192nd Culvert

Final Options Analysis Report

May 5, 2014

City of Kenmore
192nd Culvert
Final Options Analysis Report

May 2014

Prepared for:
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City of Kenmore Task Order No. 14

City of Kenmore Professional Engineering Services Contract No. 12-C1081

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List of Abbreviations

Term	Definition
cfs	Cubic feet per second (1 cfs = 0.6463 MGD
City	City of Kenmore
Ecology	Washington State Department of Ecology
gal	Gallons
gpm	Gallons per minute
HSPF	Hydrologic Simulation Program - Fortran
MG	Million Gallons
MGD	Million Gallons per Day (1 MGD = 694.44 gpm)
NAVD88	North American Vertical Datum of 1988
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service (formerly SCS)
O&M	Operations and Maintenance
OCI	Osborn Consulting, Inc.
ROM	Rough Order of Magnitude
ROW	Right of Way; Rights of Way
SCS	Soil Conservation Service (see NRCS)
SST	State Sales Tax; As of April 2014, the rate is 9.5% within City of Kenmore
SWMM5	Storm Water Management Model developed by EPA (EPA SWMM 5.0.022)
XPSWMM	Stormwater & Wastewater Management Model developed by XP Software
WAC	Washington Administrative Code
WCDG	Water Crossing Design Guidelines
WDFW	Washington Department of Fish and Wildlife

Executive Summary

This Options Analysis Report is for the 192nd Culvert improvements to address flooding of NE 192nd Street during high flows from Little Swamp Creek. The work was completed according to Task Order 14 (TO 14) as part of the On-Call Contract for Surface Water Project Design (Contract No. 12-C1081).

The Options Analysis was completed as a collaborative effort between Northwest Environmental and Osborn Consulting, Inc. (OCI)). The recommended option will be chosen by the City of Kenmore. This report presents a summary of engineering findings for use in determining a preferred option.

Summary of Options Considered

The initial options included:

- Option 1: High-flow bypass
- Option 2: Full culvert replacement (fish passage)
- Option 3: Raise NE 192nd Street at the culvert crossing one-foot to prevent road overtopping during the 25-year storm.
- No-build option

The options were discussed with Washington Department of Fish and Wildlife (WDFW) to see if any of the constraints would eliminate options. WDFW constraints were as follows:

- Option 1: High-flow bypass is allowed but is difficult to maintain. No stranding of fish can occur and a fish screen needs to be placed over the bypass. The high-flow bypass can only be for high-flow events. Parallel culverts are not permitted.
- Option 2: This is the preferred option by WDFW.
- Option 3: The depth of runoff behind the road section (berm) cannot be more than 0.2 feet for the 100-year storm event per WAC 220-110-070.

Options 1 and 2 meet the project objectives of reducing flooding. Option 3 was eliminated as more than a 0.2-foot depth occurs on the north-side of the road section for the 100-year storm event.

Summary of Results

A summary of the results is provided below.

1. Option 1 showed that an additional 24-inch bypass culvert can convey the 100-year event without flooding. This option includes an upstream catch basin/riser allowing storm events greater than the 25-year event to use both the existing and additional 24-inch

bypass pipe. . This option will more than likely not be approved by WDFW as it does not meet the code requirements for depth required in the culvert per WAC 220-110-070. It also does not meet the recommended velocity requirements for juvenile salmon as stated in the 2013 WCDG.

2. Option 2 showed that a 12-foot x 3-foot high box culvert can convey the 100-year event without flooding or overtopping. The sizing of the culvert was completed using the bankfull width for a no-slope culvert.
3. Option 3 is not feasible as the depth of the water surface elevation at the north side of the road for the 100-year event is more than 0.2 feet.
4. The no-build option will continue to have flooding for two reasons:
    a. The culvert is undersized for the 25-year event.
    b. Debris and sediment can block the culvert.

    The flooding can reach up to a foot (approximately based on SWMM modeling results discussed in **Appendix D**), which is the depth at which most cars and sport utility vehicles (SUVs) can float (NOAA, 2014). The road condition is such that there are no barriers on either side such that a car could be transported off of the road section and into the flowing creek. Moreover, because this section of road floods frequently (two or three times a year per discussion with the City), the stability of the road section is not known. One of the most dangerous flood situations is when the road section collapses or is washed away and the water surface appears normal. The City manually places signs when the road floods, but this generally occurs within business hours. It is suggested that permanent signage be placed at the creek crossing until the flooding is not a risk that states that the road is closed when flooded.

The modeling performed for the options analysis is considered preliminary and does not include downstream impacts to Swamp Creek. This needs to be further analyzed in the design phase to understand the effects of Swamp Creek.

A critical areas report has not been prepared for impacts to the creek. This needs to be further developed in the design phase and is discussed in the **Section 3**.

SECTION 1

Introduction

The purpose of this document is to refine and evaluate options for reducing flooding at NE 192nd Street where the road has a low point and the culvert does not have capacity.

PROJECT TEAM MEMBERS

This project is led and managed by Zack Richardson (City). The City contracted with the Osborn Consulting Team through the On-Call Contract for Surface Water Project Design (Contract No. 12-C1081). The team consists of Osborn Consulting, Inc. (OCI), Northwest Environmental Consulting (NWEC), and Axis Surveying and Mapping.

HISTORY

Flooding occurs at the 192nd culvert at the lowpoint in the road (see **Figure 1-1**). Based on modeling results the road floods for 25-year events or greater. The City evaluated alternatives in 2006 with the help of a consultant that included raising the road 1-foot as well as installing a high-flow bypass. The project did not proceed to construction plan preparation. It was noted that WDFW did not accept the high-flow bypass option at the time.

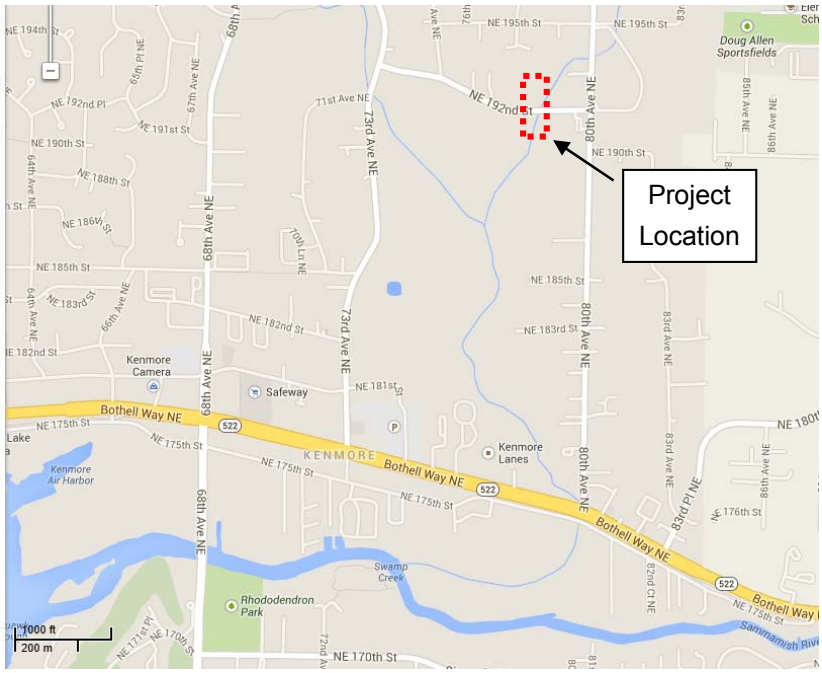

Figure 1-1. Vicinity Map

PREVIOUS ANALYSIS AND EXISTING DOCUMENT REVIEW

OCI reviewed the previous survey, modeling files (HSPF and SWMM), and memos that the City provided.

Previous Modeling and Studies Received from the City

HSPF Model – Peak Flows for Hydrologic Model (prepared by previous consultant)

The peak flows that were calculated by the HSPF model are shown in **Table 1-1** (See HSPF documentation.doc for further information):

Storm Event	HSPF Peak Flow (cfs)
2-yr	27.3
10-yr	47.1
25-yr	57.6
50-yr	65.6
100-yr	73.7

Table 1-1. Storm Event and Existing Flows from HSPF.

SWMM Model – Hydraulic Model (prepared by previous consultant)

The 2006 cross-section inputs to the SWMM model (NE 192nd xsections2.xls) were analyzed and compared with the 2014 cross-sections at the same locations (see **Appendix A**).

The XPSWMM models were reviewed (NE 192nd(25)_Existing.xp, NE 192nd(25)_raised road 0.5ft.xp, and NE 192nd(25)_raised road 0.6ft.xp).

The XPSWMM model used for modeling Little Swamp Creek included upstream cross-sections, the culvert, an overflow roadway section, as well as downstream cross-sections.

Survey

The survey prepared by the previous consultant was reviewed.

Technical Memorandum

- 192nd Roadway Flooding Project (WDFW memo.doc) – This document summarizes that WDFW did not accept the high-flow bypass for the 25-year storm event and that requirements were that the 100-year flow must be conveyed and that the hydraulic design criteria for fish passage were limited to stream simulation only and do not include provisions for high flow bypass structures. There were two previous memos that were presented to WDFW explaining that the bypass was designed such that the upstream

wetlands hydroperiod was not affected (Holser103106M.doc, 192nd correspondence with WFW.doc).

- Roadway Flood Reduction at NE 192nd Street Little Swamp Creek (H&H Tech Memo.doc) – This document summarized the peak flows from the HSPF model. The model found that the 10-year event reached an elevation of 44.20 feet and the 25-year resulted in an elevation of 45.08. The crown of the road elevation at the sag was surveyed at 45.0 feet and hence, the 25-year floods whereas the 10-year event does not.
- Alternatives for Overflow Structures (Alternatives.doc) – This document summarizes the following alternatives:
    - Installing an overflow catch basin and an additional 18-inch to 24-inch culvert.
    - Installing an upstream control weir and replacing the culvert with a 42-inch culvert.
    - Installing an inline control weir that acts as a baffle to maintain the water level upstream.

Calculation Spreadsheets

- Several spreadsheets (Dur_LSC_0406.xls, DUR_LSC_051006.xls, FFA_LSC_0406.xls, FFA_LSC_0510.xls) were provided that include preliminary calculations for the percent exceedance for a given storm event and the flow frequency based on storm event.

Photos

- Photos from 2006 were reviewed and compared to the current condition.

Environmental Checklist

- The NE192ndSEPA_Checklist1.doc was reviewed as submitted for the high-flow bypass option developed by the previous consultant.

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SECTION 2

Options Analysis

The three options considered for 192nd Culvert are:

- Option 1 – High-Flow Bypass
- Option 2 – Fish Passage Culvert
- Option 3 – Raise the road 1-foot
- Option 4 – No-Build

2013 WATER CROSSING DESIGN GUIDELINES (WCDG) SUMMARY

The WDFW has recently updated the criteria for analyzing culverts and retrofitting culverts. The methods that are preferred by WDFW are based on geomorphic design that includes the following measurements and observations:

- Bankfull Width (*the most important parameter*)
- Longitudinal Profile
- Sediment Assessment
- Potential Debris Loading
- Channel Pattern type
- Channel banks
- Constraints

An example of the geomorphic approach and culvert replacement is shown in **Figure 2-1**.

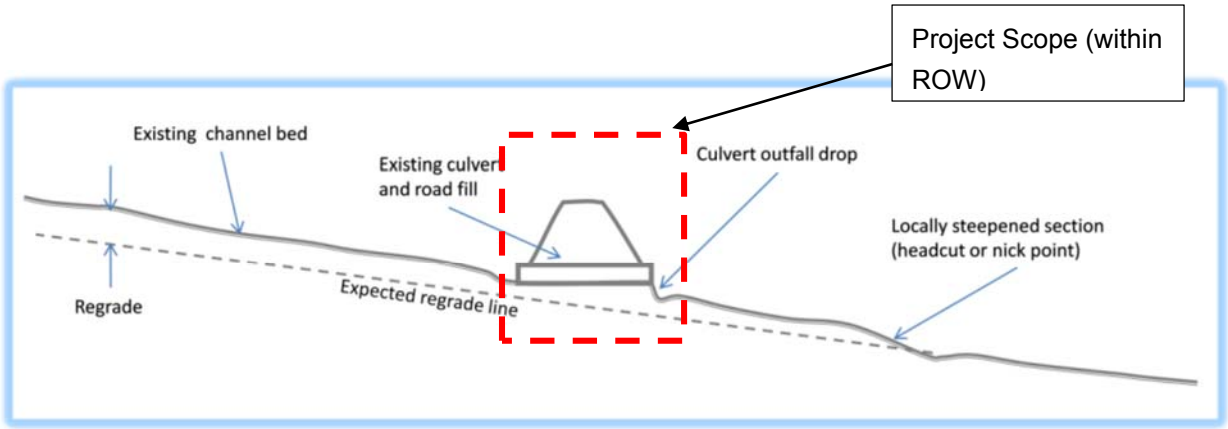

Figure 2-1. Example of geomorphic approach from WDFW *2013 Water Crossing Design Guidelines.*

As stated in the WCDG:

> *"The geomorphic approach to design is generally based on readily-measured characteristics of the natural channel in the adjacent reaches. This is in contrast to the once prevalent hydraulic culvert design method which uses criteria independent of channel conditions."*

The methods that apply to geomorphic design and are considered preferential to WDFW are:

- *No-slope* – For small culverts laid on a flat grade used for small, simple installations on low gradient streams.
- *Stream Simulation* – Culverts placed at the same grade as the stream and appropriate for larger, more complex projects on low gradient streams and most projects on high gradient streams.

The other method that can be used is the hydraulic culvert design method (which is now known as the *Hydraulic Design Fishways*, which is mostly to be used for culvert retrofits, baffle design for exceptionally long culverts or retrofits, and roughened channels for culverts that exceed the maximum stream simulation slope ratio. "Fishways" implies that this design option is only designed to pass fish, and other stream functions may be constrained. The major drawback of this method is the difficult design constraints and the ability of the culvert to pass water-borne debris and sediment.

OPTION 1: HIGH-FLOW BYPASS (HYDRAULIC DESIGN FISHWAYS METHOD)

The criteria for the high-flow bypass was confirmed with WDFW (NWEC, 2014) as a possible option. WFDW requirements are that no stranding of the fish can occur in the high-flow bypass. In order to not have stranding in the high-flow bypass, a catch basin was placed north of the culvert that receives flows from the 25-year 24-hour event or greater. Fish screens are used at the inlet/outlet on the high-flow bypass in order to not strand fish. See **Figure 2-3** for a schematic of Option 1.

The hydraulic design fishways is generally tied to the criteria listed in Washington Administrative Code (WAC) 220-110-070 Table 1 (see **Figure 2-2**).

Table 1
Fish Passage Design Criteria for Culvert Installation

Criteria	Adult Trout > 6 in. (150mm)	Adult Pink, Chum Salmon	Adult Chinook, Coho, Sockeye, Steelhead
1. Velocity, Maximum (fps)			
Culvert Length (ft)			
a. 10 - 60	4.0	5.0	6.0
b. 60 - 100	4.0	4.0	5.0
c. 100 - 200	3.0	3.0	4.0
d. > 200	2.0	2.0	3.0
2. Flow Depth Minimum (ft)	0.8	0.8	1.0
3. Hydraulic Drop, Maximum (ft)	0.8	0.8	1.0

Figure 2-2. Table 1 from WAC 220-110-070.

The resulting stages and velocities for Option 1 are provided in **Table 2-1**.

Table 2-1: Option 1 Results - High Flow Bypass

Rainfall Event	Option 1: Proposed Elevation (Stage) at Northside of Culvert (ft)	Option 1: Proposed Elevation (Stage) at Southside of Culvert (ft)	Option 1: Velocity (fps) in Ex. Culvert	Option 1: Depth (feet) in Ex. Culvert at north end of culvert
Short-Term 24-hr				
2-yr peak flow	42.41	41.25	4.94	1.41
Long-Term 7-day				
2-yr 7 day (Peak Flow)	41.41	40.81	3.63	0.97

For the 2-year peak flow the velocity is required to be less than 4.0 for trout, which the high flow bypass would fail. If the design fish species is salmon, then the velocity meets the Table 1 WAC criteria. However, the minimum depth for salmon is 1-foot for the 2-year 7 day low flow or no flow. The depth in the channel for 2 year 7 day low flow will be less than 1.0 foot as shown in

Table 2-1 (i.e. it is less than 1-foot for the 2-yr 7 day *peak flow*). The depth criteria per WAC 220-110-070 will not be met for the salmon varieties shown in **Figure 2-2**.

The 2013 WCDG mentions that juvenile salmon have a maximum velocity of 1.0 fps based on a study done by the Muckleshoot Indian Tribe Fisheries Division. The velocities shown in **Table 2-1** exceed 1.0 fps and are not conducive to juvenile salmon per the study. Therefore, it is more than likely that this approach will not be approved by WDFW.

Pros/Cons

Pros and cons are listed below.

Pros:

- Low initial cost.
- Existing utilities can remain in the same alignment without major utility conflicts.

Cons:

- This is not the preferred option by WDFW and will be extremely difficult to get permitted.
- The culvert pipes are small diameter that will result in debris blockage. This option requires more maintenance than Option 2. Debris and sediment will more than likely be ongoing maintenance problems.
- Fish screens likewise will result in debris blockage. This option will require more maintenance that Option 2. Debris and sediment will more than likely be ongoing maintenance problems.
- The culvert will need to be monitored to ensure that is meets the hydraulic design fishways criteria.
- An HPA will need to be obtained prior to providing repair.

Total Project Cost:

$131,000 includes soft costs of $49,000 (See **Appendix C** for details). Soft costs include engineering design, permitting, and construction management based on a percent of the construction line item. A more detailed scope of work is needed to provide a contractual agreement with fee.

OPTION 2: FISH CULVERT REPLACEMENT

The 2013 Water Crossing Design Guidelines list specific inputs for designing a no-slope culvert. A discussion of each of the inputs and information for the survey are provided as follows:

No-Slope Design Elements

- ***Bankfull Width Sizing of Culvert Width*** –The bankfull width was estimated off of the recent survey information using the change in slope or topographic breaks along the bank as well as the lower extent of lichens on the rockery next to the creek. See **Appendix B** for the bankfull width calculations. The result is a 12-foot wide culvert.
- ***Culvert Height Sizing***– The clearance from the bed of the culvert to the top is recommended to be a minimum of 4-feet. However, this is not feasible in the road section with the utilities that are required to be routed over the culvert. So the height of the culvert will be reduced to 3-feet.The creek whether a 3-foot or 4-foot height will require some periodic maintenance. The reduced height is a significant improvement over the existing 3-foot diameter culvert.
- ***Natural Channel Slope*** – The slope of the existing culvert is approximately 0.88 percent (see **Appendix A** for calculations).
- ***Elevation of the Natural Channel Bed at the Culvert Outlet*** – The elevation of the culvert at the existing outlet is 39.84 feet. This will be lowered to 39.77 or 20% of the rise (See **Appendix A** for calculations).
- ***Potential for Channel Regrade and Impacts Upstream of the Culvert*** – The potential for channel regrade is not considered as part of this project, but could be if needed to obtain better depth and velocities. The impacts upstream of the culvert are that the water surface elevation for the 2-year 24-hour storm event will drop by approximately 1-foot within the stream channel. The previous consultant indicated that changing culvert conditions may negatively affect upstream wetlands (Otak, 2007). However, the hydrology provided by this brief event is not long enough to provide adequate hydrology to maintain wetland conditions. Hydrology in wetlands is defined as having inundated or saturated conditions for more than 12.5% of the growing season. Areas that are saturated or inundated continuously for 5% to 12.5% of the growing season may be wetlands. The two year 24 hour event is not long enough to provide these conditions; therefore, hydrology for wetlands upstream of the culvert is likely provided by a combination of other factors such as groundwater, precipitation, and flood events. A wetland study is needed to confirm the hydrologic connection between the stream and wetland, to delineate the wetlands, and to discuss any mitigation, if required. The longer duration 2-yr 7 day peak flow represents a drop of approximately 0.6 feet. The drop is expected to be less than this for the low-flow event of the 2-yr 7 day event.

- ***Estimate of the Design Discharge (the 100-year recurrence interval flood or design flow)***
  - Note that design flows discussed for this element were used to check the no-slope culvert design width, but is not required as the bankfull width is the deemed the most important parameter. Furthermore, under the current WAC 220-110-070, only bankfull width and placement (i.e. 20% below at outlet and 40% below at inlet per WCDG) are specified as requirements for culvert design.
  - The fish passage flow can be estimated by the 2-year peak flow, which yields a velocity of approximately 1.72 feet per second.
  - The design flood flow per WAC 220-110-070 states that the 100-year peak flow will be used for the design of bridges and culverts. The 100-year flow is capable of being passed through the culvert.
- ***Downstream Impacts***-
  - The modeling provided for the options analysis was done at a planning level. As such, the SWMM model provided only extends to the south boundary of the adjacent parcel south of the culvert. The overall impacts from increasing flows from Little Swamp Creek to Swamp Creek were analyzed by a sensitivity analysis (see **Appendix D**) and is discussed further in Section 4. The sensitivity analysis showed that because Swamp Creek creates a tailwater condition at the downstream extent of Little Swamp Creek, the larger culvert will not cause adverse effects in the water surface elevation. However, sediment and debris management should be considered in the final design of the culvert.

See **Figure 2-4** for a schematic of Option 2.

The results for the stage and velocities for Option 2 are provided in **Table 2-2**.

Table 2-2 Option 2 Results - Culvert Replacement

Rainfall Event	Option 2: Proposed Elevation (Stage) at Northside of Culvert (ft)	Option 2: Proposed Elevation (Stage) at Southside of Culvert (ft)	Option 2: Velocity (fps) in 12-ft Culvert Replacement	Option 2: Depth (ft) in 12 ft Culvert Replacement
Short-Term 24-hr				
2-yr (peak flow)	41.3	41.23	1.72	1.46
10-yr	41.81	41.7	2.19	1.93
25-yr	42.07	41.93	2.39	2.16
50-yr	42.29	42.15	2.5	2.38
100-yr	42.43	42.28	2.55	2.51
Long-Term 7-day				
2-yr 7 day (peak flow)	40.8	40.78	1.18	1.01

Pros/Cons

Option 2 includes the full culvert replacement with a fish passage culvert.

Pros:

- Least maintenance required for this option.
- WDFW preferred option – geomorphic design.
- Lower velocities for juvenile fish in the culvert.

Cons:

- Utility conflicts for water and fiber optic as well as requiring that the road section be raised by about 0.5 feet to route utilities over the new culvert.
- Most costly option due to the dimensions of the culvert being 12-feet by 4 feet, which requires a concrete box culvert or bottomless box culvert.

Total Project Cost:

$390,000 includes soft costs of $145,000 (See Appendix C for details). Soft costs include engineering design, permitting, and construction management based on a percent of the construction line item. A more detailed scope of work is needed to provide a contractual agreement with fee.

OPTION 3: RAISE THE ROAD 1 FOOT

The existing model was run for the 100-yr 24-hour event to calculate the rise behind the proposed headwall/berm or road-section. The WAC 220-110-070 states that:

> "Abutments, piers, piling, sills, approach fills, etc., shall not constrict the flow so as to cause any appreciable increase (not to exceed .2 feet) in backwater elevation (calculated at the 100-year flood) or channel wide scour and shall be aligned to cause the least effect on the hydraulics of the watercourse."

This option was eliminated as the water level rises over 5-feet currently.

OPTION 4: NO-BUILD

The no-build option will continue to have flooding for two reasons:

1. The culvert is undersized for the 25-year event.
2. Debris and sediment can block the culvert.

The flooding can reach up to a foot (approximately based on SWMM modeling results discussed in **Appendix D**), which is the depth at which most cars and sport utility vehicles (SUVs) can float

(NOAA, 2014). The road condition is such that there are no barriers on either side such that a car could be transported off of the road section and into the flowing creek. Moreover, because this section of road floods frequently (two or three times a year per discussion with the City), the stability of the road section is not known. One of the most dangerous flood situations is when the road section collapses or is washed away and the water surface appears normal. The City manually places signs when the road floods, but this generally occurs within business hours. It is suggested that permanent signage be placed at the creek crossing that states that the road is closed when flooded until the flooding is not a risk.

This option is not recommended because it represents a hazardous condition in the public right-of-way and does not meet the objectives of improving the culvert to alleviate the flooding. It also is not environmentally conducive to fish passage.

RANKING OF OPTIONS

The criteria for ranking the options are: feasibility and constructability, operations and maintenance considerations, approval by WDFW, and cost.

Feasibility and Constructability

Option 1 has the least potential utility conflicts as the pipe can be placed parallel to the existing pipe which will not have conflicts with the existing utilities in the rights-of-way.

Option 2 has the greatest potential conflicts as the existing utilities need to be rerouted above or below the culvert. The water main and fiber optic duct bank are anticipated to go over the culvert and be sleeved.

All culvert work would need to occur during the summer in-water work window.

Groundwater is anticipated to be shallow and will more than likely require well points to locally dewater in the area of the culvert as this is a low point where the basin crosses through the road section. In addition, stream flows may need to be diverted by pumping.

The following are direct constructability requirements under WAC 220-110-070:

1. The culvert shall be installed in the dry or in isolation from the stream flow by installation of a bypass flume or culvert, or by pumping the stream flow around the work area.
2. Wastewater, from project activities and dewatering, shall be routed to an area outside the ordinary high water line to allow removal of fine sediment and other contaminants prior to being discharged to state waters.

Operations and Maintenance Considerations

Option 1 does not provide the height in the culvert to pass debris and will require fish screens. Hence, Option 1 has the most frequent maintenance required.

Option 2 does not meet the WDFW recommended 4-foot height for passing debris, but does have a wider section and 3-foot height. Less maintenance would be required for Option 2.

Approval by WDFW

Option 1 will more than likely not be approved by WDFW because of inadequate depth in the culvert for salmon during low flow migration periods and velocities being too high. Outside of cost, there are no fatal flaws except that Option 2 is more fish friendly.

Option 2 is the preferred WDFW option.

Total Cost Estimates

In addition to the construction line item pricing amount, the potential total cost which includes the construction contract amounts and soft costs (i.e. permitting and engineering design) have been provided (see **Table 2-3**). For further breakdown of costs, see **Appendix C**.

Table 2-3. Construction Cost Table by Option

Option	Construction Costs	Soft Cost	Total Cost
Option 1: High-Flow Bypass	**$82,000**	**$49,000**	**$131,000**
Option 2: Fish Passage Culvert	**$245,000**	**$145,000**	**$390,000**

The ranking of options (i.e. lower numbers are preferable) is shown in **Table 2-4**.

Table 2-4. Qualitative Comparison of Options

	Criteria	Scoring	Option 1: High-Flow Bypass	Option 2: Fish Passage Culvert
1	Feasibility and Constructability	1-5	2	4
2	Operations and Maintenance	1-5	5	1
3	Approval by WDFW (1 being likely, 5 not likely)	1-5	4	1
4	Construction Costs	1-5	1	4
	Total Score		**12**	**10**

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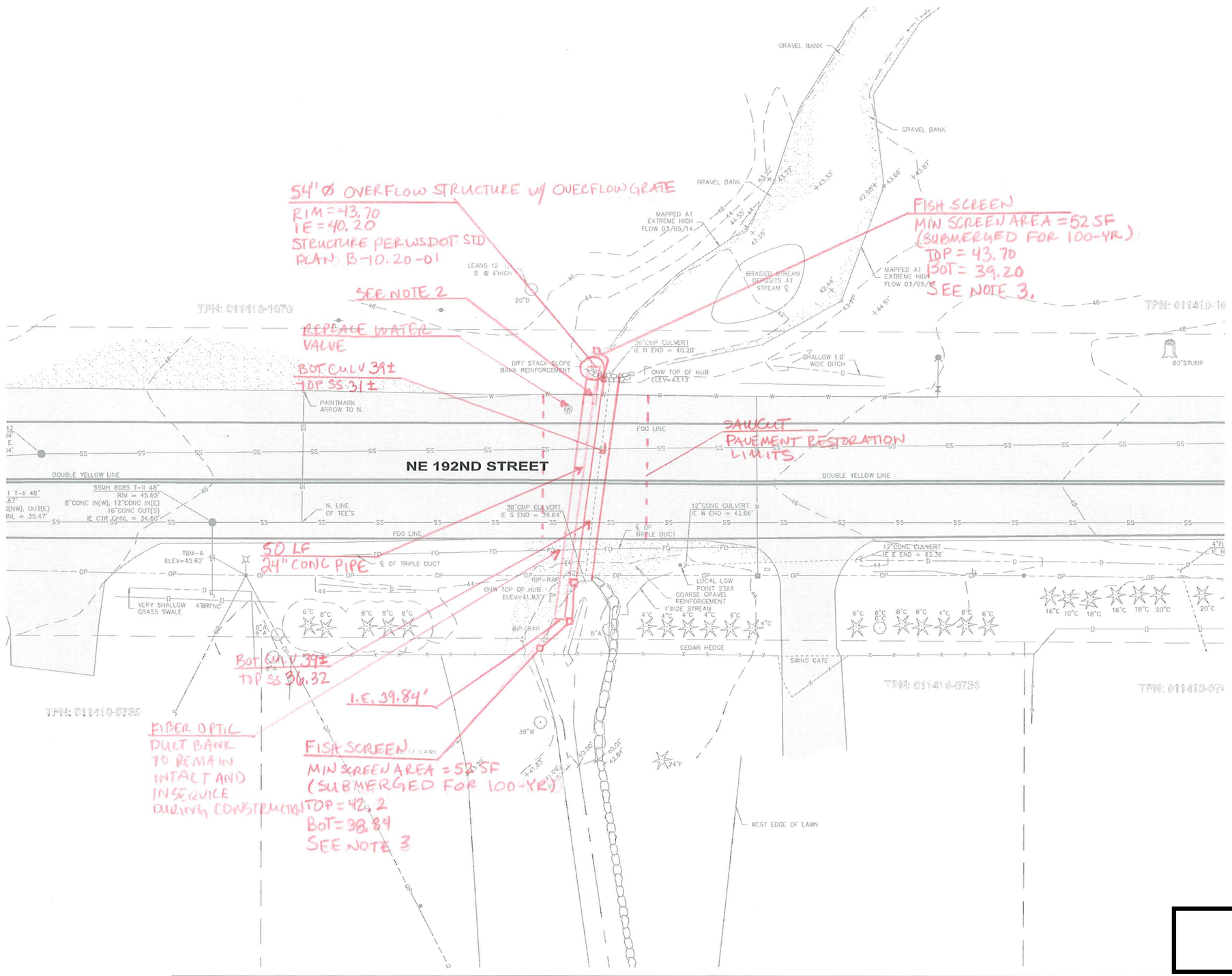
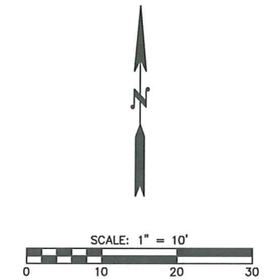




GENERAL NOTES:

1. HIGH FLOW BYPASS SHALL BE PLACED AT THE SAME INVERT AS EXISTING 36-INCH SO THAT UTILITY CROSSINGS REMAIN THE SAME.
2. ASSUME WATER MAIN IS ROUTED UNDER EXISTING CULVERT (I.E. TOP OF CULVERT = 43.20; ROAD ELEV. = 44.7 +/-)
3. FISH SCREEN SHALL CONSIST OF 54 SF OF PERFORATED PLATE, WOVEN WIRE MESH, OR PROFILE BAR PER WDFW SCREENING STANDARDS. SOURCE: 2009 WDFW FISH PASSAGE BARRIER AND SURFACE WATER DIVERSION SCREENING AND PRIORITIZATION MANUAL.

811 Know what's below. Call before you dig.

REBECAH JANE WESTON STATE OF WASHINGTON 46288 REGISTERED PROFESSIONAL ENGINEER

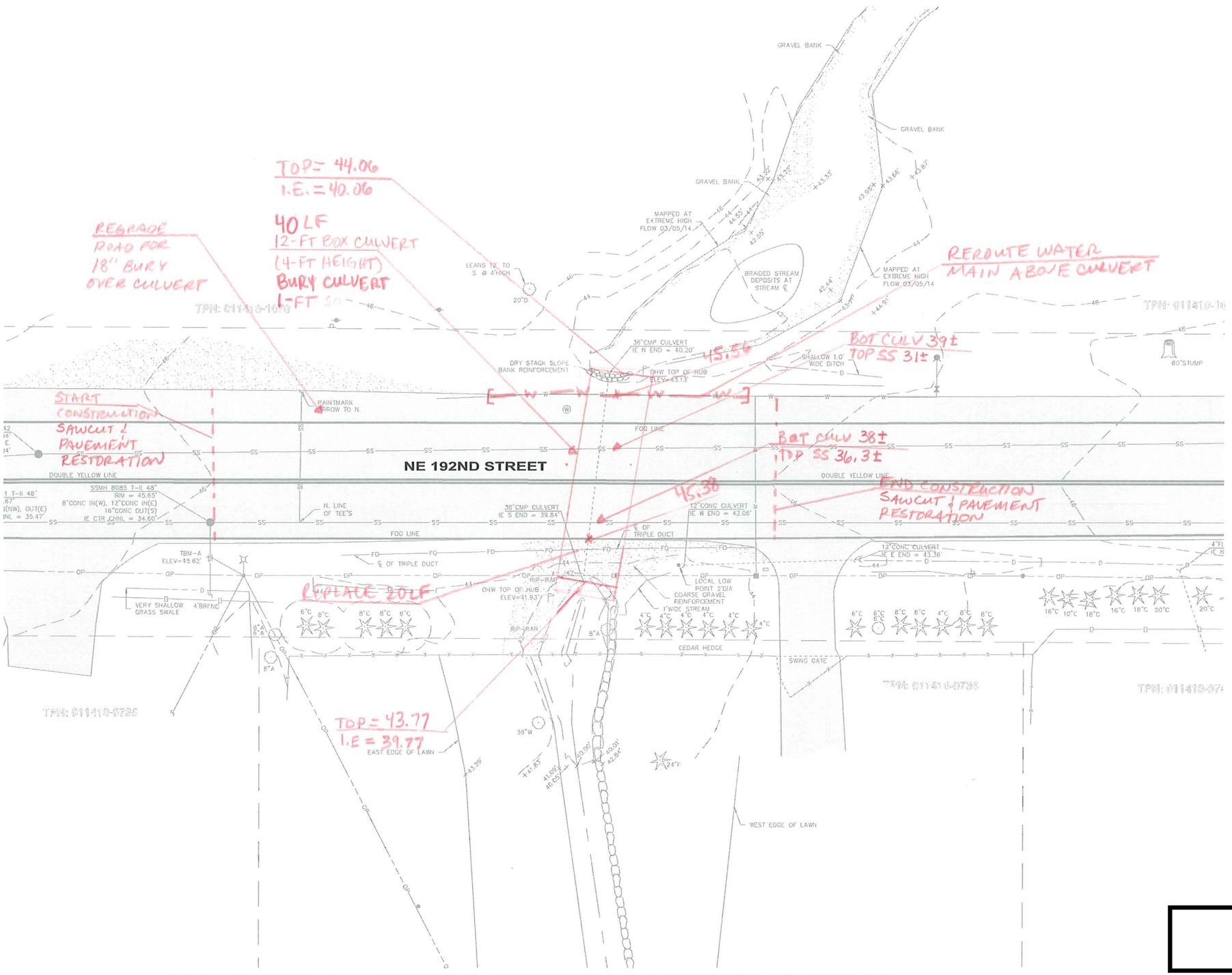
FIGURE 2-3: OPTION 1

DESIGNED BY RW DRAWN BY RDH CHECKED BY TJO	OSBORN CONSULTING INCORPORATED	OSBORN CONSULTING, INC. 1800 112th Ave. NE, Suite 220E Ph (425) 451-4009 Bellevue, WA. 98004 Fax (425) 451-4901	NO. / DATE / REVISION / BY	CITY OF KENMORE 18120 68TH AVE NE KENMORE WA 98028	NE 192ND CULVERT OPTIONS ANALYSIS CITY OF KENMORE ALTERNATIVE 1

JOB# / DWG	DATE
10-120052-14	MAR 2014
SCALE H: 1"=10' V: N/A	SHEET 3 of 5

FILE NAME: O:\PROJECTS\10-120052 KENMORE ON-CALL\TO 14_192ND CULVERT\3 CADD\SHEETS\P_10-120052-14_ALT_1.DWG
PLOT TIME: 3/24/2014 1:45 PM
USER NAME:RICHARD

SEC. 1, T. 26 N., R. 4 E., W.M.



SCALE: 1" = 10'

0 10 20 30

GENERAL NOTES:

1. ASSUMED WATER MAIN IS 8-INCH AND CAN BE ROUTED ABOVE BOX CULVERT.
2. ASSUMED FIBER OPTIC DUCT BANK TO BE ROUTED ABOVE BOX CULVERT.

Know what's below. Call before you dig.

FIGURE 2-4: OPTION 2

DESIGNED BY RW DRAWN BY RDH CHECKED BY TJO	OSBORN CONSULTING INCORPORATED	OSBORN CONSULTING, INC. 1800 112th Ave. NE, Suite 220E Ph (425) 451-4009 Bellevue, WA. 98004 Fax (425) 451-4901	NO. / DATE / REVISION / BY	CITY OF KENMORE 18120 68TH AVE NE KENMORE WA 98028	NE 192ND CULVERT OPTIONS ANALYSIS CITY OF KENMORE ALTERNATIVE 2	JOB# / DWG 10-120052-14 SCALE H: 1"=10' V: N/A	DATE MAR 2014 SHEET 4 of 5

FILE NAME: O:\PROJECTS\10-120052 KENMORE ON-CALL\TO 14_192ND CULVERT\3 CADD\SHEETS\P_10-120052-14_ALT_2.DWG
PLOT TIME: 3/24/2014 1:45 PM
USER NAME:RICHARD

SECTION 3

Steps Forward, Permitting, and Implementation Schedule

Steps Forward

The options analysis was completed at a planning level. The steps forward to construction documents once an option is selected by the City include the following tasks:

1. Prepare a geotechnical report for the type of soils in the road section and to obtain paving recommendations.
2. Determine the wetland area upstream of the culvert and provide a delineation report.
3. Pothole any utilities where the depth is required (i.e. water, fiber optic).
4. The SWMM model terminates at the south boundary of the single-family parcel directly south of the culvert. Because Little Swamp Creek continues and joins Swamp Creek, additional topographic elevations are needed to confirm the sensitivity analysis (see Appendix D).
5. Prepare a critical areas report to understand whether or not the stream water levels affect any upstream wetlands.
6. Attend a meeting with WDFW to see if the high flow bypass would be approved.
7. Obtain information from the fiber optic purveyor and North Shore Utility District about rerouting of the fiber optic and water main requirements.
8. Verifying if there are any gas lines that would need to be rerouted.
9. Verifying the costs for traffic control as this road is traveled frequently.
10. Discuss with public works and other City departments staging for the contractor as well as road closures for installing the culvert (i.e phasing the work for traffic).
11. Discuss project with the planning department for any other preferred road improvements (i.e. sidewalk improvements) to be included in the design.

Permitting

The project requires work below the Ordinary High Water Mark (OHWM) of Little Swamp Creek and will require the following local, state, and federal permits and approvals:

Federal

Section 404/401 (U.S. Corps of Engineers, Ecology may be required to approve 401 actions)

Endangered Species Act (ESA) compliance (administered by U.S. Corps of Engineers)

State

Hydraulic Project Approval (HPA) (Washington Department of Fish and Wildlife)

City of Kenmore

SEPA

Critical Areas Report

The City of Kenmore regulates streams and wetlands through Chapter 18 of the municipal code. Wetlands were not present in or immediately adjacent to Little Swamp Creek within the Right of Way. The stream is fish bearing and requires a 150-foot buffer. Any wetlands upstream or downstream of the project that are associated with Little Swamp Creek are classified as Class 1 because of the association with endangered and threatened fish species. Class 1 wetlands require a 150-foot buffer. However, modifications to the stream or stream buffer will still require a Critical Areas Report.

Implementation Schedule

It is the City of Kenmore's goal to have this project constructed during the July 2015 inwater work period. In order to meet that schedule the following timeline is suggested:

Table 3-1. Implementation Schedule

Project Phase	Start Date	End Date
Field Investigation (Potholing, Geotech Report, Additional Survey)	May 30, 2014	June 14, 2014
Permit Design Drawing Preparation	May 30, 2014	July 21, 2014
Permitting	July 21, 2014	December 31, 2014
Design – 100%	October 9, 2014	November 9, 2014
Bid Documents	November 9, 2014	February 9, 2015
Bid Opening	February 16, 2015	March 4, 2015
Construction (Inwater Work Period)	July 16, 2015	Sept 30, 2015

SECTION 4

References

NOAA (2014). During a Flood. Downloaded from http://www.floodsafety.noaa.gov/during.shtml on May 1, 2014.

Otak (2007). Technical Memorandum, 192nd Roadway Flooding Project. 10230 NE Points Drive, Suite 400, Kirkland, WA 98033.

Seattle Public Utilities, *2012 Unit Cost Report*, 2012.

Washington Administrative Code (WAC) 220-110-070: Water Crossing Structures. 2014. Downloaded from http://apps.leg.wa.gov/wac/default.aspx?cite=220-110-070 on March 28, 2014.

Washington Department of Ecology (DOE) Stormwater Management Manual for Western Washington. 2005. Downloaded from http://www.ecy.wa.gov/programs/wq/stormwater/2005manual.html on March 28, 2014.

Washington Department of Fish and Wildlife (WDFW). 2009. *Fish Passage and Surface Water Diversion Screening Assessment and Prioritization Manual*. Washington Department of Fish and Wildlife. Olympia, Washington.

Washington Department of Fish and Wildlife. 2013. *Water Crossing Design Guidelines*. WDFW. Olympia, Washington

WSDOT Bid Tabs, *Unit Bid Analysis*, downloaded on 3/25/2014 to 3/28/3014 from http://www.wsdot.wa.gov/biz/contaa/uba/bid.cfm.

Appendix A: Model Input, Cross-Sections, and Calculations (Hydrologic and Hydraulic)

Hydrologic and Hydraulic Modeling

In order to provide a hydrologic and hydraulic model that represents the flows and flooding at NE 192nd Street at the culvert, OCI updated the SWMM model by entering sections from the survey that was updated in March 2014 by Axis Surveying and Mapping (see SWMM model schematic and cross-sections in this appendix). Also note that the 2006 cross-sections were added to understand how the creek has changed over the last 8 years. It shows that north of the culvert, the creek has accumulated additional sediment. The cross-sections south of the culvert have primarily stayed with the same.

HYDROLOGIC MODELING

The hydrologic inputs to the model included peak flows from the 2-yr to the 100-yr storm events that were obtained from the HSPF model that was provided by the City. In order to obtain flood volumes and capacities within the system, OCI generated 24-hour storm events that created similar peak flows. See **Table 2-1** for a comparison of the HSPF peak flows and the SWMM peak flows that were generated using the NRCS (SCS) Type 1A 24-hour event with precipitation inputs estimated from the Washington State Department of Ecology's Stormwater Management Manual for Western Washington (2-yr, 10-yr, and 100-yr). Estimates for the 25-yr and 50-year precipitation were done by comparing the output of the model to the HSPF peak flows and adjusting the precipitation input.

	Previous Peak Flow (cfs)	SWMM (NRCS) Peak Flows (cfs)	Precipitation (inches)	Previous Model (feet)	SWMM (NRCS) Stage (feet)
2-yr	27.3	27.95	1.80		42.41
10-yr	47.1	48.44	2.60	44.20	44.01
25-yr	57.6	60.38	3.00	45.08	45.16
50-yr	65.6	68.68	3.30		45.45
100-yr	73.7	74.79	3.50		45.55

Table A-1. Comparison of peak flows from HSPF versus SWMM (NRCS Type 1A 24-hour).

The current modeling effort focused on options analysis modeling utilizing parameters from previous efforts. No additional calibration was included as part of this work authorization. The validation results show that the storm event flows and stages are relatively close and that the

SWMM model with the hydrographs added is adequate for the options analysis (see validation results in **Table A-1**).

HYDRAULIC MODELING

The overall modeling approach was to use the previously developed XP SWMM model for the Little Swamp Creek obtained from the City. OCI converted the model to EPA SWMMV5 using the Storm and Sanitary Analysis (SSA) by AutoDesk. The following were the project and analysis settings and the background on the selection of the inputs:

SWMM Project Settings:

Hydrology Runoff Specifications

- Hydrology Method: **EPA SWMMV5** was used as the hydrology method.
- EPA SWMM Infiltration Method: **Green Ampt** was selected but is not directly used as the basin runoff is calculated to match the HSPF peak flows.

Hydraulic Routing Specifications:

- Linking Routing Method: **Hydrodynamic** – This allows the model to calculate the flow in the system under a backwater condition. The other options do not calculate the flow in a backwater condition.
- Force Main Equation: **Hazen-Williams** – This is the standard for force-main equations.
- Minimimum Conduit Slope: **0%**

Computational & Reporting Options:

- **Enable Overflow Ponding at Nodes** – This affects the computational algorithms to include the overflows at nodes where the model shows flooding.
- Include Input Data in ASCII Output Report (output format)
- Include Control Actions in ASCII Output Report (output format)

SWMM Analysis Settings:

Time Steps:

- Runoff (dry weather): **15 minutes** (dry weather time step must be greater than wet weather time step)
- Runoff (wet weather): **5 minutes**
- Reporting: **5 minutes**
- Routing: **30 seconds**

Dates:

The SCS Type IA 24-hour event was used that is a hydrograph provided in the mode. As such the model length of time was specified to be 1 day. For the Washington 7-day event, 7 days were specified. The precipitation was input and discussed above in **Table A-1**.

Analysis Computations:

- **Hydrology runoff** was selected.
- **Hydraulic flow routing** was selected.

Hydrodynamic Analysis Parameters:

- Inertial terms: **Dampen** was selected to reduce the terms in the St. Venant Momentum Equations as flow comes closer to being critical and ignores them when flow is supercritical.
- Lengthening time step: **5 sec** was selected to artificially lengthen conduits so that they meet the Courant stability criterion under full-flow conditions.
- Junction Surface Area: **0** $ft^2$was selected and the model runs with the default value of 12.566 ft^2, which is the area of a 4-ft diameter manhole.

SUPERCRITICAL FLOW OCCURS WHEN:

Water surface slope & Froude number was selected and occurs when the water surface slope is greater than the conduit slope and the Froude number is greater than 1.0. This is the recommended choice from the SWMM modeling manual.

VARIABLE TIME STEP:

Safety Factor: **75%** was selected to satisfy the Courant condition within each conduit.

The set-up of the model is important as it can create numerical instability and return results that are not representative of the physics. In order to check the stability and flow balance of the system, the 2-year 24 hour existing storm event was used both at the north end of the reach as well as directly north of the culvert. The values should be the same as the creek and culvert both have enough capacity to convey the 2-year 24-hour event.

The results that we obtained were 27.95 cfs at the upstream node and 27.92 north of the culvert. This shows that the model is calculating within a reasonable tolerance and is adequate for the options analysis.

MODEL EXTENTS

The cross-sections that were input into the model are provided in this appendix. **Appendix A** based on the March 2014 survey (Axis, 2014) and King County IMAP (King County IMAP, 2014). The model extents with parcels and King County contours are provided in **Figure A-1**.

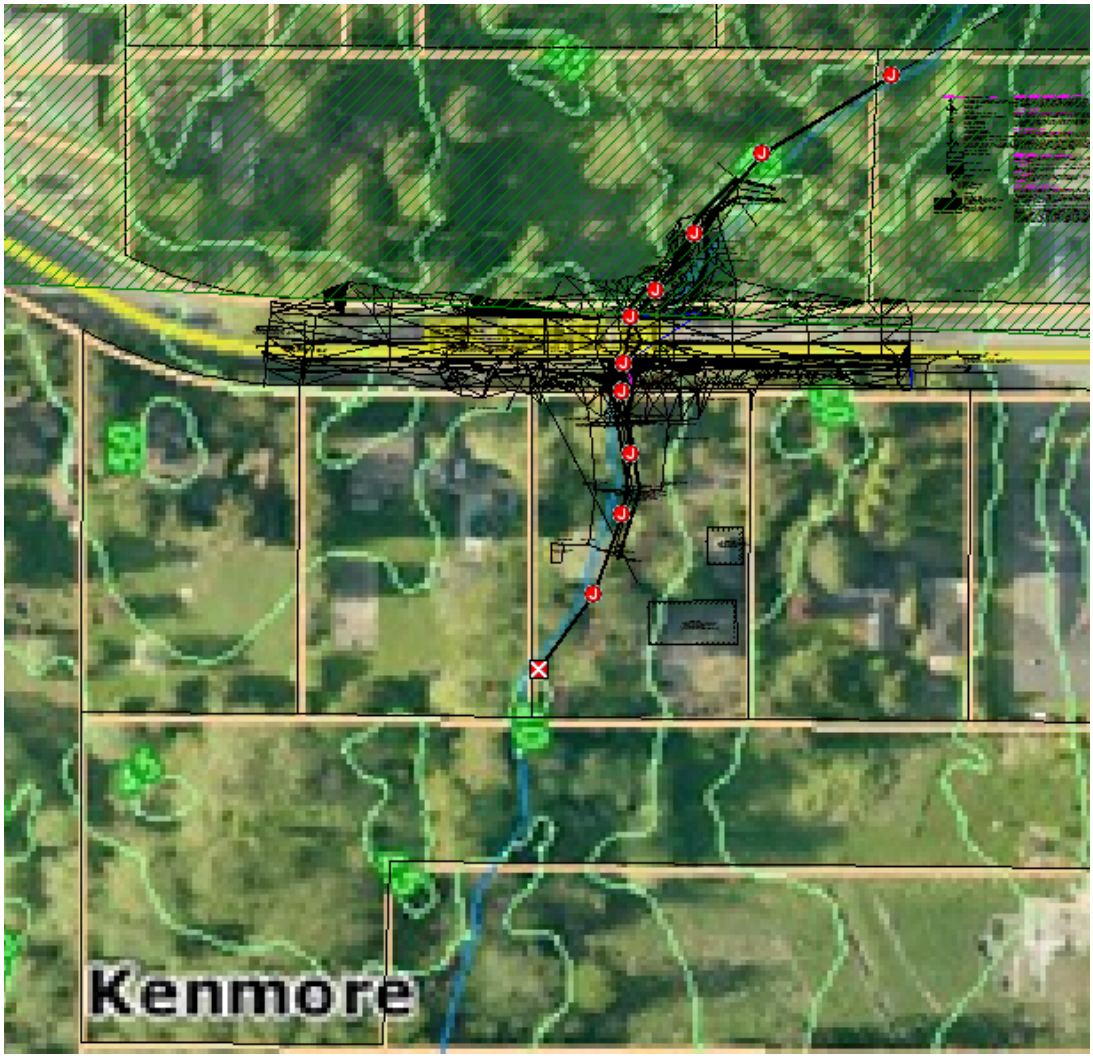
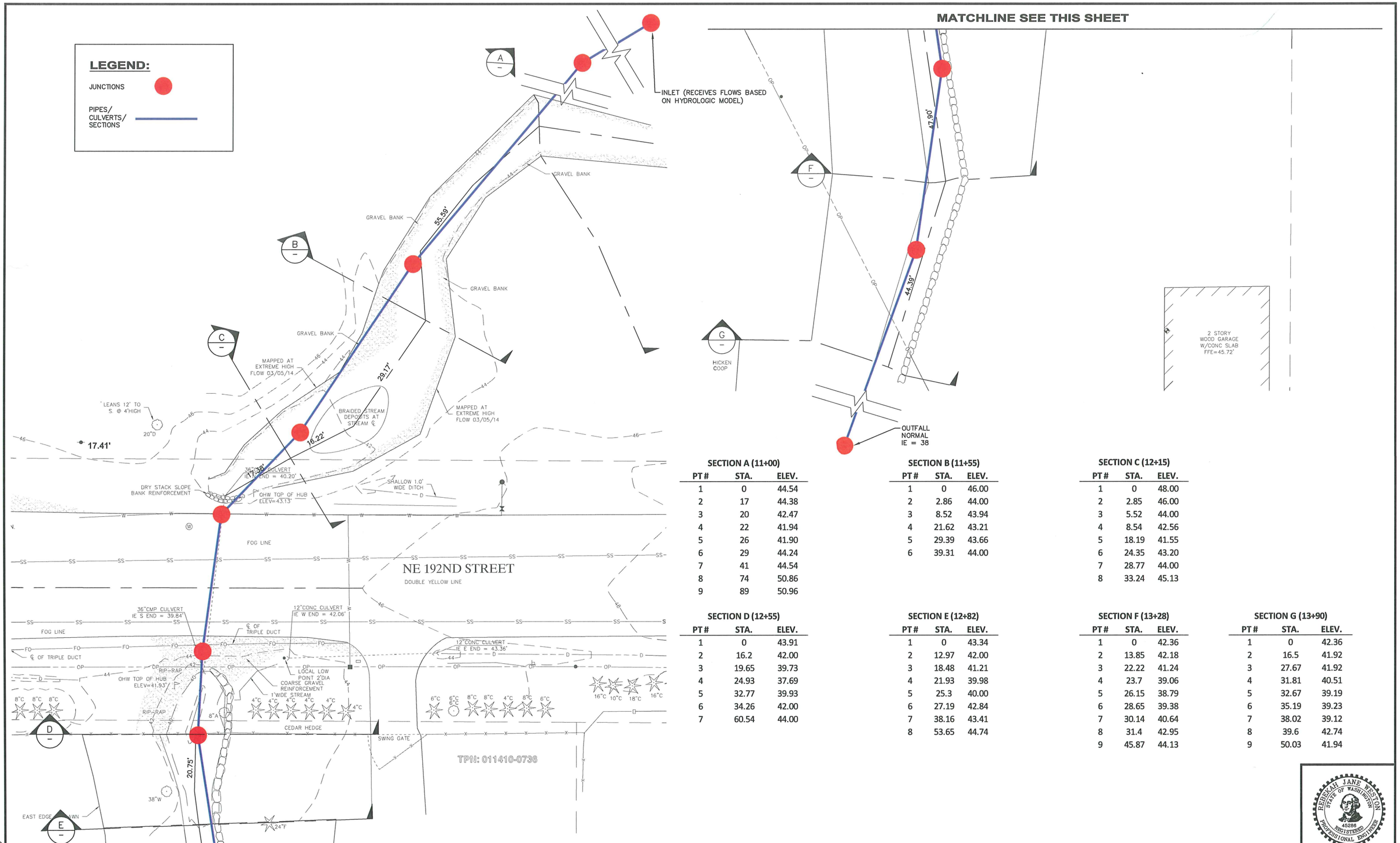


Figure A-1. Model Extents with King County IMAP parcels and contours.



SECTION A (11+00)

PT #	STA.	ELEV.
1	0	44.54
2	17	44.38
3	20	42.47
4	22	41.94
5	26	41.90
6	29	44.24
7	41	44.54
8	74	50.86
9	89	50.96

SECTION B (11+55)

PT #	STA.	ELEV.
1	0	46.00
2	2.86	44.00
3	8.52	43.94
4	21.62	43.21
5	29.39	43.66
6	39.31	44.00

SECTION C (12+15)

PT #	STA.	ELEV.
1	0	48.00
2	2.85	46.00
3	5.52	44.00
4	8.54	42.56
5	18.19	41.55
6	24.35	43.20
7	28.77	44.00
8	33.24	45.13

SECTION D (12+55)

PT #	STA.	ELEV.
1	0	43.91
2	16.2	42.00
3	19.65	39.73
4	24.93	37.69
5	32.77	39.93
6	34.26	42.00
7	60.54	44.00

SECTION E (12+82)

PT #	STA.	ELEV.
1	0	43.34
2	12.97	42.00
3	18.48	41.21
4	21.93	39.98
5	25.3	40.00
6	27.19	42.84
7	38.16	43.41
8	53.65	44.74

SECTION F (13+28)

PT #	STA.	ELEV.
1	0	42.36
2	13.85	42.18
3	22.22	41.24
4	23.7	39.06
5	26.15	38.79
6	28.65	39.38
7	30.14	40.64
8	31.4	42.95
9	45.87	44.13

SECTION G (13+90)

PT #	STA.	ELEV.
1	0	42.36
2	16.5	41.92
3	27.67	41.92
4	31.81	40.51
5	32.67	39.19
6	35.19	39.23
7	38.02	39.12
8	39.6	42.74
9	50.03	41.94

REBEKAH JANE WESTON — STATE OF WASHINGTON — 45286 — REGISTERED PROFESSIONAL ENGINEER

DESIGNED BY RJW	OSBORN CONSULTING INCORPORATED	*OSBORN CONSULTING, INC.*	CITY OF KENMORE
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CHECKED BY RJW		Bellevue, WA. 98004 Fax (425) 451-4901	KENMORE WA 98028

NO.	DATE	REVISION	BY

192ND CULVERT

SWMM MODEL & UPDATED CROSS SECTIONS

JOB# / DWG: 10-120052-14 | DATE: 3/28/14 | SCALE: H: N/A' V: N/A | SHEET 1 of 1

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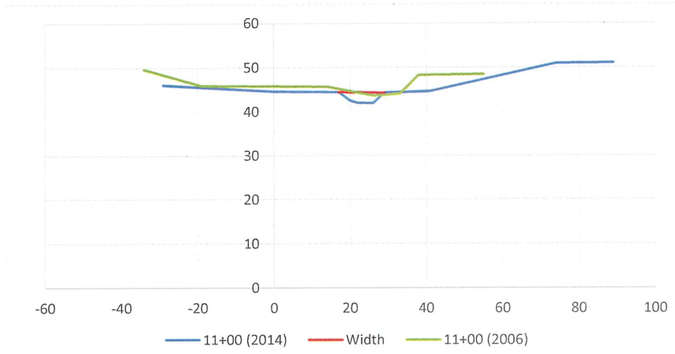
USER NAME:RICHARD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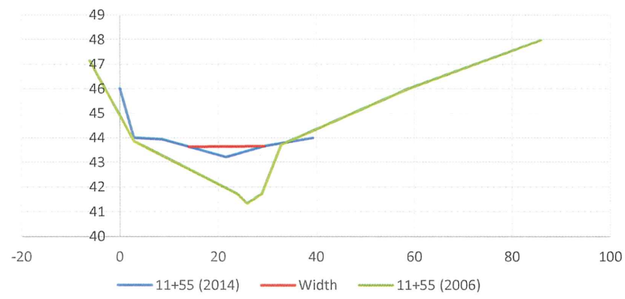
Width
11+00 (2006)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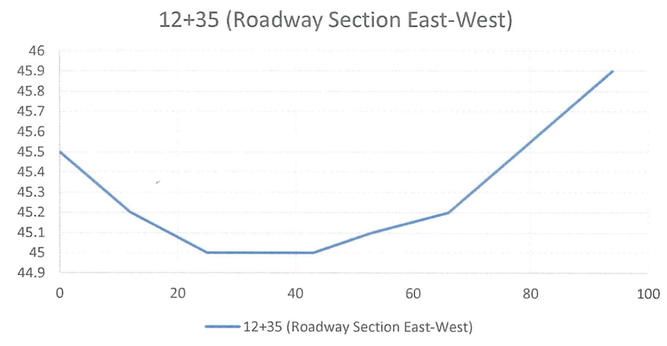
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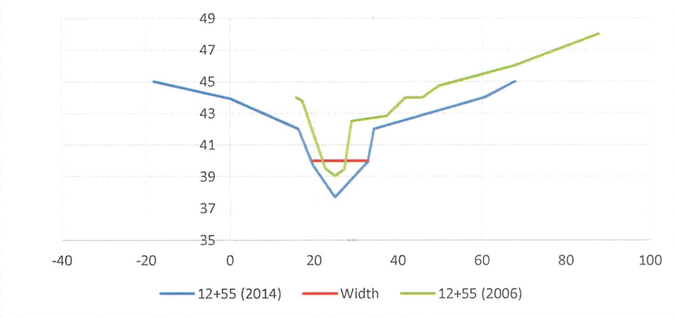
12+35 (Roadway Section East-West)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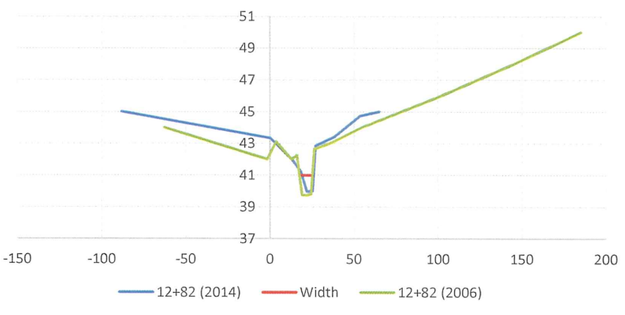
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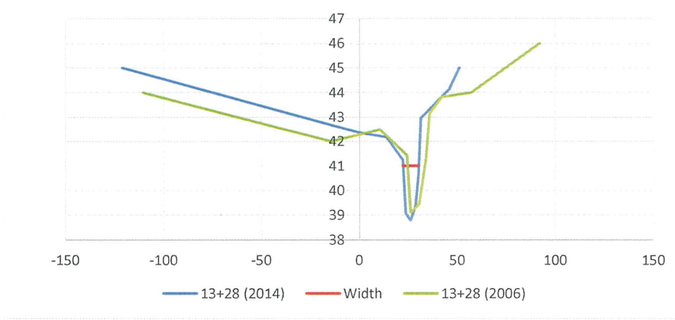
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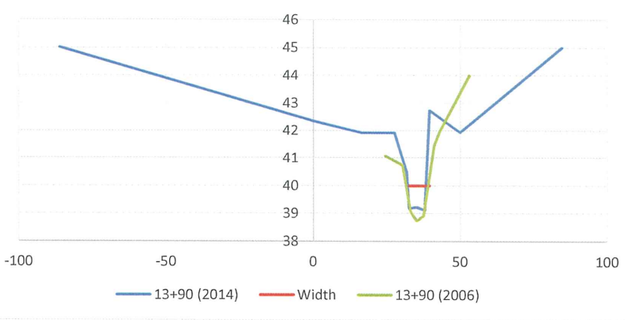
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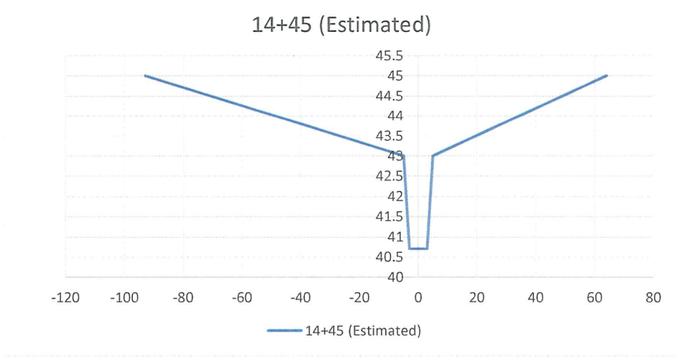

14+45 (Estimated)
14+45 (Estimated)

	Validation				Existing Conditions		Option 1: High Flow Bypass				Option 2: Culvert Replacement			
Rainfall Event	HSPF Flow (cfs)	SWMM Hydrograph Flows (cfs) @ Upstream Pipe	Precipitation (inches)	Stability Check (cfs) at 40-70-EC	Existing Elevation (Stage) at Northside of Culvert (ft)	Existing Elevation (Stage) at Southside of Culvert (ft)	Option 1: Proposed Elevation (Stage) at Northside of Culvert (ft)	Option 1: Proposed Elevation (Stage) at Southside of Culvert (ft)	Option 1: Velocity (fps) in Ex. Culvert	Option 1: Depth (feet) in Ex. Culvert at south end of culvert	Option 2: Proposed Elevation (Stage) at Northside of Culvert (ft)	Option 2: Proposed Elevation (Stage) at Southside of Culvert (ft)	Option 2: Velocity (fps) in 12-ft Culvert Replacement	Option 2: Depth (feet) in Ex. Culvert at south end of culvert
Short-Term 24-hr														
2-yr	27.3	27.95	1.8	27.92	42.41	41.25	42.41	41.25	4.94	1.41	41.3	41.23	1.72	1.46
10-yr	47.1	48.44	2.6		44.01	41.69					41.81	41.7	2.19	1.93
25-yr	57.6	60.38	3		45.16	41.92					42.07	41.93	2.39	2.16
50-yr	65.6	68.68	3.3		45.45	42.13					42.29	42.15	2.5	2.38
100-yr	73.7	74.79	3.5		45.55	42.26					42.43	42.28	2.55	2.51
Long-Term 7-day														
2-yr 7 day (Peak Flow)			1.8		41.41	40.53	41.41	40.81	3.63	0.97	40.8	40.78	1.18	1.01

Option 1 Calculations

Flows through Pipe by Storm Event	Flow (cfs)	Slope (ft/ft)	Down Inv (feet)	Up Inv (feet)	Rim (feet)	Riser Inflow for 20 cfs through bypass (feet)	Max Water Level for 100-yr event from Riser Inflow Curves (feet)	Max Water Elevation at South end of Culvert (feet)	Max Water Elevation at North end of Culvert from SWMM (feet)	Culvert Upstream Invert (feet)	Culvert Downstream Invert (feet)	Min Fish Screen Size (submerged) (ft^2)
		0.0088	39.84	40.2	43.7	0.64	44.34					
Existing 36-inch												
Q2 24 Yr	27.91							41.25	42.41	40.2	39.84	
Q100 24 Yr	31.16							42.31	44.48	40.2	39.84	
Proposed 24-inch												
Q2 24-Yr	0							41.25	41.25	40.2	39.84	52.1
Q100 24 Yr	20.84							42.31	44.43	40.2	39.84	

*Elevation at north side of road at low point is 44.70 feet.

Option 2 Calculations

Downstream Invert	Rise (ft)	% Rise Calc (ft)	Bot Culvert	Top Culvert	Road Clearance	Notes
20% Rise (Downstream)	0.36	0.072	39.768	43.768	45.268	Criteria: Bottom of culvert at outlet set below the downstream bed 20% of its rise.
40% Rise (Upstream)	0.36	0.144	40.056	44.056	45.556	Criteria: Bottom of culvert at inlet set below the downstream bed 40% of its rise.

*Top of Culvert is 3-ft above invert plus 1-foot for thickness of concrete. Note that WDFW recommends 4-foot min clearance for debris.

Riser Overflow. The nomograph in Figure 3.24 can be used to determine the head (in feet) above a riser of given diameter and for a given flow (usually the 100-year peak flow for developed conditions).

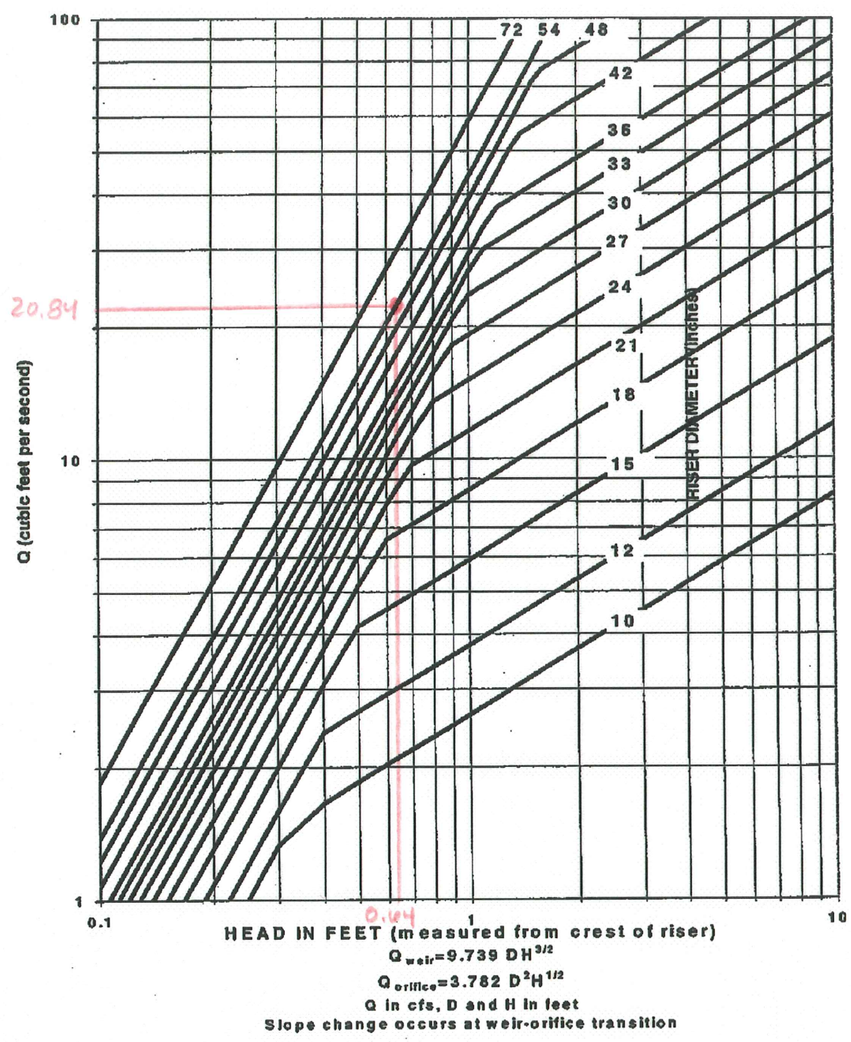


Figure 3.24 Riser Inflow Curves

Appendix B: Bankfull Width Calculations

BFW Average (from cross-sections)		
Width=	**11.14143**	ft
BFW Average (from watershed calculation)		
WA=	4.408333	sq. miles
AAP=	35.59	in/yr
Width	16.36655	ft

Note the watershed area is estimated based off of the area required to meet the HSPF flows.
Source for AAP: http://www.usa.com/kenmore-wa-weather.htm
Criteria from 2013 Water Crossing Design Guidelines

- A change in vegetation (especially the lower limit of perennial species)
- A change in slope or topographic breaks along the bank
- A change in the particle size of bank material, such as the boundary coarse cobble or gravel with fine-grained sand or silt
- Undercuts in the bank, which usually reach interior elevation slightly below the bankfull stage
- The height of depositional features, especially the top of the point bar, which defines the lowest possible level for bankfull stage
- Stain lines or the lower extent of lichens on boulders

2014 Data from Survey

11+00		Calculation #1	BFW (ft)
-29	46		12
0	44.54		
17	44.38	44.38	
20	42.47		
22	41.94		
26	41.9		
29	44.24	44.24	
41	44.54		
74	50.86		
89	50.96		
11+55		Calculation #2	15.39
0	46		
2.86	44		
8.52	43.94	43.94	
14	43.63463	43.63462595	interp.
21.62	43.21		
29.39	43.66	43.66	
39.31	44		
12+15		Calculation #3	15.81
0	48		
2.85	46		
5.52	44		
8.54	42.56	42.56	
18.19	41.55		
24.35	43.2	43.2	
28.77	44		
33.24	45.13		
12+35 (Roadway Section East-West)			54
0	45.5		
12	45.2	45.2	
25	45		
32	45		
43	45		
53	45.1		
66	45.2	45.2	
94	45.9		
12+55		Calculation #4	13.12
-18.25	45		
0	43.91		
16.2	42	42	
19.65	39.73	40	
24.93	37.69		
32.77	39.93	40	
34.26	42	42	
60.54	44		
67.85	45		
12+82		Calculation #5	6.82
-88	45		
0	43.34	43.34	
12.97	42		
18.48	41.21	41	
21.93	39.98		
25.3	40	41	
27.19	42.84	42.84	
38.16	43.41		
53.65	44.74		
65	45		
13+28		Calculation #6	7.92
-121	45		
0	42.36		
13.85	42.18	42.18	
22.22	41.24	41	
23.7	39.06		
26.15	38.79		
28.65	39.38		
30.14	40.64	41	
31.4	42.95	42.95	
45.87	44.13		
50.99	45		
13+90		Calculation #7	6.93
-86.13	45		
0	42.36		
16.5	41.92		
27.67	41.92	41.92	
31.81	40.51		
32.67	39.19	40	
35.19	39.23		
38.02	39.12		
39.6	42.74	40	
50.03	41.94		
84.73	45		
14+45	Estimated to update		
-93	45		
-5	43		
-3	40.7		
3	40.7		
5	43		
64	45		

Appendix C: Total Cost Estimate

Opinion (Estimate) of Probable Cost						
			Project No. 10-120052		Date April 01, 2014	
Project Name		192nd Culvert - Option 1				
Location		Kenmore, WA				
Owner		City of Kenmore				
Estimated By:		Rebekah Weston	**Checked By:**	TJO	**Approved By:**	
Date:		3/25/2014	**Date:**	4/1/2014	**Date:**	
ITEM NO.	**SPEC SECTION**	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL COST**
		Mobilization	1	LS	10%	$3,331.55
		Force Account	1	LS		$15,000.00
		Traffic Control	1	LS		$20,000.00
		Temporary Erosion and Sediment Control	1	LS	10%	$3,331.55
		Removing Asphalt Conc. Pavement	62	SY	$20.00	$1,244.00
		Schedule A Culvert Pipe 24 in Cl. IV Concrete	50	LF	$148.00	$7,400.00
		Structural Fill (Beneath culvert and above)	33	CY	$65.00	$2,164.50
		Type 2 54" Catch Basin with Aluminum Overflow Structure Trash Rack\Beehive Grate	1	EA	$5,300.00	$5,300.00
		Permanent Fish Screens	2	EA	$5,000.00	$10,000.00
		Crushed surfacing base course	19	TON	$55.00	$1,056.00
		HMA Cl. 1/2 In. PG 64-22	21	TON	$250.00	$5,325.00
		Structure Excavation Class B Incl. Haul	12	CY	$70.00	$826.00
			Subtotal Project Cost			**$74,978.60**
			Tax		**9.5%**	**$7,122.97**
			Subtotal Construction Line Item (+tax)			**$82,101.57**
			Easement Acquisition		**0%**	**$0.00**
			Engineering Design		**40%**	**$29,991.44**
			Permitting		**15%**	**$11,246.79**
			Construction Management		**10%**	**$7,497.86**
			Subtotal Soft Cost			**$48,736.09**
			TOTAL PROJECT COST			**$130,837.66**
			TOTAL PROJECT COST (ROUNDED)			$131,000.00

Notes:

1. For the 24-inch culvert installation it is assumed that the fiber optic duct bank can be supported for the pipe placement.
2. Mitigation required for plantings adjacent to the culvert is not included.
3. Temporary rerouting of creek flows is not included in the above cost.
4. TESC does not include additional turbidity treatment.

Opinion (Estimate) of Probable Cost						
			Project No. 10-120052		**Date** April 01, 2014	
Project Name		192nd Culvert - Option 2				
Location		Kenmore, WA				
Owner		City of Kenmore				
Estimated By:		Rebekah Weston	**Checked By:**	TJO	**Approved By:**	
Date:		3/26/2014	**Date:**	4/1/2014	**Date:**	
ITEM NO.	**SPEC SECTION**	**DESCRIPTION**	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL COST**
		Mobilization	1	LS	10%	$13,275.10
		Force Account	1	LS		$25,000.00
		Traffic Control	1	LS		$30,000.00
		Temporary Erosion and Sediment Control	1	LS	10%	$14,090.10
		Removing Asphalt Conc. Pavement	342	SY	$20.00	$6,844.00
		Removing 36-inch culvert	41	LF	$17.00	$697.00
		12 WF x 40 LF x 4 DF Box Culvert	40	LF	$1,100.00	$44,000.00
		Structural Fill (Beneath culvert)	60	CY	$65.00	$3,900.00
		Installation Box Culvert	1	LS	$44,000.00	$44,000.00
		Replace Water Main	50	LF	$110.00	$5,500.00
		Reroute Fiber Optic Duct Bank	1	LS	$5,000.00	$5,000.00
		Crushed surfacing base course	106	TON	$50.00	$5,275.00
		HMA Cl. 1/2 In. PG64-22	117	TON	$150.00	$17,535.00
		Structure Excavation Class B Incl. Haul	163	CY	$50.00	$8,150.00
			Subtotal Project Cost			**$223,266.20**
			Tax		**9.5%**	**$21,210.29**
			Subtotal Construction Line Item (+tax)			**$244,476.49**
			Easement Acquisition			**$0.00**
			Engineering Design		**40%**	**$89,306.48**
			Permitting		**15%**	**$33,489.93**
			Construction Management		**10%**	**$22,326.62**
			Soft Cost Subtotal			**$145,123.03**
			TOTAL PROJECT COST			**$389,599.52**
					TOTAL PROJECT COST (Rounded)	**$390,000.00**

Notes:

1. Temporary rerouting of creek flows is not included in the above cost.
2. Mitigation required for plantings adjacent to the culvert is not included.
3. Fiber Optic rerouting is for materials only. If conduits are small enough, 2"-3", they can be routed through the top slab of culvert.
4. TESC does not include additional turbidity treatment.

Appendix D: Sensitivity Analysis

Sensitivity Analysis

A sensitivity analysis was completed to help quantify the impacts for the replacement of the existing 36-inch culvert with a 12-foot wide by 3-foot deep fish passage culvert for the 2-year, 25-year, and 100-year events. Typically the comparison would be done between the existing peak flow rate and the proposed peak flow rate to ensure there are no downstream impacts. In this case, Swamp Creek creates a tailwater condition downstream of the Little Swamp Creek culvert, which alters the background equations to be head-driven versus gravity-driven. Hence, SWMM was used to model a range of fixed boundary conditions (i.e. from 40 feet to 45 feet NAVD 88 elevations) referred to herein as Sensitivity Analysis No. 1.

In addition, the discharge elevation at the south end was not known. Based on the contour maps from King County IMAP, it is unlikely that the discharge elevation would be greater than 42 feet. So, another sensitivity analysis (Sensitivity Analysis No. 2) was completed on varying the discharge elevation with a normal boundary condition from 40 to 45 feet.

In order to understand results of the sensitivity analysis, the continuity error for the hydraulic routing is also provided. If the elevations are within 0.01 feet, the elevations are considered to be equivalent as the software package does not provide accuracy to less than 0.01 feet.

BASE FLOOD ELEVATION

OCI reviewed the FIRM map (see **Figure D-1**) in the area to develop a tailwater elevation at the 192nd Avenue culvert as well as compared to the 100-year elevations proposed in the *Kenmore Swamp Creek Flood Reduction Improvements – Phase 1* (Otak, 2003), which is herein referred to as the "2003 study" (see **Figure D-2**).

The FIRM map shows a base flood elevation between 34 feet and 36 feet (NGVD 29). The conversion factor to NAVD 88 is approximately 3.5 feet. So the upper limit of 36 feet from the FIRM map converts to 39.5 feet (NAVD 88)

In the 2003 study, the map shows a green dashed line that delineates the extent of the backwater effect from Swamp Creek water surface elevations. This area contains cross-sections that could be interpolated between 39 feet to 44 feet. Since the hydraulics in this area are complicated, a sensitivity analysis was done where the tailwater (Sensitivity Analysis No. 1) or discharge elevation (Sensitivity Analysis No. 2) was varied in elevation from 40-feet to 45 feet (NAVD 88) to determine impacts from the backwater condition at the 192nd Culvert crossing for Little Swamp Creek. The elevation on the north side of the 192nd Avenue is 44.70 feet, which is the elevation used to assess whether or not the road floods. So, a tailwater elevation of 45 feet physically represents one condition where Swamp Creek back ups and floods 192nd Avenue from the south to the north. There are no known data (monitoring or anecdotal) that suggest that Swamp Creek backs up and floods 192nd. Therefore, this establishes an upper limit to the sensitivity analysis.

HYDRAULIC MODELING

The sensitivity analysis results for the tailwater variations is shown in **Table D-1**. The hydrologic inputs were kept the same as the shown in Appendix A for the 2-year, 25-year, and 100-year events.

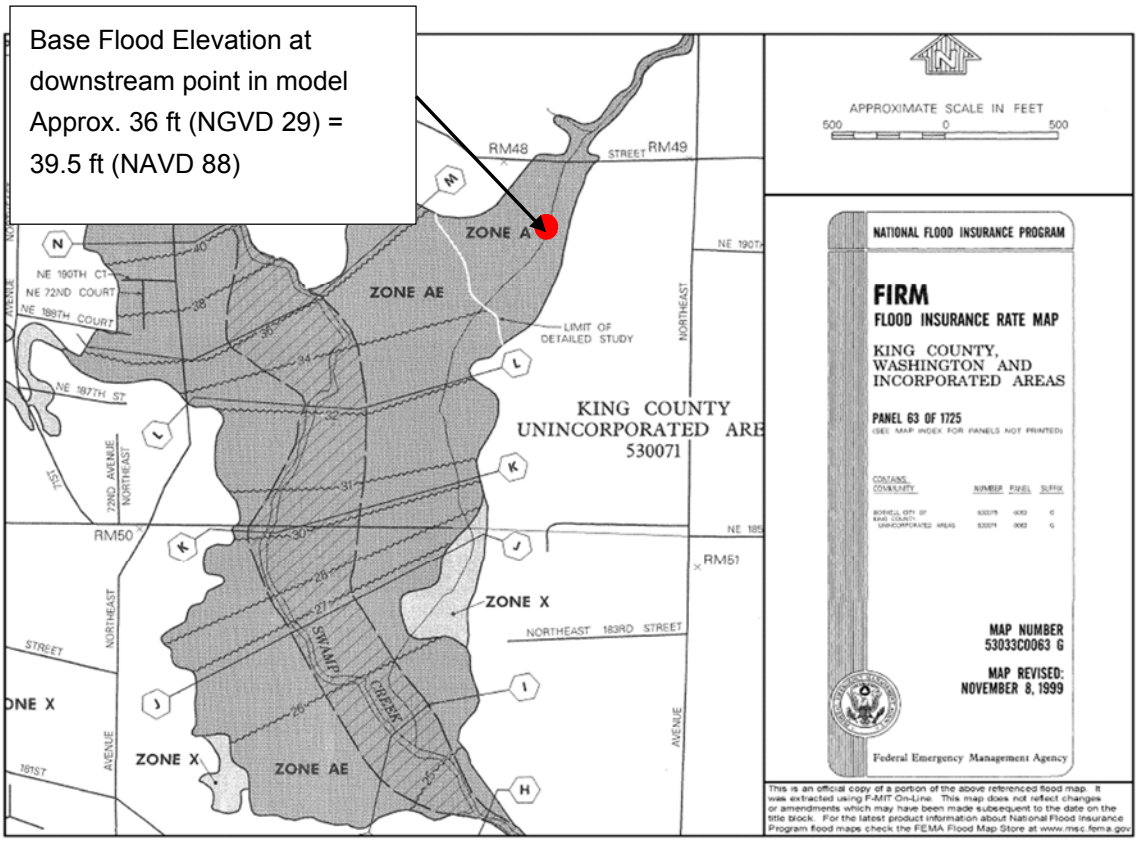
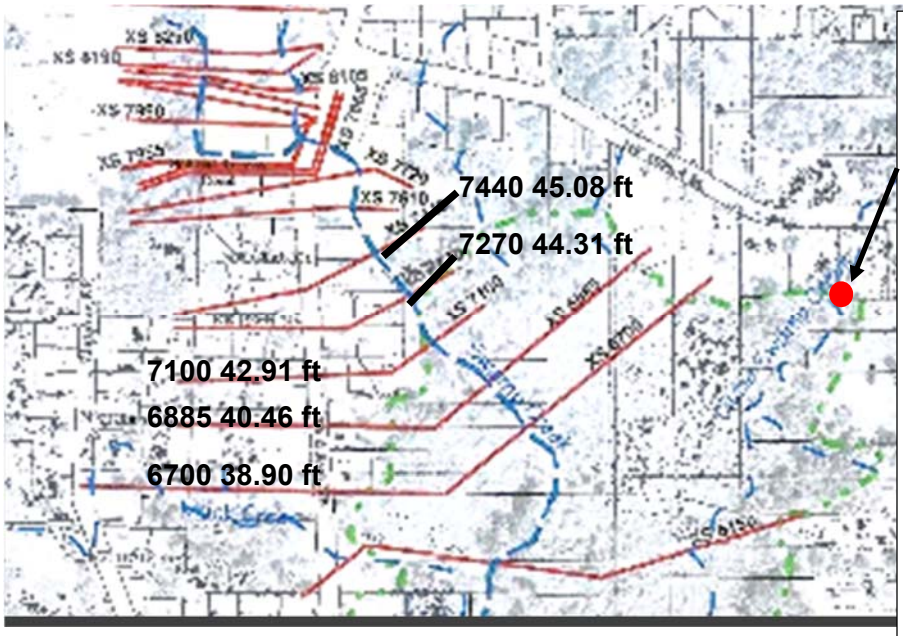


Figure D-1. FIRM Base Flood Elevation (BFE) estimate (NGVD 29).



The base flood elevations were used to develop the range of tailwater elevations. Cross-sections 6700 to 7440 were used along with the corresponding 100-year or BFE that was recalculated for the improvements for 73rd Avenue NE, which results in elevations from 39 ft to 45 ft. The green dashed line intersecting Little Swamp Creek is approx. where the 192nd Culvert SWMM model ends and the BFE is needed.

Figure D-2. 2003 Study - Base Flood Elevation (BFE) estimate (NAVD 88).

Table D-1. Sensitivity Analysis No. 1 - Tailwater Elevations						
2-year event						
Tailwater Elev. (ft) from Swamp Creek (NAVD 88)	**Fish Passage Culvert WSE (ft) (South of Culvert)**	**Fish Passage Culvert WSE (ft) (North of Culvert)**	**% Error**	**Existing WSE (ft) South of Culvert**	**Existing WSE (ft) North of Culvert**	**% Error**
40	41.23	41.3	0.00%	41.24	42.41	0.00%
41	41.32	41.38	0.00%	41.32	42.42	0.00%
42	42.11	42.11	0.01%	42.43	42.74	0.01%
43	43.12	43.15	0.06%	43.76	43.7	0.03%
44	44.23	44.21	0.24%	44.90	44.8	0.30%
45	45.12	45.14	0.83%	45.44	45.47	0.80%
WSE = Water Surface Elevation (NAVD 88)						
25-year event						
Tailwater Elev. (ft) from Swamp Creek (NAVD 88)	**Fish Passage Culvert WSE (ft) (South of Culvert)**	**Fish Passage Culvert WSE (ft) (North of Culvert)**	**% Error**	**Existing WSE (ft) South of Culvert**	**Existing WSE (ft) North of Culvert**	**% Error**
40	41.9	42.04	0.00%	41.89	45.20	0.03%
41	41.94	42.07	0.00%	41.93	45.20	0.03%
42	42.27	42.37	0.01%	42.43	45.30	0.04%
43	43.12	43.15	0.03%	43.76	45.46	0.10%
44	44.23	44.21	0.12%	44.90	45.58	0.27%
45	45.12	45.14	0.40%	45.44	45.70	0.43%
WSE = Water Surface Elevation (NAVD 88)						
100-year event						
Tailwater Elev. (ft) from Swamp Creek (NAVD 88)	**Fish Passage Culvert WSE (ft) (South of Culvert)**	**Fish Passage Culvert WSE (ft) (North of Culvert)**	**% Error**	**Existing WSE (ft) South of Culvert**	**Existing WSE (ft) North of Culvert**	**% Error**
40	42.17	42.34	0.09%	42.16	45.53	0.08%
41	42.26	42.42	0.00%	42.25	45.55	0.08%
42	42.40	42.54	0.01%	42.43	45.56	0.10%
43	43.12	43.16	0.02%	43.76	45.61	0.15%
44	44.23	44.21	0.10%	44.9	45.69	0.23%
45	45.12	45.14	0.32%	45.44	45.78	0.36%
WSE = Water Surface Elevation (NAVD 88)						

Table D-2. Sensitivity Analysis No. 2 – Discharge Elevations						
2-year event						
Normal Outlet Elevation (NAVD 88)	**Fish Passage Culvert WSE (ft) (South of Culvert)**	**Fish Passage Culvert WSE (ft) (North of Culvert)**	**% Error**	**Existing WSE South of Culvert**	**Existing WSE North of Culvert**	**% Error**
40	41.35	41.41	0.00%	41.34	42.42	0.01%
41	42.19	42.21	0.04%	42.18	42.87	0.02%
42	43.15	43.17	0.08%	43.15	43.84	0.05%
43	44.14	44.16	0.12%	44.16	44.97	0.16%
44	45.14	45.16	0.58%	45.14	45.51	0.61%
WSE = Water Surface Elevation (NAVD 88)						
25-year event						
Normal Outlet Elevation (NAVD 88)	**Fish Passage Culvert WSE (ft) (South of Culvert)**	**Fish Passage Culvert WSE (ft) (North of Culvert)**	**% Error**	**Existing WSE South of Culvert**	**Existing WSE North of Culvert**	**% Error**
40	42.65	42.72	0.01%	42.64	45.40	0.03%
41	43.32	43.39	0.02%	43.31	45.50	0.08%
42	44.5	44.58	0.06%	44.5	45.64	0.22%
43	45.63	45.71	0.30%	45.75	45.79	0.43%
WSE = Water Surface Elevation (NAVD 88)						
100-year event						
Normal Outlet Elevation (NAVD 88)	**Fish Passage Culvert WSE (ft) (South of Culvert)**	**Fish Passage Culvert WSE (ft) (North of Culvert)**	**% Error**	**Existing WSE South of Culvert**	**Existing WSE North of Culvert**	**% Error**
40	42.72	42.83	0.02%	42.71	45.59	0.12%
41	43.57	43.68	0.03%	43.56	45.65	0.14%
42	44.69	44.81	0.09%	44.69	45.75	0.22%
43	45.81	45.93	0.37%	45.93	45.99	1.38%
WSE = Water Surface Elevation (NAVD 88)						

RESULTS – SENSITIVITY ANALYSIS NO. 1

For a tailwater less than 42 feet: In all cases the water surface elevation (WSE) south of the culvert (also referred to as "downstream of the culvert") is the same or within the 0.01-ft tolerance of the software program. Since the WSE does not increase due to physical processes, no adverse impacts are anticipated.

For tailwater elevations greater than or equal to 42 feet: In all cases the WSE south of the culvert for the fish passage culvert is less than the WSE for the existing culvert. Since the WSE does not increase due to physical processes, no adverse impacts are anticipated. In general, the water surface elevations south of the fish passage culvert are lower than the existing culvert for the following reason:

> The calculation depends on the difference between the WSE north of the culvert and the WSE taken at the centerline of the pipe/culvert (i.e. note that in the fully submerged equation it is the WSE at the downstream end of the culvert). In addition there is an inversely proportional dependency on the cross-sectional area of flow. So, the results are directly correlated to the WSE north of the culvert and inversely proportional to the area of the culvert. The most sensitive parameter based on the modeling is the WSE north of the culvert. Hence, we should see a lower WSE than the existing condition culvert for the fish passage culvert as the WSE north of the culvert is lowered due to a larger culvert.

The SWMM results increase in error with the tailwater rising because the tailwater elevation is fixed at the point of discharge. Since the tailwater is fixed, the water surface elevation cannot move and typically this needs to happen in order to preserve the mass balance or continuity. Hence, solutions for this case where the continuity error is above 0.30% should not be taken as accurate solutions for both sensitivity analyses.

RESULTS – SENSITIVITY ANALYSIS NO. 2

For a discharge elevation less than 42 feet: In all cases the water surface elevation (WSE) south of the culvert is the same or within the 0.01-ft tolerance of the software program. Since the WSE does not increase due to physical processes, no adverse impacts are anticipated.

For a discharge elevation greater than or equal to 42 feet: The elevations are likely not going to be above 42 feet based on the contour maps. This will need to be confirmed with a few additional survey topographic points south of the discharge location. In addition to limitations with the continuity error discussed above (see Results- Sensitivity Analysis No. 1), water surface elevations above 46 feet are not accurate as the cross-sections provided in the model do not include elevations above 46 feet. So essentially, the model places "walls" at the 46-ft extents, which does not physically represent the system. The discharge elevations for 44 feet and 45 feet were removed from the table as this does not physically represent the system dynamics. The same relationship for determining the WSE south of the culvert discussed above in the results for Sensitivity Analysis No. 1 apply to the results for Sensitivity Analysis No. 2.