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TECHNICAL MEMORANDUM

Date: January 31, 2024

Project: 10-180049, Task Order #24: Swamp Creek Mitigation Site
To: Richard Sawyer | City of Kenmore

From: Tarelle Osborn, PE | Osborn Consulting, Inc.
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Subject: Hydrology and Hydraulics Report

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SECTION 1 INTRODUCTION

The City of Kenmore (City) has identified the property at 18727 73rd Ave NE, Kenmore, Washington (King County Parcel ID 0114-100410) as a mitigation site for the planned 68th Avenue NE Pedestrian and Bicycle Improvements Project. On the existing property, a residence and a number of detached structures are currently within the 100-year floodplain and experience routine flooding during heavy winter rainfall events. Both immediately east and surrounding these structures is a wetland area that Osborn Consulting (Osborn) delineated in November 2022 (Figure 1). As a mitigation site, the proposed project will remove the existing structures and replace the existing impervious area with native plantings and off-channel habitat. The project will also involve realigning the channel, adding large woody material (LWM), and developing a stable riffle-pool stream pattern. The intent of these proposed conditions is to provide enhanced habitat and riparian quality while also increasing flood storage and enhancing the functionality of the existing wetland area. This report discusses the hydrologic and hydraulic analysis that Osborn conducted for both the existing conditions and proposed conditions.

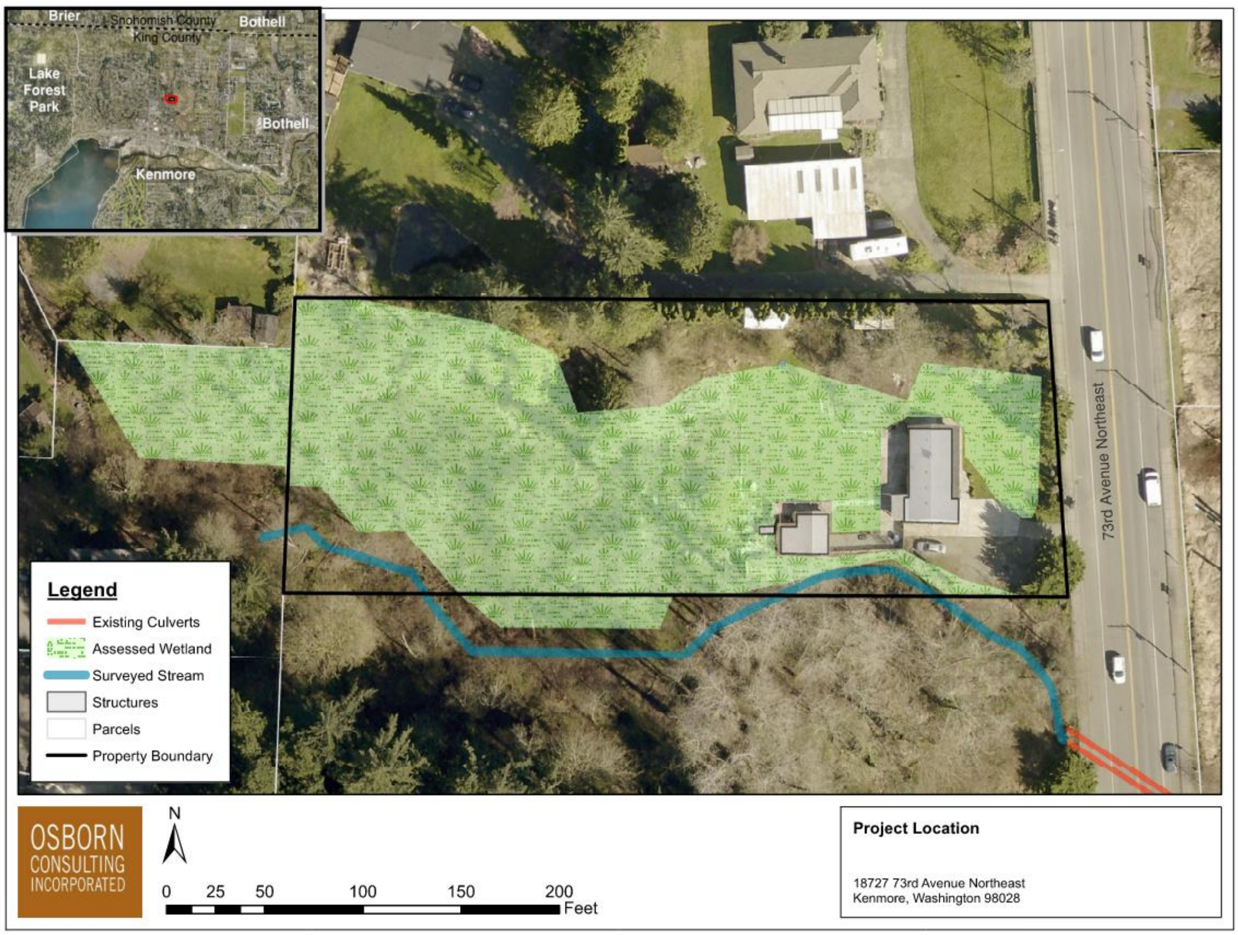

Figure 1 : Project Location

SECTION 2 HYDROLOGIC ANALYSIS

2.1 Basin Delineation

The Muck Creek basin was delineated using 2021 LiDAR that NV5 Geospatial collected for the United States Geological Survey (USGS) (NV5 Geospatial, 2021). An enclosed conveyance spatial file was provided by the City that details local stormwater and stream conveyance. These two files were used in conjunction to delineate the runoff-contributing area in the Muck Creek basin. In total, the basin covers approximately 230.75 acres and is contained within the Kenmore city limits (Figure 2).

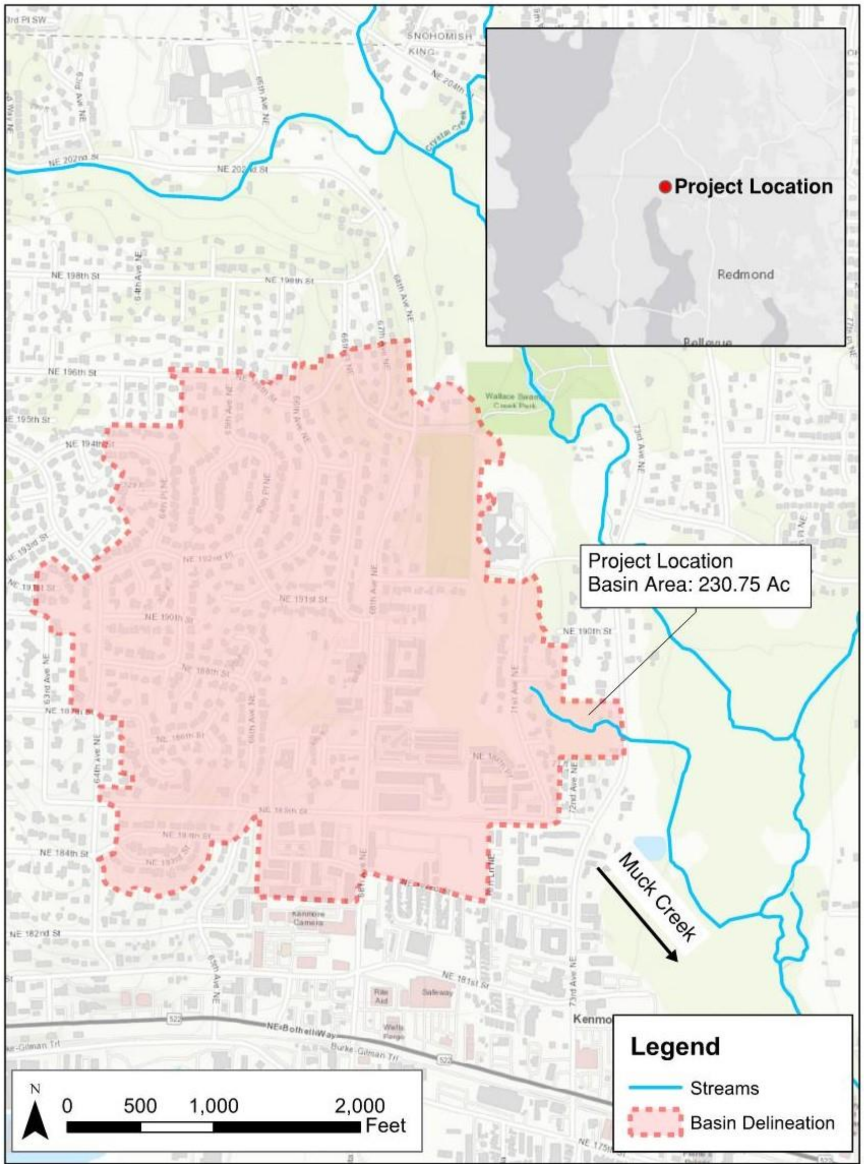

Figure 2 : Basin Delineation and Project Location

2.2 Geology and Soils

Hydrologic soil groups and steepness within the basin were determined using National Soil Conservation Service survey data. The spatial distribution and area summary of each hydrologic soil group can be found below in Figure 3. The soils in the basin are hydrologic class A, however, due to the substantial

development in the basin it is unlikely this classification is accurate. For the purposes of this model it was assumed that the hydrologic class for all soils would be class C. This assumption will result in higher flowrates due to reduced infiltration, which will provide a more conservative estimate for hydraulic modeling purposes. This data was downloaded as a shapefile and combined with the land use data described in Section 2.3.

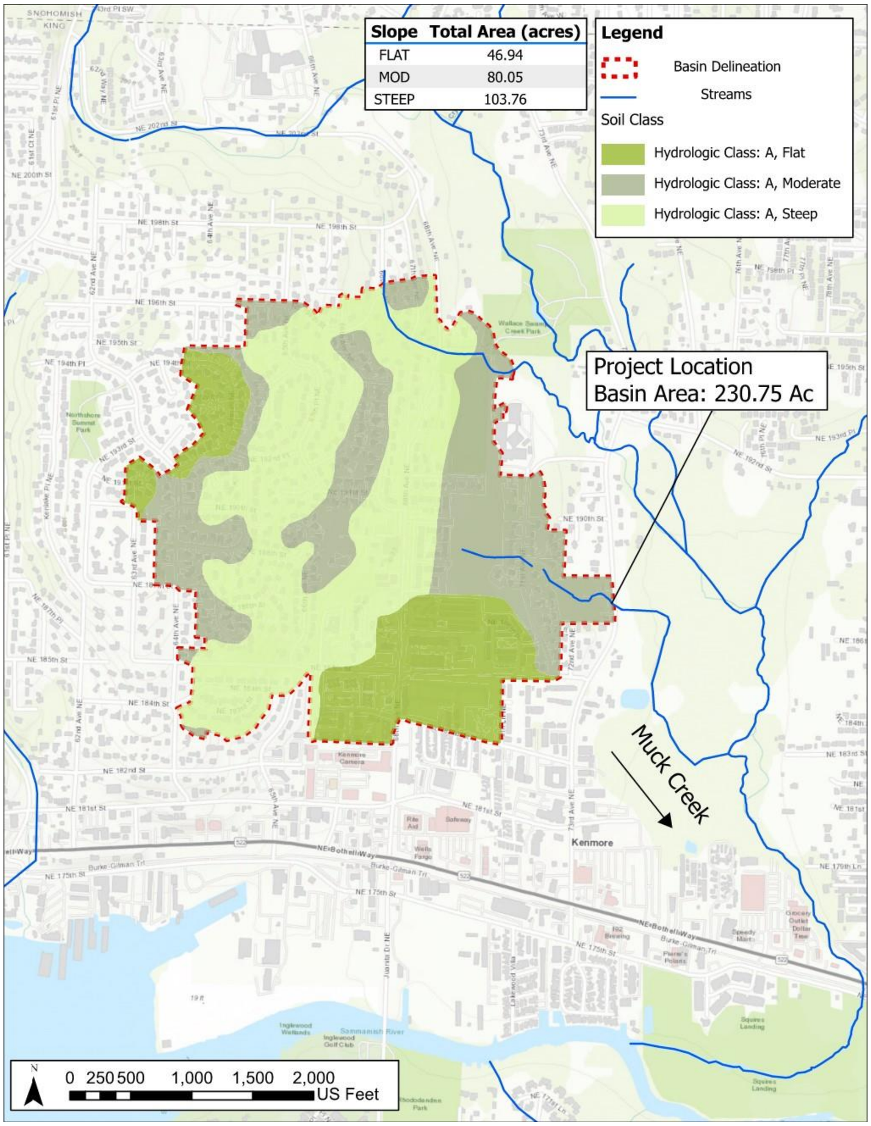

Figure 3 : Hydrologic Soil Group Distribution

2.3 Land Cover Analysis

Two different methods were considered to determine land use type and area. The first method (Method 1) utilized GIS zoning data obtained from the City of Kenmore's GIS data portal. The Kenmore Municipal Code was used to determine the maximum impervious area for each parcel, simulating the condition where the maximum impervious area is achieved per zoning designation throughout the basin (City of Kenmore, 2023). Area not included in the zoning polygons was assumed to describe the Right-of-Way area and was assigned an imperviousness of 100 percent. When compared to the existing impervious area calculations developed by the City, this method overestimated the total impervious area by 79.6 acres, or approximately 34 percent of the total basin area. As a result, this method was determined to be

inappropriate for this basin. The spatial distribution of each zone and maximum level of imperviousness is summarized in Figure 4.

The second method (Method 2) utilized an impervious GIS layer provided by the City; this layer included rooftops, parking lots, roads, and similar surfaces. This data was used in conjunction with manual delineation of forest spaces. Area not occupied by either the impervious layer or the forest delineation was assumed to be lawn space. The spatial distribution of land use and area summaries are shown below in Figure 5. Because this delineation is expected to resemble existing conditions more closely, this method was selected for subsequent modeling efforts. This method assumes that any future development or added impervious area in the basin would be mitigated by flow control facilities as required by code development regulations.

Areas from each land cover analysis were entered into MGS Flood to develop peak flows for each frequency event. This analysis is discussed below in Section 2.4.

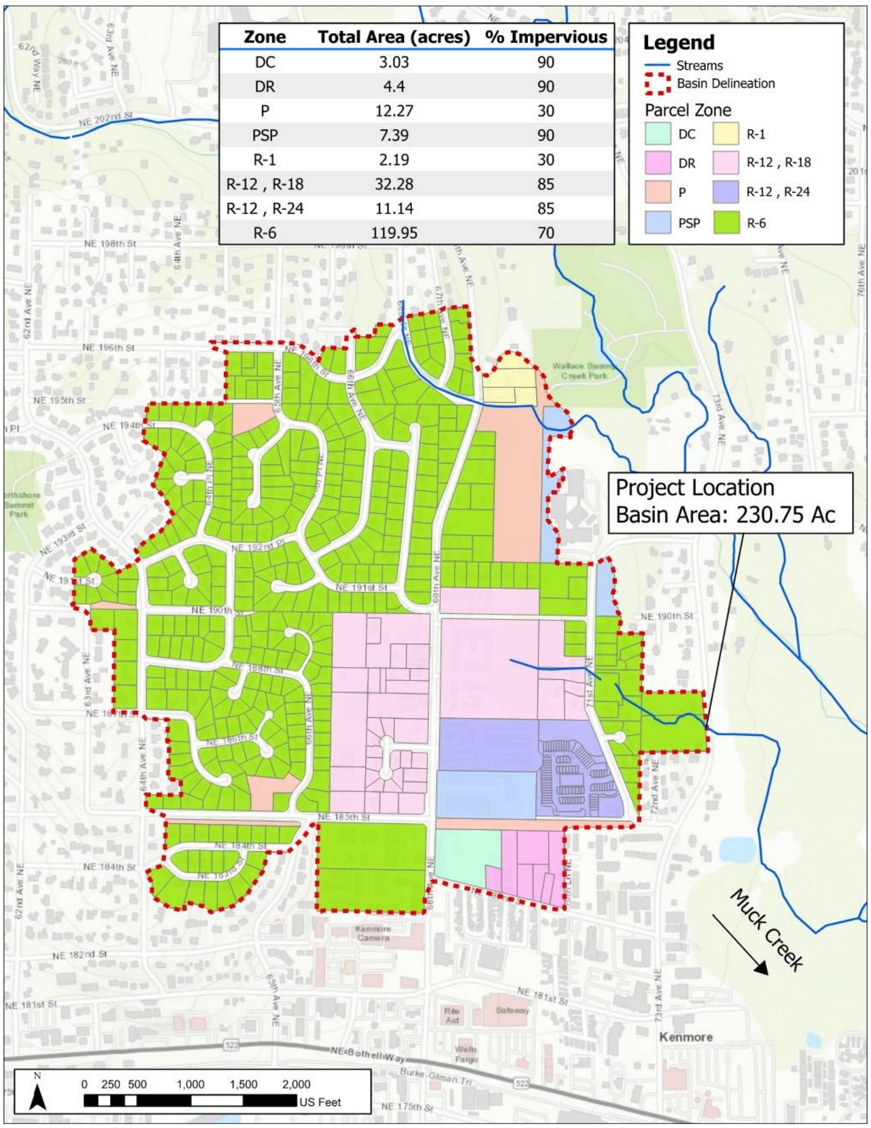

Figure 4 : Land use Analysis Method 1

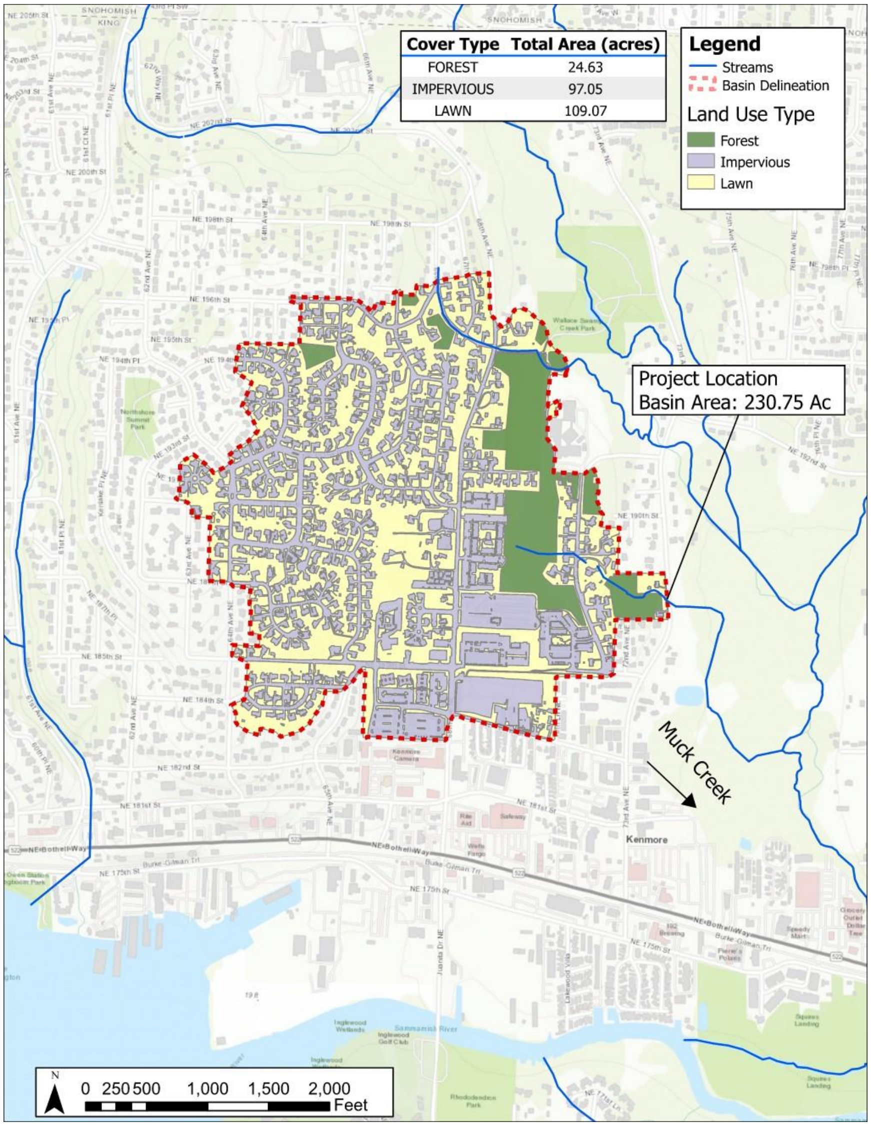

Figure 5 : Land Use Analysis Method 2

2.4 MGS Flood Modeling

Hydrologic modeling was conducted using MGSFlood, Version 4.58 (MGS Software LLC, 2022). Land use and soil data from the above analyses were added as inputs to the model, resulting in the flows below in Table 1. Flows resulting from land use areas derived from Method 2 were utilized in hydraulic modeling, described in Section 3. Though not used, flows resulting from land use Method 1 are also reported below, for reference.

Table 1. Peak Flow Summaries

Description	2-Year Peak Flow (cfs)[1]	10-Year Peak Flow (cfs)	25-Year Peak Flow (cfs)	100-Year Peak Flow (cfs)	500-Year Peak Flow (cfs)
Land Use Method 1 (not used)	93.4	155.3	196.0	310.9	437.3
Land Use Method 2	68.7	127.2	158.8	267.3	392.2

Notes
(1) cfs = cubic feet per second

SECTION 3 HYDRAULIC ANALYSIS

Hydraulic modeling was conducted using the United States Bureau of Reclamation's SRH-2D Version 3.3.1 computer program, a two-dimensional hydraulic, and sediment transport numerical model (USBR, 2020). Pre- and post-processing for this model was included using the Surface-water Modeling System (SMS) version 13.2.10 (Aquaveo, 2022). Model configuration including boundary conditions, roughness coefficients, and mesh qualities are discussed in the subsequent sections.

3.1 Existing Conditions

Below is a discussion of the model configuration and hydraulic results of the existing conditions.

3.1.1 Topographic and Bathymetric Data

Existing conditions were modeled using survey data provided by Axis Survey and Mapping (Axis Survey and Mapping, 2022), which was then combined with 2021 LiDAR data to create the model surface (USGS, 2021). The survey data included the stream thalweg, tops of banks, adjacent structures, and two existing culverts. Model parameters and inputs, as well as the corresponding results, are discussed in detail below.

3.1.2 Model Extent and Computational Mesh

The upstream extent of the computational mesh was determined such that the mesh extended beyond the backwater effects caused by the existing culverts for the maximum flow (500-year) event. The downstream mesh extents were determined using a sensitivity analysis to confirm the downstream boundary would not have an effect through the proposed wetland design. This was conducted by increasing the downstream boundary condition slope from 0.0018 to 0.1 and assessing the effects on water surface elevations (WSE) through the design reach. Because WSEs converged prior to the upstream design, it was determined that the mesh had been extended sufficiently downstream.

Cells within the channel were modeled using patch-type cells to capture the more singular-directional flow expected in this region. By contrast, flow through the overbanks exhibited more irregular flow directions and was modeled using paving-type cells. Where structures on the property to the north were surveyed, null areas were assigned to represent the blockages caused by the home and storage structure.

Model extents, cell type distribution, and the existing alignment are shown below in Figure 6.

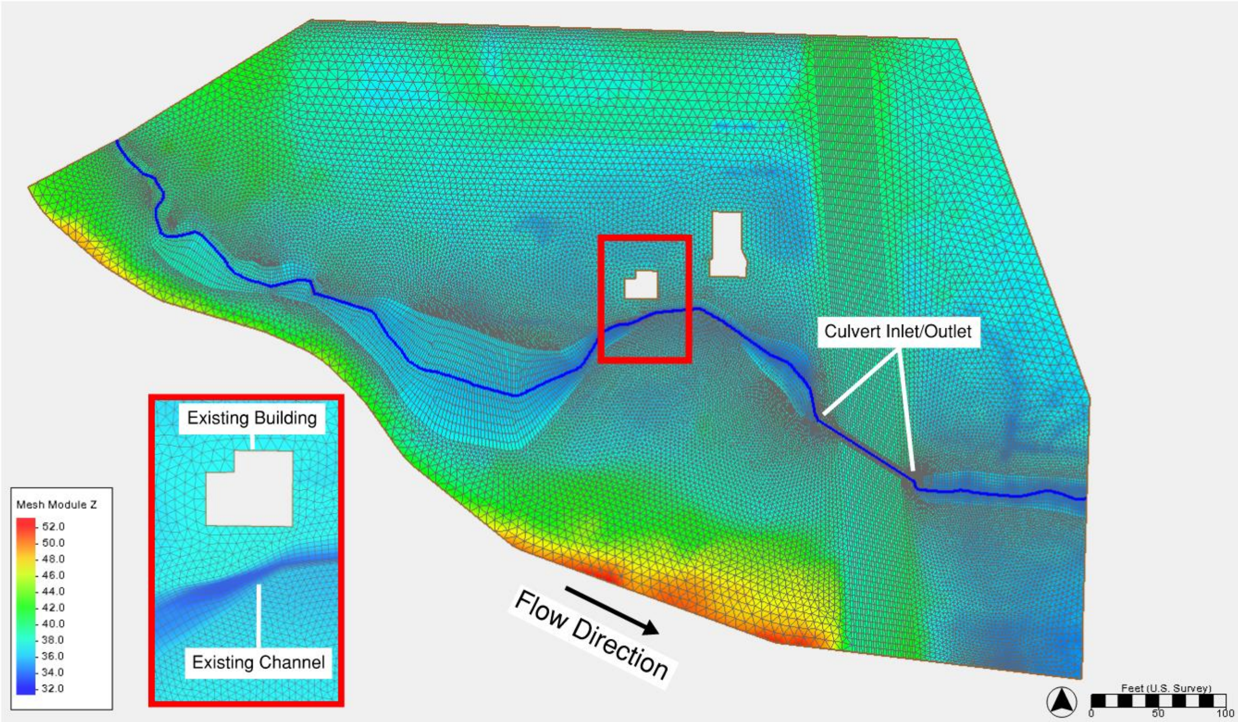

Figure 6 : Existing Mesh Extents and Cell Type Distribution

3.1.3 Boundary Conditions

Boundary conditions consisted of one inflow, four outflow, and one HY-8 culvert boundary. The placement of these boundaries is displayed in Figure 7. The inflow boundary conditions used the Inlet-Q (subcritical flow) type with a constant discharge conveyance distribution at the inlet. Inflow rates were varied for each flow event at the inlet boundary, as described in Table 1.

Several discrete flow paths result when flow escapes the channel, necessitating the four separate outflow boundaries. Outflow boundary conditions used the Exit-H (subcritical flow) type with a rating curve defined water surface elevation (WSE). Rating curves for each exit boundary were generated with user-input composite Manning's n values, slope, and flow step. Because the flow expected to leave through Exit-H 1-3 was anticipated to be significantly lower than what would leave through Exit-H 4, a smaller flow step was used for these boundaries. A summary of the inputs for each exit boundary rating curve can be found below in Table 2.

The two existing culverts were modeled using a single HY-8 boundary placed at the farthest extents of either of the two culverts. An attempt was made to model the two culverts with separate HY-8 boundaries as their inlets and outlets were staggered; however, this caused significant model instabilities at the culvert boundaries. The geometric inputs for each culvert are shown below in Figure 8 and Figure 9.

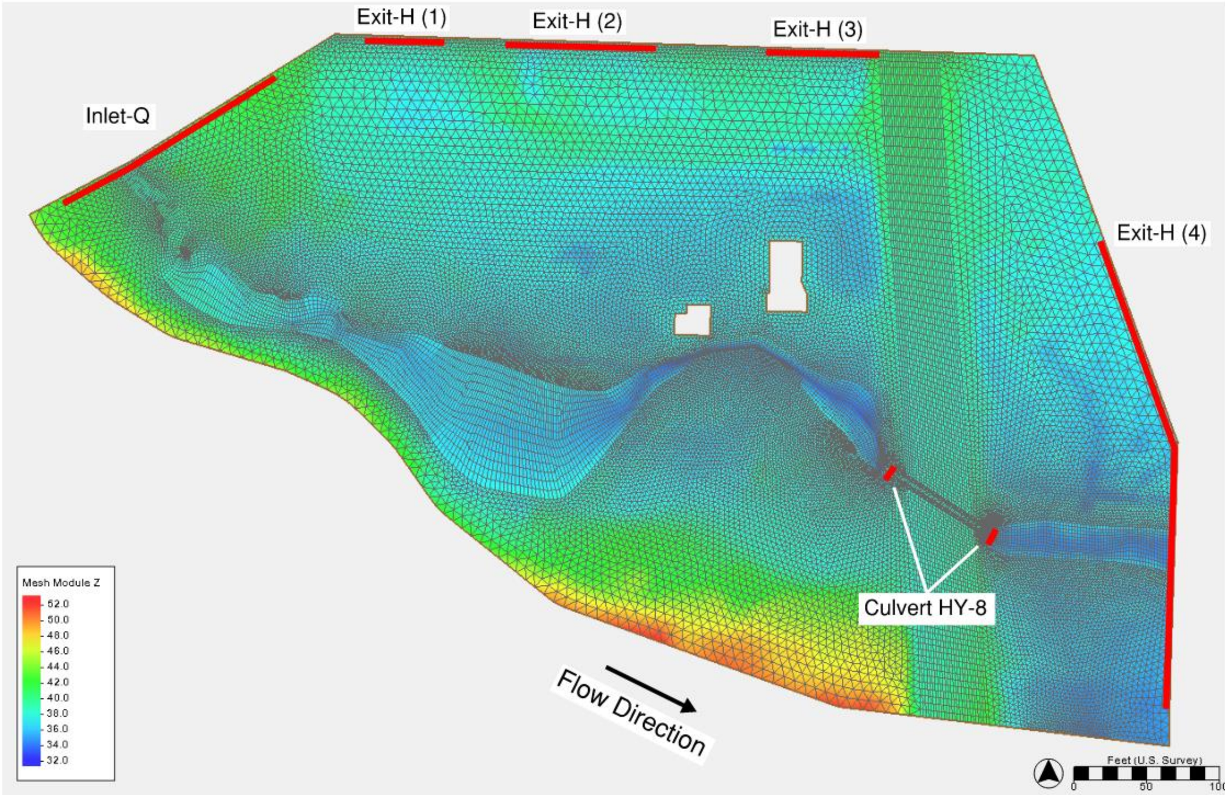

Figure 7 : Existing Conditions Boundary Condition Configuration

Table 2 : Exit Boundary Rating Curve Inputs

Exit Boundary	Composite Manning's	Slope	Flow Step (cfs)
Exit-H (1)	0.023	0.0001	2
Exit-H (2)	0.019	0.0001	2
Exit-H (3)	0.022	0.0001	2
Exit-H (4)	0.054	0.0018	5

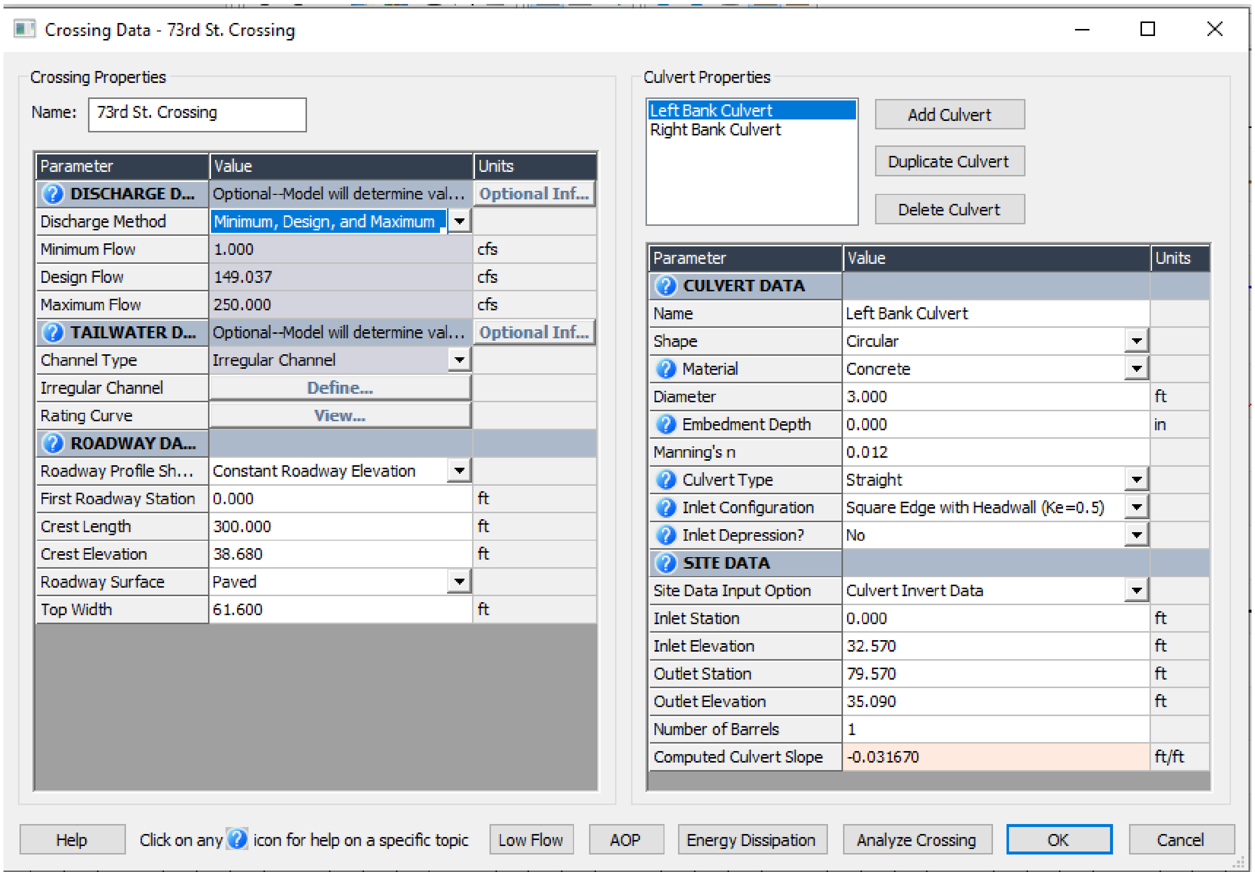

Figure 8 : Left Bank Culvert HY-8 Inputs

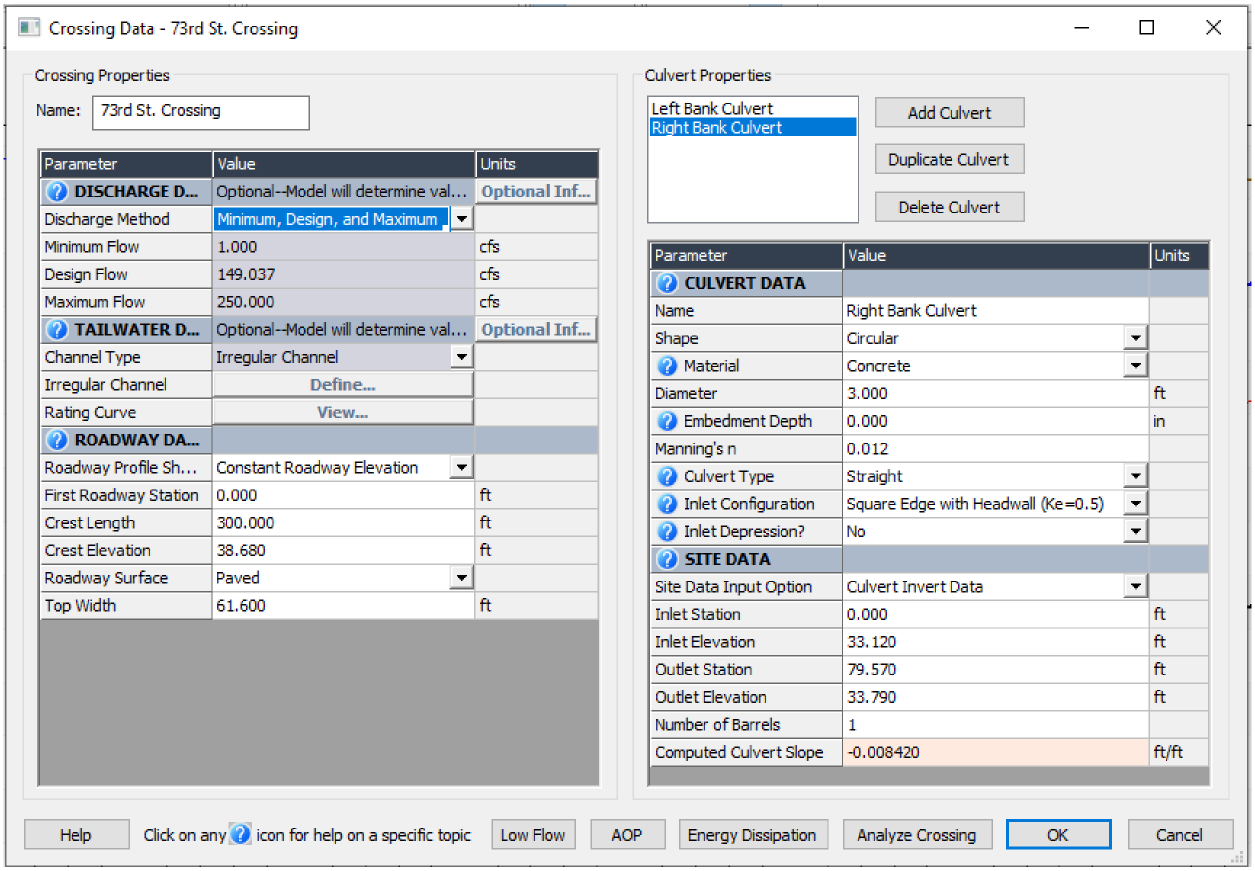

Figure 9 : Right Bank Culvert HY-8 Inputs

3.1.4 Manning's Roughness Coefficients

Channel and forested floodplain roughness values were calculated using the method outlined in Arcement and Schneider's *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains* (Arcement & Schneider, 1989). This method accounts for separate contributing roughness factors in the channel, including the effects of obstructions and amount of vegetation, and sums them for a single roughness value. Floodplain roughness through the forested upstream area was assigned using photo references of the floodplains with calibrated Manning's roughness values. The remaining roughness values, for areas such as road surfaces and lawn space, were assigned using the U.S. Army Corps of Engineers' *HEC-RAS River Analysis System Hydraulic Reference Manual* (USACE, 2021). For all roughness values outside the channel, a ten percent reduction was applied to account for features such as degree of surface irregularity that were explicitly modeled in the two-dimensional modeling. A summary of the values used, as well as the spatial distribution of values, are shown below in Table 3 and Figure 10.

Table 3 : Existing Conditions Roughness Coefficients

Land Use Type	Manning's Roughness
Existing Channel	0.055
Forested Overbanks	0.18
Pavement	0.014
Gravel with Grass	0.025
Manicured lawn	0.023
Dense Canary Grass	0.045

Figure 10 : Existing Conditions Roughness Coefficient Spatial Distribution

3.1.5 Results

Hydraulic results for average channel water surface elevation (WSE), maximum channel depth, average channel velocity, and average channel shear were analyzed at representative locations for the existing conditions. Cross section locations are shown below in Figure **11** and results are summarized in Table 4. Due to the backwater caused by the existing culverts, velocities for the 2-year event upstream of the inlets are less than 1 foot per second (fps) through the channel. Similarly, shear forces ranged from approximately 0.0 to 1.0 pound per square foot (lb/SF).

The 2-year flooding depths and extents for the existing conditions are shown in below in Figure 12. Flooding is shown escaping the channel and expanding up to approximately 230 feet in width to include

the structures to the north. This suggests frequent inundation outside of the channel, which would support the wetland-type features existing on the property. The maximum channel depth is approximately 4.1 feet, observed through the region where the channel narrows and a local depression has formed upstream of the culvert (approximately STA 3+27). Depths over 4 feet were observed only in the channel for approximately 200 feet upstream of the culvert inlet where the channel had narrowed approaching the culverts. Otherwise, channel and overbank depths were typically observed to be less than 2 feet.

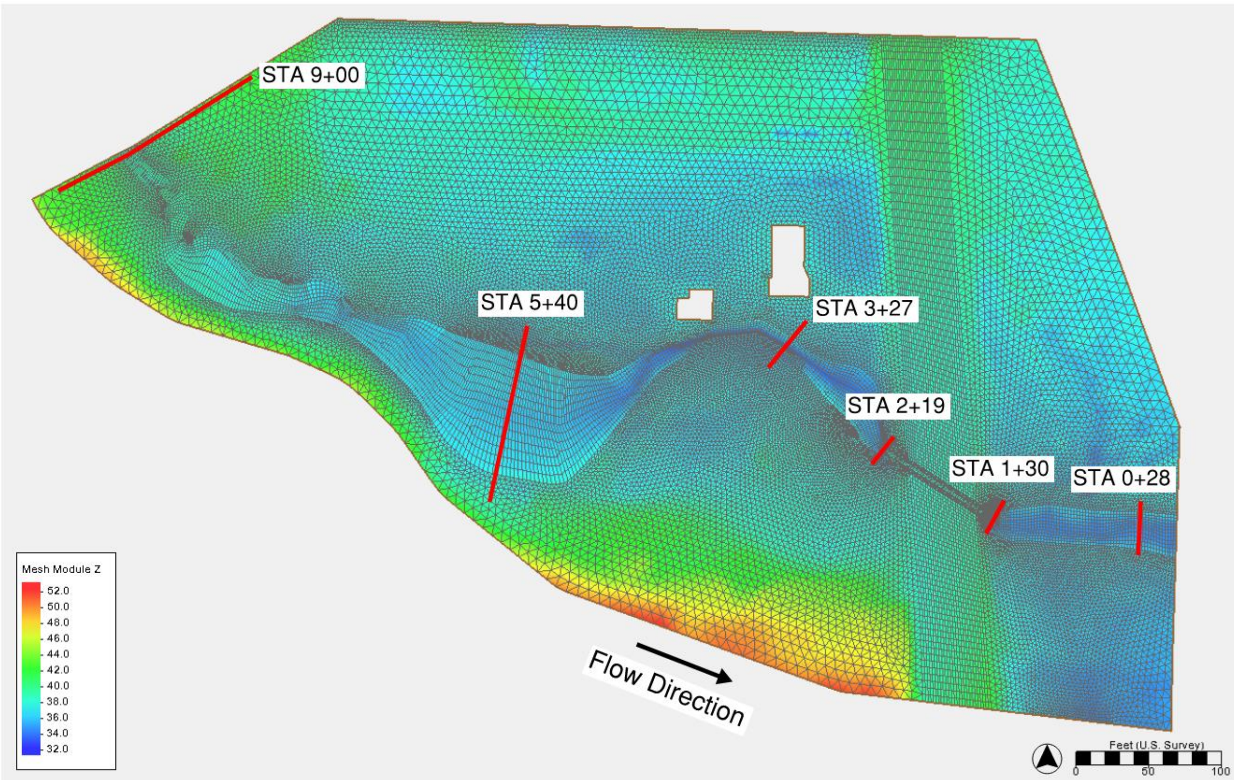

Figure 11 : Existing Conditions Hydraulic Analysis Locations

Table 4 : Existing Conditions Hydraulic Analysis Summary

Hydraulic Parameter	Cross Section (Existing Stationing)	2-Year	100-Year	500-Year
Average WSE (feet)	0+28	36.5	37.3	37.5
	1+30 (Culvert Inlet)	36.9	37.4	37.6
	2+19 (Culvert Outlet)	37.4	39.0	39.2
	3+27	37.7	39.3	39.5
	5+40	37.9	39.4	39.6
	9+00	41.0	41.7	42.0
Max Depth (feet)	0+28	1.8	2.5	2.8
	1+30 (Culvert Inlet)	2.9	3.4	3.6
	2+19 (Culvert Outlet)	4.1	5.7	5.9
	3+27	4.2	5.8	6.0
	5+40	1.8	3.3	3.6
	9+00	1.7	2.5	2.7
	0+28	2.2	2.2	2.2

Hydraulic Parameter	Cross Section (Existing Stationing)	2-Year	100-Year	500-Year
Average Velocity (feet)	1+30 (Culvert Inlet)	3.4	5.5	5.8
	2+19 (Culvert Outlet)	1.6	2.1	2.3
	3+27	0.8	0.6	0.8
	5+40	0.5	0.7	0.9
	9+00	0.9	1.5	1.8
Average Shear (lb/SF)	0+28	0.4	0.3	0.3
	1+30 (Culvert Inlet)	1.0	2.4	2.5
	2+19 (Culvert Outlet)	0.6	1.1	1.3
	3+27	0.2	0.1	0.2
	5+40	0.0	0.0	0.1
	9+00	0.1	0.2	0.2

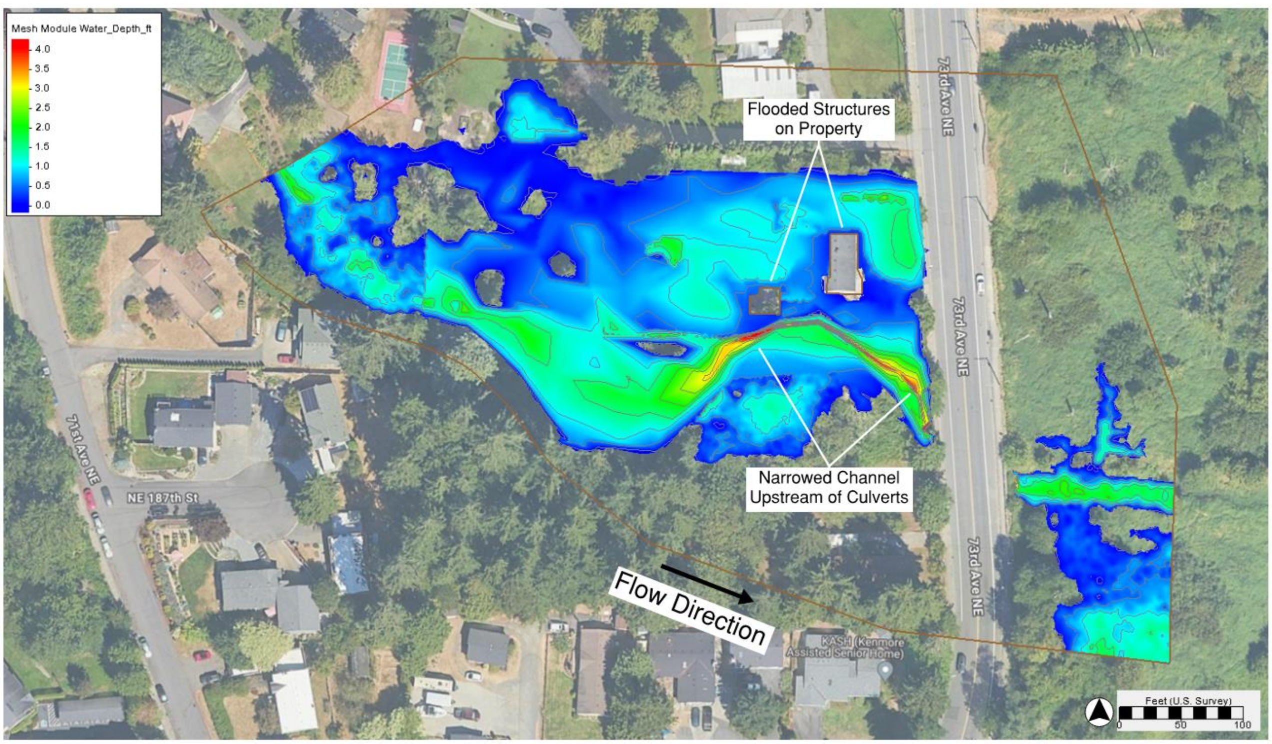

Figure 12 : Existing Conditions 2-year Flooding Depth Map

3.2 Proposed Conditions

Proposed conditions include the removal of the existing structures, realignment of the channel, engineered pools, and grading through the project reach for additional flood mitigation. The proposed realignment will direct the channel northward and will include channel meander for improved hydraulic complexity and increased channel habitat length. Within the channel, large woody material (LWM) will be placed to promote pool formation, provide fish habitat, and supply long-term biodegradable material. Designed pools will be incorporated intermittently within the channel banks to initiate habitat complexity during the construction phase of the project. Adjacent to the channel, areas of deep depressions were included to provide pools for additional low-velocity fish and amphibian habitat.

Below is a discussion of the model configuration and hydraulic results for the proposed conditions.

3.2.1 Topographic and Bathymetric Data

The proposed conditions surface was generated using Civil 3D modeling, which was incorporated into the existing survey and LiDAR composite surface. The corridor included intermittent depressions to explicitly model engineered pools within the channel. In the overbanks, flood storage was integrated as local depressions in the surface.

3.2.2 Model Extent and Computational Mesh

The upstream and downstream mesh extents used in the existing condition were deemed appropriate for the proposed conditions and were utilized in this modeling stage.

Similar to the existing conditions, patch-type cells were used through the proposed channel and patch-type cells were used to capture the complex flow paths in the overbanks. Because the existing structures in the upstream reach are expecting to be removed in the proposed conditions, no null regions were used. The mesh extents and cell type distribution are shown below in Figure 13.

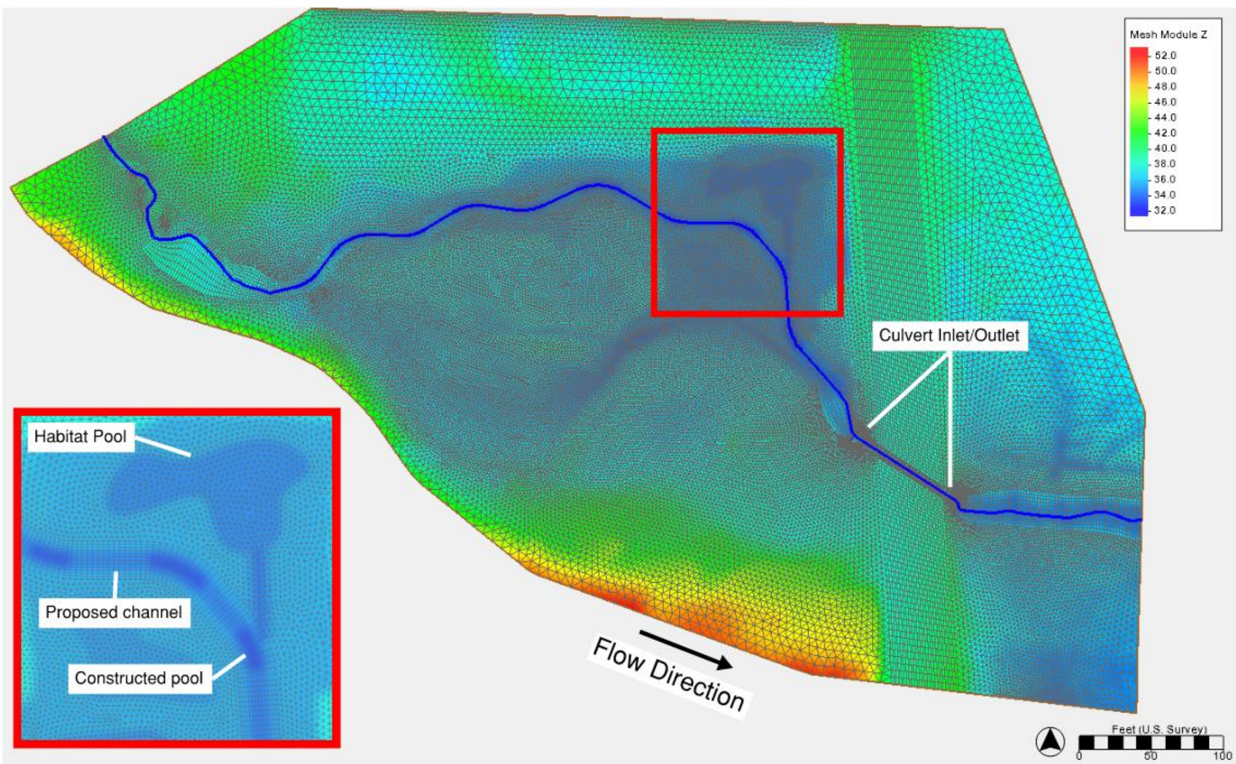

Figure 13 : Proposed Conditions Mesh Extents and Cell Type Distribution

3.2.3 Boundary Conditions

Because there were no changes to the existing culvert conditions, there were no changes to the location or configuration of the boundary conditions in the proposed conditions. See Section 3.1.3 for details regarding boundary condition placement and inputs.

3.2.4 Manning's Roughness Coefficients

Overbank roughness as well as roughness through the abandoned existing channel were maintained from the existing conditions. The new proposed channel roughness was calculated using the method

outlined in Arcement and Schneider's *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains* (Arcement & Schneider, 1989). The resulting roughness coefficient from this analysis was 0.06, which was calculated with the assumption that there would be an increase in obstruction due to the placed LWM and reduced vegetation in the channel compared to existing conditions. All coefficients used in the proposed design are summarized in 5, and the spatial distribution of each coefficient is shown in Figure 14.

Table 5 : Proposed Conditions Roughness Coefficients

Land Use Type	Manning's Roughness
Existing Channel	0.055
Proposed Channel	0.06
Forested Overbanks	0.18
Pavement	0.014
Gravel with Grass	0.025
Manicured lawn	0.023
Dense Canary Grass	0.045

Figure 14 : Proposed Conditions Roughness Coefficient Spatial Distribution

3.2.5 Results

Hydraulic results for average channel WSE, maximum channel depth, average channel velocity, and average channel shear were analyzed at representative locations for the proposed conditions. Cross section locations are shown below in Figure 15, and results are summarized in Table 6. Similar to the

existing conditions, velocities through the channel upstream of the existing culverts were observed as 1.0 fps or less, and shear forces ranged from approximately 0.0 to 1.1 lb/SF for the 2-year event. However, though the depth and velocity range is similar between the existing and proposed conditions, the proposed design offers a much higher hydraulic diversity throughout the project reach. For instance, the existing channel has one region where depths increase immediately upstream of the culvert inlet. By comparison, the proposed channel will have performed pools throughout the length of the project reach, which are expected to serve as habitat and velocity shelter for aquatic life. During the lifespan of the design, it is expected that the inclusion of LWM will continue to promote the natural development of pools and sediment aggradation. In addition, the proposed design is expected to provide habitat for multiple life stages for a variety of species through the inclusion of habitat pools. Based on the 2-year results, these features are expected to be frequently engaged and available for aquatic habitat.

The flooding depths and extents for the proposed 2-year event are shown below in Figure 16. Similar to the existing conditions, the maximum floodplain width observed upstream was approximately 230 feet. However, though the flooding extents are similar to the existing conditions, the proposed condition offers additional habitat variety, as evidenced by the flooding of habitat pools adjacent to the channel and abandoned existing channel during the 2-year event.

Results from this analysis suggest that, overall, the 2-year flooding extents will closely follow the existing conditions with the addition of some flood reduction near the upstream-most model extent. This reduction is likely due to the additional grading and flood storage that are offered in the proposed condition. A comparison of the existing and proposed 2-year flooding extents can be found below in Figure 17.

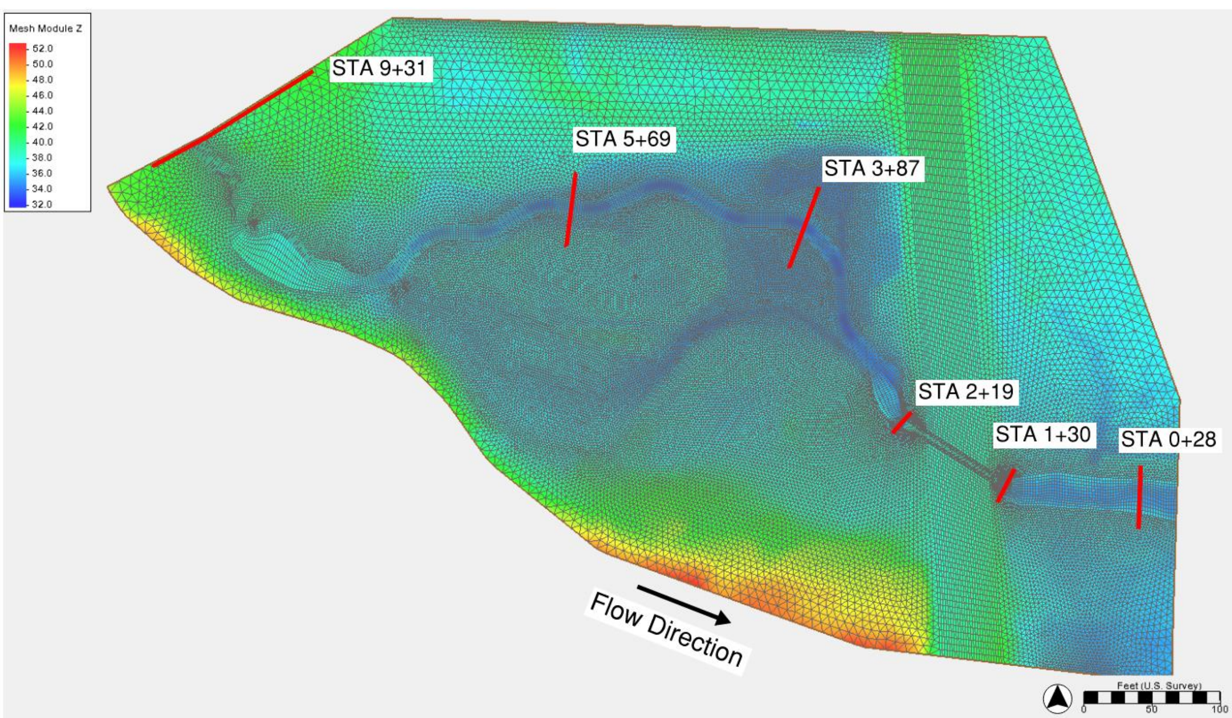

Figure 15 : Proposed Conditions Hydraulic Analysis Cross Section Locations

Table 6 : Proposed Conditions Hydraulic Analysis Summary

Hydraulic Parameter	Cross Section (Existing Stationing)	2-Year	100-Year	500-Year
Average WSE (feet)	0+28	36.5	37.3	37.5
	1+30 (Culvert Outlet)	36.9	37.4	37.6
	2+19 (Culvert Inlet)	37.4	39.1	39.2
	3+87	37.6	39.3	39.5
	5+69	37.7	39.3	39.6
	9+31	41.1	41.8	42.0
Max Depth (feet)	0+28	1.8	2.5	2.8
	1+30 (Culvert Outlet)	2.9	3.4	3.6
	2+19 (Culvert Inlet)	4.1	5.8	5.9
	3+87	4.3	6.0	6.2
	5+69	2.7	4.4	4.6
	9+31	1.7	2.5	2.7
Average Velocity (feet)	0+28	2.2	1.8	1.8
	1+30 (Culvert Outlet)	3.4	4.8	4.3
	2+19 (Culvert Inlet)	1.3	1.8	2.1
	3+87	0.2	0.3	0.4
	5+69	0.3	0.4	0.6
	9+31	1.0	1.8	2.0
Average Shear (lb/SF)	0+28	0.4	0.3	0.3
	1+30 (Culvert Outlet)	1.1	2.1	1.8
	2+19 (Culvert Inlet)	0.4	0.9	1.1
	3+87	0.0	0.0	0.1
	5+69	0.0	0.1	0.1
	9+31	0.1	0.1	0.1

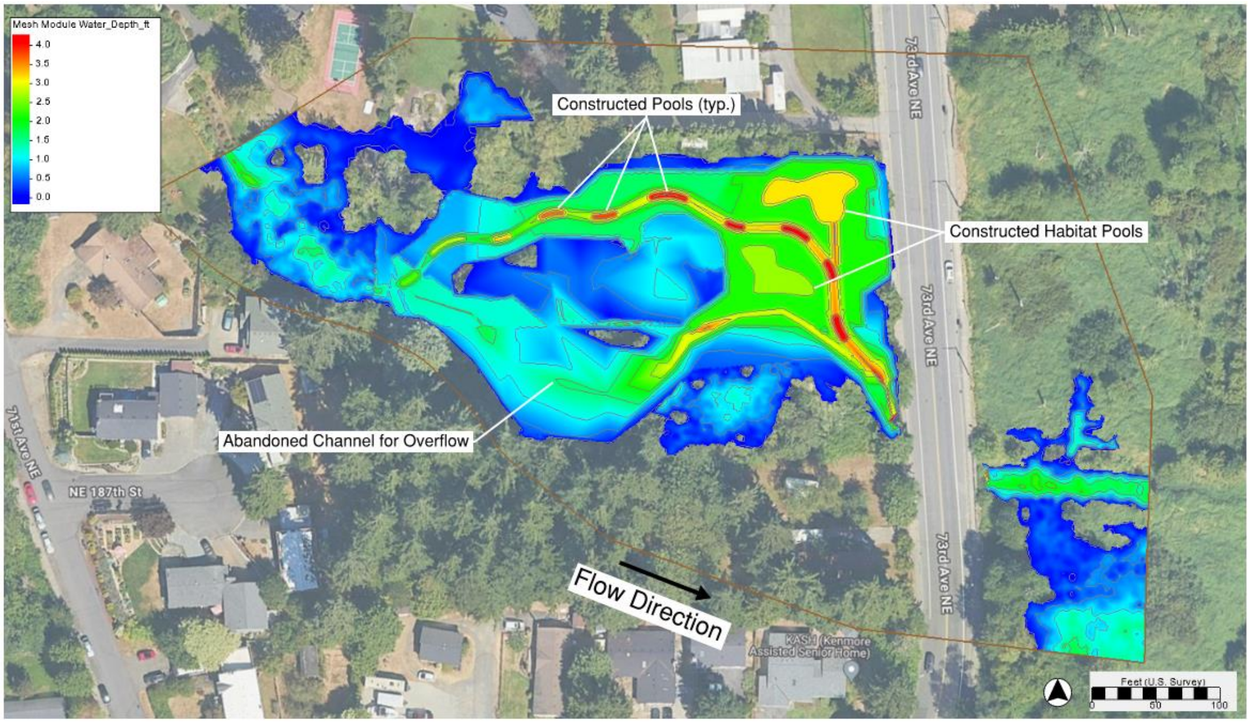

Figure 16 : Proposed Conditions 2-year Flooding Depth Map

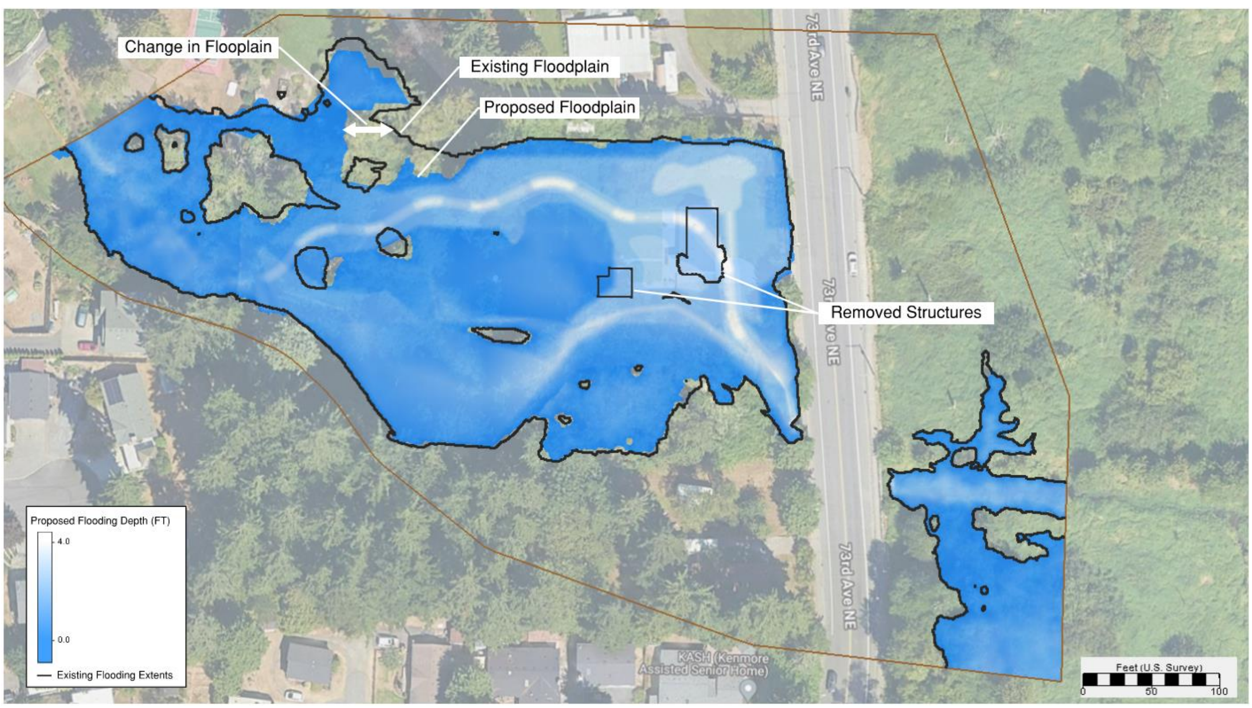

Figure 17 : Comparison of Existing and Proposed 2-year Flooding Extents

SECTION 4 GROUNDWATER MONITORING WELLS

Three groundwater monitoring wells were installed on the site in December 2022 to gather subsurface water elevation information to inform site design elevations. Groundwater elevations from each of the sites from December 2022 through July 2023 are shown below in Figure 18

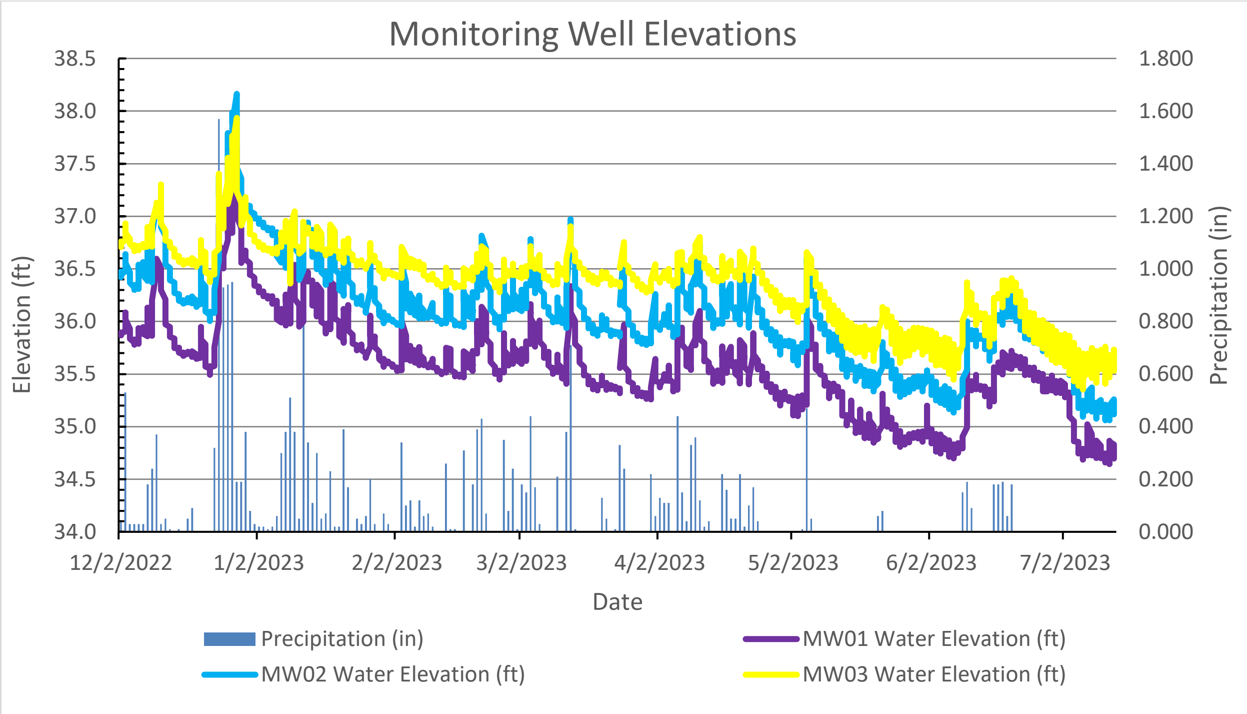

Figure 18 : Groundwater Elevation and Precipitation Data

As shown in the figure, water levels on the site generally range from 35.5 to 37.0 feet during the winter and early spring, with one higher peak after a period with significant precipitation. Based on these results, a design elevation of 35.5 was chosen for the proposed wetland areas. . It is expected that the site will be inundated into the early spring, and drier during the summer with some inundation after larger rain events.

SECTION 5 DISCUSSION

The proposed design is anticipated to provide overall habitat improvement and hydraulic complexity through the project reach. The existing conditions show limited habitat variety through the channel, with the only significant variation occurring as a narrowing and deepening of the channel immediately upstream of the culvert inlets. Complexity in the form of LWM, pools, and channel meander were also not observed in significant quantities during the 2022 site visit. The proposed conditions, though similar in flooding extents, is expected to provide additional habitat diversity in the form of channel and habitat pools, in-channel LWM, and channel meander. Hydraulic results from the 2-year flow indicate that these elements will be frequently engaged with active as well as low-velocity flow, suggesting the proposed improvement features will provide habitat for a variety of species and life stages.

SECTION 6 REFERENCES

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