

WisDOT Aquatic Organism Passage Design Study

Ann-Marie Kirsch, PE State Roadway Drainage Engineer National Hydraulic Engineering Conf. Iowa City, Iowa August 2014



WisDOT AOP Design Study Presentation Outline

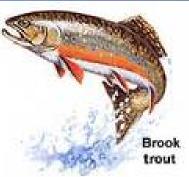
- 1. Overview
- 2. Site Locations
- 3. Field Data Collection
 - a. Survey Cross Sections (At least 3 US and DS)
 - b. Survey Stream Thalweg (> 200 ft US and DS) and Existing Culvert Data
 - c. Stream Bed Samples Upstream and Downstream
 - d. Stream Crossing Field Data
 - e. Site Photos

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

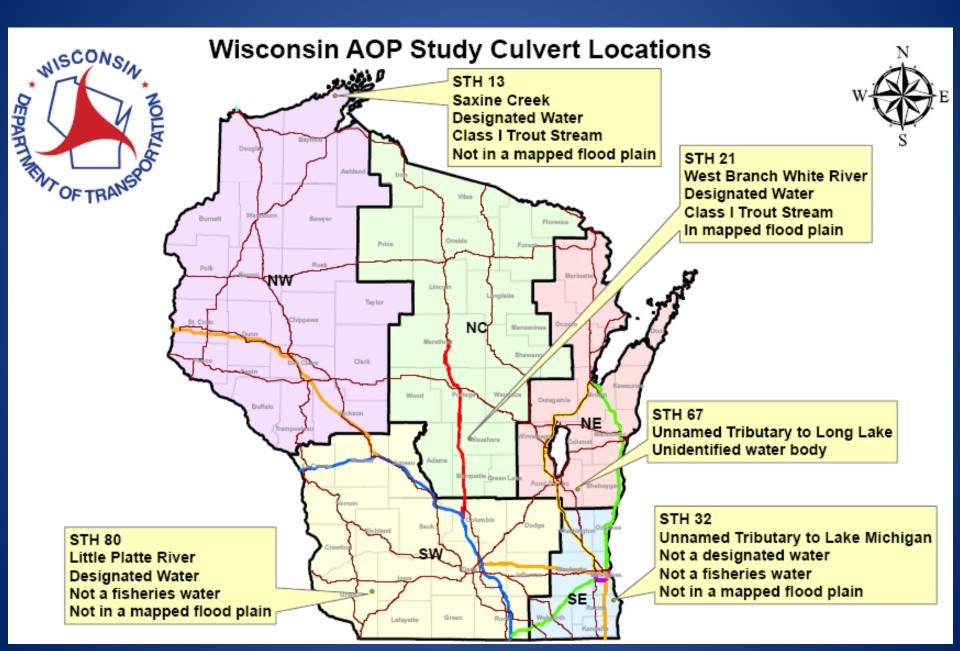


- WisDOT currently does not have a procedure for AOP design.
- WDNR is requesting consideration of AOP more frequently on projects.
- Evaluate HEC-26 as an appropriate tool for AOP Design
- Compare current culvert design procedures with recently released HEC 26 – <u>Culvert Design</u> for Aquatic Organism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



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STH 13 – Saxine Creek in Bayfield County



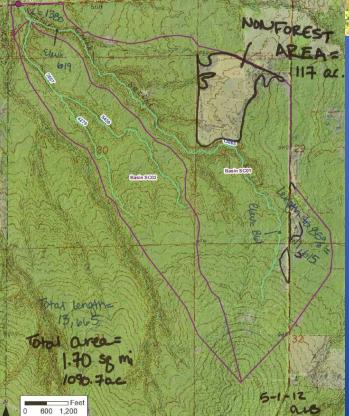


Table 2.2.6	
Stream Crossing Fiel	
Bank Flow Width (ft)	12.5
Measured Structure Water Velocity (ft/sec)	3.07
Stream Velocity (ft/sec)	1.19
Stream Depth (ft)	0.35
Scour Pool Length and Width (ft)	20.4' x 38.75'
Scour Pool Depth (ft)	3.3
Upstream Pond Length and Width (ft)	None
Upstream Pond Depth	None
Is the outlet of the structure perched?	Yes
Is the structure water velocity greater than 3 feet/second during <u>baseflow</u> ?	Yes





STH 21 - White River in Waushara County







Table 2.3.6	
Stream Crossing Fiel	
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 baseflow?	Yes
Is the depth ratio less than 0.1?	No



■

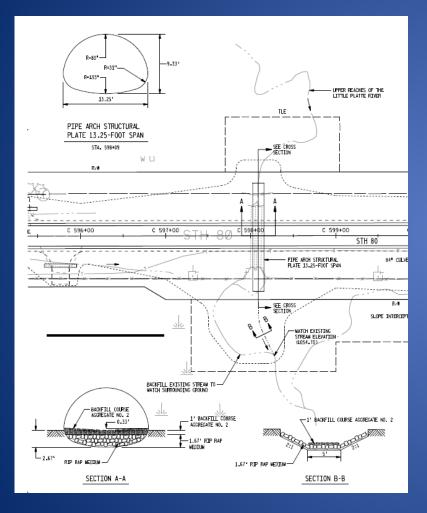
STH 80 – Little Platt River in Grant County



	100
(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?	?

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STH 80 – Little Platt River in Grant County









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

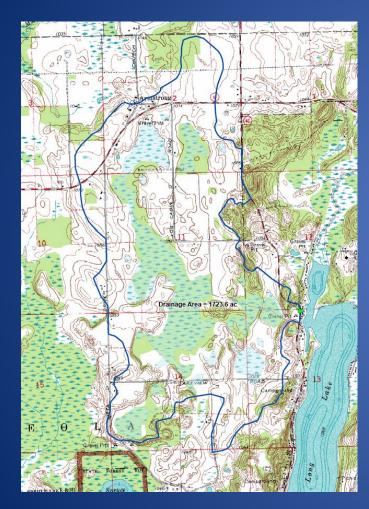


Table 2.1.5	
Stream Crossing Field	Data
Bank Flow Width (ft)	11.16
Measured Structure Water Velocity	
(ft/sec)	1.1
Stream Velocity (ft/sec)	1.44
Stream Depth (ft)	0.1
Scour Pool Length and Width (ft)	13.4'x13.6'
Scour Pool Depth (ft)	1.0'
Upstream Pond Length and Width (ft)	43'x3.2'
Upstream Pond Depth (ft)	look at survey datat
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
	A A A







STH 32 – Unnamed Trib to Lake Michigan – Racine County





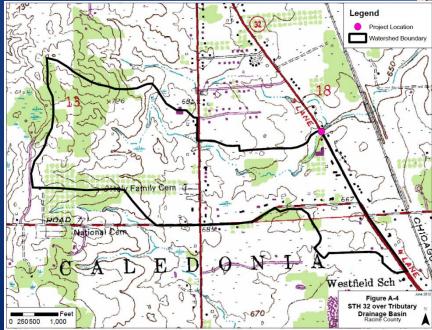
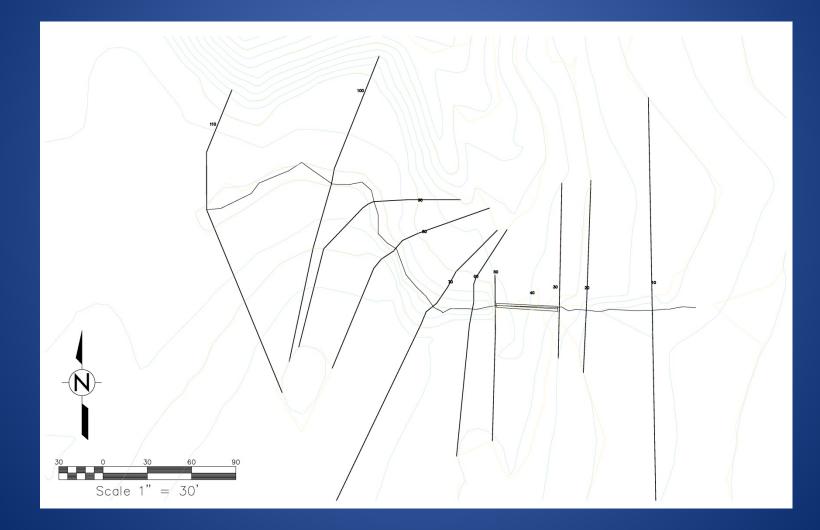
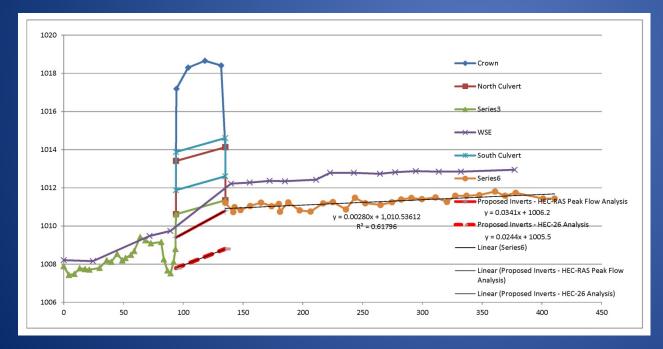


Table 2.1.5	
Stream Crossing Fi	eld Data
Bank Flow Width (ft)	10.66
Measured Structure Water Velocity	
(ft/sec)	0.55
Stream Velocity (ft/sec)	0.42
Stream Depth (ft)	0.3
Scour Pool Length and Width (ft)	33.3' x 14.4'
Scour Pool Depth (ft)	look at survey datat
Upstream Pond Length and Width (ft)	None
Upstream 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

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

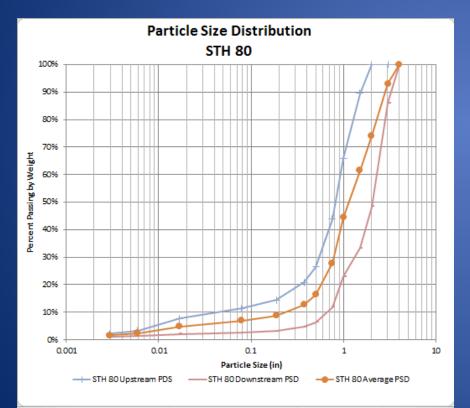


Survey – Stream Thalweg (> 200 ft US and DS) and Existing Culvert Data





Stream Bed Samples Upstream and Downstream





					lieve T	est Data					
Dry Sample and Tare (grams)	Tare (grams)	Cumulative Pan Tare Weight (grams)		Siev Openi Size	10	Cumulati Weight Retained (grams)	1	Percent			
2353.70	0.00	0.0			5	0.00		100.0			
					5	245.80		98.0			
					4	1331.60		89.2			
					8	2655.10		78.5			
					0	2846.30		77.0			
					6	3669.90		70.3			
						5052.60		59.1			
				*	0	6553.50		47.0			
						9347.80		24.3			
				#10		11506.60		6.9			
				#2	0	11620.40		5.9			
				Frac	ional	Compon	ents				
		Gravel				Sand			_	Fines	
Cobbles	Coarse	Fine	Total	Coarse	Me	dium	Fine	Tota	l Silt	Clay	Total
0.0	0.0	10.8	10.8	12.2	3	0.0	41.1	83.3	3		5.9
D ₁₀	D15	D ₂₀	D36)	>50	D ₆₀		DBO	Das	Dgg	D ₉₅
0.2016	0.2447	0.2765	0.32	81 0	4516	0.624	6	2.6785	3.6994	4.9855	7.1070
Fineness	c,	c,	1								
Modulus	3.10	0.85	-								

Stream Crossing Field Data

.0) No

, i.		1						
Stream Crossing Data Sheet		Site ID:						
General Information			NAME OF COLUMN					
	and Brand Roden Talas	Date: 24	1. L. 2011					
Road Name/Number: STH (, 7	Sveg Payne / Rodney Taylor		2011					
Stream Name: Utangard trab	1 11 - 1 51 11							
Stream Name: Ulunamed trub	to N. and of long Lake N.	43' 41.303'						
GPS Waypoint:	Lat/Long: (J (088' 10.383'						
Additional Location								
comments:								
Road Information	Contraction of the second second							
Road Type: Federal (State) County	Town Tribal Private	Other:						
Road Surface: Aspect Paved Gravel Sand	Native Surface Other:							
Fill Depth (ft): Road Width (ft):	28' Structure Length (ft):1	40.9'						
Crossing Information								
Structure Type: Culvert(s) no.: 2 B	rosion Information		The local sector of the		12501784			
Structure Shape St	Fill out all that apply. Use blank rows for				ninent e	rosion along stream		
Round	banks within 50 feet of crossing. Left an					Material Froded		
Square/Rectangle (Erosion Dimensions (ft)	Total	Erosio		Material Eroded Sand, Silt, Clay, Gravel,		
Open Bottom Square/Rectangle	Location of Erosion	Length Width Dept	th (Cubic feet)	Reachi Stream	ing	Loam, Sandy Loam or		
Pipe Arch Z	Road Approach – Left		(one ready	-		Gravelly Loam		
Open Bottom Arch Stu	Road Approach – Right				No			
	Road over Crossing	-			No			
Ellipse	Upstream Ditch – Left VA			1. 0	No	217.4		
(3)	Upstream Ditch - Right Double of	mon at bod			No	3 alt da		
Structure Height (ft): 3 2 St	Downstream Ditch - Left	mon of bond		10	No	SIII Chan		
Structure Width (ft):1 3 2 St	Downstream Ditch – Right							
Fill out for primary culvert (culvert #1). If multiple culverts	Upstream Embankment – Left							
² Fill out, if present. ³ For a culvert, record the water depth at the inlet [() and ou	Upstream Embankment - Right	rish Passage	Determina	ation S	umm	nary	Site ID:	
	Downstream Embankment - Left	Follow these suidel		Normal III		f Pak The	sholds may need to be modifie	d if the addression is
Stream Information	Downstream Embankment – Right –	to evaluate passage					sholds may need to be module	a il the objective is
Stream Flow: None								
Bankfull Width (ft): avc. 11.16 s		Passability = 0	a questions san	he annuar	and Supe	Most ", then the crossing barrier	species and life stages cannot	pass at most flows.
			the structure per		ieu yes	, then the crossing barrier	score = o.	(Yes) No
Scour Pool Length & Width (ft):2 L= 13.					n 3 feet,	/second during baseflow?		Yes No
Fish Passage Information	If there is erosion occurring, can correct	 Is the depth rat Structure water dep 	io less than 0.1?	1" 1	Green	m water depth: 1.5"	 Depth Ratio: 	Yes No
Is the structure perched?	address the problem?	structure water dep		- /	34/64	in water deptit	= Deput Ratio.	0.5
is there a scour pool at the outlet?		Passability = 0.5	CARL THE YEAR				ecles and/or life stages cannot	pass at most flows.
is there substrate through the structure's entire	Multiple Culverts	If any of the followi 1. Is the water de				", then the crossing barrier	score = 0.5.	Yes No
Does the structure substrate match the stream	Number multiple cells from left to right					econd during baseflow?		Yes No
substrate? Is water in the structure moving faster than in the	Culvert # Width (ft) Height (ft)					ral substrate through its ent	ire length?	(Yes) No
stream?	2	Passability = 0.9						
Is water in the structure shallower than in the st	3		ne questions can	he answer	red "ves	", then the crossing barrier		larrier at high flows.
		1. Is there a scour	pool below the s	tructure?		,		(Yes) No
	Photos	Is the constricti	on ratio less than					Yes No
	Site ID	Structure width:		_ / Stre	eam bar	nkfull width: 11-16	= Constriction Ratio:	0.27
	🖼 Road Approach – Left	Passability = 1			1.3953			Not a barrier.
	Upstream Conditions			swered "no	o", ther	the crossing barrier score =	1, and then following	
		statements are all t						
	Additional Site Comments	 The outlet of th The structure w 			feet/sec	ond during baseflow.		
	Culvert diagram, erosion, channel condi	3. The ratio of the	structure water	depth to st	tream v	vater depth is greater than (0.1 (depth ratio).	
	its bottlen board 2 nmp		h in the structure			2 feet.		
			cour pool below			I width is greater than 0.5 (o	(intristing satio)	
						tural substrate through its e		
		The structure	e is shorter than	30 feet and	d has na	atural substrate through its o	entire length, or	
		The structure	e is shorter than	30 feet and	d does r	not have natural substrate th	arough its entire length.	
		Additional Commer	nts					100

Table 2.2.6	
Stream Crossing Fiel	
Bank Flow Width (ft)	12.5
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Is the outlet of the structure perched?	Yes
Is the structure water velocity greater than 3 feet/second during baseflow?	Yes









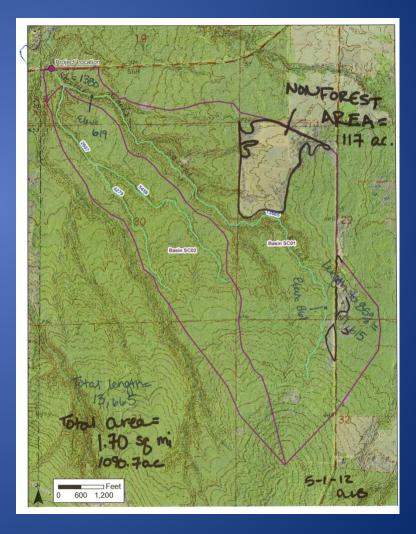
Hydrology Analysis

THIA 2.0 Watershed Delineation and Bunoff Analysi

Drainage Basin Mapping

Dece 1 of 1

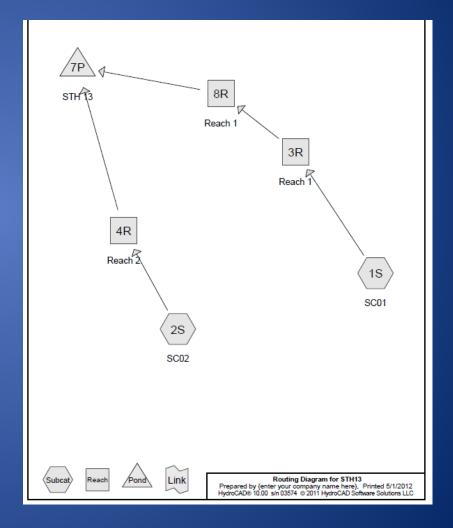
-THIA HOME ASDSS LTHIA Tutorials and Help Process: 3 separate ways to locate our point:	
Search / Zoom and Click Delineate*,	Calculate Impervious area Run TIR-S5L-THA Model Run SWAT Download KML Check the checkbox to display streaming WMS layer
 or type in your location oordinates. 	Streaming Layer HIT Sediment HIT Erosion Wisconsin HUC 8, 10, and 12 NHD water layer
8) select 12 digit HUC	Metalata
earch for or Zoom-in to your area.	from ,
Search Search	the man
In the stream whose watershed you limit be analyze 'our location's series intershed of that point's calculated; here had of that point's calculated; here you can run L-TAR model on it or enter a specific latitude-longitude elect 'Lati-Lon' button below; limit se? 20000 to se? 200000 and tatule within 45 00000 to 42 000000 lateL UTM Zone IR koordinates meters; range of X should be stime 4000 to 400000 and Y within 710000 to 5200000	All A
UTM Z16 Lat-Lon ((or Lat): ((or Lon): Done	L'IL Star
o run analysis on a specific 12 DIGIT HUC, click the "HUC 12" auton and select the desired ratershed.	
HUC 12	
bout Us	



Hydrology Analysis

USGS Regression and HydroCAD

24		
25		
	Drainage Basin Characteristics:	<u></u>
27		
28	Area Equations = 4	- 1
29	Drainage Area = 1.7 mi.^2	
30		
31	Slope (S):	
32	© 10%, Elevation is approximately = 619 ft.	
33	@ 85% , Elevation is approximately = 861 ft.	1
34	total length is approximately = 2.6 mi.	
35		
36	S = 124 ff /mi	
37		
38	Storage (ST) = 1.0 %	
39		
40	Forest Cover (FOR) = 89.3%	
40	1010ar 00101 (1010) - 03.376	
42	Precipitation Intensity Index (INTENS):	
42	Precipitation intensity index (in revs):	
		1
44	I _{24,25} value to be used in computations = 4.79 in.	
45		
46	Annual Snowfall (SN):	
47	Value from chart = 70 in.	
48		
49	Soil Permeability (SP):	
50	Value from chart = 0.12 in./hr.	4
51		-1
52	Technique 1 - Regression Equation Vaules at Project Site:	
53		-1
54	Area Equation Number = 4	
55	Drainage Area (A) = 1.70 sq. mi. Ave. Annual Snow. (SN) = 70 inches	
56	Slope (S) = 124 ft./mi. Precip Int. Index (I24,25) = 4.79 inches	
57	Storage (ST) = 1 % Soil Permeability (SP) = 0.12 in./hr.	4
58	Forest Cover (FOR) = 89 %	- 11
59	Q(2) = 181 cfs	
60	Q(5) = 314 cfs	- 1
61	Q(10) = 416 cfs	
62	Q(25) = 551 cfs	- 1
63	Q(50) = 652 cfs	- 11
64	Q(100) = 759 cfs	- 8
65		
	Technique 2- Gage Comparisons:	<u></u>
67		-1
68	Gage Station # 4026200 Sand River Tributary near Red Cliff, WI	4
69	Project Site Gage Station	-11
70	Basin Number = 4 4	



Hydrology Analysis

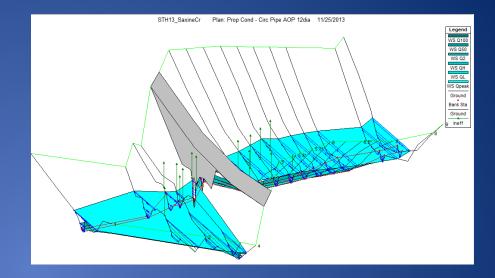
Flow Selection

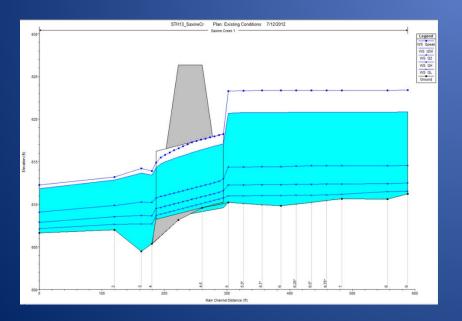
		Table 2.2.2 Value Sum					
	Peak Flows (cfs)						
	HydroCAD USGS						
Recurrence Interval	Inflow	Outflow	Regression Equation	Selected			
QL ¹	-	-	-	4			
QH ¹	26	24	45	30			
2-yr	103	96	181	118			
25-yr	458	377	551	401			
50-yr	534	447	651	575			
100-yr	682	520	759	700			
¹ QL and QH are evaluate the AC 25% of the 2-ye	OP culvert :						

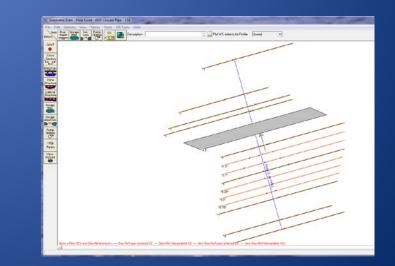
Hydraulic Analysis – HEC-RAS Modeling

For -

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

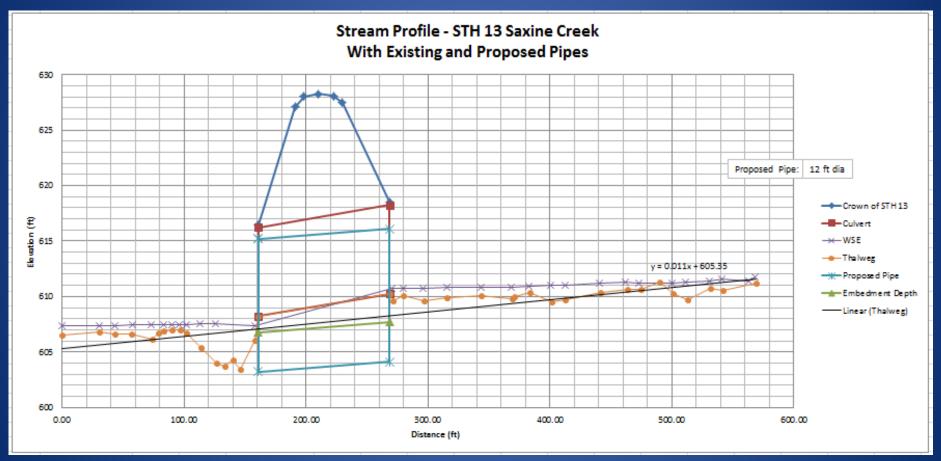






Stream Profile Analysis

Stream Profile Analysis



... to set pipe slope and embedment depth

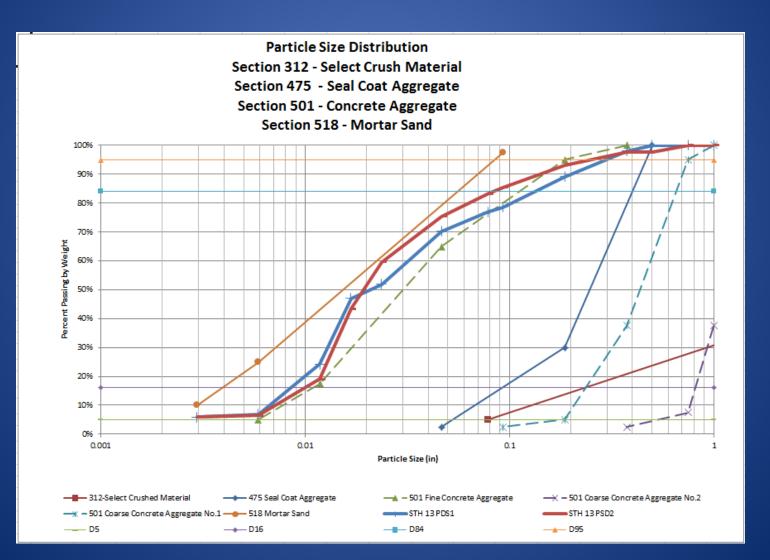
Culvert Bed Gradation Selection

Particle Size Distribution

e: 8/26/1										
CS Class	ification: S	P-SM		Sie	ve Test	Data				
Dry Sample and Tare (grams)	Tare (grams)			Sieve Opening Size	W	nulative eight tained rams)	Percent Finer			
675.50	0.00	0.	00	.75		0.00	100.0			
	.5 281.00 97.8									
				.375 #4		98.40 64.50	97.6 93.2			
				#4 #8		44.30 44.20	93.2 85.5			
				#10		17.00	83.3			
				#16		20.20	75.4			
				#30	51	10.70	59.7			
				#40		78.20	43.4			
				#50		59.70	19.1			
				#100 #200		50.90	6.5 5.9			
						31.40 nponents				
				Traotio						
Cobbles	Coarse	Gravel Fine	Total	Coarse	Mediun	Sand n Fine	e Total	Silt	Fines	Total
0.0	0.0	6.8	6.8	9.9	39.9				City	5.9
									_	
D ₁₀	D ₁₅	D ₂₀	D30	D5	0	D ₆₀	D80	D85	D ₉₀	D95
0.1968	0.2545	0.3049	0.3528	0.47	65	0.6056	1.5837	2.2775	3.4820	5.7983
Fineness	6		٦							
Modulus	с _и	С _с	_							
2.63	3.08	1.04								

te: 8/26/1	scription: Po 1 sification: SI		d sand wit	h silt						
				Sie	ve Test Da					
Dry Sample and Tare (grams)	Tare (grams)	Cumula Pan Tare We (gram	eight	Sieve Opening Size	Cumula Weig Retair (gran	iht ned	Percent Finer			
2353.70	0.00	0.0		.5	0	.00	100.0			
				.375	245.	.80 98.0				
				#4	1331.		89.2			
				#8	2655.		78.5			
				#10 #16	2846. 3669.		77.0 70.3			
				#16 #30	5052		70.3 59.1			
				#30	6553.		47.0			
				#50	9347.		24.3			
				#100	11506.	.60	6.9			
				#200	11620.	.40	5.9			
				Fractio	nal Comp	onents				
Cobbles		Gravel			Sa				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	D30	D50	0 D	60	D ₈₀	D85	D ₉₀	D95
0.2016	0.2447	0.2765	0.3281	0.45	16 0.6	246	2.6785	3.6994	4.9855	7.1070
Fineness Modulus	Cu	Cc	٦							
2.74	3.10	0.85								
2.74	.3.10	0.85	_							

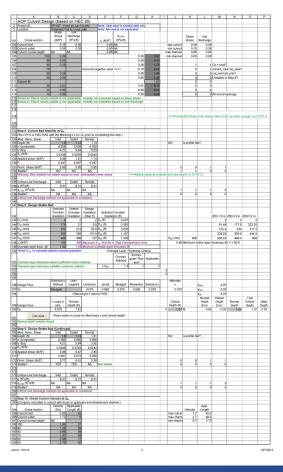
Culvert Bed Gradation Selection Site and WisDOT Standard PSDs



HEC-26 Analysis

Iterative Design Approach Using HEC-26 and HEC-RAS

1A	A	B	c	D	E	F	0	н	T	J	K	L	M	N	0	ſ
Ā	OP Culvert Des	gn (base	d on HE													Ľ
	toject ID: scation lesignerChecker:	STH 67 - F	ond du Lac C	County	Note: User	input in she	ded cells on plicable r additional	у.	-	-						-
К	ecetion:	Unnemed 1 JGV	rip to Long	Lang	Note: NA //	earls not ap	piscable. r.ariddiane/	milance				-				ŀ
ò	late:	1/6/2012							ERR							t
\$1	tep 1. Design Flows									-						L
19	5 (T ² 6)	50		Assume Q-	50 year ever	st.										L
2	a, (11°a)	3		_					_	_		_				Ļ
f	k, (ft ² 6)	,										-				ŀ
152	tep 2. Project Reach a	nd Represe	ntative Cha	nnel Charac	deristics	-		-	-	-		-				t
la	Enter up to two gradatio	ne or up to b	wo pebble oo	ounds on the	PebbleCour	(tab)										t
		USI								D _{in} (mm)	20.0	90.0	0.0	0.0		Т
	ly (mm)	0	0.4													Ι
0	l _{io} (mm) l _{io} (mm)	0.075	11													L
D	l _{ao} (mm)	0.39	38							GM	0					L
D	an (mm)	5	81							GC .	0					L
0	l ₂₅ (mm)	20	90							SM	0	_				L
	led material cohesive?	NO	YES or NO	_					-	SC MI	0	_				ŀ
		NU				-		-	-	CI.	0	-	-			ł
P	fasticity Index foid ratio		Enter If bed See spread	I material is i	cohesive.					MH	0					t
M	oid ratio		obe spread	sheet work	NEXT.					ĊН	0					t
1.	tep 3. Dynamic Equilit http://www.commed.com/ tep 4. Analyze and mi								0		0	-				ł
븮	tep 3. Dynamic Equili	prium Dis secondo	heet 1						-			-				ł
100	step performed outside	the spreads	neec)					-	-	-	-	-	-			t
\$	tep 4. Analyze and mit	ligate charv	el instabilit	W.												t
			heet if need	ed.)												t
ŧ.	ter & Davies Ba	4.8.4.4	_	_	_	_	_	_	-	-		_				f
e	tep 5. Design Bed Gra Enter selected gradation (mm) (mm)	See Green	tie Gradetie	n Plot tab fo	r niet)											ł
fő	(mm)	2		0.007	phone p	D ₊ should	be less than	or equal to ;	2.001	D ₂₁ (men)	88.2	_	2			t
		5.0	D (ff)	0.018	1	1							13			t
	lso (mm)	50.8	D ₅₀ (ft)	0.010	1	-		-	-	-		-	28			t
6	lu (mm)	101.6	Day (H)	0.333	1				-				61			t
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Step 12. Provide Low-flow c	hannel in culvert.						_	-					
Complete step outside of spre	eadsheet, if needed	5)											
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Step 2. Project Reach and R 1. If one or both gradations and	epresentative Cha	annel Charao	cteristics										
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Culvert Sized for AOP at each Site

Table 2.2.5										
Culvert Characteristic Comparisons										
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



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'	
		3' Dia. CM Pipe				
STH 67	Unnamed Trib to Long Lake	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?

