

WisDOT Aquatic Organism Passage Design Study

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WisDOT AOP Design Study Presentation Outline

1. Overview
2. Site Locations
3. Field Data Collection
 - a. Survey – Cross Sections (At least 3 US and DS)
 - b. Survey – Stream Thalweg (> 200 ft US and DS) and Existing Culvert Data
 - c. Stream Bed Samples – Upstream and Downstream
 - d. Stream Crossing Field Data
 - e. Site Photos

WisDOT AOP Study Presentation Outline (cont.)

4. Hydrology Analysis

- a. Drainage Basin Mapping
- b. USGS Regression and HydroCAD
- c. Flow Selection

5. HEC-RAS/HY-8 Modeling

6. Stream Profile Analysis

7. Culvert Bed Gradation Selection

8. HEC-26 Analysis

9. Study Results



WisDOT AOP Study Overview



- WisDOT currently does not have a procedure for AOP design.
- WDNR is requesting consideration of AOP more frequently on projects.
- Evaluate HEC-26 as an appropriate tool for AOP Design
- Compare current culvert design procedures with recently released HEC 26 – *Culvert Design for Aquatic Organism Passage*



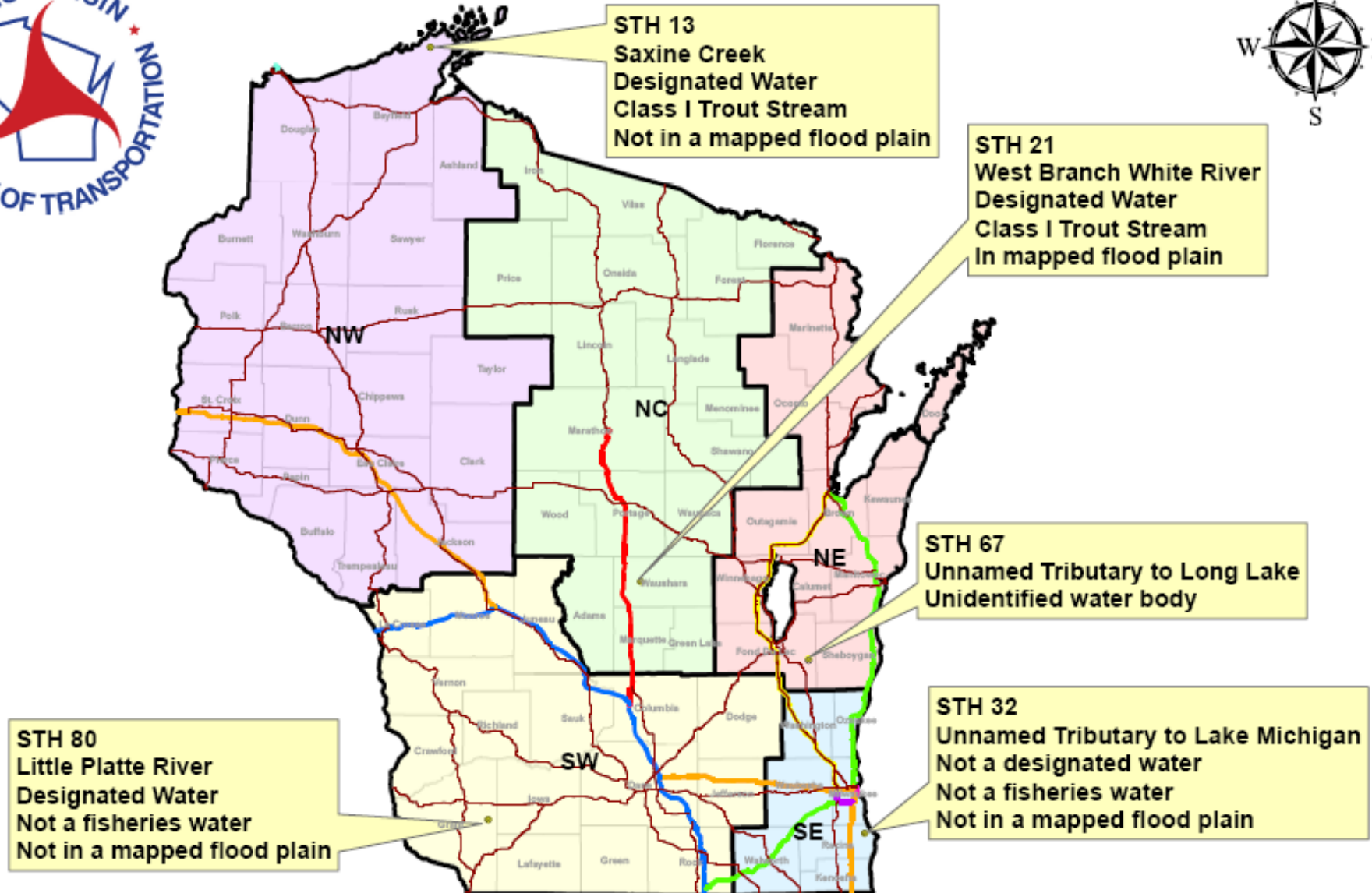
WisDOT AOP Study Overview

- WisDOT is working in cooperation with the WDNR on this study
- Results used to develop policy to define where AOP should be applied and to what extent
- And develop AOP design procedures based on results of the study

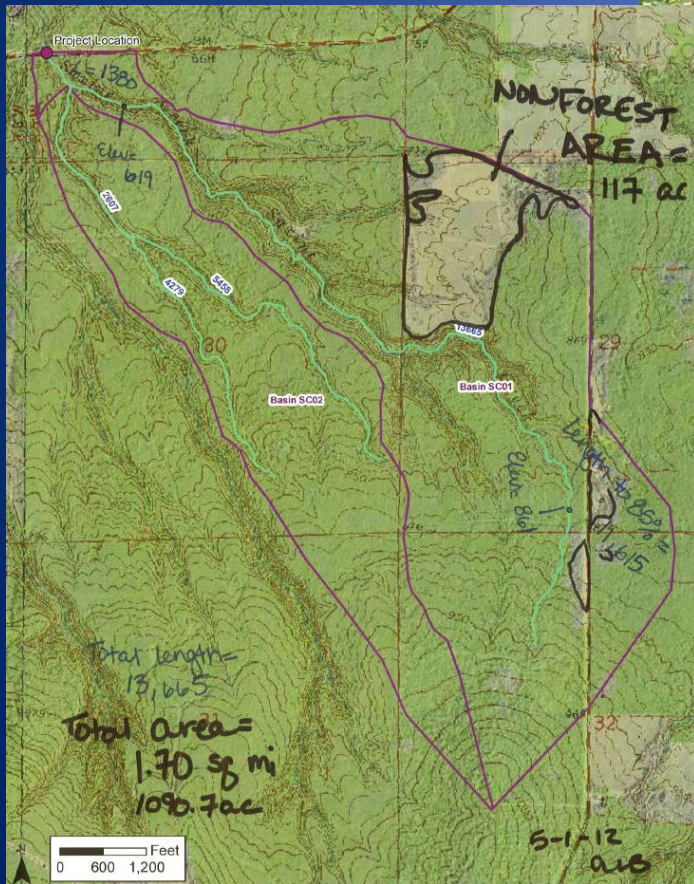
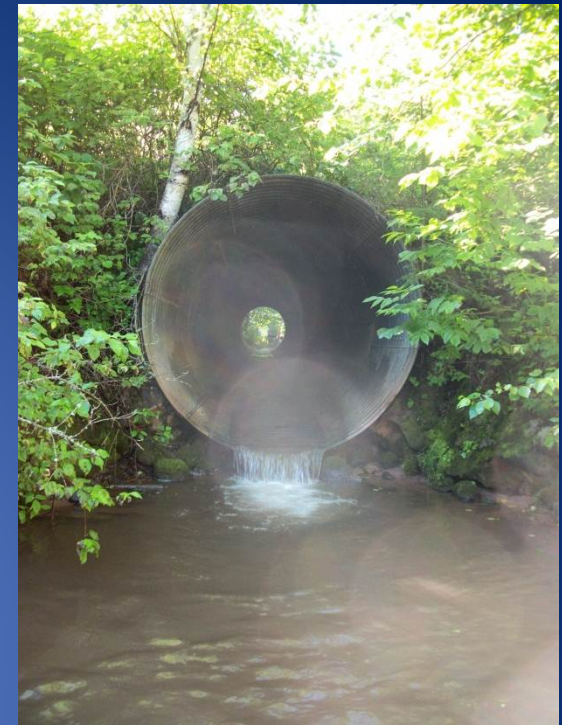
Site Locations



Wisconsin AOP Study Culvert Locations



STH 13 – Saxine Creek in Bayfield County



Bank Flow Width (ft)	12.5
Measured Structure Water Velocity (ft/sec)	3.07
Stream Velocity (ft/sec)	1.19
Stream Depth (ft)	0.35
Scour Pool Length and Width (ft)	20.4' x 38.75'
Scour Pool Depth (ft)	3.3
Upstream Pond Length and Width (ft)	None
Upstream Pond Depth	None
Is the outlet of the structure perched?	Yes
Is the structure water velocity greater than 3 feet/second during baseflow?	Yes



STH 21 - White River in Waushara County

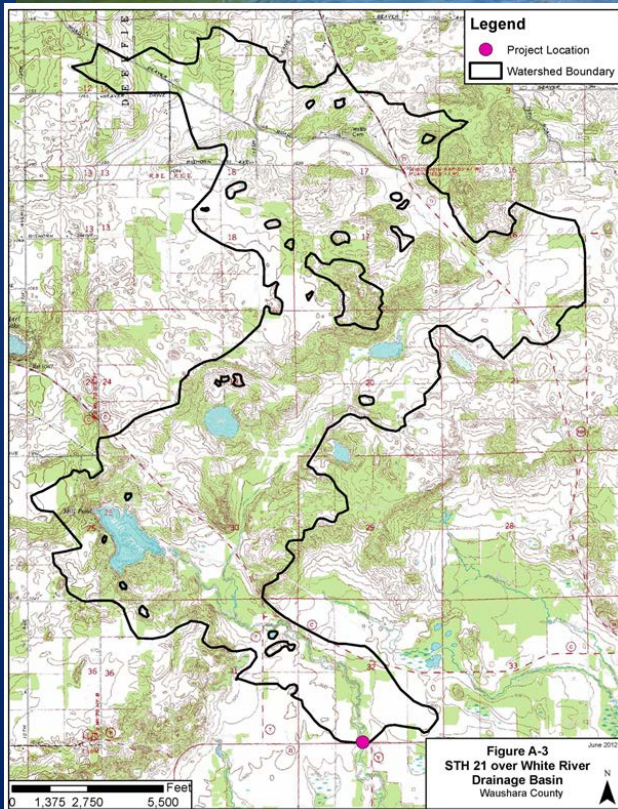


Table 2.3.6	
Stream Crossing Field Data	
Bank Flow Width (ft)	23.75
Measured Structure Water Velocity (ft/sec)	6.4
Stream Velocity (ft/sec)	2.02
Stream Depth (ft)	2.0
Scour Pool Length and Width (ft)	66' x 43.5'
Scour Pool Depth (ft)	4
Upstream Pond Length and Width (ft)	None
Upstream Pond Depth	None
Is the outlet of the structure perched?	No
Is the structure water velocity greater than 3 feet/second during <u>baseflow</u> ?	Yes
Is the depth ratio less than 0.1?	No



STH 80 – Little Platt River in Grant County

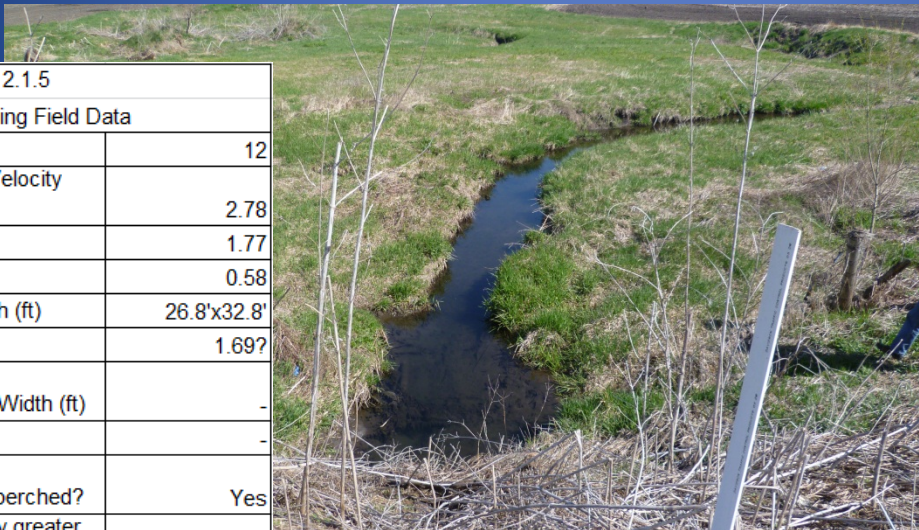
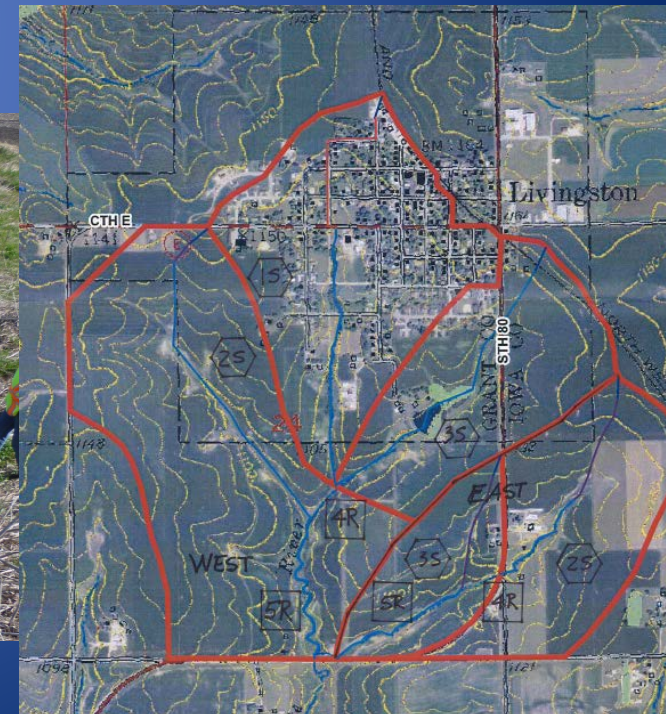


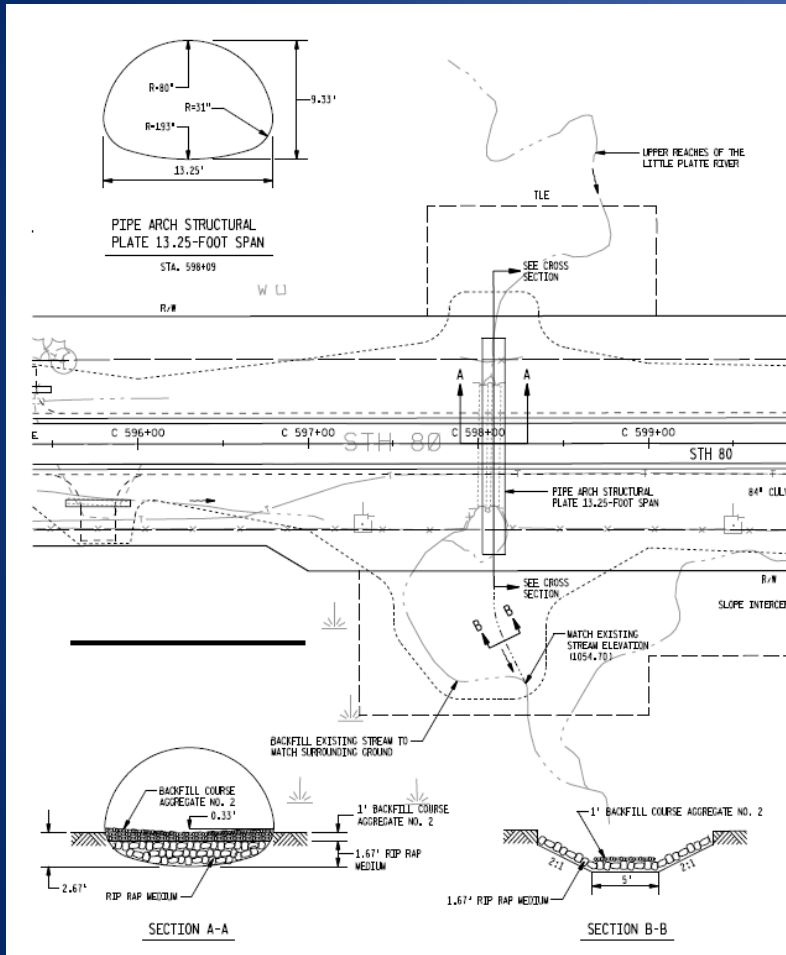
Table 2.1.5

Stream Crossing Field Data

Bank Flow Width (ft)	12
Measured Structure Water Velocity (ft/sec)	2.78
Stream Velocity (ft/sec)	1.77
Stream Depth (ft)	0.58
Scour Pool Length and Width (ft)	26.8'x32.8'
Scour Pool Depth (ft)	1.69?
Upstream Pond Length and Width (ft)	-
Upstream Pond Depth (ft)	-
Is the outlet of the structure perched?	Yes
Is the structure water velocity greater than 3 feet/second during baseflow?	No
Is the depth ratio less than 0.1?	?



STH 80 – Little Platt River in Grant County



STH 67 – Unnamed Trib to Long Lake in Fond du Lac County

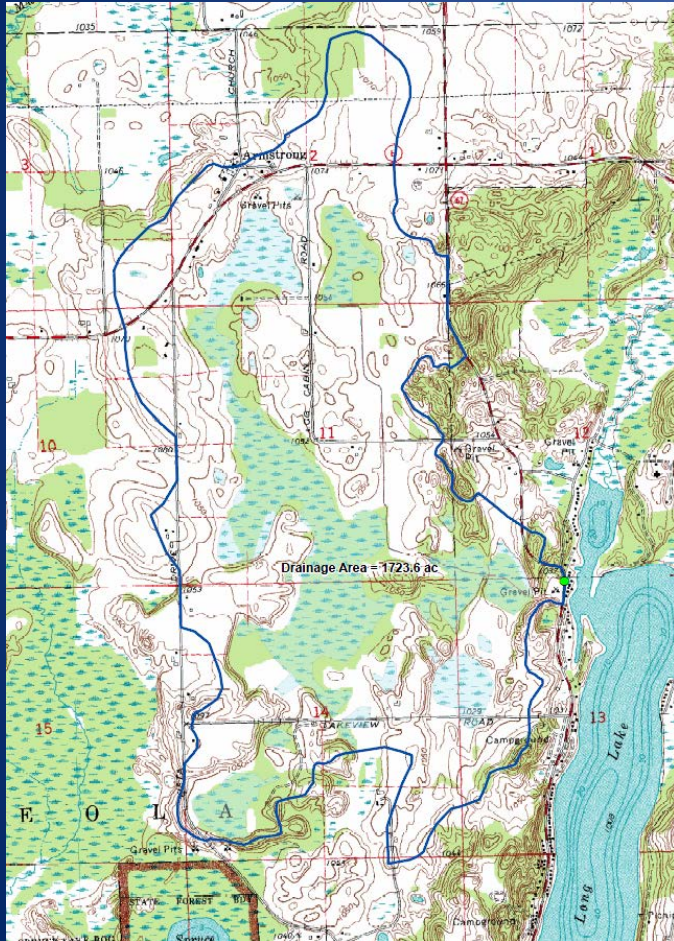
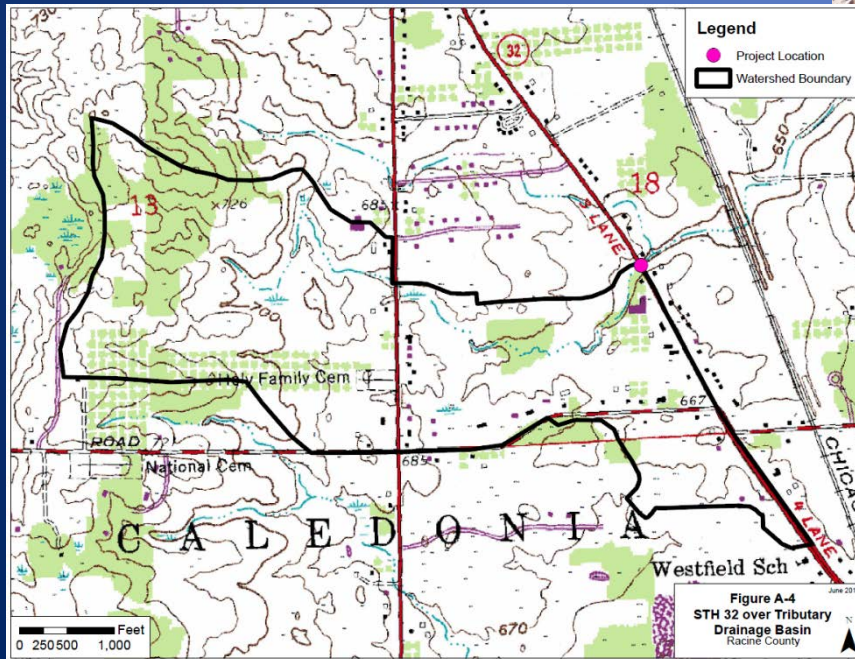


Table 2.1.5 Stream Crossing Field Data	
Bank Flow Width (ft)	11.16
Measured Structure Water Velocity (ft/sec)	1.1
Stream Velocity (ft/sec)	1.44
Stream Depth (ft)	0.1
Scour Pool Length and Width (ft)	13.4'x13.6'
Scour Pool Depth (ft)	1.0'
Upstream Pond Length and Width (ft)	43'x3.2'
Upstream Pond Depth (ft)	look at survey data
Is the outlet of the structure perched?	Yes
Is the structure water velocity greater than 3 feet/second during baseflow?	No
Is the depth ratio less than 0.1?	No



STH 32 – Unnamed Trib to Lake Michigan – Racine County



Bank Flow Width (ft)	10.66
Measured Structure Water Velocity (ft/sec)	0.55
Stream Velocity (ft/sec)	0.42
Stream Depth (ft)	0.3
Scour Pool Length and Width (ft)	33.3' x 14.4'
Scour Pool Depth (ft)	look at survey data
Upstream Pond Length and Width (ft)	None
Upstream Pond Depth (ft)	None
Is the outlet of the structure perched?	Yes
Is the structure water velocity greater than 3 feet/second during baseflow?	No
Is the depth ratio less than 0.1?	No

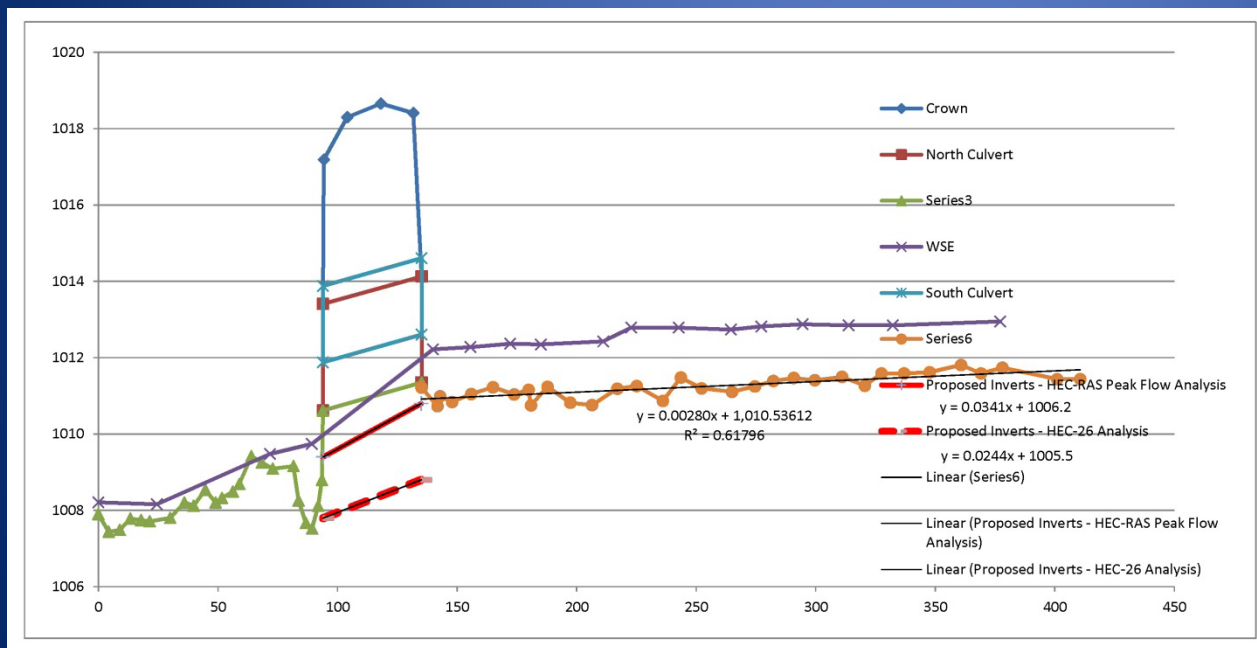
Field Data Collection

Survey – Cross Sections (At least 3 US and DS)



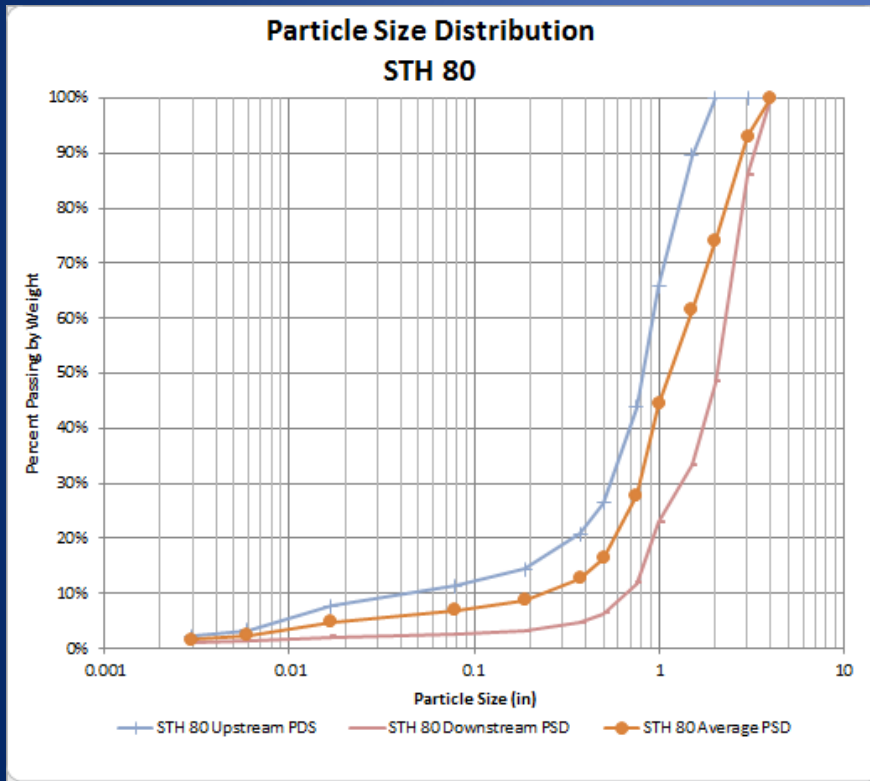
Field Data Collection

Survey – Stream Thalweg (> 200 ft US and DS) and Existing Culvert Data



Field Data Collection

Stream Bed Samples Upstream and Downstream



Material Description: Poorly graded sand with silt
Date: 9/26/11
USCS Classification: SP-SM

Dry Sample and Tare (grams)		Cumulative Pan Tare Weight (grams)		Sieve Test Data		
Sample	Tare	Tare	Weight	Sieve Opening Size	Cumulative Retained Weight (grams)	Percent Finer
12353.70	0.00	0.00	0.00	5	0.00	100.0
				375	245.80	98.0
				#4	1331.60	89.2
				#8	2655.10	78.5
				#10	2846.30	77.0
				#16	3669.90	70.3
				#30	5052.60	59.1
				#40	6553.50	47.0
				#60	9347.80	24.3
				#100	11506.80	6.9
				#200	11620.40	5.9

Cobbles		Gravel			Sand			Fines		
	Coarse	Fine	Total	Coarse	Medium	Fine	Total	Silt	Clay	Total
0.0	0.0	10.8	10.8	12.2	30.0	41.1	83.3			5.9

D ₁₀	D ₁₅	D ₂₀	D ₃₀	D ₅₀	D ₆₀	D ₈₀	D ₈₅	D ₉₀	D ₉₅
0.2016	0.2447	0.2765	0.3281	0.4516	0.6246	2.6785	3.6994	4.9855	7.1070

Fineness Modulus	C _u	C _c
2.74	3.10	0.85

Field Data Collection

Stream Crossing Field Data

Stream Crossing Data Sheet Site ID: _____

General Information

Name of Observer(s): Jesse Vossbeck / Greg Payne / Rebek Taylor Date: 26 July 2011

Road Name/Number: SRH 67

Stream Name: Unnamed trib. to N. end of Long Lake

GPS Waypoint: _____ Lat/Long: N 43° 41.303' W 108° 10.381'

Additional Location Comments: _____

Road Information

Road Type: Federal State County: _____ Town: _____ Tribal: _____ Private: _____ Other: _____

Road Surface: Asphalt Gravel Sand Native Surface Other: _____

Fill Depth (ft): _____ Road Width (ft): 28' Structure Length (ft): 40.9'

Crossing Information

Structure Type: Culvert(s) no.: 2

Structure Shape: Round Square/Rectangle Open Bottom Square/Rectangle Pipe Arch Open Bottom Arch Ellipse

Structure Height (ft): 3 2

Structure Width (ft): 3 2

Erosion Information

Fill out all that apply. Use blank rows for additional locations. Additional locations may include prominent erosion along stream banks within 50 feet of crossing. Left and right are facing downstream. Note any comments below.

Location of Erosion	Erosion Dimensions (ft)			Total Erosion (Cubic feet)	Erosion Reaching Stream		Material Eroded Sand, Silt, Clay, Gravel, Loam, Sandy Loam or Gravelly Loam
	Length	Width	Depth		Yes	No	
Road Approach - Left					Yes	No	
Road Approach - Right					Yes	No	
Road over Crossing					Yes	No	
Upstream Ditch - Left					Yes	No	
Upstream Ditch - Right					Yes	No	
Downstream Ditch - Left					Yes	No	
Downstream Ditch - Right					Yes	No	
Upstream Embankment - Left					Yes	No	
Upstream Embankment - Right					Yes	No	
Downstream Embankment - Left					Yes	No	
Downstream Embankment - Right					Yes	No	

Fish Passage Determination Summary Site ID: _____

Follow these guidelines to determine "passability" for a range of fish species. Thresholds may need to be modified if the objective is to evaluate passage for a particular species. Answer all questions.

Passability = 0 Most species and life stages cannot pass at most flows.

If any of the following questions can be answered "yes", then the crossing barrier score = 0.

- Is the outlet of the structure perched? Yes No
- Is the structure water velocity greater than 3 feet/second during baseflow? Yes No
- Is the depth ratio less than 0.1? Yes No

Structure water depth: 4 3/4" / Stream water depth: 1.5" = Depth Ratio: 0.5

If there is erosion occurring, can correct address the problem? Yes No

Passability = 0.5 Some species and/or life stages cannot pass at most flows.

If any of the following questions can be answered "yes", then the crossing barrier score = 0.5.

- Is the water depth in the structure is less than 0.2 feet? Yes No
- Is the structure water velocity between 2-3 feet/second during baseflow? Yes No
- Is the structure longer than 30 feet and lacks natural substrate through its entire length? Yes No

Passability = 0.9 Barrier at high flows.

If any of the following questions can be answered "yes", then the crossing barrier score = 0.9.

- Is there a scour pool below the structure? Yes No
- Is the constriction ratio less than 0.5? Yes No

Structure width: 3 / Stream bankfull width: 11.6 = Constriction Ratio: 0.27

Passability = 1 Not a barrier.

If all of the above questions were answered "no", then the crossing barrier score = 1, and then following statements are all true:

- The outlet of the structure is not perched.
- The structure water velocity is less than 2 feet/second during baseflow.
- The ratio of the structure water depth to stream water depth is greater than 0.1 (depth ratio).
- The water depth in the structure is greater than 0.2 feet.
- There is not a scour pool below the structure.
- The ratio of the structure width to stream bankfull width is greater than 0.5 (constriction ratio).
- The structure is longer than 30 feet and has natural substrate through its entire length, or
□ The structure is shorter than 30 feet and has natural substrate through its entire length, or
□ The structure is shorter than 30 feet and does not have natural substrate through its entire length.

Additional Comments

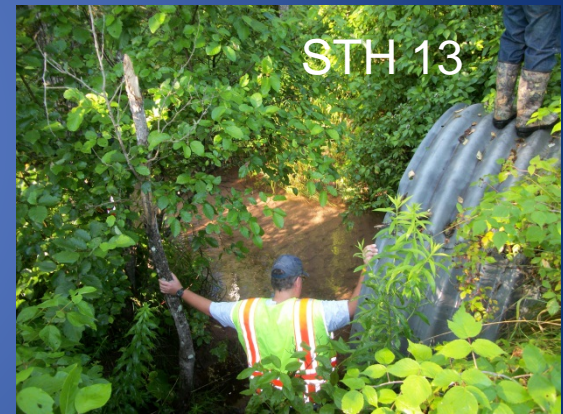
Culvert diagram, erosion, channel condition better based on map

Table 2.2.6
Stream Crossing Field Data

Bank Flow Width (ft)	12.5
Measured Structure Water Velocity (ft/sec)	3.07
Stream Velocity (ft/sec)	1.19
Stream Depth (ft)	0.35
Scour Pool Length and Width (ft)	20.4' x 38.75'
Scour Pool Depth (ft)	3.3
Upstream Pond Length and Width (ft)	None
Upstream Pond Depth	None
Is the outlet of the structure perched?	Yes
Is the structure water velocity greater than 3 feet/second during baseflow?	Yes

Field Data Collection

Site Photos



Hydrology Analysis

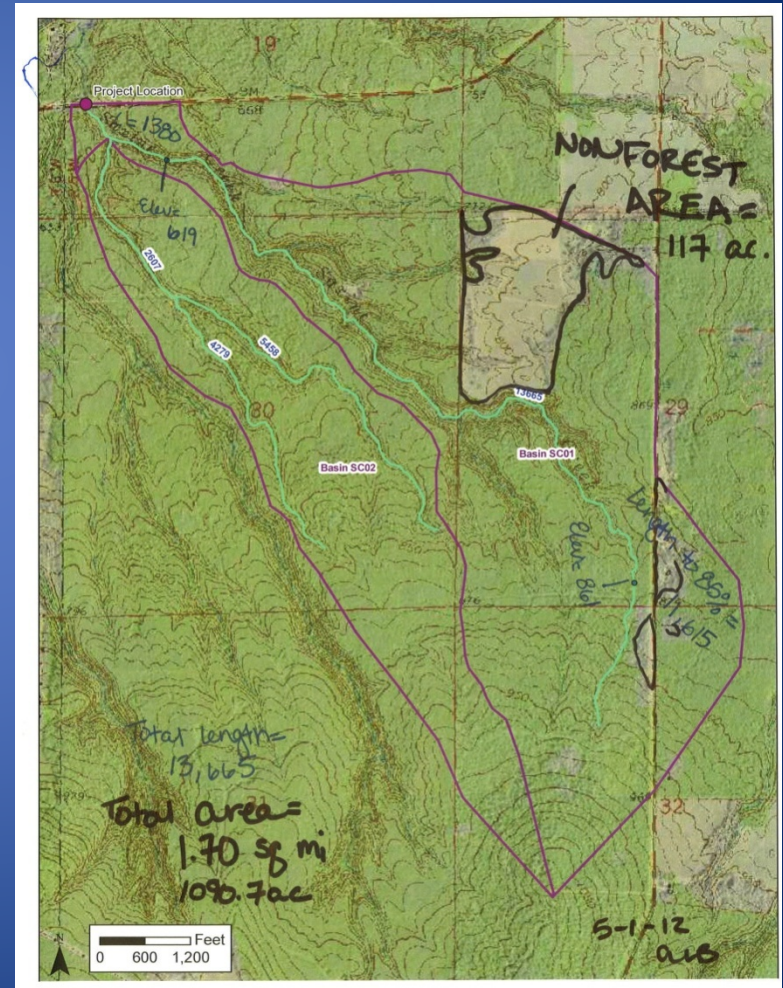
Drainage Basin Mapping

L-THIA 2.0 Watershed Delineation and Runoff Analysis

Page 1 of 1

The screenshot shows the L-THIA 2.0 web interface. On the left is a navigation menu with links like 'L-THIA HOME' and 'MSDSS L-THIA Tutorials and Help'. The main content area contains instructions for users, including 'Process: 3 separate ways to locate your point:' and options for 'Calculate Impervious area', 'Run TR-55 L-THIA Model', 'Run Calibrated L-THIA Model', and 'Run SWAT'. A search bar is present, and a map shows a green-shaded watershed area. Handwritten notes on the map include 'Elev = 1380' and 'Elev = 619'. A scale bar at the bottom indicates 0, 600, and 1,200 feet.

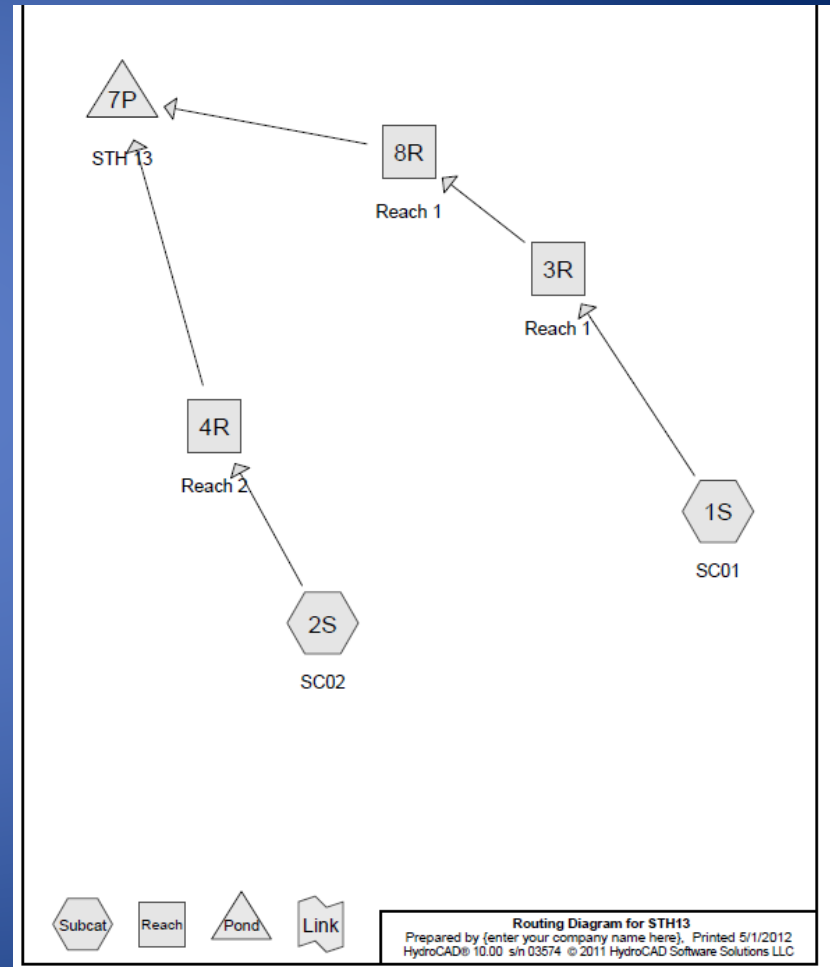
https://engineering.purdue.edu/mapserve/LTHIAWD/wi/lthia2_wi.html?del=0&watershed... 10/5/2011



Hydrology Analysis

USGS Regression and HydroCAD

Drainage Basin Characteristics:			
Area Equations =	4		
Drainage Area =	1.7 mi ²		
Slope (S):			
@ 10% , Elevation is approximately =	619 ft.		
@ 85% , Elevation is approximately =	861 ft.		
total length is approximately =	2.6 mi.		
S =	124 ft./mi.		
Storage (ST) =	1.0 %		
Forest Cover (FOR) =	89.3%		
Precipitation Intensity Index (INTENS):			
I _{24,25} value to be used in computations =	4.79 in.		
Annual Snowfall (SN):			
Value from chart =	70 in.		
Soil Permeability (SP):			
Value from chart =	0.12 in./hr.		
Technique 1 - Regression Equation Values at Project Site:			
Area Equation Number =	4	Ave. Annual Snow (SN) =	70 inches
Drainage Area (A) =	1.70 sq. mi.	Precip Int. Index (I _{24,25}) =	4.79 inches
Slope (S) =	124 ft./mi.	Soil Permeability (SP) =	0.12 in./hr.
Storage (ST) =	1 %		
Forest Cover (FOR) =	89 %		
Q(2) =	181 cfs		
Q(5) =	314 cfs		
Q(10) =	416 cfs		
Q(25) =	551 cfs		
Q(50) =	652 cfs		
Q(100) =	759 cfs		
Technique 2 - Gage Comparisons:			
Gage Station #	4026200 Sand River Tributary near Red Cliff, WI		
Basin Number =	4	Gage Station	4



Hydrology Analysis

Flow Selection

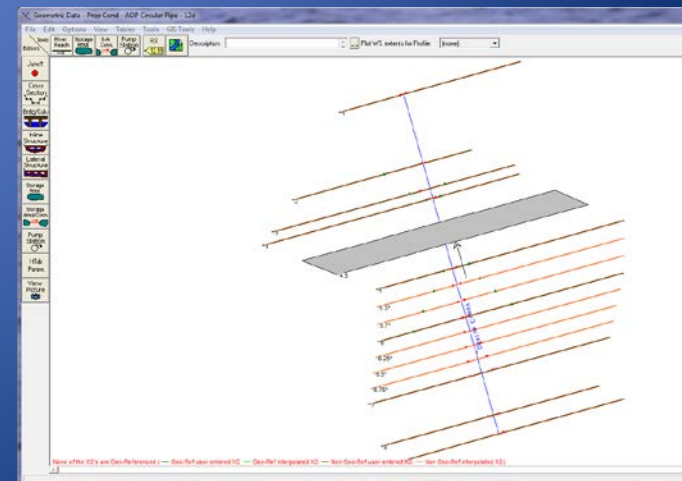
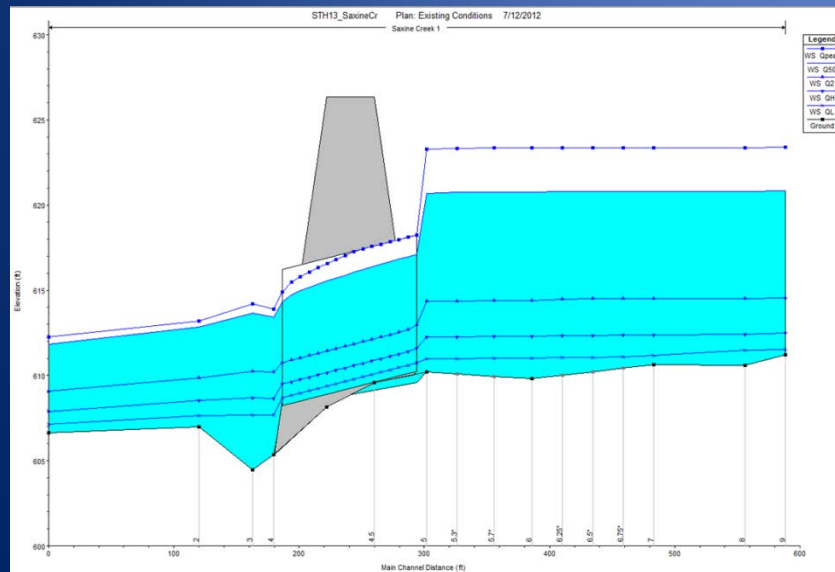
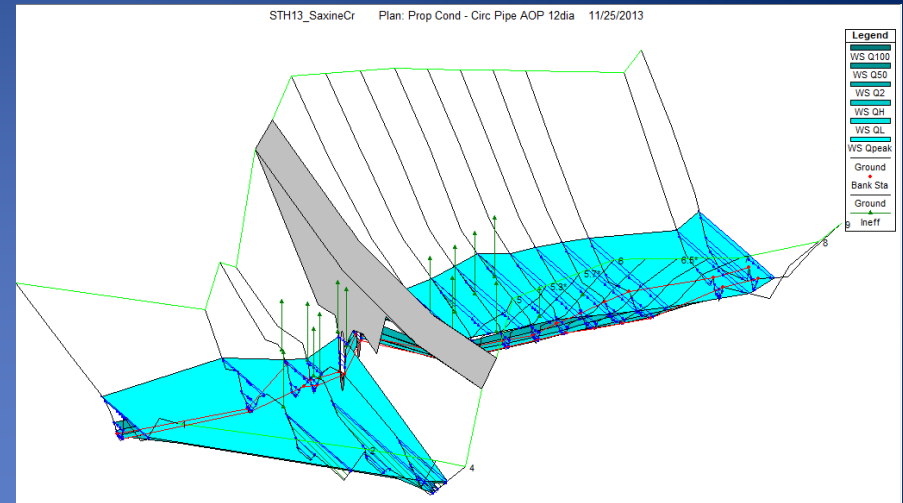
Recurrence Interval	Peak Flows (cfs)			
	HydroCAD		USGS Regression Equation	Selected
	Inflow	Outflow		
QL ¹	-	-	-	4
QH ¹	26	24	45	30
2-yr	103	96	181	118
25-yr	458	377	551	401
50-yr	534	447	651	575
100-yr	682	520	759	700

¹QL and QH are the low and high flows, respectively, used to evaluate the AOP culvert size, as described in HEC-26. QH is 25% of the 2-year flow.

Hydraulic Analysis – HEC-RAS Modeling

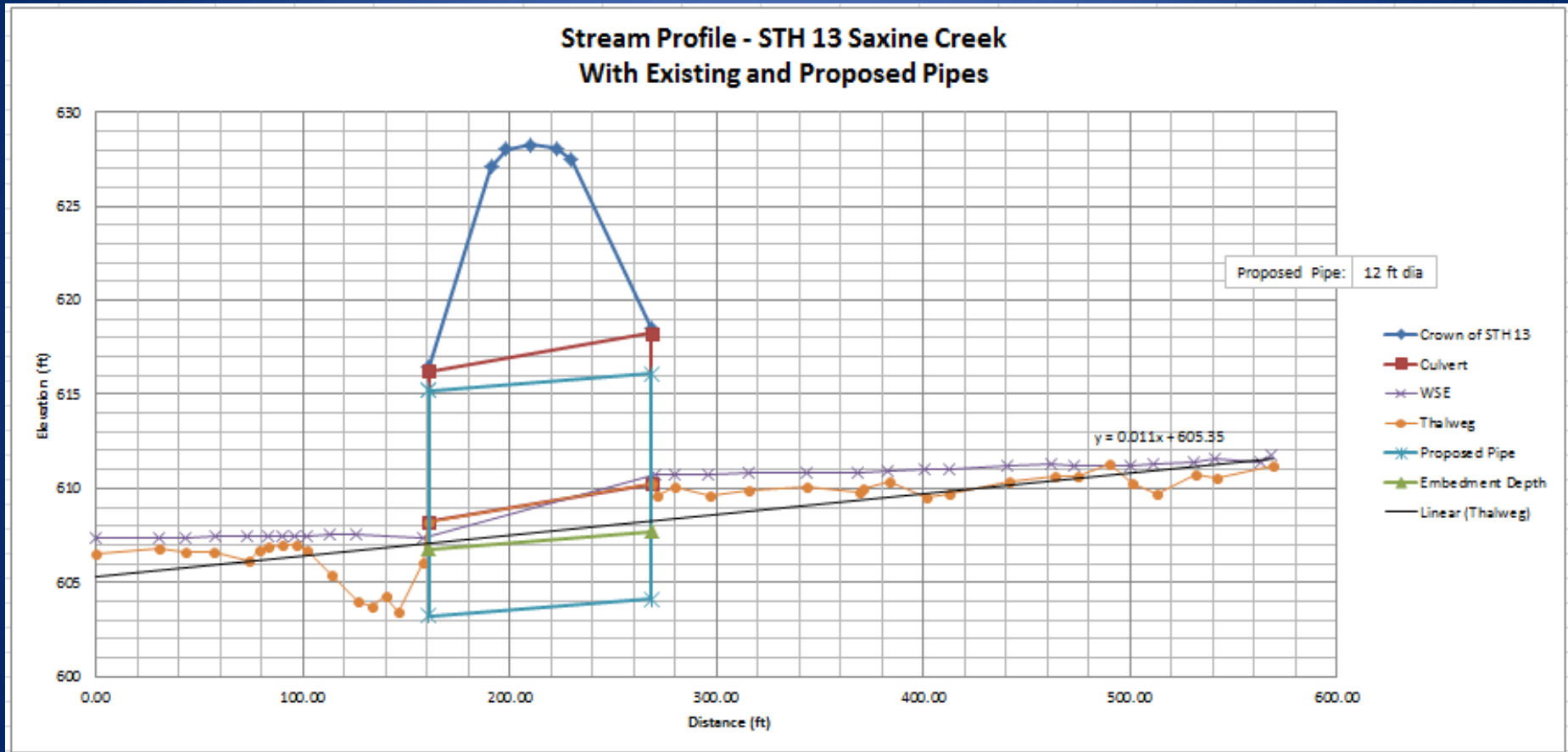
For -

- Sizing culverts for peak and low flows
- Evaluating channel velocities



Stream Profile Analysis

Stream Profile Analysis



... to set pipe slope and embedment depth

Culvert Bed Gradation Selection

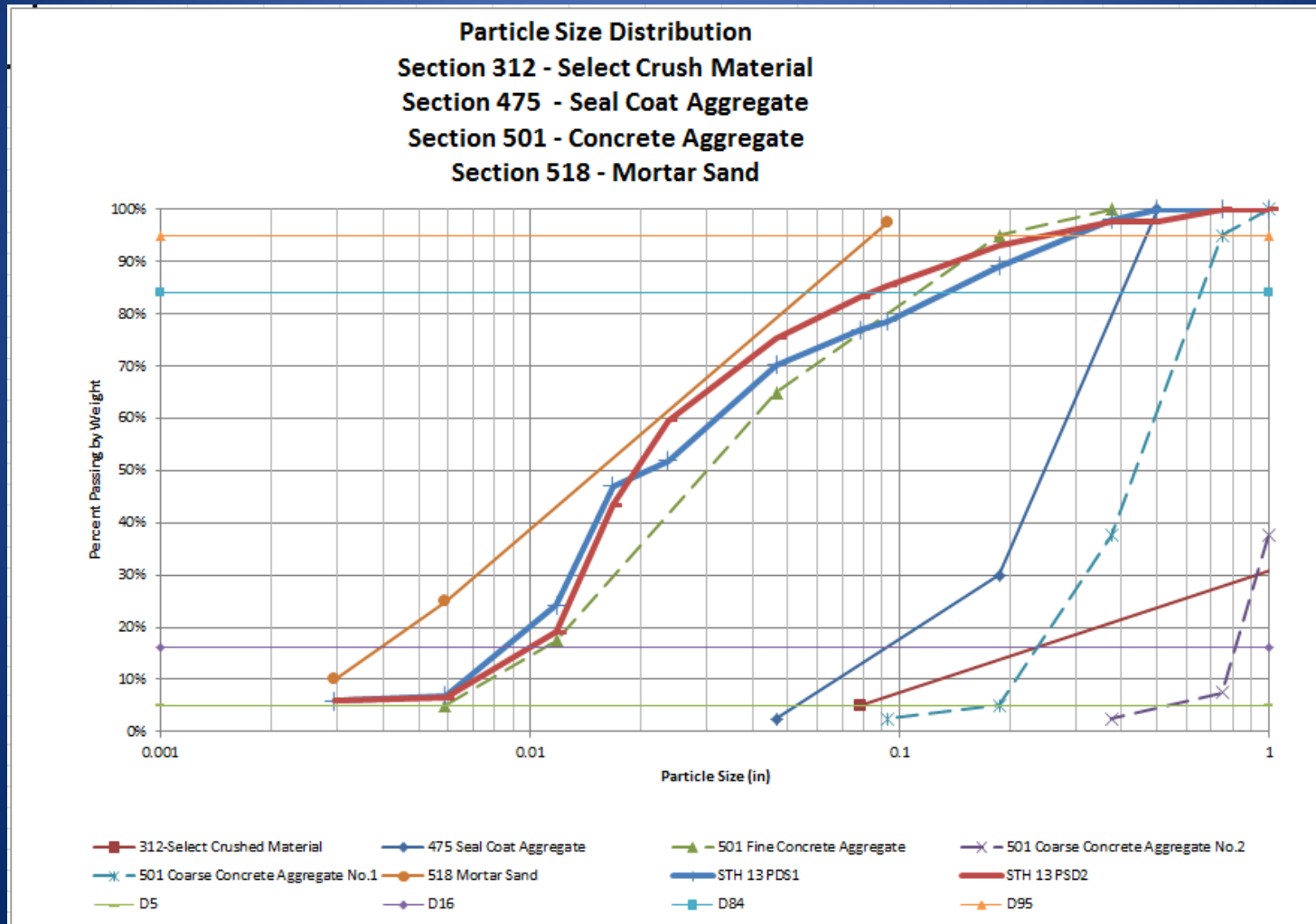
Particle Size Distribution

GRAIN SIZE DISTRIBUTION TEST DATA										9/19/2011	
Project: STH 13											
Project Number: 60220570											
Sample Number: STH-13 8-21-11											
Material Description: Poorly graded sand with silt											
Date: 8/26/11											
USCS Classification: SP-SM											
Sieve Test Data											
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer						
12675.50	0.00	0.00	.75	0.00	100.0						
			.5	281.00	97.8						
			.375	298.40	97.6						
			#4	864.50	93.2						
			#8	1844.20	85.5						
			#10	2117.00	83.3						
			#16	3120.20	75.4						
			#30	5110.70	59.7						
			#40	7178.20	43.4						
			#50	10259.70	19.1						
			#100	11850.90	6.5						
			#200	11931.40	5.9						
Fractional Components											
Cobbles	Gravel			Sand			Silt	Fines Clay		Total	
	Coarse	Fine	Total	Coarse	Medium	Fine		Total	Clay		
0.0	0.0	6.8	6.8	9.9	39.9	37.5	87.3			5.9	
D ₁₀	D ₁₅	D ₂₀	D ₃₀	D ₅₀	D ₆₀	D ₈₀	D ₈₅	D ₉₀	D ₉₅		
0.1968	0.2545	0.3049	0.3528	0.4765	0.6056	1.5837	2.2775	3.4820	5.7983		
Fineness Modulus	C _u	C _c									
2.63	3.08	1.04									
AECOM											

GRAIN SIZE DISTRIBUTION TEST DATA										9/19/2011
Project: STH 13										
Project Number: 60220570										
Sample Number: STH-13 8-17-11										
Material Description: Poorly graded sand with silt										
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USCS Classification: SP-SM										
Sieve Test Data										
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)	Sieve Opening Size	Cumulative Weight Retained (grams)	Percent Finer					
12353.70	0.00	0.00	.5	0.00	100.0					
			.375	245.80	98.0					
			#4	1331.60	89.2					
			#8	2655.10	78.5					
			#10	2846.30	77.0					
			#16	3669.90	70.3					
			#30	5052.60	59.1					
			#40	6553.50	47.0					
			#50	9347.80	24.3					
			#100	11506.60	6.9					
			#200	11620.40	5.9					
Fractional Components										
Cobbles	Gravel			Sand			Silt	Fines Clay		Total
	Coarse	Fine	Total	Coarse	Medium	Fine		Total	Clay	
0.0	0.0	10.8	10.8	12.2	30.0	41.1	83.3			5.9
D ₁₀	D ₁₅	D ₂₀	D ₃₀	D ₅₀	D ₆₀	D ₈₀	D ₈₅	D ₉₀	D ₉₅	
0.2016	0.2447	0.2765	0.3281	0.4516	0.6246	2.6785	3.6994	4.9855	7.1070	
Fineness Modulus	C _u	C _c								
2.74	3.10	0.85								
AECOM										

Culvert Bed Gradation Selection

Site and WisDOT Standard PSDs



HEC-26 Analysis

Iterative Design Approach Using HEC-26 and HEC-RAS

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1 AOP Culvert Design (based on HEC 26)																
1 Project ID	HEC-26 Analysis															
2 Location	HEC-26 Analysis															
3 Design/Drawn	HEC-26 Analysis															
4 Date	HEC-26 Analysis															
2 Step 1 Design Flow																
10 Design flow	10	Assume 0-50 year event														
11 Design flow	10	Assume 0-50 year event														
12 Design flow	10	Assume 0-50 year event														
3 Step 2 Project Reach and Representative Channel Characteristics																
13 Enter up to five gradations or up to ten sub-reaches on the Plan/Cross tab																
14 Sub-reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
15 Sub-reach length (ft)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
16 Sub-reach width (ft)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
17 Sub-reach depth (ft)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18 Sub-reach velocity (ft/s)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19 Sub-reach roughness (ft)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20 Sub-reach slope (ft/ft)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21 Sub-reach material	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22 Sub-reach stability	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23 Sub-reach notes																
3 Step 3 Dynamic Equilibrium																
24 Step performed outside this spreadsheet																
3 Step 4 Analysis and mitigate channel instability																
25 Step performed outside this spreadsheet																
3 Step 5 Design Bed Gradation																
26 Enter bed gradation, see Channel Characterization tab for help																
27 Sub-reach	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
28 Sub-reach length (ft)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
29 Sub-reach width (ft)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
30 Sub-reach depth (ft)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
31 Sub-reach velocity (ft/s)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
32 Sub-reach roughness (ft)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
33 Sub-reach slope (ft/ft)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
34 Sub-reach material	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
35 Sub-reach stability	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
36 Sub-reach notes																
3 Step 6 Align and Size Culvert																
37 Enter culvert data, see Design tab for help																
38 Culvert length (ft)	100															
39 Culvert width (ft)	10															
40 Culvert depth (ft)	1															
41 Culvert velocity (ft/s)	1															
42 Culvert roughness (ft)	1															
43 Culvert slope (ft/ft)	1															
44 Culvert material	1															
45 Culvert stability	1															
46 Culvert notes																
3 Step 7 Estimate Manning's n and Normal Depth																
47 Enter Manning's n method or supply a Manning's n for each flow																
48 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
49 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
50 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
51 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
52 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
53 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
54 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
55 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
56 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
57 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
58 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
59 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
60 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
61 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
62 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
63 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
64 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
65 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
66 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
67 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
68 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
69 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
70 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
71 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
72 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
73 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
74 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
75 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
76 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
77 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
78 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
79 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
80 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
81 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
82 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
83 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
84 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
85 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
86 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
87 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
88 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
89 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
90 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
91 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
92 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
93 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
94 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
95 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
96 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
97 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
98 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
99 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
100 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
101 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
102 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
103 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
104 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
105 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
106 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
107 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
108 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
109 Manning's n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
110 Manning's n	1	2	3	4												

Study Results

Culvert Sized for AOP at each Site

Characteristic	Existing Culvert	Proposed Standard Design Culvert	Proposed AOP Culvert
Shape	Circular	Circular	Circular
Pipe Type/Material	Corrugated Metal Pipe	Corrugated Metal Pipe	Corrugated Metal Pipe
End Treatment	Pipe Projecting From Fill	Headwall	Headwall
Pipe Length	107.4	107.4	107.4
Upstream Invert Elevation	610.26	607.70	604.10
Downstream Invert Elevation	608.22	606.80	603.20
Diameter (ft)	8.0	8.0	12.0
Span (ft)	-	-	-
Height (ft)	-	-	-
Pipe slope (ft/ft)	0.019	0.0084	0.0083
Embedment Depth (ft)	0.0	0.0	3.6
Manning's n for Top	0.03	0.024	0.024
Manning's n for Bottom	n/a	n/a	0.040

- Evaluation of Suitability of HEC-26 Process for WisDOT Highways
- Policy Recommendations to WisDOT for Addressing AOP Issues

Study Results

Existing and Proposed Culverts - Draft

Highway	Creek	Existing Pipe	Bank Flow Width	Proposed Pipe	Embedment Depth
STH 13	Saxine Creek	8' Dia. CM Pipe	12.5'	12' Dia. CM Pipe	3.6'
STH 21	White River	6' Dia. CM Pipe	23.75'	5' x 20' Box Culvert	2'
STH 80	Little Platte River	2 - 5' Dia. CM Pipes	12'	9.33' x 12.25' CM Arch Pipe	2.67'
STH 67	Unnamed Trib to Long Lake	3' Dia. CM Pipe 2' Dia. CM Pipe	11.2'	5.92' x 8.59' CM Arch Pipe	2.33'
STH 32	Unnamed Trib to Lake Michigan	6' x 4' Box Culvert	10.66'	8' x 6' Box Culvert	2'



Questions?

