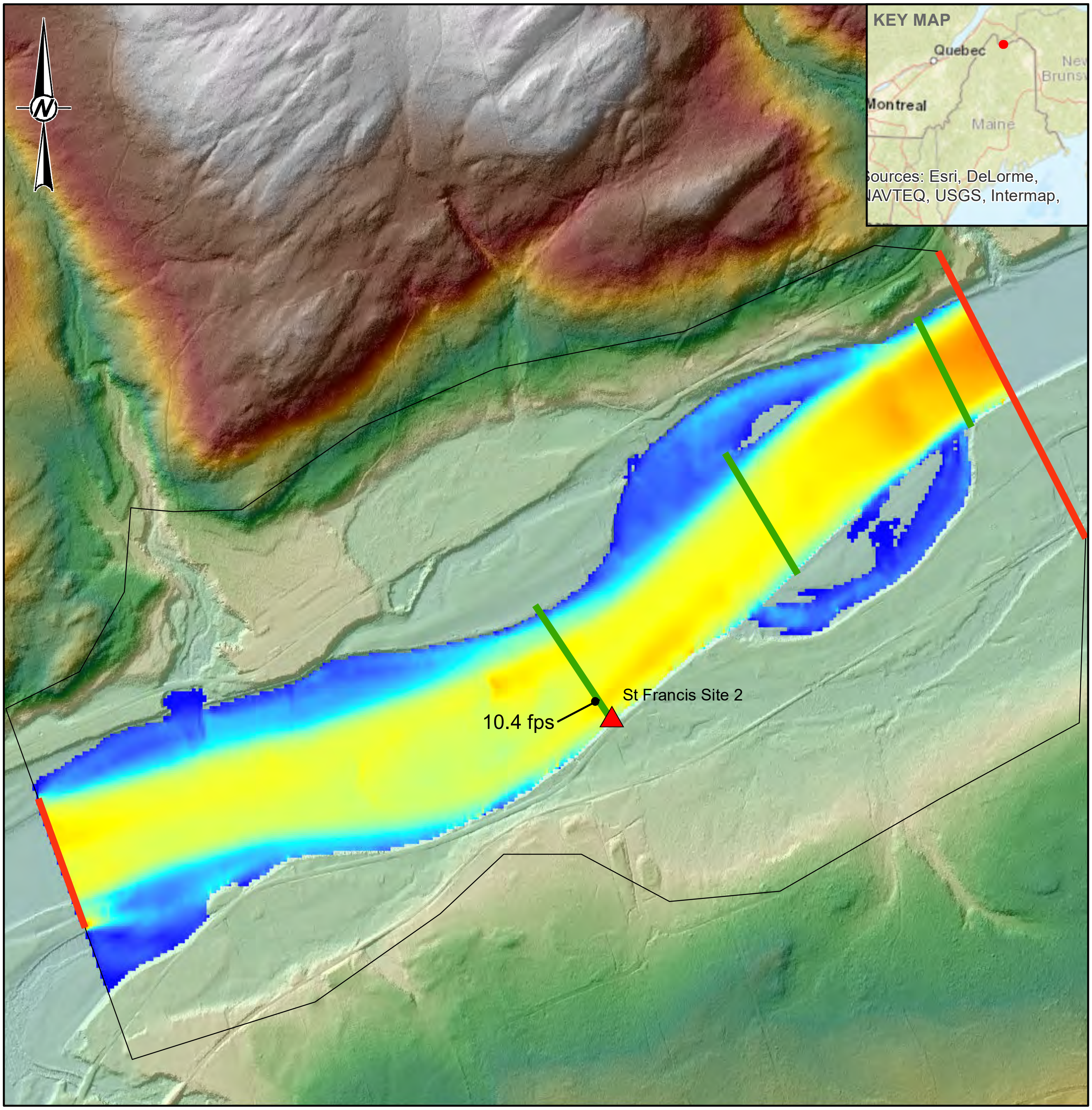
Golder Associates Inc. (Golder). 2019a. Technical Memorandum. Hydrologic and Hydraulic Evaluation of Existing Conditions – Slope Stabilization of State Route 161 at Francis and Allagash. March 12, 2019.

Golder. 2019b. Technical Memorandum. Basis of Design (BOD) Summary for Hydrotechnical Engineering – Slope Stabilization of State Route 161 at Francis and Allagash. March 12, 2019.

Golder. 2019c. Technical Memorandum. 2D River Hydraulic Modeling – Slope Stabilization of State Route 161 at Francis and Allagash. March 12, 2019.

APPENDIX A

TUFLOW Preliminary Modeling Results



LEGEND

- Boundary Condition
- Surveyed cross-sections
- Model Domain

Velocity (fps)
High : 15
Low : 0

PRELIMINARY

0 375 750 1,500
Feet

NOTE(S)
1. LINE NOTES
2. LINE NOTES
3. LINE NOTES

REFERENCE(S)
1. REFERENCE 1
2. REFERENCE 2
3. REFERENCE 3

CLIENT
MAINE DOT

PROJECT
EVALUATION AND STABILIZATION OF UNSTABLE SLOPES
STATE ROUTE 161, ST. FRANCIS AND ALLAGASH, MAINE

TITLE
2D MODELING RESULTS - VELOCITY
100-YEAR EVENT (NO ICE)
ST FRANCES SITE

CONSULTANT

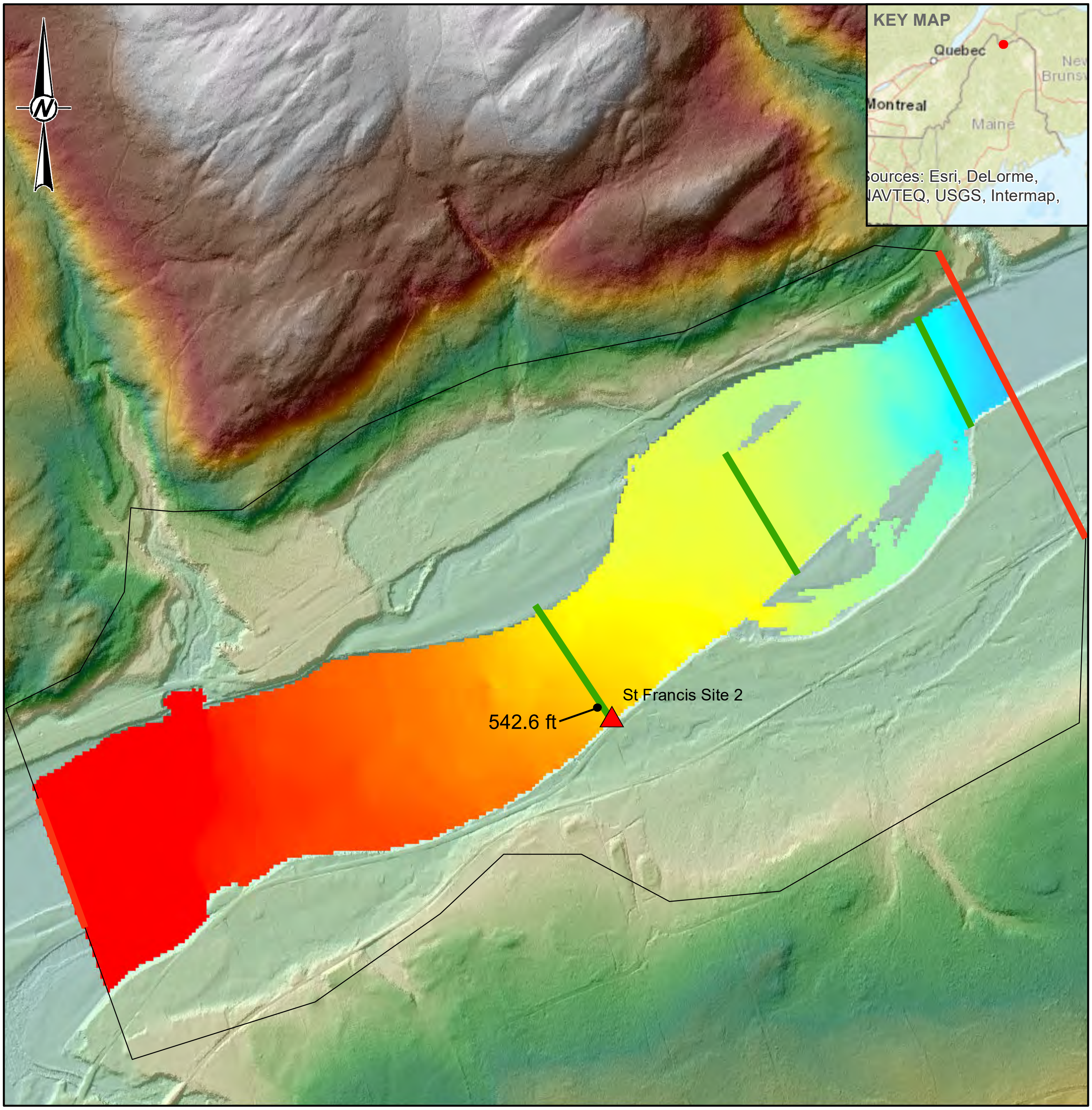
Golder Associates

YYYY-MM-DD	2016-10-31
DESIGNED	SJS
PREPARED	SJS
REVIEWED	####
APPROVED	####

PROJECT NO.	CONTROL	REV.	FIGURE
1659907	####	A	**A-1**

PATH: G:\MaineDOT\Allagash\99_PROJECTS\1659907_Allagash\02_PRODUCTION\MXD\FIGURES\RevA\1659907_001_TUFLOW_StFrancis.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
1 in
0



LEGEND

Boundary Condition

Surveyed cross-sections

Model Domain

WSE (ft) - NAVD88

High : 545

Low : 536

PRELIMINARY

0 375 750 1,500

Feet

CLIENT

MAINE DOT

PROJECT

EVALUATION AND STABILIZATION OF UNSTABLE SLOPES
STATE ROUTE 161, ST. FRANCIS AND ALLAGASH, MAINE

TITLE

2D MODELING RESULTS - WSE
100-YEAR EVENT (NO ICE)
ST FRANCES SITE

CONSULTANT

Golder Associates

YYYY-MM-DD	2016-10-31
DESIGNED	SJS
PREPARED	SJS
REVIEWED	####
APPROVED	####

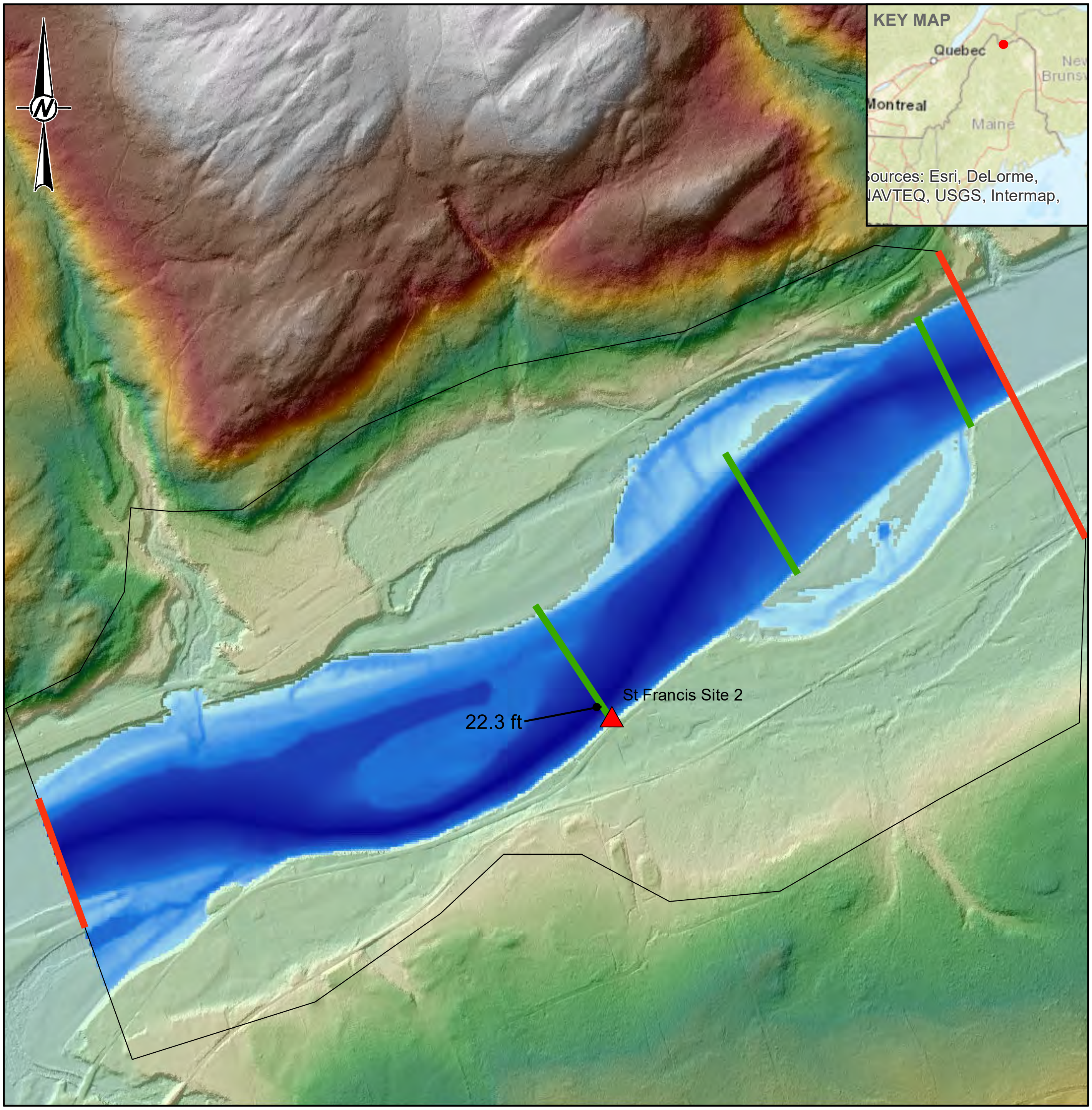
PROJECT NO.	CONTROL	REV.	FIGURE
1659907	####	A	**A-2**

NOTE(S)
1. LINE NOTES
2. LINE NOTES
3. LINE NOTES

REFERENCE(S)
1. REFERENCE 1
2. REFERENCE 2
3. REFERENCE 3

PATH: G:\MaineDOT\Allagash\99_PROJECTS\1659907_Allagash\02_PRODUCTION\MXD\FIGURES\RevA\1659907_002_TUFLOW_StFrancis.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A



LEGEND

- Boundary Condition
- Surveyed cross-sections
- Model Domain

Depth (ft)
High : 22
Low : 0

PRELIMINARY

0 375 750 1,500
Feet

NOTE(S)
1. LINE NOTES
2. LINE NOTES
3. LINE NOTES

REFERENCE(S)
1. REFERENCE 1
2. REFERENCE 2
3. REFERENCE 3

CLIENT
MAINE DOT

PROJECT
EVALUATION AND STABILIZATION OF UNSTABLE SLOPES
STATE ROUTE 161, ST. FRANCIS AND ALLAGASH, MAINE

TITLE
2D MODELING RESULTS - DEPTH
100-YEAR EVENT (NO ICE)
ST FRANCES SITE

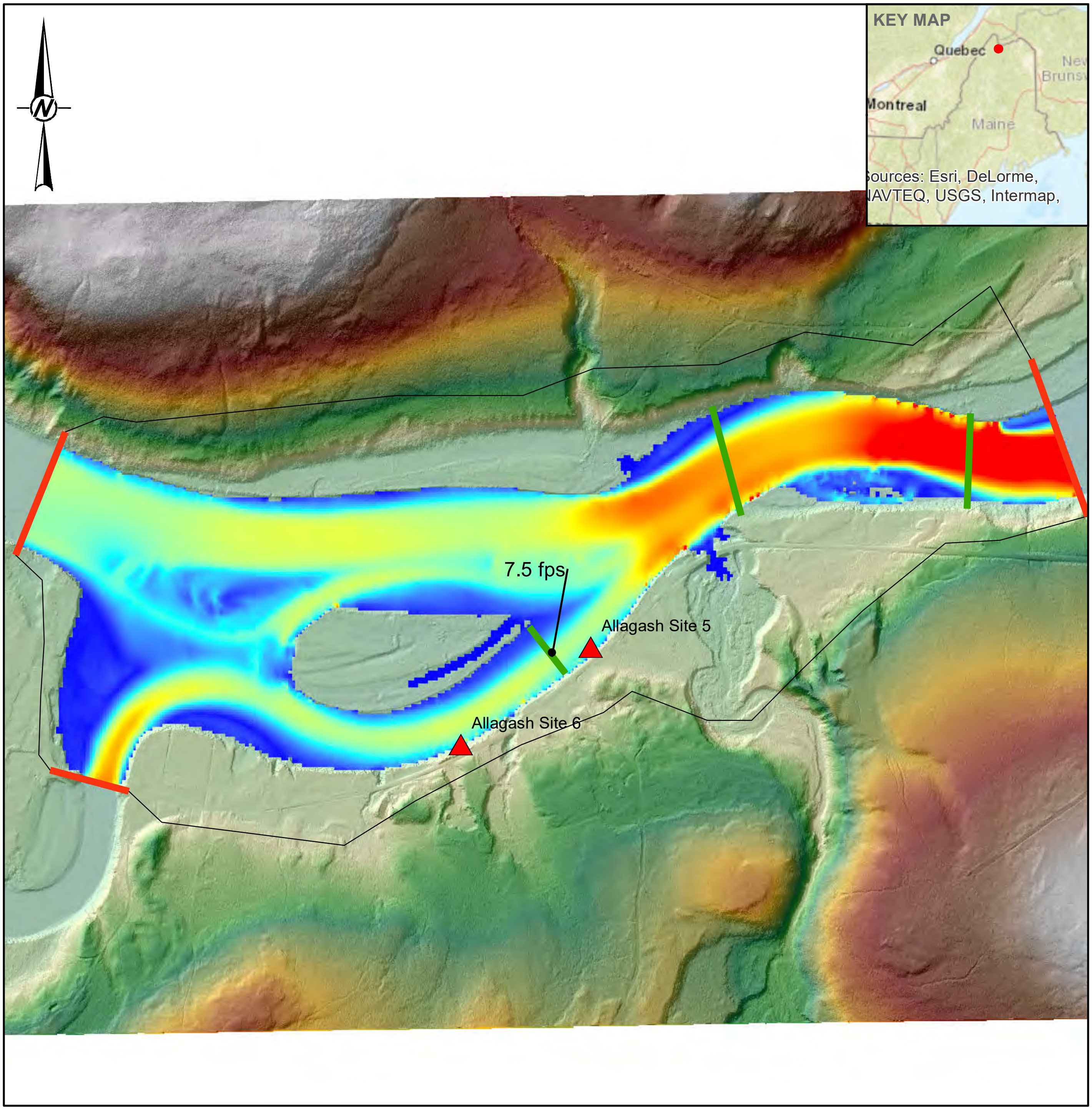
CONSULTANT
Golder Associates

YYYY-MM-DD	2016-10-31
DESIGNED	SJS
PREPARED	SJS
REVIEWED	####
APPROVED	####

PROJECT NO.	CONTROL	REV.	FIGURE
1659907	####	A	A-3

PATH: G:\MaineDOT\Allagash\99_PROJECTS\1659907_Allagash\02_PRODUCTION\MXD\FIGURES\RevA\1659907_003_TUFLOW_StFrancis.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
0 1 in



LEGEND

- Boundary Condition
- Surveyed cross-sections
- Model Domain

Velocity (fps)
High : 15
Low : 0

PRELIMINARY

0 400 800 1,600
Feet

NOTE(S)
1. LINE NOTES
2. LINE NOTES
3. LINE NOTES

REFERENCE(S)
1. REFERENCE 1
2. REFERENCE 2
3. REFERENCE 3

CLIENT
MAINE DOT

PROJECT
EVALUATION AND STABILIZATION OF UNSTABLE SLOPES
STATE ROUTE 161, ST. FRANCIS AND ALLAGASH, MAINE

TITLE
2D MODELING RESULTS - VELOCITY
100-YEAR EVENT (NO ICE)
ALLAGASH SITE

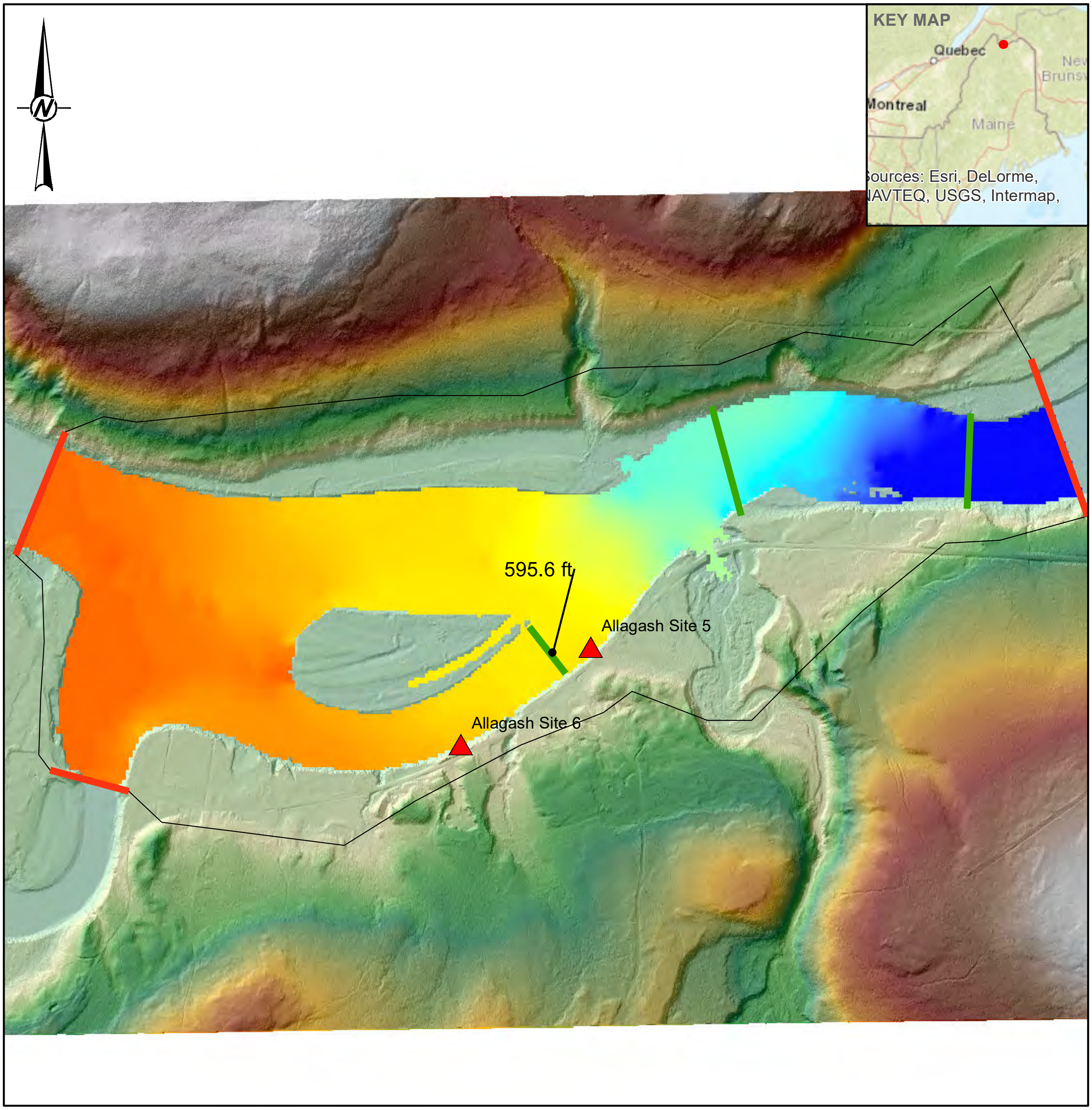
CONSULTANT
Golder Associates

YYYY-MM-DD	2016-10-31
DESIGNED	SJS
PREPARED	SJS
REVIEWED	####
APPROVED	####

PROJECT NO.	CONTROL	REV.	FIGURE
1659907	####	A	**A-4**

PATH: G:\MaineDOT\Allagash\99_PROJECTS\1659907_Allagash\02_PRODUCTION\MXD\FIGURES\RevA\1659907_004_TUFLOW_Allagash.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
0 1 in



LEGEND

- Boundary Condition
- Surveyed cross-sections
- Model Domain

WSE (ft) - NAVD88
High : 599
Low : 588

PRELIMINARY

0 400 800 1,600
Feet

NOTE(S)
1. LINE NOTES
2. LINE NOTES
3. LINE NOTES

REFERENCE(S)
1. REFERENCE 1
2. REFERENCE 2
3. REFERENCE 3

CLIENT
MAINE DOT

PROJECT
EVALUATION AND STABILIZATION OF UNSTABLE SLOPES
STATE ROUTE 161, ST. FRANCIS AND ALLAGASH, MAINE

TITLE
2D MODELING RESULTS - WSE
100-YEAR EVENT (NO ICE)
ALLAGASH SITE

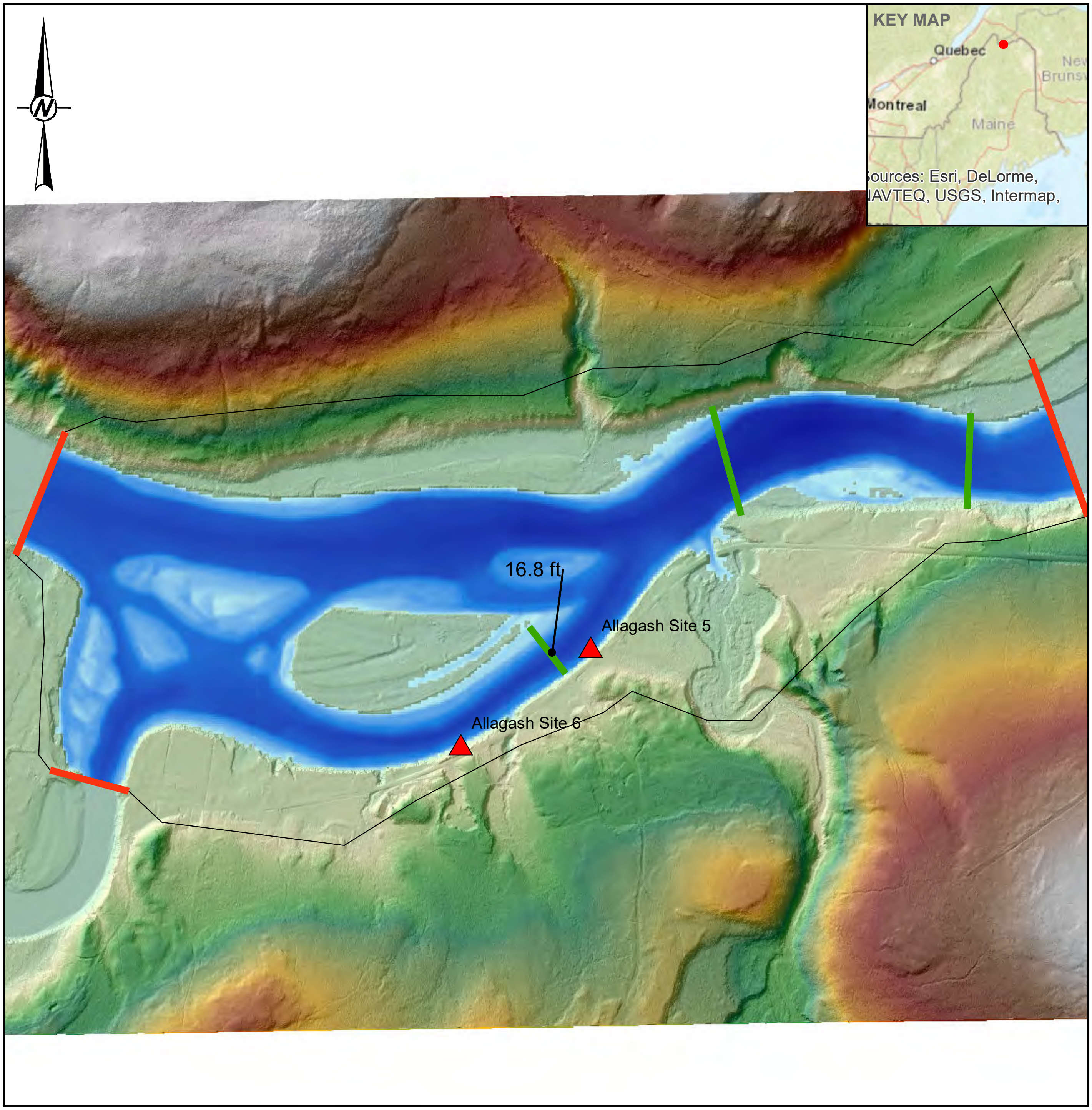
CONSULTANT
Golder Associates

YYYY-MM-DD	2016-10-31
DESIGNED	SJS
PREPARED	SJS
REVIEWED	####
APPROVED	####

PROJECT NO.	CONTROL	REV.	FIGURE
1659907	####	A	**A-5**

PATH: G:\MaineDOT\Allagash\99_PROJECTS\1659907_Allagash\02_PRODUCTION\MXD\FIGURES\RevA\1659907_005_TUFLOW_Allagash.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
0 1 in



LEGEND

- Boundary Condition
- Surveyed cross-sections
- Model Domain

Depth (ft)
High : 22
Low : 0

PRELIMINARY

0 400 800 1,600
Feet

NOTE(S)
1. LINE NOTES
2. LINE NOTES
3. LINE NOTES

REFERENCE(S)
1. REFERENCE 1
2. REFERENCE 2
3. REFERENCE 3

CLIENT
MAINE DOT

PROJECT
EVALUATION AND STABILIZATION OF UNSTABLE SLOPES
STATE ROUTE 161, ST. FRANCIS AND ALLAGASH, MAINE

TITLE
2D MODELING RESULTS - DEPTH
100-YEAR EVENT (NO ICE)
ALLAGASH SITE

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-10-31
DESIGNED	SJS
PREPARED	SJS
REVIEWED	####
APPROVED	####

PROJECT NO.	CONTROL	REV.	FIGURE
1659907	####	A	**A-6**

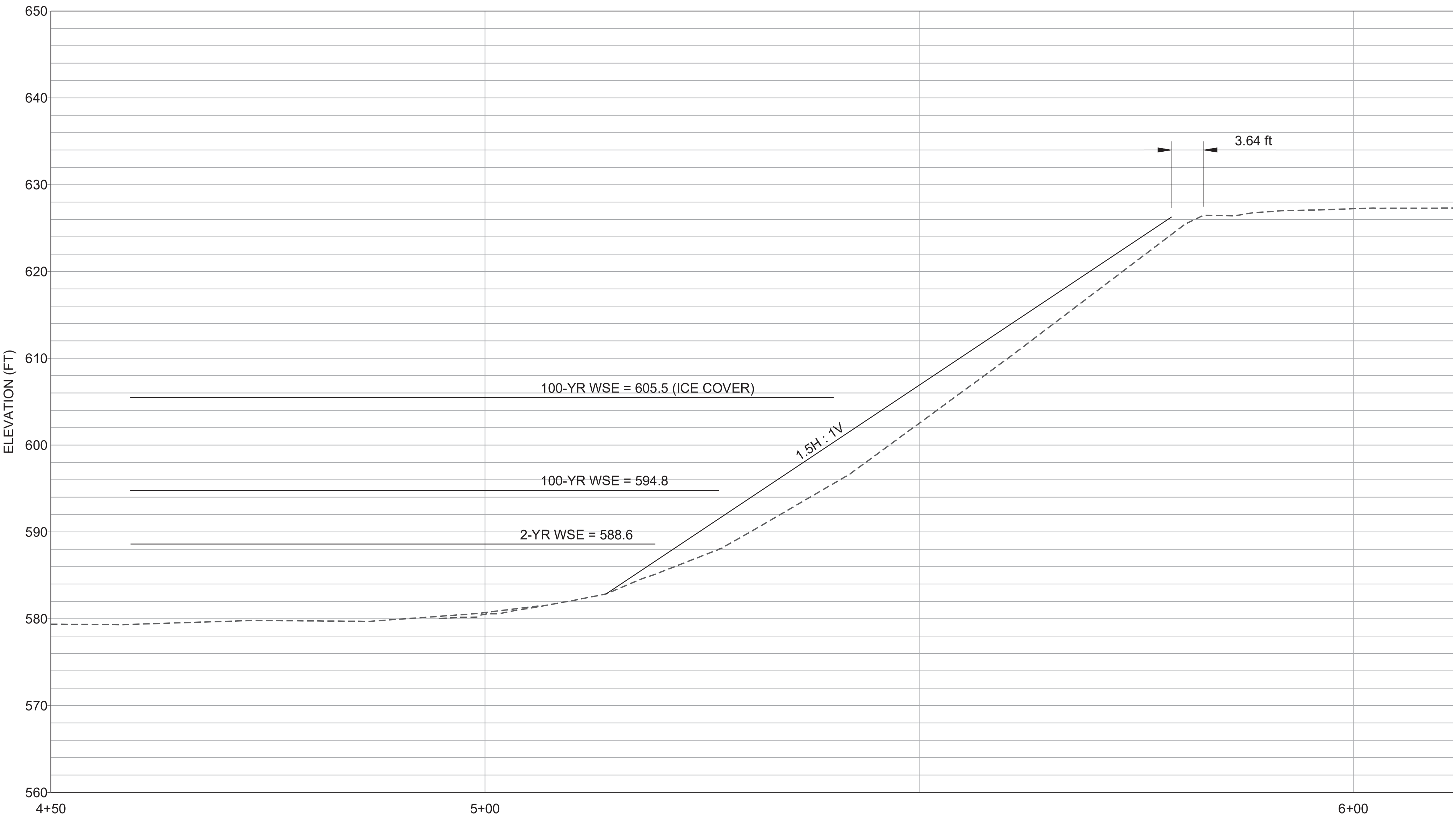
PATH: G:\MaineDOT\Allagash\99_PROJECTS\1659907_Allagash\02_PRODUCTION\MXD\FIGURES\RevA\1659907_006_TUFLOW_Allagash.mxd

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

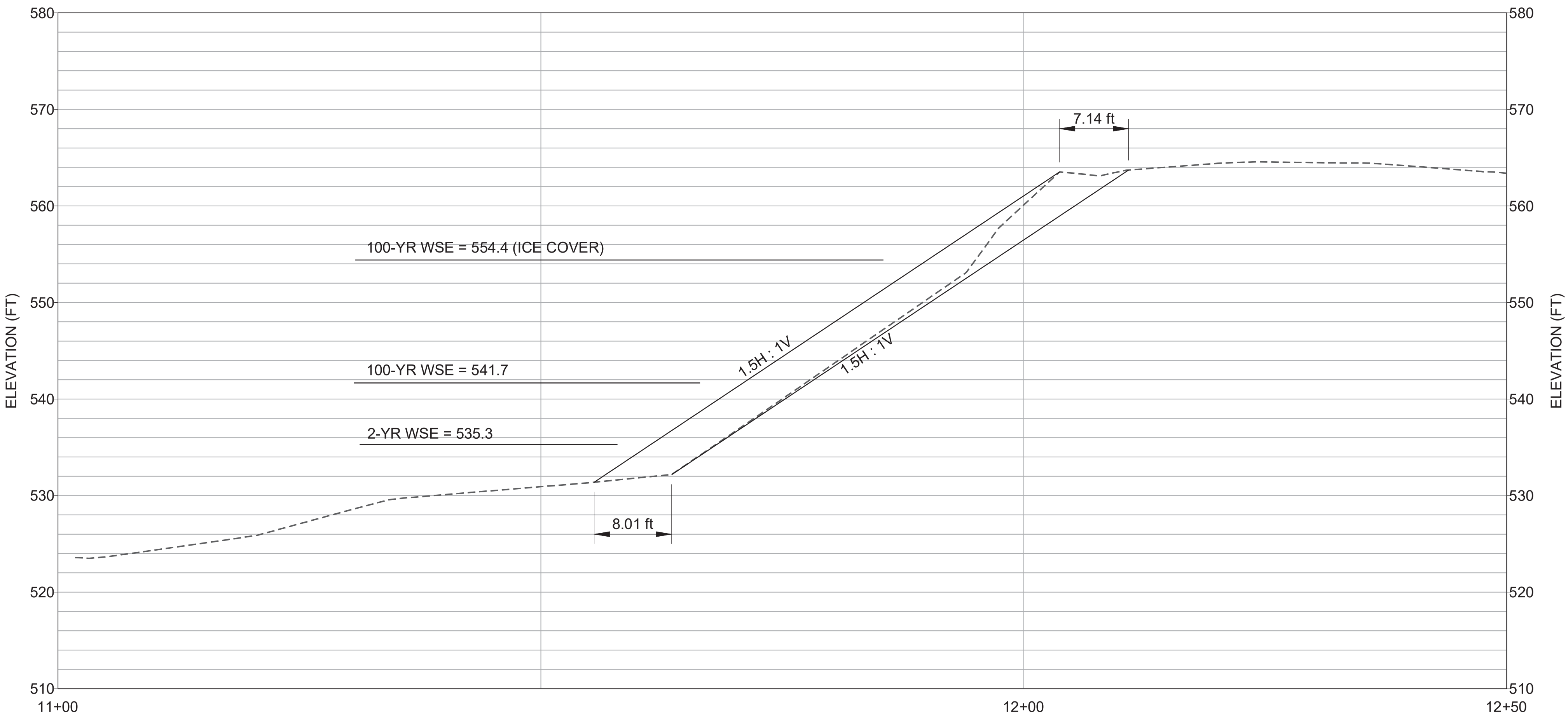
0 1 in

APPENDIX B

Preliminary Flood Level Sections



ALLAGASHXS003



STFRANCISXS003

APPENDIX C

Preliminary Riprap Calculations

PRELIM Riprap Revetment Design Calculations (100-year design event)

MaineDOT / Allagash Project

created by: SS

checked by: AQK

These calculations provide design guidance for sizing the rock for dumped riprap used for bank protection. The NCHRP study, Report 568 "Riprap Design Criteria, Recommended Specification, and Quality control" (Lagasse et al. 2006), evaluated numerous procedures for sizing revetment riprap, and recommends using the method developed by Maynord (1989, 1990) and published by the U.S. Army Corps of Engineers (USACE) as Engineering Manual No. 1110-2-1601 (EM-1601) (USACE 1991). The procedure uses both velocity and depth as its

	Allagash	St Francis
V_avg, Channel x-c average velocity (ft/s)	6.85	9.21
water surface elevation (ft)	594.77	541.66
channel invert (ft)	575.87	520.53
y, local depth of flow (ft)	18.9	21.13
bank slope (xH:1)	1.8	1.8
Θ, bank angle (degrees)	29.1	29.1
Θ, bank angle (radians)	0.51	0.51
K1, Side slope correction factor	0.82	0.82
Rc, Radius of curvature of channel bend (ft)	4000	4000
W, Width of water surface (ft)	700	1000
Rc/W	5.71	4.00
V_des, Characteristic velocity for design (ft/s)	9.22	13.14
Sf, safety factor	2	2
CS, stability coefficient	0.3	0.3
CV, veloctiy distribution coefficient	1.13	1.16
CT, blanket coefficient	1	1
V_des, Characteristic velocity for design (ft/s)	9.22	13.14
K1, Side slope correction factor	0.82	0.82
Sg, Specific gravity of riprap	2.65	2.65
g, gravitational acceleration (ft/s^2)	32.2	32.2
d_30, Particle size for which 30% is finer by weight (ft)	0.75	1.81
d_50, Particle size for which 50% is finer by weight (ft)	0.90	2.17

The EM-1601 equation can be used with uniform or gradually varying flow. Coefficients are included to account for the desired safety factor for design, specific gravity of the riprap stone, bank slope, and bendway character. The EM-1601 equation is:

$$d_{30} = y(S_f C_S C_V C_T)\left[\frac{(V_{des})}{\sqrt{K_1(S_g - 1)gy}}\right]^{2.5} \tag{4.1}$$

where:

d_{30}	=	Particle size for which 30% is finer by weight, ft (m)
y	=	Local depth of flow, ft (m)
S_f	=	Safety factor (must be > 1.0)
C_S	=	Stability coefficient (for blanket thickness = d_{100} or $1.5d_{50}$, whichever is greater, and uniformity ratio d_{85}/d_{15} = 1.7 to 5.2) = 0.30 for angular rock = 0.375 for rounded rock
C_V	=	Velocity distribution coefficient = 1.0 for straight channels or the inside of bends = 1.283 - 0.2log(R_c/W) for the outside of bends (1.0 for R_c/W > 26) = 1.25 downstream from concrete channels = 1.25 at the end of dikes
C_T	=	Blanket thickness coefficient given as a function of the uniformity ratio d_{85}/d_{15}. C_T = 1.0 is recommended because it is based on very limited data.
V_{des}	=	Characteristic velocity for design, defined as the depth-averaged velocity at a point 20% upslope from the toe of the revetment, ft/s (m/s) For natural channels, $V_{des} = V_{avg}(1.74 - 0.52\log(R_c/W))$ $V_{des} = V_{avg}$ for $R_c/W > 26$ For trapezoidal channels, $V_{des} = V_{avg}(1.71 - 0.78 \log(R_c/W))$ $V_{des} = V_{avg}$ for $R_c/W > 8$
V_{avg}	=	Channel cross-sectional average velocity, ft/s (m/s)
K_1	=	Side slope correction factor $K_1 = \sqrt{1 - \left(\frac{\sin(\theta - 14°)}{\sin(32°)}\right)^{1.6}}$ where: θ is the bank angle in degrees
R_c	=	Centerline radius of curvature of channel bend, ft (m)
W	=	Width of water surface at upstream end of channel bend, ft (m)
S_g	=	Specific gravity of riprap (usually taken as 2.65)
g	=	Acceleration due to gravity, 32.2 ft/s^2 (9.81 m/s^2)

APPENDIX D

Scour Calculations

Bend Scour Analysis (FHWA Method) - Allagash Site

Maine DOT / Highway 161 Slope Stabilization at Allagash and St Francis
Created by: GK 11/18/2016
Checked by: SJS 11/22/2016

Reference for methodology: HEC-23 2nd Edition Chapter 4 & HEC-23 1st Edition Chapter 4.3.5

Hydraulic Data

	100-yr	500-yr
Cross-section	4536.26	4536.26
Channel Top Width, W, ft	550	600
Cross Sectional Area, sf	6000	7200
Hydraulic Depth, Y, ft	10.9	12.0
Max Chl Depth (ft)	16.5	19

Bend Scour

Dmxb/Dmnc = 1.8 - 0.051* (Rc/W) + 0.0084 * (W/Dmnc)

	100-yr	500-yr
age Depth of the Approach Section, D_{mnc} (ft)	10.9	12.0
Width of the Channel W (ft)	550.0	600.0
Radius of Curvature, R_c (ft)	2000.0	2000.0
R_c/W	3.6	3.3
W/D_{mnc}	50.4	50.0
D_{mxb}/D_{mnc}	2.04	2.05
Maximum Depth in the Bend, $D_{mxb\ (ft)}$	22.23	24.60
Existing Depth in the Bend, D_b (ft)	16.50	19.00
Bend Scour, y_s (ft)	**5.7**	**5.6**

Scour Calculation (USBR Method) - Allagash Site

Maine DOT / Highway 161 Slope Stabilization at Allagash and St Francis
Created by: GK 11/18/2016
Checked by: SJS 11/22/2016

Reference for methodology: The purpose of the below calculations are to estimate the potential vertica
and channel geometry. The first set of three calculations follow the empirical procedures outlined in USI

Hydraulic Conditions Proposed Crossing Locations based on HEC-RAS Results
Cross Section 3 - 301.57

Recurrence Interval	Flow (cfs), Q	Min. Channel Elevation (ft)	Water Surface Height (ft)	Max. Depth (ft)	Velocity (ft/s)
2	58000	565.27	581.06	15.79	8.84
5	78000	565.27	583.17	17.9	9.78
10	92000	565.27	584.49	19.22	10.33
25	108000	565.27	585.81	20.54	10.97
50	120000	565.27	586.72	21.45	11.43
100	133000	565.27	587.67	22.4	11.89
500	163000	565.27	589.7	24.43	12.88

Summary of Scour Calculation Results (from below)

Recurrence Interval	Flow (cfs), Q	Niell (1973)	Lacey (1930)	Blench (1969)	Average Scour Depth
2	68000	5.5	3.0	3.5	4.0
5	92000	6.8	3.3	4.2	4.8
10	108000	7.6	3.5	4.6	5.2
25	127000	8.6	3.7	5.1	5.8
50	141000	9.3	3.8	5.4	6.2
100	156000	10.1	3.9	5.8	6.6
500	191000	11.9	4.2	6.5	7.5

Calculation of Scour Depth using Neill (1973)

Variable	Cross Section 1	
Average Incised Channel Depth at Bankfull, d_i	9.94	Assume ~ 2-yr flow
Unit Discharge at Bankfull, q_i	87.9	Assume ~ 2-yr flow
Exponent Factor, m	0.85	(50 mm grain size)
Multiplying Factor, Z	0.55	Straight Reach / Moderate Bend (See

Cross Section 3 - 283.77

Recurrence Interval	Flow (cfs), Q	Design Flood Unit Discharge, qf (ft2/s)	Scour Depth Below Floodwater, df (ft)	Depth of Scour, ds (ft)
2	68000	87.9	9.9	5.5
5	92000	113.1	12.3	6.8
10	108000	129.8	13.8	7.6
25	127000	149.8	15.6	8.6
50	141000	165.1	17.0	9.3
100	156000	181.5	18.4	10.1
500	191000	219.0	21.6	11.9

Calculation of Scour Depth using Lacey (1930)

Variable **Value**

Bend Scour Analysis (FHWA Method) - St Fracis Site

Maine DOT / Highway 161 Slope Stabilization at Allagash and St Francis

Created by: GK 11/18/2016

Checked by: SJS 11/22/2016

Reference for methodology: HEC-23 2nd Edition Chapter 4 & HEC-23 1st Edition Chapter 4.3.5

	100-yr	500-yr
Hydraulic Data		
Cross-section	4381.79	4381.79
Channel Top Width, W, ft	1100	1110
Cross Sectional Area, sf	16940	19170
Hydraulic Depth, Y, ft	15.4	17.3
Max Chl Depth (ft)	21	23

Bend Scour

Dmxb/Dmnc = 1.8 - 0.051* (Rc/W) + 0.0084 * (W/Dmnc)

	100-yr	500-yr
age Depth of the Approach Section, D_{mnc} (ft)	15.4	17.3
Width of the Channel W (ft)	1100.0	1110.0
Radius of Curvature, R_c (ft)	4000.0	4000.0
R_c/W	3.6	3.6
W/D_{mnc}	71.4	64.3
D_{mxb}/D_{mnc}	2.21	2.16
Maximum Depth in the Bend, $D_{mxb\ (ft)}$	34.10	37.24
Existing Depth in the Bend, D_b (ft)	21.00	23.00
Bend Scour, y_s (ft)	**13.1**	**14.2**

Scour Calculation (USBR Method) - St Francis Site

Maine DOT / Highway 161 Slope Stabilization at Allagash and St Francis
Created by: GK 11/18/2016
Checked by: SJS 11/22/2016

Reference for methodology: The purpose of the below calculations are to estimate the potential ver
material, and channel geometry. The first set of three calculations follow the empirical procedures o
The publication outlines three methods estimating scour depths, based on research from Neill (1973

Hydraulic Conditions Proposed Crossing Locations based on HEC-RAS Results
Cross Section 3 - 283.77

Recurrence Interval	Flow (cfs), Q	Min. Channel Elevation (ft)	Water Surface Height (ft)	Max. Depth (ft)
2	68000	518.06	532.05	13.99
5	92000	518.06	533.94	15.88
10	108000	518.06	535.09	17.03
25	127000	518.06	536.36	18.3
50	141000	518.06	537.24	19.18
100	156000	518.06	538.15	20.09
500	191000	518.06	540.11	22.05

Summary of Scour Calculation Results (from below)

Recurrence Interval	Flow (cfs), Q	Niell (1973)	Lacey (1930)	Blench (1969)
2	68000	5.1	3.0	3.1
5	92000	6.6	3.3	3.8
10	108000	7.5	3.5	4.2
25	127000	8.6	3.7	4.7
50	141000	9.4	3.8	5.0
100	156000	10.2	3.9	5.3
500	191000	12.0	4.2	6.0

Calculation of Scour Depth using Neill (1973)

Variable	Cross Section 3	
Incised Channel Depth at Bankfull, d_i	9.36	Assume ~ 2-yr flow
Unit Discharge at Bankfull, q_i	72.2	Assume ~ 2-yr flow
Exponent Factor, m	0.85	(50 mm grain size)
Multiplying Factor, Z	0.55	Straight Reach / Mode

Cross Section 3 - 283.77

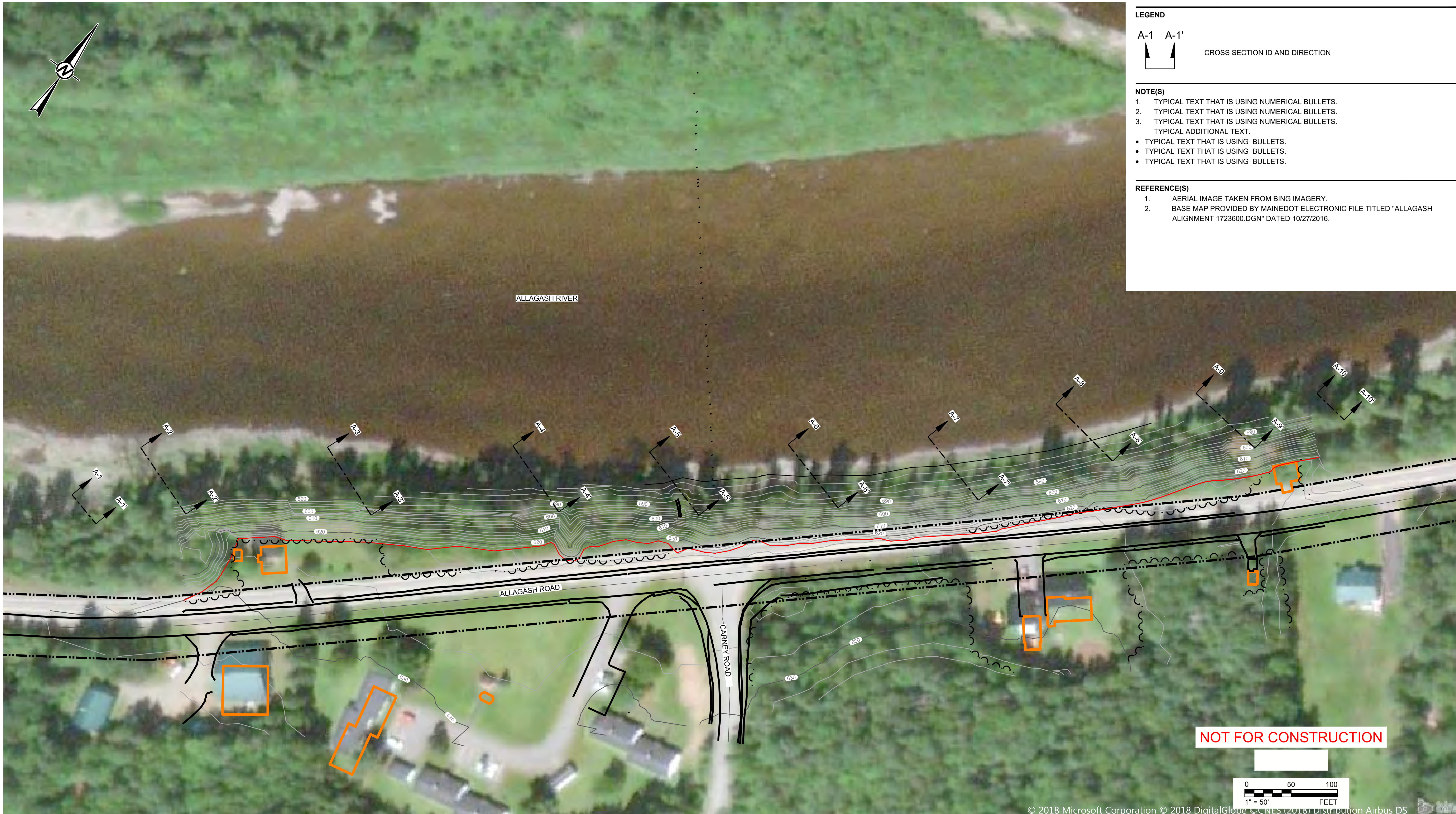
Recurrence Interval	Flow (cfs), Q	Design Flood Unit Discharge, qf (ft2/s)	Scour Depth Below Floodwater, df (ft)
2	68000	72.2	9.4
5	92000	96.8	12.0
10	108000	113.1	13.7
25	127000	132.3	15.7
50	141000	146.3	17.1
100	156000	161.2	18.5
500	191000	195.5	21.8

Calculation of Scour Depth using Lacey (1930)

Variable **Value**

APPENDIX E

Preliminary Allagash Typical Bendway Weir Plan View Layouts



LEGEND

A-1 A-1' CROSS SECTION ID AND DIRECTION

NOTE(S)

1. TYPICAL TEXT THAT IS USING NUMERICAL BULLETS.
2. TYPICAL TEXT THAT IS USING NUMERICAL BULLETS.
3. TYPICAL TEXT THAT IS USING NUMERICAL BULLETS. TYPICAL ADDITIONAL TEXT.

- TYPICAL TEXT THAT IS USING BULLETS.
- TYPICAL TEXT THAT IS USING BULLETS.
- TYPICAL TEXT THAT IS USING BULLETS.

REFERENCE(S)

1. AERIAL IMAGE TAKEN FROM BING IMAGERY.
2. BASE MAP PROVIDED BY MAINEDOT ELECTRONIC FILE TITLED "ALLAGASH ALIGNMENT 1723600.DGN" DATED 10/27/2016.

CLIENT
MAINE DEPARTMENT OF TRANSPORTATION

PROJECT
ALLAGASH SLOPE STABILIZATION
BENDWAY WEIR
ALLAGASH, MAINE

CONSULTANT
Golder Associates

YYYY-MM-DD	2018-01-22
PREPARED	MPB
DESIGN	SCS
REVIEW	AQK
APPROVED	AQK

TITLE
SITE PLAN - ALLAGASH

PROJECT No.	PHASE	Rev.	FIGURE
165-9907	4	----	001

APPENDIX F

Preliminary St. Francis Typical Bendway Weir Plan View Layouts

LEGEND

A-1 A-1' CROSS SECTION ID AND DIRECTION

NOTE(S)

1. TYPICAL TEXT THAT IS USING NUMERICAL BULLETS.
2. TYPICAL TEXT THAT IS USING NUMERICAL BULLETS.
3. TYPICAL TEXT THAT IS USING NUMERICAL BULLETS. TYPICAL ADDITIONAL TEXT.

- TYPICAL TEXT THAT IS USING BULLETS.
- TYPICAL TEXT THAT IS USING BULLETS.
- TYPICAL TEXT THAT IS USING BULLETS.

REFERENCE(S)

1. AERIAL IMAGE TAKEN FROM BING IMAGERY.
2. BASE MAP PROVIDED BY MAINEDOT ELECTRONIC FILE TITLED "ALLAGASH ALIGNMENT 1723600.DGN" DATED 10/27/2016.

CLIENT
MAINE DEPARTMENT OF TRANSPORTATION

CONSULTANT

Golder Associates

YYYY-MM-DD	2018-01-22
PREPARED	MPB
DESIGN	SCS
REVIEW	AQK
APPROVED	AQK

PROJECT
ALLAGASH SLOPE STABILIZATION
BENDWAY WEIR
ST FRANCIS, ME

TITLE
SITE PLAN - ST FRANCIS

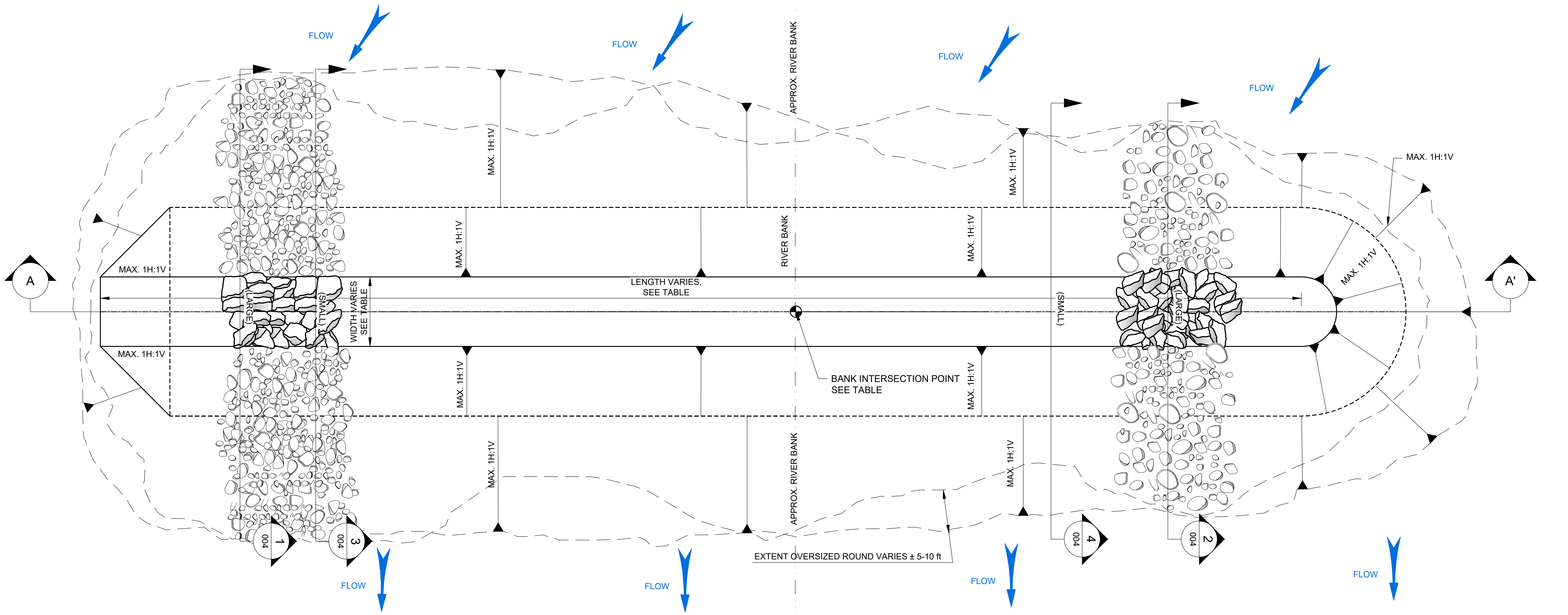
PROJECT No.	PHASE	Rev.	FIGURE
165-9907	4	----	002

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI D

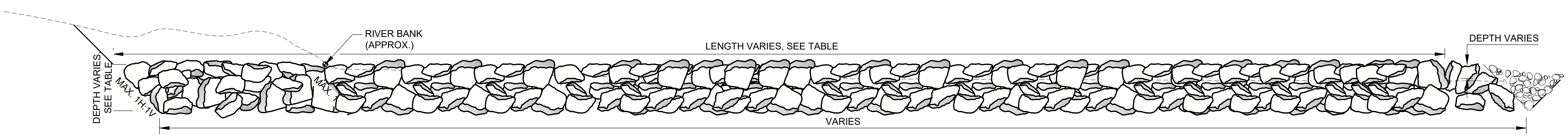
Path: C:\Users\MBoisvert\Desktop\ | File Name: 1659907004002.dwg

APPENDIX G

Preliminary Typical Bendway Weir Profile/Section Views



SCALE N.T.S. 1 BENDWAY WEIR DETAIL



SCALE: N.T.S. A BENDWAY WEIR PROFILE

NOT FOR CONSTRUCTION

LEGEND

CORE RIPRAP

OVERSIZED ROUND MIXED WITH NATIVE EXCAVATED SEDIMENT

APPROXIMATE TOE OF RIPRAP CORE

APPROXIMATE EXTENTS OVERSIZED ROUND

NOTE

1. FINAL CONFIGURATION AND LOCATION OF STRUCTURES AND ASSOCIATED WORK TO BE DETERMINED BASED ON SITE CONDITIONS AT THE TIME OF CONSTRUCTION, AND AS DIRECTED BY OWNERS REPRESENTATION.

CLIENT
MAINE DEPARTMENT OF TRANSPORTATION

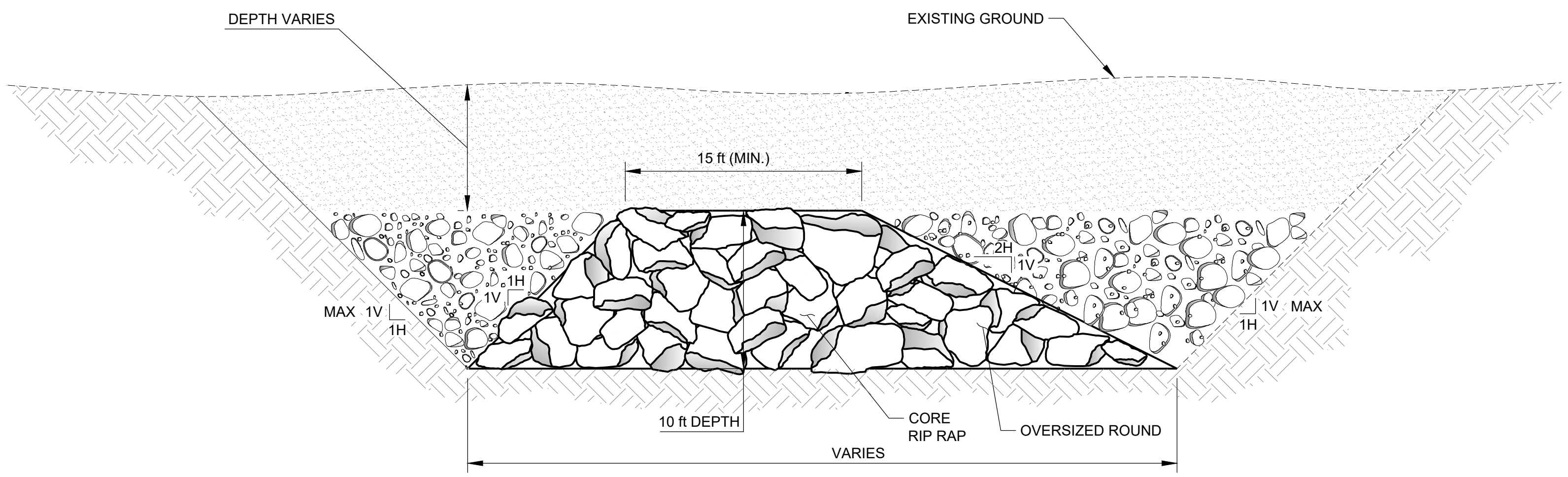
CONSULTANT
Golder Associates

YYYY-MM-DD	2018-01-22
PREPARED	MPB
DESIGN	SCS
REVIEW	AQK
APPROVED	AQK

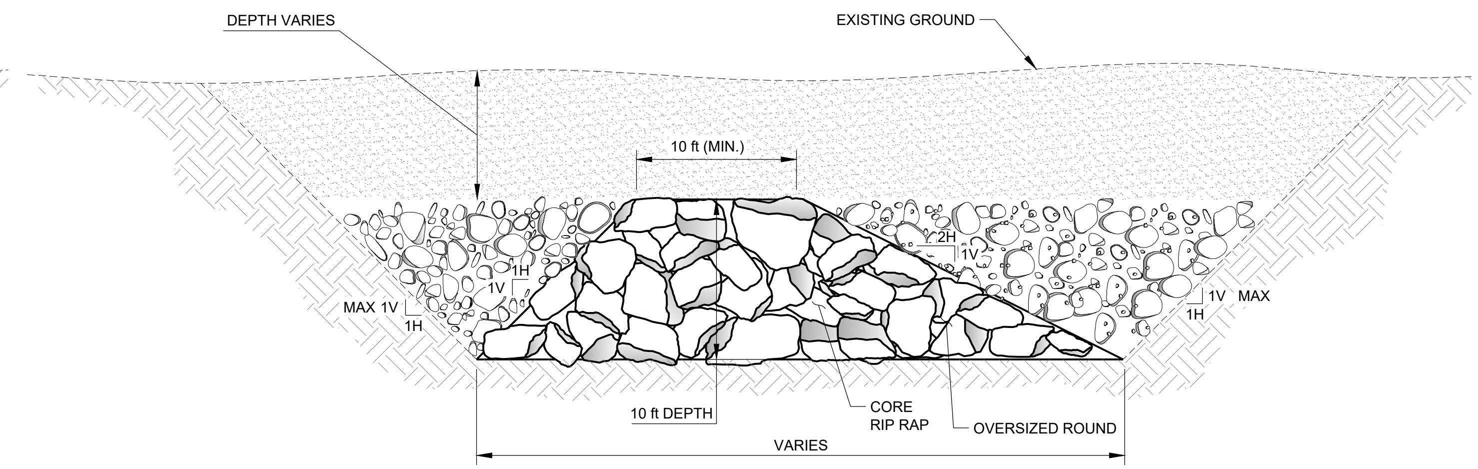
PROJECT
ALLAGASH SLOPE STABILIZATION
BENDWAY WEIR
ALLAGASH, MAINE

TITLE
TYPICAL PROFILE

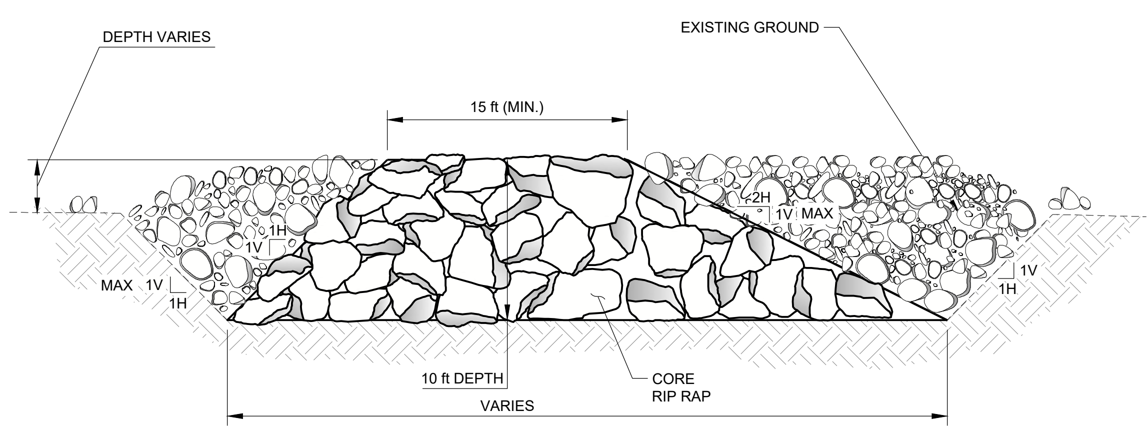
PROJECT No.	PHASE	Rev.	FIGURE
165-9907	4	----	003



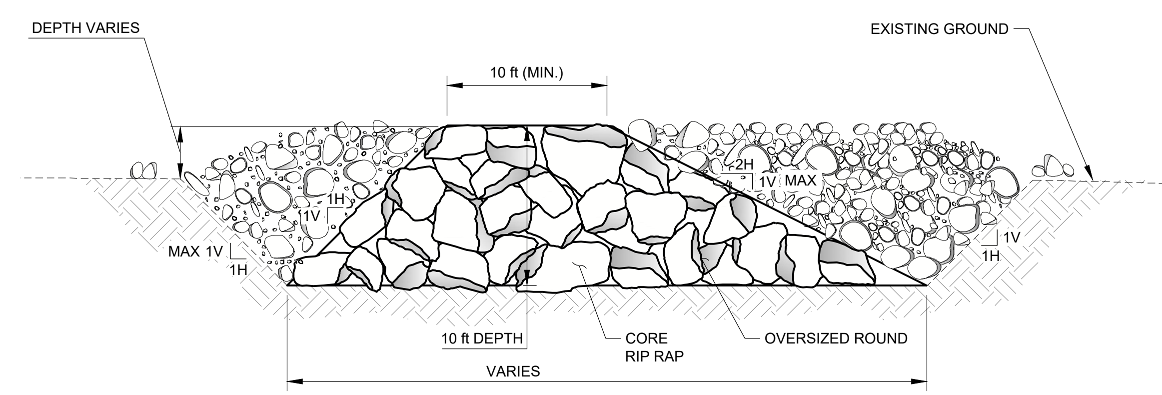
SCALE: A (1) IN-BANK SECTION LARGE - TYP.



SCALE: A (3) IN-BANK SECTION SMALL - TYP.



SCALE: A (2) OUT-BANK SECTION LARGE - TYP.



SCALE: A (4) OUT-BANK SECTION SMALL - TYP.

Bendway Weir	Length (ft)	Typical Section	Upstream Slope (XH:1V)	Top Width (ft)	Height (ft)	Downstream Slope (XH:1V)	Bottom Width (ft)	Orientation (Deg)1	Approx Riprap Volume (CY)
A-1	40	DETAIL 3 and 4	1	10	10	2	40	60	718
A-2	45	DETAIL 3 and 4	1	10	10	2	40	60	775
A-3	86	DETAIL 3 and 4	1	10	10	2	40	60	1481
A-4	86	DETAIL 3 and 4	1	10	10	2	40	60	1481
A-5	86	DETAIL 3 and 4	1	10	10	2	40	60	1481
A-6	86	DETAIL 3 and 4	1	10	10	2	40	60	1481
A-7	86	DETAIL 3 and 4	1	10	10	2	40	60	1481
A-8	86	DETAIL 3 and 4	1	10	10	2	40	60	1481
A-9	86	DETAIL 3 and 4	1	10	10	2	40	60	1481
A-10	40	DETAIL 3 and 4	1	10	10	2	40	60	689
SF-1	40	DETAIL 1 and 2	1	15	10	2	45	60	778
SF-2	86	DETAIL 1 and 2	1	15	10	2	45	60	1672
SF-3	86	DETAIL 1 and 2	1	15	10	2	45	60	1672
SF-4	86	DETAIL 1 and 2	1	15	10	2	45	60	1672
SF-5	86	DETAIL 1 and 2	1	15	10	2	45	60	1672
SF-6	40	DETAIL 1 and 2	1	15	10	2	45	60	778

NOT FOR CONSTRUCTION

NOTES

1. FINAL CONFIGURATION AND LOCATION OF STRUCTURES AND ASSOCIATED WORK TO BE DETERMINED BASED ON SITE CONDITIONS AT THE TIME OF CONSTRUCTION, AND AS DIRECTED BY THE OWNERS REPRESENTATION.

0 6 12
SCALE: A FEET

CLIENT
MAINE DEPARTMENT OF TRANSPORTATION

CONSULTANT

Golder Associates

YYYY-MM-DD	2018-01-22
PREPARED	MPB
DESIGN	SCS
REVIEW	AQK
APPROVED	AQK

PROJECT
ALLAGASH SLOPE STABILIZATION
BENDWAY WEIR
ALLAGASH, MAINE

TITLE
TYPICAL SECTIONS

PROJECT No.	PHASE	Rev.	FIGURE
165-9907	4	----	004

APPENDIX M

Slope Stability Analysis

GOLDER

CALCULATIONS

Date:	6/8/2018	**Made by:**	CJS
Project No.:	1659907	**Checked by:**	JDL
Subject:	Global Stability Analysis	**Reviewed by:**	MSP
Project Short Title:	St. Francis & Allagash Slope Stabilization		

1.0 Purpose
Calculate global factor of safety for the slopes next to the road at existing conditions and proposed grades. Determine if ground stabilization is required.

2.0 Method
Use Slide slope stability analysis software to analyze global stability.

3.0 References
1) Bowles, Joseph E., (1982), "Foundation Analysis and Design," McGraw-Hill, Inc., pp 100.
2) Golder Associates boring logs, Report Appendix E.
3) Rocscience Slide Software Package version 7.036, dated May 24, 2018.
4) Holtz, Robert D. and Kovacs, William D., "An Introduction to Geotechnical Engineering," Prentice-Hall, Inc., Upper Saddle River, New Jersey, 1981.
6) Golder Internal Direct Shear Database titled "Golder internal DShrDatabase.xlsx"

4.0 Attachments
1) Slide Output Figures

5.0 Assumptions
1) The load applied by the road and traffic is modeled at 250 psf.
2) Cohesive layers (at St. Francis) are assumed to exhibit fully undrained behavior (φ' = 0). Coarse grained soils are assumed to exhibit fully drained behavior (c' = 0).
3) Final design slopes are installed at 1.75H:1V with material layering and subsurface benching as shown in the design drawings (Figure 2).
4) The rip rap and cushion layers are free draining.
5) The geotextile interface is not included in the slide model due to limitations modeling the thinness of the layer. Based on a compilation of Golder's internal Direct Shear Database (Reference 6), the interface shear strength along the geotextile is anticipated to be greater than the interface strength between the cushion and reworked fill. Therefore, the model is conservatively modeled without the geotextile. However, Golder recommends conducting interface shear testing between the cushion material and the geotextile prior to construction to confirm this assumption.
6) Preliminary analyses indicated seimic stability was unlikely to be an issue, so it was not evaluated for final design.
7) Steady state ground water conditions are based on field observations and measurements at the time of drilling. The rapid drawdown scenario is intended to simulate an ice jam and assumes that the river and groundwater have risen to the 100 year flood elevation followed by a release of the ice jam. When the ice jam has released the river is level is assumed to drop while the groundwater table stays elevated. We have assumed that drainage layers drain the fill, cushion and rip rap at the same rate that the river drops (i.e. free draining).
8) The 100 year flood elevation for St. Francis is at 554 ft. and the 100 year flood elevation for Allagash is 606 ft.

6.0 Calculation
6.1 Material Properties
Determine input parameters to build the soil model in Slide. Use field N values, existing soil slope angles, and local engineering experience to develop soil and riprap parameters. The field N values are shown on the boring logs (Reference 2). Table 6.1 below summarizes the material properties used in the slide models for the St. Francis and Allagash sites.

GOLDER

CALCULATIONS

Date: 6/8/2018 **Made by:** CJS

Project No.: 1659907 **Checked by:** JDL

Subject: Global Stability Analysis **Reviewed by:** MSP

Project Short Title: St. Francis & Allagash Slope Stabilization

Table 6.1: St. Francis Material Properties

Material Name	Unit Weight (pcf)	Strength Type	Cohesion (psf)	Friction Angle (°)	Comments
Riprap	140	Mohr-Coulomb	0	42	Based on local engineering experience for specified material
Structural Fill	120	Mohr-Coulomb	0	34	Based on local engineering experience, and assumption that reworked native fill will have less strength than the undisturbed material
Grubbing	120	Mohr-Coulomb	50	32	Assumed properties
Cushion	125	Mohr-Coulomb	0	34	Based on local engineering experience for specified material
Alluvium	120	Mohr-Coulomb	0	32	Based on DCP testing results and local experience with rounded river gravels
Glacial Stream Deposit	120	Mohr-Coulomb	0	37	Based on observed SPT blow counts and exisiting slope angles assuming FS~=1
Glacial Lake Bottom Deposit	120	Mohr-Coulomb	1500	0	Based on pocket penetrometer readings, SPT blow counts, and field observations
Ablation Till	130	Mohr-Coulomb	0	39	Based on observed SPT blow counts and exisiting slope angles assuming FS~=1

Table 6.2: Allagash Material Properties

Material Name	Unit Weight (pcf)	Strength Type	Cohesion (psf)	Friction Angle (°)	Comments
Riprap	140	Mohr-Coulomb	0	42	Based on local engineering experience for specified material
Structural Fill	120	Mohr-Coulomb	0	34	Based on local engineering experience, and assumption that reworked native fill will have less strength than the undisturbed material
Grubbing	120	Mohr-Coulomb	50	32	Assumed properties
Cushion	125	Mohr-Coulomb	0	34	Based on local engineering experience for specified material
Alluvium	120	Mohr-Coulomb	0	32	Based on DCP testing results and local experience with rounded river gravels
Glacial Stream Deposit	120	Mohr-Coulomb	0	38	Based on observed SPT blow counts and exisiting slope angles assuming FS~=1
Ablation Till	130	Mohr-Coulomb	0	39	Based on observed SPT blow counts and exisiting slope angles assuming FS~=1

6.2 Groundwater Conditions

For both St. Francis and Allagash, the water levels for the stability models are based on the observed water levels during the drilling program. The initial conditions and the final design slopes were also analyzed under rapid drawdown conditions where the initial water table was set to the 100 year flood elevations (elevation 540 ft. for St. Francis and elevation 606 ft. for Allagash) and the post drawdown water table was the water levels observed during drilling

Date: 6/8/2018 **Made by:** CJS
Project No.: 1659907 **Checked by:** JDL
Subject: Global Stability Analysis **Reviewed by:** MSP
Project Short Title: St. Francis & Allagash Slope Stabilization

6.3 Slope Conditions Analyzed

Use the soil layer parameters above to analyze the following scenarios:

1) Representative Allagash slope sections lunder the following conditions:
   - Initial conditions with normal water table and rapid drawdown
   - Final riprap slope condition with normal water table and rapid drawdown

2) Representative St. Francis slope sections under the following conditions:
   - Initial conditions with normal water table and rapid drawdown
   - Final riprap slope condition with normal water table and rapid drawdown

7.0 Results

The results of the Slide stability analyses are summarized in the following tables. Table 7.1 is a summary of the St. Francis results and Table 7.2 is a summary of the Allagash results.

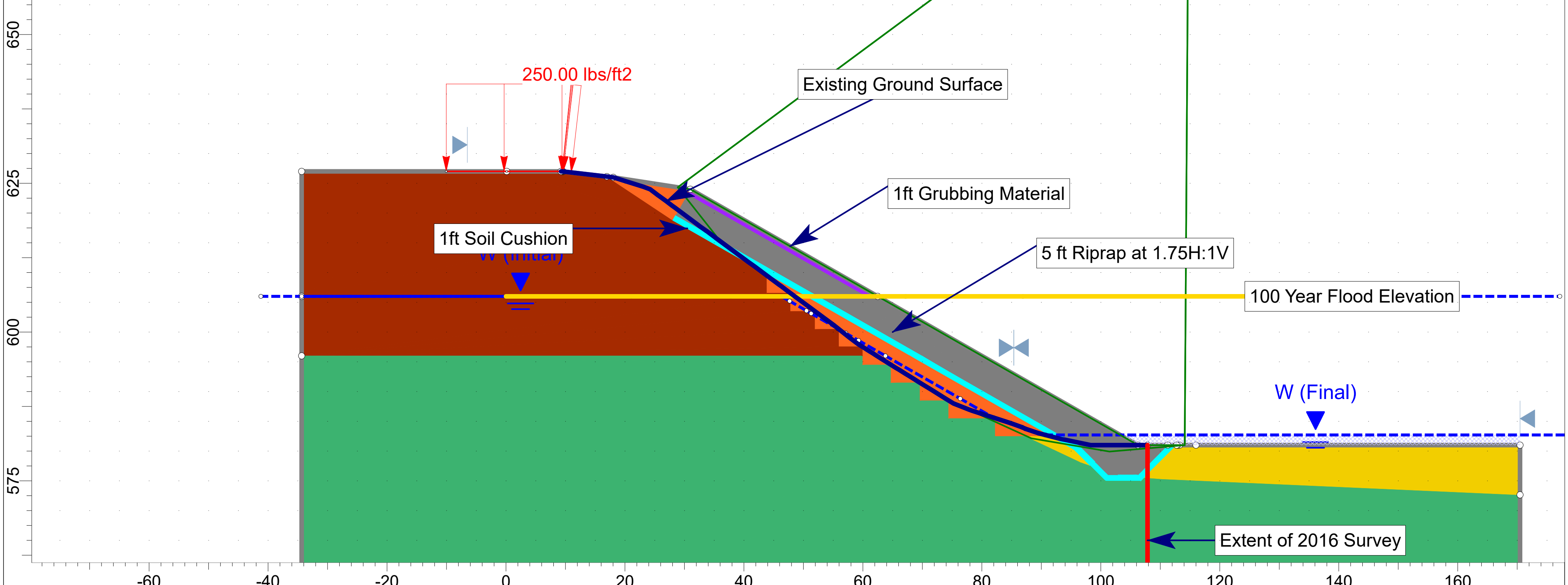
Figure #	Site	Section	Station	GW Case	FS
AL-1	Allagash	2	107+88	Rapid Drawdown	1.29
AL-2				Steady State	1.34
AL-3		5	109+38	Rapid Drawdown	1.30
AL-4				Steady State	1.33
AL-5		9	111+38	Rapid Drawdown	1.29
AL-6				Steady State	1.33
AL-7		11	112+38	Rapid Drawdown	1.30
AL-8				Steady State	1.30
SF-1	St Francis	2	5+78	Rapid Drawdown	1.30
SF-2				Steady State	1.30
SF-3		8	8+78	Rapid Drawdown	1.40
SF-4				Steady State	1.40
SF-5		13	11+28	Rapid Drawdown	1.26
SF-6				Steady State	1.34
SF-7		17	13+78	Rapid Drawdown	1.25
SF-8				Steady State	1.43

8.0 Conclusion and Recommendations

● Proposed stabilized river slopes analyzed are stable against global stability failures and indicate FS>1.3 for normal water level and FS>1.1 for rapid drawdown case, as detailed.

● Construction conditions (i.e. setback requirements for loads [equipment, material stockpiles, etc.] at crest, temporary access roads on the slope, and toe of slope excavations for riprap) warrant further analyses during PS&E phase, or prior to construction when the construction strategy is understood.

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium		120	Mohr-Coulomb	0	32
Abla. on Till		130	Mohr-Coulomb	0	39
Structural Fill		120	Mohr-Coulomb	0	34
Rip Rap		140	Mohr-Coulomb	0	42
Glacial Stream Deposit		120	Mohr-Coulomb	0	38
Grubbing		120	Mohr-Coulomb	50	32
Cushion		125	Mohr-Coulomb	0	34



Golder Associates

SLIDEINTERPRET 7.036

Project Allagash Slope Stability

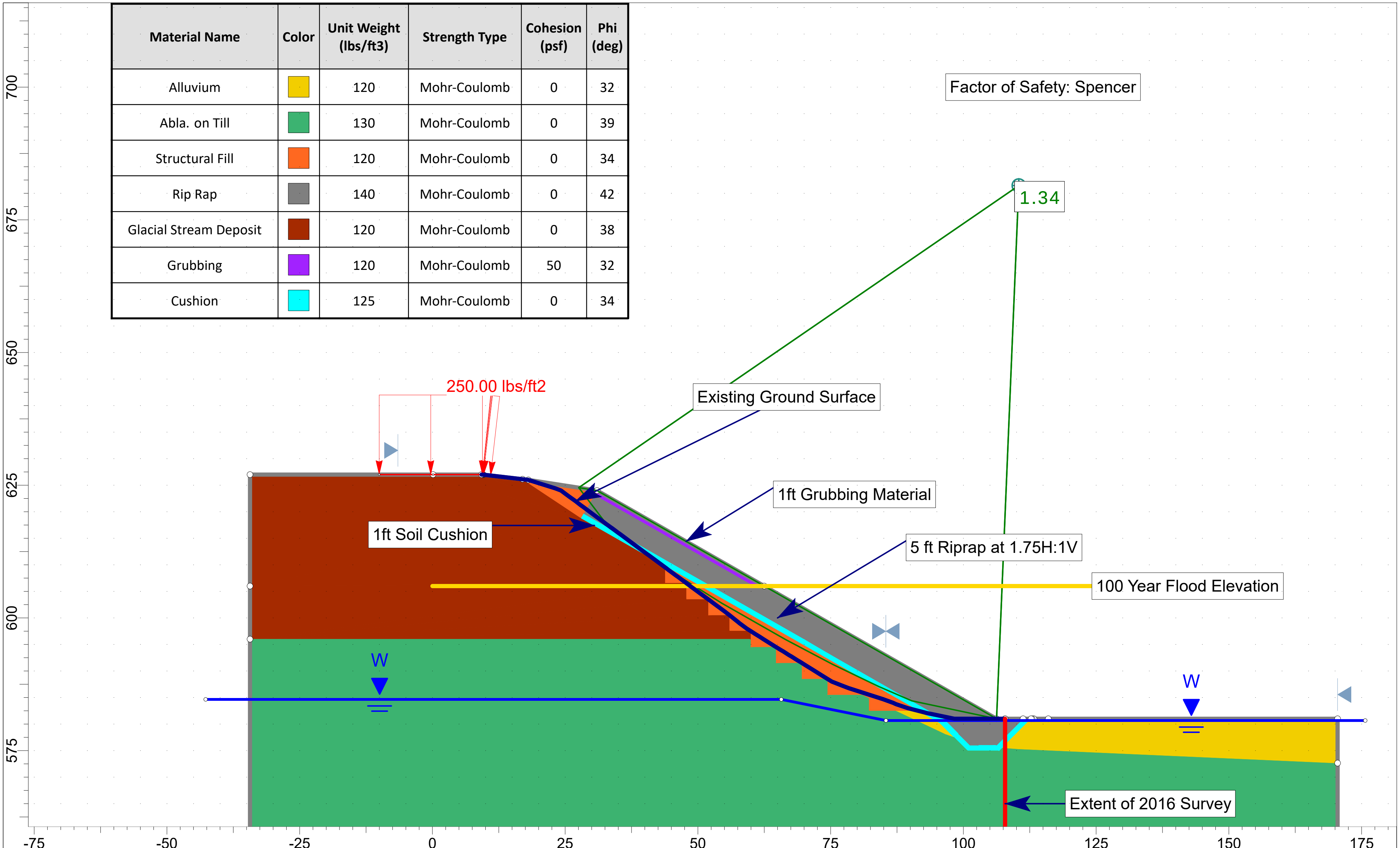
Analysis Description Station 107+88, Section 2, Final 1.75H:1V Slope Rapid Drawdown

Drawn By CJS | *Checked by:* JDL | *Reviewed by:* MSP | *Scale* 1:300

Date 6/1/2018

Figure AL-1

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium		120	Mohr-Coulomb	0	32
Abla. on Till		130	Mohr-Coulomb	0	39
Structural Fill		120	Mohr-Coulomb	0	34
Rip Rap		140	Mohr-Coulomb	0	42
Glacial Stream Deposit		120	Mohr-Coulomb	0	38
Grubbing		120	Mohr-Coulomb	50	32
Cushion		125	Mohr-Coulomb	0	34



Golder Associates

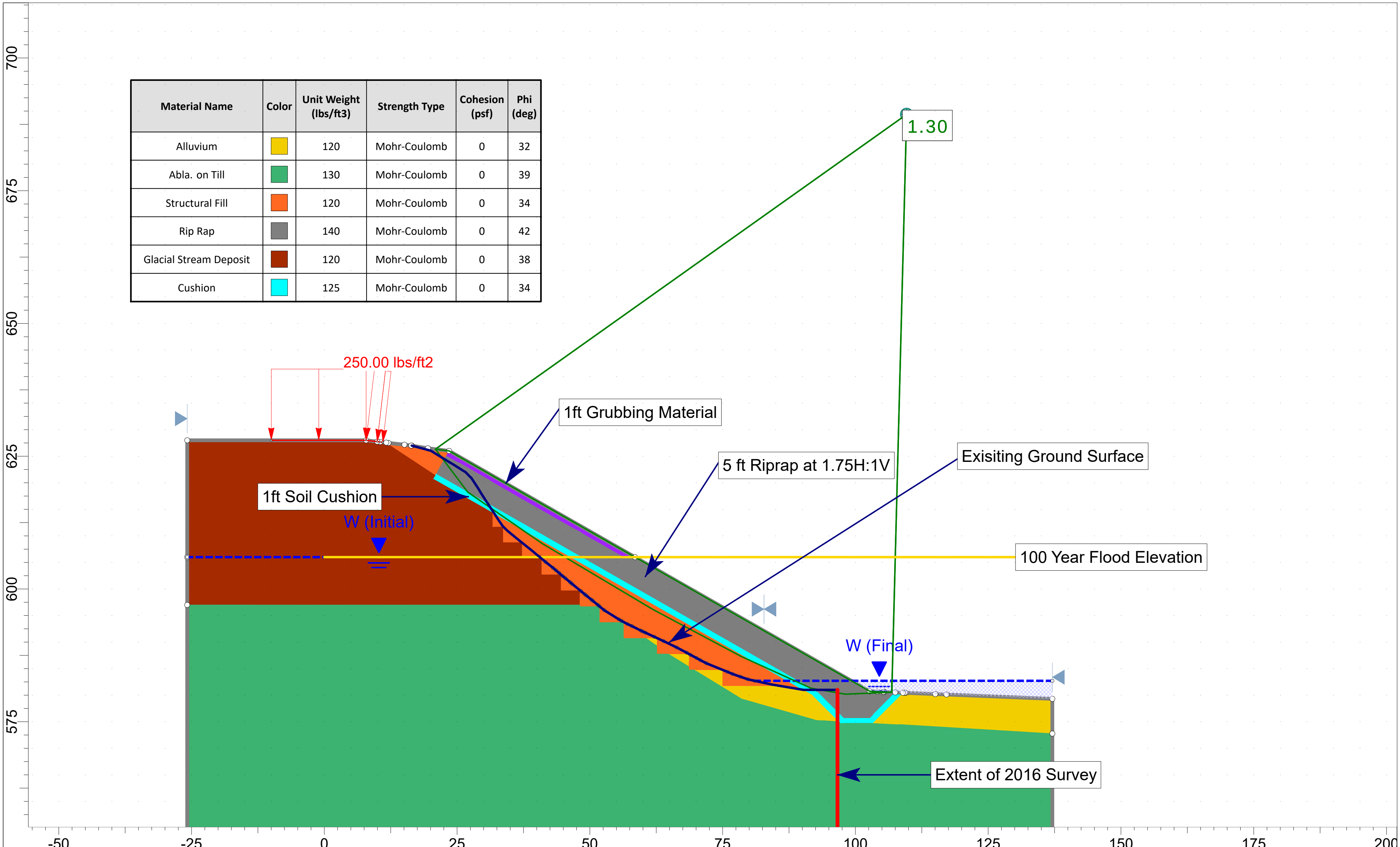
SLIDEINTERPRET 7.036

Project	Allagash Slope Stability
Analysis Description	Station 107+88, Section 2, Final 1.75H:1V Slope Steay State Groundwater

Drawn By CJS | *Checked by:* JDL | *Reviewed by:* MSP | *Scale* 1:300

Date 6/1/2018

Figure AL-2



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium		120	Mohr-Coulomb	0	32
Abla. on Till		130	Mohr-Coulomb	0	39
Structural Fill		120	Mohr-Coulomb	0	34
Rip Rap		140	Mohr-Coulomb	0	42
Glacial Stream Deposit		120	Mohr-Coulomb	0	38
Cushion		125	Mohr-Coulomb	0	34

Golder Associates

SLIDEINTERPRET 7.036

Project
Allagash Slope Stability

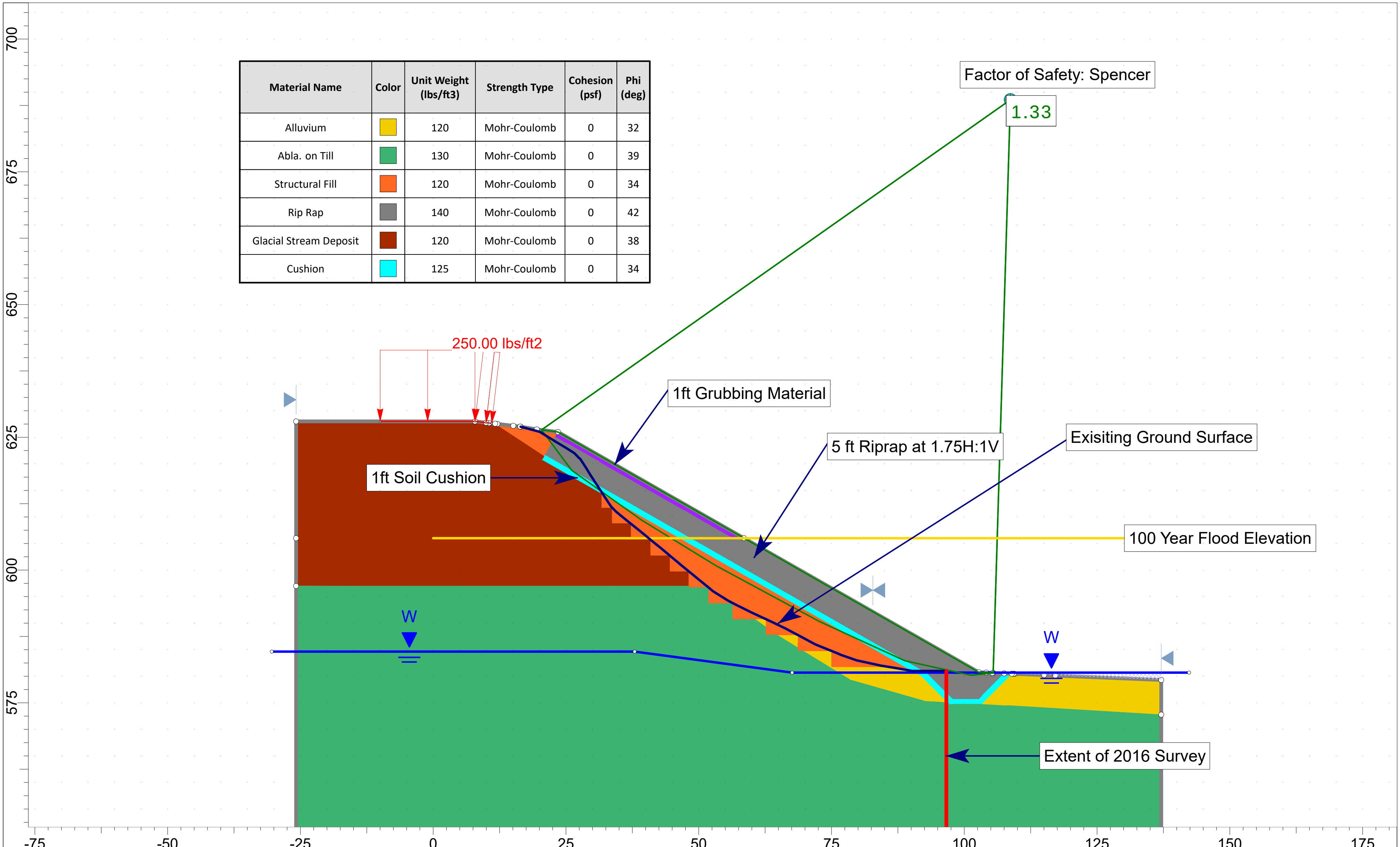
Analysis Description
Station 109+38, Section 5, Final 1.75H:1V Slope Rapid Drawdown

Drawn By CJS | *Checked by:* JDL | *Reviewed by:* MSP | *Scale* 1:300

Date 6/1/2018

Figure AL-3

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium		120	Mohr-Coulomb	0	32
Abla. on Till		130	Mohr-Coulomb	0	39
Structural Fill		120	Mohr-Coulomb	0	34
Rip Rap		140	Mohr-Coulomb	0	42
Glacial Stream Deposit		120	Mohr-Coulomb	0	38
Cushion		125	Mohr-Coulomb	0	34



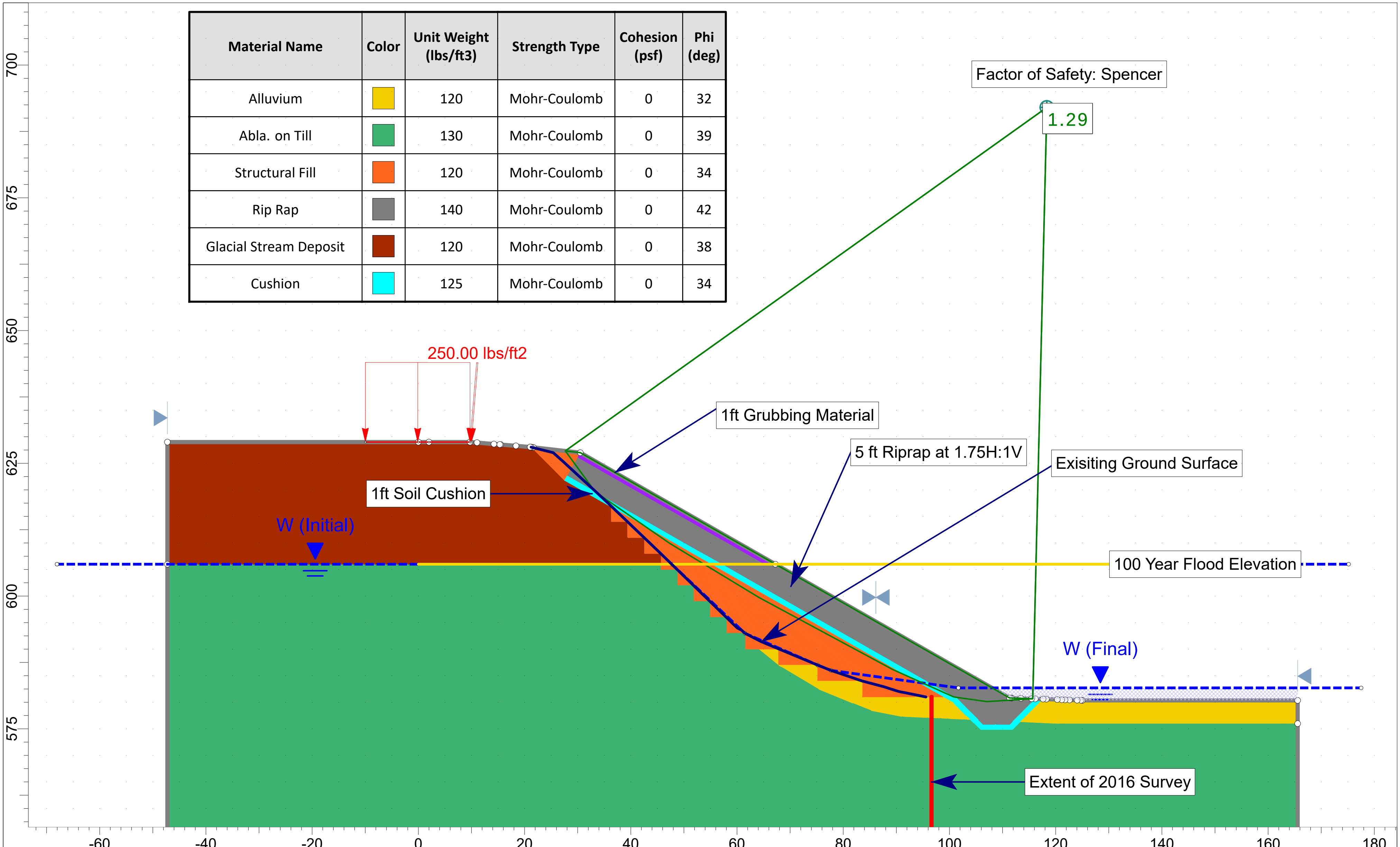
Golder Associates

SLIDEINTERPRET 7.036

Project	Allagash Slope Stability
Analysis Description	Station 109+38, Section 5, Final 1.75H:1V Slope Steady State Groundwater
Drawn By CJS	*Checked by:* JDL
Reviewed by: MSP	*Scale* 1:300
Date	6/1/2018

Figure AL-4

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium		120	Mohr-Coulomb	0	32
Abla. on Till		130	Mohr-Coulomb	0	39
Structural Fill		120	Mohr-Coulomb	0	34
Rip Rap		140	Mohr-Coulomb	0	42
Glacial Stream Deposit		120	Mohr-Coulomb	0	38
Cushion		125	Mohr-Coulomb	0	34

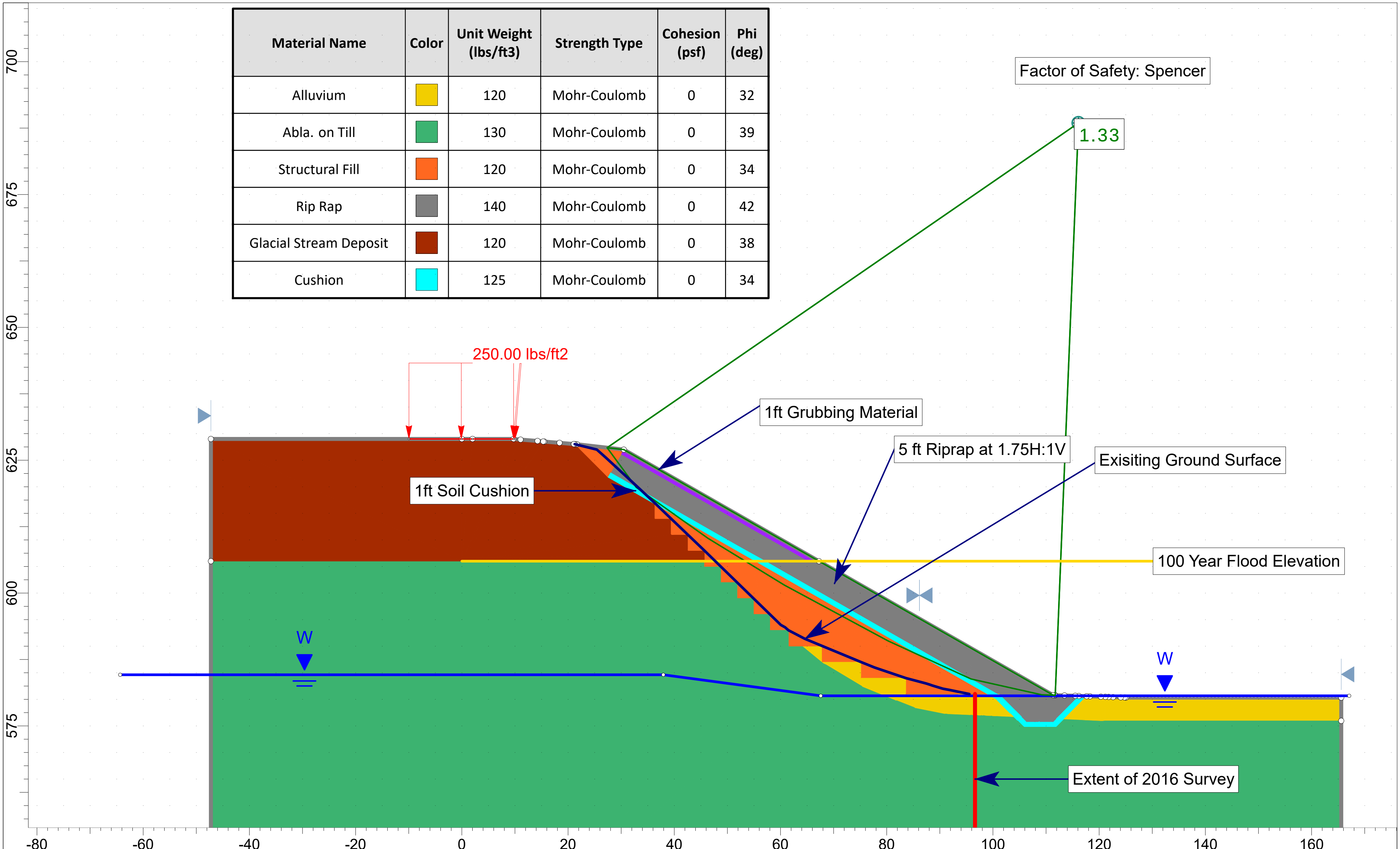


Golder Associates

SLIDEINTERPRET 7.036

Project	Allagash Slope Stability
Analysis Description	Station 111+38, Section 9, Final 1.75H:1V Slope Rapid Drawdown
Drawn By CJS	*Checked by:* JDL
Reviewed by: MSP	*Scale* 1:300
Date	6/1/2018

Figure AL-5



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium	Yellow	120	Mohr-Coulomb	0	32
Abla. on Till	Green	130	Mohr-Coulomb	0	39
Structural Fill	Orange	120	Mohr-Coulomb	0	34
Rip Rap	Gray	140	Mohr-Coulomb	0	42
Glacial Stream Deposit	Dark red	120	Mohr-Coulomb	0	38
Cushion	Cyan	125	Mohr-Coulomb	0	34

Golder Associates

SLIDEINTERPRET 7.036

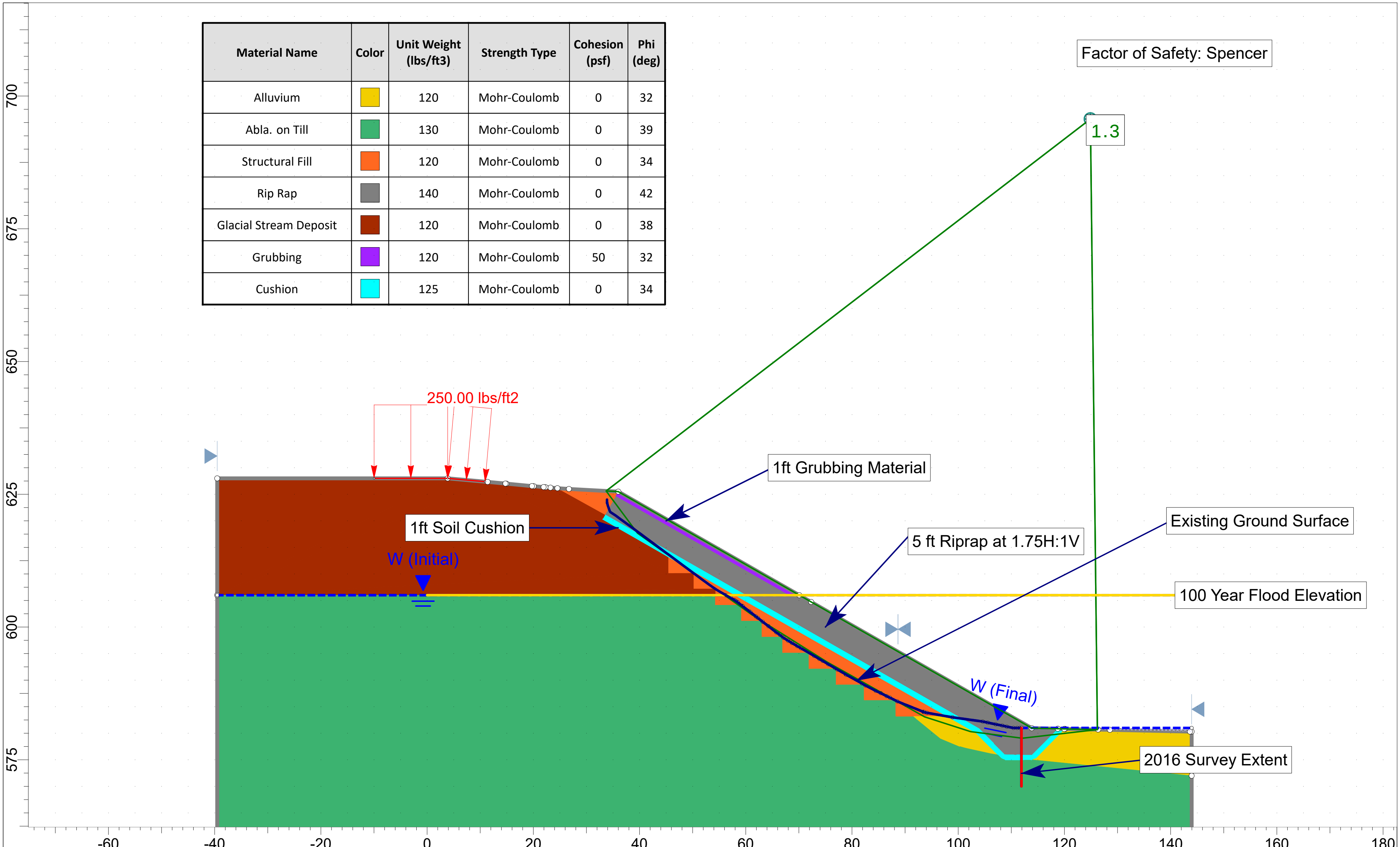
Project: Allagash Slope Stability

Analysis Description: Station 111+38, Section 9, Final 1.75H:1V Slope Steady State Groundwater

Drawn By CJS | *Checked by:* JDL | *Reviewed by:* MSP | *Scale* 1:300

Date 6/1/2018

Figure AL-6



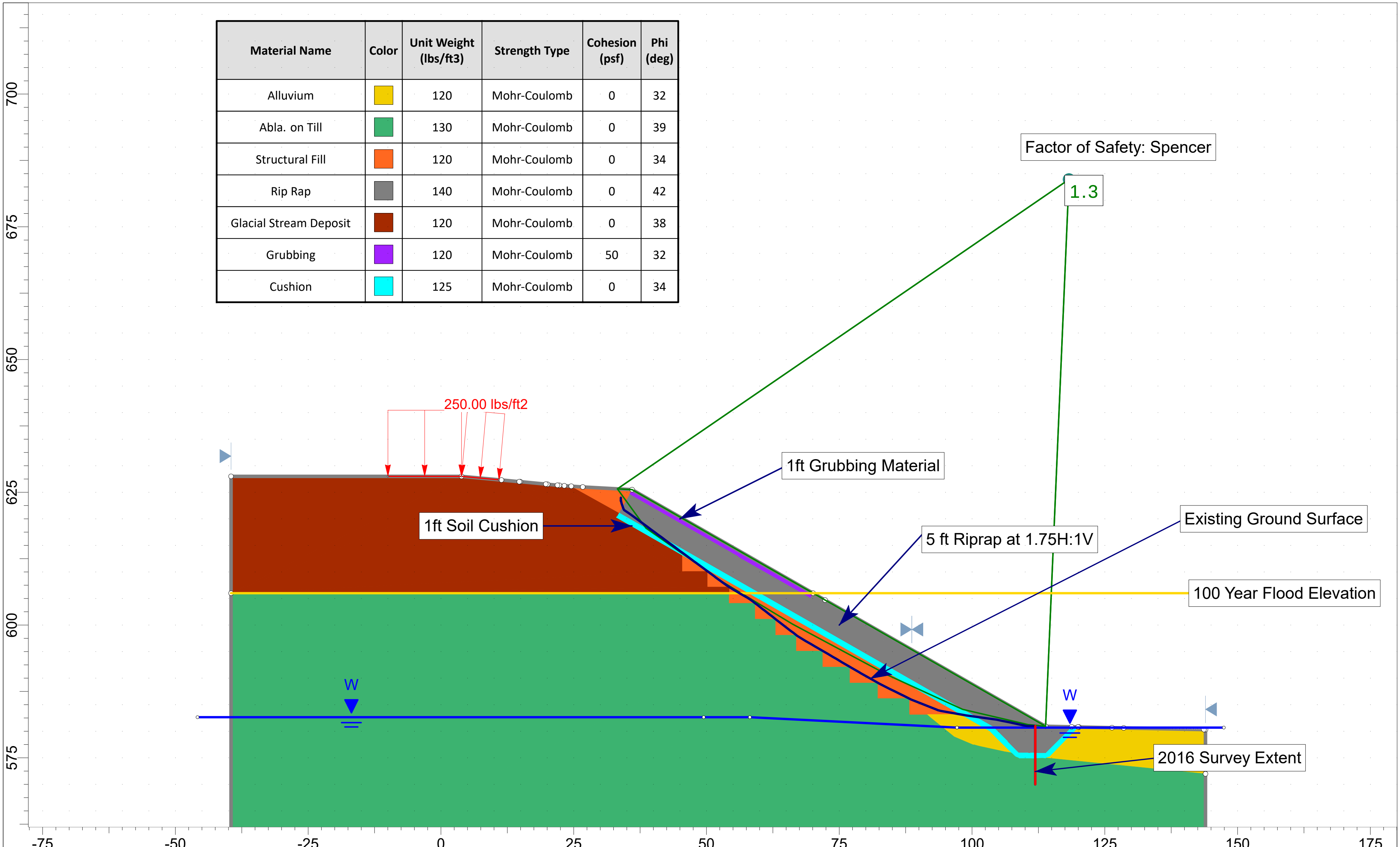
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium		120	Mohr-Coulomb	0	32
Abla. on Till		130	Mohr-Coulomb	0	39
Structural Fill		120	Mohr-Coulomb	0	34
Rip Rap		140	Mohr-Coulomb	0	42
Glacial Stream Deposit		120	Mohr-Coulomb	0	38
Grubbing		120	Mohr-Coulomb	50	32
Cushion		125	Mohr-Coulomb	0	34

Golder Associates

SLIDEINTERPRET 7.036

Project	Allagash Slope Stability						
Analysis Description	Station 112+38, Section 11, Final 1.75H:1V Slope Rapid Drawdown						
Drawn By	CJS	*Checked by:*	JDL	*Reviewed by:*	MSP	*Scale*	1:300
Date	6/1/2018						

Figure AL-7



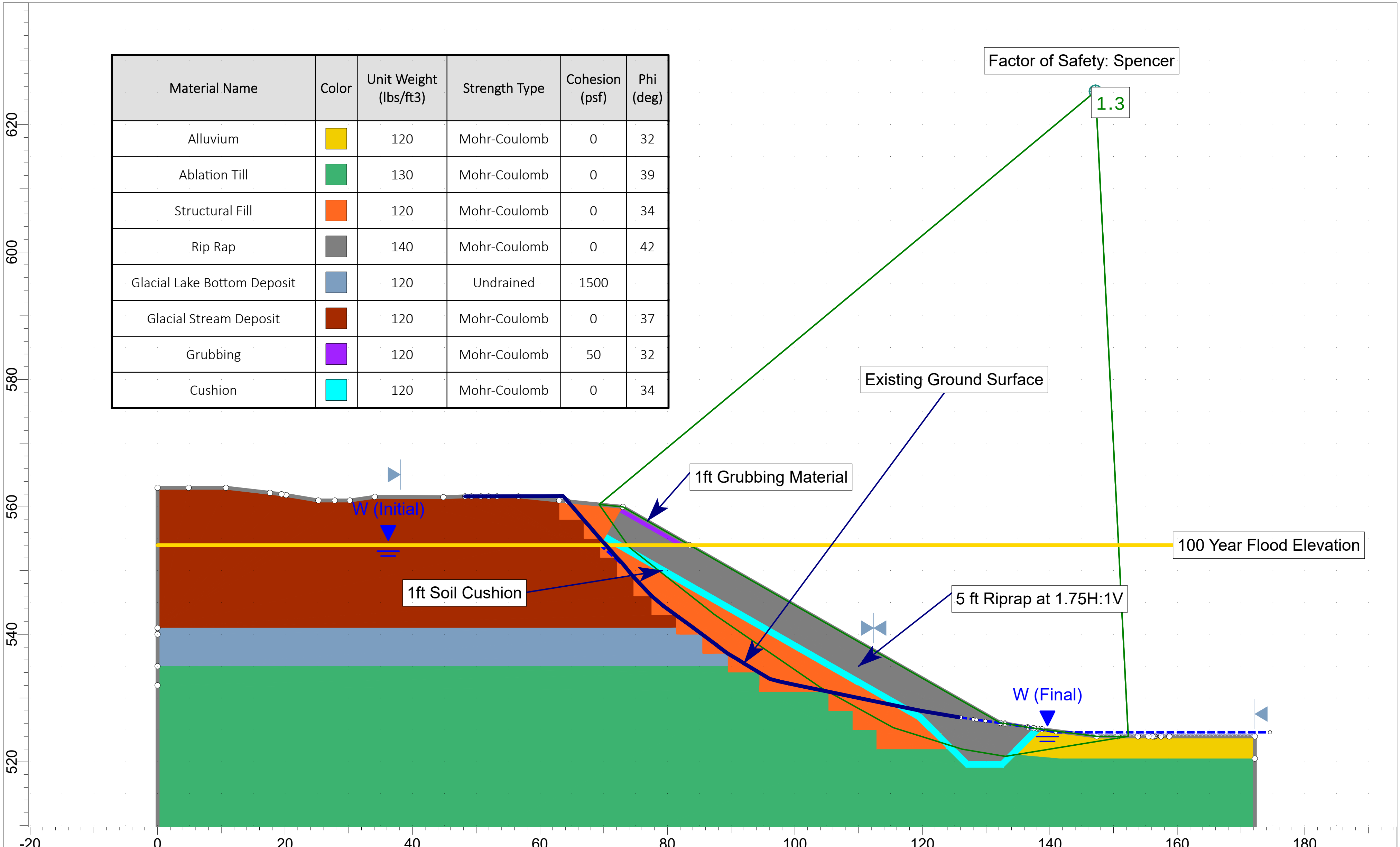
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium	Yellow	120	Mohr-Coulomb	0	32
Abla. on Till	Green	130	Mohr-Coulomb	0	39
Structural Fill	Orange	120	Mohr-Coulomb	0	34
Rip Rap	Grey	140	Mohr-Coulomb	0	42
Glacial Stream Deposit	Brown	120	Mohr-Coulomb	0	38
Grubbing	Purple	120	Mohr-Coulomb	50	32
Cushion	Cyan	125	Mohr-Coulomb	0	34

Golder Associates

SLIDEINTERPRET 7.036

Project	Allagash Slope Stability
Analysis Description	Station 112+38, Section11, Final 1.75H:1V Slope Steady State Groundwater
Drawn By	CJS
Checked by:	JDL
Reviewed by:	MSP
Scale	1:300
Date	6/1/2018

Figure AL-8



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium		120	Mohr-Coulomb	0	32
Ablation Till		130	Mohr-Coulomb	0	39
Structural Fill		120	Mohr-Coulomb	0	34
Rip Rap		140	Mohr-Coulomb	0	42
Glacial Lake Bottom Deposit		120	Undrained	1500	
Glacial Stream Deposit		120	Mohr-Coulomb	0	37
Grubbing		120	Mohr-Coulomb	50	32
Cushion		120	Mohr-Coulomb	0	34

Golder Associates

SLIDEINTERPRET 7.036

Project St. Francis Unstable Slopes

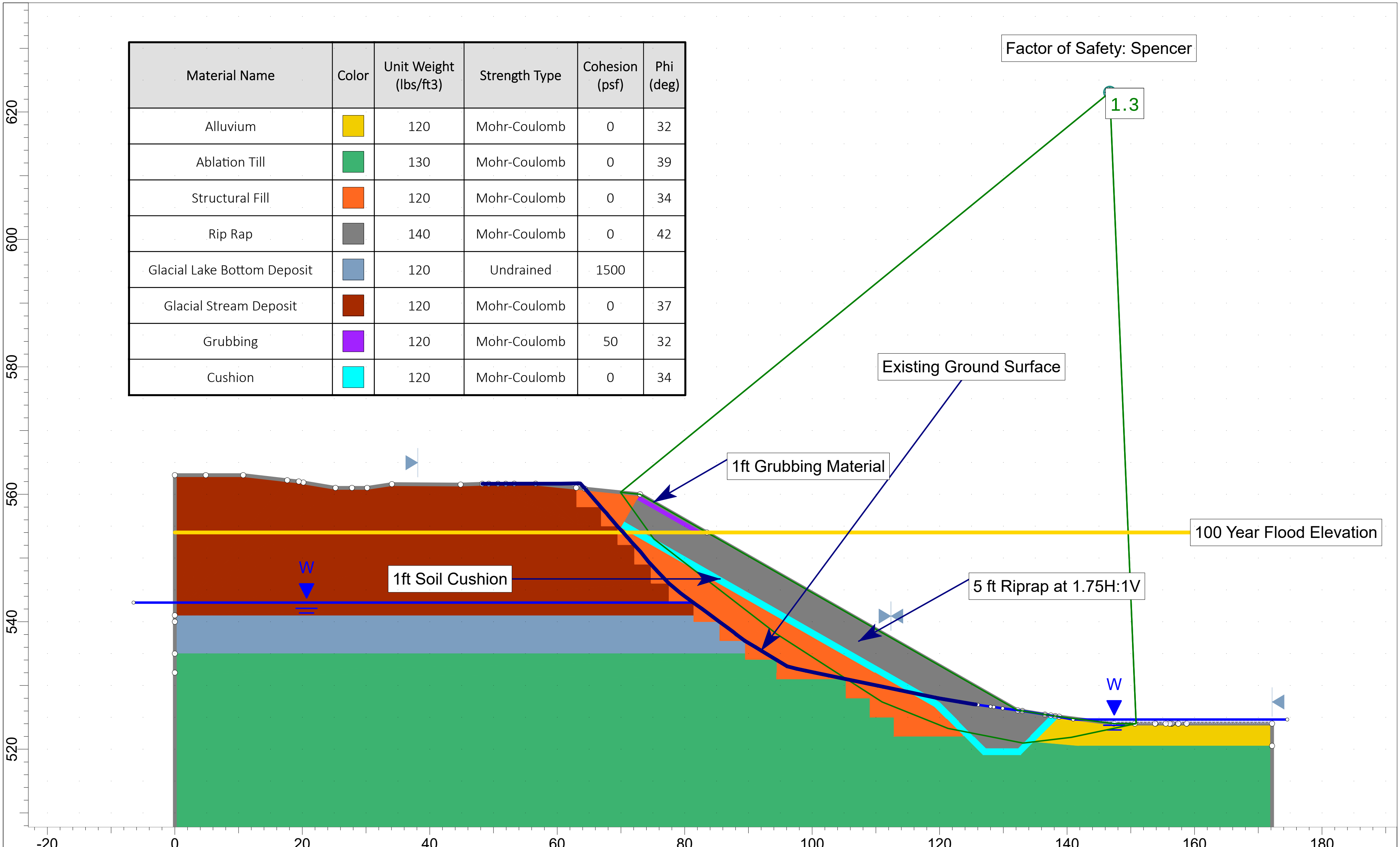
Analysis Description Station 5+78, Section 2, 1.75H:1V Final Slope Rapid Drawdown

Drawn By CJS | *Checked by:* JDL | *Reviewed by:* MSP | *Scale* 1:250

Date 6/1/2018

Figure SF-1

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium		120	Mohr-Coulomb	0	32
Ablation Till		130	Mohr-Coulomb	0	39
Structural Fill		120	Mohr-Coulomb	0	34
Rip Rap		140	Mohr-Coulomb	0	42
Glacial Lake Bottom Deposit		120	Undrained	1500	
Glacial Stream Deposit		120	Mohr-Coulomb	0	37
Grubbing		120	Mohr-Coulomb	50	32
Cushion		120	Mohr-Coulomb	0	34



SLIDEINTERPRET 7.036

Project

St. Francis Unstable Slopes

Analysis Description

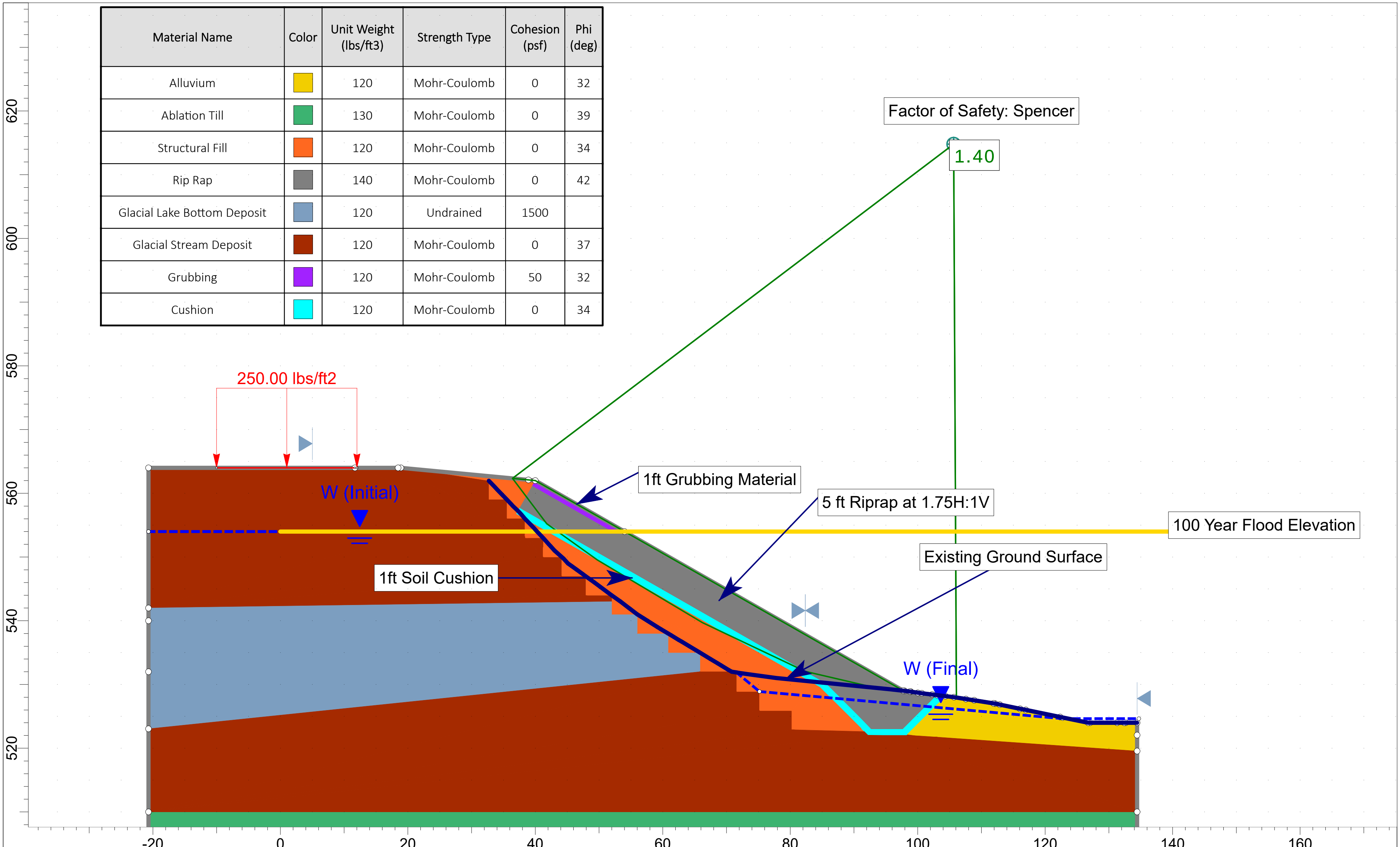
Station 5+78, Section 2, 1.75H:1V Final Slope Steady State Groundwater

Drawn By CJS	*Checked by:* JDL	*Reviewed by:* MSP	*Scale* 1:250

Date 6/1/2018

Figure SF-2

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium		120	Mohr-Coulomb	0	32
Ablation Till		130	Mohr-Coulomb	0	39
Structural Fill		120	Mohr-Coulomb	0	34
Rip Rap		140	Mohr-Coulomb	0	42
Glacial Lake Bottom Deposit		120	Undrained	1500	
Glacial Stream Deposit		120	Mohr-Coulomb	0	37
Grubbing		120	Mohr-Coulomb	50	32
Cushion		120	Mohr-Coulomb	0	34



Project: St. Francis Unstable Slopes

Analysis Description: Station 8+78, Section 8, 1.75H:1V Final Slope Rapid Drawdown

Drawn By	Checked by:	Reviewed by:	Scale
CJS	JDL	MSP	1:250

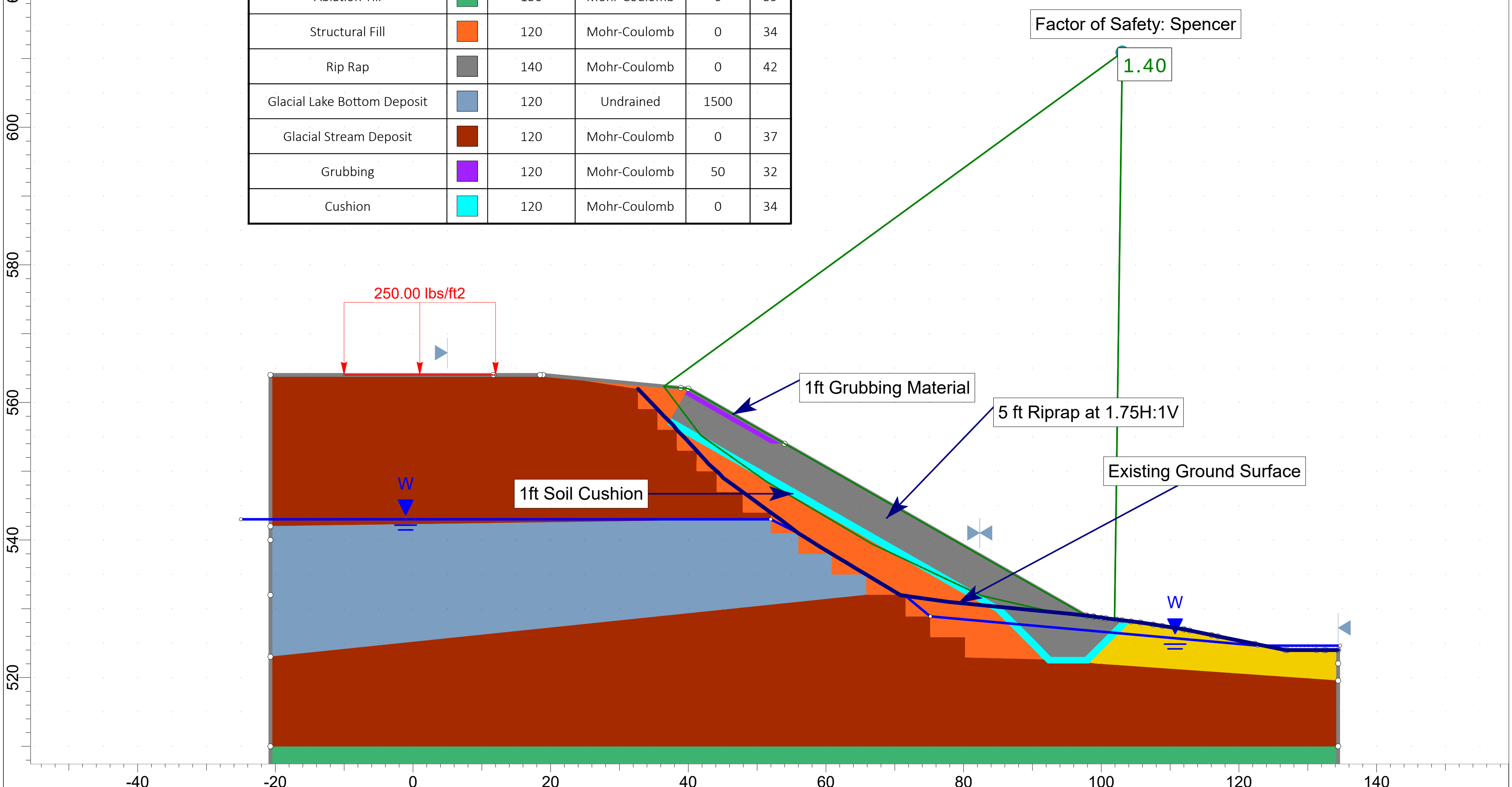
Date: 6/1/2018

Figure SF-3

Golder Associates

SLIDEINTERPRET 7.036

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium	Yellow	120	Mohr-Coulomb	0	32
Ablation Till	Green	130	Mohr-Coulomb	0	39
Structural Fill	Orange	120	Mohr-Coulomb	0	34
Rip Rap	Gray	140	Mohr-Coulomb	0	42
Glacial Lake Bottom Deposit	Light blue	120	Undrained	1500	
Glacial Stream Deposit	Dark red	120	Mohr-Coulomb	0	37
Grubbing	Purple	120	Mohr-Coulomb	50	32
Cushion	Cyan	120	Mohr-Coulomb	0	34



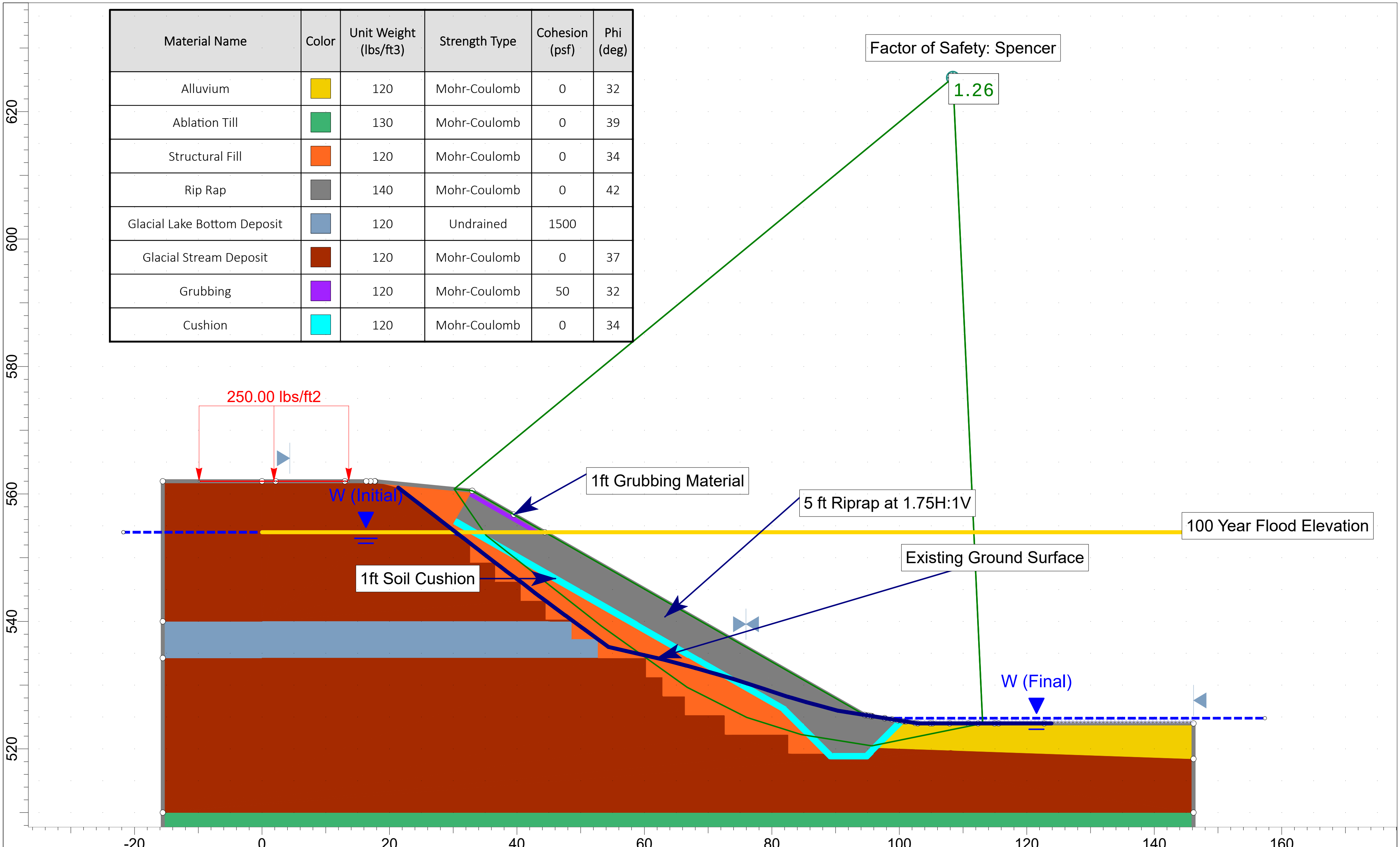
Golder Associates

SLIDEINTERPRET 7.036

Project	St. Francis Unstable Slopes
Analysis Description	Station 8+78, Section 8, 1.75H:1V Final Slope Steady State Groundwater
Drawn By	CJS
Checked by:	JDL
Reviewed by:	MSP
Scale	1:250
Date	6/1/2018

Figure SF-4

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium	Yellow	120	Mohr-Coulomb	0	32
Ablation Till	Green	130	Mohr-Coulomb	0	39
Structural Fill	Orange	120	Mohr-Coulomb	0	34
Rip Rap	Grey	140	Mohr-Coulomb	0	42
Glacial Lake Bottom Deposit	Blue-grey	120	Undrained	1500	
Glacial Stream Deposit	Dark red	120	Mohr-Coulomb	0	37
Grubbing	Purple	120	Mohr-Coulomb	50	32
Cushion	Cyan	120	Mohr-Coulomb	0	34



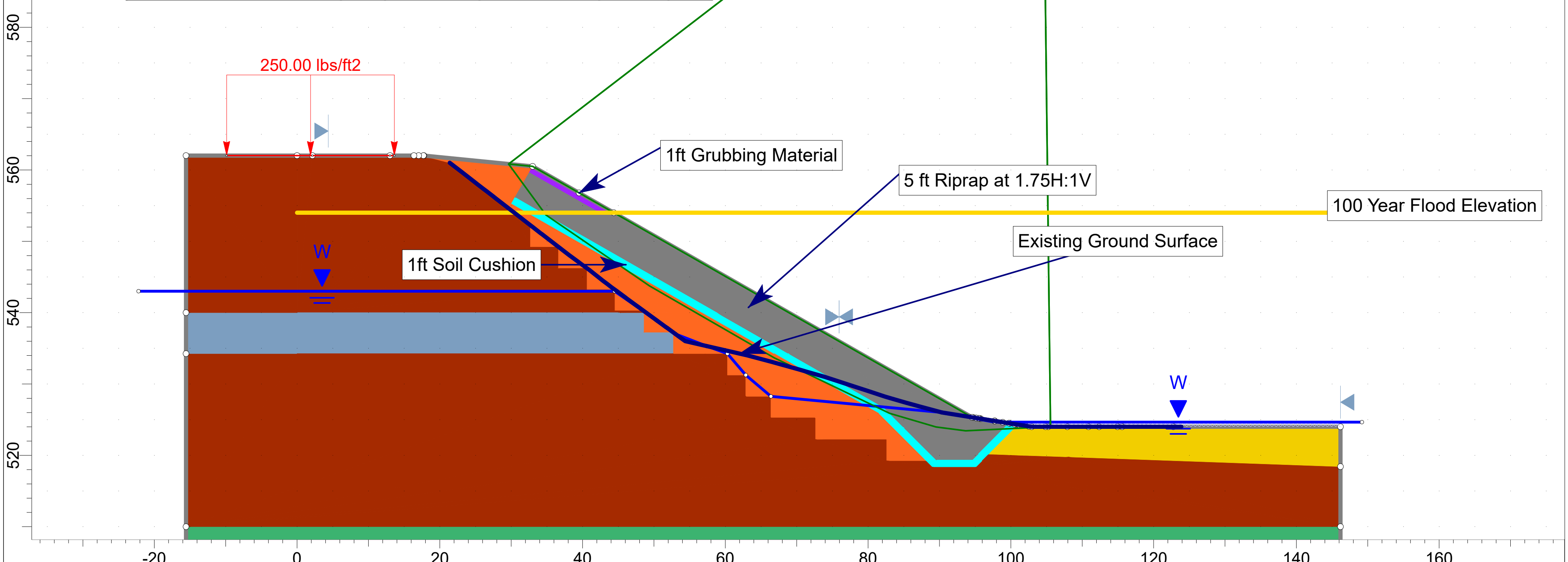
Golder Associates

SLIDEINTERPRET 7.036

Project	St. Francis Unstable Slopes
Analysis Description	Station 11+28, Section 13, 1.75H:1V Riprap Final Slope Rapid Drawdown
Drawn By CJS	*Checked by:* JDL
Reviewed by: MSP	*Scale* 1:250
Date	6/1/2018

Figure SF-5

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium		120	Mohr-Coulomb	0	32
Ablation Till		130	Mohr-Coulomb	0	39
Structural Fill		120	Mohr-Coulomb	0	34
Rip Rap		140	Mohr-Coulomb	0	42
Glacial Lake Bottom Deposit		120	Undrained	1500	
Glacial Stream Deposit		120	Mohr-Coulomb	0	37
Grubbing		120	Mohr-Coulomb	50	32
Cushion		120	Mohr-Coulomb	0	34



Golder Associates

SLIDEINTERPRET 7.036

Project
St. Francis Unstable Slopes

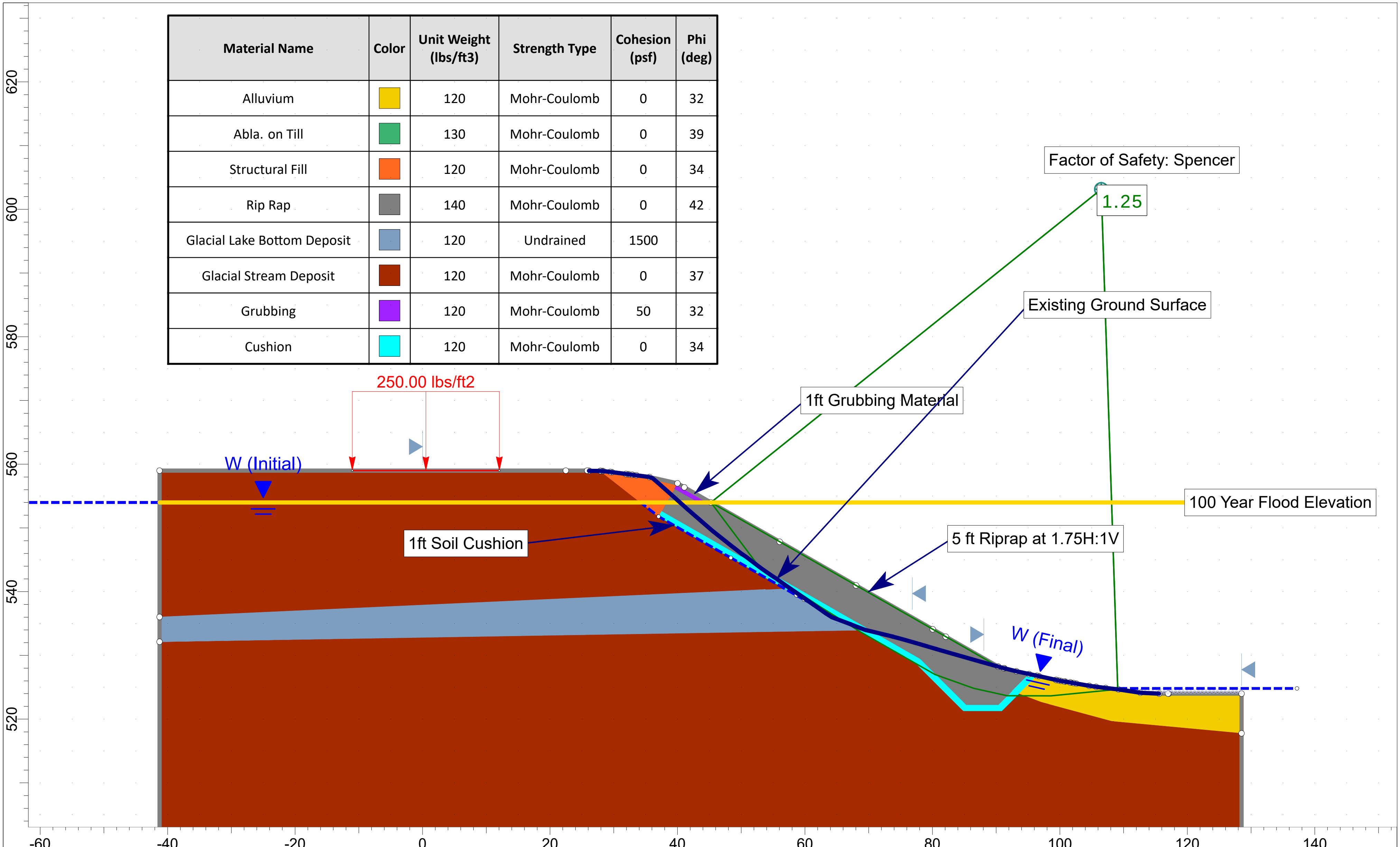
Analysis Description
Station 11+28, Section 13, 1.75H:1V Riprap Final Slope Steady State Groundwater

Drawn By CJS | *Checked by:* JDL | *Reviewed by:* MSP | *Scale* 1:250

Date 6/1/2018

Figure SF-6

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium		120	Mohr-Coulomb	0	32
Abla. on Till		130	Mohr-Coulomb	0	39
Structural Fill		120	Mohr-Coulomb	0	34
Rip Rap		140	Mohr-Coulomb	0	42
Glacial Lake Bottom Deposit		120	Undrained	1500	
Glacial Stream Deposit		120	Mohr-Coulomb	0	37
Grubbing		120	Mohr-Coulomb	50	32
Cushion		120	Mohr-Coulomb	0	34



Project

St. Francis Unstable Slopes

Analysis Description

Station 13+78, Section 17, 1.75H:1V Riprap Final Slope Rapid Drawdown

Drawn By CJS	*Checked by:* JDL	*Reviewed by:* MSP	*Scale* 1:250

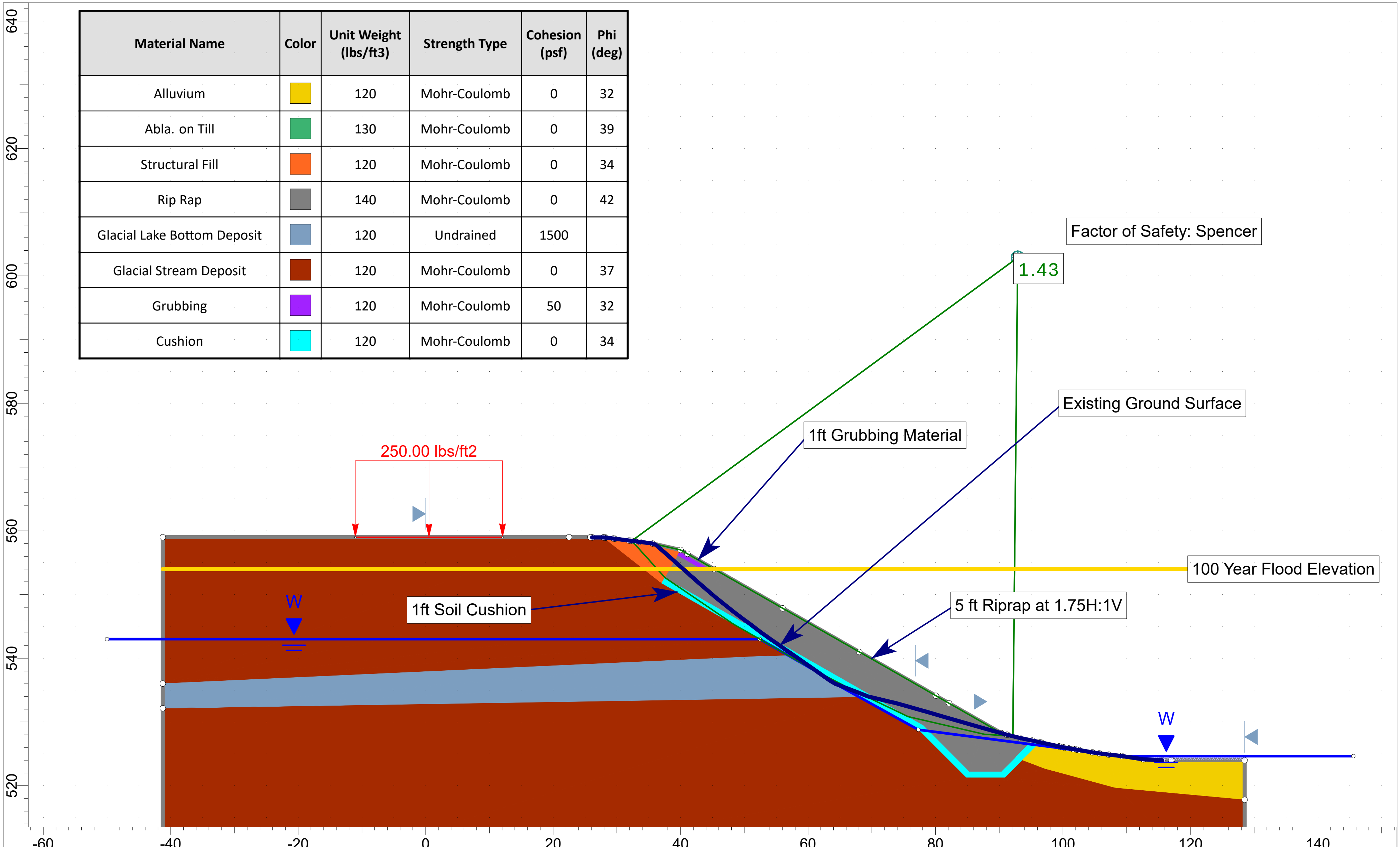
Date 6/1/2018

Figure SF-7

Golder Associates

SLIDEINTERPRET 7.036

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Alluvium		120	Mohr-Coulomb	0	32
Abla. on Till		130	Mohr-Coulomb	0	39
Structural Fill		120	Mohr-Coulomb	0	34
Rip Rap		140	Mohr-Coulomb	0	42
Glacial Lake Bottom Deposit		120	Undrained	1500	
Glacial Stream Deposit		120	Mohr-Coulomb	0	37
Grubbing		120	Mohr-Coulomb	50	32
Cushion		120	Mohr-Coulomb	0	34



Golder Associates

SLIDEINTERPRET 7.036

Project
St. Francis Unstable Slopes

Analysis Description
Station 13+78, Section 17, 1.75H:1V Riprap Final Slope Steady State Groundwater

Drawn By CJS | *Checked by:* JDL | *Reviewed by:* MSP | *Scale* 1:250

Date 6/1/2018

Figure SF-8

APPENDIX N

Final PDR-PIC Drawings

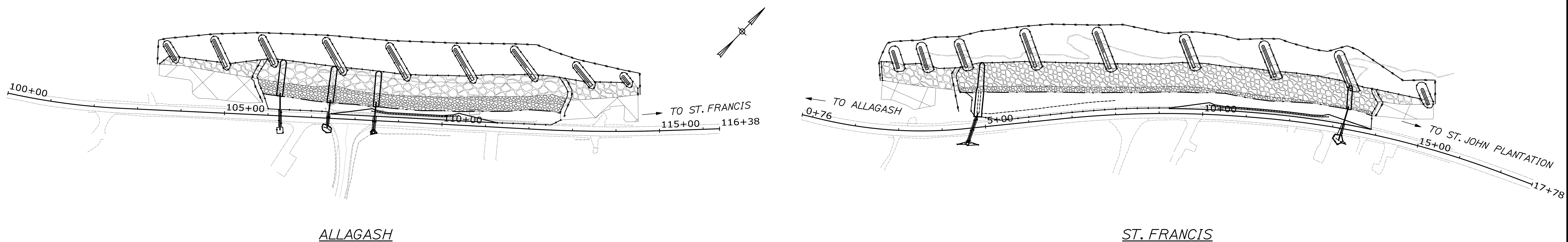
STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

PLAN LEGEND

Town, County, State	Centerline-Existing
Property Lines	Centerline-Proposed
R/W Lines-Existing	Travelway-Existing
R/W Lines-Proposed	Travelway-Proposed
Culvert-Existing	Railroad
Culvert Proposed	Catch Basins: Existing, Proposed
Curbing: Existing, Proposed	Manholes: Existing, Proposed
Type 1	Proposed Underdrain
Type 3	Proposed Ditch
Type 5	Existing Ditch
Outline of Bodies of Water	Utility Poles: Existing, Proposed
Boring HB-XXX-###	Fire Hydrants: Existing, Proposed
	Existing Water Line
Pavement Core PC-#	Existing San. Sewer
	Existing San. Sewer Manhole
Test Pit TP-XXX-###	Guardrail-Existing
	Guardrail-Proposed
Probe P-#.#X	Guardrail-Cable, Other
#.# = Depth	Exposed Bedrock
X = W (Weathered Rock)	Buildings
R (Refusal)	Trees: Conifer, Deciduous
NR (No Refusal)	Tree Line
	Clearing Limit Line

ALLAGASH-ST. FRANCIS
AROOSTOOK COUNTY
ROUTE 161
STATE PROJECT NO. 17236.00
PROJECT LENGTH : 0.45 MILES

INDEX OF SHEETS

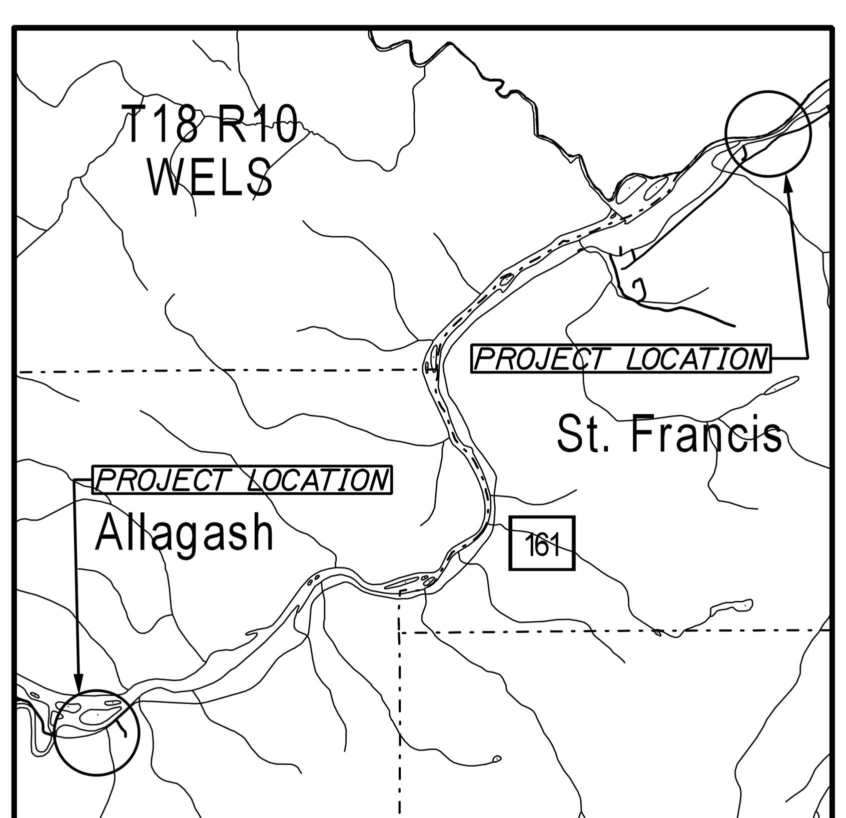


LAYOUT SCALE

100 0 100 200

Scale In Feet

FINAL PDR-PIC
DECEMBER 13, 2018



0 2 4

Scale In Miles

LOCATION MAP

TRAFFIC DATA - ALLAGASH

Current (2018) AADT	690
Future (2038) AADT	830
DHV - % of AADT	11%
Design Hour Volume	91
% Heavy Trucks (AADT)	20%
Directional Distribution (DHV)	52%
Design Speed (mph)	40 MPH
Functional Class:	Major Urban Collector
Corridor Priority	3

TRAFFIC DATA - ST. FRANCIS

Current (2018) AADT	930
Future (2038) AADT	1120
DHV - % of AADT	10%
Design Hour Volume	112
% Heavy Trucks (AADT)	18%
Directional Distribution (DHV)	51%
Design Speed (mph)	50 MPH
Functional Class:	Major Urban Collector
Corridor Priority	3

PROJECT LOCATION:	Route 161 in the town of Allagash Route 161 in the town of St. Francis
PROGRAM AREA:	Highway Program
SCOPE OF WORK:	Slope Stabilization

017236.00

STATE OF MAINE DEPARTMENT OF TRANSPORTATION

APPROVED | DATE

COMMISSIONER:

CHIEF ENGINEER:

PROJECT INFORMATION: SIGNATURE | P.E. NUMBER | DATE

PROGRAM
PROJECT MANAGER
DESIGNER
CONSULTANT
PROJECT RESIDENT
CONTRACTOR
PROJECT COMPLETION DATE

ALLAGASH-ST. FRANCIS
ROUTE 161

TITLE SHEET

SHEET NUMBER

1

OF 10

Date:12/13/2018

Username:

Division:

Filename: 001_Title.dgn

ESTIMATED QUANTITIES			
ITEM NO.	DESCRIPTION	UNIT	QUANTITY
			WIN 017236.00 ROUTE 161
201.11	CLEARING	AC	
202.203	PAVEMENT BUTT JOINTS	SY	
203.20	COMMON EXCAVATION	CY	
203.25	GRANULAR BORROW	CY	
304.16	AGGREGATE BASE COURSE - TYPE C	CY	
403.210	HOT MIX ASHALT, 9.5 MM NOMINAL MAXIMUM SIZE	TON	
403.211	HOT MIX ASHALT, 9.5 MM NOMINAL MAXIMUM SIZE (SHIMMING)	TON	
403.213	HOT MIX ASHALT, 12.5 MM NOMINAL MAXIMUM SIZE (BASE AND INTERMEDIATE BASE COURSE)	TON	
409.15	BITUMINOUS TACK COAT, APPLIED	GAL	
511.07	COFFERDAM: ALLAGASH	LS	
511.07	COFFERDAM: ST. FRANCIS	LS	
526.301	TEMPORARY CONCRETE BARRIER, TYPE I (ALLAGASH)	LS	
526.301	TEMPORARY CONCRETE BARRIER, TYPE I (ST. FRANCIS)	LS	
527.34	WORK ZONE CRASH CUSHION	UN	
603.199	24 INCH CULVERT PIPE OPTION III	LF	
603.209	30 INCH CULVERT PIPE OPTION II	LF	
606.1301	31" W-BEAM GUARDRAIL - MID-WAY SPLICE (STEEL POST, 8" OFFSET BLOCKS, SINGLE FACE)	LF	
606.1305	31" W-BEAM GUARDRAIL - MID-WAY SPLICE FLARED TERMINAL (31" HEIGHT)	EA	
606.356	UNDERDRAIN DELINEATOR POST	EA	
610.08	PLAIN RIPRAP	CY	
610.16	HEAVY RIPRAP	CY	
610.XX	EXTRA HEAVY RIPRAP	CY	
610.18	STONE DITCH PROTECTION	CY	
615.07	LOAM	CY	
618.14	SEEDING METHOD NUMBER 2	UN	
619.12	MULCH	UN	
620.58	EROSION CONTROL GEOTEXTILE - FOR PIPE INLETS	SY	
620.XX	EROSION CONTROL GEOTEXTILE - FOR DOWNSPOUTS (FUTURE SPECIAL PROVISION TO BE PROVIDED)	SY	
620.XXX	EROSION CONTROL GEOTEXTILE - FOR RIPRAP SLOPE (FUTURE SPECIAL PROVISION TO BE PROVIDED)	SY	
629.05	HAND LABOR, STRAIGHT TIME	HR	
631.10	AIR COMPRESSOR (INCLUDING OPERATOR)	HR	
631.11	AIR TOOL (INCLUDING OPERATOR)	HR	
631.12	ALL PURPOSE EXCAVATOR (INCLUDING OPERATOR)	HR	
631.13	BULLDOZER (INCLUDING OPERATOR)	HR	
631.172	TRUCK-LARGE (INCLUDING OPERATOR)	HR	
631.18	CHAIN SAW RENTAL (INCLUDING OPERATOR)	HR	
631.22	FRONT END LOADER (INCLUDING OPERATOR)	HR	
639.19	FIELD OFFICE, TYPE B	EA	
643.72	TEMPORARY TRAFFIC SIGNAL: ALLAGASH - ROUTE 161	LS	
643.72	TEMPORARY TRAFFIC SIGNAL: ALLAGASH - DRIVEWAY STATION 106+75	LS	
643.72	TEMPORARY TRAFFIC SIGNAL: ALLAGASH - CARNEY ROAD	LS	
643.72	TEMPORARY TRAFFIC SIGNAL: ALLAGASH - DRIVEWAY STATION 111+25	LS	
643.72	TEMPORARY TRAFFIC SIGNAL: ALLAGASH - DRIVEWAY STATION 113+50	LS	
643.72	TEMPORARY TRAFFIC SIGNAL: ST. FRANCIS - ROUTE 161	LS	
643.72	TEMPORARY TRAFFIC SIGNAL: ST. FRANCIS - DRIVEWAY STATION 8+25	LS	
643.72	TEMPORARY TRAFFIC SIGNAL: ST. FRANCIS - DRIVEWAY STATION 9+75	LS	
643.72	TEMPORARY TRAFFIC SIGNAL: ST. FRANCIS - DRIVEWAY STATION 13+00	LS	
643.72	TEMPORARY TRAFFIC SIGNAL: ST. FRANCIS - DRIVEWAY STATION 14+50	LS	
652.33	DRUM	EA	
652.34	CONE	EA	
652.35	CONSTRUCTION SIGNS	SF	
652.36	MAINTENANCE OF TRAFFIC CONTROL DEVICES (ALLAGASH)	CD	
652.36	MAINTENANCE OF TRAFFIC CONTROL DEVICES (ST. FRANCIS)	CD	
652.38	FLAGGERS	HR	
656.75	TEMPORARY SOIL EROSION AND WATER POLLUTION CONTROL (ALLAGASH)	LS	
656.75	TEMPORARY SOIL EROSION AND WATER POLLUTION CONTROL (ST. FRANCIS)	LS	
659.10	MOBILIZATION (ALLAGASH)	LS	
659.10	MOBILIZATION (ST. FRANCIS)	LS	

FINAL PDR-PIC
DECEMBER 13, 2018

1. CLEARING LIMITS SHALL BE 10 FEET BEYOND AND PARALLEL TO THE CONSTRUCTION SLOPE LINES OR AS SHOWN ON THE PLANS UNLESS OTHERWISE AUTHORIZED BY THE RESIDENT.

2. GRUBBING IN FILL AREAS HAS BEEN SHOWN ON THE CROSS SECTIONS AND THE QUANTITIES NOTED. THESE LIMITS ARE APPROXIMATE AND HAVE BEEN USED FOR ESTIMATING PURPOSES ONLY. ACTUAL GRUBBING LIMITS MAY VARY BASED ON FIELD CONDITIONS AS DIRECTED BY THE RESIDENT.

3. WHERE DEEMED NECESSARY BY THE RESIDENT, UNSUITABLE EXCESS MATERIAL SHALL BE REMOVED FROM THE EDGES OF SHOULDERS AND PLACED IN DESIGNATED AREAS OR DISPOSED OF. PAYMENT WILL BE MADE UNDER THE APPROPRIATE CONTRACT ITEMS.

4. ALL INSLOPE AND DITCHES IN CUT AREAS SHALL BE GRADED AS SHOWN ON THE TYPICALS OR FLATTER, OR AS DIRECTED BY THE RESIDENT.

5. THE CONTRACTOR SHALL PLAN AND CONDUCT THEIR WORK ACCORDINGLY SO THAT UPON COMPLETION OF THE PROJECT THERE IS NO DROP-OFF FROM THE EDGE OF SHOULDER PAVEMENT.

6. THE CONTRACTOR SHALL PLACE SUITABLE EXISTING OR OTHER MATERIAL ACCEPTABLE TO THE RESIDENT ON ALL PAVEMENT EDGES TO ALLOW A DROP OFF NO GREATER THAN THE SURFACE PAVEMENT THICKNESS. THE MATERIAL SHALL BE GRADED TO MATCH THE EXISTING INSLOPE OR AS DIRECTED BY THE RESIDENT BEFORE SURFACE IS PLACED. THE CONTRACTOR WILL BE PAID UNDER APPROPRIATE EQUIPMENT RENTAL ITEMS. BORROW IS NOT AUTHORIZED UNTIL ALL ACCEPTABLE WASTE MATERIAL HAS BEEN UTILIZED. SEED AND MULCH WILL BE PAID FOR AT THE CONTRACT UNIT PRICE.

7. ALL WASTE MATERIAL NOT USED ON THE PROJECT SHALL BE DISPOSED OF OFF THE PROJECT IN ACCEPTABLE WASTE AREAS REVIEWED BY THE RESIDENT. GRADING, SEEDING AND MULCHING OF WASTE AREAS SHALL BE CONSIDERED INCIDENTAL.

8. REQUIRED DITCH PROTECTION SHOWN ON THE PLANS OR IN THE CONSTRUCTION NOTES IS FOR ESTIMATING PURPOSES ONLY. THE ACTUAL TYPE AND LOCATION OF DITCH PROTECTION MAY BE ALTERED BY THE RESIDENT.

9. GRANULAR BORROW USED TO BACKFILL MUCK EXCAVATION OR IN LOW WET AREAS TO 1 FOOT ABOVE WATER LEVEL OR OLD GROUND SHALL MEET REQUIREMENTS FOR GRANULAR BORROW MATERIAL FOR UNDERWATER BACKFILL AS SPECIFIED IN STANDARD SPECIFICATION 703.19.

10. EXISTING INSLOPES IN PROPOSED FILL AREAS SHALL BE BENCHED BY EXCAVATING STEPS OF SUFFICIENT WIDTH TO PERMIT PLACING AND COMPACTING THE FILL MATERIAL ALONG WITH THE MATERIAL REMOVED.

11. EXISTING CULVERTS AND CATCH BASINS WILL BE CLEANED AS DIRECTED BY THE RESIDENT UNDER THE APPROPRIATE PAY ITEMS.

12. NO EXISTING DRAINAGE SHALL BE ABANDONED, REMOVED OR PLUGGED WITHOUT PRIOR APPROVAL OF THE RESIDENT.

13. INLETS AND OUTLETS OF ALL CULVERTS SHALL BE RIPRAPPED UNLESS OTHERWISE NOTED ON THE PLANS OR DIRECTED BY THE RESIDENT.

14. THE CULVERT SIZES SHOWN ON THE PLANS AND CROSS SECTIONS ARE FOR SMOOTHLINED PIPES. FOR COMPARABLE CORRUGATED SIZES SEE THE DRAINAGE TABULATION.

15. GUARDRAIL END TREATMENTS SHALL BE INSTALLED CONCURRENTLY WITH THE PLACEMENT OF EACH SECTION OF BEAM GUARDRAIL.

16. HOLES CREATED BY GUARDRAIL REMOVAL WILL BE FILLED AND COMPACTED WITH APPROVED MATERIALS AS DIRECTED BY THE RESIDENT. PAYMENT TO BE CONSIDERED INCIDENTAL TO THE GUARDRAIL ITEMS.

17. ALL EXISTING GUARDRAIL SHALL BE REMOVED AND BECOME THE PROPERTY OF THE CONTRACTOR. REMOVAL AND DISPOSAL SHALL BE CONSIDERED INCIDENTAL TO THE GUARDRAIL ITEMS.

18. TWO REFLECTORIZED FLEXIBLE G.R. MARKERS (ITEM 606.353) WILL BE INSTALLED AT EACH GUARDRAIL END.

19. LOAM HAS BEEN ESTIMATED FOR DISTURBED LAWN AREAS. ACTUAL PLACEMENT OF THE LOAM SHALL BE AS NOTED ON THE PLANS OR DESIGNATED BY THE RESIDENT.

20. UNLESS OTHERWISE NOTED SEEDING METHOD NO. 1 SHALL BE UTILIZED ON ALL LAWNS AND DEVELOPED AREAS; SEEDING METHOD NO. 2 SHALL BE UTILIZED ON ALL OTHER AREAS.

21. LOAM SHALL BE PLACED TO A NOMINAL DEPTH OF 4 INCHES IN LAWN AREAS AND 2 INCHES IN ALL OTHER AREAS UNLESS OTHERWISE NOTED OR DIRECTED.

22. ANY DAMAGE TO THE SLOPES CAUSED BY THE CONTRACTOR'S EQUIPMENT, PERSONNEL, OR OPERATION SHALL BE REPAIRED TO THE SATISFACTION OF THE RESIDENT. ALL WORK, EQUIPMENT, AND MATERIALS REQUIRED TO MAKE REPAIRS SHALL BE AT THE CONTRACTOR'S EXPENSE.

23. THE PROJECT GEOTECHNICAL REPORT TITLED XXXXX, SOILS REPORT 20XX-XX, DATE CAN BE ACCESSED AT THE MAINEDOT WEBSITE HTTP://WWW.MAINE.GOV/MDOT/CONTRACTORS/.

24. GEOTECHNICAL INFORMATION FURNISHED OR REFERRED TO IN THE BID DOCUMENTS IS FOR THE USE OF THE BIDDERS. NO ASSURANCE IS GIVEN THAT THE INFORMATION OR INTERPRETATIONS WILL BE REPRESENTATIVE OF THE ACTUAL SUBSURFACE CONDITIONS THROUGHOUT THE CONSTRUCTION SITE. MAINEDOT WILL NOT BE RESPONSIBLE FOR ANY INTERPRETATIONS OR CONCLUSION DRAWN FROM THE GEOTECHNICAL INFORMATION. THE BORING LOGS PROVIDED IN THE BID DOCUMENTS (IF ANY) PRESENT FACTUAL AND INTERPRETIVE SUBSURFACE INFORMATION COLLECTED AT DISCRETE LOCATIONS. DATA PROVIDED MAY NOT BE REPRESENTATIVE OF THE SUBSURFACE CONDITIONS BETWEEN BORING LOCATIONS.

25. AREAS REQUIRING FILL ON THE PROJECT WILL COME FROM SUITABLE EXCAVATION FROM EXCAVATION, DITCH AND INSLOPE OR EQUIPMENT RENTAL AREAS.

26. ESTIMATED QUANTITIES FOR REQUIRED STRUCTURAL EARTH EXCAVATION, DRAINAGE AND MINOR STRUCTURES ARE INFORMATIONAL ONLY AND REPRESENT THE APPROXIMATE MINIMUM QUANTITY REQUIRED TO INSTALL DRAINAGE STRUCTURES. ADDITIONAL EXCAVATION FOR THE CONTRACTOR'S CONVENIENCE OR TO COMPLY WITH BACKSLOPING REQUIREMENTS WILL NOT BE PAID FOR DIRECTLY BUT WILL BE CONSIDERED INCIDENTAL TO THE RELATED DRAINAGE ITEMS.

27. NO SEPARATE PAYMENT FOR SUPERINTENDENT OR FOREMAN WILL BE MADE FOR THE SUPERVISION OF EQUIPMENT AND LAYOUT OF WORK BEING PAID FOR UNDER THE EQUIPMENT RENTAL ITEMS.

28. UNDETERMINED LOCATIONS SHALL BE DETERMINED BY THE RESIDENT.

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

017236.00

WIN 017236.00

HIGHWAY PLANS

PROJ. MANAGER	R.SOUCY	BY	DATE
DESIGN-DETAILED			
CHECKED-REVIEWED			
DESIGN2-DETAILED2			
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

SIGNATURE

P.E. NUMBER

DATE

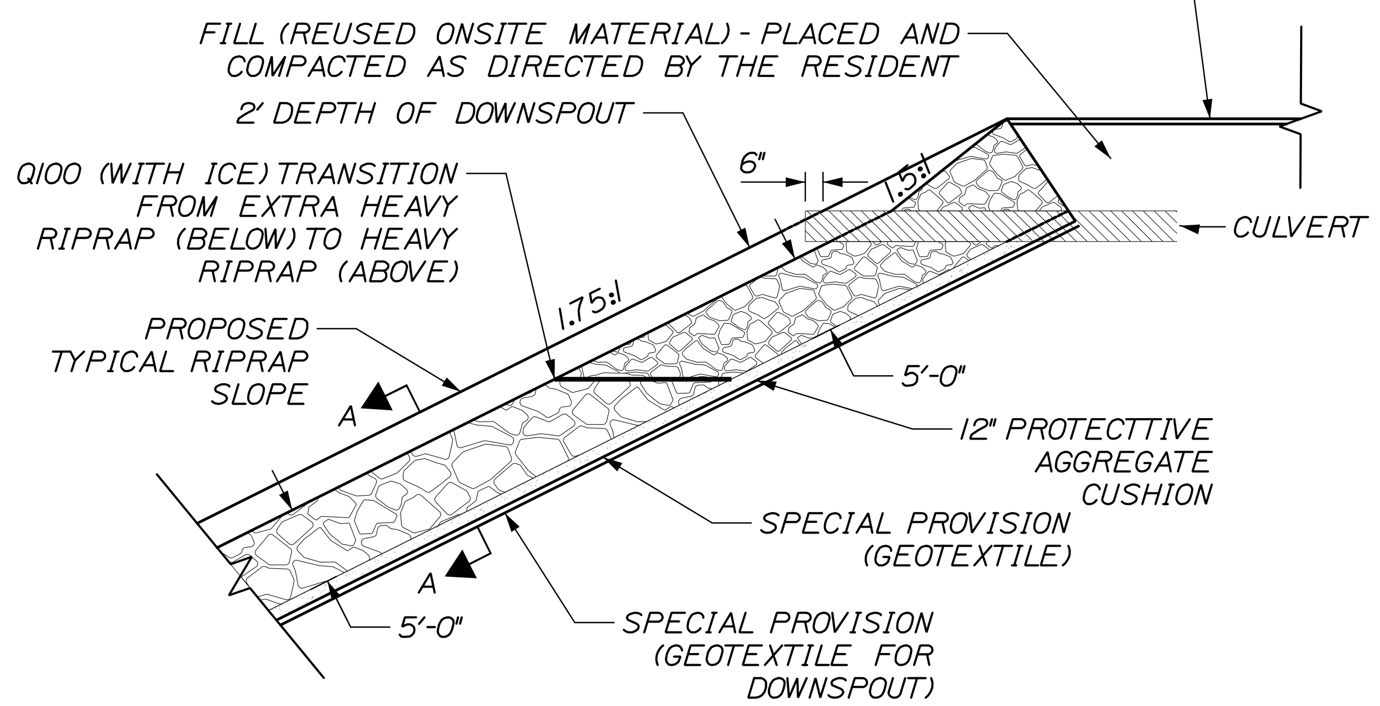
ALLAGASH-ST. FRANCIS
ROUTE 161

EST. QTY./ GENERAL NOTES

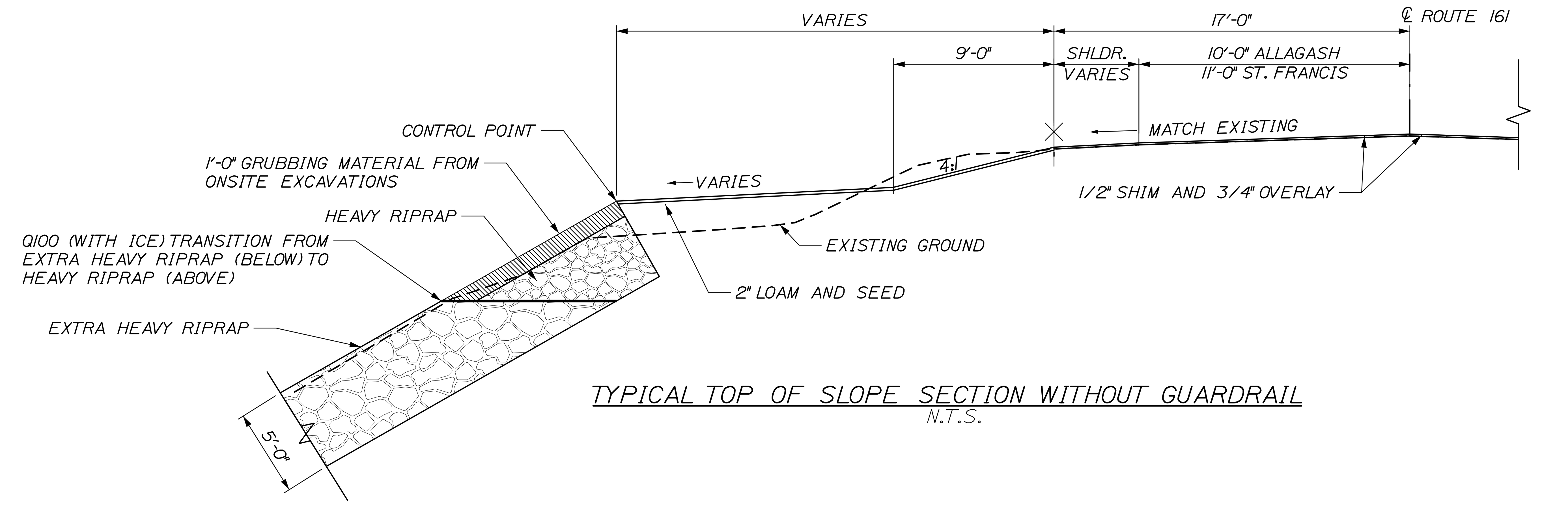
SHEET NUMBER
2
OF 10

Filename: 002_General Notes.dgn
Division:
Username:
Date:12/13/2018

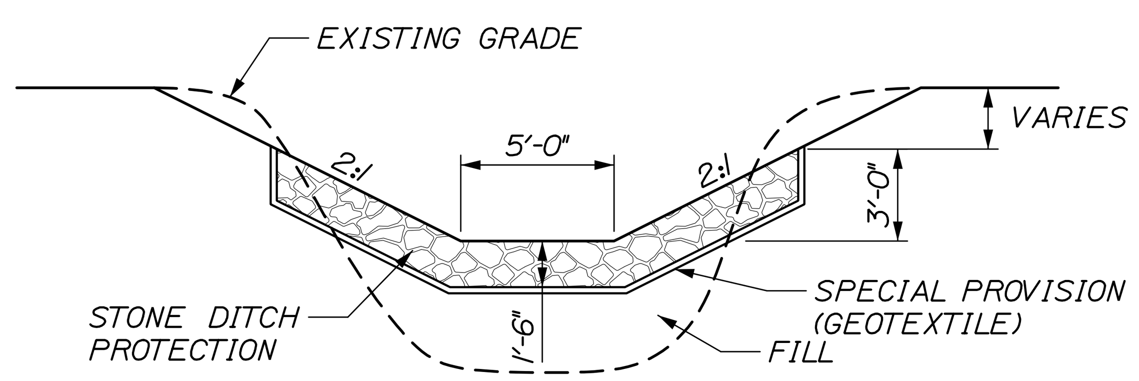
FINAL PDR-PIC
DECEMBER 13, 2018



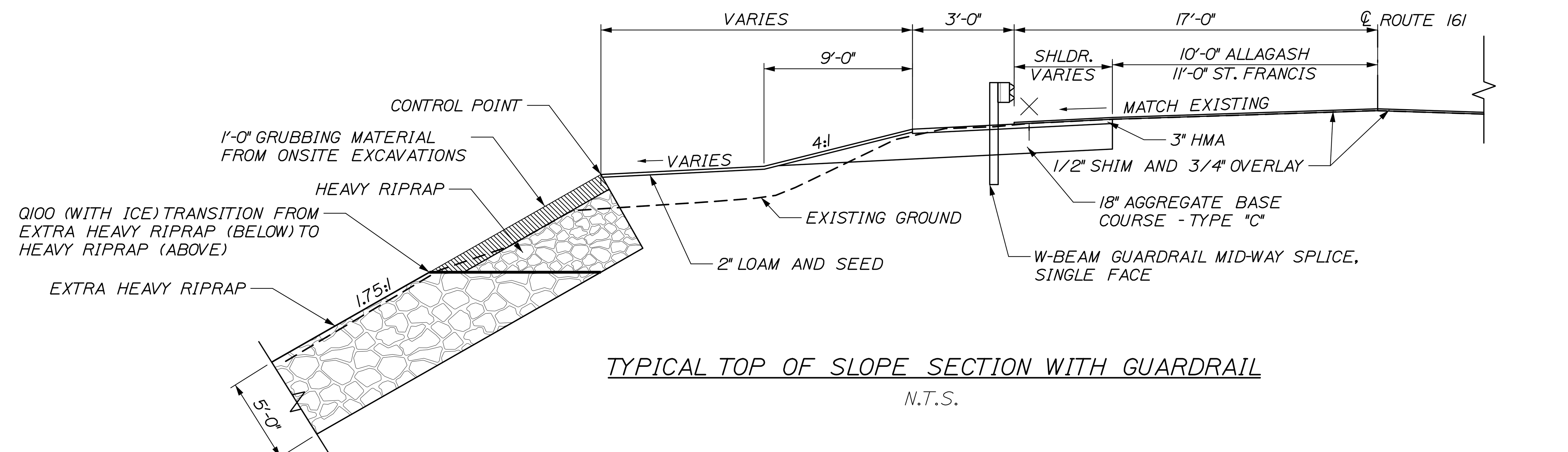
TYPICAL DOWNSPOUT SECTION
N.T.S.



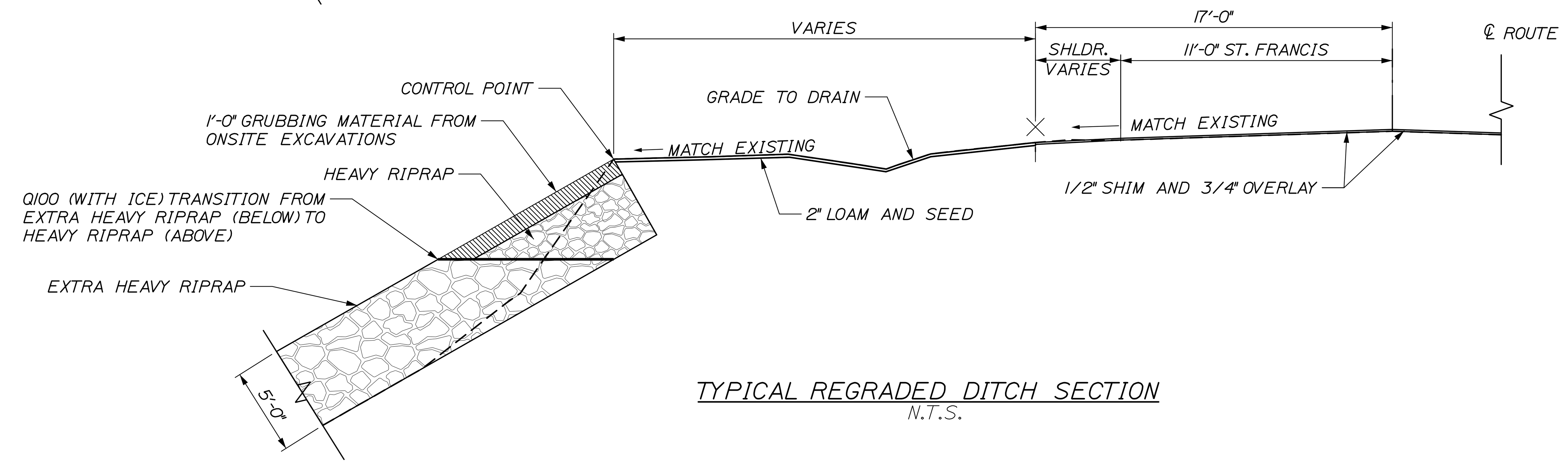
TYPICAL TOP OF SLOPE SECTION WITHOUT GUARDRAIL
N.T.S.



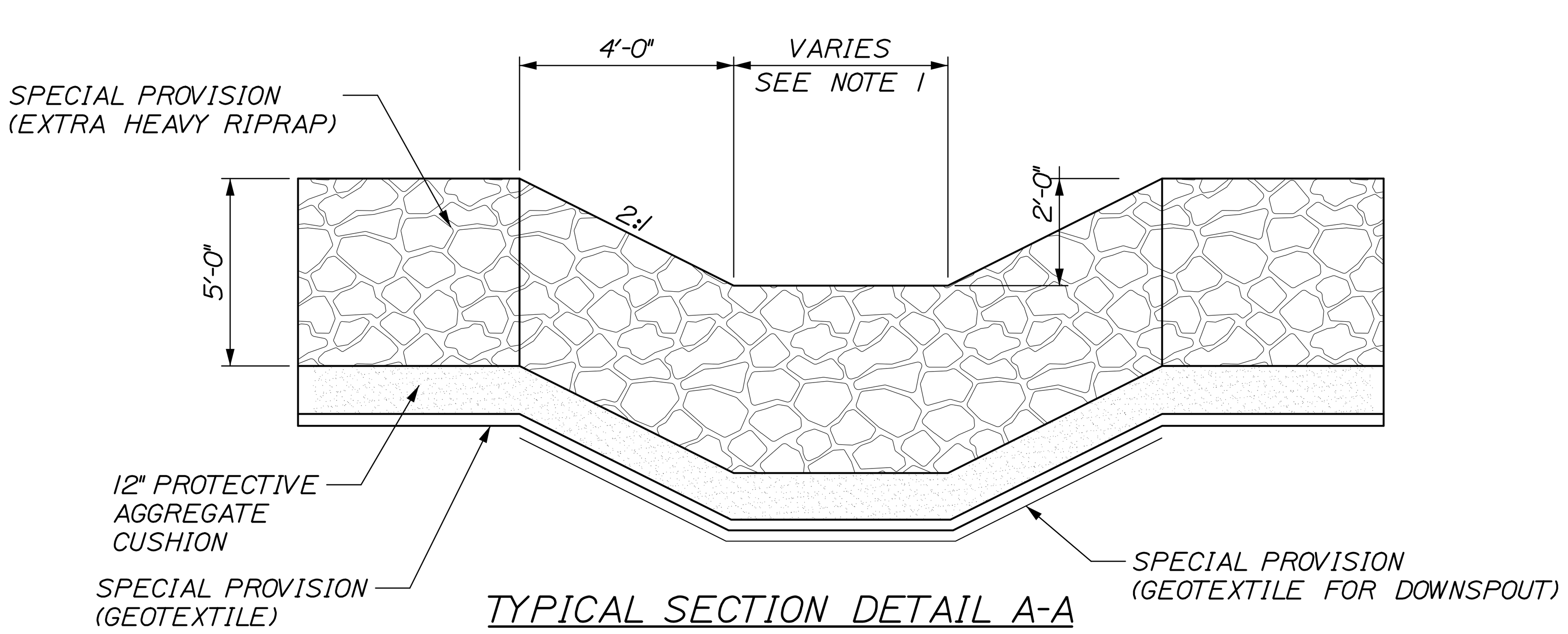
TYPICAL STONE DITCH
SECTION B-B
N.T.S.



TYPICAL TOP OF SLOPE SECTION WITH GUARDRAIL
N.T.S.

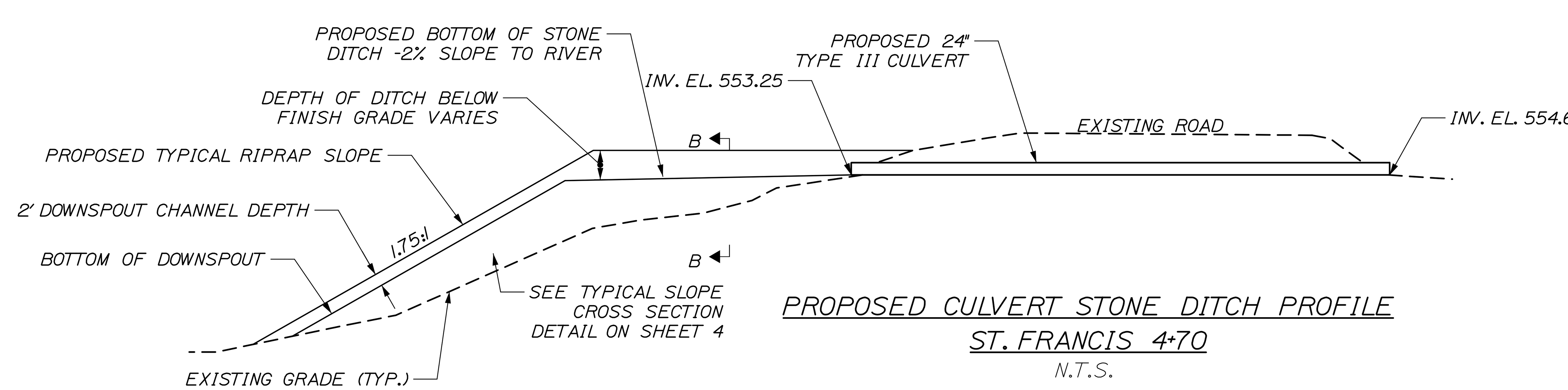


TYPICAL REGRADED DITCH SECTION
N.T.S.



TYPICAL SECTION DETAIL A-A
(LOOKING DOWNSLOPE)
N.T.S.

NOTE:
1. DOWNSPOUT WIDTH VARIES.
-4FT FOR CULVERT DOWNSPOUT
-5FT FOR SLOPE DITCH DOWNSPOUT



PROPOSED CULVERT STONE DITCH PROFILE
ST. FRANCIS 4+70
N.T.S.

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
017236.00
WIN 017236.00
HIGHWAY PLANS

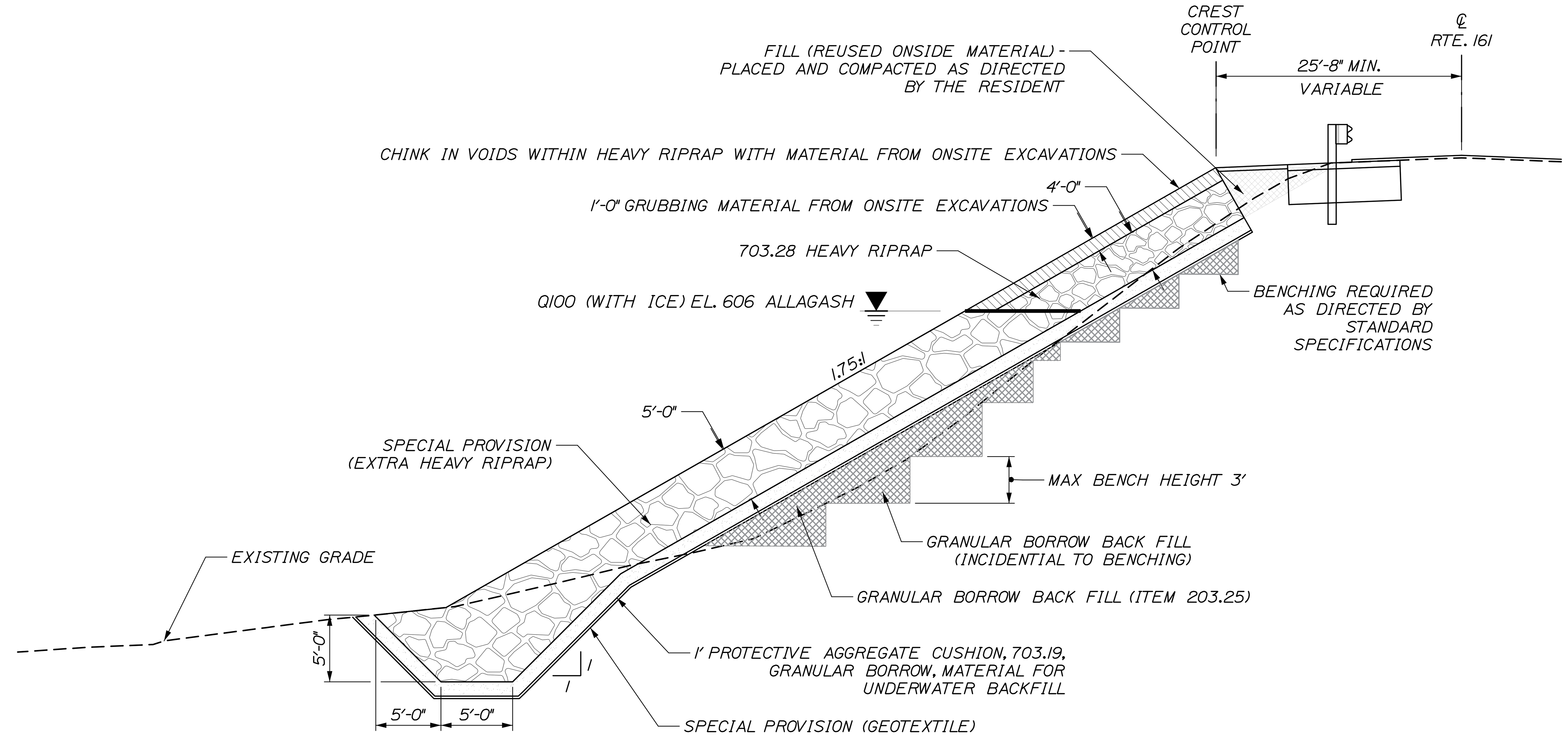
	BY	DATE
PROJ. MANAGER	R.SOUCY	
DESIGN-DETAILED		
CHECKED-REVIEWED		
DESIGN2-DETAILED2		
DESIGN3-DETAILED3		
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE
P.E. NUMBER
DATE

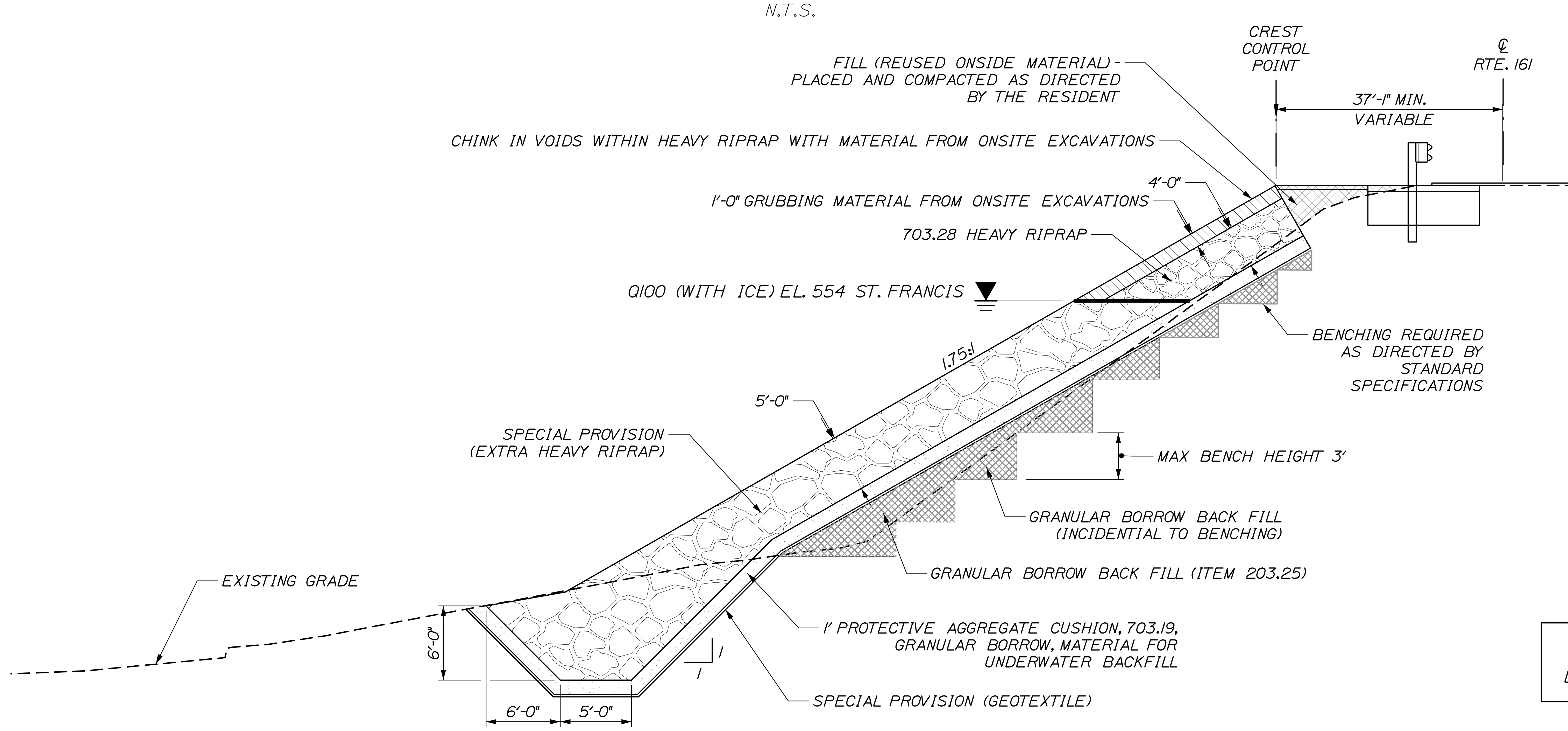
ALLAGASH-ST. FRANCIS
ROUTE 161
TYPICAL SECTIONS

SHEET NUMBER
3
OF 10

Date:12/13/2018
Username:
Division:
Filename: 003_Typical Sections 1.dgn



TYPICAL SLOPE CROSS SECTION
ALLAGASH
N.T.S.



TYPICAL SLOPE CROSS SECTION
ST. FRANCIS
N.T.S.

FINAL PDR-PIC
DECEMBER 13, 2018

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

017236.00

WIN
017236.00
HIGHWAY PLANS

		BY	DATE
PROJ. MANAGER	R.SOUCY		
DESIGN-DETAILED			
CHECKED-REVIEWED			
DESIGN2-DETAILED2			
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

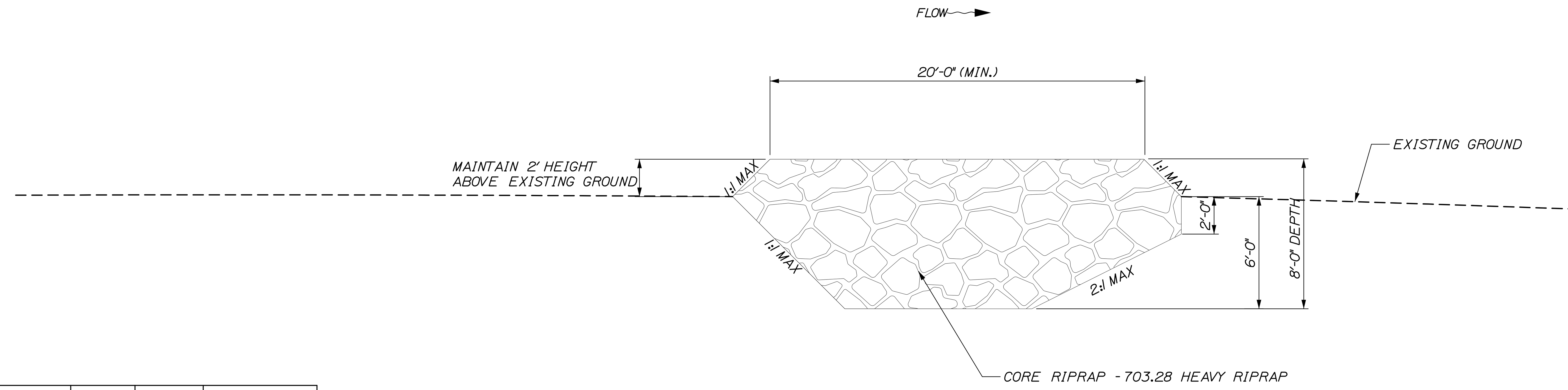
SIGNATURE
P.E. NUMBER
DATE

ALLAGASH-ST. FRANCIS
ROUTE 161

TYPICAL SECTIONS

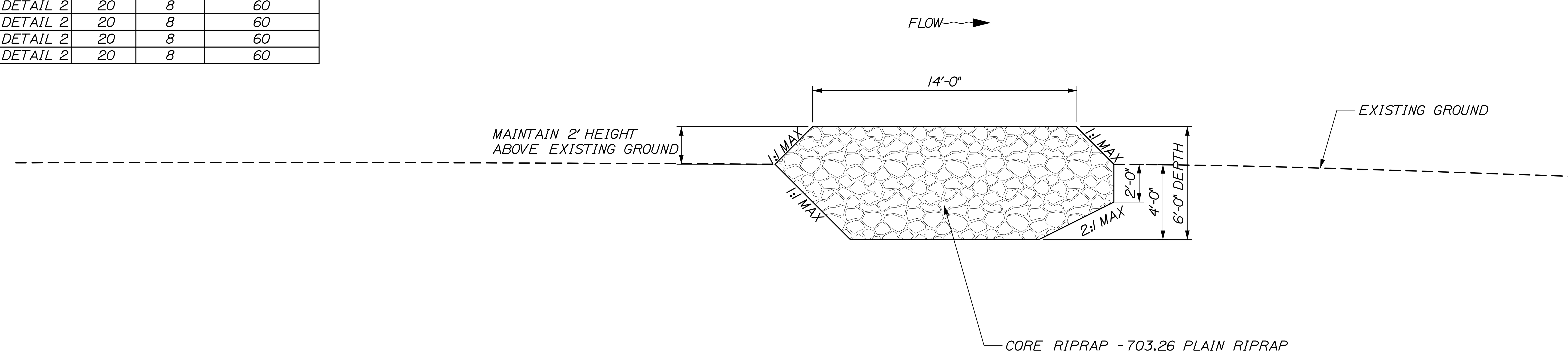
SHEET NUMBER
4
OF 10

Filename: 004_Typical Sections 2.dgn
Division:
Username:
Date:12/13/2018



DETAIL 2: ST. FRANCIS

BENDWAY WEIR	LENGTH (FT)	TYPICAL SECTION	TOP WIDTH (FT)	DEPTH (FT)	ORIENTATION (DEG)
A-1	50	DETAIL 1	14	6	60
A-2	76	DETAIL 1	14	6	60
A-3	73	DETAIL 1	14	6	60
A-4	90	DETAIL 1	14	6	60
A-5	91	DETAIL 1	14	6	60
A-6	90	DETAIL 1	14	6	60
A-7	90	DETAIL 1	14	6	60
A-8	67	DETAIL 1	14	6	60
A-9	31	DETAIL 1	14	6	60
SF-1	52	DETAIL 2	20	8	60
SF-2	64	DETAIL 2	20	8	60
SF-3	68	DETAIL 2	20	8	60
SF-4	92	DETAIL 2	20	8	60
SF-5	100	DETAIL 2	20	8	60
SF-6	80	DETAIL 2	20	8	60
SF-7	86	DETAIL 2	20	8	60
SF-8	92	DETAIL 2	20	8	60
SF-9	55	DETAIL 2	20	8	60



DETAIL 1: ALLAGASH

FINAL PDR-PIC
DECEMBER 13, 2018

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

017236.00

WIN
017236.00

HIGHWAY PLANS

SIGNATURE

P.E. NUMBER

DATE

		BY	DATE
PROJ. MANAGER	R.SOUCY		
DESIGN-DETAILED			
CHECKED-REVIEWED			
DESIGN2-DETAILED2			
DESIGN3-DETAILED3			
REVISIONS 1			
REVISIONS 2			
REVISIONS 3			
REVISIONS 4			
FIELD CHANGES			

ALLAGASH-ST. FRANCIS
ROUTE 161

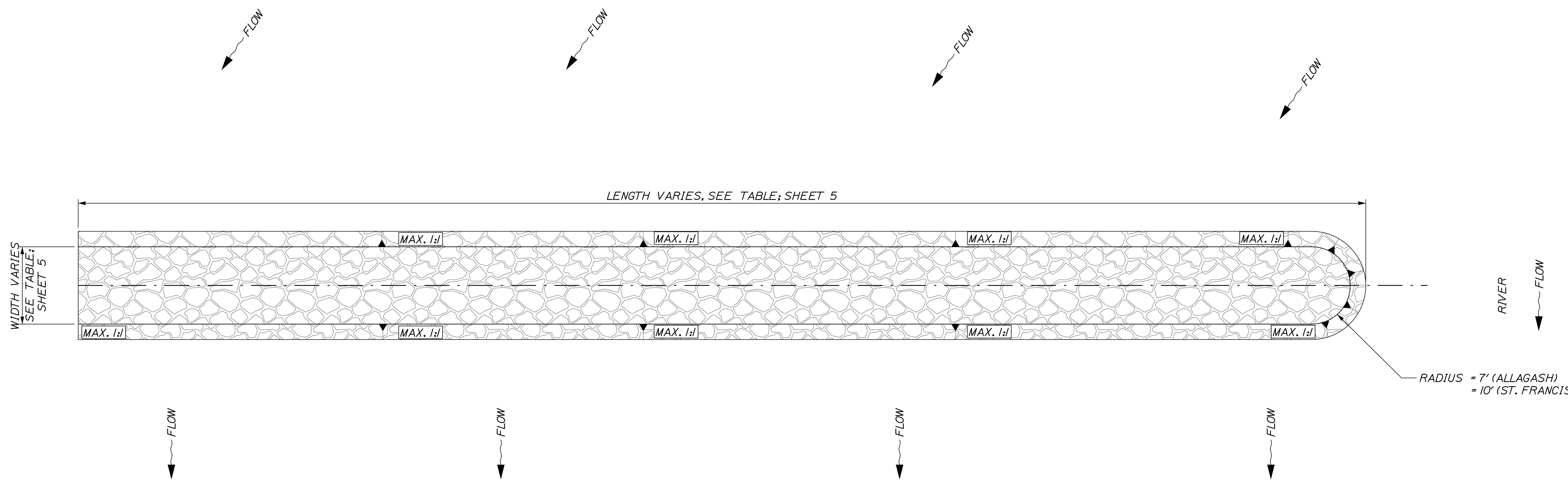
WEIR SECTION

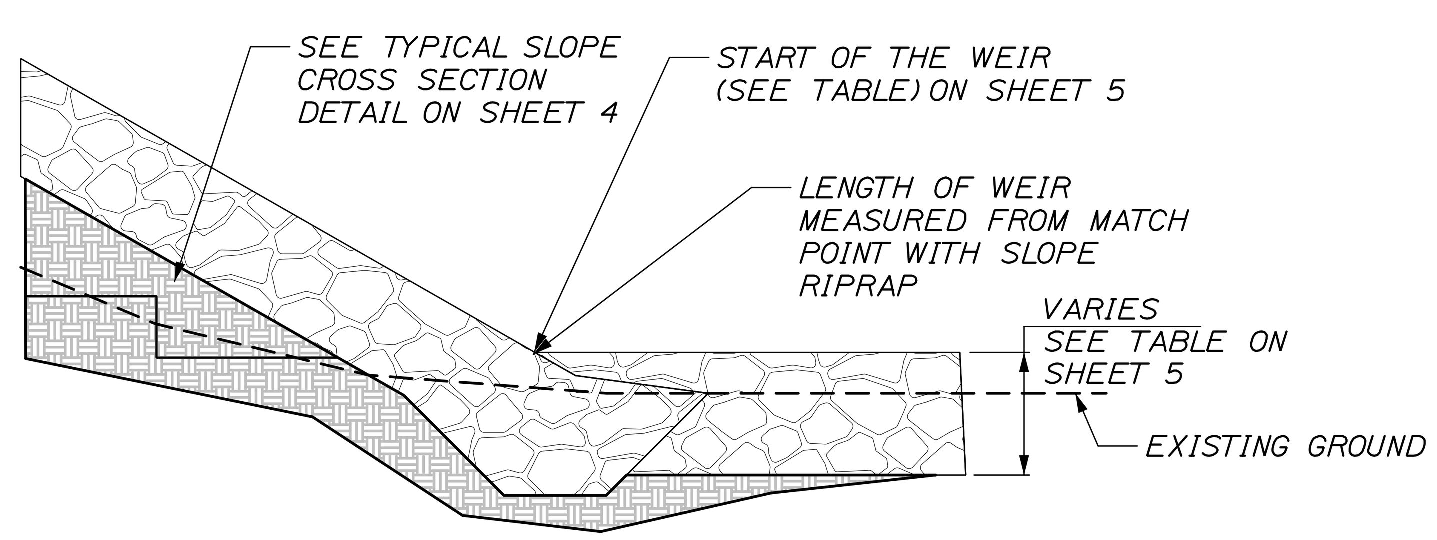
SHEET NUMBER

5

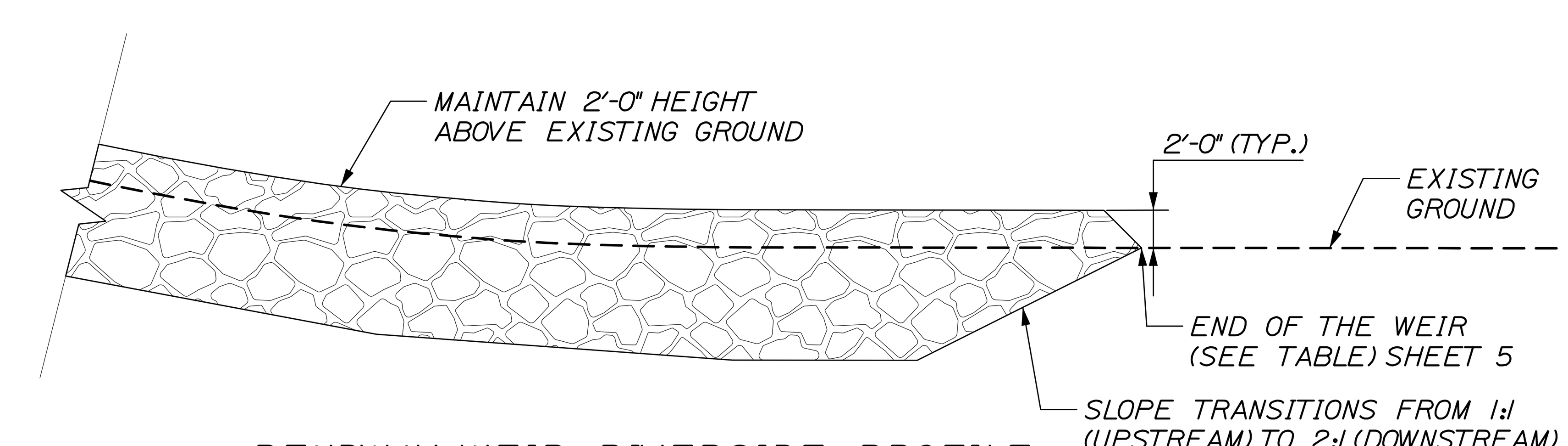
OF 10

Date:12/13/2018
Username:
Division:
Filename: 006_Weir Detail.dgn





BENDWAY WEIR INTO RIPRAP PROFILE



BENDWAY WEIR RIVERSIDE PROFILE

FINAL PDR-PIC
DECEMBER 13, 2018

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

017236.00

WIN
017236.00

HIGHWAY PLANS

	BY	DATE
PROJ. MANAGER	R.SOUCY	
DESIGN-DETAILED		
CHECKED-REVIEWED		
DESIGN2-DETAILED2		
DESIGN3-DETAILED3		
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE

P.E. NUMBER

DATE

ALLAGASH-ST. FRANCIS
ROUTE 161

WEIR DETAIL

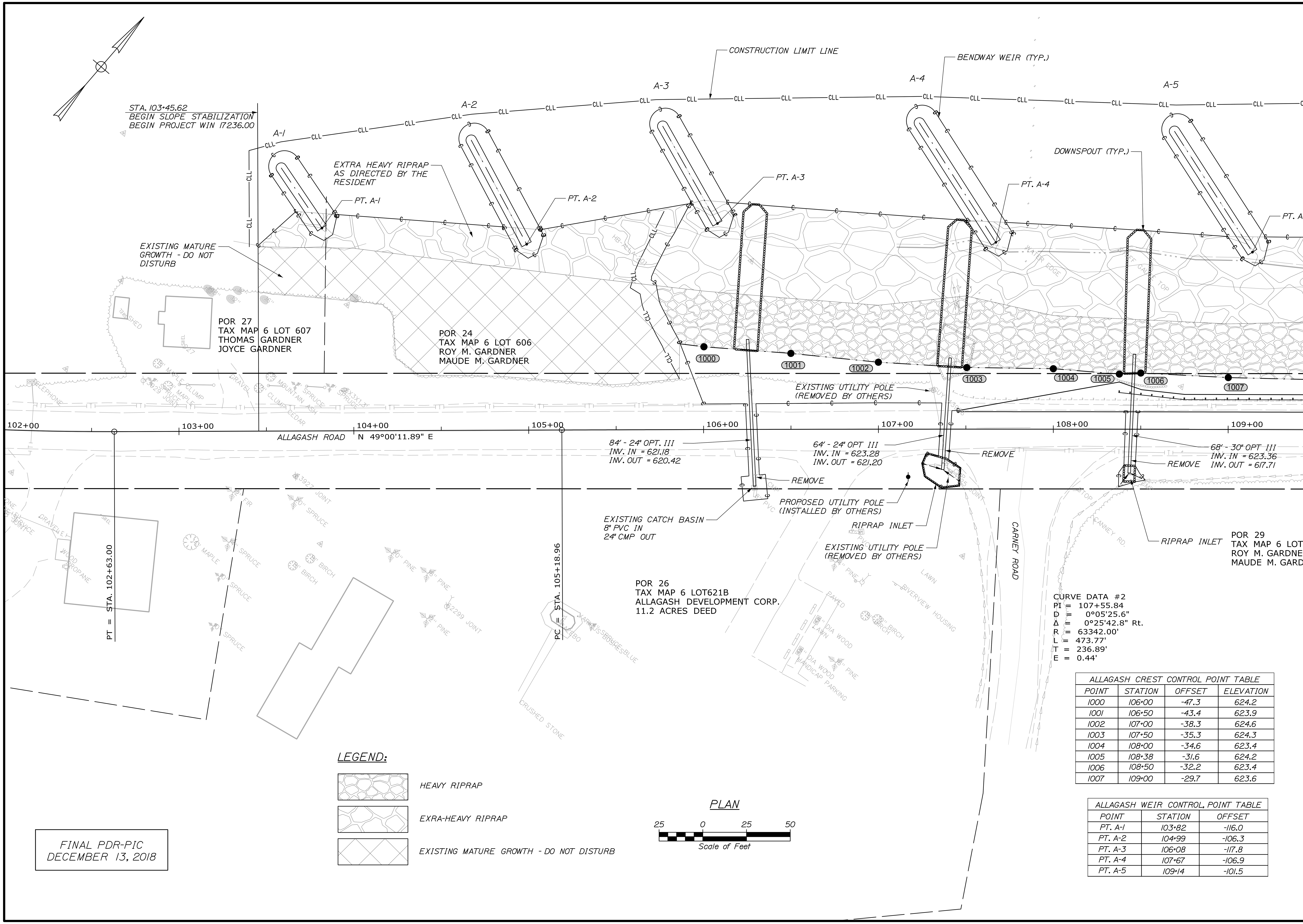
SHEET NUMBER
6
OF 10

Date:12/13/2018

Username:

Division:

Filename: 007_Allagash Plan 1.dgn



CURVE DATA #2
PI = 107+55.84
D = 0°05'25.6"
Δ = 0°25'42.8" Rt.
R = 63342.00'
L = 473.77'
T = 236.89'
E = 0.44'

ALLAGASH CREST CONTROL POINT TABLE

POINT	STATION	OFFSET	ELEVATION
1000	106+00	-47.3	624.2
1001	106+50	-43.4	623.9
1002	107+00	-38.3	624.6
1003	107+50	-35.3	624.3
1004	108+00	-34.6	623.4
1005	108+38	-31.6	624.2
1006	108+50	-32.2	623.4
1007	109+00	-29.7	623.6

ALLAGASH WEIR CONTROL POINT TABLE

POINT	STATION	OFFSET
PT. A-1	103+82	-116.0
PT. A-2	104+99	-106.3
PT. A-3	106+08	-117.8
PT. A-4	107+67	-106.9
PT. A-5	109+14	-101.5

FINAL PDR-PIC
DECEMBER 13, 2018

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

017236.00

WIN
017236.00

HIGHWAY PLANS

SIGNATURE

P.E. NUMBER

DATE

PROJ. MANAGER R.SOUCY
DESIGN-DETAILED
CHECKED-REVIEWED
DESIGN2-DETAILED2
DESIGN3-DETAILED3
REVISIONS 1
REVISIONS 2
REVISIONS 3
REVISIONS 4
FIELD CHANGES
BY
DATE

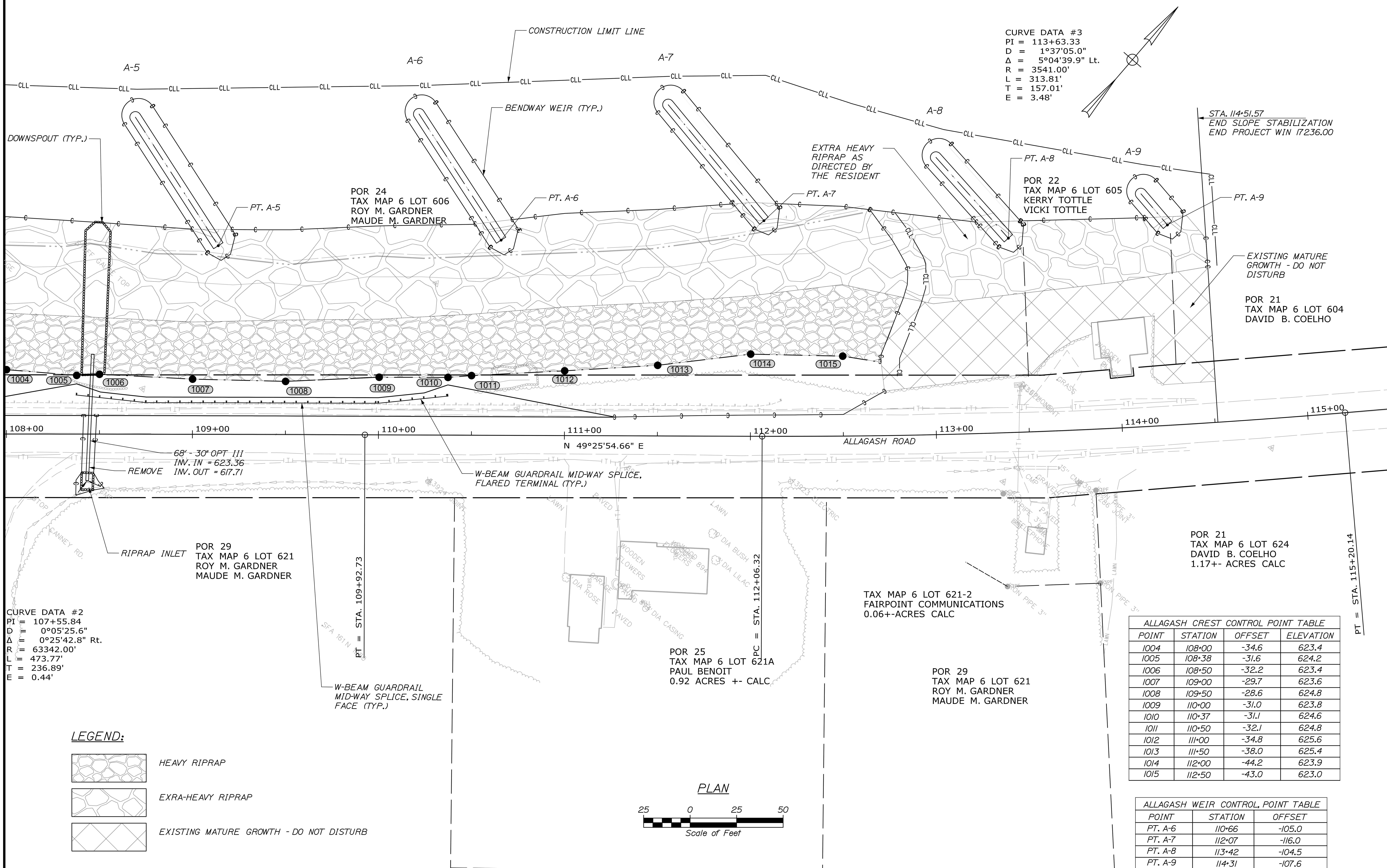
ALLAGASH-ST. FRANCIS
ROUTE 161

ALLAGASH PLAN

SHEET NUMBER

7

OF 10



ALLAGASH CREST CONTROL POINT TABLE			
POINT	STATION	OFFSET	ELEVATION
1004	108+00	-34.6	623.4
1005	108+38	-31.6	624.2
1006	108+50	-32.2	623.4
1007	109+00	-29.7	623.6
1008	109+50	-28.6	624.8
1009	110+00	-31.0	623.8
1010	110+37	-31.1	624.6
1011	110+50	-32.1	624.8
1012	111+00	-34.8	625.6
1013	111+50	-38.0	625.4
1014	112+00	-44.2	623.9
1015	112+50	-43.0	623.0

ALLAGASH WEIR CONTROL, POINT TABLE		
POINT	STATION	OFFSET
PT. A-6	110+66	-105.0
PT. A-7	112+07	-116.0
PT. A-8	113+42	-104.5
PT. A-9	114+31	-107.6

LEGEND:

- HEAVY RIPRAP
- EXRA-HEAVY RIPRAP
- EXISTING MATURE GROWTH - DO NOT DISTURB

FINAL PDR-PIC
DECEMBER 13, 2018

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

017236.00

WIN 017236.00

HIGHWAY PLANS

SIGNATURE
P.E. NUMBER
DATE

PROJ. MANAGER R.SOUCY
DESIGN-DETAILED
CHECKED-REVIEWED
DESIGN2-DETAILED2
DESIGN3-DETAILED3
REVISIONS 1
REVISIONS 2
REVISIONS 3
REVISIONS 4
FIELD CHANGES
BY
DATE

ALLAGASH-ST. FRANCIS
ROUTE 161

ALLAGASH PLAN

SHEET NUMBER
8
OF 10

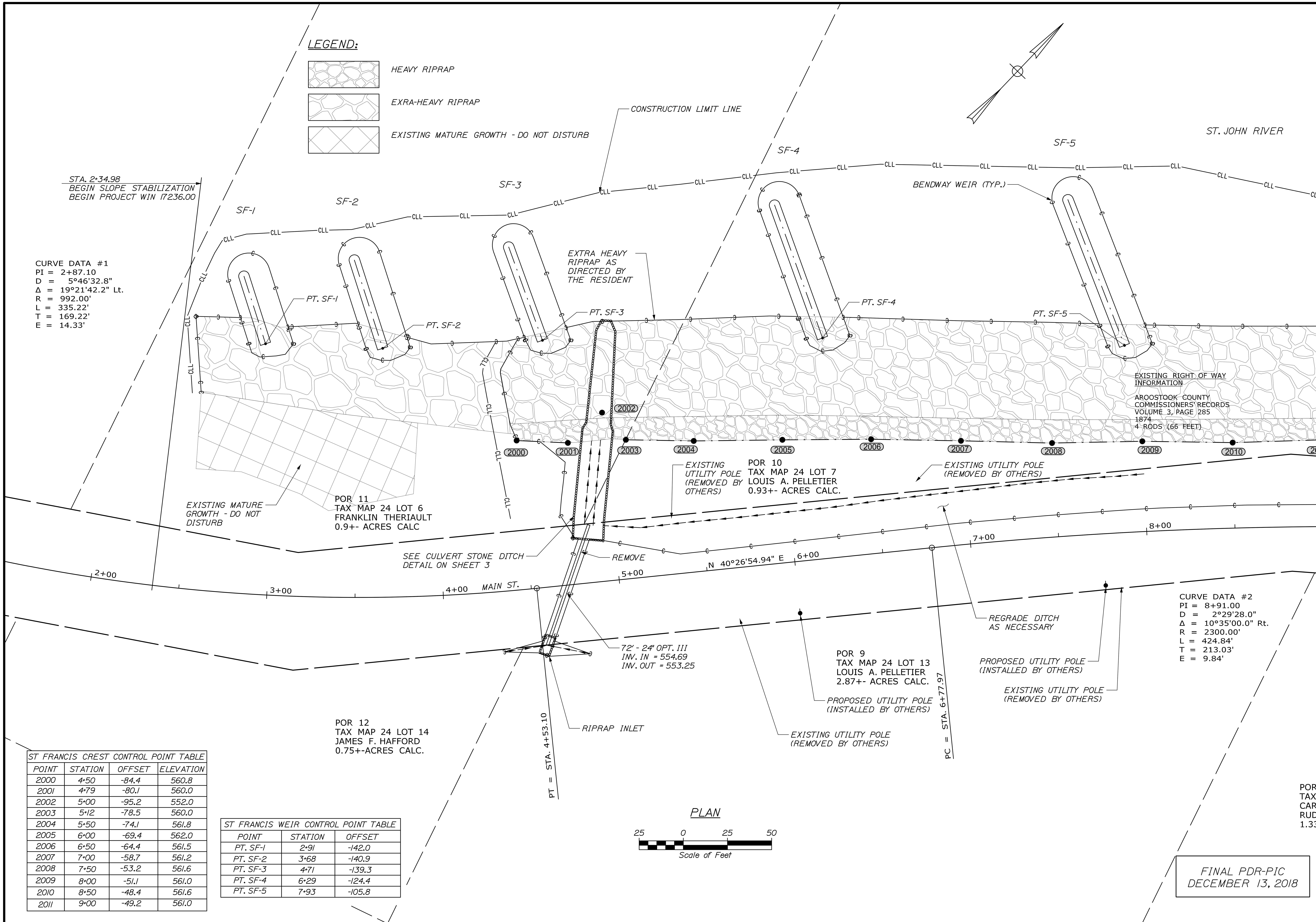
Date:12/13/2018
Username:
Division:
Filename: 008_Allagash Plan 2.dgn

Date:12/13/2018

Username:

Division:

Filename: 009_St. Francis Plan 1.dgn



ST FRANCIS CREST CONTROL POINT TABLE			
POINT	STATION	OFFSET	ELEVATION
2000	4+50	-84.4	560.8
2001	4+79	-80.1	560.0
2002	5+00	-95.2	552.0
2003	5+12	-78.5	560.0
2004	5+50	-74.1	561.8
2005	6+00	-69.4	562.0
2006	6+50	-64.4	561.5
2007	7+00	-58.7	561.2
2008	7+50	-53.2	561.6
2009	8+00	-51.1	561.0
2010	8+50	-48.4	561.6
2011	9+00	-49.2	561.0

ST FRANCIS WEIR CONTROL POINT TABLE		
POINT	STATION	OFFSET
PT. SF-1	2+91	-142.0
PT. SF-2	3+68	-140.9
PT. SF-3	4+71	-139.3
PT. SF-4	6+29	-124.4
PT. SF-5	7+93	-105.8

FINAL PDR-PIC
DECEMBER 13, 2018

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

017236.00

WIN
017236.00

HIGHWAY PLANS

SIGNATURE

P.E. NUMBER

DATE

PROJ. MANAGER | R.SOUCY
DESIGN-DETAILED
CHECKED-REVIEWED
DESIGN2-DETAILED2
DESIGN3-DETAILED3
REVISIONS 1
REVISIONS 2
REVISIONS 3
REVISIONS 4
FIELD CHANGES

BY

DATE

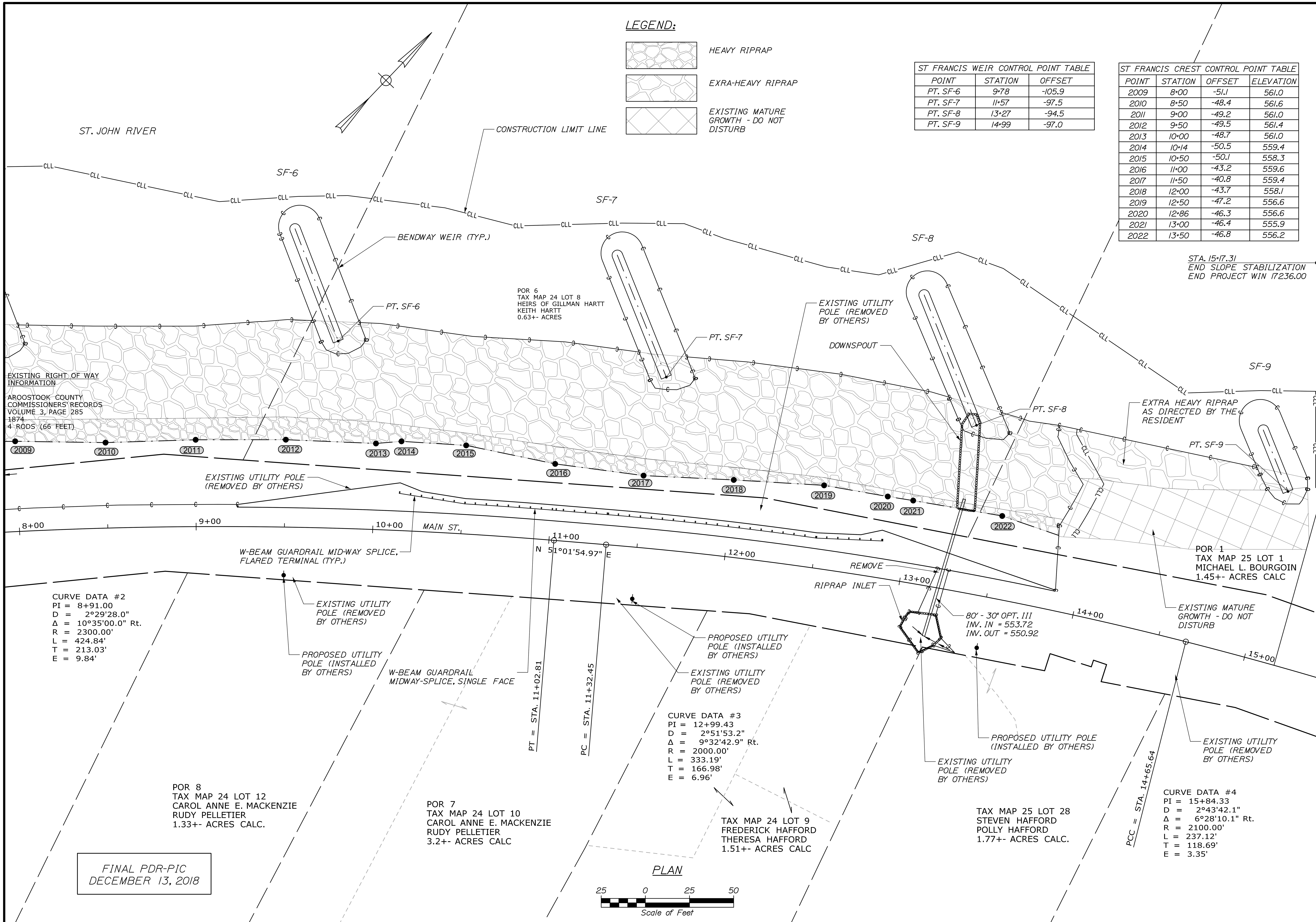
ALLAGASH-ST. FRANCIS
ROUTE 161

ST. FRANCIS PLAN

SHEET NUMBER

9

OF 10



ST FRANCIS WEIR CONTROL POINT TABLE

POINT	STATION	OFFSET
PT. SF-6	9+78	-105.9
PT. SF-7	11+57	-97.5
PT. SF-8	13+27	-94.5
PT. SF-9	14+99	-97.0

ST FRANCIS CREST CONTROL POINT TABLE

POINT	STATION	OFFSET	ELEVATION
2009	8+00	-51.1	561.0
2010	8+50	-48.4	561.6
2011	9+00	-49.2	561.0
2012	9+50	-49.5	561.4
2013	10+00	-48.7	561.0
2014	10+14	-50.5	559.4
2015	10+50	-50.1	558.3
2016	11+00	-43.2	559.6
2017	11+50	-40.8	559.4
2018	12+00	-43.7	558.1
2019	12+50	-47.2	556.6
2020	12+86	-46.3	556.6
2021	13+00	-46.4	555.9
2022	13+50	-46.8	556.2

FINAL PDR-PIC
DECEMBER 13, 2018

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION

017236.00

WIN
017236.00

HIGHWAY PLANS

	BY	DATE
PROJ. MANAGER	R.SOUCY	
DESIGN-DETAILED		
CHECKED-REVIEWED		
DESIGN2-DETAILED2		
DESIGN3-DETAILED3		
REVISIONS 1		
REVISIONS 2		
REVISIONS 3		
REVISIONS 4		
FIELD CHANGES		

SIGNATURE

P.E. NUMBER

DATE

ALLAGASH-ST. FRANCIS
ROUTE 161

ST. FRANCIS PLAN

SHEET NUMBER
10
OF 10

Date:12/13/2018

Username:

Division:

Filename: 010_St. Francis Plan 2.dgn

GOLDER

golder.com

GOLDER

golder.com