Brookwood Intersection Hydraulic & Hydrologic Analysis

PREPARED FOR: City of Hillsboro and Washington County, Oregon

PREPARED BY: Morgan Ruark/CH2M HILL

REVIEWED BY: Mark Anderson/CH2M HILL, Rick Attanasio/CH2M HILL

COPIES: Steve Lampert, City of Hillsboro

DATE: May 10, 2012

Summary

This memorandum presents the results of the CH2M HILL hydraulic and hydrologic modeling of the Waible Creek watershed. This modeling developed flows at selected locations near the Brookwood Parkway and Highway 26. These flows are used to evaluate existing and hydraulic structures in the watershed for the existing and future land use conditions.

The modeling for this project was done in XP-SWMM. A description of methodology and results is included below.

In this analysis, existing crossings at NW Brookwood Parkway, Highway 26 East and West, NW Helvetia Road, and NW Schaaf Road have been evaluated. Additionally, peak flows at future crossings have been developed. The project area, including existing and future crossings of concern, is shown in Figure A1, in the Appendix.

Introduction

The area north of Hillsboro is experiencing high levels of public and private development. ODOT is currently working on the Highway 26 Interchange, which will include drainage modifications. The City of Hillsboro and Washington County want to understand any expected flooding in this area, and how various changes to the current drainage conditions may change the expected flooding.

The intent of this work is to develop existing and future flows at ten locations near NW Brookwood Parkway and NW Highway 26. These flows will be used to evaluate existing hydraulic structures in the watershed.

In order to develop the flows at the selected locations, numerical modeling was used. This memorandum presents the results of the Hydrologic and Hydraulic numerical modeling. Modeling was done using the XP-SWMM software package.

Hydrology

The Natural Resources Conservation Service (NRCS) TR-55 methodology was used to develop runoff flows for the Waible Creek watershed. Further description of the methodology is included below.

Rainfall

Rainfall depths for the design storms were selected as detailed in the Brookwood Intersection Hydraulic and Hydrologic Analysis – Design Storm Selection Technical Memorandum from February 10, 2012. These rainfall depths are shown in Table 1, below. A Type IA storm distribution was used for these rainfall depths.

TABLE 1
24-hour duration Design Storm Depths, Waible Creek Watershed

Return Interval	Rainfall Depth (in)
2 year	2.50
10 year	3.45
25 year	3.90
50 year	4.02
100 year	4.50

Subbasin Delineation

The subbasin delineation included in the Watershed 2000 Master Plan was used as a basis for the Waible Creek watershed subbasin delineation. Subbasins in the Waible Creek watershed were split at suitable points to determine peak flows at crossings, including NW Sewell Road, Crossing #2, NW 253rd Avenue, NW Brookwood Parkway, NW Highway 26, NW Helvetia Road, NW Schaaf Road, NW Jacobson Road, and NW Century Boulevard. Boundary adjustments to the delineation were also made using available LIDAR data. A map of this delineation is included in Figure A2 of the Appendix.

Land Use

Zoning data was used to determine existing and future land uses. GIS data from Metro was used to determine current zoning. This file, with vacant areas within the urban growth boundary determined to be pasture, was used as existing conditions land use. For future conditions land use, all vacant areas within the urban growth boundary were assigned their build-out zoning. Based on these requirements, land use within the watershed is primarily rural/open space pasture, with some areas of industrial land use located in the southeastern portion of the watershed. A small area of commercial land use, located at the current site of the Helvetia Tavern, is located in the northern portion of the watershed. A map of the existing and future land use is included in Figure A3a and A3b of the Appendix.

Soil Types

U. S. Department of Agriculture soil survey data was used to determine soil types for the watershed. The Waible Creek watershed is primarily composed of silt loams, including hydrologic C-type soils with slow infiltration rates, hydrologic D-type soils with very slow infiltration rates found along the major waterways, and hydrologic B-type soils with moderate infiltration rates found at selected locations, primarily in the southeast portion of the watershed. A map of the hydrologic soil type is included in Figure A4 of the Appendix.

Curve Numbers

Curve numbers were assigned based on the existing and future land use and hydrologic soil type assigned above. A composite curve number was calculated for each subbasin for both existing and future conditions.

Time of Concentration Calculations

Likely flow paths were developed for each subbasin, and times of concentration were calculated. For subbasins in the southeastern portion of the watershed, shorter path lengths or paths including less sheet flow were used to represent the likely impacts of increased impervious area in future conditions. A summary of subbasin characteristics is included in Table A1 of the Appendix.

Results

The XP-SWMM Runoff module calculates flow values for each subbasin individually. Flows are routed through the watershed in the Hydraulics module. A summary of peak flow values at individual subbasins for existing and future conditions is shown in Tables A2a and A2b of the Appendix.

Hydraulics

Channel routing was used to connect the individual subbasin runoff hydrographs. Pipe and weir connections were also used to evaluate flows at specific locations. This methodology is further discussed below. Both the existing conditions and future conditions hydrology were evaluated using the existing conditions hydraulic model in order to determine deficiencies in the current system and the impact of further development.

Channel Routings

Channel lengths and slopes were determined for each individual reach in the watershed using the LIDAR data provided by Clean Water Services. Cross sections representing each reach were also extracted from the LIDAR. Because the LIDAR data used the North American Vertical Datum of 1988 (NAVD88), these elevations were converted to the National Geodetic Vertical Datum of 1929 (NGVD29). A Manning's "n" of 0.08 for overbanks and 0.035 for channels was used, based on Table 5-6 of *Open-Channel Hydraulics* (Chow, 1959). These values were selected as typical for straight streams with grassy vegetation and overbanks. Channel routing input data is included in Table A3 of the Appendix.

Boundary Conditions

A normal depth boundary condition was assumed at the confluence of McKay Creek and Waible Creek. Additionally, a check was performed to see if the McKay Creek backwater had any influence on flows within the Waible Creek watershed. The McKay Creek 100-year base flood elevation found in the FEMA Flood Insurance Study for Washington County was used.

Based on this review, it was determined that the backwater from McKay Creek had no effect on flows upstream of the confluence of Waible Creek and Storey Creek. Stream delineations can be seen in Figure A2 in the Appendix. This confluence was downstream of all crossings analyzed in this model. Therefore, normal depth was used as a boundary condition for this

watershed. All results included in this report were the product of the normal depth boundary condition in the Waible Creek watershed model.

Survey Data and Stream Crossings

Survey was performed in late December of 2011. This survey included cross sections and pipe characteristics at six crossings. Elevations are reported using NGVD'29 vertical datum. The survey locations and sheets are included in Figures A5 and A6 of the Appendix.

These survey results, along with as-built information for the NW Brookwood Parkway crossing, were used to develop the road crossings in the XP-SWMM hydraulic model. A summary of the crossings used in the XP-SWMM model for existing and future conditions is found in Table 2, below.

TABLE 2
Existing Conditions Stream Crossings, Waible Creek Watershed (Based on Field Survey)

		Crossing Characteristics			
Location	**Crossing Number**	**Culvert Size**	**Culvert Length (feet)**	**Culvert Inverts**	**Top of Road Elevation**
NW Brookwood Parkway	4	2 @ 47"x71" CMP Arch	113	182.3/181.3 182.2/181.9	189.5
NW Highway 26 – East	5	3' CMP	219	189.8/189.5	200.3
NW Highway 26 – West	7	5'H x 8'W RCBC	263.6	175.9/176.3[1]	191.4
NW Groveland Drive	8	8.1'H x 21'W Bridge	37	175.2/175.2	185.3
NW Helvetia Road	9	7'H x 13.7'W RCBC	32.4	180.1/180.0	188.6
NW Schaaf Road	10	6' RCP	32	179.5/179.6[1]	186.0

All elevations in NGVD29, feet.

[1] Adverse slope at this location

As can be seen in Table 2 above, the culverts at NW Highway 26 West and NW Schaaf Road have an adverse slope, with the downstream inverts at a greater elevation than upstream inverts. Additionally, while NW Groveland Drive has a measured length of 21 feet, it is represented as 37 feet long in the model. This was done to assist with model stability, and has negligible impact on the resulting WSEs.

Results

Existing and future flow values at selected locations are shown in Tables 3 and 4, below. A complete summary of peak flow values is shown in Tables A4a and A4b of the Appendix, and a map showing 25 year Existing Conditions Peak Flows at the crossings is found in Figure 1.

TABLE 3
Existing Conditions Peak Flows at Selected Stream Crossings, Waible Creek Watershed

Location	Crossing Number	Peak Flow (cfs)				
		2 year	10 year	25 year	50 year	100 year
Proposed NW Sewell Road	1	157.6	318.7	412.7	436.9	519.3
Proposed Crossing #2	2	152.5	300.3	390.7	412.2	483.5
Proposed NW 253rd Avenue – South	3	56.7	104.8	130.0	135.8	155.2
NW Brookwood Parkway	4	59.9	105.9	131.4	137.5	159.4
NW Highway 26 – East	5	16.5	33.3	40.2	41.7	47.0
Proposed NW 253rd Avenue – North	6	86.6	196.6	263.6	281.4	341.5
NW Highway 26 – West	7	86.7	197.0	263.9	281.9	340.4
NW Groveland Drive	8	86.7	197.1	264.0	282.1	340.4
NW Helvetia Road	9	88.7	213.0	280.4	294.6	345.8
NW Schaaf Road	10	81.8	197.3	260.4	274.4	330.5

TABLE 4
Future Conditions Peak Flows at Selected Stream Crossings, Waible Creek Watershed

Location	Crossing Number	Peak Flow (cfs)				
		2 year	10 year	25 year	50 year	100 year
Proposed NW Sewell Road	1	219.9	401.6	501.8	526.1	604.6
Proposed Crossing #2	2	225.5	384.5	478.2	500.7	570.3
Proposed NW 253rd Avenue – South	3	101.8	154.8	173.6	178.2	200.4
NW Brookwood Parkway	4	104.6	161.4	183.2	188.5	206.8
NW Highway 26 – East	5	39.3	51.6	57.3	58.7	62.5
Proposed NW 253rd Avenue – North	6	106.1	229.9	298.4	317.3	372.7
NW Highway 26 – West	7	106.2	229.9	297.2	315.6	370.9
NW Groveland Drive	8	106.3	229.9	297.2	315.5	370.8
NW Helvetia Road	9	114.6	244.5	310.9	328.9	375.6
NW Schaaf Road	10	93.3	211.8	274.7	283.7	344.6

As can be seen above, the future conditions produce increased flows throughout the system. The greatest increases in peak flows occur during the 2 year storm, particularly at NW Highway 26 East (increased flows of 138%), NW Brookwood Parkway (75%), and Proposed NW 253rd Avenue South (80%) - three sequential crossings on the southern branch of Waible Creek, where much of the proposed development would occur. The northern branch of Waible Creek, with less proposed development, sees less increase in peak flows at NW Schaaf Road through NW 253rd Avenue North (from 14% to 29% increase in flows).

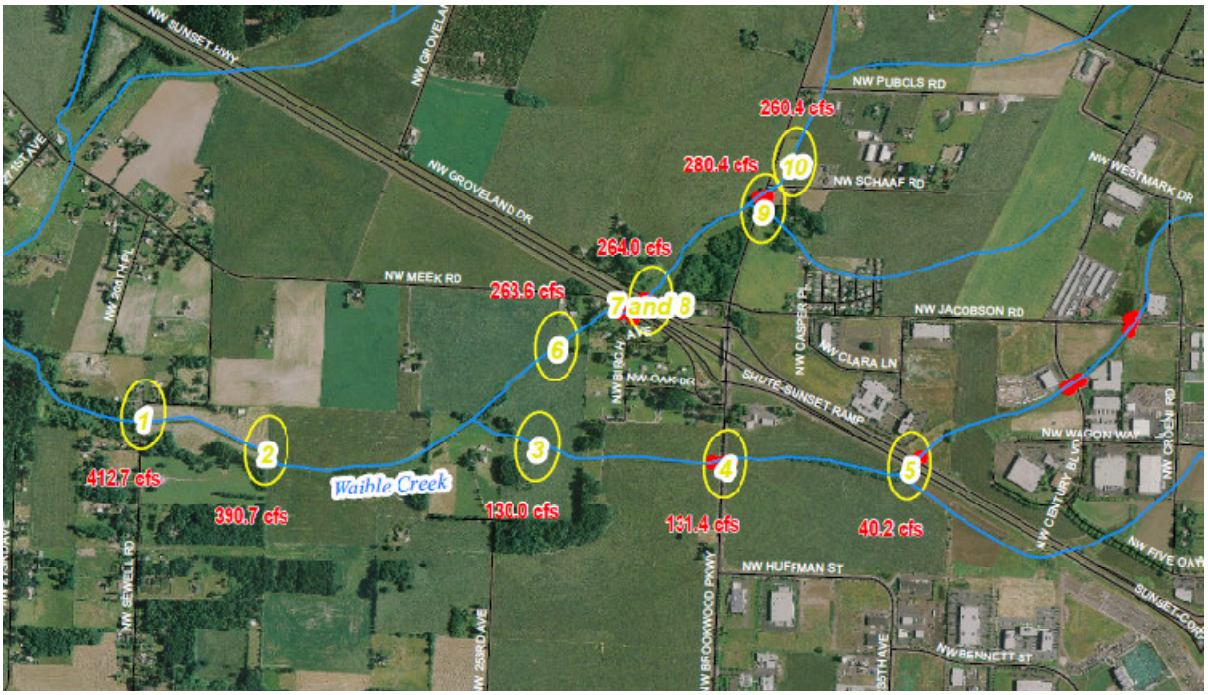


FIGURE 3
Existing Conditions 25 year Peak Flows at Selected Stream Crossings, Waible Creek Watershed

A comparison of peak water surface elevations (WSEs) for the 2 year, 25 year, and 100 year events for existing and future hydrologic conditions (using the existing channel and culvert sizing and geometry) can be seen in Table 5, below.

TABLE 5
Existing and Future Conditions Stream Crossings Peak Water Surface Elevations, Waible Creek Watershed

		Peak Water Surface Elevations (feet)					
		2 year		25 year		100 year	
Location	Top of Road Elevation	Existing	Future	Existing	Future	Existing	Future
NW Brookwood Parkway	189.5	184.3	185.2	185.5	186.0	185.7	186.3
NW Highway 26 – East	200.3	192.0	194.3	194.3	197.0	195.3	197.8
NW Highway 26 – West	191.4	179.5	179.9	181.4	181.6	181.9	182.1
NW Groveland Drive	185.3	179.6	179.9	181.5	181.7	182.0	182.2
NW Helvetia Road	188.6	183.0	183.4	185.2	185.4	185.5	185.6
NW Schaaf Road	186.0	183.2	183.6	185.8	186.0	186.2	186.3

All elevations in NGVD29, feet.

Peak Water Surface Elevations at upstream culvert face

As seen in Table 5, above, the future hydrologic conditions will include increased WSEs at all locations. NW Schaaf Road experiences slight road overtopping during the 100 year event for both existing conditions and future conditions flows. This flooding is consistent

with the overtopping observed at this location during the January 19, 2012 flood event. At this location, where overtopping occurs at elevation 186.0 feet, the increased flows will produce greater overtopping.

Additionally, the culvert crossings at NW Highway 26 East and West are surcharged under most flow conditions. At the crossing at NW Highway 26 East, the current undersized culvert at this location appears to cause surcharge upstream of the crossing at NW Century Avenue and NW Jacobson Avenue, due to backwater conditions. At the crossing at NW Highway 26 West, the undersized crossing causes flooding immediately upstream, at NW Groveland Drive.

Conclusions

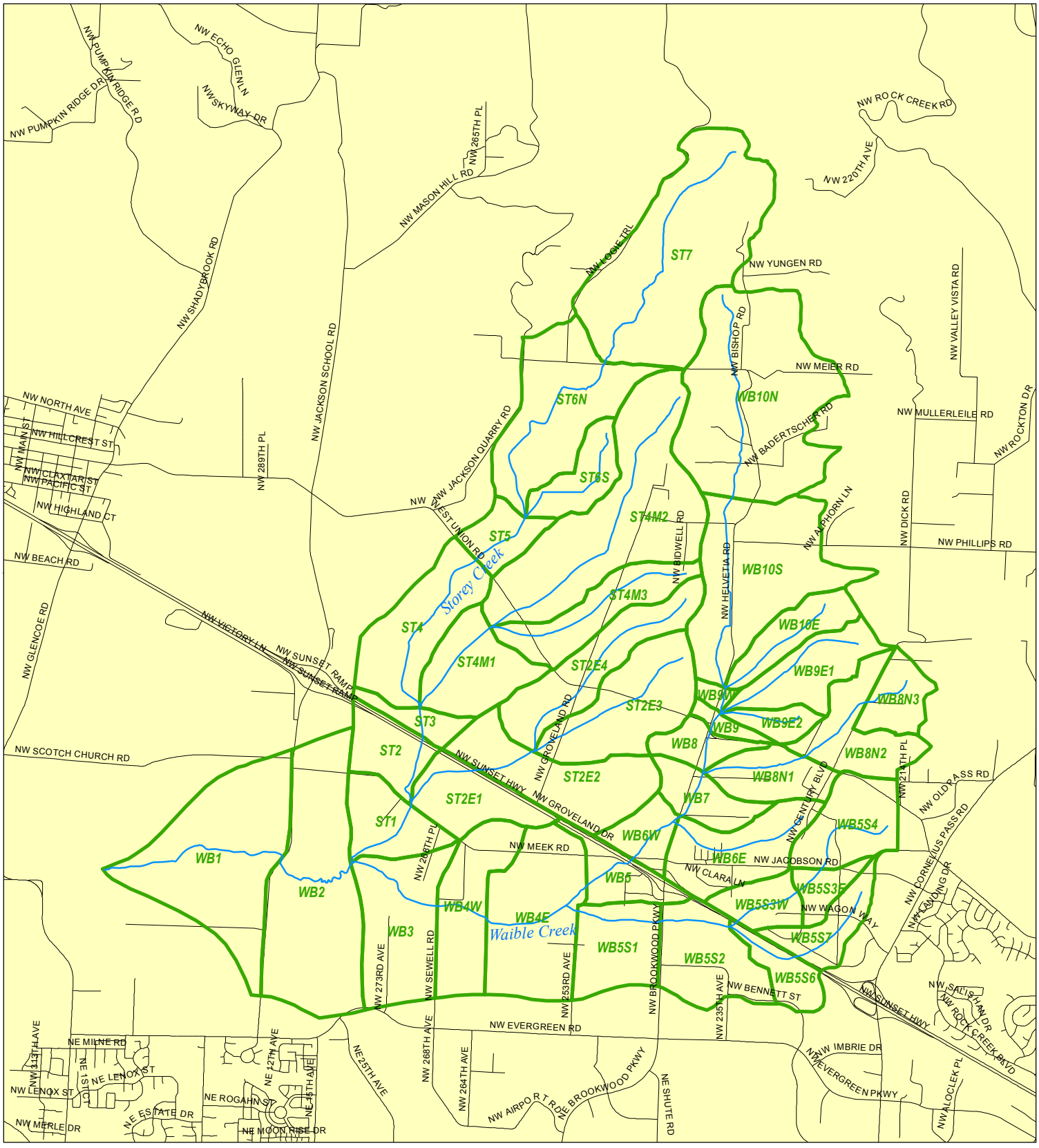
Peak flows have been generated for 5 storm events (the 2 year, 10 year, 25 year, 50 year, and 100 year storms of 24-hour duration) within the Waible Creek watershed for both existing and future land use conditions.

The results from this analysis show increased flow values throughout the Waible Creek watershed areas of concern. These increased flows produce increased WSEs at existing crossings. At NW Schaaf Road, the road overtops during both the existing and future conditions 100 year event. Crossings at NW Highway 26 East and West experience pressure flow under most flow conditions. At NW Highway 26 East, this surcharge produces increased WSEs upstream of the undersized culvert.

Appendices

Figure A1: Waible Creek Project Area
Helvetia Interchange Area Map

Brookwood Intersection Hydraulic & Hydrologic Analysis
City of Hillsboro and Washington Counrty, Oregon
April 20, 2012

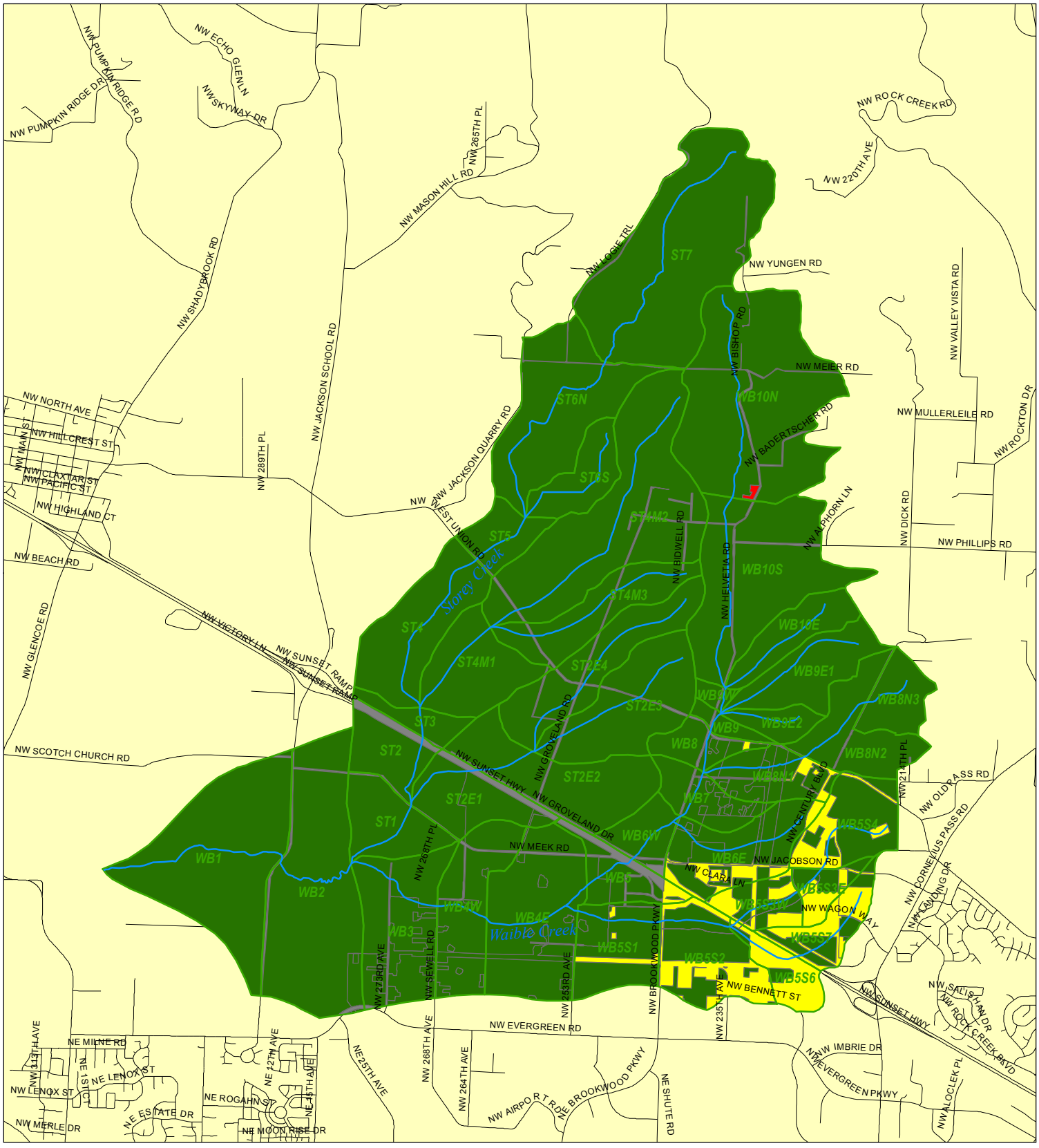


Legend

- Streams
- Streets
- Subbasin

Figure A2: Waible Creek Subbasins

Brookwood Intersection Hydraulic & Hydrologic Analysis
City of Hillsboro and Washington Counrty, Oregon
April 20, 2012



Legend

Streams
Streets
Subbasin

Existing Conditions Land Use

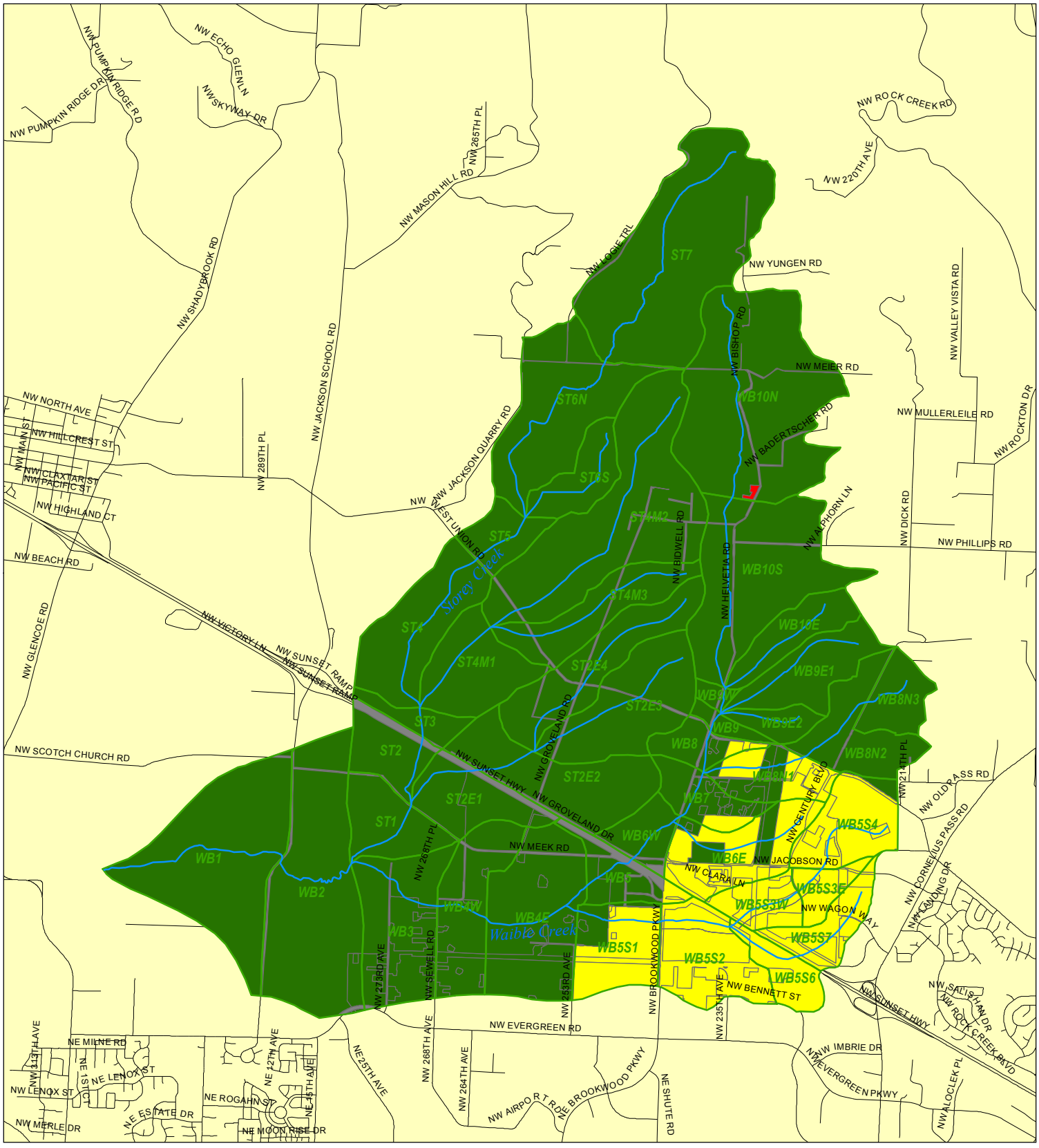
- **Commercial**
- **Industrial**
- **Rural**
- **Transportation**

N
W E
S

2,000 0 0 2,000
Feet

Figure A3a: Waible Creek Existing Land Use

Brookwood Intersection Hydraulic & Hydrologic Analysis
City of Hillsboro and Washington Counrty, Oregon
April 20, 2012



Legend

Streams

Streets

Subbasin

Future Conditions Land Use

- Commercial
- Industrial
- Rural
- Transportation

N W E S

2,000 0 0 2,000

Feet

Figure A3b: Waible Creek Future Land Use

Brookwood Intersection Hydraulic & Hydrologic Analysis
City of Hillsboro and Washington Counrty, Oregon
April 20, 2012

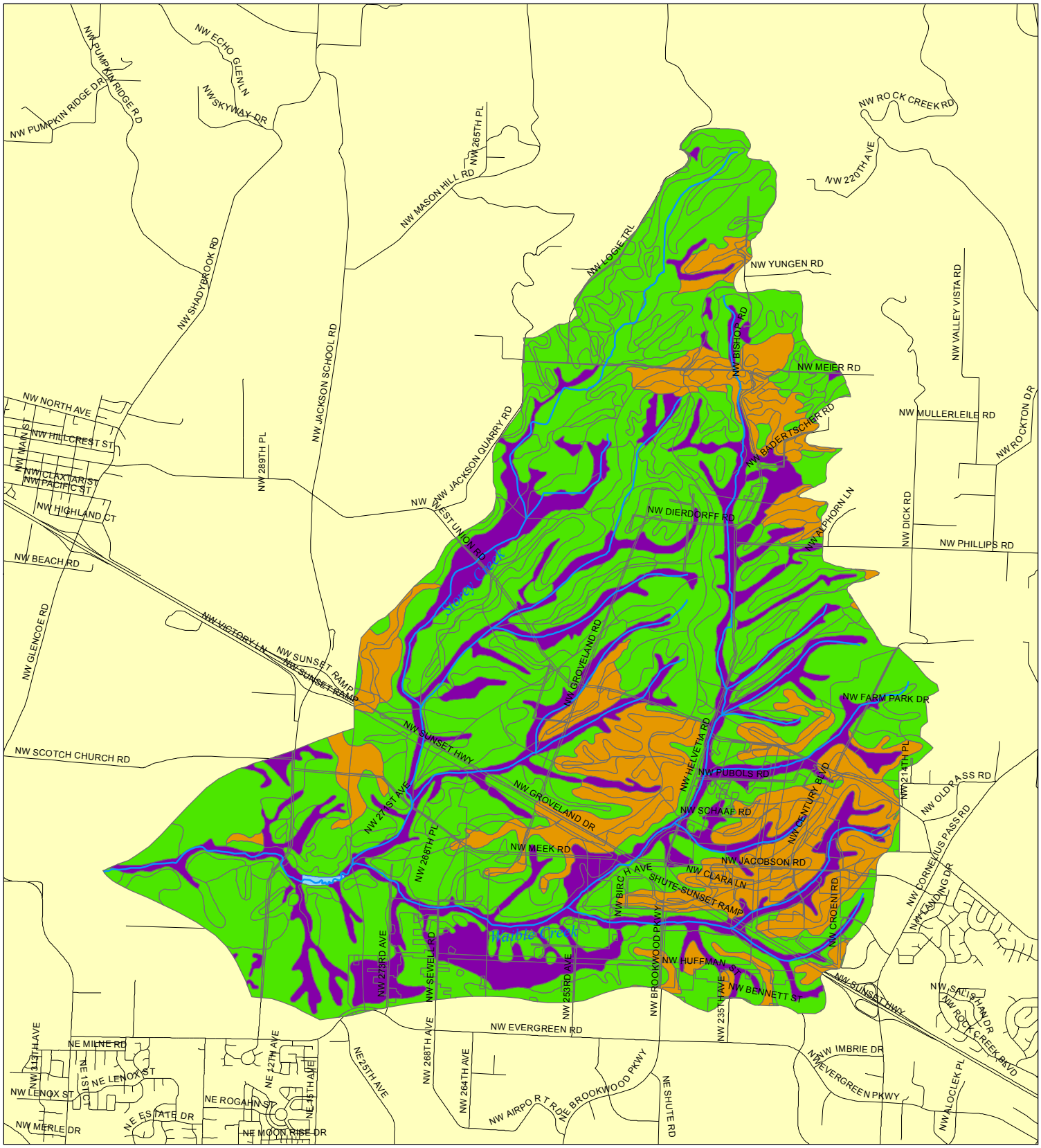


Figure A4: Waible Creek Hydrologic Soil Types

Brookwood Intersection Hydraulic & Hydrologic Analysis
City of Hillsboro and Washington Counrty, Oregon
April 20, 2012

N
W E
S

500 250 0 500
Feet

Legend

- Streams
- Streets
- Subbasin
- Survey Points

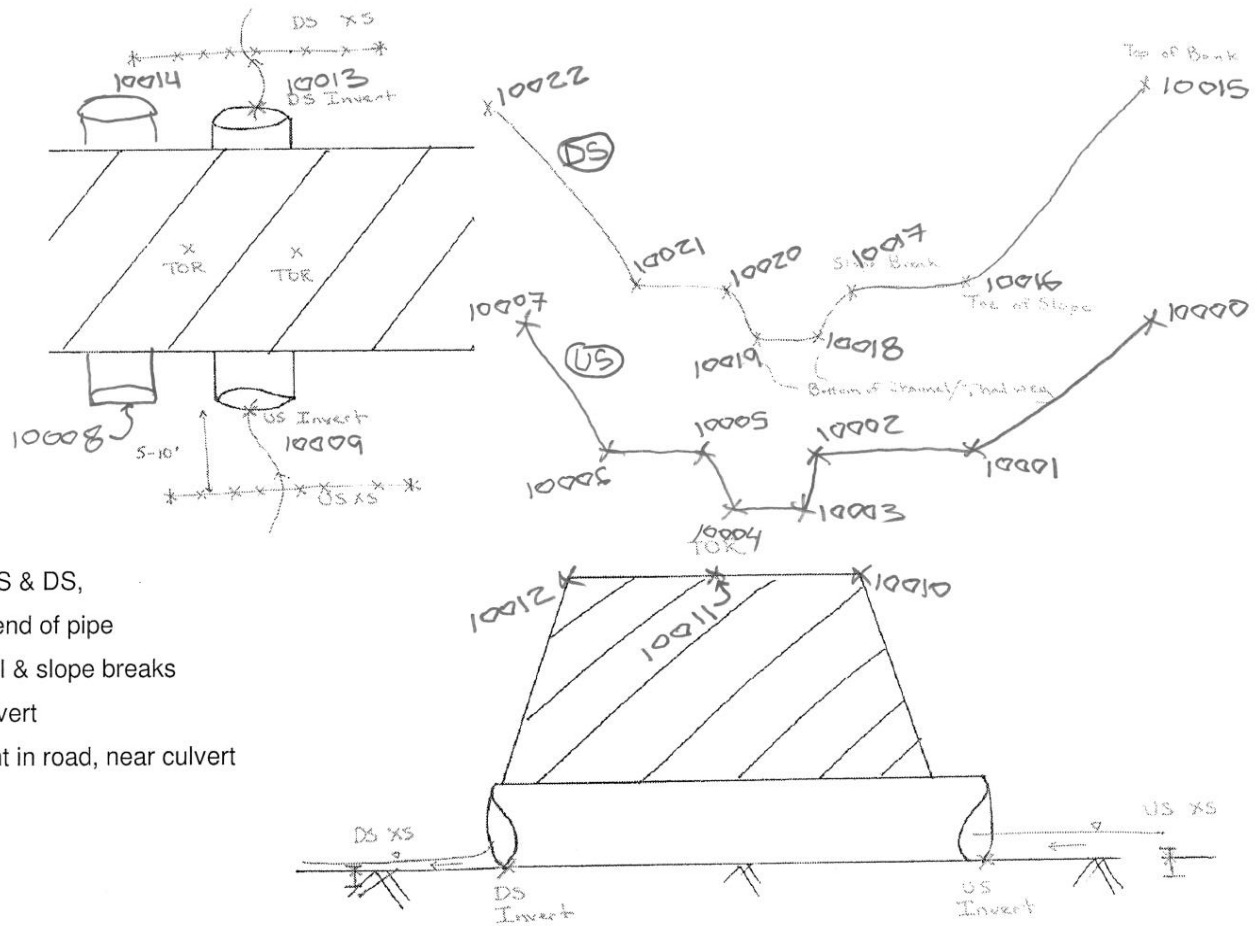
Figure A5: Waible Creek Survey Locations

Brookwood Intersection Hydraulic & Hydrologic Analysis
City of Hillsboro and Washington Counrty, Oregon
April 20, 2012

Culvert Survey Data Sheet

Project: BROOKWOOD
Date: 12/22/11
Crew: M. GREEN, M. STEINER

Location: NW JACOBSON RD
Points ID:
Picture ID:



Points Required:

Channel	Cross Section US & DS,
	5 - 10 feet from end of pipe
	Points at channel & slope breaks
Culvert	US Invert, DS Invert
TOR	1 to 2 at low point in road, near culvert
High water marks	As available

Culvert Information:

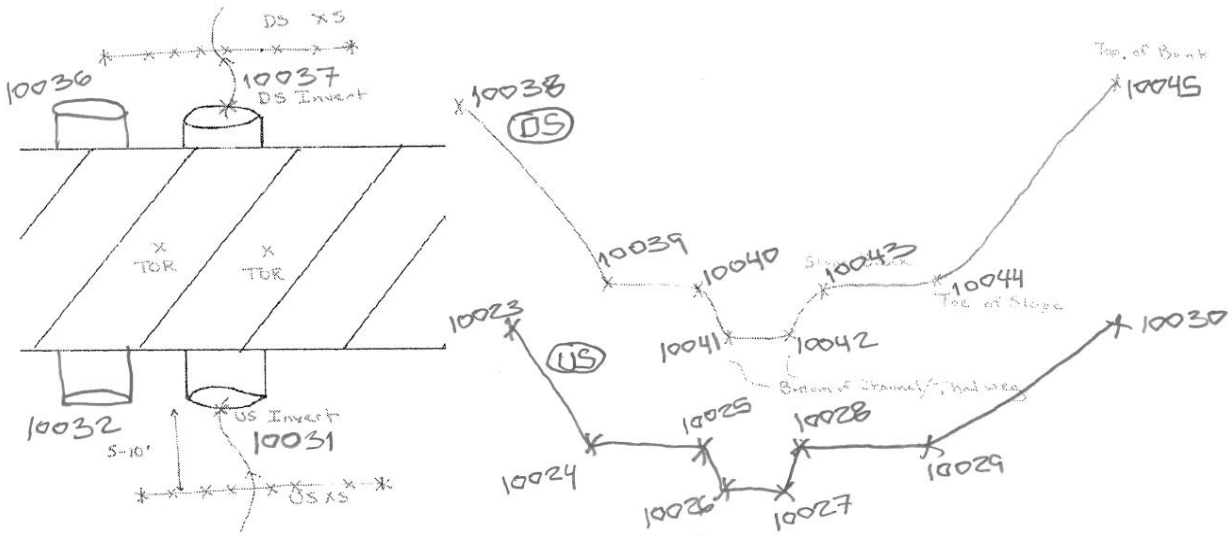
Number 2
Size 36"
Length 114.12'

Shape	(Round)	Box	Arch	Elliptical	Other	
Material	RCP	(CMP)	DIP	HDPE	Other	
Condition	New	(Good)	Fair	Poor		
Pipe Conveyance	(Clean)	1/4 Full	1/2 Full	3/4 Full	Full	Perched
Pipe Edge Entrance	Headwall		Flush with Fill			Projecting MITERED

Culvert Survey Data Sheet

Project: BROOKWOOD
Date: 12/22/11
Crew: M. GREEN, M. STEINER

Location: NW CENTURY BLVD
Points ID:
Picture ID:



Points Required:

Channel	Cross Section US & DS,
	5 - 10 feet from end of pipe
	Points at channel & slope breaks
Culvert	US Invert, DS Invert
TOR	1 to 2 at low point in road, near culvert
High water marks	As available

Culvert Information:

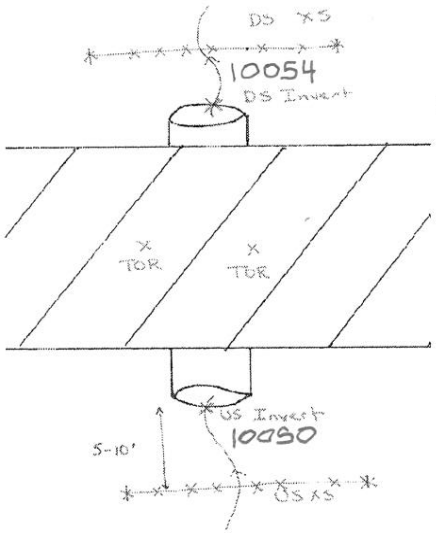
Number 2
Size 30"
Length 91.03'

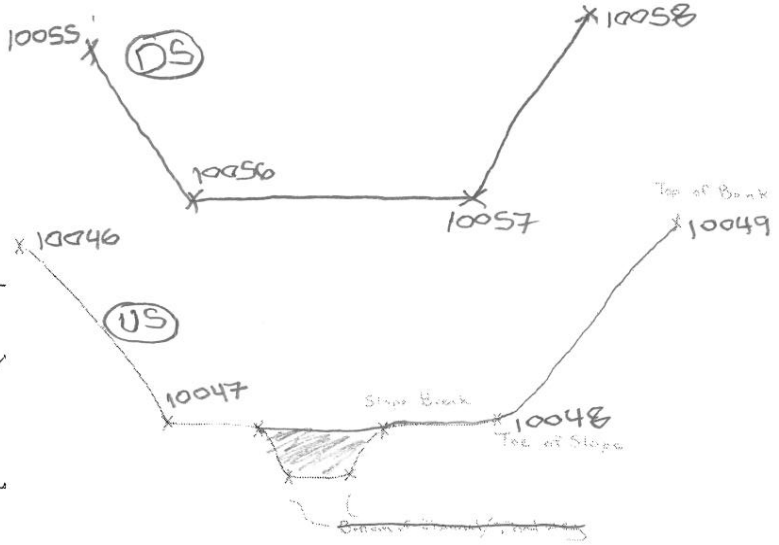
Shape	(Round)	Box	Arch	Elliptical	Other	
Material	RCP	(CMP)	DIP	HDPE	Other	
Condition	New	(Good)	Fair	Poor ← HARD TO REALLY ASSESS SINCE 1/2 FULL		
Pipe Conveyance	Clean	1/4 Full	(1/2 Full)	3/4 Full	Full	Perched
Pipe Edge Entrance	Headwall		Flush with Fill			(Projecting)

Culvert Survey Data Sheet

Project: BROOKWOOD
Date: 12/22/11
Crew: M. GREEN, M. STEINER

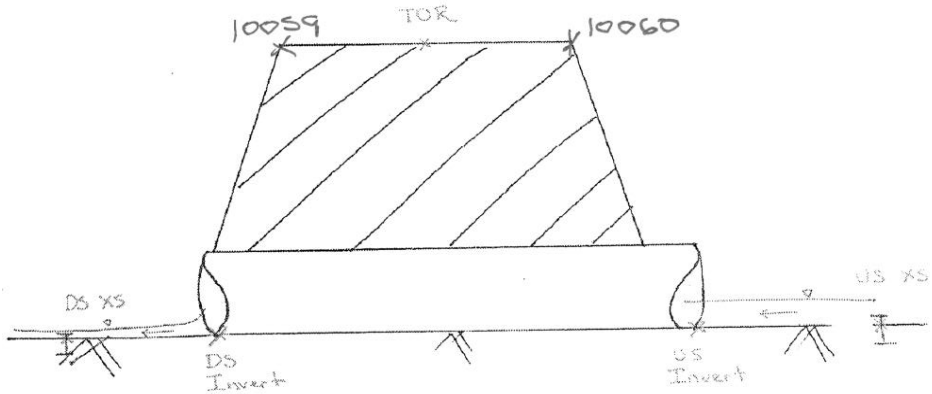
Location: HIGHWAY 26 (EAST)
Points ID:
Picture ID:





Points Required:

Channel	Cross Section US & DS,
	5 - 10 feet from end of pipe
	Points at channel & slope breaks
Culvert	US Invert, DS Invert
TOR	1 to 2 at low point in road, near culvert
High water marks	As available



Culvert Information:

Number 1
Size 36"
Length 219.33'

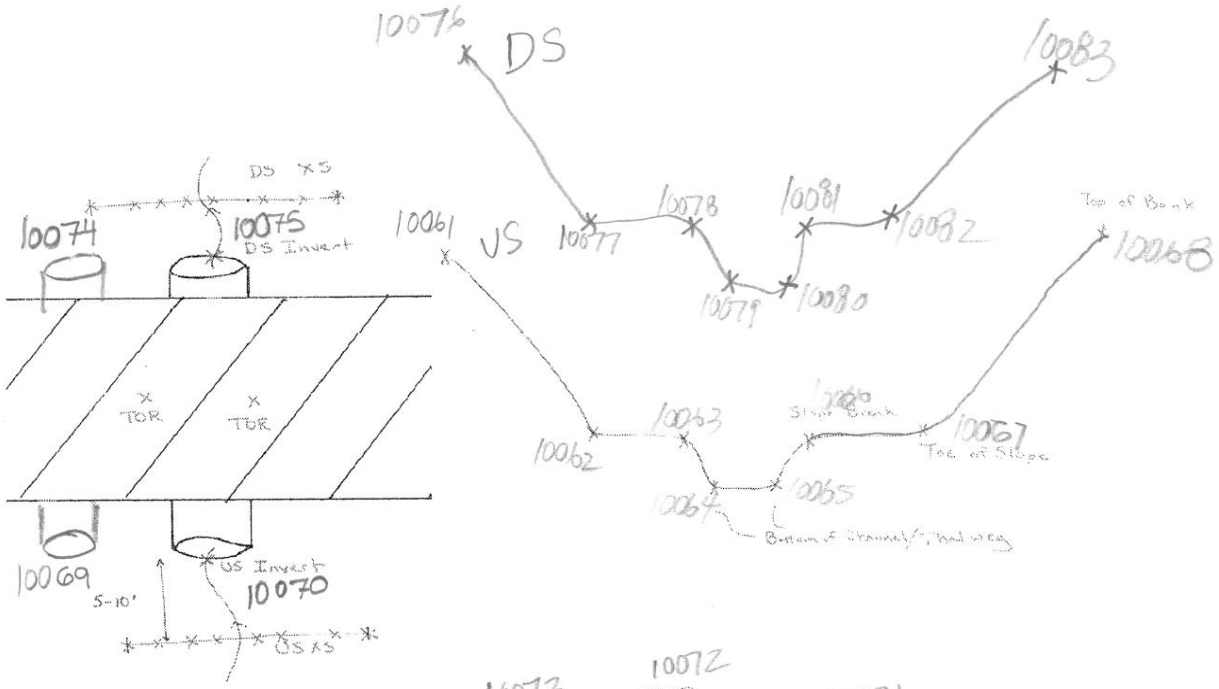
Shape	(Round)	Box	Arch	Elliptical	Other	
Material	(RCP) - US	(CMP) DS	DIP	HDPE	Other	
Condition	New	(Good)	Fair	Poor		
Pipe Conveyance	(Clean)	1/4 Full	1/2 Full	3/4 Full	Full	Perched
Pipe Edge Entrance	(Headwall)		Flush with Fill			Projecting

→ US HEADWALL & MITERED

Culvert Survey Data Sheet

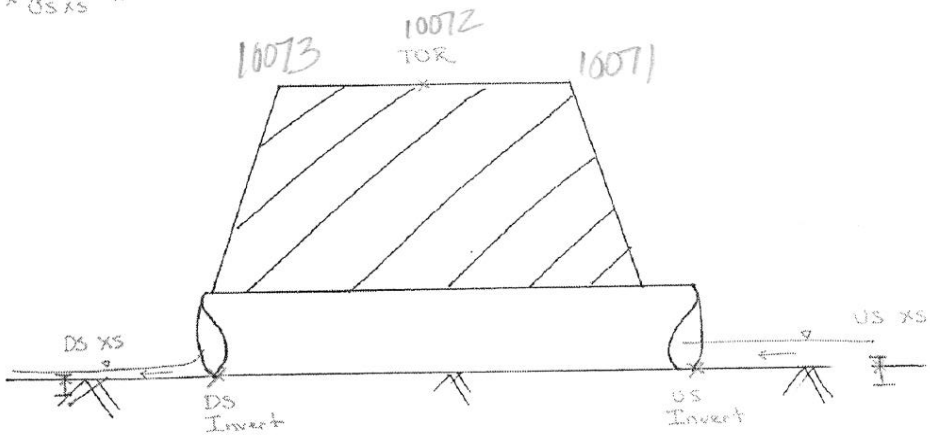
Project: BROOKWOOD
Date: 12/22/11
Crew: M GREEN, M STEINER

Location: NE BROOKWOOD PKWY
Points ID:
Picture ID:



Points Required:

Channel	Cross Section US & DS,
	5 - 10 feet from end of pipe
	Points at channel & slope breaks
Culvert	US Invert, DS Invert
TOR	1 to 2 at low point in road, near culvert
High water marks	As available



Culvert Information:

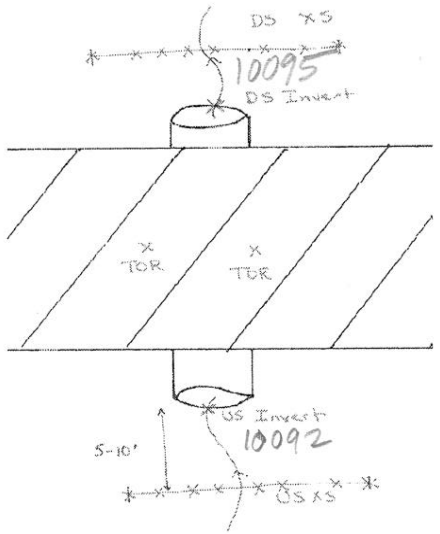
Number 2
Size 48"
Length

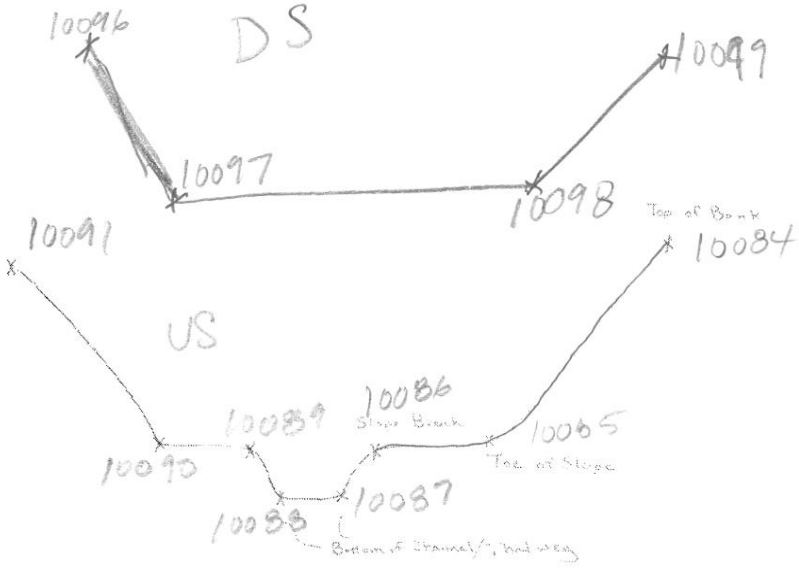
Shape	(Round)	Box	Arch	Elliptical	Other	
Material	RCP	(CMP)	DIP	HDPE	Other	
Condition	New	(Good)	Fair	Poor		
Pipe Conveyance	(Clean)	1/4 Full	1/2 Full	3/4 Full	Full	Perched
Pipe Edge Entrance	Headwall		Flush with Fill			Projecting (MITERED)

Culvert Survey Data Sheet

Project: BROOKWOOD
Date: 12/22/11
Crew: M. GREEN, M STEINER

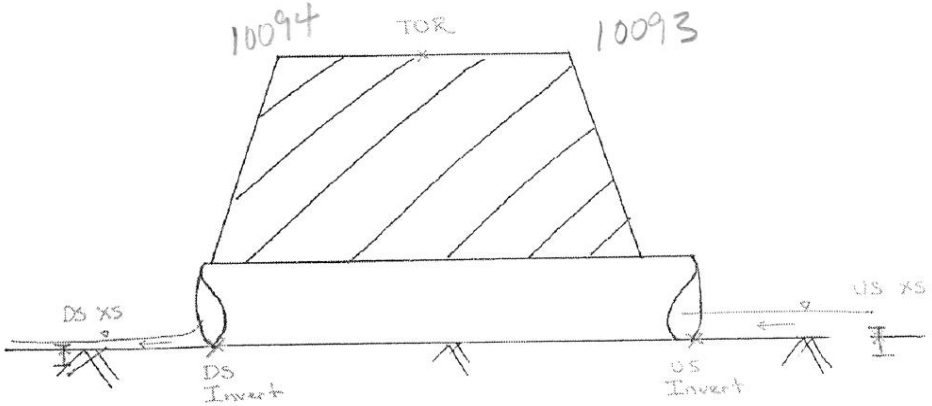
Location: HIGWAY 26 W
Points ID:
Picture ID:





Points Required:

Channel	Cross Section US & DS,
	5 - 10 feet from end of pipe
	Points at channel & slope breaks
Culvert	US Invert, DS Invert
TOR	1 to 2 at low point in road, near culvert
High water marks	As available



Culvert Information:

Number 1
Size 5' high, 8' wide
Length

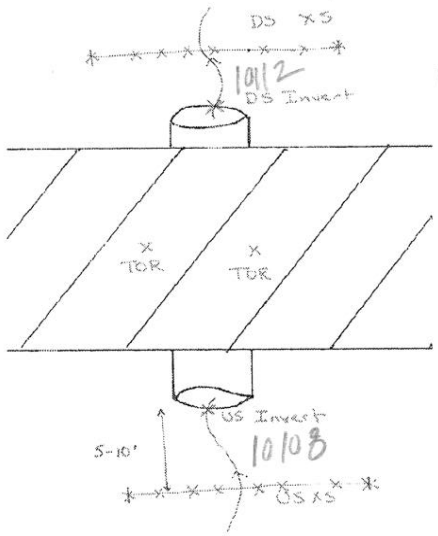
Shape	Round	Box	Arch	Elliptical	Other	
Material	RCP Concrete	CMP	DIP	HDPE	Other	
Condition	New	Good	Fair	Poor		
Pipe Conveyance	Clean	1/4 Full	1/2 Full	3/4 Full	Full	Perched
Pipe Edge Entrance	Headwall		Flush with Fill			Projecting

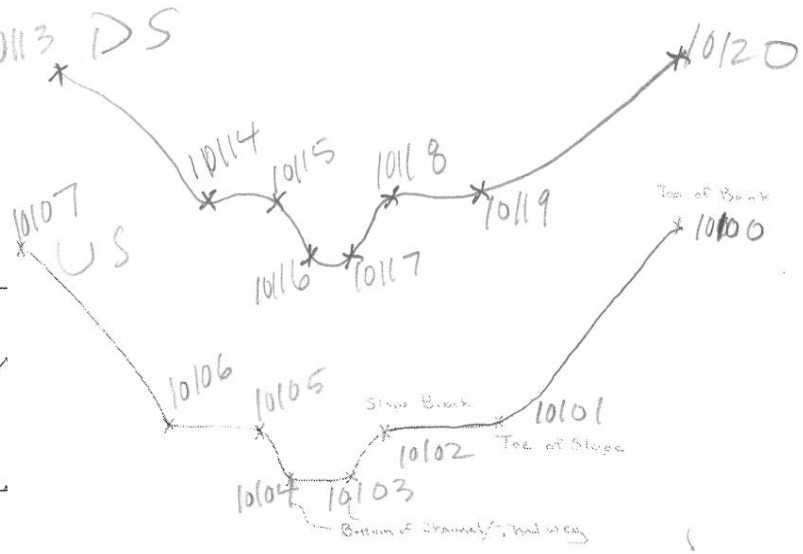
+ Wingwall

Culvert Survey Data Sheet

Project: BROOKWOOD
Date: 12/23/11
Crew: M. GREEN, M. STEINER

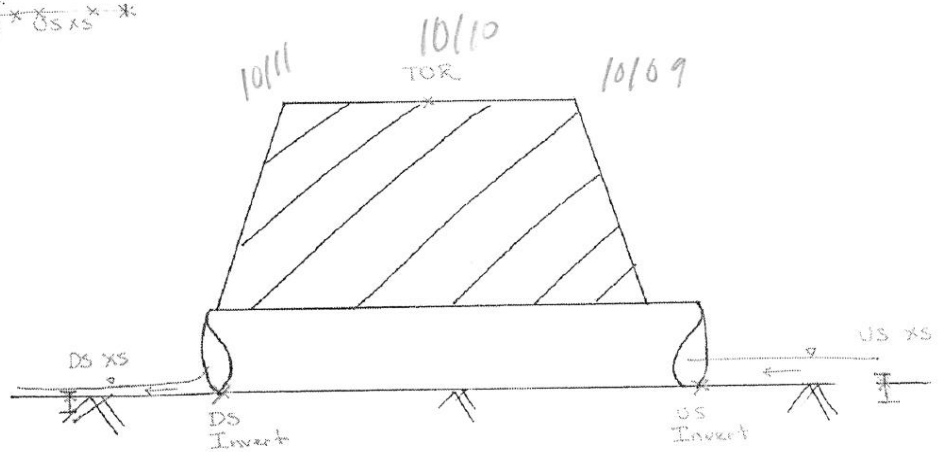
Location: HELVATIA RD.
Points ID:
Picture ID:





Points Required:

Channel	Cross Section US & DS,
	5 - 10 feet from end of pipe
	Points at channel & slope breaks
Culvert	US Invert, DS Invert
TOR	1 to 2 at low point in road, near culvert
High water marks	As available



Culvert Information:

Number 1
Size 13.7' wide, 7' TALL
Length

Shape	Round	Box	Arch	Elliptical	Other	
Material	RCP	CMP	DIP	HDPE	Other → WOOD	
Condition	New	Good	Fair	Poor		
Pipe Conveyance	Clean	1/4 Full	1/2 Full	3/4 Full	Full	Perched
Pipe Edge Entrance	Headwall		Flush with Fill			Projecting

culvert spanned entire length and flush with bottom of road

Table A1: Waible Creek Subbasin Characteristics

ID	Stream	Area (sq ft)	Area (ac)	Existing Composite CN	Proposed CN	Tc (min)
ST1	Storey Creek	5461364.84	125.38	**74**	74	47.8
ST2	Storey Creek	4551836.37	104.50	**76**	76	32.8
ST2E1	Storey Creek	6077285.49	139.52	**78**	78	46.8
ST2E2	Storey Creek	10395682.53	238.65	**71**	71	57.7
ST2E3	Storey Creek	10650458.68	244.50	**70**	70	46.2
ST2E4	Storey Creek	9135196.96	209.72	**74**	74	55.2
ST3	Storey Creek	2160130.26	49.59	**74**	74	33.9
ST4	Storey Creek	9627076.42	221.01	**72**	72	44.5
ST4M1	Storey Creek	7412159.83	170.16	**75**	75	41.1
ST4M2	Storey Creek	21733532.08	498.93	**75**	75	53.3
ST4M3	Storey Creek	7103282.42	163.07	**77**	77	49.3
ST5	Storey Creek	3375568.53	77.49	**77**	77	37.8
ST6N	Storey Creek	13566103.14	311.43	**75**	75	27.7
ST6S	Storey Creek	4347399.55	99.80	**76**	76	31.8
ST7	Storey Creek	24295220.21	557.74	**73**	73	23.9
WB1	Waible Creek	18780797.47	431.15	**75**	75	47.8
WB2	Waible Creek	19596894.39	449.88	**76**	76	25.4
WB3	Waible Creek	10599792.65	243.34	**76**	76	35.1
WB4E	Waible Creek	13188877.74	302.77	**75**	75	28.7
WB4W	Waible Creek	8210974.14	188.50	**75**	75	15.8
WB5	Waible Creek	4094649.46	94.00	**80**	81	13.3
WB5S1	Waible Creek	6616214.48	151.89	**76**	88	19.1
WB5S2	Waible Creek	7998601.34	183.62	**80**	91	21.2
WB5S3E	Waible Creek	2300237.69	52.81	**78**	89	11.9
WB5S3W	Waible Creek	3391382.04	77.86	**79**	89	12.6
WB5S4	Waible Creek	6696378.21	153.73	**73**	88	13.9
WB5S6	Waible Creek	3207054.98	73.62	**89**	91	32.8
WB5S7	Waible Creek	4146689.68	95.19	**82**	90	22.2
WB6E	Waible Creek	8192132.37	188.07	**72**	85	17.8
WB6W	Waible Creek	3127819.89	71.80	**72**	72	17.4
WB7	Waible Creek	3961046.10	90.93	**70**	73	37.1
WB8	Waible Creek	2802744.07	64.34	**71**	73	9.6
WB8N1	Waible Creek	4922216.04	113.00	**74**	83	47.0
WB8N2	Waible Creek	6813302.74	156.41	**72**	72	27.3
WB8N3	Waible Creek	3743853.54	85.95	**75**	75	35.5
WB9	Waible Creek	1156699.27	26.55	**73**	73	24.7
WB9E1	Waible Creek	6393252.39	146.77	**75**	75	29.2
WB9E2	Waible Creek	2114046.65	48.53	**71**	71	37.7
WB9W	Waible Creek	728471.67	16.72	**77**	77	23.1
WB10E	Waible Creek	4519976.68	103.76	**75**	75	28.8
WB10N	Waible Creek	24161791.11	554.68	**72**	72	23.5
WB10S	Waible Creek	16481315.30	378.36	**75**	75	33.1

Table A2a: Waible Creek Subbasins - Existing Conditions Peak Flows

		Peak Flows (cfs)				
ID	**Stream**	**2 year**	**10 year**	**25 year**	**50 year**	**100 year**
ST1	Storey Creek	6.6	19.8	27.3	29.4	38.3
ST2	Storey Creek	8.5	22.4	30.0	32.1	40.9
ST2E1	Storey Creek	12.8	30.3	39.8	42.4	53.2
ST2E2	Storey Creek	7.6	26.4	38.4	41.8	56.1
ST2E3	Storey Creek	6.7	25.7	38.3	41.9	57.1
ST2E4	Storey Creek	10.6	31.5	43.5	46.8	60.8
ST3	Storey Creek	2.9	8.8	12.2	13.1	17.0
ST4	Storey Creek	8.5	30.1	42.9	46.5	61.8
ST4M1	Storey Creek	11.0	30.9	42.0	45.1	58.0
ST4M2	Storey Creek	29.7	83.1	113.1	121.4	156.1
ST4M3	Storey Creek	13.3	33.2	44.1	47.1	59.5
ST5	Storey Creek	6.9	17.2	22.8	24.3	30.7
ST6N	Storey Creek	23.1	65.0	88.4	95.0	122.1
ST6S	Storey Creek	8.3	21.8	29.2	31.2	39.8
ST7	Storey Creek	30.1	100.5	140.4	151.5	198.5
WB1	Waible Creek	26.4	74.4	101.2	108.7	139.8
WB2	Waible Creek	39.8	104.6	139.9	149.7	190.6
WB3	Waible Creek	19.3	51.1	68.4	73.3	93.4
WB4E	Waible Creek	21.9	62.1	84.3	90.5	116.0
WB4W	Waible Creek	15.6	43.3	58.3	62.5	80.1
WB5	Waible Creek	15.2	32.5	41.5	44.0	54.0
WB5S1	Waible Creek	14.4	37.8	50.6	54.1	68.8
WB5S2	Waible Creek	27.9	60.1	77.0	81.7	100.9
WB5S3E	Waible Creek	6.9	15.9	20.7	22.0	27.4
WB5S3W	Waible Creek	11.6	25.6	33.0	35.0	43.2
WB5S4	Waible Creek	9.5	30.8	42.9	46.2	60.3
WB5S6	Waible Creek	21.3	35.9	43.0	44.9	52.6
WB5S7	Waible Creek	17.4	34.9	44.0	46.5	56.7
WB6E	Waible Creek	9.0	33.1	47.1	51.0	67.3
WB6W	Waible Creek	3.4	12.6	17.9	19.3	25.5
WB7	Waible Creek	2.6	10.6	15.8	17.2	23.4
WB8	Waible Creek	2.7	11.0	15.6	16.9	22.5
WB8N1	Waible Creek	5.8	17.7	24.4	26.3	34.2
WB8N2	Waible Creek	6.7	24.5	34.8	37.8	50.2
WB8N3	Waible Creek	5.9	16.6	22.5	24.2	31.1
WB9	Waible Creek	1.4	4.8	6.7	7.2	9.4
WB9E1	Waible Creek	10.8	30.4	41.3	44.3	56.8
WB9E2	Waible Creek	1.6	6.2	9.1	9.9	13.3
WB9W	Waible Creek	1.7	4.2	5.5	5.9	7.4
WB10E	Waible Creek	7.5	21.2	28.8	30.9	39.6
WB10N	Waible Creek	24.0	89.1	126.6	137.1	181.6
WB10S	Waible Creek	26.5	74.7	101.6	109.1	140.1

Table A2b: Waible Creek Subbasins - Future Conditions Peak Flows

		Peak Flows (cfs)				
ID	**Stream**	**2 year**	**10 year**	**25 year**	**50 year**	**100 year**
ST1	Storey Creek	6.6	19.8	27.3	29.4	38.3
ST2	Storey Creek	8.5	22.4	30.0	32.1	40.9
ST2E1	Storey Creek	12.8	30.3	39.8	42.4	53.2
ST2E2	Storey Creek	7.6	26.4	38.4	41.8	56.1
ST2E3	Storey Creek	6.7	25.7	38.3	41.9	57.1
ST2E4	Storey Creek	10.6	31.5	43.5	46.8	60.8
ST3	Storey Creek	2.9	8.8	12.2	13.1	17.0
ST4	Storey Creek	8.5	30.1	42.9	46.5	61.8
ST4M1	Storey Creek	11.0	30.9	42.0	45.1	58.0
ST4M2	Storey Creek	29.7	83.1	113.1	121.4	156.1
ST4M3	Storey Creek	13.3	33.2	44.1	47.1	59.5
ST5	Storey Creek	6.9	17.2	22.8	24.3	30.7
ST6N	Storey Creek	23.1	65.0	88.4	95.0	122.1
ST6S	Storey Creek	8.3	21.8	29.2	31.2	39.8
ST7	Storey Creek	30.1	100.5	140.4	151.5	198.5
WB1	Waible Creek	26.4	74.4	101.2	108.7	139.8
WB2	Waible Creek	39.8	104.6	139.9	149.7	190.6
WB3	Waible Creek	19.3	51.1	68.4	73.3	93.4
WB4E	Waible Creek	21.9	62.1	84.3	90.5	116.0
WB4W	Waible Creek	15.6	43.3	58.3	62.5	80.1
WB5	Waible Creek	16.8	34.6	43.8	46.4	56.6
WB5S1	Waible Creek	47.0	80.4	96.7	101.1	118.7
WB5S2	Waible Creek	69.1	111.0	131.1	136.5	157.9
WB5S3E	Waible Creek	18.1	30.2	36.0	37.6	43.9
WB5S3W	Waible Creek	27.1	45.3	54.1	56.5	65.9
WB5S4	Waible Creek	48.8	83.4	100.4	105.0	123.4
WB5S6	Waible Creek	24.6	39.5	46.7	48.6	56.3
WB5S7	Waible Creek	33.0	54.2	64.5	67.2	78.2
WB6E	Waible Creek	46.4	85.5	105.2	110.6	132.2
WB6W	Waible Creek	3.4	12.6	17.9	19.3	25.5
WB7	Waible Creek	4.4	14.5	20.3	22.0	28.9
WB8	Waible Creek	4.2	13.2	18.2	19.7	25.6
WB8N1	Waible Creek	17.5	34.4	43.1	45.4	55.0
WB8N2	Waible Creek	6.7	24.5	34.8	37.8	50.2
WB8N3	Waible Creek	5.9	16.6	22.5	24.2	31.1
WB9	Waible Creek	1.4	4.8	6.7	7.2	9.4
WB9E1	Waible Creek	10.8	30.4	41.3	44.3	56.8
WB9E2	Waible Creek	1.6	6.2	9.1	9.9	13.3
WB9W	Waible Creek	1.7	4.2	5.5	5.9	7.4
WB10E	Waible Creek	7.5	21.2	28.8	30.9	39.6
WB10N	Waible Creek	24.0	89.1	126.6	137.1	181.6
WB10S	Waible Creek	26.5	74.7	101.6	109.1	140.1

Table A3: Waible Creek Channel Routings

Link	Stream	Upstream Node	Upstream Elevation	Downstream Node	Downstream Elevation	Length (ft)	Conduit Class	Area (sq ft)	Channel Manning's "n"	Maximum Width (ft)	Maximum Depth (ft)
ST1R	Storey Creek	ST2J2	161	WB3J2	157.00	2660	Natural	1755.18	0.035	347	10
ST2E1R	Storey Creek	ST2E2J	176	ST2J2	161.00	2466	Natural	1867.20	0.035	325	10
ST2E2R	Storey Creek	ST2E3J	181	ST2E2J	176.00	1783	Natural	2695.32	0.035	762	10
ST2R	Storey Creek	ST3J	167	ST2J2	161.00	2121	Natural	1949.27	0.035	353	10
ST3R	Storey Creek	ST4J2	170	ST3J	167.00	892	Natural	1622.03	0.035	355	10
ST4M1R	Storey Creek	ST4M2J	183	ST4J2	170.00	3219	Natural	1827.90	0.035	446	10
ST4R	Storey Creek	ST5J	195	ST4J2	170.00	5619	Natural	1822.53	0.035	463	10
ST5R	Storey Creek	ST6J	209	ST5J	195.00	2030	Natural	3995.45	0.035	935	10
ST6R	Storey Creek	ST7	290	ST6J	209.00	6676	Natural	3180.64	0.035	829	10
GroveDr	Waible Creek	WB6WJ	175.2	Node155	175.20	37	Natural	146.72	0.035	21	8.1
Link125	Waible Creek	WB6W1	175.91	Node155	175.20	35	Natural	1019.81	0.035	361	8
WB10SR	Waible Creek	WB10N	234	WB10J	193.00	6030	Natural	2387.73	0.035	462	10
WB1R	Waible Creek	WB2J	151	WB1J	139.00	5774	Natural	6444.90	0.035	428	20
WB2R	Waible Creek	WB3J2	157	WB2J	151.00	3297	Natural	5815.72	0.035	385	20
WB3R	Waible Creek	WB4WJ	161	WB3J2	157.00	3119	Natural	5261.32	0.035	427	20
WB4ER	Waible Creek	WB5J2	170	WB4EJ	166.00	2596	Natural	2734.02	0.035	536	12
WB4WR	Waible Creek	WB4EJ	166	WB4WJ	161.00	1589	Natural	3216.02	0.035	453	15
WB5R	Waible Creek	Node146	176.31	WB5J1	171.00	1671	Natural	2061.50	0.035	511	10
WB5R2	Waible Creek	WB5J1	171	WB5J2	170.00	880	Natural	2013.65	0.035	417	10
WB5S0R	Waible Creek	WB5S1J	175	WB5J2	170.00	408	Natural	1806.08	0.035	354	9.47
WB5S1R	Waible Creek	Node147	181.26	WB5S1J	175.00	2557	Natural	2329.58	0.035	765	10
WB5S2R	Waible Creek	WB5S3WJ2	189.45	WB5S2J	182.19	2117	Natural	3561.35	0.035	923	9.67
WB5S3ER	Waible Creek	Node149	201.81	WB5S3EJ	196.78	982	Natural	1658.33	0.035	465	10
WB5S3WR	Waible Creek	Node148	195.63	WB5S3WJ1	189.75	2096	Natural	1201.39	0.035	368	10
WB5S5R	Waible Creek	WB5S6J	189.5	WB5S3WJ2	189.45	10	Natural	2735.32	0.035	491	9.07
WB5S6R	Waible Creek	WB5S6.5	201	WB5S6J	189.50	2294	Natural	2735.32	0.035	491	9.07
WB67R	Waible Creek	WB6E1	180.1	Node151	179.63	160	Natural	3947.56	0.035	1189	11
WB6ER	Waible Creek	WB6EJ	180.6	WB6E1	180.10	100	Natural	99.83	0.035	48	5
WB6R	Waible Creek	Node145	179.97	WB6WJ	175.20	1631	Natural	1217.20	0.035	368	8.54
WB7R	Waible Creek	WB8J	184	WB7J	179.50	1493	Natural	2538.84	0.035	805	10
WB8N1R	Waible Creek	WB8N2J	201	WB8J	184.00	3164	Natural	2525.74	0.035	547	10
WB8N2R	Waible Creek	WB8N3	220	WB8N2J	201.00	2524	Natural	2239.95	0.035	386	10
WB8R	Waible Creek	WB9J	187	WB8J	184.00	1267	Natural	2407.48	0.035	786	10
WB9R	Waible Creek	WB9EWJ	191	WB9J	187.00	614	Natural	3303.47	0.035	768	10
WB9WR	Waible Creek	WB10J	193	WB9EWJ	191.00	762	Natural	493.67	0.035	322	5

Table A4a: Waible Creek Existing Conditions Peak Flows

	Peak Flows (cfs)				
Link	**2 year**	**10 year**	**25 year**	**50 year**	**100 year**
Bwood1	37.3	58.8	71.1	73.9	83.8
Bwood2	22.6	47.2	60.3	63.6	75.6
BwoodW	0.0	0.0	0.0	0.0	0.0
Cent_weir	0.0	0.0	0.0	0.0	0.0
Century1	10.8	27.9	32.7	33.5	38.8
Century2	3.8	15.5	23.1	25.4	32.0
FREE # 1	342.2	724.0	995.1	1069.7	1328.0
GroveDr	86.7	197.1	264.1	282.1	340.4
GroveW1	0.0	0.0	0.0	0.0	0.0
GroveW2	0.0	0.0	0.0	0.0	0.0
H26E_Weir	0.0	0.0	0.0	0.0	0.0
HELVP	88.7	213.1	280.5	294.6	345.8
HelvWeir	0.0	0.0	0.0	0.0	0.0
Hwy26E.1	16.6	33.3	40.2	41.7	47.0
Hwy26W.1	-86.7	-197.0	-263.9	-282.0	-340.4
Hwy26WW	0.0	0.0	0.0	0.0	0.0
Jacob_Weir	0.0	0.0	0.0	0.0	0.0
Jacob1	4.4	15.2	21.4	23.1	30.3
Jacob2	4.9	15.4	21.0	22.6	29.1
Link125	-86.7	-197.0	-264.0	-282.0	-340.4
PIPE3	17.3	34.6	37.3	37.3	37.3
Schaaf.1	-81.8	-197.4	-260.4	-274.5	-292.4
SchaafW	0.0	0.0	0.0	0.0	38.2
ST1R	138.8	336.7	501.1	537.3	661.7
ST2E1R	24.5	58.0	104.8	117.6	162.1
ST2E2R	17.3	58.2	83.2	90.3	110.2
ST2R	105.1	283.1	396.2	411.4	491.1
ST3R	103.3	281.2	389.1	403.9	483.3
ST4M1R	35.8	94.2	133.6	143.4	181.3
ST4R	53.4	145.2	195.1	207.5	270.4
ST5R	52.5	159.2	224.0	240.8	301.9
ST6R	25.4	90.3	128.3	138.7	164.3
WB10SR	20.4	51.3	63.1	68.6	86.3
WB1R	325.0	689.0	944.2	1015.6	1262.6
WB2R	314.8	653.8	906.9	974.4	1204.8
WB3R	163.9	331.7	429.2	454.5	541.3
WB4ER	152.5	300.3	390.7	412.2	483.5
WB4WR	157.6	318.7	412.7	436.9	519.3
WB5R	86.6	196.7	263.7	281.4	341.5
WB5R2	92.1	205.3	274.6	292.8	354.1
WB5S0R	68.4	124.2	155.5	163.4	195.4
WB5S1R	56.7	104.8	130.0	135.9	155.2
WB5S2R	43.1	76.5	93.1	96.8	108.7
WB5S3ER	8.8	29.9	41.8	45.1	58.8
WB5S3WR	11.8	37.6	48.5	51.0	62.7
WB5S5R	32.2	48.9	62.1	64.6	73.2
WB5S6R	14.0	21.6	29.2	30.3	33.1
WB67R	-81.7	-197.0	-259.8	-274.0	-321.5
WB6ER	8.9	31.8	45.2	49.2	66.1
WB6R	88.5	207.6	275.3	290.6	343.1
WB7R	80.9	197.8	266.4	276.7	314.0
WB8N1R	10.9	33.1	45.8	49.1	61.3
WB8N2R	5.2	14.2	19.2	20.5	25.8
WB8R	63.5	147.9	201.5	208.1	264.5
WB9R	62.0	149.1	206.7	223.2	292.0
WB9WR	49.8	127.6	168.8	180.3	236.6

Table A4b: Waible Creek Future Conditions Peak Flows

	Peak Flows (cfs)				
Link	**2 year**	**10 year**	**25 year**	**50 year**	**100 year**
Bwood1	58.7	85.1	93.6	95.9	103.2
Bwood2	46.1	76.4	89.7	92.8	103.7
BwoodW	0.0	0.0	0.0	0.0	0.0
Cent_weir	0.0	0.0	0.0	0.0	0.0
Century1	33.5	43.9	46.9	47.7	51.8
Century2	25.3	36.7	39.8	40.6	45.0
FREE # 1	403.3	830.1	1101.7	1174.4	1422.5
GroveDr	106.3	230.0	297.2	315.5	370.8
GroveW1	0.0	0.0	0.0	0.0	0.0
GroveW2	0.0	0.0	0.0	0.0	0.0
H26E_Weir	0.0	0.0	0.0	0.0	0.0
HELVP	114.6	244.6	310.9	328.9	386.0
HelvWeir	0.0	0.0	0.0	0.0	0.0
Hwy26E.1	39.3	51.6	57.3	58.7	62.5
Hwy26W.1	-106.2	-229.9	-297.2	-315.6	-370.9
Hwy26WW	0.0	0.0	0.0	0.0	0.0
Jacob_Weir	0.0	0.0	0.0	0.0	0.0
Jacob1	24.6	42.1	48.2	50.1	58.7
Jacob2	24.0	41.6	52.2	54.8	64.6
Link125	-106.2	-229.9	-297.2	-315.5	-370.9
PIPE3	32.8	37.3	37.3	37.3	37.2
Schaaf.1	-93.4	-211.8	-274.7	-283.7	-284.0
SchaafW	0.0	0.0	0.0	10.9	60.7
ST1R	137.3	336.9	500.0	536.8	654.2
ST2E1R	24.4	58.0	105.2	118.0	162.1
ST2E2R	17.3	58.2	83.2	90.2	110.2
ST2R	105.0	282.7	396.1	411.3	490.9
ST3R	103.2	280.9	389.0	403.8	483.1
ST4M1R	35.8	94.1	133.5	143.3	181.3
ST4R	53.3	145.2	195.1	207.6	270.4
ST5R	52.4	159.2	224.0	240.8	301.9
ST6R	25.4	90.3	128.3	138.7	164.3
WB10SR	20.4	51.3	63.0	68.5	86.3
WB1R	386.1	792.5	1050.3	1119.7	1357.3
WB2R	372.1	760.8	1010.8	1077.0	1296.4
WB3R	224.4	414.7	518.1	543.5	626.6
WB4ER	225.6	384.5	478.3	500.7	570.4
WB4WR	219.9	401.7	501.8	526.1	604.6
WB5R	106.1	229.9	298.5	317.4	372.8
WB5R2	111.9	239.1	309.0	327.7	385.0
WB5S0R	126.3	211.3	241.6	246.7	274.5
WB5S1R	101.8	154.8	173.6	178.2	200.4
WB5S2R	71.0	102.6	113.1	115.7	125.1
WB5S3ER	47.9	82.1	98.8	103.3	121.3
WB5S3WR	51.4	77.0	83.9	85.6	93.9
WB5S5R	36.6	62.2	70.1	72.7	81.4
WB5S6R	18.8	32.6	34.3	34.7	35.5
WB67R	-93.2	-211.5	-274.4	-292.9	-336.0
WB6ER	45.9	83.5	103.7	109.0	372.7
WB6R	113.0	239.5	306.3	324.2	372.8
WB7R	91.5	210.1	278.0	291.8	323.2
WB8N1R	10.9	33.0	45.5	48.8	60.5
WB8N2R	5.2	14.2	19.2	20.5	25.8
WB8R	63.3	147.2	202.1	213.1	250.3
WB9R	62.0	148.5	206.4	223.0	291.8
WB9WR	49.8	127.9	168.7	180.2	236.6