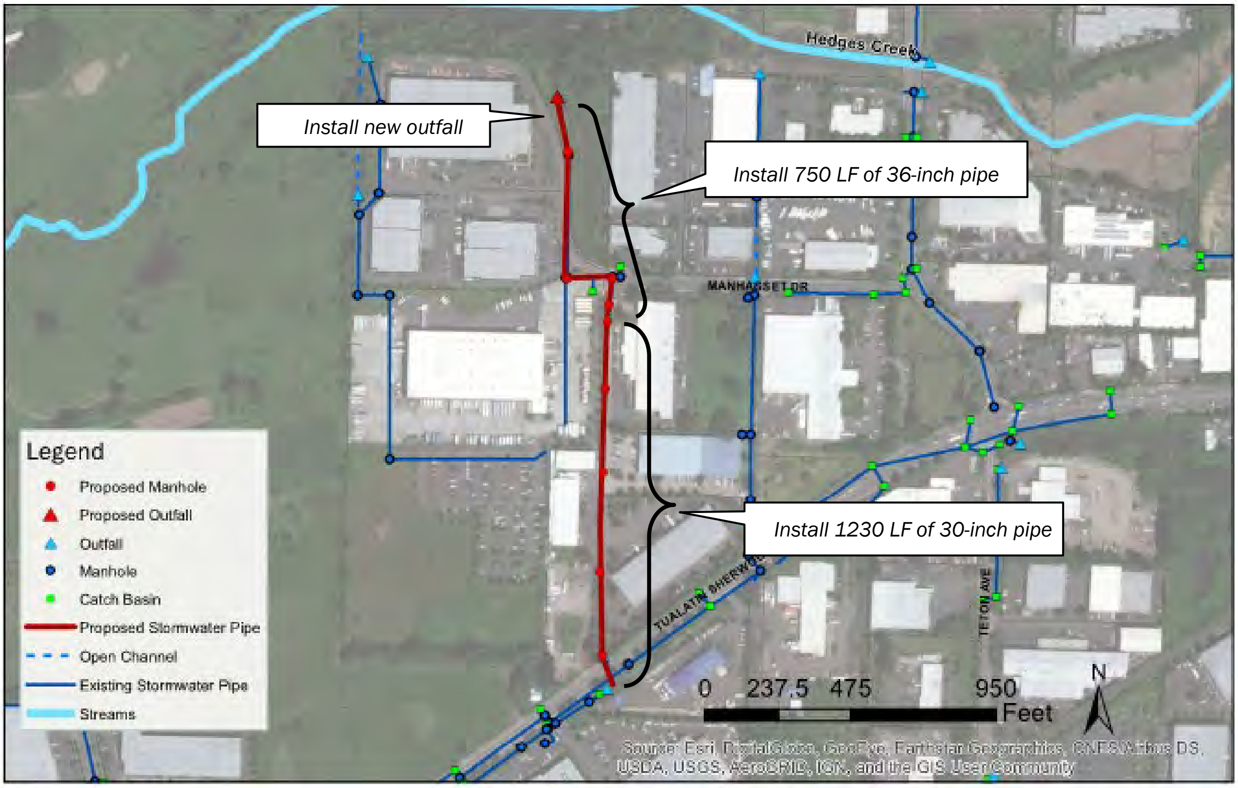
Appendix A: CIP Fact Sheets



Project Identifier	CIP #1
Project Name	Manhasset Storm System Improvements
Detailed Location	Manhasset Drive
Model File	HE_MA_ALT05.xp
Contributing Drainage Area	41.4 acres
Estimated Existing / Future Impervious %	64.0%/73.4%
Project Objective(s)	Increases System Capacity (Flood Control)

Project Background

City staff and residents have reported frequent flooding of the open conveyance channel between private properties from Tualatin-Sherwood Road to Manhasset Drive. Stormwater flows have exceeded the capacity of the channel, overtopping the banks of the channel and impacting adjacent parking lots and structures.

During a site visit in June 2016, debris from nearby properties was found in the channel. Curbs separating the channel and surrounding private property had been removed, allowing additional stormwater to enter the channel. Flow is further restricted due to large hydraulic losses associated with the ditch inlet at the end of Manhasset Drive and the shallow slope of the pipes downstream to the outfall at Hedges Creek.

The current conveyance system consists of 1,050 linear feet (LF) of open channel, 180 LF of 21-inch-diameter pipe and 750 LF of 27-inch-diameter pipe.

Hydraulic modeling of the system confirms the channel and pipe system is undersized for the contributing drainage area.

Project Description

This project addresses localized flooding by piping the existing open channel conveyance and upsizing select pipe segments.

This project replaces the existing 1,050 LF of open channel and 180 LF of 21-inch-diameter pipe with 1,230 linear feet (LF) of 30-inch-diameter pipe. The project replaces the existing 750 LF of 27-inch-diameter pipe from Manhasset Drive to the outfall to Hedges Creek with 750 LF of 36-inch-diameter pipe to reduce potential flooding during the 25-year design storm event.

The project also includes landscaping, the installation of nine manholes (five along the open channel alignment will have grated lids), and a new outfall to Hedges Creek.

Design Considerations

- Only planning-level hydraulic calculations have been performed to identify conceptual sizing. For design, detailed topographic survey and hydraulic analysis is needed to determine the appropriate invert elevations and pipe diameters to maintain necessary cover depth in this flat terrain.
- Due to the shallow grade of the proposed pipe in the lower portions of the installed system, sediment accumulation may present a maintenance issue and will require regular attention to ensure proper drainage and to prevent flooding.

Planning-level Cost Estimate

Capital Expense Total (including contingency)	$ 1,171,000
Engineering and Permitting (25%)	$ 293,000
Administration (10%)	$ 117,000
Capital Project Implementation Cost Total*	**$ 1,581,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Image 1. Observed flooding of drainage ditch during December 2015 storm

Image 2. Grated inlet and rock lined channel at downstream end of drainage ditch

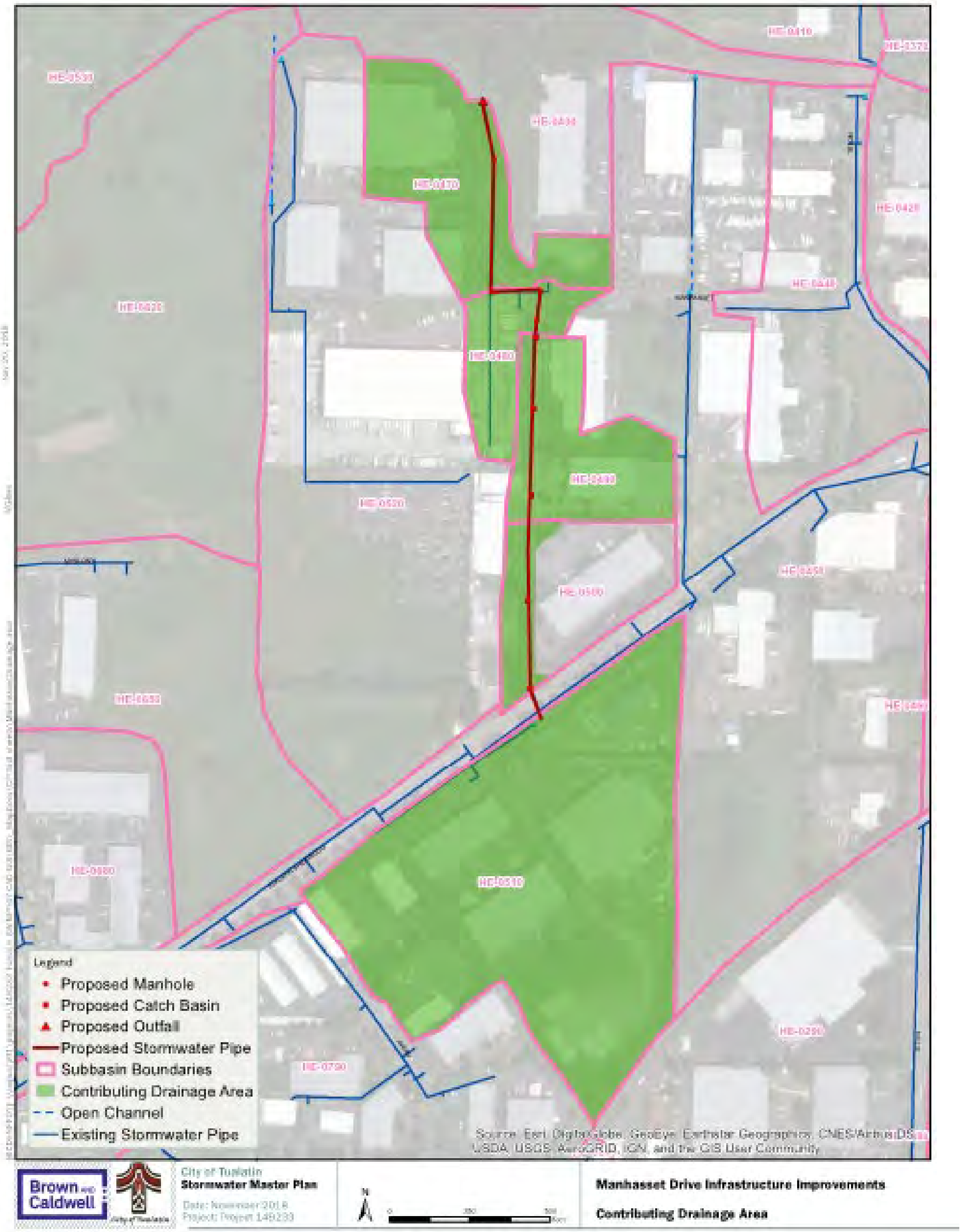
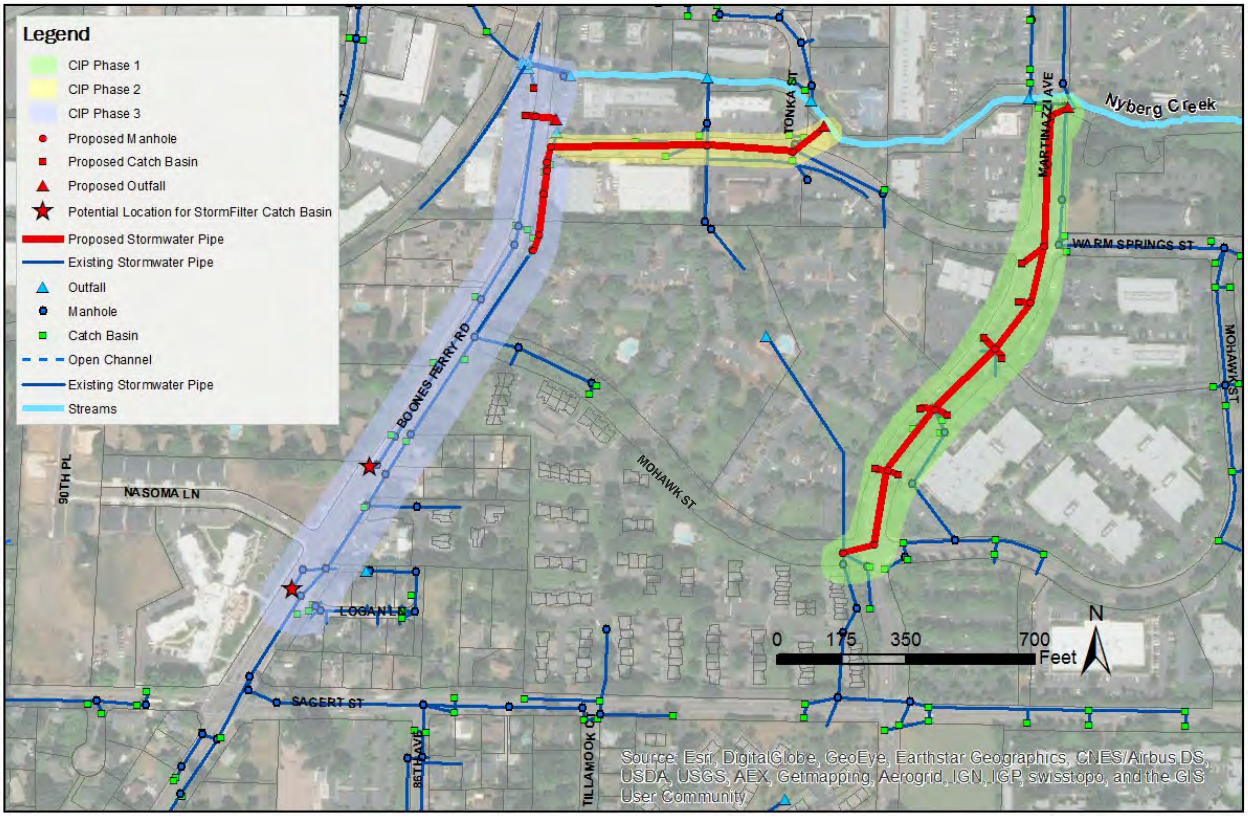


Image 3. Contributing drainage area



Project Identifier	CIP #2
Project Name	Nyberg Creek Stormwater Improvements
Detailed Location	Nyberg Creek between Boones Ferry Road and Martinazzi Avenue
Model File	NY_ALT06.xp
Contributing Drainage Area	443.2 acres
Estimated Existing / Future Impervious %	47.4%/56.4%
Project Objective(s)	Increases System Capacity (Flood Control), Increases Water Quality Treatment (Retrofit)

Project Background

City staff and the public have identified routine flooding along Boones Ferry Road. The affected area, from Boones Ferry Road to Martinazzi Avenue, is relatively flat, contains aging infrastructure, and requires frequent maintenance to remove accumulated sediment. Gravel and railway ballast debris transported from the nearby railroad open conveyance channel (see CIP #7) accumulates in this portion of the storm system.

Hydraulic modeling of the system confirms that undersized pipes near the intersections of Warm Springs Street and Boones Ferry Road and Warm Springs Street and Tonka Street contribute to roadway flooding. Two StormFilter catch basin units located on Boones Ferry Road, north of Warm Springs Street, are located at a roadway sag and regularly clog due to accumulated sediment, which also contributes to roadway flooding.

Project Description

This project alleviates localized flooding between Boones Ferry Road and Martinazzi Avenue by upsizing undersized pipe segments, relocating StormFilter catch basin units, and rerouting stormwater flow from select areas away from locations experiencing routine flooding.

Due to the significant cost and extent of the project, the project has been broken into three phases. Phase 1 includes installation of a new trunkline down Martinazzi Avenue from Mohawk Street to Nyberg Creek. Phase 2 includes installation of a 48-inch pipe along Warm Springs Street and a new outfall to Nyberg Creek. Phase 3 includes upsizing the existing storm system along Boones Ferry Road and diversion of flow to the new system on Warm Springs Street. Phases should be constructed in consecutive order.

Detailed activities by phase are listed below:

Phase 1

Phase 1 must first be constructed to redirect approximately 51 acres of contributing drainage area from areas prone to flooding at Warm Springs Street and Tonka Street. This phase is also recommended prior to implementation of CIP #4 (Mohawk Apartments Stormwater Improvements). This phase includes the following:

- Disconnection of the existing stormwater system from the south at Mohawk Street.
- Replacement of existing infrastructure on Martinazzi with 1500 LF of 24-inch pipe from existing node 263397 (CIP system naming is 263397_NY-0290) to existing node 270963.
- Installation of 9 manholes and 8 catch basins along Martinazzi Avenue. 440 LF of 12-inch inlet leads are also reflected in the cost estimate for the connection of new and existing catch basins.
- Construction of a new outfall to Nyberg Creek east of the bridge crossing with Martinazzi Avenue.

It is recommended that Phase 1 be completed in conjunction with the anticipated repair of the sanitary sewer system along this section of roadway to minimize disturbance and costs.

Phase 2

Phase 2 increases capacity of the stormwater system down Warm Springs Street to support redirection of flow from Boones Ferry Road. This phase includes the following:

- Installation of 800 LF of 48-inch pipe down Warm Springs Street from existing node 270971 to new outfall (CIP system naming is Node569) to route flow west to east.
- Installation of 4 manholes and 5 connections to existing infrastructure for the new pipe down Warm Springs Street.
- Construction of a new outfall to Nyberg Creek, northeast of the intersection of Tonka Street and Warm Springs Street.

Phase 3

Phase 3 reflects infrastructure modifications necessary to connect to new infrastructure installed during Phase 2. Hydraulic modeling shows that the four pipe sections on the east side of Boones Ferry Road south of Warm Springs Street are under capacity. This phase includes the following:

- Replacement of 250 LF of 30-inch pipe with 250 LF of 36-inch pipe from 262848 to 262844 and replacement of 75 LF of 36-inch pipe with 75 LF of 42-inch pipe from 262844 to a new manhole at the intersection of Boones Ferry Road and Warm Springs Street.
- Replacement of 60 LF of 18-inch pipe across Boones Ferry Road with 60 LF of 24-inch pipe.
- Installation of 6 manholes down Boones Ferry Road.
- Removal and replacement of the two existing StormFilter units on Boones Ferry Road with sumped catch basins. Sumped catch basins are recommended due to the high sediment load this area experiences.
- Installation of at least two StormFilter catch basins further south on Boones Ferry Road (see potential locations indicated in Figure 3). These new StormFilter units should treat a contributing drainage area equal to or larger than the drainage area associated with the removed units. The units shall be configured in an offline orientation to tie into existing infrastructure. 150 LF of 12-inch inlet leads are also reflected in the cost estimate for the connection of new StormFilter catch basins.

Design Considerations

- Construction phasing should follow the phase schedule outlined above and consider project concurrence in conjunction with other CIPs (i.e., CIP #4, CIP #7).
- Detailed downstream analysis of the Nyberg Creek system is in progress. Proposed outfall locations were identified based on observed capacity in the open channel system and conceptual-level hydraulic modeling.
- A preliminary hydraulic model of proposed infrastructure and system modifications demonstrates a significant decrease in flooding for events up to the 25-year design storm.
- Only planning level calculations have been performed to identify conceptual layout and system sizing. Detailed topographic survey is needed to determine appropriate invert elevations and verify pipe diameters to maintain necessary cover and convey the design event.

Planning-level Cost Estimate		
Phase 1	Capital Expense Total (including contingency)	$ 1,051,000
	Engineering and Permitting (35%)	$ 368,000
	Administration (10%)	$ 105,000
	Capital Project Implementation Cost Total*	**$ 1,523,000**
Phase 2	Capital Expense Total (including contingency)	$ 863,000
	Engineering and Permitting (35%)	$ 302,000
	Administration (10%)	$ 86,000
	Capital Project Implementation Cost Total*	**$ 1,252,000**
Phase 3	Capital Expense Total (including contingency)	$ 472,000
	Engineering and Permitting (25%)	$ 118,000
	Administration (10%)	$ 47,000
	Capital Project Implementation Cost Total*	**$ 637,000**
Total	**Capital Project Implementation Cost Total***	**$ 3,412,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Figure 1. Construction details of Phase 1

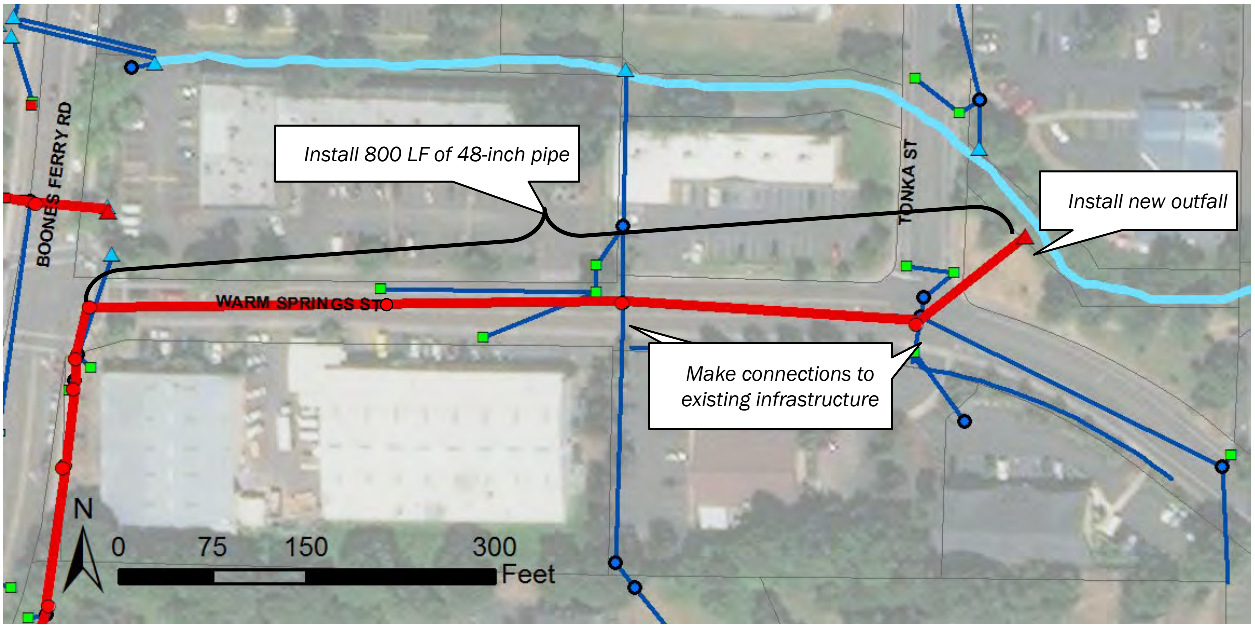


Figure 2. Construction details of Phase 2

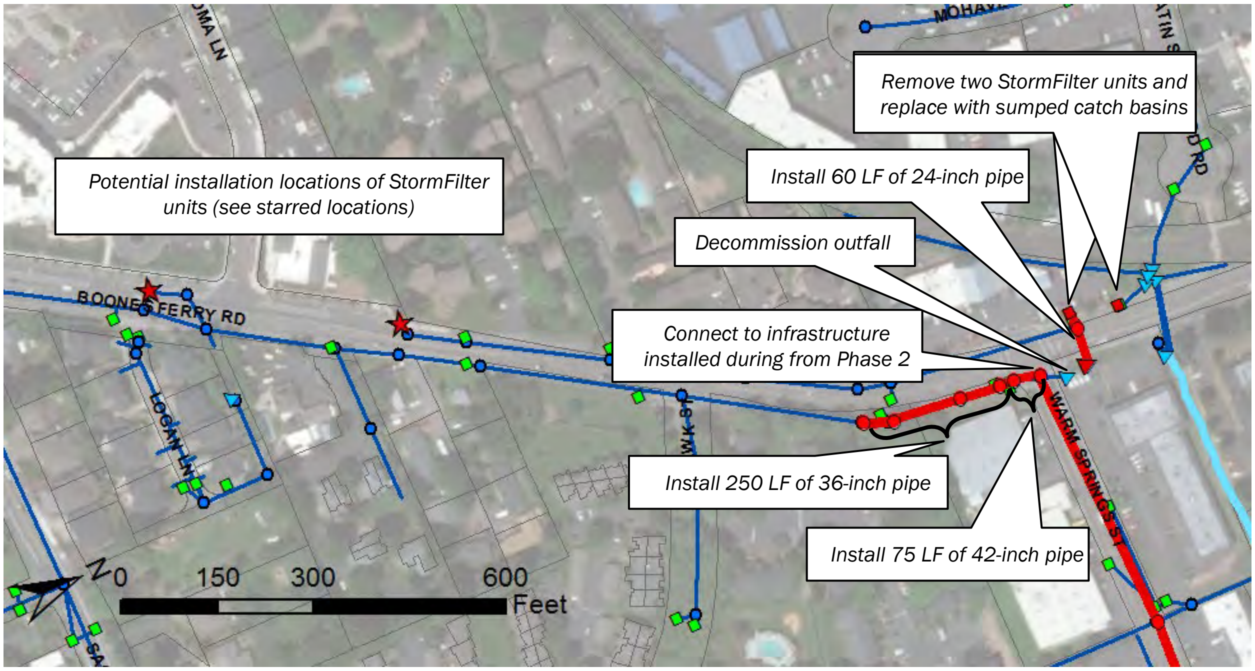
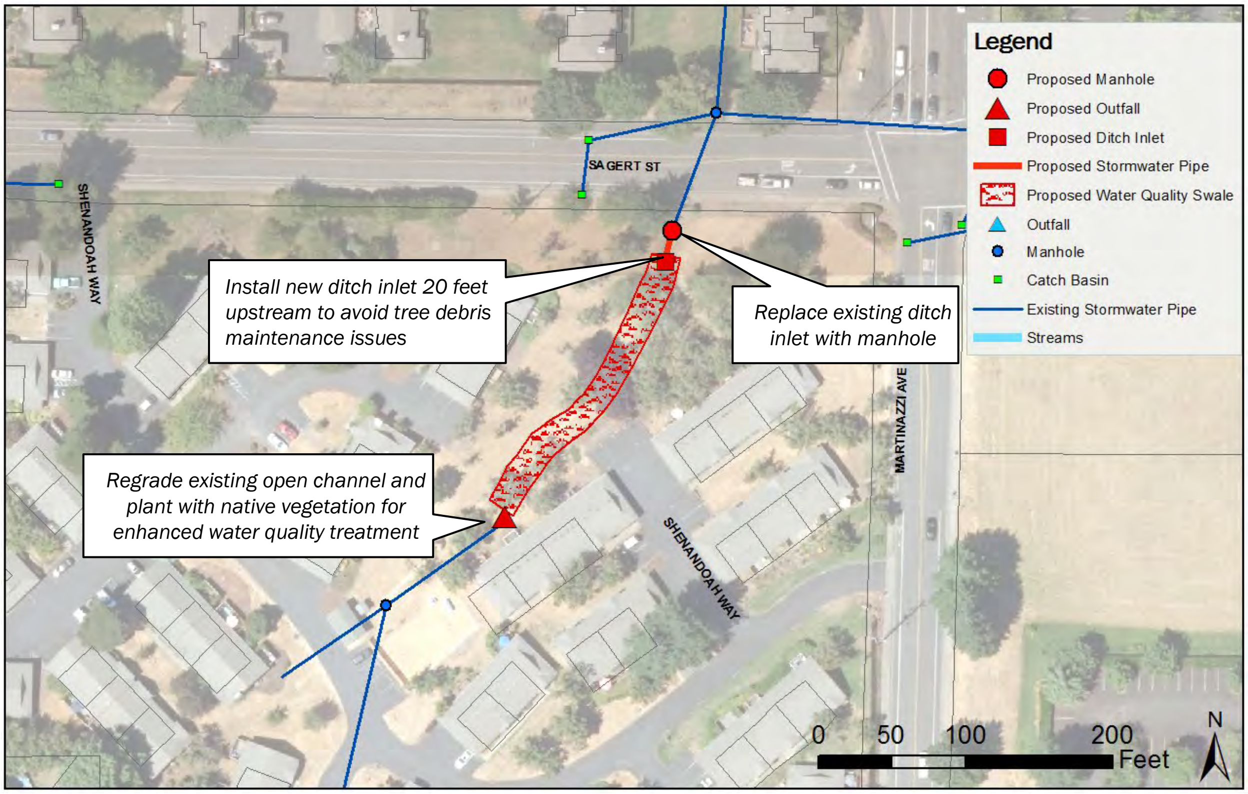


Figure 3. Construction details of Phase 3



Project Identifier	CIP #3
Project Name	Sandalwood Water Quality Retrofit
Detailed Location	Sagert Street and Martinazzi Avenue
Model File	N/A
Contributing Drainage Area	37.6 acres
Estimated Existing/Future Impervious %	43.3%/53.3%
Objective(s) Addressed	Addresses Erosion; Increases Water Quality Treatment (Retrofit)

Project Background

The Sandalwood Condominiums have a piped stormwater system that outfalls to a 220-foot-long open channel conveyance on the north side of the property. The conveyance channel discharges to a ditch inlet (260393) adjacent to Sagert Street.

City staff identified erosion and capacity concerns related to the open channel conveyance system. This project site was also identified during a water quality retrofit evaluation as a potential stormwater treatment facility retrofit. The open channel conveyance system experienced flooding in December 2015, likely due to debris from a nearby tree clogging the ditch inlet. During a site visit in June 2016, incision and bank sloughing were observed, especially near the upstream end of the open channel.

Project Description

This project addresses erosion concerns by regrading the existing open channel conveyance and adding plantings for enhanced water quality treatment.

This project includes widening and regrading of the existing open channel conveyance to increase capacity and minimize erosion along its banks. The resulting 10' wide by 220' long swale will include amended soils and vegetation enhancement to improve water quality treatment function and enhance visual appeal.

The outfall to the channel will be reinforced with rip rap to dissipate the energy as the stormwater exits the upstream collection system. Check dams will be installed to reduce velocities and enhance water quality treatment through the system.

A new ditch inlet will be installed, twenty feet south of its current location, to prevent debris accumulation. The existing ditch inlet (260393) will be replaced with a manhole and 20 LF of 30-inch pipe will connect the new ditch inlet to the manhole. The manhole may be installed with a grated lid to act as an emergency overflow.

Design Considerations

- Facility sizing and design is based on the Clean Water Services Low Impact Development Approaches (LIDA) Handbook and should be referenced for design guidelines on water quality swales.
- Final swale alignment should consider potential grading impacts to the existing trees.
- Only planning level calculations have been performed to identify conceptual layout and sizing. For design, detailed topographic survey is needed to determine the extent of grading required and appropriate invert elevations to maintain necessary slope and convey the design event.

Planning-level Cost Estimate

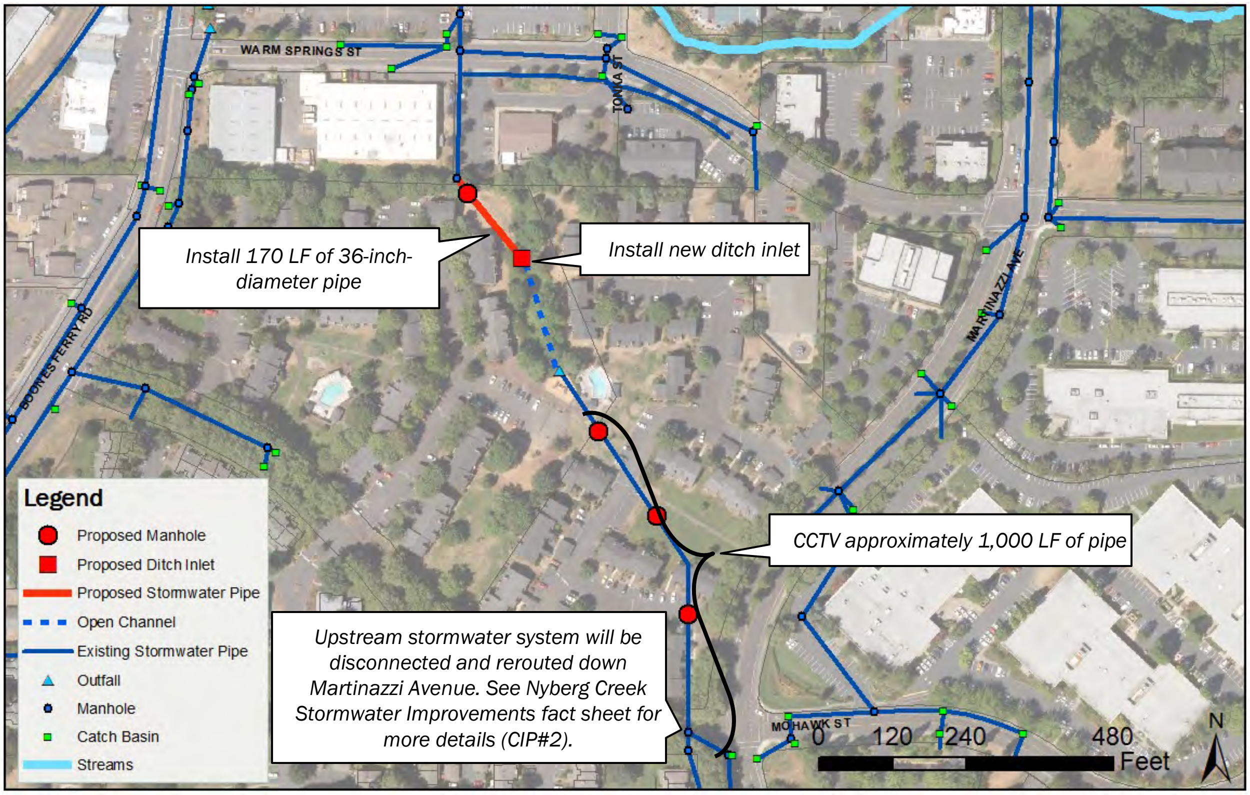
Capital Expense Total (including contingency)	$ 79,000
Engineering and Permitting (25%)	$ 20,000
Administration (10%)	$ 8,000
Capital Project Implementation Cost Total*	**$ 107,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Image 1. Incision and sloughing in the open channel

Image 2. Tree debris clogging the ditch inlet at the downstream end of the open channel



Project Identifier	CIP #4
Project Name	Mohawk Apartments Stormwater Improvements
Detailed Location	8325 SW Mohawk Street
Model File	N/A
Contributing Drainage Area	8.9 acres[1]
Estimated Existing / Future Impervious %	49.1%/58.8%
Objective(s) Addressed	Increases System Capacity (Flood Control); Addresses Maintenance Need

Project Background

City staff identified the stormwater system through the Mohawk Apartments as capacity limited. The section of pipe from west of the intersection with Martinazzi Avenue and Mohawk Street to the open conveyance channel has an unknown alignment, condition, material and unverified size. The alignment shown on the figure above is an approximation based on the City's GIS data.

The existing ditch inlet (260409) downstream from the open channel is undersized during high flow events and bypasses down the adjacent embankment, causing flooding at the intersection of Tonka Street and Warm Springs Street and impacting downstream private properties along Warm Springs Street. The corrugated metal pipe downstream of the ditch inlet is in poor condition according to City staff and requires replacement.

Project Description

This project alleviates localized flooding and replaces aging and deteriorating infrastructure. Localized flooding is also addressed in part by CIP #2 (Nyberg Creek Stormwater Improvements).

This project includes 1,000 linear feet (LF) of CCTV video inspection to determine/ verify the pipe condition, location, material and size west of the intersection of Martinazzi Avenue and Mohawk Street to the existing open channel conveyance. Three manholes will be installed along this pipe alignment for maintenance access. This pipe will remain in service to convey drainage from the Todd Village Apartments.

[1] *Contributing drainage area reflects disconnection of the upstream stormwater system at Sagert Street and routed down Martinazzi Avenue in accordance with the Nyberg Creek Stormwater Improvements (CIP # 2)*

Downstream of the open channel, a new ditch inlet will be installed to replace the existing grated inlet. Limited earthwork and invasive vegetation removal will be conducted to regrade the channel and direct flow to the inlet. 170 LF of corrugated metal pipe will be removed and replaced with 170 LF of 36-inch-diameter HDPE pipe.

Design Considerations

- Project scheduling should consider the Nyberg System Improvements (CIP #2), as stormwater flows to this system will be reduced as part of that project due to disconnection and rerouting of the upstream stormwater conveyance pipe down Martinazzi Avenue.
- Easement acquisition has not been included in this cost estimate.
- Based on the results of the CCTV inspection, the section of pipe from Mohawk Street to the open channel may need to be replaced or rehabilitated with cure-in-place pipe lining or similar. This repair is not included in this cost estimate.
- Ongoing sediment removal and vegetation management is required to maintain capacity in the open channel system. Regular maintenance should be conducted.

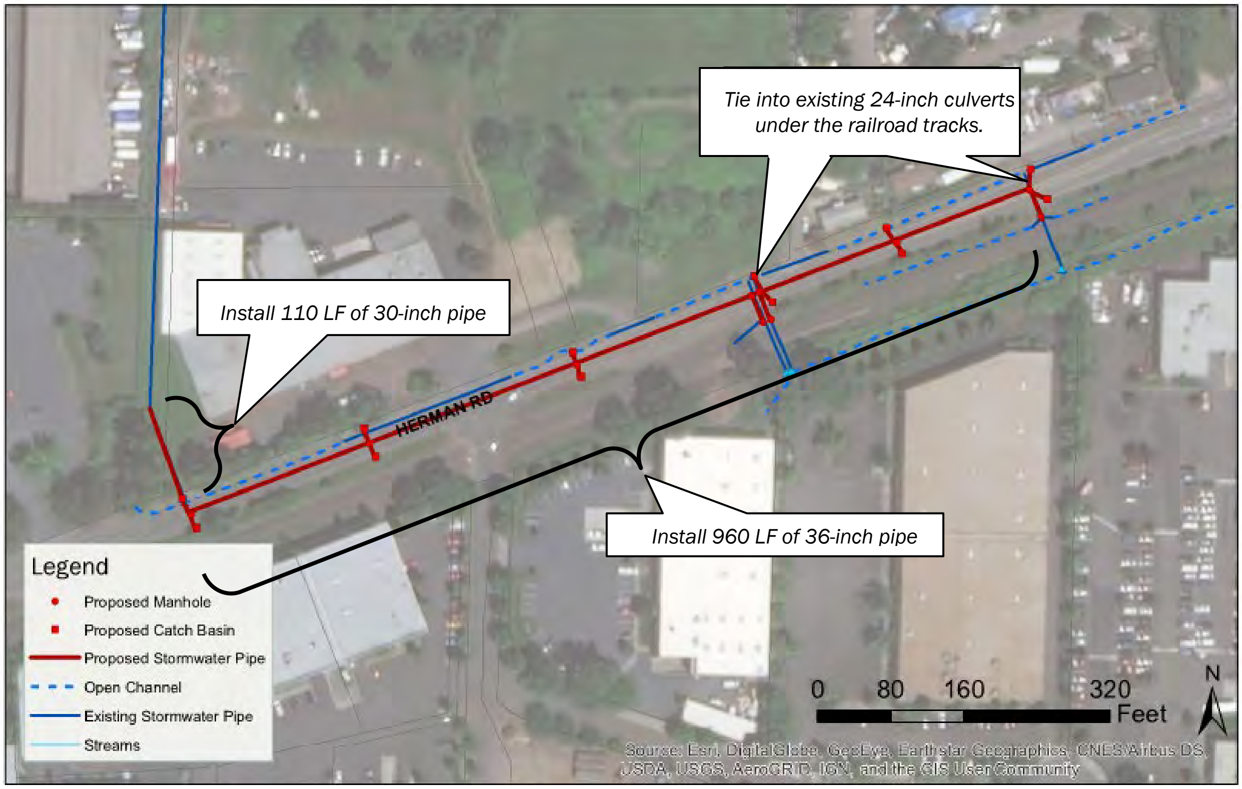
Planning-level Cost Estimate

Capital Expense Total (including contingency)	$ 218,000
Engineering and Permitting (25%)	$ 55,000
Administration (10%)	$ 22,000
Capital Project Implementation Cost Total*	**$ 295,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Image 1. Grated inlet and open channel near Mohawk Apartments



Project Identifier	CIP #5
Project Name	Herman Road Storm System
Detailed Location	Herman Road between Teton Avenue and Tualatin Road
Model File	HE_HE_ALT01.xp
Contributing Drainage Area	42.6 acres
Estimated Existing/Future Impervious %	56.1%/71.3%
Objective(s) Addressed	Increases System Capacity (Flood Control)

Project Background

The stormwater system along Herman Road receives runoff from 42.6 acres of industrial and medium density residential land use. The area is subject to frequent flooding due to limited grade and a lack of drainage infrastructure. Stormwater is conveyed via roadside ditches and open channels to culverts under the adjacent railroad right-of-way. The railroad culverts are deeper than the upstream and downstream infrastructure, creating a hydraulic constraint and backwater effects along the northern side of Herman Road.

City staff identified Herman Road as a future roadway widening project and drainage improvements are needed in conjunction with roadway design.

Hydraulic modeling of the existing conveyance system confirms that the elevation of the railroad culverts results in backwater effects and flooding of the open channel/ditch system along Herman Road. The existing ditches and culverts along Herman Road also appear to be undersized for the contributing drainage areas and design flows.

Project Description

This project provides guidance towards design of a stormwater collection and conveyance system associated with future Herman Road improvements.

This project includes installation of 110 linear feet (LF) of 30-inch-diameter pipe from existing node 322601 to the centerline of Herman Road and 960 LF of 36-inch-diameter pipe down Herman Road to collect and convey runoff from Herman Road and the surrounding contributing area, replacing the existing open channel/ditch conveyance system. Consideration of the final road vertical profile and pipe cover should be incorporated into the design. This project includes the installation of 10 manholes, 4 connections to existing stormwater pipes/culverts, and 12 catch basins with an associated 420 LF of 12-inch inlet leads.

To maximize slope and utilize the current pipe alignment under the railroad tracks, the existing culverts under the railroad will act as the low points for the new conveyance system.

Design Considerations

This project has been sized for the 25-year storm event. Due to the elevation of the railroad culverts, the proposed layout is anticipated to surcharge at the 2-year storm event.

Only planning-level hydraulic calculations have been performed to identify conceptual sizing. For design, detailed topographic survey and hydraulic analysis is needed to determine appropriate invert elevations and verify pipe diameters to maintain necessary cover and convey the design event.

Project design and construction to occur in conjunction with the roadway widening project. Water quality treatment for new and replaced impervious surface and asphalt resurfacing associated with the pipe installation is not reflected in project cost and will be addressed with roadway design.

Due to the shallow grade of the proposed pipe, sediment accumulation may present a maintenance issue and will require regular attention to ensure proper drainage to prevent flooding.

Planning-level Cost Estimate	
Capital Expense Total (including contingency)	$ 758,000
Engineering and Permitting (25%)	$ 189,000
Administration (10%)	$ 76,000
Capital Project Implementation Cost Total*	**$ 1,023,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

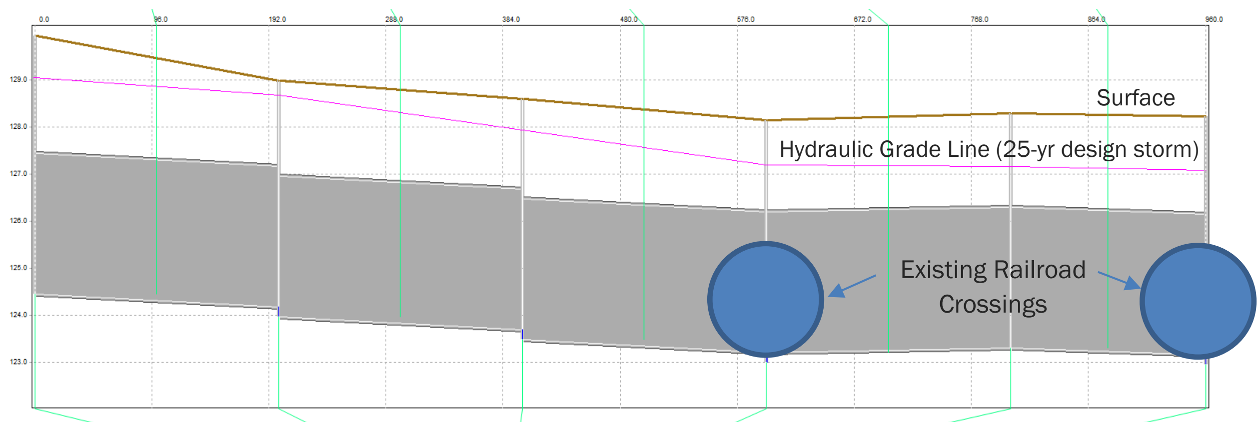


Image 1. Proposed pipe layout along Herman Road

Image 2. Ditch along the northern side of Herman Road

Project Identifier	CIP #6
Project Name	Blake Street Culvert Replacement
Detailed Location	Blake Street and 105th Avenue
Model File	HE_BL_ALT02.xp
Contributing Drainage Area	414.0 acres
Estimated Existing/Future Impervious %	38.3%/46.8%
Objective(s) Addressed	Increases System Capacity (Flood Control); Addresses Erosion

Project Background

The existing culvert under 105th Avenue is reported to be undersized by City staff. The upstream end is routinely blocked with debris. The culvert is located along Hedges Creek in a mostly residential neighborhood.

The existing layout of the stream channel creates 90-degree bends on either side of the culvert which are reinforced by rock and concrete walls to prevent bank erosion. The upstream rock wall is failing due to erosive flows impacting the road embankment. 105th Avenue is unimproved and a roadway widening, and improvement project is in the planning stages.

Project Description

This project provides guidance towards sizing and design of a replacement culvert at Blake Street and 105th Avenue associated with the future 105th Avenue roadway improvements.

The project will replace the existing culvert with an 84-inch culvert, sized to convey the 100-year design storm flow. The new culvert will be installed along the natural stream alignment, roughly a 45-degree angle under the road, to optimize the movement of water downstream, reduce hydraulic losses due to the 90-degree bends upstream and downstream of the culvert, decrease erosion potential, and reduce the potential for debris and sediment accumulation. Design and construction should occur with scheduled roadway improvements.

Design Considerations

Only planning-level hydraulic calculations have been performed to identify conceptual sizing. For design, detailed topographic survey and hydraulic modeling is needed to verify culvert sizing and determine appropriate invert elevations to maintain necessary cover and convey the design event.

Local roadway drainage collection and water quality infrastructure design will be completed in conjunction with roadway improvements. The vertical curve of the current roadway alignment and elevation difference between the current roadway surface and the stream channel is not sufficient to provide cover for the proposed 84-inch replacement culvert.

Per Oregon Department of Fish and Wildlife feedback in 2017, this reach of Hedges Creek is not fish bearing and fish passage design is not necessary. However, agencies such as the Army Corps of Engineers, Division of State Land, and Department of Environmental Quality may have additional design and permitting requirements not reflected in the current project cost.

Planning-level Cost Estimate

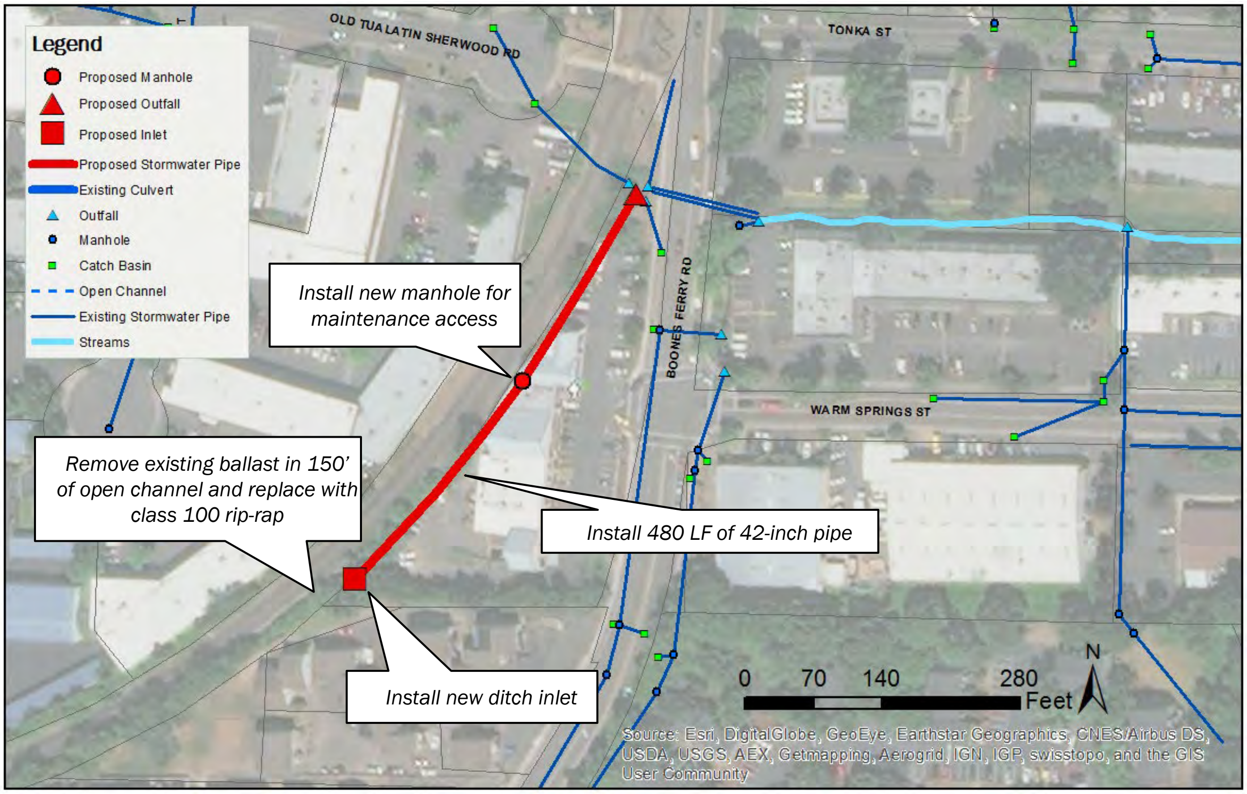
Capital Expense Total (including contingency)	$ 381,000
Engineering and Permitting (35%)	$ 133,000
Administration (10%)	$ 38,000
Capital Project Implementation Cost Total*	**$ 552,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Image 1. Downstream end of culvert with rock/concrete wall for erosion prevention

Image 2. Upstream end of culvert



Project Identifier	CIP #7
Project Name	Boones Ferry Railroad Conveyance Improvements
Detailed Location	Boones Ferry Road and Warm Springs Road
Model File	NY_ALT06.xp
Contributing Drainage Area	160.0 acres
Estimated Existing/Future Impervious %	44.0%/53.1%
Objective(s) Addressed	Addresses Maintenance Need; Addresses Erosion; Increases System Capacity (Flood Control)

Project Background

City staff identified the ditch inlet at the downstream end of the open conveyance channel that runs adjacent to the ODOT railroad right-of-way as an ongoing maintenance issue. A site visit conducted in December 2016 confirmed that gravel and railroad ballast materials are being transported from the open channel and deposited downstream.

City staff also identified flooding and backwater conditions at this location, which has impacted local businesses during large rainfall events. Hydraulic modeling of the open channel and piped system revealed that the pipe is undersized for the contributing drainage area. During the December 2016 site visit, it was confirmed that gravel and ballast material had accumulated in the pipe system and was beginning to fill culverts under Boones Ferry Road, further limiting capacity.

Project Description

This project addresses localized flooding and the need for frequent maintenance along the open conveyance channel adjacent to the ODOT right-of-way.

This project adds large rock along the railroad ballast to stabilize the channel and reduce transport of gravel material into the City's stormwater collection system. The downstream pipe will be upsized to increase flow capacity and improve maintenance access. Specific activities include:

- Remove existing gravel and ballast material along 150 ft of the open conveyance channel, directly upstream of the existing ditch inlet. Install Class 100 rip-rap along the railroad ballast to reduce the potential for material transport.
- Install a new ditch inlet to minimize hydraulic losses at the upstream end of the pipe.
- Replace 480 LF of 36-inch-diameter pipe with 42-inch-diameter pipe.

- Install a 72-inch manhole along pipe alignment for improved maintenance access.
- Install a new outfall to the open channel area directly west of Boones Ferry Road. Add rip-rap for energy dissipation.

Design Considerations

- The open conveyance channel will require regular inspection and maintenance to prevent material transport.
- The pipe is city-owned but located partially on ODOT property and will require close coordination with ODOT and the railroad administration during construction.
- Only planning level hydraulic calculations have been performed to identify conceptual sizing. For design, detailed topographic survey and hydraulic analysis is needed to determine the appropriate invert elevations and pipe diameters to maintain necessary cover and convey the design event.

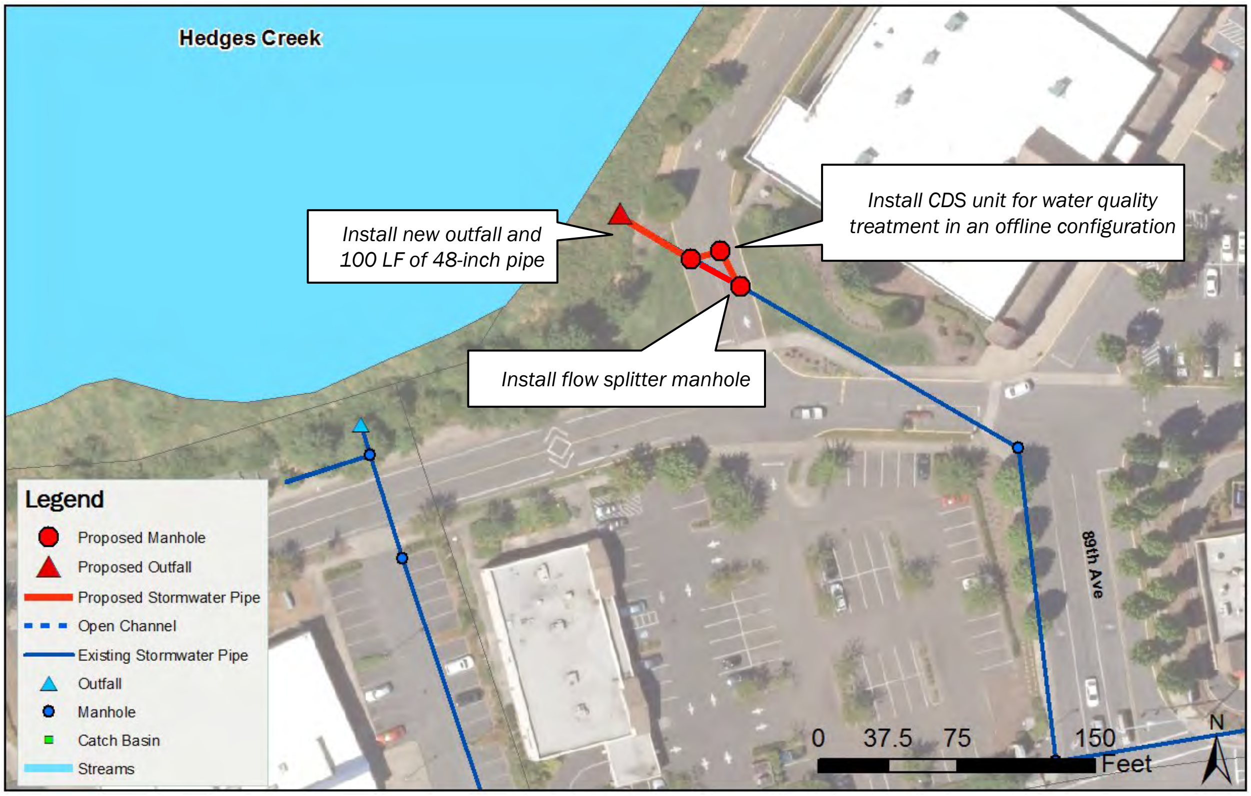
Planning-level Cost Estimate	
Capital Expense Total (including contingency)	$ 356,000
Engineering and Permitting (35%)	$ 124,000
Administration (10%)	$ 36,000
Capital Project Implementation Cost Total*	**$ 515,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Image 1. Ditch inlet at downstream end of railroad open channel

Image 2. Accumulated ballast and debris upstream of culverts across Boones Ferry Road



Project Identifier	CIP #8
Project Name	89th Avenue Water Quality Retrofit
Detailed Location	Outfall at 89th Avenue
Model File	N/A
Contributing Drainage Area	28.9 acres
Estimated Existing/Future Impervious %	75.1%/75.2%
Objective(s) Addressed	Increases Water Quality Treatment (Retrofit)

Project Background

This project was originally identified in the City of Tualatin's Capital Improvement Plan 2017-2021. The upstream stormwater collection system discharges to Hedges Creek wetland and has no water quality treatment. Clean Water Services' (CWS) National Pollutant Discharge Elimination System (NPDES) Stormwater Permit requires retrofit of stormwater systems in partner jurisdictions to provide water quality treatment.

The upstream stormwater conveyance system is relatively shallow with minimal slope. Additionally, the water surface elevation in the wetlands at the outfall is relatively high. Due to the limited drop through the conveyance system and the large contributing drainage area, few water quality treatment devices could be implemented. Contech's CDS hydrodynamic separator unit was selected due to its minimum drop requirements and ability to remove trash and coarse sediment from large contributing drainage areas.

Project Description

This project provides additional water quality treatment for the contributing drainage area to address water quality retrofit objectives referenced in CWS' NPDES permit.

This project includes installation of a Contech CDS hydrodynamic separator (Model CDS3025), with a treatment flow rate of 2.4 cfs. The facility will be installed in an offline configuration, which requires a flow splitter manhole upstream to direct low flows to the CDS unit. The project also includes the installation 50 LF of 24-inch-diameter pipe and 100 LF of 48-inch-diameter pipe to support connections to existing infrastructure and a new outfall structure.

Design Considerations

- Easements may be required to optimize the layout and capture the largest possible drainage area. Easement acquisition is not included in this cost estimate.
- Contech was consulted to verify system sizing and pricing based on the contributing drainage area, proposed system configuration and available drop. Only planning level calculations have been performed to identify conceptual layout.
- Detailed topographic survey is needed to determine the appropriate invert elevations and verify pipe diameters to maintain necessary cover and convey the design event.

Planning-level Cost Estimate

Capital Expense Total (including contingency)	$ 209,000
Engineering and Permitting (15%)	$ 31,000
Administration (10%)	$ 21,000
Capital Project Implementation Cost Total*	**$ 262,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Image 1. Location of proposed water quality manhole

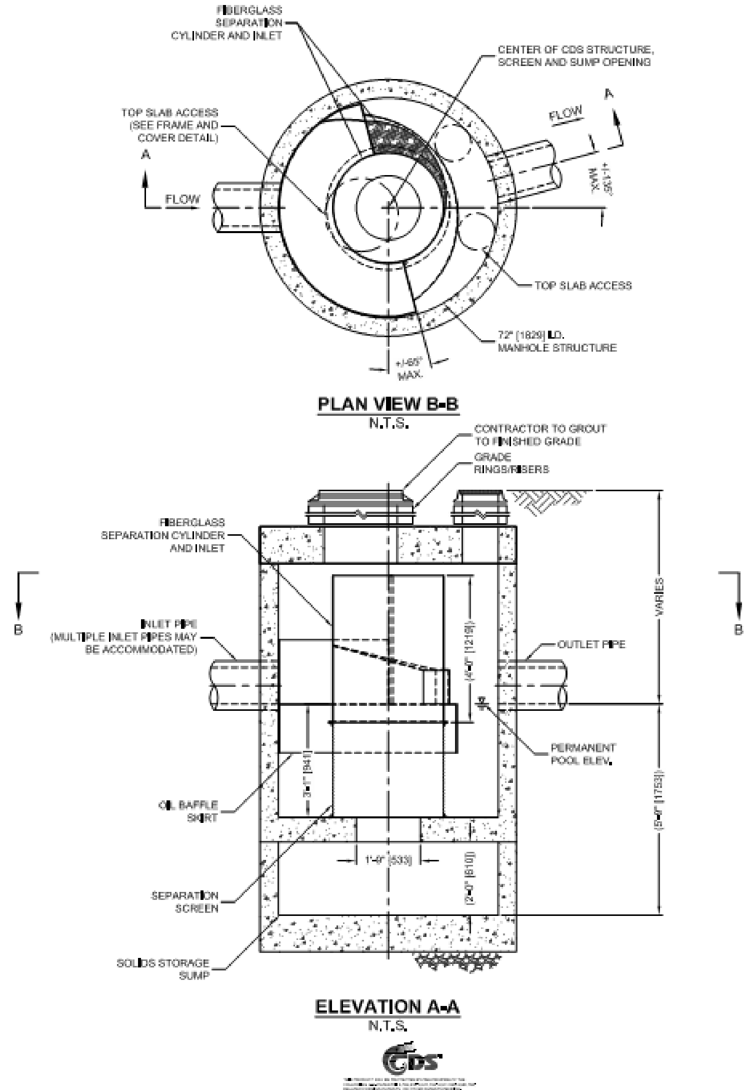


Image 2. Standard detail of Contech CDS3025 unit

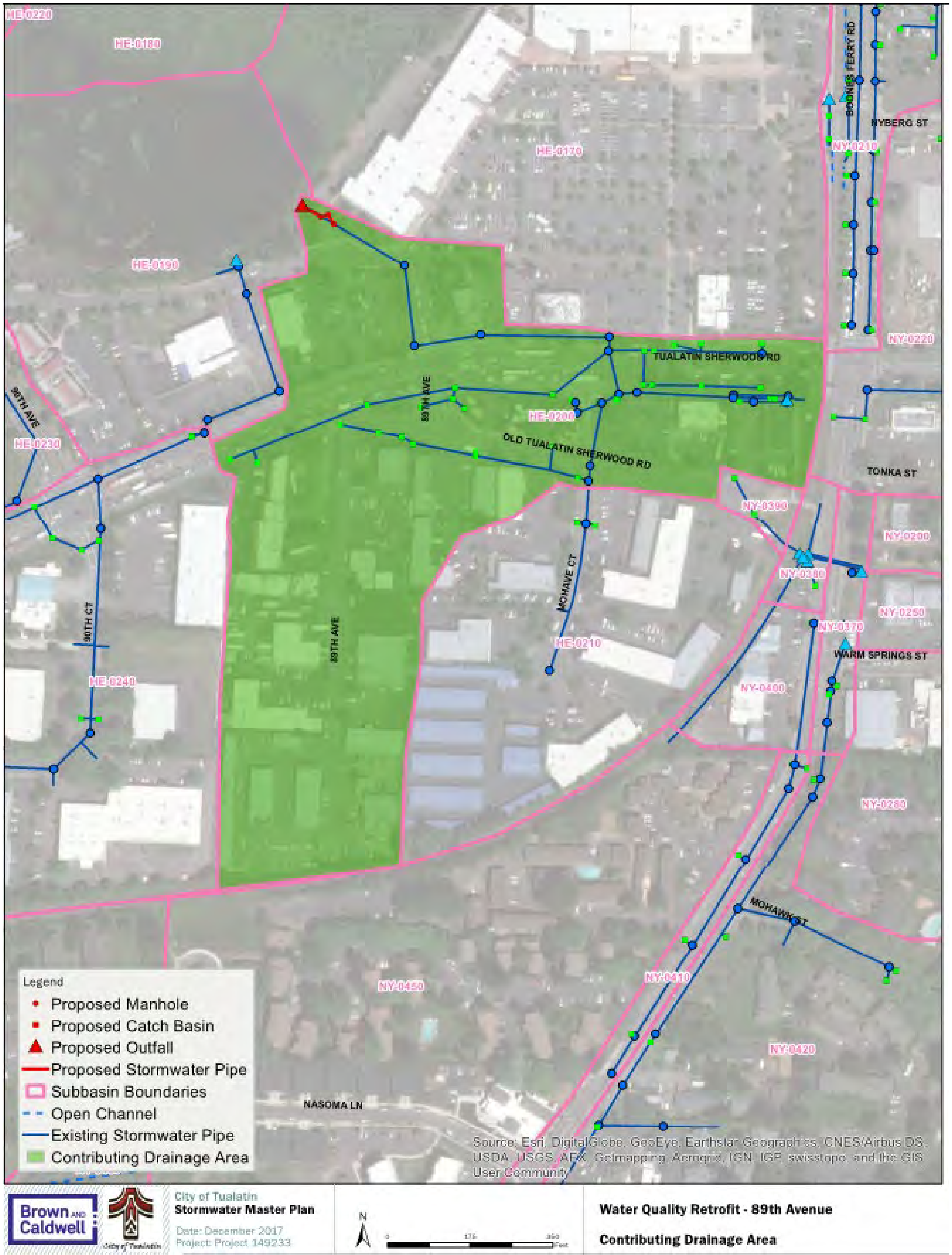
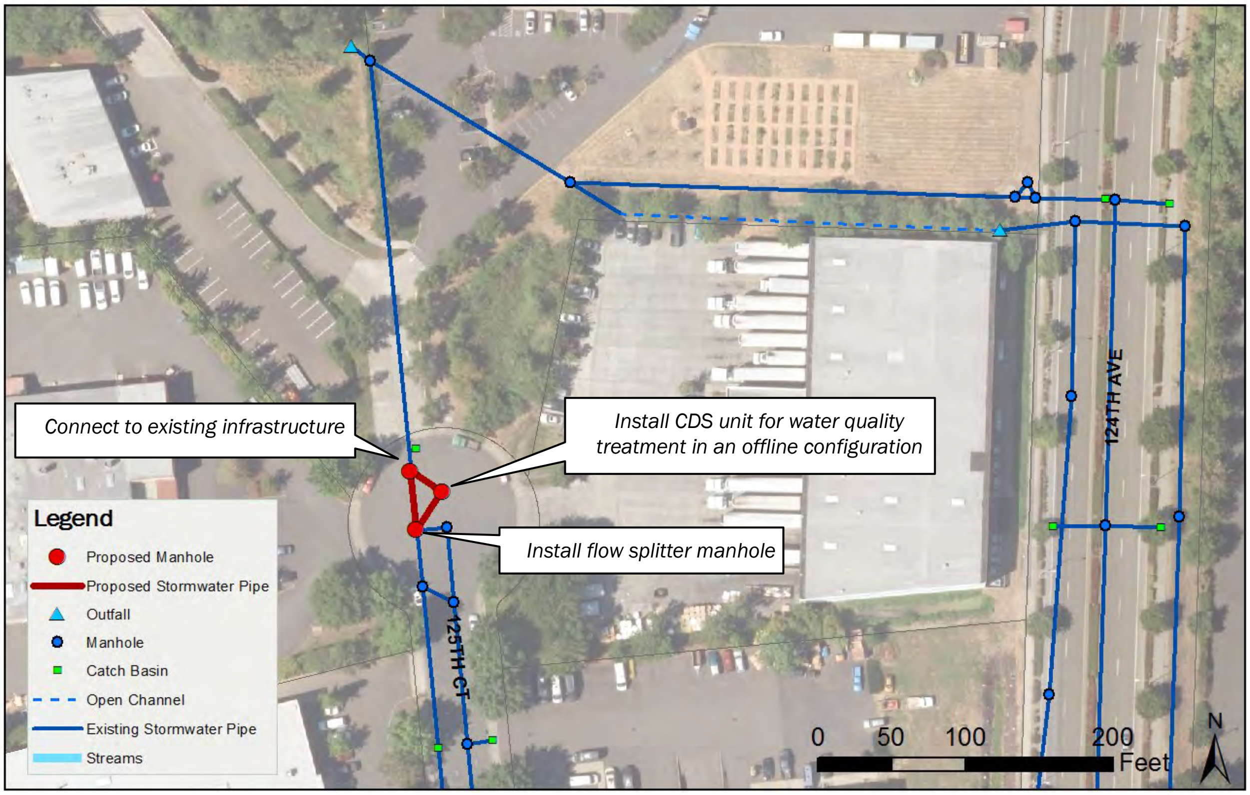


Image 3. Contributing drainage area



Project Identifier	CIP #9
Project Name	125th Court Water Quality Retrofit
Detailed Location	Outfall at 125th Court
Model File	N/A
Contributing Drainage Area	29.3 acres
Estimated Existing/Future Impervious %	52.8%/71.8%
Objective(s) Addressed	Addresses Water Quality Treatment (Retrofit)

Project Background

This project was originally identified in the City of Tualatin's Capital Improvement Plan 2017-2021. The upstream stormwater collection system discharges to the Hedges Creek wetland and has no water quality treatment. Clean Water Service's (CWS) National Pollutant Discharge Elimination System (NPDES) Stormwater Permit requires retrofit of stormwater systems in partner jurisdictions to provide water quality treatment.

The upstream stormwater conveyance system is relatively shallow with minimal slope. Additionally, the water surface elevation in the wetlands at the outfall is relatively high. Due to the limited drop through the conveyance system and the large contributing drainage area, few water quality treatment devices could be implemented. Contech's CDS hydrodynamic separator unit was selected due to its minimum drop requirements and ability to remove trash and coarse sediment from large contributing drainage areas.

Project Description

This project provides additional water quality treatment for the contributing drainage area to address water quality retrofit objectives referenced in CWS' NPDES permit.

This project includes installation of a Contech™ CDS hydrodynamic separator (Model CDS3025), with a treatment flow rate of 2.4 cfs. The facility will be installed in an offline configuration, which requires a flow splitter manhole upstream to direct low flows to the CDS unit. The project also includes the installation of 50 LF of 24-inch-diameter pipe and 50 LF of 36-inch-diameter pipe to support connections to existing infrastructure.

Design Considerations

- Contech TM was consulted to verify system sizing and pricing based on the contributing drainage area, proposed system configuration and available drop. Only planning level calculations have been performed to identify conceptual layout.
- Detailed topographic survey is needed to determine the appropriate invert elevations and verify pipe diameters to maintain necessary cover and convey the design event.

Planning-level Cost Estimate

Capital Expense Total (including contingency)	$ 165,000
Engineering and Permitting (15%)	$ 25,000
Administration (10%)	$ 16,000
Capital Project Implementation Cost Total*	**$ 206,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

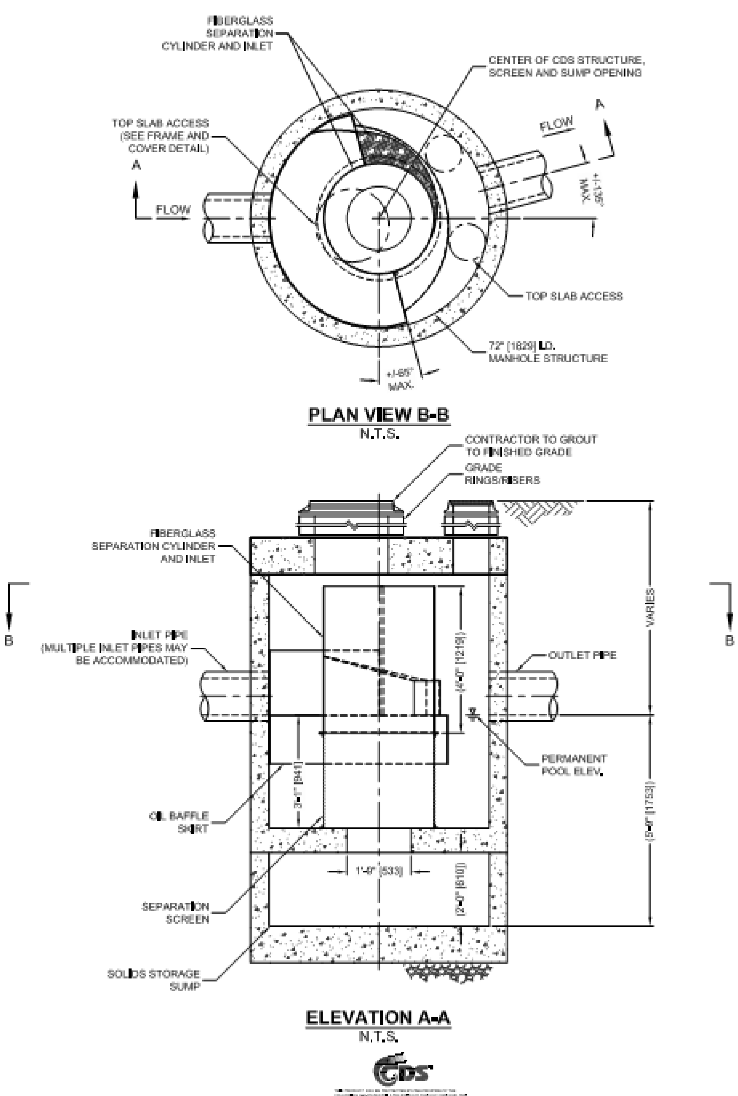
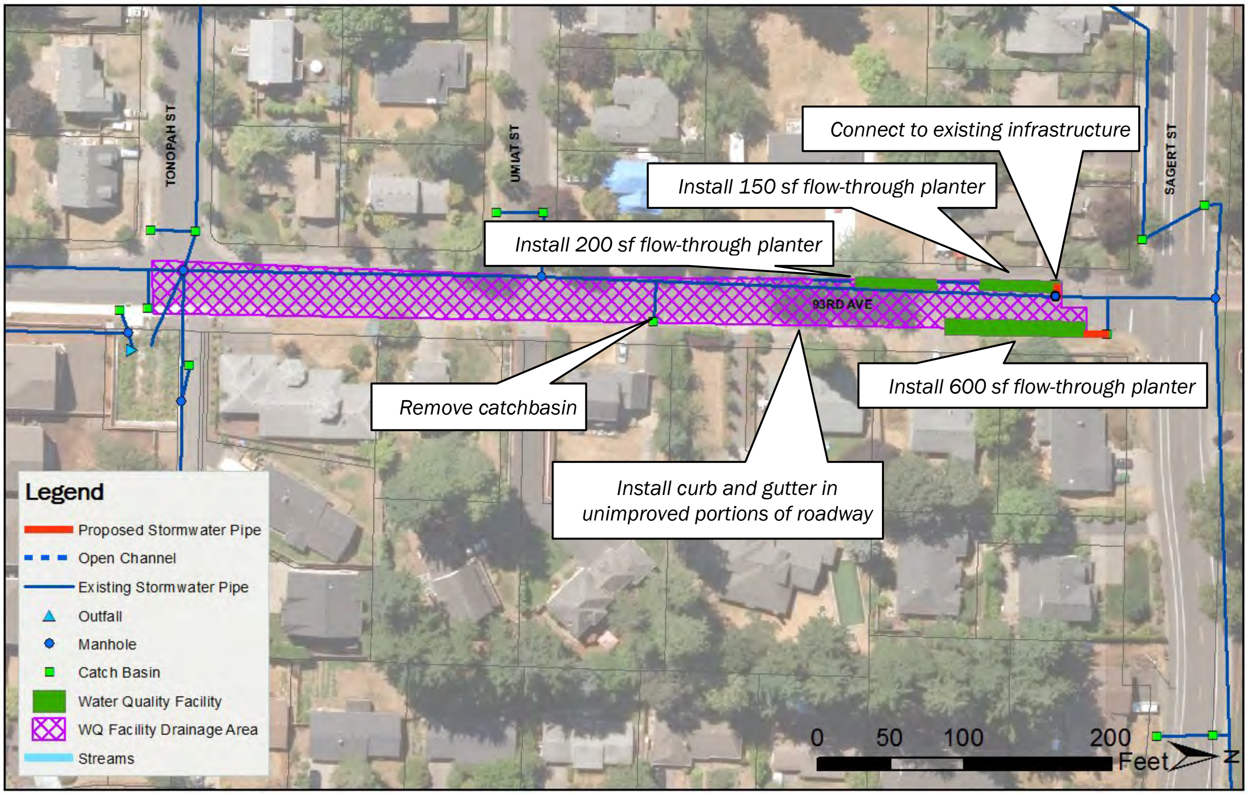


Image 1. Standard detail of Contech CDS3025 unit

Image 3. Contributing drainage area



Project Identifier	CIP #10
Project Name	93rd Avenue Green Street
Detailed Location	93rd Avenue between Umiat Street and Sagert Street
Model File	N/A
Contributing Drainage Area	15,000 square feet
Estimated Existing/Future Impervious %	100%/100%
Objective(s) Addressed	Increases Water Quality Treatment (Retrofit)

Project Background

This project site was identified during a water quality retrofit evaluation as a potential green street pilot project to provide water quality treatment for 93rd Avenue between Umiat Street and Sagert Street.

This section of roadway is unimproved, and runoff is conveyed in roadside ditches before entering a 30-inch concrete stormwater pipe near the intersection of Sagert Street.

Project Description

This project provides additional water quality treatment for the contributing drainage area to address water quality retrofit objectives referenced in Clean Water Services' (CWS) National Pollutant Discharge Elimination System permit. This project features a green street to manage stormwater runoff on an unimproved roadway.

The proposed project includes the installation of stormwater planters to treat approximately 15,000 sf of impervious surface from the roadway, sidewalks and property frontage along the unimproved right-of-way. Due to the poor infiltration characteristics of the soils in this area, flow-through planters with an underdrain and overflow are specified. The graphic above shows potential locations for planters. Curb inlets are assumed at each planter location for purposes of the cost estimate, and the overflow will be piped to the existing conveyance system.

In conjunction with green street facilities, approximately 550 linear feet (LF) of curb and gutter will be installed along 93rd Avenue to direct stormwater runoff to the water quality facilities. The outlets of the water quality facilities will be connected to existing stormwater infrastructure on 93rd Avenue, which drains to a trunk line in Sagert Street.

Design Considerations

- Facility sizing is based on the CWS Low Impact Development Approaches (LIDA) Handbook.
- Street improvements including sidewalk construction have not been included in this cost estimate. Installation of curb and gutter has been included in this cost estimate. It is assumed that green street facility installations will be conducted in conjunction with other roadway improvements.
- Public outreach may be needed to inform local resident and receive feedback regarding the right of way improvements and potential loss of street parking.
- Only planning level calculations have been performed to identify conceptual layout. For design, detailed topographic survey is needed to verify existing infrastructure, determine the appropriate invert elevations and verify facility sizing.

Planning-level Cost Estimate

Capital Expense Total (including contingency)	$ 166,000
Engineering and Permitting (25%)	$ 42,000
Administration (10%)	$ 17,000
Capital Project Implementation Cost Total*	**$ 224,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Image 1. Roadside ditches and unimproved roadway at the north end of 93rd Avenue

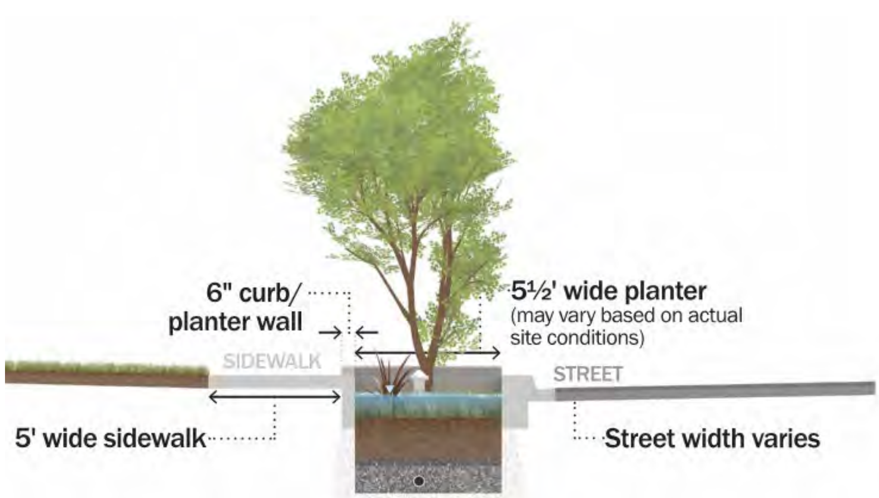
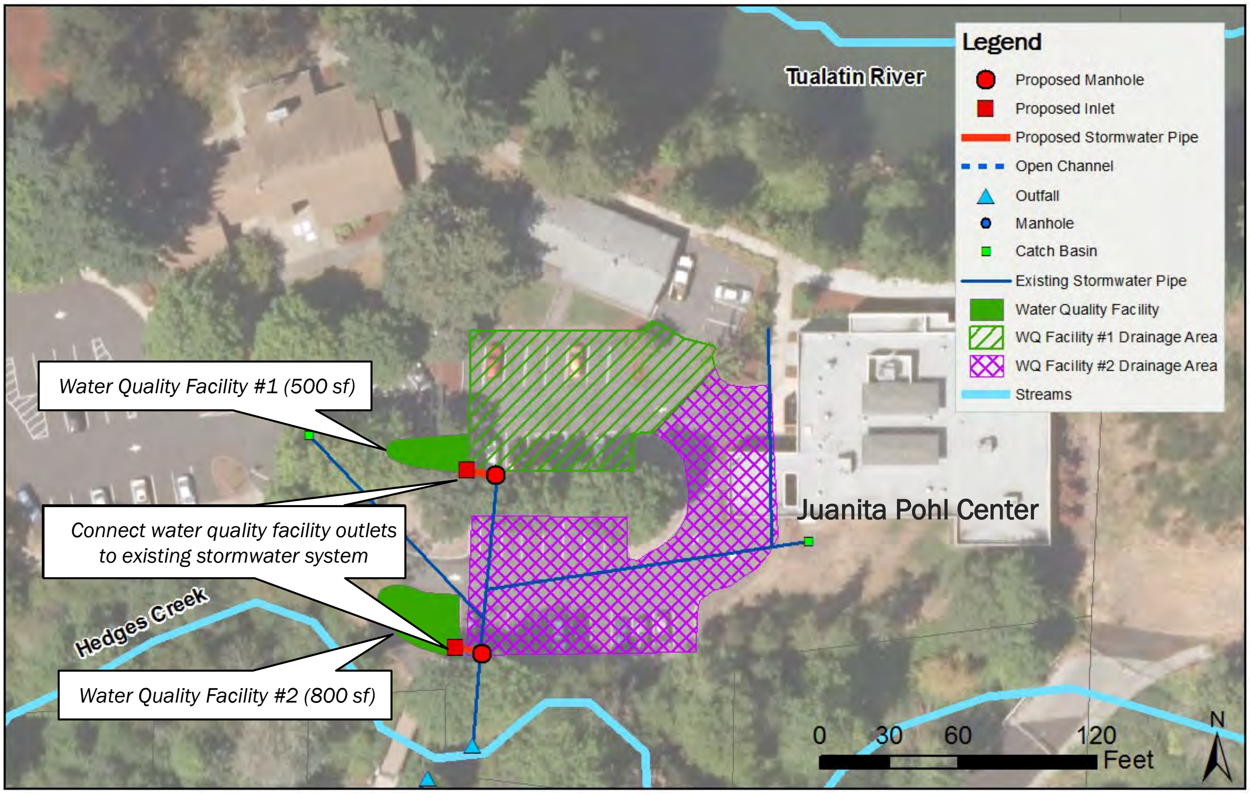


Image 2. Typical green street facility cross section



Project Identifier	CIP #11
Project Name	Juanita Pohl Water Quality Retrofit
Detailed Location	Juanita Pohl Center
Model File	N/A
Contributing Drainage Area	0.4 acres
Estimated Existing/Future Impervious %	100%/100%
Objective(s) Addressed	Increases Water Quality Treatment (Retrofit)

Project Background

This project site was identified during a water quality retrofit evaluation as a potential site to provide treatment for the parking area associated with the Juanita Pohl Center. The parking area is City-owned with a large contributing impervious drainage area (approximately 15,500 sf) that is currently untreated and discharges directly into Hedges Creek.

Project Description

This project provides additional water quality treatment for the contributing drainage area (parking lot) to address water quality retrofit objectives referenced in Clean Water Services' (CWS) National Pollutant Discharge Elimination System permit.

The proposed project includes regrading existing landscape islands to install raingardens for water quality treatment. The existing landscape islands are currently covered with bark chips and not substantially planted with vegetation. Specific activities include:

- Excavation and regrading of the landscape areas and back filling with drain rock and amended soils to support the water quality facility installation.
- Installation of check dams to minimize potential erosion.
- Installation of curb and curb cuts to serve as inlets to the facilities and associated piping to connect the facility overflows to downstream structures (i.e., manholes).
- Plant the facility with native vegetation suitable for a water quality facility.
- Minor repaving of parking stalls near the facilities.

Design Considerations

- Facility sizing is based on the CWS' Low Impact Development Approaches (LIDA) Handbook.
- Only planning level calculations have been performed to identify conceptual layout and sizing. Detailed topographic survey is needed to determine the appropriate invert elevations and optimum facility layout and configuration.

Planning-level Cost Estimate

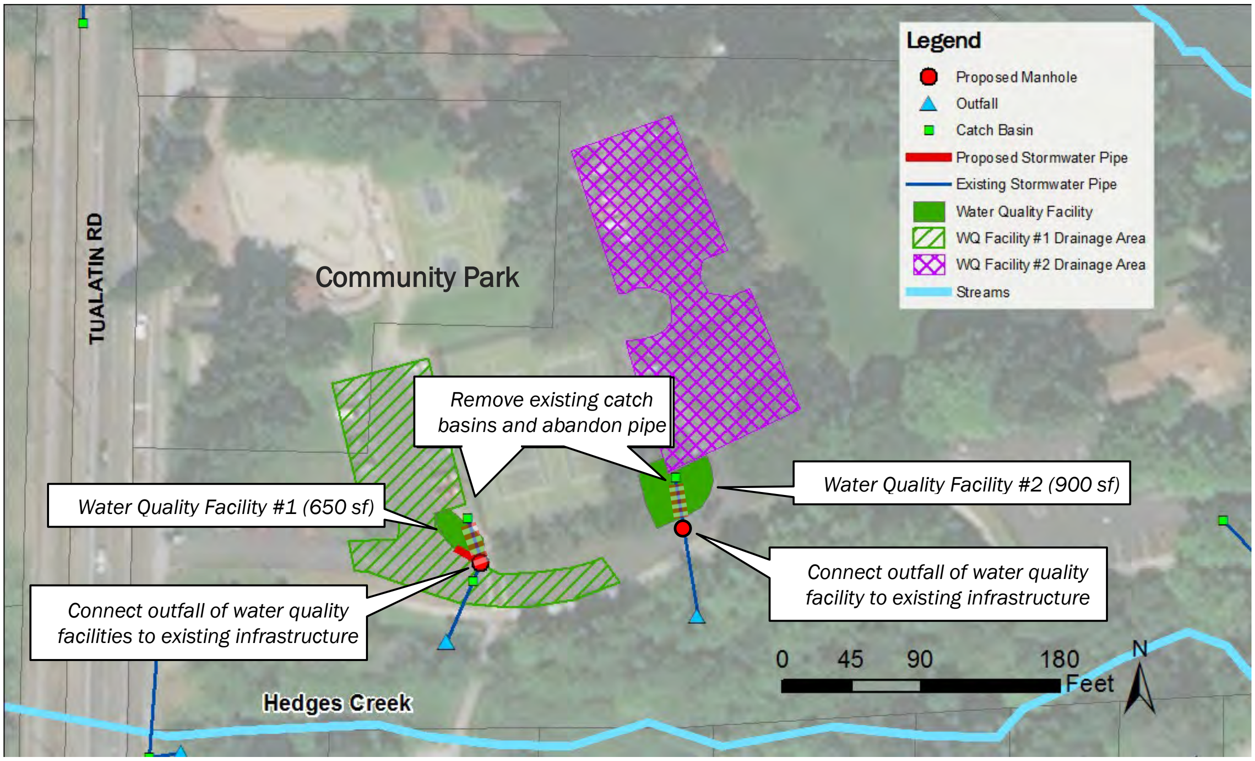
Capital Expense Total (including contingency)	$ 116,000
Engineering and Permitting (25%)	$ 29,000
Administration (10%)	$ 12,000
Capital Project Implementation Cost Total*	**$ 156,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Image 1. Proposed location for water quality facility #1

Image 2. Proposed location for water quality facility #2



Project Identifier	CIP #12
Project Name	Community Park Water Quality Retrofit
Detailed Location	Tualatin Community Park
Model File	N/A
Contributing Drainage Area	0.6 acres
Estimated Existing/Future Impervious %	100 %/100%
Objective(s) Addressed	Increases Water Quality Treatment (Retrofit)

Project Background

This project site was identified during a water quality retrofit evaluation as a potential site to provide treatment for the parking area associated with Tualatin Community Park. The parking area is City-owned with a large contributing impervious drainage area (approximately 25,000 sf) that is currently untreated and discharges directly into Hedges Creek.

Project Description

This project provides additional water quality treatment for the contributing drainage area (parking lot) to address water quality retrofit objectives referenced in Clean Water Services' (CWS) National Pollutant Discharge Elimination System permit.

The proposed project includes regrading existing landscape islands to install raingardens for water quality treatment. The existing landscape islands are currently covered with bark chips and not substantially planted with vegetation. Specific activities include:

- Excavation and regrading of the landscape areas and back filling with drain rock and amended soils to support the water quality facility installation.
- Address existing utilities, light pole, signage, etc.
- Installation of curb and curb cuts to serve as inlets to the facilities and associated piping to connect the facility overflows to downstream structure (i.e., manhole).
- Plant the facility with native vegetation suitable for a water quality facility.

Design Considerations

- Facility sizing is based on the CWS' Low Impact Development Approaches (LIDA) Handbook.
- Only planning level calculations have been performed to identify conceptual layout and sizing. For design, detailed topographic survey is needed to determine the appropriate invert elevations and optimum facility layout and configuration.
- Two established trees are located within the footprint for water quality facility #2. One of the trees may need to be removed and replaced to make room for the treatment facility.

Planning-level Cost Estimate

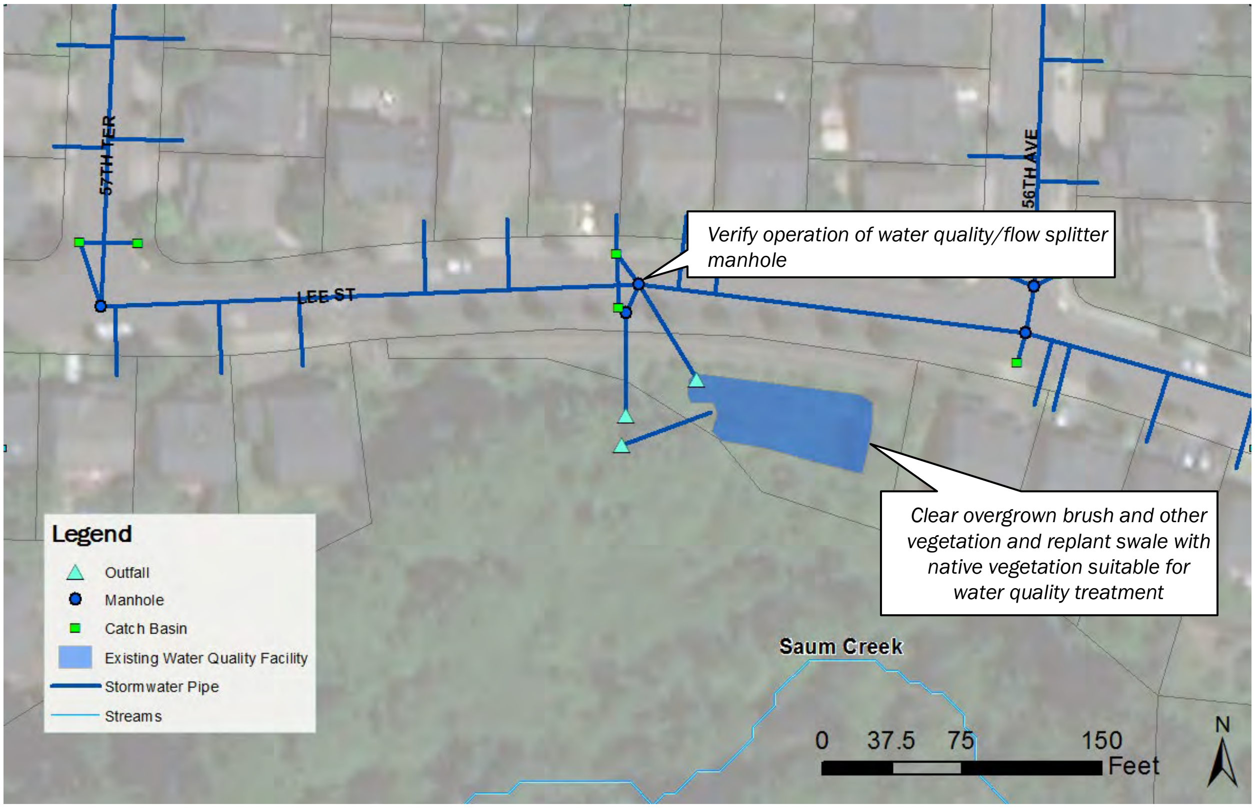
Capital Expense Total (including contingency)	$ 117,000
Engineering and Permitting (25%)	$ 29,000
Administration (10%)	$ 12,000
Capital Project Implementation Cost Total*	**$ 158,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Image 1. Proposed location for Water Quality Facility #1

Image 2. Proposed location for Water Quality Facility #2



Project Identifier	CIP #13
Project Name	Water Quality Facility Restoration-Venetia
Detailed Location	Lee Street and 56th Avenue
Model File	No modeling
Contributing Drainage Area	6.5 acres
Estimated Existing/Future Impervious %	42.2%/52.0%
Objective(s) Addressed	Addresses Maintenance Need; Improves Water Quality

Project Background

This water quality facility receives residential and roadway stormwater drainage from residential development along Lee Street. The original facility design includes a meandering swale for water quality treatment. From the swale, stormwater discharges south directly to Saum Creek. A high flow bypass upstream of the swale controls stormwater flow rates to the swale.

This facility was reported in need of repairs by City staff, and due to access limitations, has not received regular maintenance. During a site visit in June 2016, overgrown vegetation was observed but the facility appeared functional. The overgrown vegetation appeared to have caused nuisance backwatering, which partially washed out an existing access path. The outfall is located at the southwest end of the swale but was not inspected due to a locked gate.

Project Description

This project restores the public water quality facility to its original function by removing accumulated sediment and overgrown vegetation, amending soils and replanting. This project also reestablishes an existing maintenance access.

Specific activities include:

- Clear the trees and large brush growing in the swale.
- Remove accumulated sediment along swale bottom, regrade and replace with amended soils and mulch.
- Replant facility with native vegetation suitable for a water quality facility.
- Verify that the water quality/flow splitter manhole upstream of the facility is operational and diverting the water quality design flow to the facility.

Design Considerations

- Routine maintenance should be conducted to ensure proper functionality.
- Project design should confirm whether the flow splitter manhole needs to be repaired or replaced. Structure and pipe replacement costs are not assumed in the cost estimate.

Planning-level Cost Estimate

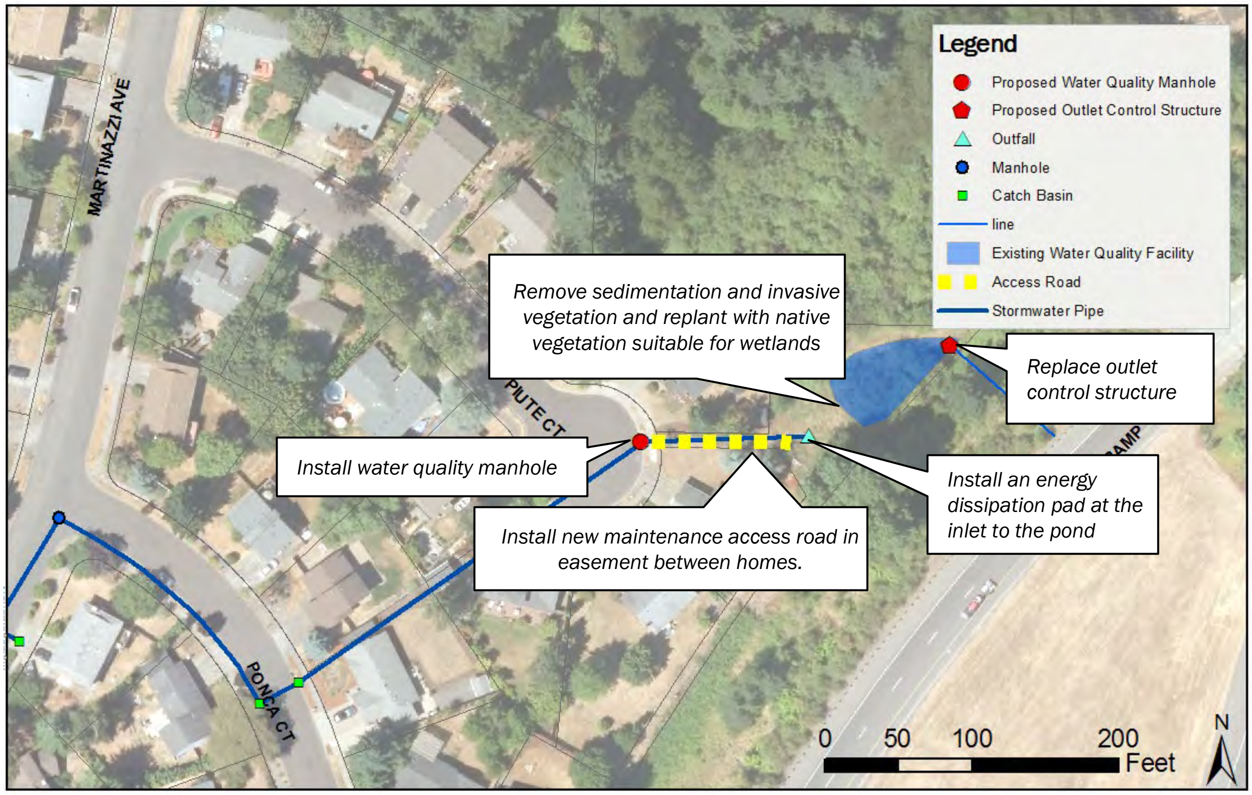
Capital Expense Total (including contingency)	$ 52,000
Engineering and Permitting (15%)	$ 8,000
Administration (10%)	$ 5,000
Capital Project Implementation Cost Total*	**$ 65,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Image 1. Overgrown swale as seen from Lee Street

Image 2. Alternate view of vegetation growing in swale



Project Identifier	CIP #14
Project Name	Water Quality Facility Restoration-Piute Court
Detailed Location	8187 Piute Court
Model File	No modeling
Contributing Drainage Area	28.5 acres
Estimated Existing/Future Impervious %	42.8%/52.7%
Objective(s) Addressed	Addresses Maintenance Need; Improves Water Quality

Project Background

The water quality facility at the end of Piute Court receives residential stormwater drainage from development along Martinazzi Avenue and Iroquois Drive (not shown on map). Stormwater discharges to the facility from the west via a storm pipe from Piute Court. This facility was reported in need of repairs by City staff. During a site visit conducted December 2016, sediment accumulation was observed, and the facility was overgrown with invasive reed canary grass.

A field ditch inlet is located at the north end of the pond, which serves as the outlet control structure. It is believed to discharge east under Interstate 205, but staff were unable to verify the downstream point of discharge.

The City has an easement for maintenance access between homes on Piute Court, but there is currently no access road.

Project Description

This project restores the public water quality facility to its original function by removing accumulated sediment and overgrown vegetation, amending soils and replanting. This project also establishes a dedicated maintenance access road.

Specific activities include:

- Install a 100-foot-long gravel access road in the easement located between homes on Piute Court.
- Remove accumulated sediment and invasive vegetation, regrade the existing facility, and add amended soils and mulch.
- Replant the bottom and sides of facility with riparian/wetland vegetation. Add temporary irrigation.
- Install an energy dissipation pad at the pond inlet.
- Replace the existing ditch inlet with an outfall control structure.
- Install a water quality manhole upstream of the facility, in Piute Court, to reduce sediment load and minimize future maintenance needs.

Design Considerations

- The downstream point of discharge from the pond is currently unknown, and may require coordination with ODOT.
- Routine maintenance should be conducted to ensure proper functionality.
- Additional easements, property acquisition, and private property enhancements associated with installation of the access road (planting, fencing, etc.) is not reflected in the cost estimate.

Planning-level Cost Estimate

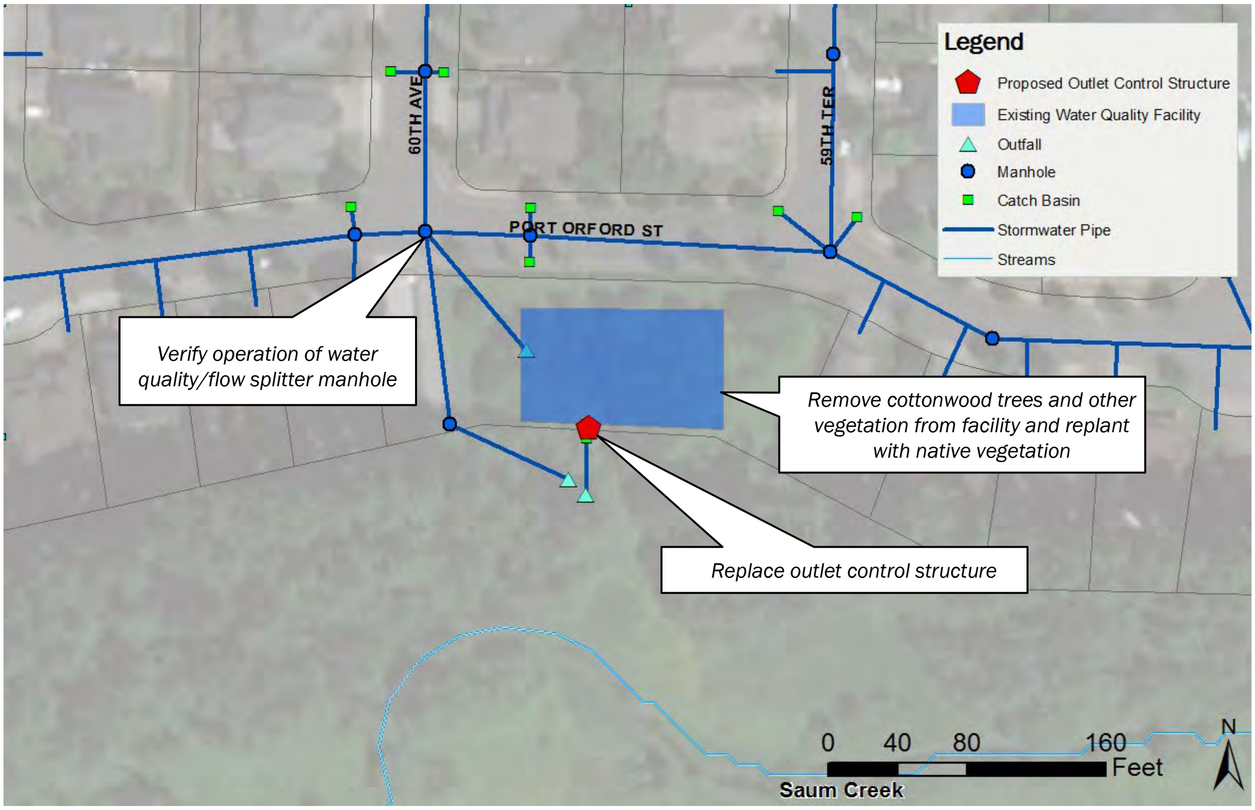
Capital Expense Total (including contingency)	$ 83,000
Engineering and Permitting (15%)	$ 12,000
Administration (10%)	$ 8,000
Capital Project Implementation Cost Total*	**$ 104,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Image 1. Invasive reed canary grass covers most of the bottom of the water quality facility

Image 2. Sediment deposition near outfall of stormwater system



Project Identifier	CIP #15
Project Name	Water Quality Facility Restoration-Sequoia Ridge
Detailed Location	Port Orford Street between SW 59th Terrace and SW 60th Avenue
Model File	No modeling
Contributing Drainage Area	21.7 acres
Estimated Existing/Future Impervious %	37.3%/50.8%
Objective(s) Addressed	Addresses Maintenance Need; Improves Water Quality

Project Background

The water quality facility south of Port Orford Street receives residential stormwater drainage from the surrounding neighborhood. Stormwater discharges to the facility from the northwest and flows south directly into Saum Creek after treatment. The pond is designed to have a capacity of approximately 15,500 cubic feet of storage.

This facility was included as a project in the City's 2017-2021 Capital Improvement Plan and maintenance needs were confirmed by City staff. Mature cottonwood trees are currently growing within the footprint of the pond. During a site visit conducted in December 2016, the outlet control structure appeared clogged with vegetation and debris. No water was seen entering the structure via the low flow pipe and there is standing water in the facility. The outfall from the facility to Saum Creek appeared to be in good condition.

Project Description

This project restores the public water quality facility to its original function by removing accumulated sediment and overgrown vegetation, amending soils and replanting. This project also replaces the outlet control structure to allow the facility to discharge.

Specific activities include:

- Clear all cottonwood trees and other vegetation from the facility.
- Remove accumulated sediment and invasive vegetation and add amended soils.
- Replant the bottom and sides of facility with riparian/wetland vegetation suitable for a stormwater pond. Add temporary irrigation.

- Verify that the water quality/flow splitter manhole upstream of the facility is operational and diverting the water quality design flow to the facility. Remove sediment as needed.
- Install energy dissipation pad at pond inlet.
- Redesign the outlet control structure to have functional low flow pipe and high flow overflow. Remove the current cap and install an overflow plate in accordance with current CWS design standards.

Design Considerations

- Routine maintenance should be conducted to ensure proper functionality.
- Project design should verify sizing of the outlet control structure including the low flow pipe. Pipe replacement has not been included in the cost estimate.
- Project design should confirm whether the flow splitter manhole needs to be repaired or replaced. Structure and pipe replacement costs are not assumed in the cost estimate.

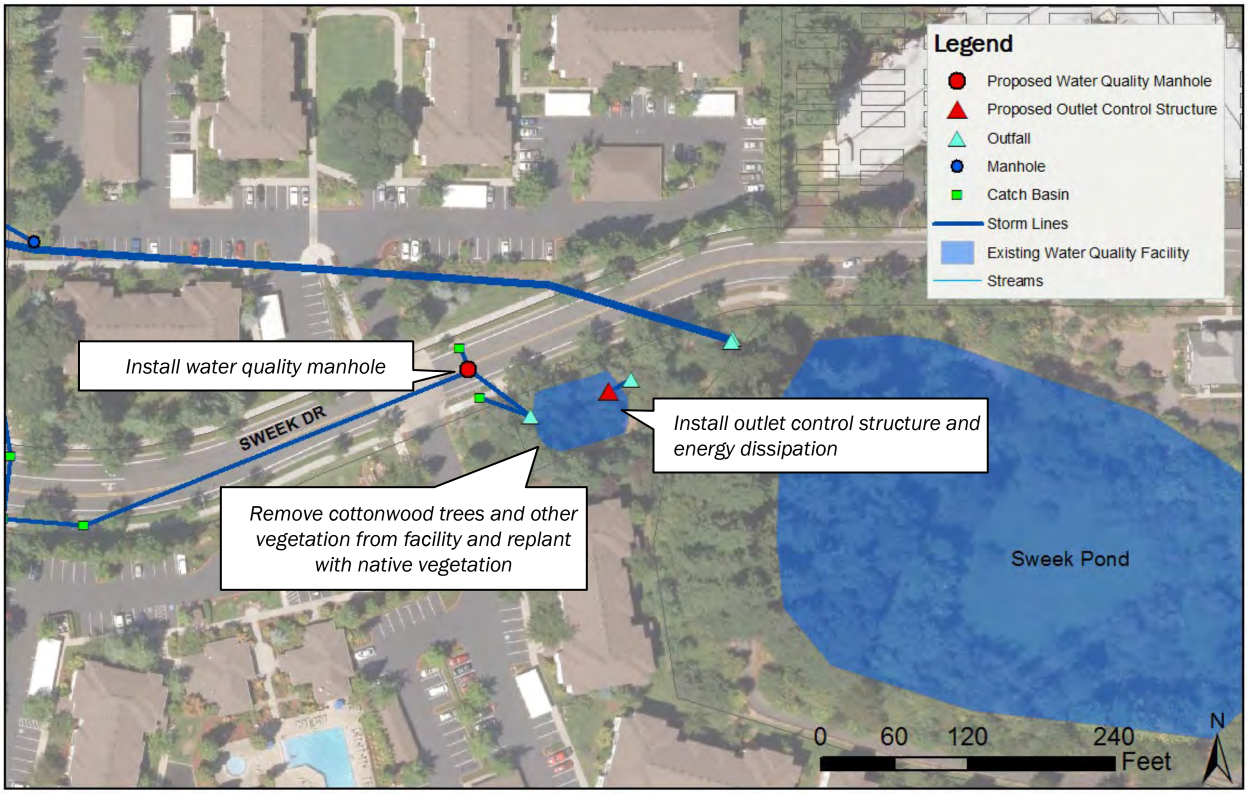
Planning-level Cost Estimate	
Capital Expense Total (including contingency)	$ 67,000
Engineering and Permitting (15%)	$ 10,000
Administration (10%)	$ 7,000
Capital Project Implementation Cost Total*	**$ 83,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Image 1. Large cottonwood trees in water quality facility

Image 2. Existing pond outfall control structure



Project Identifier	CIP #16
Project Name	Water Quality Facility Restoration-Sweek Drive Pond
Detailed Location	Sweek Drive and Tualatin Road
Model File	No modeling
Contributing Drainage Area	2.5 acres
Estimated Existing/Future Impervious %	41.5%/50.3%
Objective(s) Addressed	Address Maintenance Need; Improves Water Quality

Project Background

The water quality facility south of Sweek Drive treats stormwater runoff from Sweek Drive and a portion of 90th Avenue. This facility appears to discharge freely, without a control structure, to the larger Sweek Pond, located directly to the east.

This facility was included as a project in the City's 2017-2021 Capital Improvement Plan and maintenance needs were confirmed by City staff. During a site visit conducted in December 2016, mature cottonwood trees and other vegetation were seen growing throughout the pond bottom.

Project Description

This project restores the public water quality facility to its original function by removing accumulated sediment and overgrown vegetation, amending soils and replanting. This project includes installation of an outlet control structure to better utilize storage.

Specific activities include:

- Clear all cottonwood trees and other vegetation from the facility.
- Remove accumulated sediment and invasive vegetation and add amended soils.
- Replant the bottom and sides of the facility with native vegetation suitable for a stormwater pond. Add temporary irrigation.
- Install a water quality manhole upstream of the pond to minimize sediment loading.
- Install an energy dissipation pad at the pond inlet
- Install a new outlet control structure and energy dissipation pad.

Design Considerations

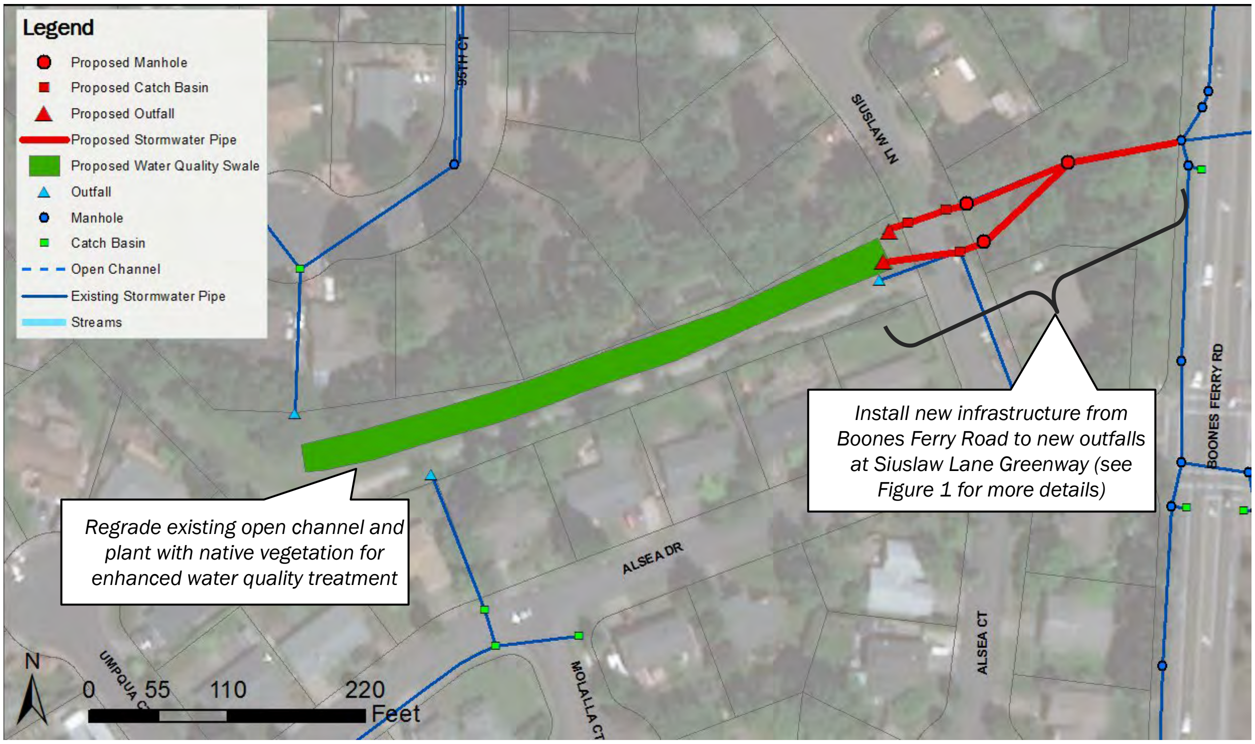
- Routine maintenance should be conducted to ensure proper functionality.

Planning-level Cost Estimate	
Capital Expense Total (including contingency)	$ 83,000
Engineering and Permitting (15%)	$ 12,000
Administration (10%)	$ 8,000
Capital Project Implementation Cost Total*	**$ 103,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Image 1. Vegetation and cottonwood trees growing in the water quality facility



Project Identifier	CIP #17
Project Name	Siuslaw Water Quality Retrofit
Detailed Location	Siuslaw Lane Greenway
Model File	N/A
Contributing Drainage Area	70.3 acres
Estimated Existing/Future Impervious %	39.4%/48.3%
Objective(s) Addressed	Addresses Maintenance Need; Increases Water Quality Treatment (Retrofit)

Project Background

The existing open channel conveyance system in the greenway along Siuslaw Lane receives residential stormwater drainage from nearby neighborhoods. Stormwater enters the open channel from Boones Ferry Road and discharges to a ditch inlet adjacent to 98th Avenue.

City staff identified this site during a water quality retrofit evaluation as a potential stormwater treatment facility retrofit. During a site visit in December 2016, sediment was observed near the two outfalls to the open channel. The corrugated metal pipes were also reported to be in poor condition and significant rust and corrosion was observed.

Project Description

This project replaces infrastructure that is in poor condition and provides water quality treatment in the form of a bioswale.

The stormwater conveyance system will be replaced from Boones Ferry to the outfalls at the existing greenway. This includes the installation of 350 LF of 30-inch-diameter pipe and 100 LF of 48-inch-diameter pipe. A flow splitter/water quality manhole will be installed along this alignment to minimize sediment loading to the new bioswale. The project also includes replacement of 3 catch basins, 2 manholes, and the installation of 5 check dams and energy dissipation at the outfall to the open channel.

The proposed project also includes grading the existing open channel conveyance to serve as a bioswale for water quality treatment. The resulting 15-ft-wide by 500-ft-long bioswale will include amended soils and vegetation enhancement to improve water quality treatment and enhance visual appeal.

Design Considerations

- Water quality facility sizing and design is based on the Clean Water Services Low Impact Development Approaches (LIDA) Handbook. The LIDA Handbook should be referenced for design guidelines on swales.
- Routine maintenance should be conducted to ensure proper functionality.

- Final swale alignment and configuration must consider potential grading impacts to the existing trees and the paved walking path.
- Only planning level calculations have been performed to identify conceptual layout and sizing. Detailed topographic survey is needed to determine the extent of grading required, the existing size and elevation of the upstream collection system, and appropriate invert elevations to maintain necessary slope and convey the design event.

Planning-level Cost Estimate	
Capital Expense Total (including contingency)	$ 336,000
Engineering and Permitting (25%)	$ 84,000
Administration (10%)	$ 34,000
Capital Project Implementation Cost Total*	**$ 454,000**

Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.

Additional Project Information

Image 1. Existing outfalls to Siuslaw Lane Greenway

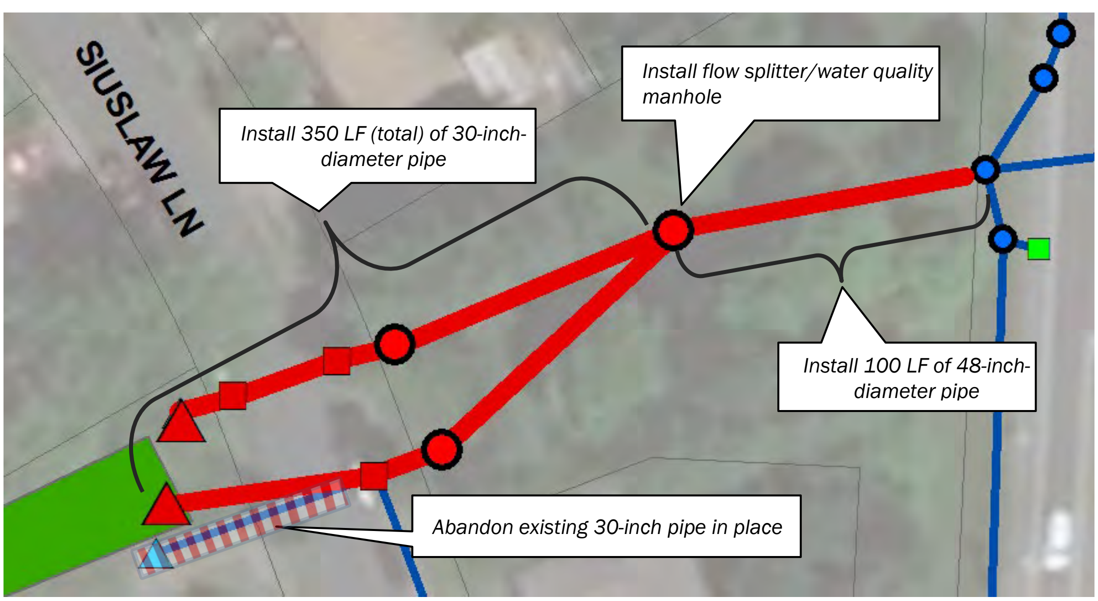
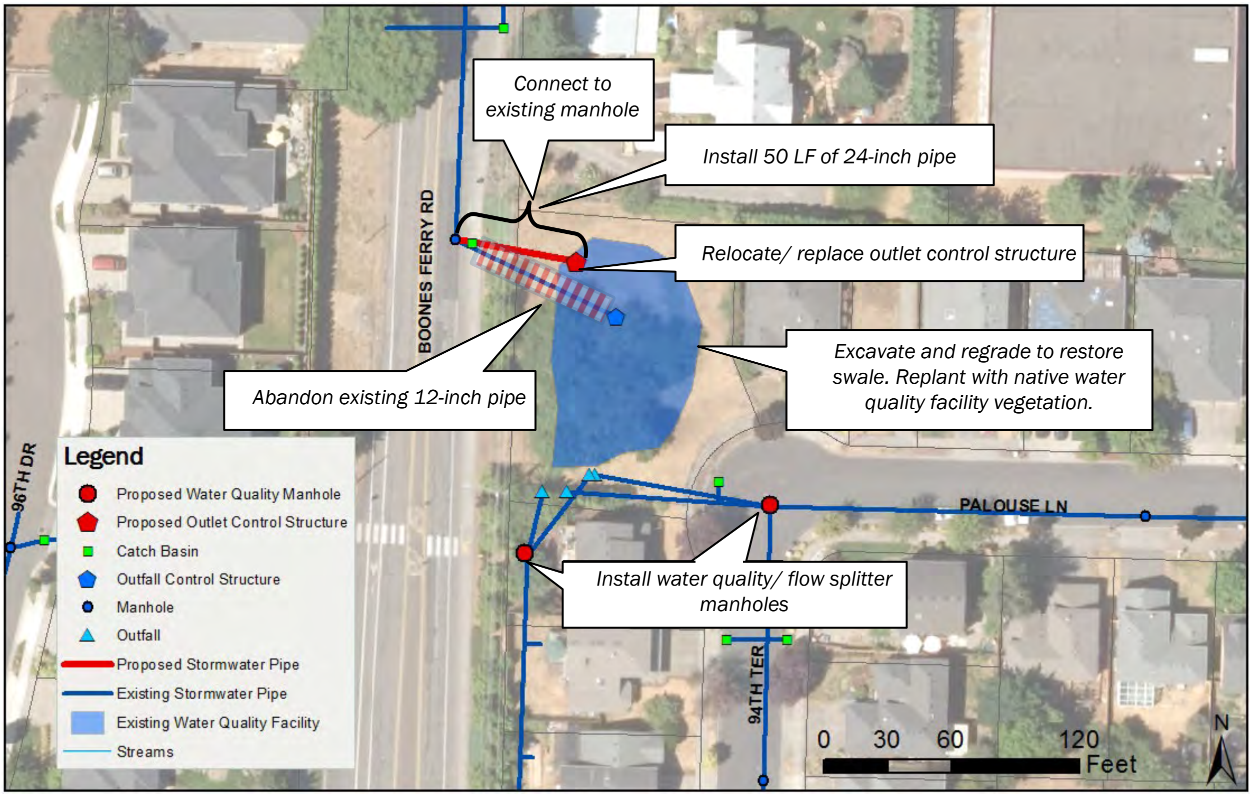


Figure 1. Construction details of new infrastructure



Project Identifier	CIP #18
Project Name	Water Quality Facility Restoration-Waterford
Detailed Location	Palouse Lane and 94th Terrace
Model File	No modeling
Contributing Drainage Area	19.4 acres
Estimated Existing/Future Impervious %	44.8%/54.6%
Objective(s) Addressed	Address Maintenance Need; Improves Water Quality

Project Background

The water quality facility located between Palouse Lane and Boones Ferry Road receives residential stormwater runoff from the surrounding neighborhood. Stormwater discharges to the facility from the south. Stormwater discharges from the facility to the west via a pipe under Boones Ferry Road. As-builts indicate the pond was designed to be approximately 4 feet deep with a bottom area of 2,500 square feet. The original design included a water quality swale around the pond perimeter to provide pretreatment of low flows. High flows discharge directly to the pond and bypass the swale.

This facility was included as a project in the City's 2017-2021 Capital Improvement Plan and maintenance needs were confirmed by City staff.

During a site visit in December 2016, accumulated sediment was found to have filled in the swale causing all water to bypass the swale. There is little/no vegetation present in the pond and swale. The outlet of the facility is in the middle of the pond, preventing maintenance during high water events.

Project Description

This project restores the public water quality facility to its original function by removing accumulated sediment and overgrown vegetation, amending soils and replanting. This project also relocates the outlet structure to improve maintenance access.

Specific activities include:

- Clear invasive and unwanted vegetation from the facility.
- Excavate and regrade as needed to maximize water quality function and restore to original design.
- Remove accumulated sediment and replace with amended soils.

- Replant the swale and bottom and sides of the pond facility with native vegetation suitable for a swale and water quality pond. Add temporary irrigation.
- Relocate and replace the outlet control structure to the edge of pond for improved maintenance access.
- Replace inlet rip rap for increased energy dissipation.
- Install two water quality/flow splitter manholes upstream of facility to minimize sediment loading.

Design Considerations

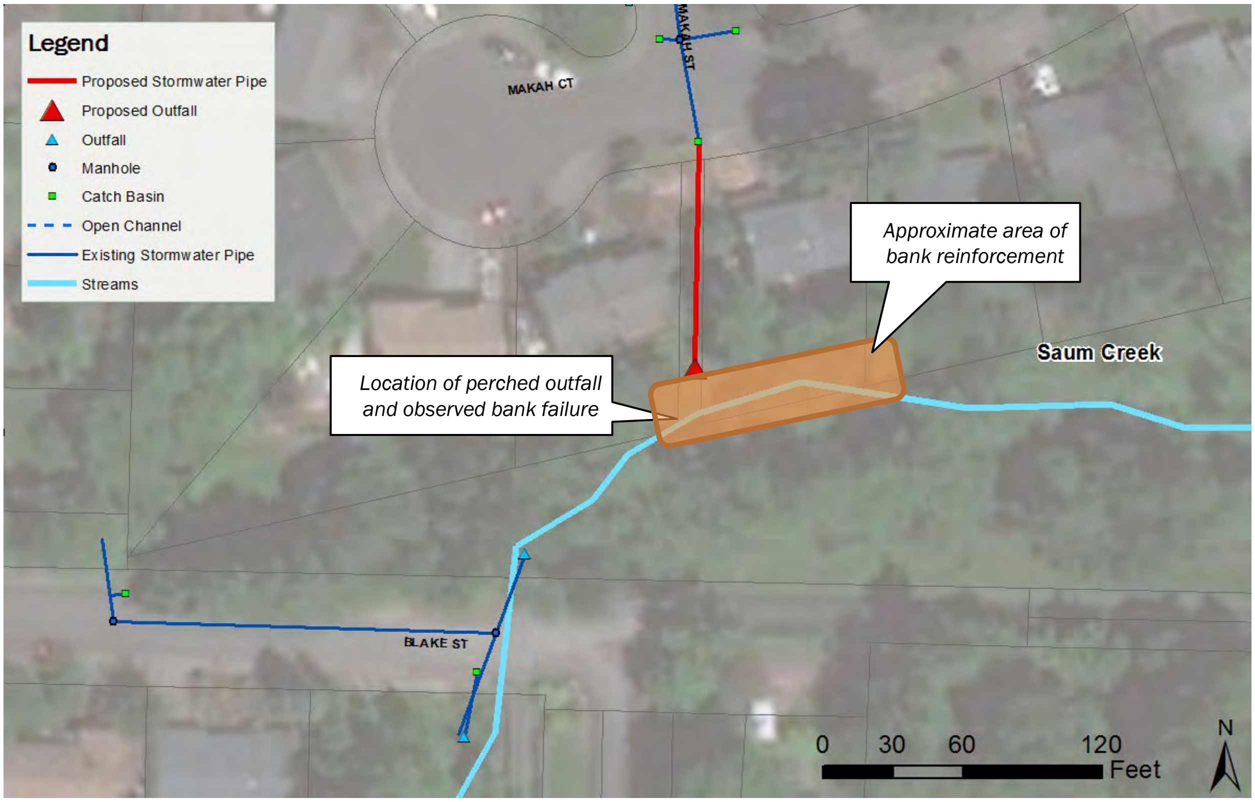
- Routine maintenance should be conducted to ensure proper functionality.
- Project design should verify sizing and configuration of the flow control manholes and outlet control structure. Detailed topographic survey is needed to confirm appropriate invert elevations and pipe diameters. Inlet pipe replacement is not included in the cost estimate.
- Project design should evaluate sizing and configuration of the outlet control structure to optimize storage and mitigation of peak flow rates and the duration of flow to Hedges Creek. If enhanced flow control is provided, this project may qualify as a retrofit opportunity.

Planning-level Cost Estimate	
Capital Expense Total (including contingency)	$ 144,000
Engineering and Permitting (15%)	$ 22,000
Administration (10%)	$ 14,000
Capital Project Implementation Cost Total*	**$ 180,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Image 1. Waterford water quality facility as seen from Palouse Lane



Project Identifier	CIP #19
Project Name	Saum Creek Hillslope Repair
Detailed Location	Blake Street at Saum Creek
Model File	N/A
Contributing Drainage Area	142.2 acres to Saum Creek/5.0 acres to outfall
Estimated Existing /Future Impervious %	39.4%/46.8%
Objective(s) Addressed	Addresses Erosion; Addresses Maintenance Need

Project Background

City staff and adjacent property owners identified the outfall into Saum Creek at Blake Street as an erosion and bank stability concern. City maintenance staff report severe bank erosion at this location. Site visits, including a field stream assessment in September 2017, revealed bank erosion along the unprotected bank slope and groundwater seepage along the bank itself. The outfall from Blake Street is perched approximately 7 feet above the creek bed. Bank failure was also observed approximately 100 feet downstream, suggesting the need for a geotechnical evaluation of the reach. Saum Creek itself appears stabilized due to a clay/hard pan layer which prevents downcutting at this location.

The cause of the bank failure is not clear. Stormwater pipe condition deficiencies have been reported upstream of the outfall, which could contribute to slope instability, depending on subsurface geologic conditions and preferential flow paths. The storm pipe and outfall require replacement due to structural deficiencies identified by City staff.

Project Description

This project replaces infrastructure that is in poor condition and allocates funding resources to investigate and address existing slope instability.

This project includes replacement of the storm pipe from Makah Ct. to the outfall and outfall reconstruction and extension to the stream channel. Hillslope rehabilitation will be conducted in conjunction with the pipe and outfall replacement to incorporate energy dissipation and minimize future erosion and slope instability. A lump sum of $20,000 is reflected in the cost estimate for a geotechnical evaluation prior to design and construction, to evaluate hillslope rehabilitation options.

Potential rehabilitation and bank stabilization options include rock buttresses or the import of new fill material and horizontal plantings. These options are typical approaches to correcting typical bank failures. For planning-level cost estimation purposes, installation of rock buttresses is proposed (Figure 1). However, upon geotechnical consultation and consideration of the final pipe and outfall design, bioengineering solutions may be feasible and/or appropriate (Figure 2).

Design Considerations

- Only planning level calculations have been performed to identify pipe size and hillslope reinforcement needs to determine a conceptual project cost.
- A geotechnical evaluation is recommended prior to detailed design to evaluate soil and groundwater conditions in this area and select a preferred design approach in consideration of site conditions and constraints.

Planning-level Cost Estimate

Capital Expense Total (including contingency)	$ 104,000
Geotechnical Engineering (LS)	$ 20,000
Engineering and Permitting (35%)	$ 37,000
Administration (10%)	$ 10,000
Capital Project Implementation Cost Total*	**$ 171,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

Image 1. Perched outfall from Blake Street with severe bank failure

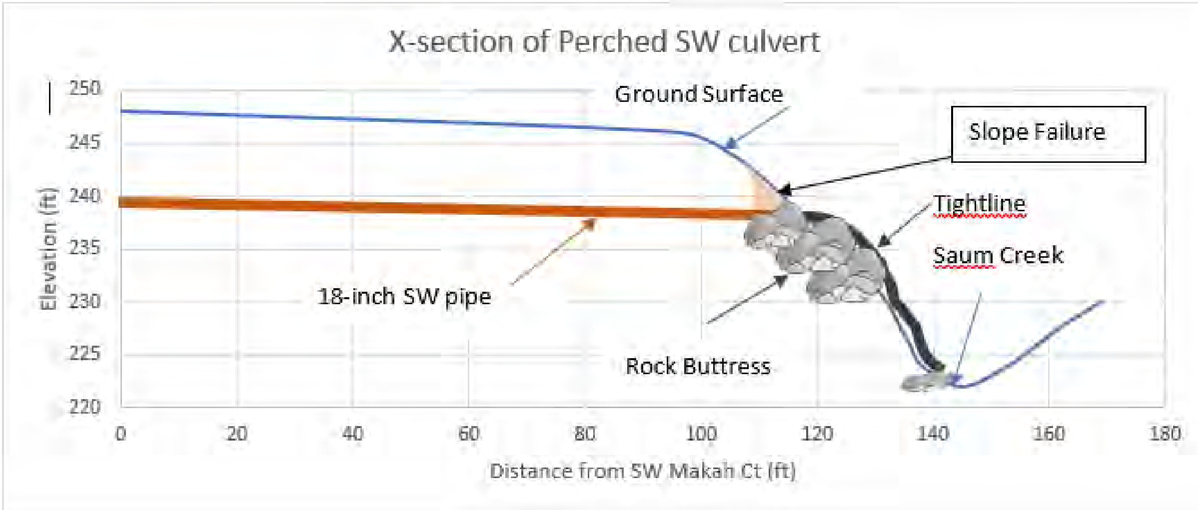


Figure 1. Hillslope Rehabilitation Option - Rock Buttress

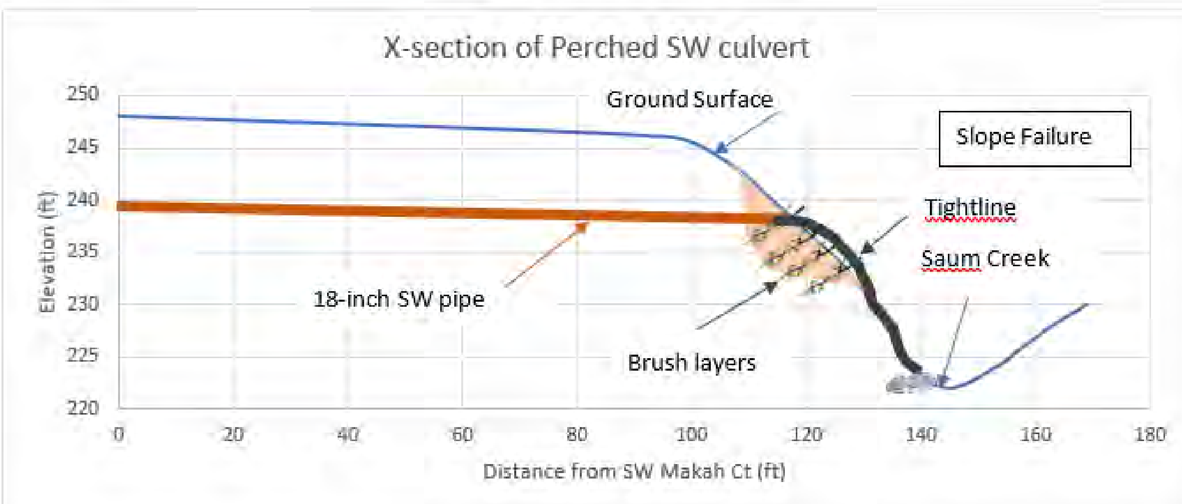
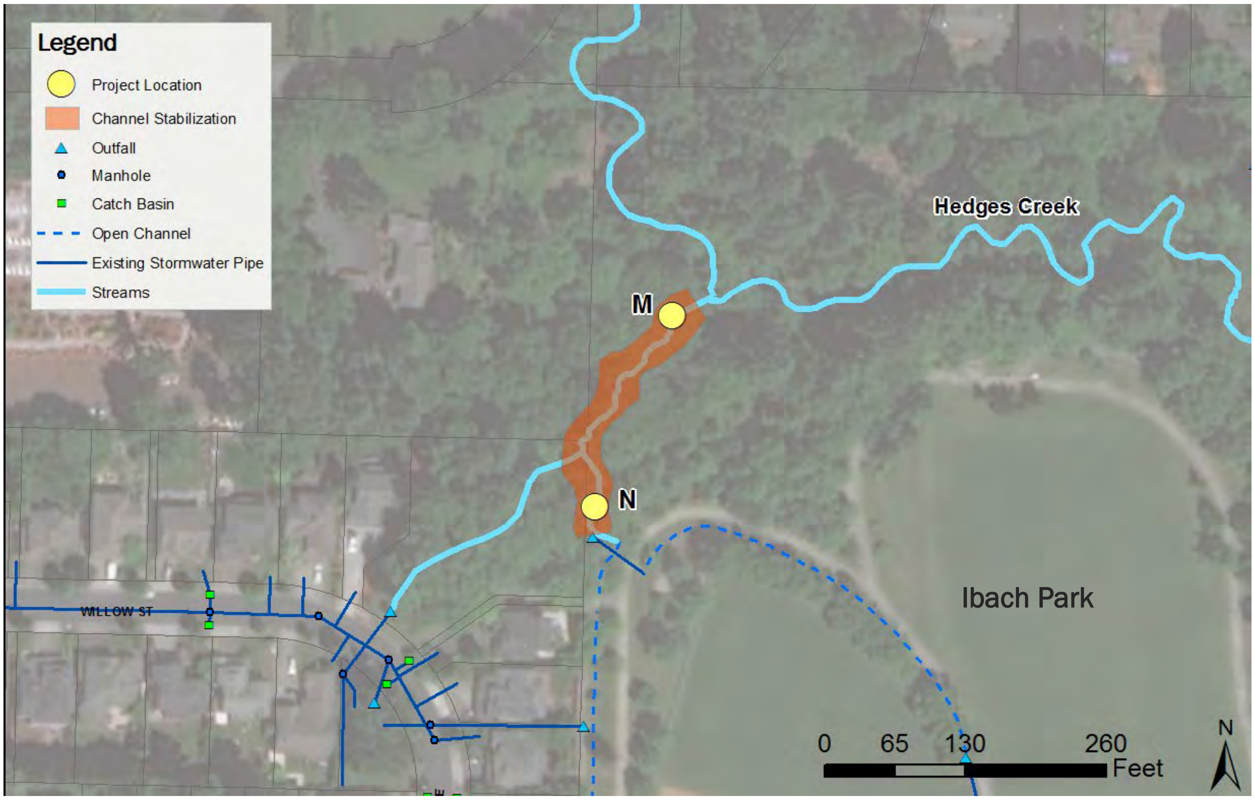


Figure 2. Hillslope Rehabilitation Option – Bioengineering with Brush Layering



Project Identifier	CIP #20
Project Name	Hedges Creek Stream Repair
Detailed Location	SW 106th Ave and Willow Street at Hedges Creek
Model File	N/A
Contributing Drainage Area	32.7 acres to outfall
Estimated Existing/Future Impervious %	23.5%/29.3%
Project Objective(s)	Addresses Erosion

Project Background

Site visits, including a field stream assessment in September 2017, identified active bank erosion in this stream reach vicinity and potential project needs. This project was also identified through a separate evaluation for the City Parks Department (Hedges Creek Stream Assessment, February 2018).

The outfall at the corner of SW Willow Street and SW 106th Ave discharges stormwater runoff to a tributary to Hedges Creek from upland residential development. Development in this area appears to be constructed with limited stormwater flow control, resulting in hydromodification along this tributary. Location 'M' was observed to have active erosion occurring adjacent to, upstream and downstream of an existing sanitary manhole. Location 'N' was not visited as part of the stream assessment but reflects similar erosion conditions as location 'M' with evidence of erosion at the pipe outfall. Observations for Location 'N' are documented in the separate evaluation for the City Parks Department.

Project Description

This project addresses instream channel erosion and threatened public infrastructure.

Corrective actions are referenced directly from the Hedges Creek Stream Assessment by others. Site 'N' activities include an outfall extension, bioengineered slopes, streambed fill and vegetation restoration. Site 'M' activities include open channel excavation, stream bed fill, and installation of a retaining wall.

Design Assumptions and Considerations

- Detailed design information related to the proposed corrective actions are included in the "Hedges Creek Stream Assessment, SW Ibach Street to SW 105th Avenue", February 2018, GreenWorks PC and OTAK, Inc.
- Costs summarized below were taken directly from the "Hedges Creek (SW Ibach Road to SW 105th Avenue) Stream Assessment, CIP Opinion of Construction Costs for Identified Sites", February 2018, GreenWorks PC and OTAK, Inc.
- Corrective actions employed along this reach should consider both protection of sanitary system infrastructure and channel and outfall stabilization to prevent further erosion.

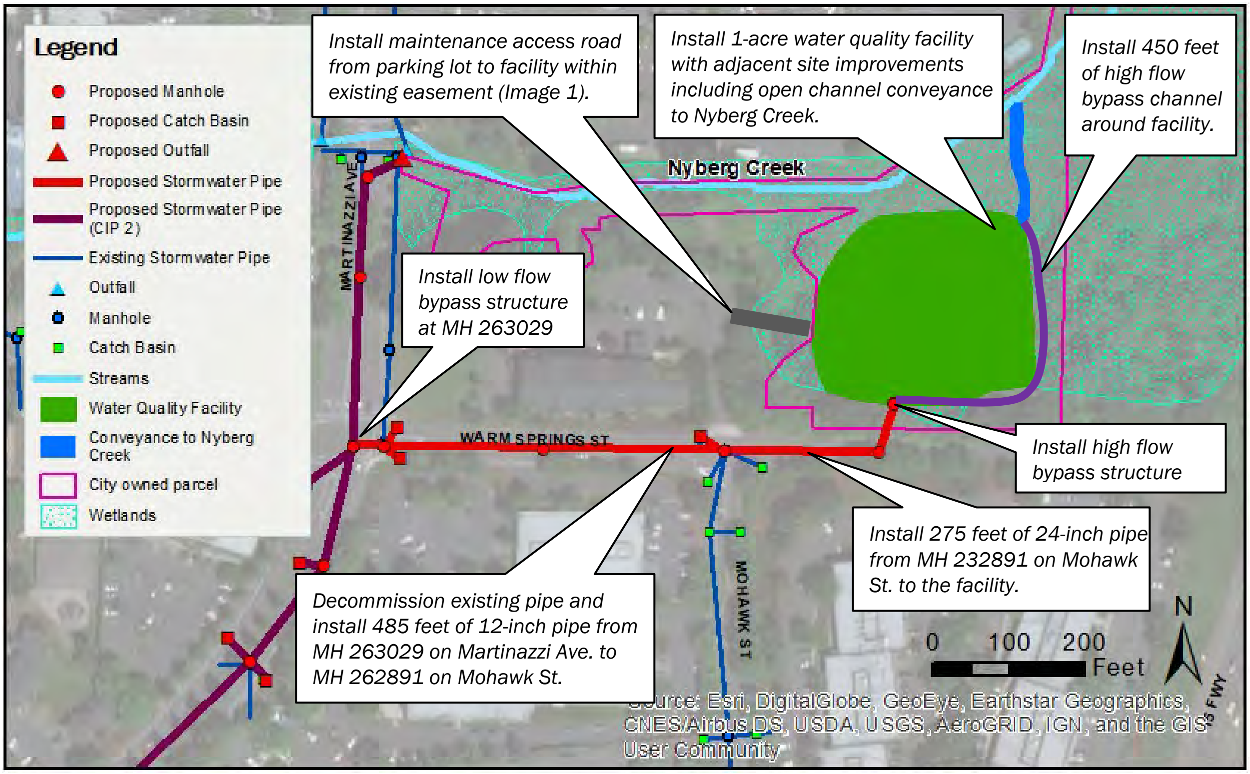
Planning-level Cost Estimate Locations 'M and N'*	
Capital Expense Total (including contingency)	See referenced study
Engineering and Permitting	See referenced study
Project Administration	See referenced study
Capital Project Implementation Cost Total (Location M)	**$ 147,000**
Capital Project Implementation Cost Total (Location N)	**$ 180,000**
Capital Project Total (Location M and N)	**$ 327,000**

**Planning level cost estimates based on "Hedges Creek (SW Ibach Road to SW 105th Avenue) Stream Assessment, CIP Opinion of Construction Costs for Identified Sites", February 2018, GreenWorks PC and OTAK, INC.*

Additional Project Information

Image 1. Location 'M' exposed sanitary manhole and incised tributary

Image 2. Location 'N' outfall and channel erosion (photo provided by OTAK)



Project Identifier	CIP #21
Project Name	Nyberg Water Quality Retrofit
Detailed Location	Warm Springs Street east of Martinazzi Avenue at City-owned parcel adjacent to Nyberg Creek
Model File	N/A
Contributing Drainage Area	89.7 acres
Estimated Existing /Future Impervious %	55.1%/62.2%
Project Objective(s)	Increases Water Quality Treatment (Retrofit)

Project Background

The City recently acquired property adjacent to Nyberg Creek and identified it as a water quality retrofit opportunity, due to the potential for treatment of a large contributing area with high pollutant load potential. Site reconnaissance including review of physical site conditions and potential conveyance system routing was conducted. A desktop GIS evaluation to assess environmental overlays and floodplain extents was also conducted.

Approximately 90 acres of contributing area can be routed to the facility via the existing storm pipe on Mohawk Street and pending construction of CIP #2, Phase 1 along Martinazzi Avenue.

The property is heavily vegetated with mature alder and cottonwood trees. Invasive vegetation dominates the site, specifically blackberries in the upper (higher) portion of the site and reed canary grass in lower portions of the site. Most of the property and proposed facility footprint is within the boundary of the 100-year floodplain and a delineated wetland (W4 per local wetlands inventory). Development of this site as a water quality facility will require federal and state permitting via a Joint Permit Application. Permitting requirements anticipated include an updated wetland delineation, wetland mitigation, and a FEMA no-rise evaluation. Additional site-specific requirements may be identified during the permitting process by the Army Corps of Engineers and Oregon Department of State Lands (Agencies).

Project Description

This project provides water quality treatment for a large upstream, untreated contributing drainage area. The conceptual design was developed to maximize water quality treatment based on physical site conditions and available area within the City-acquired property. A 1.5-acre total footprint was identified per discussions with City staff. This area assumes approximately 1-acre for the water quality facility and the remaining 0.5-acres for adjacent site improvements and grading.

The project concept does not provide flow control or address instream channel improvements. Low flows (water quality flow) from contributing drainage area along Martinazzi Avenue will be diverted to the facility while higher flows will continue to be routed down Martinazzi Avenue to the outfall at Nyberg Creek. Total flow from subbasins NY-0230 and NY-0171 (along Warm Springs Street and Mohawk Street) will initially be routed to the facility, and peak flows will be routed around the facility to Nyberg Creek via a high flow bypass channel. Elements of the conceptual design reflected in the cost estimate include:

- Installation of a low flow bypass structure at the intersection of Martinazzi Avenue and Warm Springs Street.
- Installation of 485 LF of 12-inch pipe on Warm Springs Street between Martinazzi Avenue and Mohawk Street.
- Installation of 275 LF of 24-inch pipe on Warm Springs Street between Mohawk Street and the facility.
- Installation of 4 manholes and 3 catch basins along Warm Springs. 100 LF of 12-inch inlet leads are also reflected in the cost estimate for the connection of new and existing catch basins.
- Installation of a flow control structure and debris forebay at the inlet to the facility. The flow control structure will include a high flow bypass channel around facility to discharge to Nyberg Creek.
- Installation of approximately 1 acre of a tiered water quality facility (i.e., raingarden) with beehive overflows and piped connections to the high flow bypass channel. 75 LF of 12-inch piping to connect beehive overflows within the facility to the bypass channel are also reflected in the cost estimate.
- Construction of new open channel conveyance to outfall to Nyberg Creek.

Design Considerations

- To capture and treat the maximum drainage area (90 acres) described in this CIP, it must be constructed concurrently or following CIP #2, Phase 1 (Nyberg Creek Stormwater Improvements). Alternatively, the facility could be designed to only treat stormwater conveyed along Warm Springs Street and Mohawk Street.
- An updated wetland delineation will be required to confirm wetland boundaries, mitigation requirements, and wetland condition.
- Actual treatment area and facility footprint to be determined during the preliminary design phase and may vary based on results from the updated wetland delineation.
- 1.5 acres of wetland mitigation is included in the cost estimate; actual mitigation area requirements will be determined by DSL during the permitting process. Wetland mitigation cost was based on a $155,000 per acre price quoted by the Butler Mitigation Bank in the Tualatin Valley, dated March 2019.
- Cost to acquire additional construction or maintenance easements are not included in the cost estimate.

Planning-level Cost Estimate	
Capital Expense Total (including contingency)	$ 1,234,000
Engineering and Permitting (35%)	$ 432,000
Administration (10%)	$ 123,000
Wetland Delineation (LS)	$ 15,000
Wetland Mitigation (LS)	$ 233,000
Capital Project Implementation Cost Total*	**$ 2,037,000**

**Planning level cost estimates estimated in 2018 dollars, rounded to the nearest thousand. The rounded total cost is based on non-rounded subtotals.*

Additional Project Information

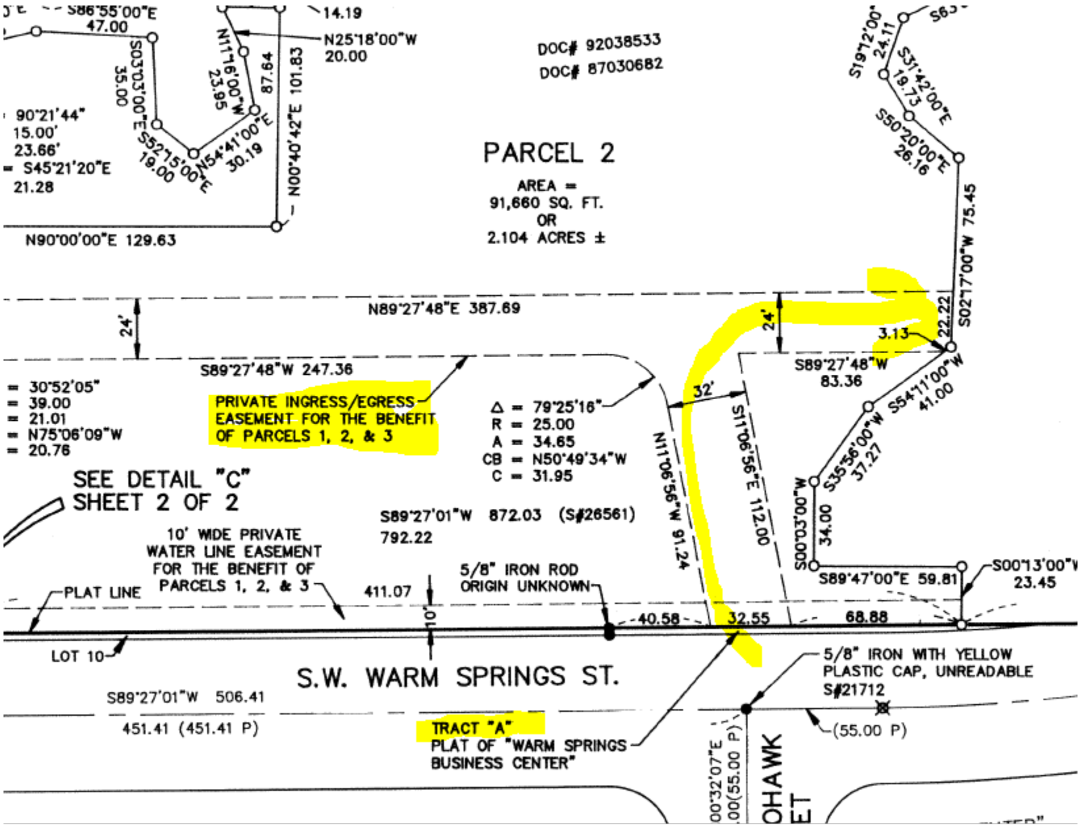


Image 1: Existing easement for site access

Image 2: Existing easement for site access, looking east

Image 3: Proposed location for water quality facility

Appendix B: Data Compilation and Preliminary Stormwater Project Development (TM1)

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Technical Memorandum

Prepared for: City of Tualatin

Project title: Stormwater Master Plan

Project no.: 149233

Technical Memorandum #1

Subject: Data Compilation and Preliminary Stormwater Project Development

Date: April 24, 2017

To: Dominique Huffman, P.E., City Project Manager

From: Angela Wieland, P.E., BC Project Manager

Prepared by: Angela Wieland, P.E.

Reviewed by: Krista Reininga, P.E.

Limitations:

This document was prepared solely for City Tualatin in accordance with professional standards at the time the services were performed and in accordance with the contract between the City of Tualatin and Brown and Caldwell dated April 11, 2016. This document is governed by the specific scope of work authorized by City of Tualatin; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by the City of Tualatin and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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Introduction

The City of Tualatin (City) is developing a stormwater master plan update to guide stormwater program and capital project decisions. The stormwater master plan (SMP) will address both water quantity and quality for constructed systems under the City's management. The master plan requires a clear understanding of existing and future runoff conditions across the city to identify long-term stormwater project needs.

This technical memorandum (TM1) has been developed to document the following:

- Data collection and compilation efforts to date,
- Stormwater planning criteria as identified through code review efforts, and
- Methods used to preliminarily identify stormwater project opportunities, including the water quality assessment to define water quality retrofit opportunity areas.

Through the data collection efforts, which included workshops with City staff and multiple site visits, a preliminary list of 16 stormwater project opportunities have been vetted and are anticipated for stormwater project development as part of the master planning effort.

Section 1 of this TM1 summarizes the data compilation efforts, specifically receipt of GIS data and review of various reports and studies. Section 2 outlines the criteria used for stormwater planning based on review of the Tualatin Development Code (TDC), Public Works Construction Code, and Clean Water Services (CWS) Design and Construction Standards. Section 3 outlines the process and results of the preliminary stormwater project identification efforts, which included stormwater system surveys, a water quality assessment, and site visits.

Section 1: Data Compilation and Review

In April 2016, BC provided a list of data needs to the City to initiate the master planning project effort. Data needs included GIS system information, background data and reports, City organizational information, stormwater surveys, maintenance program information and procedures, and additional financial information to support the sanitary and stormwater utility rate evaluations.

The project kick-off meeting was conducted on May 16, 2016. Data needs were discussed during the meeting and clarification was provided as necessary. BC's data request was primarily fulfilled over the course of four months (May through October 2016) as part of six separate data packages. Outstanding data needs (as of March 2017) are primarily related to financial information to support the sanitary rate evaluation. This delay is related to sanitary master planning schedule delays and changes related to the sanitary capital improvement project (CIP) total project cost. A summary of financial information in support of the rate evaluations is not included as part of this TM.

This section summarizes results of the data compilation and review efforts, specific for GIS system data and background reports and studies.

1.1 GIS System Data

GIS system data were provided in geodatabase format to BC as part of three data submittals: May 24, 2016, May 31, 2016, and August 4, 2016. GIS system data included shapefiles defining city limits, concept planning areas (future growth areas), waterbodies, taxlots, planning district coverage (zoning), impervious coverage, drainage basins, City-owned open space (parks, greenways, and natural areas), water quality facilities, and multiple natural resource overlay districts. Additional, individual shapefiles were provided to BC intermittently since August 2016 to address specific questions or to supplement previously provided information.

LIDAR and aerial photos were provided to BC on an external hard drive on June 14, 2016 and downloaded directly by BC.

Base map data including taxlots, soils, streams, and roadways/ right of way (ROW) were developed as a subset of METRO RLIS data and were provided by the City directly. BC did not process or obtain additional external information to support the data compilation effort unless identified to address an observed data gap.

BC independently reviewed the GIS data to identify applicable shapefiles for use in supporting system mapping, hydrologic analysis, and future hydraulic evaluations. Initial observations and data gaps were identified for discussion with the City. Proposed data assumptions and interpretations were documented.

Attachment A, Table A-1 summarizes GIS data received by date and outlines the initial observations, data gaps, and proposed data assumptions. Metadata or source data is summarized. Relevant fields to be used in the master planning efforts are indicated. Table A-1 was provided to the City in draft form to facilitate discussion of data gap resolution (see Section 1.1.2).

1.1.1 Preliminary Mapping

In conjunction with review of the GIS system data, BC prepared preliminary maps identifying project extents, major drainage basins and natural features, topography and soils, and stormwater drainage system features.

Preliminary mapping is included in Attachment B, Figures 1 through 3.

1.1.2 GIS Data Use Assumptions

BC met with the City on July 28, 2016 to review the initial GIS data summary and discuss gap resolution. Preliminary mapping was provided to facilitate discussion.

Table 1-1 summarizes the major data gaps and proposed resolutions. Detailed documentation of data gap resolution and data assumptions by topic is documented in Attachment A, Table A-1.

Table 1-1. GIS System Data Gaps and Assumptions

Data Need	Data Gap	Data Resolution and Assumptions
Land Use	No comprehensive land use coverage was available.	BC developed based on planning district coverage, developable lands coverage (vacant or infill), and undevelopable open space. See Section 2.3.
Undevelopable Open Space Areas	Multiple open space layers were provided. Interpretation of overlay districts was needed to accurately characterize open spaces as developable or undevelopable.	BC developed based on areas designated as wetlands, NRPO, Wetlands Protection Areas (a subset of the Wetland Protection District [WPD]), and City-owned parks, greenways, and natural areas. Development is permitted in the Wetland Fringe Area (WFA) and Sweek Pond Management Area, so these areas were excluded as part of the WPD.
Concept Planning Areas	Planning district and developable (vacant) lands coverage was only available for the Northwest and Southwest Concept Planning Areas. Input was needed to confirm how concept planning areas should be included in the project extents.	Concept planning areas were included in the project extents. The Basalt Creek Concept Planning Area was included in the hydrology modeling effort based on existing development coverage only.
Drinking and Irrigation Wells	Well location information was not available and is necessary to obtain rule authorizations and complete a system assessment.	Work to assess rule authorizations and develop a system evaluation was deferred. No additional work is needed now.

1.2 Datum Conversion

As part of the GIS data review, BC conducted a cursory review of available storm system data. Storm system information (size, material, elevations) was provided in both a structure GIS layer and a pipe GIS layer. Missing data were observed in both layers. BC proposed addressing gaps in rim elevation data by supplementing existing data with rim elevations interpreted from LIDAR. However, use of LIDAR assumes consistent datums (NAVD 88) are being used.

To determine whether a different datum was reflected in the City's GIS, BC conducted an initial comparison of rim elevations from GIS with rim elevations interpreted from LIDAR (NAVD88 datum), and most rim information in GIS appeared to be inconsistent with elevations interpreted from LIDAR (see Figure 1-1). The average elevation difference of approximately 3 to 4 feet is consistent with the datum correction of 3.52 feet between NGVD 29 and NAVD 88.

In July 2016, a decision was made to convert the City's system information to the NAVD 88 datum. Thus, the City universally corrected their system elevation data by +3.52' to align more accurately with the NAVD 88 datum. The system information was updated and provided to BC in August 2016. A follow up review was conducted of the corrected rim elevation data (see Figure 1-2). Although some discrepancies existed, the corrected elevation data appeared more consistent with elevations interpreted from LIDAR. A decision was made to move forward with the corrected elevation data.

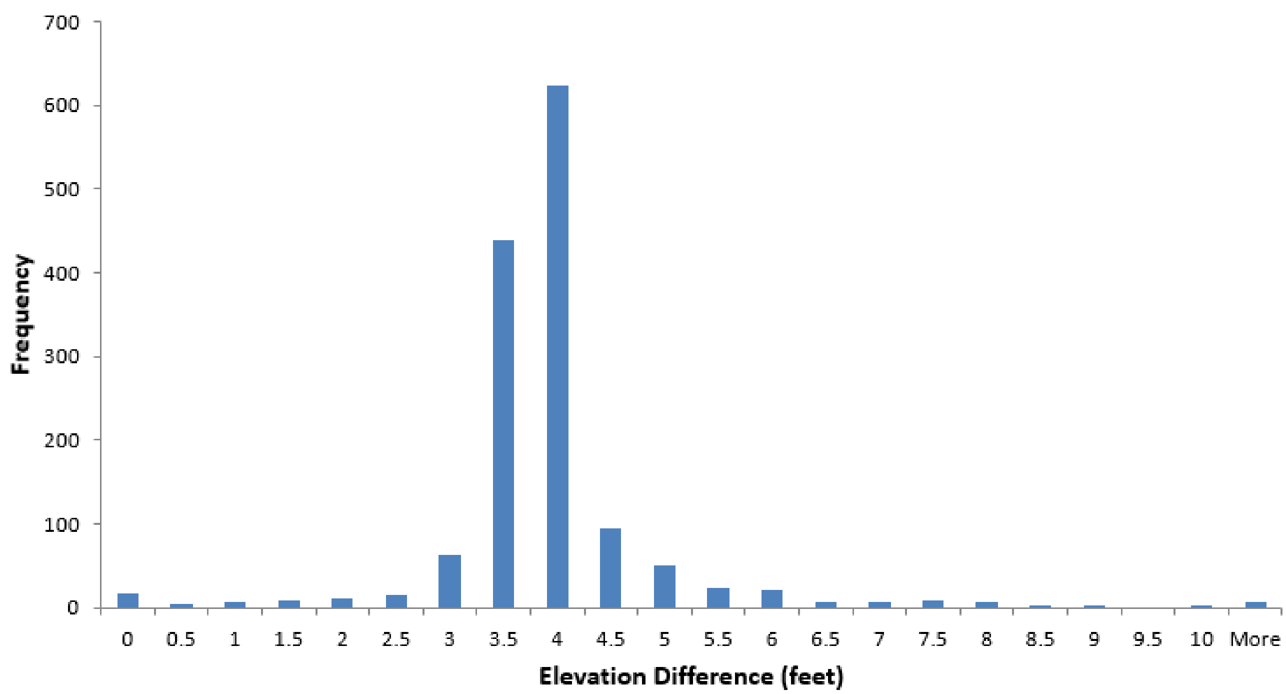


Figure 1-1: Original GIS Rim Elevation Comparison with LIDAR (July 2016)

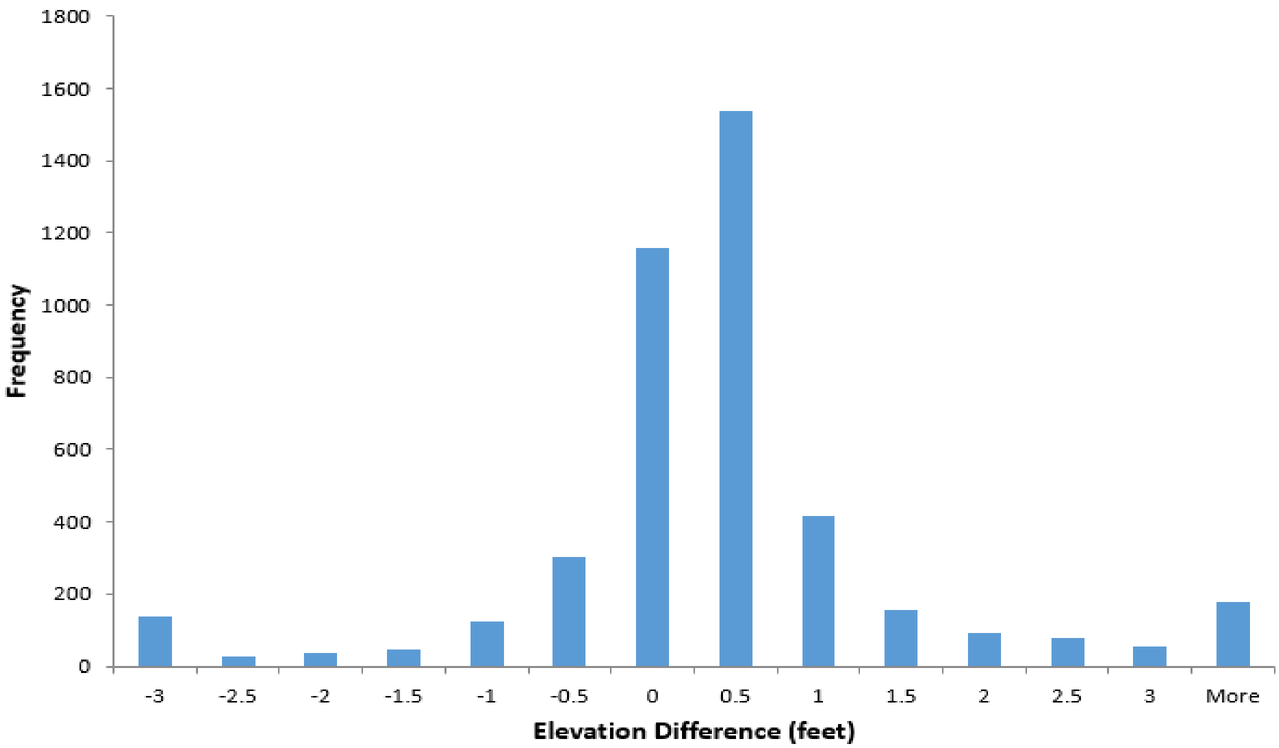


Figure 1-2: Updated GIS Rim Elevation Comparison with LIDAR (August 2016)

1.3 Reports and Studies

The City's last stormwater master plan was completed in 1972. Identified capital improvement project needs are now outdated no longer reflective of current development activities, population growth, and regulatory drivers.

Throughout the last 10 years, the City has been one of the fastest growing communities in Oregon, which has prompted the need to invest in infrastructure and consider long range planning and policy decisions to support businesses and residential life. BC obtained copies of various planning-level reports and studies prepared since the last stormwater master plan to help inform areas of high growth potential and identify stormwater system deficiencies and needs. Reports and studies reviewed and considered for this master plan update are detailed in Table 1-2.

Table 1-2 Existing Stormwater Planning Documentation and Reports

Report	Date	Summary and application to the SMP
Tualatin Drainage Plan Report	1972	Provides background information and historic basis for the need to update the SMP.
Hedges Creek Wetlands Master Plan	2002	Provides stormwater management recommendations (culvert upsizing under Tualatin Road, sediment removal) related to the 29-acre Hedges Creek Wetlands.
Bridgeport Area Stormwater Master Plan	2005	Provides stormwater system information and a subbasin delineation in the Bridgeport Development Area.
Southwest Tualatin Concept Plan	2010	Provides guidance for industrial development in southwest Tualatin. Planning district/ zoning designation is available.

Table 1-2 Existing Stormwater Planning Documentation and Reports		
Report	Date	Summary and application to the SMP
Basalt Creek Existing Conditions Report	2014	Provides surrounding land use and demographic information for the Basalt Creek Planning Area. Does not provide official planning district/ zoning designation or proposed transportation corridors.

Section 2: Stormwater Basis of Planning

Design standards related to the sizing and design of stormwater infrastructure are described in the City of Tualatin Public Works Construction Code (PW Standards), dated February 2013. The City often defers to the Clean Water Services (CWS) Design and Construction Standards (2007) and the CWS LIDA Handbook (2009) for water quality and detention facility-specific sizing and design standards.

Additional planning guidelines used to develop the basis of planning for this SMP are described in the City of Tualatin Development Code (TDC) and the Tualatin City Charter, Chapter XI. The TDC, specifically Chapters 3, 5, 6, 7, 8, 71, and 72 define assumptions related to the planning district designations and open space designations that informed the development of land use coverage and hydrologic modeling assumptions for this project. The Tualatin City Charter, Chapter XI, documents protection of city-owned parks and open space and sets limitations on the use of public property for alternative purposes including stormwater management without an approving vote, if such use was not already in place.

Collectively, these documents compose the basis of planning criteria and assumptions used in development of the SMP.

Attachment A, Table A-2 includes a summary of code and additional background data reviewed to establish the stormwater basis of planning criteria.

2.1 Stormwater Regulatory Drivers

Regulatory drivers considered in the context of this SMP include Phase I National Pollutant Discharge Elimination System (NPDES) municipal separate storm sewer (MS4) permit requirements and regulatory drivers associated with the total maximum daily load (TMDL) program and 303(d) listings for receiving waters.

2.1.1 NPDES Permit Requirements

The City is a co-implementer on the CWS watershed-based NPDES permit, along with 12 other jurisdictions in Washington County, for management of stormwater runoff. CWS' NPDES permit was reissued in May 2016 after being administratively extended for seven years after the previous permit expired in 2009.

Implementation of CWS' NPDES permit is outlined in the CWS Stormwater Management Plan (SWMP). Stormwater activities or best management practices (BMPs) are outlined to address the elements of the permit:

- Illicit Discharge Detection and Elimination
- Industrial and Commercial Facilities
- Construction Site Runoff Control
- Education and Outreach
- Public Involvement and Participation
- Post-Construction Stormwater Management

- Pollution Prevention for Municipal Operations
- Stormwater Management Facilities Operation and Maintenance Activities

Coordination efforts between co-implementers (including the City) and CWS are identified in the SWMP and outlined in more detail in intergovernmental agreements with CWS for specific permit elements. The City maintains IGAs with CWS for erosion and sediment control and system operation and maintenance.

In addition to the permit elements listed above, the reissued NPDES permit requires CWS and co-implementers to prepare a stormwater retrofit strategy, prepare a hydromodification assessment (to address instream channel erosion and modifications), conduct environmental monitoring activities, and develop TMDL pollutant load reduction benchmarks (see Section 2.1.2). These additional requirements will influence the City's stormwater program over the next permit term and will presumably result in increased focus and efforts on stormwater retrofits for water quality improvements, instream natural channel conditions and protection measures, and stormwater design standards to protect receiving waters from increases in pollutant discharge, peak flows, and increased flow duration.

2.1.2 TMDL and 303(d) Listings

The majority (approximately 97%) of the City discharges to the Tualatin River and tributaries. Major tributaries include Nyberg Creek, Hedges Creek, Cummins Creek and Saum Creek. Area along the northern portion of the City discharges north directly to the Tualatin River, whereas the tributaries generally run east-west across the City before discharging into the Tualatin River. The Tualatin River is a major tributary to the Willamette River.

The remainder (approximately 3%) of the City discharges to Basalt Creek, a tributary located in the southern portion of the City, which runs south to Coffee Lake Creek in the City of Wilsonville before discharging to the Middle Willamette River.

Water quality impairment and exceedance of water quality standards in the Willamette and Tualatin Rivers have prompted these rivers and corresponding tributaries to be placed on the State 303(d) list for various parameters of concern. TMDLs have then been developed to address specific sources of pollutant loading. CWS is identified as a discharge management agency (DMA) in the respective Tualatin Subbasin and Willamette Basin TMDLs, and the City is identified as a contributing municipality associated with CWS. As such, TMDL pollutant load reductions (in the form of TMDL benchmarks) are required as part of the CWS NPDES permit compliance and represent another regulatory driver promoting implementation of BMPs to reduce pollutant discharges in stormwater.

The Tualatin Subbasin TMDL was developed in 2001 and amended in 2012 to address various sources of pollutants including stormwater runoff from urbanized areas. Pollutants addressed in the TMDL include temperature, bacteria (*E. coli*), chlorophyll a and pH (total phosphorus is used as a surrogate measure), and DO (ammonia and settleable volatile solids are used as a surrogate measure). Pollutant load allocations are established by source and vary by stream reach and whether the discharge occurs to the tributary or mainstem.

The Willamette Basin TMDL was developed in 2006. Pollutants addressed in the TMDL include temperature, bacteria (*E.coli*), and mercury. Like the Tualatin Subbasin TMDL, pollutant load allocations are also established by source and vary based on the location of such discharge.

Additional water quality impairments relevant to the City are reflected on the effective (2012) 303(d) list for receiving waters within the City. Parameters of concern for the Tualatin River include ammonia, biological criteria, copper, iron, lead, and zinc. Parameters of concern for the Middle Willamette River include aldrin, biological criteria, DDT/DDE, dieldrin, iron, and polychlorinated biphenyls (PCBs). Such parameters represent additional targeted parameters for pollutant reduction with the City's stormwater program, as TMDLs are slated for development for these parameters in the future.

2.2 Design Standards and Criteria

BC reviewed both the City's PW Standards and the CWS Design and Construction Standards (2007) and the CWS LIDA Handbook (2009) to establish planning criteria relevant to the analysis of the City's stormwater system. Planning criteria will help identify where the system has capacity limitations and the basis for design of stormwater projects for water quality, condition improvements, and capacity. Assumptions specific to the development of land use and impervious percentages by land use are described in Section 2.3. Applicable design criteria are referenced in Table 2-1.

Table 2-1. Drainage Standards and Design Criteria		
Criteria	Source	Value
Water Quality Facility Design	PW Standards (206.8)	Design to requirements of CWS Design and Construction Standards and CWS LIDA Handbook. Specific to the PW Standards, facilities are required to have 4' or 6' vinyl coated chain link fencing.
Water Quantity Facility Design	PW Standards (206.8) CWS Design and Construction Standards	Design to requirements of CWS Design and Construction Standards. Match pre- and post-development flow for the 2-year, 10-year, and 25-year, 24-hour storm events.
Pipe Design Storm	PW Standards (206.3)	Design to the 25-year storm event. Surcharge during the 25-year is not permissible.[1]
Pipe Size	PW Standards (206.4)	10" minimum diameter for pipe from catch basins to the main in the public right-of-way 12" minimum diameter for mains in the public right-of-way
Manning's Roughness	PW Standards (Table 206-8)	Varies by material and shape
Pipe Material	PW Standards (206.4)	Concrete, PVC, Ductile Iron, and Aluminum Spiral Rib Pipe
Pipe Cover	CWS Design and Construction Standards	Table 5-2, varies by pipe material
Structure Spacing	PW Standards (206.4)	250' maximum for 10" pipe; 400' maximum for 12" pipe
Manhole Size	PW Standards (206.6)	48" diameter minimum

1. *The City's Public Works standards reference the rational method for conveyance design. SBUH was an approved equivalent as discussed with the City during the July 28, 2016 meeting.*

In conjunction with their recently reissued NPDES Permit, CWS is undertaking a 3-year, phased approach to update their Design and Construction Standards. The phased approach is proposed to meet new permit requirements related to the: 1) impervious threshold for requiring treatment, 2) prioritization of low impact design approaches (LIDA) and green infrastructure (GI), and 3) strategies and priorities for addressing hydromodification impacts. CWS published their updated Design and Construction Standards to address items 1) and 2) on March 28, 2017 and the updates are scheduled to take affect April 22, 2017. Although most changes proposed now do not directly affect the design standards and criteria being used for the SMP, more significant updates are listed below for reference.

- Updated/ added definitions for LIDA, modify or modification (related to impervious surface), redevelopment,
- Requirements for water quality treatment for development activities that create or modify 1,000 square feet or greater impervious surface, including single family development on lots of existing record.
- Explicit provisions emphasizing use of LIDA and GI in Chapter 4 (Runoff Treatment and Control).
- Adjusted criteria for treatment of existing/ undisturbed impervious area when new/ modified impervious area is applied to a project site. These criteria replace former Table 4-1 of the 2007 CWS Design and Construction Standards.

- Incorporation of a simplified sizing factor (6%) for sizing LIDA facilities (planters, raingardens) for water quality where onsite infiltration is >2 inches/ hour. This standard was previously in the LIDA Handbook.
- Incorporation of LIDA facility design criteria from the LIDA Handbook directly into the Design and Construction Standards.
- A summary of approved approaches (facilities) to meet water quality and water quantity criteria (new Table 4-1).
- Updated procedures for performance and corrective actions to adhere to the two-year warranty period for water quality or quantity facilities.

It should be noted that CWS will again be modifying their Design and Construction Standards to address hydromodification needs. The targeted timeframe for this phase of the modifications is April 2018.

2.3 Land Use and Impervious Coverage

As described in Section 1.1.2, land use coverage was not available for the City in GIS. Land use coverage is needed to hydrologically evaluate (model) the City and calculate associated stormwater runoff volumes and flows by subbasin. Both existing and future development conditions will be evaluated to identify where flows are expected to increase and inform CIP sizing.

2.3.1 Land Use Development

A preliminary land use coverage was developed based on established planning district boundaries, undevelopable open space areas, and vacant lands subject to future development. Following development of the preliminary land use coverage, BC met with City engineering and planning staff on August 26, 2016 to verify preferred land use categories, actual land use coverage, and impervious area assumptions by land use. Following the meeting, minor adjustments were made related to the institutional land use coverage, undevelopable open space, and vacant lands coverage based on actual site usage. The final land use coverage was verified on October 25, 2016 and is shown in Attachment B, Figure 4.

To develop the land use coverage, planning districts were consolidated into general land use categories. Roadway right-of-way (ROW) is incorporated into the planning district coverage, and therefore incorporated into the land use coverage. One exception is the Oregon Department of Transportation (ODOT) corridor, which was defined separately. Feedback from City staff during the August 26th meeting resulted in an expansion of the institutional land use coverage to include school and medical (hospital) facilities otherwise classified as a commercial planning district. Table 2-2 summarizes the consolidation of planning district boundaries into general land use categories.

Vacant lands were determined based on the City-provided GIS coverage of developable lands. Developable lands were categorized as vacant, infill, or redevelopable. To develop existing land use coverage, vacant lands were defined as those areas that are currently undeveloped and when developed, will increase in impervious surface (and associated runoff volume). Future land use coverage will exclude vacant lands and simulate only the underlining land use coverage. BC reviewed aerial imagery to verify the development condition of the vacant, infill, and redevelopable areas. From this review, areas classified as vacant and infill were used to define the vacant land use coverage. Although areas classified as redevelopable could result in increased impervious coverage when developed in the future, a conservative assumption was made to assume these areas are currently developed. Feedback from City staff refined the vacant lands coverage based on recent development activities.

Undevelopable open space areas were identified based on City-provided GIS coverage of City-owned parks, greenways, and natural areas; the City's Wetland Protection Area (WPA); wetlands (both significant and less significant), and the City's Natural Resource Protection Overlay (NRPO) District. Based on conditions outlined in the TDC, these areas are unlikely to develop or change from their current site usage (imperviousness). Undeveloped open space areas excluded wetland fringe areas and area covered by the Sweek Pond Management Area, as these areas may be subject to future development.

City-owned parks, greenways, and natural areas are classified separately from the other undevelopable open space areas due to the additional impervious area (parking areas, paths, etc.) on these sites. City-owned parks, greenways, and natural areas are subject to the Tualatin City Charter, Chapter XI. These areas are public property and, per the Charter, may not be used or developed in a way that causes a major change in the properties use or function without a legal vote by the public. The City has interpreted this provision as limiting these areas from being developed, including being used to facilitate the installation of stormwater facilities. Feedback from City staff resulted in the inclusion of private open space areas (golf courses, parks) into this land use category.

Finally, the Basalt Creek planning area is located outside of the city limits but included as part of this SMP. Planning district coverage has not yet been established for this area. A separate land use category (Basalt Creek planning area) was established to reflect existing development conditions in this area. Future growth and development is expected, but the timeframe is unknown. For purposes of this SMP, future development conditions will not be evaluated or assessed hydrologically for this area.

Table 2-2. Land Use Categories and Impervious Percentages

Planning District Designation	Modeled land use category	Impervious % (existing)	Impervious % (future)
Low Density Residential	Low-density residential (LDR)	43	53
Medium Low Density Residential	Medium-density residential (MDR)	45	55
Medium High Density Residential			
High Density Residential	High-density residential (HDR)	50	60
High Density High Rise Residential			
General Commercial	Commercial (COM)	78	78
Central Commercial			
Medical Commercial			
Office Commercial			
Recreational Commercial			
General Manufacturing	Industrial (IND)	74	74
Light Manufacturing			
Manufacturing Business Park			
Manufacturing Park			
Institutional	Institutional (INS)	35	35
	Vacant, developable (VAC)[a]	5	Consistent with the underlying land use designation.
	Open Space (OSP), undevelopable – Parks, Greenways, Natural Areas, Private [b]	5	5
	Open Space (OSP), undevelopable – WPA, Setbacks, NRPO, Wetlands[b]	4	4

Table 2-2. Land Use Categories and Impervious Percentages			
Planning District Designation	Modeled land use category	Impervious % (existing)	Impervious % (future)
	Transportation (ODOT Corridor)	46	46
	Basalt Creek/ rural residential	7	7

a. *Vacant land use reflects area with new or infill development potential. Future development conditions assume development of vacant lands consistent with their associated planning district designation.*

b. *Open space land use reflects area with no foreseeable development potential.*

2.3.2 Impervious Percentages by Land Use

Impervious coverage by land use was directly calculated using City-provided GIS coverage of impervious surface and supplemented with City-provided GIS coverage of building footprints and right-of-way. Final impervious percentages by land use category are reflected in Table 2-2.

Impervious surface information in GIS was available for most city area except for the low density residential planning district. Impervious surface coverage reflects building rooftop, pavement, and parking areas. The impervious surface coverage was combined with the right-of-way coverage to yield a total impervious area for each land use category (except the low density residential and the Basalt Creek categories). The percentage impervious was directly calculated from the impervious area and the total area for each land use.

For the low-density residential land use coverage, GIS coverage of the building footprints was combined with the right-of-way coverage to directly calculate the percentage impervious.

For the Basalt Creek planning area, aerial imagery was reviewed to estimate a percent impervious representative of existing land use conditions. Three tax lots were selected at random and the observed impervious surface areas (rooftop, parking areas, driveways) were digitized. The percentage impervious applied to the Basalt Creek planning area was calculated based on the digitized impervious area and the total area for the three tax lots.

For each residential (low-density, medium, density, and high density) land use category, aerial imagery was reviewed to spot check the calculated impervious percentages against observed development conditions. Small, distributed impervious surfaces (patios, decks, detached garages, driveways) specific to residential land use is often overlooked in the delineation of building footprint areas (as used for the low-density residential impervious calculations) or other impervious surfaces in GIS. For each land use category, five tax lots were selected at random and the impervious coverage was estimated and compared with the overall calculated impervious percentage. Results of the aerial verification effort did not result in changes to the impervious percentages based on direct calculations.

Due to the potential for redevelopment and infill amongst the residential land use categories, a separate future condition impervious percentage was defined for the low density, medium density, and high density residential land use categories. Each calculated impervious percentage (reflecting existing development conditions) was increased by 10 percentage points to account for added impervious surface area expected with redevelopment. This increase was made independent from the anticipated development of vacant land use.

The existing and future impervious percentages by land use were compared to values used by surrounding communities to ensure general regional consistency. The percentages were also compared with maximum lot densities defined by planning district in the TDC, which reflect the minimum landscaping requirements. Both comparisons did not result in changes to the impervious percentages estimated for this SMP.

Section 3: Preliminary Stormwater Project Identification

The City opted to develop their SMP using a collaborative approach with engineering, planning, and operations staff to initially assess known stormwater system problems and identify areas where infrastructure improvement, replacement, or retrofit is needed to address an issue. Preliminary stormwater project opportunities were identified through a combination of surveys (distributed to engineering and maintenance staff), a water quality retrofit evaluation, and workshops/ meetings/ site visits with City staff. Portions of the stormwater system that require a modeling approach to evaluate capacity limitations and project concepts were also identified. This overall process allows the City to focus resources and develop information for areas and projects likely to be prioritized in a capital improvement program.

Attachment A, Table A-3 summarizes the results of this collaborative effort including identified preliminary stormwater problem areas and project opportunity areas. Table A-3 includes site visit observations and notes and details related to project concepts and modeling needs.

3.1 Stormwater Surveys

BC provided a stormwater questionnaire to City engineering and maintenance staff in May 2016 to solicit feedback related to the condition and function of the stormwater system. Staff were asked to specifically identify and describe areas of the system that experience regular flooding, need infrastructure replacement, require frequent maintenance, need new infrastructure installed, and experience water quality problems. Staff were also asked to comment on what they consider top priority issues or projects to be addressed in the SMP.

Completed questionnaires, along with a separate GIS layer of stormwater trouble areas maintained by the City, were used to develop a list of preliminary stormwater problem areas. A total of 32 preliminary stormwater problem areas were identified and categorized as follows:

- Capacity (bank overtopping)
- Capacity (other)
- Maintenance
- Erosion
- Infrastructure Needs
- Infrastructure Replacement
- Water Quality

BC and the City reviewed the preliminary stormwater problem areas during a series of meetings from June to October 2016. Areas were qualified for follow-up site visits and/or consideration as a stormwater project opportunity area to be evaluated as part of the SMP. Stormwater problem areas identified based on capacity (bank overtopping) were generally excluded during this review, as stream capacity and natural system flooding was not evaluated as part of this SMP.

Table A-3 provides a comprehensive list of the preliminary stormwater problem areas as identified by City staff.

3.2 Water Quality Retrofit Evaluation

As a co-implementer on the CWS NPDES permit, retrofit of the stormwater system to improve water quality is a primary objective for this SMP. Stormwater retrofits, specifically the installation of water quality treatment in areas not otherwise treated, will be a focus for CWS over the next NPDES permit term and allows the City to aid in the reduction of TMDL and 303(d) pollutants to improve overall water quality conditions in the Tualatin and Willamette Basins.

Retrofit opportunities will focus on the use of low impact development approaches (LIDA) to the extent possible, consistent with CWS' proposed retrofit strategy. LIDA includes the use of raingardens, swales, and planters, which promote infiltration and runoff volume reduction in addition to treatment.

3.2.1 Methodology

BC evaluated opportunities to install water quality facilities or retrofits in conjunction with observed stormwater problem areas (as referenced in Section 3.1), documented capital improvement project needs (per City's 2017-2021 Capital Improvement Plan), and available public lands that would support installation of a stormwater treatment facility.

Aligning water quality retrofits with observed stormwater problem areas allows project concepts to be developed to address multiple objectives. Each preliminary stormwater problem area was discussed with City staff and potential project concepts identified to determine if water quality could be supported. As identified, project concepts were expanded to reflect the installation of new water quality facilities (i.e., raingarden, swale) in conjunction with conventional stormwater infrastructure (pipes, catchbasin) needs. Project concepts were also revised to incorporate redesign or reconfiguration of an existing water quality facility to improve treatment, retention or flow control.

The City's 2017-2021 Capital Improvement Plan included nine identified stormwater projects. Two of these projects qualify as a stormwater retrofit. These projects reflect treatment of large contributing drainage areas using a pretreatment manhole/ proprietary treatment technology to target trash and debris removal. Although use of a proprietary treatment technology is not CWS's preferred retrofit approach, these proposed projects are in a flat and fully developed area of the City with limited opportunity to use a surface-based LIDA. These two projects would meet CWS' outfall retrofit program objectives (CWS 2016 SWMP, Section 7.6). Thus, these two projects were maintained as a stormwater project opportunity for this SMP. It should be noted that the other seven stormwater projects identified in the Capital Improvement Plan are either in progress or already reflected as a preliminary stormwater problem area and being considered in this SMP.

Publicly owned properties, particularly those in a natural or park-like setting often provide opportunity to incorporate water quality treatment into a developed landscape. As described previously, the Tualatin City Charter, Chapter XI limits the use of publicly owned parks, greenways, and natural areas to be used outside of its original intent without a public vote. Therefore, City-owned property <u>not</u> subject to the Charter provisions were identified and evaluated as potential water quality retrofit opportunity areas. These areas included larger parcels without current treatment. Topographic and site usage constraints were considered in the identification of water quality retrofit opportunities, and the resulting, identified areas were generally larger, public parking areas or areas within the road right-of-way.

3.2.2 Results

A total of 15 water quality retrofit opportunities were identified, and 10 retrofit opportunities overlapped with preliminary stormwater problem areas. These water quality retrofit opportunity areas were included in site visits and evaluated as a potential stormwater project opportunity area.

Table A-3 lists identified water quality retrofit opportunities and incorporates the water quality retrofit element into proposed project concepts as applicable. Attachment B, Figure 5 maps the preliminary stormwater problem areas and water quality retrofit opportunities. Figure 5 also details public property considered for use in the water quality retrofit evaluation.

3.3 Site Visits

BC and City staff conducted two site visits to verify preliminary stormwater problem areas and water quality retrofit opportunities, one on June 29, 2016 and one on December 7, 2016. The site visits were used to verify and qualify the problem areas and retrofit opportunities as a stormwater project opportunity to be evaluated and costed in this SMP. The site visits were also used to explore preliminary project concepts.

Prior to each site visit, BC and City staff met to finalize site visit locations, the site visit schedule, and discuss any accessibility or access constraints. Maps were distributed detailing upstream and downstream conveyance. Site visits were documented via meeting minutes and photo logs.

For those locations identified as a problem area due to frequent maintenance needs, effort was made during the site visits to investigate potential sources of pollutant loading. Frequent maintenance needs were often the result of excessive sediment accumulation, debris accumulation, vegetative overgrowth, and backwater conditions. Although maintenance is routinely conducted by the City, select problem areas were identified for consideration as part of a city-wide programmatic stormwater project to proactively inspect and maintain infrastructure at an increased frequency.

3.4 Stormwater Project Opportunity Areas

Following the compilation of stormwater surveys and completion of the water quality retrofit assessment and site visits, a total of 16 stormwater project opportunity areas and two city-wide, programmatic efforts were identified. These areas/ efforts represent the City's initial stormwater project list to be developed and costed as part of the SMP.

Table A-3 identifies the stormwater project opportunity areas and city-wide programmatic efforts. Attachment B, Figure 6 maps the stormwater project opportunity areas and includes a summary of each area by project category(ies). Project categories are as follows:

- Maintenance/ Asset Management – reflects areas experiencing more frequent maintenance needs that would be incorporated into a maintenance inspection and cleaning program.
- Maintenance – refers to stormwater facilities requiring extensive, one time maintenance.
- Direct replacement – refers to the direct replacement of infrastructure that is failing.
- Upsize infrastructure – refers to the replacement and upsizing of infrastructure that is capacity limited.
- New infrastructure – refers to the installation of new infrastructure, often in locations of pending or future development.
- Water quality retrofit – refers to the installation of treatment or flow control to support water quality improvements.

Stormwater project opportunities may be added or removed during stormwater project development. Additionally, the stormwater project opportunity areas may be combined or broken down into phases as project concepts are refined. An upcoming stormwater project planning workshop will be held to discuss and refine these project concepts and opportunity areas.

3.4.1 Programmatic Opportunities

Two city-wide programmatic opportunities were identified to support ongoing assessment and maintenance of existing infrastructure and public water quality facilities. Identification of these activities as a programmatic opportunity means that an annual budget allocation (as opposed to a one-time budget allocation) would be needed to support these efforts. The preliminary project concepts are identified as follows:

1. Public Infrastructure Improvements – This program would include annual pipe inspections (CCTV inspections), targeted maintenance efforts for pipes and inlets (outside of the scheduled maintenance frequency), and an annual pipe replacement program to address condition deficiencies. Asset age is not currently documented in the City's GIS; however, the City may want to establish a system lifetime age and assume city-wide replacement of the piped infrastructure over a defined timeframe.
2. Public Water Quality Retrofits – Most public water quality facilities manage runoff from subdivisions or other low density residential areas and are located adjacent to private residences (see Figure 5). Often the public is unaware these facilities exist. Citizen complaints are common and are related to system performance and sizing. The City is considering an ongoing program to review and reengineer existing public water quality facilities to ensure visibility and maximize performance.

3.4.2 Modeling Needs

Five stormwater project opportunity areas were identified where hydraulic modeling of the stormwater system would help inform observed capacity limitations and refine project concepts. These areas were reviewed with City staff on February 2, 2017 and the extent of hydraulic modeling and survey needs were verified. Detail related to the system modeling objectives and extent is outlined in Table A-3.

1. Stormwater Project Opportunity Area 4 – Manhassat
2. Stormwater Project Opportunity Area 5 – Boones Ferry Road at Oil Can Henrys
3. Stormwater Project Opportunity Area 7 – Herman Road
4. Stormwater Project Opportunity Area 9 – Sagert Street at the Shenandoah Apartments
5. Stormwater Project Opportunity Area 10 – Mohawk Apartments

3.4.3 Next Steps

Stormwater project development will occur based on the preliminary project concepts outlined in Table A-3.

System survey was completed in April 2017 in support of the hydraulic modeling efforts. Hydraulic modeling for the identified project opportunity areas is scheduled to occur from April to June 2017.

City staff will participate in a project development workshop following completion of the hydraulic modeling efforts. The workshop will be used to review preliminary results from the hydraulic modeling effort and facilitate discussion of the proposed project concepts including programmatic and asset management project concepts. The outcome from this workshop will include a final stormwater project list for costing and inclusion in the SMP.

Section 4: References

City of Tualatin (City). 2016. *Capital Improvement Plan 2017 to 2021.*

Clean Water Services (CWS). 2016. Stormwater Management Plan

Oregon Department of Environmental Quality (DEQ). National Pollutant Discharge Elimination System (NPDES) Watershed-based Waste Discharge Permit. Issued to Clean Water Services. Effective May 31, 2016.

DEQ 303(d) database. http://www.deq.state.or.us/wq/assessment/rpt2012/search.asp#db. Accessed April 17, 2017.

Attachment A: Matrices

Table A-1: GIS Data Review and Data Gaps

Initial Data Request	Source (Received From)	Date Received	Database Name (if applicable)	File Name	Feature Class	Data Type-Base or Storm	Layer Notes (from City)	Datum	Relevant Fields	Initial Observations and Identified Gaps	Outstanding Questions (per 7-28-16 and 8-24-16 mtgs)	Data Assumptions and Gap Resolution
Base GIS Data												
City Limits	City of Tualatin	5/24/2016 and 8/4/2016	StormMasterPlan.gbd and StormMasterPlan_Additional_Data.gdb	CITY	polygon	Base	City limits	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	acres, status, shape_length, shape_area	All data is populated.	What is the date of the City limits file?	City provided an updated city limits shapefile on 8/4/16 reflecting July 2016 to use as the baseline. BC adjusted the baseline city limits in October 2016 per comments from City planning to add an omitted annexation from spring 2016.
UGB	City of Tualatin	5/24/2016	StormMasterPlan.gbd	UGB	polygon	Base	Tualatin's planning area boundary	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	area, perimeter, UGB, UGB ID, acres, shape ST area, shape ST length, shape length, shape area	All data is populated. No concept planning areas defined. Boundary does appear to include SW Industrial area, however it is not specifically identified as such.	What concept planning areas should be reflected in the MP? - NW Tualatin Concept Plan (2005) - SW Tualatin Concept Plan (2010) - Basalt Creek Concept Plan (2016)	Concept planning areas to be shown conceptually and included in the subbasin delineation and current condition hydrologic calculations only. City provided planning area shapefile reflecting concept planning area delineation on 8/4/16 (see "other data" rows at end of table).
Taxlots	City of Tualatin	5/24/2016	StormMasterPlan.gbd	parcels	polygon	Base	Subset of May 2016 Metro RLIS release	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	Area, Owner, Owner Address, BLDG SQFT, a_t_acres, landuse, lat, lont, gis_acres, shape_length, shape_area	All data is populated. Not clipped to the UGB (Tualatin's planning area boundary).		BC to clip to UGB.
Roads and Roadway Classifications	City of Tualatin	5/24/2016	StormMasterPlan.gbd	FUNC_CLASS_F	line	Base	Tualatin's functional classification for future collectors and arterials	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	Street_name, type, class, shape_length	All data is populated. Clipped to UGB.	Do the future collectors and arterials extend to the UGB? Outside UGB?	No additional future collector delineation within or outside of UGB. Use data as available.
	City of Tualatin	5/24/2016	StormMasterPlan.gbd	FUNC_CLASS	line	Base	Tualatin's functional classification for existing collectors and arterials	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	street_name, functional class name, functional class code, owner, shape_length	All data is populated. Clipped to city limits.		BC to use unclipped regional collector and arterial data from Metro.
	City of Tualatin	5/24/2016	StormMasterPlan.gbd	FREEWAYS	line	Base	Subset of RLIS freeways layer	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	street name, ftype, length	All data is populated.	Does City have ODOT ROW?	To the extent ODOT area appears to drain to City system, BC will delineate subbasins accordingly. For mapping purposes, subbasins composed primarily of ODOT area will be shown as "outside of study area". City provided ROW shapefile on 8/4/16 (see below).
	City of Tualatin	8/4/2016	StormMasterPlan_Additional_Data.gdb	ROW		Base	Polygon file of ROWs.			Includes both ODOT and city, possibly county. Extends beyond City limits and UGB. Does not indicate ownership of the ROW.		BC to use ROW shapefile to define ODOT ROW and County ROW that are not specifically modeled unless the City's subbasin delineation extends.
Existing Land Use or Impervious Coverage	City of Tualatin	5/31/2016 and 7/21/2016	StormMasterPlan_2.gdb and DevelopableLands.shp	DevelopableLand	polygon	Base	Shows net developable land within Tualatin. This layer was derived from Metro's Regional Vacant Lands inventory (2011) using local knowledge to correct errors of omission and commission. Currently updated through 2015. Land deemed "constrained" was removed from the inventory and the remainder categorized into the following categories: vacant, infill and redevelopable. Lands currently considered "developed" are not included in this dataset. 7/7/16 - Constrained lands were defined as 100-year floodplain, floodway, NRPO, 50-foot buffer on all streams and wetlands, steep slopes. Constrained lands were built using the RLIS stm_line layer and could be rebuilt using the also-provided "Streams" layer. 7/7/16 - Developable land is categorized - Vacant, Redevelopable, Infill, Null - What do these mean, which should we use to reflect land that is undeveloped and can develop? (BC to spot check against aerials). Net vacant land within Tualatin. Parcels deemed entirely vacant (no noticeable improvements) regardless of size are included as well as the vacant portions of parcels greater 1/2 acres.Net infill land within Tualatin, OR. Vacant portions of parcels totaling less than 1/2 acre. Land deemed by staff to have redevelopment potential.	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	Dev_type, Shape_area	City did not provide existing land use coverage. Land use coverage will have to be developed using developable lands. Vacant lands appear to be empty lots/fields which are available for development. Redevelopable lands often contain existing structures (parking lots, buildings, etc.) or require fill/grading (e.g. the old quarries in the SW Industrial Area). Only 7 areas identified as infill, mostly small parcel and generally vacant.	Should constrained lands be removed based on the Streams layer as opposed to the stm_line layer? In the designation of vacant and redevelopable lands, confirm the difference in how these lands were assigned? Should a vacant land use classification be used for all developable land categories (including infill) or only those large parcel new developments?	BC/ City staff met with planning on August 24, 2016 to confirm land use assumptions. Based on outcome from meeting, BC created a land use coverage based on their planning districts, undevelopable open space, and developable lands deemed vacant. See specific designations described below. Vacant lands (excluding those defined as redevelopable) to be used to define lands developing into a future land use.

Table A-1: GIS Data Review and Data Gaps

Initial Data Request	Source (Received From)	Date Received	Database Name (if applicable)	File Name	Feature Class	Data Type-Base or Storm	Layer Notes (from City)	Datum	Relevant Fields	Initial Observations and Identified Gaps	Outstanding Questions (per 7-28-16 and 8-24-16 mtgs)	Data Assumptions and Gap Resolution
Existing Land Use or Impervious Coverage (continued)	City of Tualatin	5/31/2016	StormMasterPlan_2.gdb	impervious	polygon	Base	Impervious surface mapping for commercial & industrial land, schools, churches and multi-family sites	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	Type, Shape_area	All data is populated. No impervious surface mapping for residential planning districts.	Per TDC Chapter 5, a buildable density is provided per residential planning district in code but not an impervious percentage. How should density be equated to an impervious percentage? Should mapped impervious be used to develop impervious percentages rather than local data?	Impervious percentage by planning districts are not available. The City wishes to calculate them. Literature values are not preferred. Based on outcome from August 24, 2016 meeting, BC directly calculated impervious percentage by planning district using impervious coverage information where available. For the low density residential planning district (where mapped impervious coverage is not available), impervious percentages were calculated based on 1) rooftop and roadway coverage and 2) building density for residential planning districts. BC used aerials to truth check impervious coverage for residential planning districts. BC proposed impervious percentages by land use category for existing and future model development.
Zoning	City of Tualatin	5/24/2016	StormMasterPlan.gbd	PLANDIST	polygon	Base	Tualatin's planning districts. Tualatin is a "one map" city.	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	CZONE, CLASS, ACRES, Zone Name, Shape_Length, Shape_Area	All data is populated. Existing and future land use to be based on zone name designation. Classes of land use include Residential, Commercial, Industrial, and Institutional. Zone names include: Central Commercial, General Commercial, General Manufacturing, High Density High Rise Residential, High Density Residential, Institutional, Light Manufacturing, Low Density Residential, Manufacturing Business Park, Manufacturing Park, Medical Commercial, Medium High Density Residential, Medium Low Density Residential, Office Commercial, Recreational Commercial, Vacant (Infill, Vacant, Redevelopable) Parks, Open Space, and Natural Area	Have planning district coverages been established for concept planning areas? Does the City have impervious assumptions by planning district that include roads?	Land use categories based on consolidated planning districts. Categories include Industrial, Commercial, Institutional, High Density Residential, Medium Density Residential, Low Density Residential. Refined planning district (zoning) coverage not available for all concept planning areas. Existing land use based on vacant and open space designation to be used in existing hydrologic calculations. Basalt Creek concept planning area to be modeled based on existing impervious coverage (per aerials). Institutional land use coverage refined during meeting with planning on August 24 to include schools and hospitals.
Topographic Contours	City of Tualatin	5/24/2016	StormMasterPlan.gbd	Contours_2ft	line	Base	Built by CWS primarily from 2014 LIDAR	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601	elevation	All data is populated. Not clipped to the UGB (Tualatin's planning area boundary).		BC to clip to area surrounding UGB.
	City of Tualatin	5/24/2016	StormMasterPlan.gbd	Contours_10ft	line	Base	Built by CWS primarily from 2014 LIDAR	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601	elevation	All data is populated. Not clipped to the UGB (Tualatin's planning area boundary).		BC to clip to area surrounding UGB.
LIDAR	City of Tualatin	6/6/2016 and 6/14/16	LIDAR	LIDAR, subfolders (45122c6, 45122c7, 45122c8, 45122d6, 45122d7, 45122d8)	DEM	Base	Contains gridded LIDAR data for Tualatin and the surrounding area.	GCS_NAD_1983_2011. NAVD88 vertical datum	elevation	The 45122c7 grid omitted from initial data submittal. This data is in the NAVD88 vertical datum where most other stormwater structures are in NGVD 29.		
Basin Boundaries	City of Tualatin	5/24/2016	StormMasterPlan.gbd	strm_basin	polygon	Base	Major stream basins: Cummins Creek, Hedges Creek, Nyberg Creek, Saum Creek, Seely Ditch, Tualatin River. 7/7/16 - How were the basins delineated (automated, per HUC boundaries, etc.? The layer "strm_basin" is of unknown provenance with no documentation. Project should probably use the CWS basin data.	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	area, perimeter, basin, basin ID, basin name, acres, shape ST area, Shape ST length, shape length, shape area	All data is populated. Basin delineation varies from CWS basin delineation throughout the city.	Will the basin differences preclude our subbasin delineation efforts? Should one data source be relied on over another, given that the subbasin boundaries will be refined for modeling purposes?	Major basin and subbasin delineation is not considered accurate. BC to use CWS basin data to aid in new subbasin delineation effort for hydrologic analysis.
	BC/Clean Water Services	5/16/2016	----	subbasins	polygon	Base	Sub-basins generated from merging polygons in "subbasins.shp" from Clean Water Services, used to create project kick-off map	none	area_, perimeter, basin_id, bas_name, acres, shape_area	All data is populated. Basins are smaller than strm_basin. Do not extend into concept planning areas.		
Aerial Photos	City of Tualatin	6/6/2016	2015 6inch Air Photos	Multiple files received.	photo	Base	Aerial photography from 2015. 6 inch resolution.		N/A	Full coverage within city limits. Few tiles in nearby town of Sherwood are missing.		
Soils	City of Tualatin	5/24/2016	StormMasterPlan.gbd	Soils	polygon	Base	Subset of Metro RLIS layer	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	AREA, CODE, CLASS, county, CLASS.	Missing hydrologic soil group (A, B, C, D) for all soils. Often MUSYM field from NRCS soil files is used to translate to soil reports. File is not clipped to planning area.	What does the class field represent? What does the Code field represent?	BC to use NRCS soil information to develop GIS coverage by hydrologic soil type. Gaps in hydrologic soil group coverage to be interpreted from surrounding soil type.

Table A-1: GIS Data Review and Data Gaps

Initial Data Request	Source (Received From)	Date Received	Database Name (if applicable)	File Name	Feature Class	Data Type-Base or Storm	Layer Notes (from City)	Datum	Relevant Fields	Initial Observations and Identified Gaps	Outstanding Questions (per 7-28-16 and 8-24-16 mtgs)	Data Assumptions and Gap Resolution
Streams and Water Bodies	City of Tualatin	5/24/2016	StormMasterPlan.gbd	waterbodies	polygon	Base	Subset of layer created by Metro and Watershed Sciences from LIDAR data. Layer overlaps with streams layer.	NAD_1983_HARN_StatePlane_Oregon _North_FIPS_3601_Feet_Intl	WB number, type, sub-area, source, create date, created by, modification date, modifier, modification source, notes, shape ST area, Shape ST length, shape length, shape area	Reflect major waterbodies. Sub-area is completely blank (null), all modification details are blank (null). No names are given, even for major water bodies such as Lake Oswego.	Should this layer be used for any reason?	Layer will not be used in mapping.
	City of Tualatin	5/24/2016	StormMasterPlan.gbd	streams	line	Base	Subset of layer created by Metro and Watershed Sciences from LIDAR data. This layer has better positional accuracy, but it has not been released on RLIS. 7/7/16 - Should this layer be used versus the stm_line? The layer "streams" is quite a bit better in terms of positional accuracy and is better registered with the aerial photography, LIDAR and contour data we've provided. I'd recommend using this layer over Metro's stm_line	NAD_1983_HARN_StatePlane_Oregon _North_FIPS_3601	segment number, WS_ID, IN_Metro, Hydro ID, Is_Piped, pipe ID, pipe SRC, NHD code, FCODE_DESC, name, LLID, HUC12, LIDAR, subarea, source, create date, modification date, modifier, modification source, motes, type, period, shape length	817 of 3391 streams are missing LLID.		BC to use this layer to define and map waterbodies in the City.
	City of Tualatin	5/24/2016	StormMasterPlan.gbd	Ponds	polygon	Base	Areas of year-round ponded or standing water within Tualatin. Overlaps with some wet ponds in public water quality facilities.	NAD_1983_HARN_StatePlane_Oregon _North_FIPS_3601_Feet_Intl	NAME, Shape_Length,Shape_ Area	21 of 29 are missing names.	Is missing information due to the fact no pond names exist?	
	City of Tualatin	5/24/2016	StormMasterPlan.gbd	stm_line	line	Storm	Streams, Subset of Metro RLIS layer	NAD_1983_HARN_StatePlane_Oregon _North_FIPS_3601_Feet_Intl	Length, shape_length	All data is populated		Layer will not be used in mapping.
Parks and Open Space Mapping	City of Tualatin	5/24/2016	StormMasterPlan.gbd	Parks_Greenways_Nat ural_Areas	polygon	Base	All city-owned parks, greenways and natural areas. Some overlap with WPD and NRPO.	NAD_1983_HARN_StatePlane_Oregon _North_FIPS_3601_Feet_Intl	NAME, ACRES, TYPE, Shape_Length, Shape_Area	All data is populated	Are these areas assumed to be undevelopable? Are the greenways and natural areas included in shapefile designated as significant? How may parks and greenways by used to support stormwater management? (see City charter)	Areas represent undevelopable open space for purpose of land use coverage. Include in open space land use coverage. Additional discussion and legal interpretation of city charter required to verify how/ if public open space may be used for stormwater management.
Wetlands and Sensitive Areas	City of Tualatin	5/24/2016	StormMasterPlan.gbd	WPD	polygon	Base	Tualatin's Wetland Protection District. Sweek Pond Management Area and Wetlands Fringe Areas are identified in shapefile.	NAD_1983_HARN_StatePlane_Oregon _North_FIPS_3601_Feet_Intl	area, perimeter, WPD, WPD ID, type, acres, shape ST area, shape ST length, Shape length, shape area	All data is populated. Per Chapter 71, development may occur within the WPD in areas defined as Sweek Pond Management Area (SPMA) and Wetland Fringe Area (WFA).	Should this layer be used to define open space area (unlikely to develop or redevelop)?	Wetland Protection Area (WPA) only to be used in open space land use coverage. Most WPA already reflected in NRPO and wetland coverage.
	City of Tualatin	5/24/2016	StormMasterPlan.gbd	Wetlands	polygon	Base	1996 LWI updated through 2008 for any wetland fills, creation and delineations. 7/7/16 - Why aren't all wetlands covered by NRPO? Only certain "significant" wetlands are included in the NRPO. The criteria for this can be found in Tualatin Development Code Chapter 72: Natural Resource Protection Overlay District	NAD_1983_HARN_StatePlane_Oregon _North_FIPS_3601_Feet_Intl	area, perimeter, wet, wet ID, w_1, acres, shape ST area, Shape ST Length, shape length, shape area	29 missing area, 23 missing perimeter and WET (What is WET?), 25 missing w_1 (What is w_1?)	Should this layer be used to define open space area (unlikely to develop or redevelop)?	Assume all are undevelopable and include in open space land use coverage. Per meeting 8/24/16, less significant wetlands (outside of NRPO and included in this shapefile) should also be considered undevelopable.
	City of Tualatin	5/24/2016	StormMasterPlan.gbd	NRPO	polygon	Base	Tualatin's Natural Resource Protection Overlay Districts. 7/7/16 - Why doesn't it include parks and wetlands? How is this area managed and used by the City? Are there constraints on development or the installation of SW management facilities here? The definition of NRPO was provided in the layer's metadata. It is also available (in more depth) in Tualatin Development Code Chapter 72: Natural Resource Overlay District (NRPO)	NAD_1983_HARN_StatePlane_Oregon _North_FIPS_3601_Feet_Intl	Acres, Resource Type, NPRO Class, Site Code, x_coord, y_coord, Resource Name, shape_length, shape_area	All data is populated. Coverage does not include parks and all wetlands. Per Chapter 72.060, minor public enhancements may be installed but no other significant development activity.	Should this layer be used to define open space area (unlikely to develop or redevelop)?	Use to supplement open space land use coverage.

Table A-1: GIS Data Review and Data Gaps

Initial Data Request	Source (Received From)	Date Received	Database Name (if applicable)	File Name	Feature Class	Data Type-Base or Storm	Layer Notes (from City)	Datum	Relevant Fields	Initial Observations and Identified Gaps	Outstanding Questions (per 7-28-16 and 8-24-16 mtgs)	Data Assumptions and Gap Resolution
Drinking Water and Irrigation Wells	City of Tualatin	5/31/2016	StormMasterPlan_2.gdb	wr_v_pod_public	point	Base	Oregon Water Right Points of Diversion - Statewide point dataset published by Oregon Water Resources Department **7/7/16** - Per DH - We are going to assume DEQ's data is correct and ask that you use that data source (DH)	NAD_1983_Oregon_Statewide_Lambert_Feet_Intl	use_code, use_code_description, rate_cfs, max_rate_cfs, acre_feet, acre_feet_est, max_acre_feet, source, tributary_to, streamcode	This data appears to reflect surface water diversions and not drinking water wells. Point shapefile. Contains many more fields than wr_v_pou_public.	How does the City want to address UIC rule authorization or UIC retrofits in the Master Plan?	Per 7-21-16 call, rule authorization activities associated with Phase 005 will not be conducted. UICs deemed a maintenance concern to be addressed with CIP development.
	City of Tualatin	5/31/2016	StormMasterPlan_2.gdb	wr_v_pou_public	polygon	Base	Oregon Water Right Places of Use - Statewide polygonal dataset published by Oregon Water Resources Department	NAD_1983_Oregon_Statewide_Lambert_Feet_Intl	snp_id, shape_area, use_code, use_code_description, remarks	This data appears to reflect surface water intakes. Polygon shapefile. What is pou_display, app_char, app_nbr, permit_char, permit_number, cert_nbr, claim_nbr?	See above.	
	City of Tualatin	5/31/2016	StormMasterPlan_2.gdb	OR_Groundwater_DWSAs_ORLAMBERT_Ver5_09JAN2015	polygon	Base	Drinking water source areas - Statewide polygonal dataset published by Oregon Department of Environmental Quality	NAD_1983_Oregon_Statewide_Lambert_Feet_Intl	pws_id, Tinwsys_na, tinwsf_nam, src_label, epa_method, or_method, comments, area, perimeter, acres, actv_stat	Contains only major wells for the state of Oregon. Does not reference ASR wells. Two wells are located within Tualatin city limits for Tri-County Industrial Park with times of travel between 1 and 15 years. This data does not appear to reflect all drinking water wells. Unknown acronyms/abbreviations (tinwsys_is, fips_cnty, sens_zone)	See above.	
Other	City of Tualatin	5/24/2016	StormMasterPlan.gbd	BASALTCREEK_JURIS	polygon	Base	The Basalt Creek Concept Plan boundary is provided as a proposed approximate jurisdictional boundary. **7/7/16** - City will provide data once they have more accurate information to provide.	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	acre, future_jurisdiction, shape_length, shape_area	All data is populated. Approximate road alignment and planning districts still required.	When will planning district and road information be made available?	No road or planning districts established. BC to move forward with subbasin delineation efforts and existing condition hydrologic calculations using current information/ aerial verification of impervious.
	City of Tualatin	5/31/2016	StormMasterPlan_2.gdb	TroubledSpots	point	Base	Point dataset of locations prone to seasonal flooding; identified during "kick-off" meeting **7/7/16** - Will update and coordinate with ops for areas (DH)	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	notes	Trouble spots as points with notes, but missing polygons to cover whole area of flooding issues. Mapped areas vary from identified hot spots and received surveys.	When will data be received? Have locations been internally vetted to ensure they are representative of storm system flooding and not floodplain inundation?	Shapefile used in the vetting and determination of stormwater problem areas and modeling needs (see Table A-3).
	City of Tualatin	8/4/2016	StormMasterPlan_Additional_Data.gdb	TroubleAreas	polygon	Base	Polygon shapefile of identified trouble areas.			13 areas identified: -Nyberg Ln and Stafford Hills Club -Tualatin Sherwood Rd and Martinazzi Ave outfall south of Fred Meyers -Blake St east of Martinazzi - Outfall south from Dakota Chieftain greenway -Blake St east of Martinazzi - Outfall north of street -Behind Oil Can Henry's and Casa de Robles Apartments - adjacent to RR track -End of 125th Ct - east side (Caruso Products) -Greenspace between Boones Ferry Rd and Siuslaw Ln -Borland Rd south of Meridian Park Hospital -Herman Rd (between Tualatin Rd and Teton) -Sagert and 93rd Ave -Warm Springs St at Elks Club (8350 SW Warm Springs) -East side of 124th Ave north of Leveton Rd -End of SW Piute Ct Also contains brief descriptions of each problem area. Does not reflect Manhassat or Sandalwood (previously discussed).		Shapefile used in the vetting and determination of stormwater problem areas and modeling needs (see Table A-3).

Table A-1: GIS Data Review and Data Gaps

Initial Data Request	Source (Received From)	Date Received	Database Name (if applicable)	File Name	Feature Class	Data Type-Base or Storm	Layer Notes (from City)	Datum	Relevant Fields	Initial Observations and Identified Gaps	Outstanding Questions (per 7-28-16 and 8-24-16 mtgs)	Data Assumptions and Gap Resolution
Other (continued)	City of Tualatin	8/4/2016	StormMasterPlan_Additional_Data.gdb	building_footprints	polygon	Base	Contains footprints of buildings within city limits and a portion of SW Concept Plan Area.			Includes buildings from all land uses including residential. - 7524 total buildings identified. - 6108 are missing land use class. - 6050 are missing addresses.		To be used in the calculation of impervious coverage by planning district.
	City of Tualatin	8/4/2016	StormMasterPlan_Additional_Data.gdb	tualland	polygon	Base	City owned property			Contains types (Accessway, Greenway, Management Land, Natural Area, Park, Parking Lot, Public Storm Drainage, Right-of-way, Street Plug, Utility, Water Quality Facility, Water Reservoir) and property names.		To be used to help identify area with the potential to install stormwater treatment/ conveyance/ detention systems as part of CIP development.
	City of Tualatin	8/4/2016	StormMasterPlan_Additional_Data.gdb	NW_Concept_Plan_Area	polygon	Base	Polygon file of NW Concept Planning Area.					To be used to define concept planning area boundary and project extents.
	City of Tualatin	8/4/2016	StormMasterPlan_Additional_Data.gdb	SW_Concept_Plan_Area	polygon	Base	Polygon file of SW Concept Planning Area.					To be used to define concept planning area boundary and project extents.
	City of Tualatin	4/3/2017	Tualatin_Land.gbd	Tualatin_Land	polygon	Base	Revised city-owned property			Updated version of tuallands. Changes include revisions to parks, greenways, and natural areas.		TBD. Currently used for the water quality assessment.
Storm GIS Data												
Piped Storm Drainage System	City of Tualatin	5/24/2016 and 8/4/2016	StormMasterPlan.gbd and StormMasterPlan_Additional_Data.gdb	stormpt	point	Storm	Storm structures (e.g., manholes, catch basins, outfalls, etc.) & also contains UICs (Drywell=Yes) **7/7/16** - Rim elevations ranged from 300+ to 100+ - is that amount of drop expected? Are there areas/ features where datum issues may be expected? Yes, that range of rim elevations is to be expected. All elevations (when available) were taken from the relevant public works asbuilts. It is assumed that most of these were tied to NAVD27, but Tualatin's code allows for "any known datum" and the datum is often not specified in the asbuilts.	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	asset ID, asset type, sump, as built, WQ, IEO, IEIE, IEW, IEIN, IEIS, rim elevation, bottom elevation, depth, owner, jetbook, OP_ID, dry well, diversion	Asset types of interest are ditch inlet, catch basin, clean out, flow structure, culvert in, culvert out, manhole, outfall and UICs. Relevant fields include: RimElev. IEO, IEIE, IEIW, IEIN, IEIS, Asset_id Attributes of interest include invert elevations in/out, bottom elevations or rim elevations. The 10 UICs are missing bottom elevations, and 1,670 culverts/MH/outfalls are missing IEOs, see "DataOverviewMap_34x44.mxd" for visual representation. Various structures are also missing RIM elevations.	Does the City still wish for the NAVD88 datum to be used for the master plan? What time frame should be expected for making the datum correction? What does the field "Jetbook" refer to? Contains entries such as Blue-SD, Gray-SD, Red-SD, etc.	Missing rim elevations to be surveyed (if surveyor is obtaining other system information) or estimated from LIDAR. City provided converted data on 8/4/16. Converted data appears to have elevations 3.52' higher than previous data to align with the NAVD88 vertical datum. BC compared updated rim elevations to LIDAR. Results documented in TM1.
	City of Tualatin	5/24/2016 and 8/4/2016	StormMasterPlan.gbd and StormMasterPlan_Additional_Data.gdb	stormli	line	Storm	Storm lines	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	asset ID, storm line type, storm line material, diameter, length, slope, as built, upstream asset ID, downstream asset ID, upstream elevation, downstream elevation, owner, jetbook, shape length	Over 2,000 lines are missing either upstream or downstream elevations (inverts), see "DataOverviewMap_34x44.mxd" for visual representation. 201 pipes have missing/unknown storm line material. 197 pipes are missing diameters. Other missing elements that can be determined using inverts include: slope, length.	Does the City still wish for the NAVD88 datum to be used for the master plan? What time frame should be expected for making the datum correction?	City provided converted data on 8/4/16. Converted data appears to have elevations 3.52' higher than previous data to align with the NAVD88 vertical datum.
Open Channel Drainage System	City of Tualatin	5/24/2016	StormMasterPlan.gbd	ditches	line	Storm	Storm water conveyance ditches - THIS IS OUTDATED	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl				Do not use.
	City of Tualatin	5/31/2016	StormMasterPlan_2.gdb	ditches	line	Storm	Storm water conveyance ditches. **7/7/16** - Is cross section information available? There is sometimes cross section information available in the asbuilt series the ditch has been captured from. IF such info would be helpful, we could search the asbuilts and provide those that are relevant.	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	asset ID, asset type, as built, length ft, owner, shape ST length, shape length	All data is populated. No cross-sectional information, no elevation information.		BC to use LIDAR and field survey to develop channel cross sections for modeled portions of the system. As-built information to be provided by the City where available.
	City of Tualatin	8/5/2016	StormMasterPlan_Additional_Data.gdb	Ditches		Storm	Storm water conveyance ditches.			Still missing cross-sectional data. Appears no changes have been made from previously received shapefile.		
Public Water Quality Facilities	City of Tualatin	5/24/2016	StormMasterPlan.gbd	wq_fac	polygon	Storm	Tualatin's public water quality facilities. **7/7/16** - Is area served delineated? Current delineation reflects footprint area The area served has not been delineated, but could derived for most of the facilities assuming the "area served" would be more-or-less the subdivision platt it came from.	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	asset ID, facility type, water quality facility name, acres served, as built, date completed, WQF number, WQF notes, X coordinate, Y coordinate, impervious surface, address, shape length, shape area	Polygon file reflecting footprint. 33 missing acres served, 2 missing as built, 9 missing completion date, 8 missing WQF number, 42 missing WQF notes (others include notes about dimensions, volume, etc.), impervious surface attribute either "null" or "zero". No delineation of areas/acres served provided.	Is additional information available from CWS? Would the City be able to provide the drainage area of each public facility (in order to evaluate retrofit potential for water quality).	Drainage areas for public facilities not readily available. May obtain from City following CIP workshop and identification of potential water quality CIPs/ retrofits. City provided tualland GIS shapefile to distinguish all areas and facilities that may be considered for stormwater CIP development.
Private Water Quality Facilities	City of Tualatin	5/24/2016	StormMasterPlan.gbd	PWQF	point	Storm	Tualatin's private water quality facilities **7/7/16** - What does the field PWQF_GEO refer to? It's a Boolean attribute that indicates whether or not we have identified exactly where the private water quality facility is located on the parcel. We have some records of private water quality facilities but it is not known to us where they are exactly located (PWQF_GEO = 'No')	NAD_1983_HARN_StatePlane_Oregon_North_FIPS_3601_Feet_Intl	PWQF_ID, PWQD_TYPE, WQP_ID	Point file. Does not contain any information related to size/area served. 12 Missing WQP_ID, not sure if relevant.	What fields are used by the City to track active facilities and maintenance needs? Is this information available from CWS?	

Table A-2: Code and Background Data Review						
Initial Data Request	Data Received and Reviewed	Data Source	Date Received	Information Summary	Outstanding Questions (per 7-28-16 and 8-24-16 mtgs)	Master Plan Application & Assumptions
List of stormwater-related CIPs completed in the last 5-10 years	None Received	----	----	No data to date	Will we be receiving this data? Are there current stormwater CIPs that should be reflected in the MP?	Updated stormwater system information accounts for any known system improvements. Current stormwater CIPs to be reviewed for potential inclusion in the MP.
Completed staff survey, listing drainage problem areas and water quality concerns – compiled by maintenance and engineering staff	Two completed surveys and storm hot spot list	City	6/2/2016	Survey - 1) Bert, included maintenance problem areas, and 2) Engineering Staff Storm area hot spots list includes 12 locations (roads or intersections) and reference storm infrastructure (ditch inlet, culvert, etc.) but no reference to the problem. Surveys included general area reference, but limited detail regarding scope and scale of problem. Some areas appear to be floodplain and natural system related instead of system capacity issues. Storm area hot spot locations and survey reference locations vary from mapped problem areas. Current problem areas include areas currently being addressed with other projects (wetlands behind Fred Meyer) and general natural system/ floodplain flooding.	Should maintenance-related projects be included in CIP?	Identified stormwater problem areas to be mapped and investigated during site visits. Problem areas due to capacity deficiency, maintenance concern, or infrastructure need will require more focused study, possible survey, and possible hydraulic modeling. Maintenance related CIPs to be considered if proposed maintenance frequency or activity is outside current schedule.
Photos/ information reflecting observed system flooding or capacity deficiencies	Manhasset Photos	City	6/2/2016	Manhasset system flooding from 12-8-15 storm event.	Are other system flooding photos available related to other problem areas?	Limited photos of active flooding are available. Photos to be used to reference potential source of problem area. (BC staff took additional images of Manhassat during a site visit with city staff on 6-29-16). Photos to be used to help validate system hydraulic models.
	Manhasset Survey and Easement information	City	6/29/2016	Manhasset property survey (1971 and 1996). Manhasset area survey (1986 and 1989). Easement information (UPS) and TL 100/200. Dated 1987 and 1995	Survey information is prior to current development. Are there more recent asbuilts, private development drainage infrastructure information? Should private system modeling be conducted/ considered as part of the master plan? Only where problem area is located?	No additional asbuilt information available. Data to be used to confirm drainage patterns and contributing area to public system. Survey data will supplement available information as required.
City Organizational Chart	City Organization Chart 2015-16	City	6/2/2016	Organization chart provided at department head level. Phone directory also provided.		Points of contact
Stormwater program staffing allocations	City completed data needs list - direct documentation	City	6/2/2016	Engineering 0.5 fte and Maintenance 2 fte	Is current staff available to support implementation of the MP and meet maintenance commitments? Is additional staff needed or warranted?	Maintenance activities and frequencies are mandated by CWS. Maintenance staff is lean, but additional staff is unlikely. City will likely contract out additional maintenance via CIP. City staff allocations will inform staffing assessment as part of the financial evaluation.
Stormwater maintenance procedures, frequencies and schedules (street sweeping, public water quality facility maintenance, private water quality facility inspection)	City completed data needs list - direct documentation	City	6/2/2016	WQF – inspections 1 every 4 years, 25% of facilities inspected each year (Bethany). See maintenance program report from Bert.	How does the city currently inspect/ensure inspection and maintenance of private water quality BMP's? Should this be a future consideration? Are public facilities inspected at same frequency? The report refers to maintenance of vegetated facilities being contracted. Does the City want to take on that responsibility? Does the City maintain a time sheet reporting system to track time spent with each activity? Is sweeping conducted by the City and is stormwater program budget spent on sweeping currently?	Maintenance responsibilities will be evaluated when considering additional staffing needs. Public facilities include subdivisions and may be a focus of a retrofit program. Public facilities are inspected once every four years. Maintenance obligations to be accounted for in staff evaluation. No time sheet reporting system. Staff evaluation to use average time/ activity referenced in other master plans.
	Collection System Maintenance Quarterly Report	City	6/2/2016	Report identifies annual targets for pipeline cleaning, manhole maintenance, catch basin cleaning, TV inspections, water quality manhole cleaning, vegetated facility maintenance, filter maintenance, detention facility maintenance, and sweeping.		Maintenance responsibilities will be evaluated when considering additional staffing needs.

Table A-2: Code and Background Data Review						
Initial Data Request	**Data Received and Reviewed**	**Data Source**	**Date Received**	**Information Summary**	**Outstanding Questions (per 7-28-16 and 8-24-16 mtgs)**	**Master Plan Application & Assumptions**
Stormwater Ordinance(s) and other applicable municipal code and development code sections, link or hardcopy	Link provided: Tualatin Development Code (TDC) Chapter 14 - Drainage Plan and Surface Water Management	City	6/2/2016	Defines 10 principal drainage basins. Major receiving waters are Tualatin River, Hedges Creek, Nyberg Creek, and Saum Creek. References Tualatin Drainage Plan, NW Tualatin Concept Plan (2005), SW Tualatin Concept Plan (2010), and Hedges Creek Subbasin (HCP) Plan/ Hedges Creek Subbasin Strategies Report (1995). The Hedges Creek Plan includes stormwater management activities, facilities, and programs. HCS Plan requires onsite detention for new development in Hedges Creek Subbasin. Section 14.040: Defines objectives for surface water management in Tualatin	Are their drainage improvements identified in any of the plans (Hedges Creek specifically) that haven't been installed/ implemented and should be considered? Should the NW and SW Tualatin Concept Plans be referenced for facility installations, stormwater drainage options? Are these proposed options currently reflected in the GIS?	NW and SW Concept Planning areas to be included in project area extents. Plans should be referenced for applicable design criteria as necessary. No anticipated CIPs stem from the plans.
	TDC Chapter 03-05 - Soil Erosion, Surface Water Management, Water Quality Facilities, and Building and Sewers	BC download	6/7/2016	3-05-050: Erosion control permit required for 500 sf land disturbance or slope > 20% 3-05-200: Mitigation of downstream system impacts addressed through onsite detention, enlargement of downstream system, or SDCs. Downstream analysis required for min 0.25 mile downstream or point where contributing area is less that 10% total. Onsite facility required where identified downstream deficiency, identified regional detention, or located in Hedges Creek subbasin. IF downstream deficiency, match post development to predevelopment for the 2 through 100 year storms, otherwise match 25 year storm. 3-05-240: Detention sizing per King County Surface Water Design Manual. For SFR, assume each lot contributes 2,640 sf impervious. 3-5-310, 350, 360, 430: Water quality treatment required for all development except construction of one or two family dwellings. Design standard is 0.36"/4 hours with average return period of 96 hours. Phosphorus performance standard of 65% removal. No water quality facility placement in existing or created wetlands unless mitigation action approved by city (only location exemption identified).	Should regional detention be sized to match the 2, 10, 25, and 100 year predevelopment flow per PW Stds or sized per CWS Stds only up to 25 yr? Are regional detention areas (as referenced in 3-05-200) identified and should be considered under this MP? For impervious surface calculations and financial calculations, is 2,640 still the EDU? Are there additional, documented water quality sizing guidelines we should consider? CWS has not yet established/ publicized updated online/ offline flow through standards (analysis has shown current standards adequate for offline).	Detention standards are per CWS (up to 25 year). Potential change to CWS standards in the future (flow duration/ continuous simulation analysis for facility design) but not to be included in CIP sizing at this time. Regional detention may be considered in the Hedges Creek subbasin or other areas where capacity limitations exist. 2,640 sf EDU is correct. Water quality design standards are per CWS.
	TDC Chapter 5 - Residential Planning Growth	BC download	7/14/2016	Provides plan densities per acre for medium/ multi family residential planning districts. Defines development type in each residential planning district.	Are there any changes that are anticipated future changes the plan districts? Should manufactured home parks be considered low density residential for land use purposes as defined in Section 5.040? Maximum density in this category is 6.4 units/ acre - what density range should be used here? Medium low density includes condos, townhouses, duplexes, and other multi-family dwellings - should density range of 10 units/ acre be maintained?	Per land use meeting (8-24-16), manufactured home parks are considered low density residential. Density ranges for all residential development to be used to validate impervious assumptions by land use.
	TDC Chapter 6 - Commercial Planning Districts	BC download	7/25/2016	Defines the various commercial planning district designations.	For existing land use, should all commercial be grouped together?	Per land use meeting (8-24-16), density and landscape requirements for overlay districts to be used to validate impervious assumptions by land use. Per land use meeting (8-24-16), commercial planning district designation to be reviewed. Hospitals and schools to be classified as institutional land use.
	TDC Chapter 7 - Manufacturing Planning Districts	BC download	7/25/2016	Defines the various industrial/ manufacturing planning district designations.	For existing land use, should all manufacturing be grouped together?	Per land use meeting (8-24-16), industrial and manufacturing planning district designations to be grouped together. Per land use meeting (8-24-16), density and landscape requirements for overlay districts to be used to validate impervious assumptions by land use.
	TDC Chapter 8 - Public, Semi-Public, and Misc. Land Use	BC download	7/25/2016	Defines the miscellaneous land uses in the City that do not fit into residential, commercial or industrial land use classifications. Includes government offices, utility facilities, schools, churches and retirement homes.	Should schools, churches, retirement homes and hospitals be categorized similarly? Currently only one institutional planning district parcel - should these be included? Currently they are reflected in LD residential and medium density residential.	Per land use meeting (8-24-16), commercial planning district designation to be reviewed. Hospitals and schools to be classified as institutional land use.
	TDC Chapter 71 - Wetland Protection District	BC download	7/25/2016	Defines established wetland protection district (WPD). WPD includes three subdistricts - 1) the Wetland Protected Area (WPA), which contains marshes and wetlands protected by chapter; 2) Sweek Pond Management Area, which contains Sweek Pond and adjacent area; and 3) the wetlands fringe area (WFA), which contains the balance of land contained in WPD and what is now or will be subject to development and usage. Permanent structures need to be set back 40' from WPA. Development is permitted in WFA per planning district designation. Utilities, habitat protection, gardens, parking, etc. are permitted in Sweek Pond Management Area. No permanent structures in WPA.	Should the entire WPD be considered preserved or protected for purposes of defining an open space land use coverage? Should only the WPA and SPMA be reflected?	Only the wetland protection area (WPA) to be identified as undevelopable open space land use.
	TDC Chapter 72 - Natural Resource Protection Overlay District	BC download	7/25/2016	Designates significant natural resources, which excludes artificially created wetlands but includes greenways and natural areas. Area overlaps with the WPD in some cases. The purpose of the area as defined is to provide sufficient area for stormwater runoff to reduce flood hazards and enhance water quality. Section 72.060 - Through a development review process, the city may allow use of greenways and natural areas for storm drainage purposes. Section 72.150 - Modifications for Storm Drainage Improvements - this chapter does not prevent the City from altering, enlarging, piping or modifying a creek channel in the NRPO District upon a finding that such modification is necessary.	Should the NRPO be considered an area for stormwater management or should it be limited to the greenways and natural areas within the NRPO?	The NRPO to be considered undevelopable open space area. Meeting with City attorney did not occur to verify assumptions of the charter. Although indicated in code, the charter prohibits use of greenways, natural areas, and City-owned parks from being used for stormwater management if that was not the intended use.

Table A-2: Code and Background Data Review						
Initial Data Request	**Data Received and Reviewed**	**Data Source**	**Date Received**	**Information Summary**	**Outstanding Questions (per 7-28-16 and 8-24-16 mtgs)**	**Master Plan Application & Assumptions**
Stormwater Ordinance(s) and other applicable municipal code and development code sections, link or hardcopy (continued)	Tualatin City Charter	City	6/2/2016	Chapter XI - Protection of City Owned Parks and Open Space. Purpose: Prevent transfer, sale, vacation or major change in the use of city parks without approving vote. To preserve...recreational value from incompatible and non-park development. Definition (Major Change): Change in use of a park from a recreation or preservation use to a non-park use unrelated to public recreation or preservation. Approval by Voters: Required if the city wants to "cause, undertake, or allow any development or construction that causes a major change in the use of the park or some part thereof". Designated parks (12), natural areas, and greenways are listed.	Does the City interpret these guidelines as preventing installation of surface water quality or detention features in a park? Is the list of protected parks, natural areas, greenways included in the Charter up to date?	Meeting with City attorney did not occur to verify assumptions of the charter. Although indicated in code, the charter prohibits use of greenways, natural areas, and City-owned parks from being used for stormwater management if that was not the intended use. The charter should be used as guidelines regulating stormwater facility placement.
City-specific Stormwater Design Standards (aside from those referenced in municipal code) for stormwater treatment, detention, and/or conveyance, link or hardcopy	Link provided: Public Works Construction Code (February 2013)	City	6/2/2016	Chapter 206 Storm Drainage Design - Use rational method for sizing pipe. Runoff coefficients and rainfall intensity provided. Table 206-1: Provides associated zone designation and residential swelling density per planning district designation. Section 206.3: Conveyance system to be designed for 25 year storm event. Surcharge during 25 year event not permitted.. Section 206.4.00: Minimum public system pipe size is 12" diameter. Maximum of 400' between structures. Section 206.6.00: Minimum 48" diameter manhole. Section 206.8.00: Design of surface water quality and detention facilities to CWS Design and Construction Standards (2007). Swale side slope limited to 4:1. 4' or 6' fencing required for all facilities; 12' Portland Cement access road required	Are these design criteria accurate?	Use for conveyance system sizing. Use of SCS/SBUH method (as used in SWMM) is acceptable for pipe design (variance from current city code).
	CWS Design and Construction Standards (2007)	BC download	4/29/2016	4.03.4 - Water quantity facilities to be designed to match pre and post development flow for 2, 10, and 25 year. 4.05 - Defines impervious area requiring treatment for redevelopment sites. 4.06 - Defines water quality facility design standards (by facility) 5.06 - Minimum pipe slope shall provide min velocity of 2.5 fps.	Are there preferred treatment or detention systems or approaches? What are the appropriate rainfall depths?	Underground detention systems are not preferred. Per CWS (Detail 1280) 2 year = 2.5", 10 yr = 3.45", 25 yr = 3.9", 100 = 4.5" CWS design standards shall be used for the sizing of specific water quality and detention facilities.
	CWS LIDA Handbook (2009)	BC download	4/29/2016	Provides additional design guidelines for LIDA facilities including use of sizing factors for select facilities		Use design standards for the sizing of specific facilities.
Copy of IGA(s) with Clean Water Services for related stormwater program implementation	IGA for Erosion Control Inspections	City	6/2/2016	District assumes primary responsibility for managing the erosion and sediment control program. This includes inspection of properties for compliance with rules, enforcement, and review of erosion plan revisions (within 10 days). District summarizes work accomplished and invoices the City. The City collects fees, reviews plans submitted with development proposal, issues permits and forwards permits and plans to District. City pays District 100% of actual costs.	Are there other applicable IGAs for inspection and plan review of stormwater facilities?	No additional IGAs provided.
Most recent annual report to CWS	Stormwater Annual Report, 2013-2014 reporting year	City	6/2/2016	Summarizes District and City's responsibility related to stormwater management. Co implementers required to inspect 25% of private water quality facilities annually	Does the City have responsibility related to illicit discharge investigations or is there an IGA with the District? Is LIDA required or promoted by the District for use in the City?	LIDA is a preferred treatment approach per new NPDES MS4 permit. Maintenance responsibilities will be evaluated when considering additional staffing needs.
Other Information	Basalt Creek Concept Plan and joint meeting with Wilsonville materials	BC download	4/26/2016	Describes proposed boundary and planning district delineations	Has the boundary been finalized? Are planning district delineations available for planning purposes in GIS? Are there roadway alignments available in GIS? Maps are available online currently.	Boundary has been finalized but no established future roadways or planning district coverage. Area to be included in the MP. Existing land use only to be evaluated. Martin provided boundary of concept planning areas in GIS via 8/4/16 data submittal.
	Bridgeport Area Stormwater Master Plan (2005)	BC download	4/26/2016	Details the storm drainage system and water quality facility installation for the Bridgeport area.	Has the water quality facility been installed? Does it provide detention benefit? Is there asbuilts?	Bridgeport MP subbasin delineation used to define subbasins for this MP effort.
	Tualatin Drainage Plan Report (1972)	BC download	4/26/2016	1972 Storm Drainage Master Plan		Background material only.
	Public Water Quality Facility Asbuilts (5 facilities)	City	1/9/2017	Provides design detail for select water quality facilities.		Use to define maintenance or redesign concepts for CIP development.
	Hedges Creek Wetlands Master Plan	City	3/2/2017	Provides project recommendations (culvert upsizing under Tualatin Road, sediment removal) related to the 29-acre Hedges Creek Wetlands.		Use to inform Natural Resource investigation efforts.

Table A-3: Stormwater Problem Areas and Project Opportunities

Preliminary Stormwater Problem Area ID	WQ Retrofit Opportunity	Stormwater Project Opportunity Area ID	Location Name	Basin/ Waterbody	Source	Problem Description	Problem/ Project Area Summary	Site Visit Summary (per 6-29-16 and 12-7-16 site visits)	Project Category	Preliminary Project Concept	Modeling (Y/N)	Modeling Data Needs
1			Nyberg Ln (near Browns Ferry Park)	Nyberg Creek	City GIS	Capacity (bank overtopping)	Frequent flooding of road. Source unclear - Tualatin R or Nyberg Creek. Low road profile and undersized culvert under Nyberg Ln that floods Stafford Hills Club. Flooding due to backwater conditions. Per 6/29/16 mtg - not a MP issue.	Not required	N/A	Not required	N	
2		1	Martinazzi Ave (near Tualatin-Sherwood Rd)	Nyberg Creek	Questionnaire-Staff City GIS	Capacity (pipe grade) Maintenance	Subject to over curb flooding in heavy rain events. Originally considered backwater issue. Current HEC modeling project with CWS to remove sediment and improve capacity in Nyberg Creek.	12/7/16 - Windshield survey conducted. Backwater influences from Nyberg Creek. See Opportunity Area #5 - High flow bypass down Martinazzi to Izzy's Pond (12"). Low flow pipe (42") discharges to downstream end of culvert under Martinazzi and is almost fully submerged. This attributes to sediment accumulation in the pipe down Martinazzi.	Maintenance/ Asset Management	Pipe replacement (parallel pipe) or reconfiguration/ rerouting. More frequent maintenance program (larger asset management program).	No, however modeling of Opp Area #5 may extend down to this location as needed	
3			Tualatin Sherwood Ave (near Martinazzi Ave)	Nyberg Creek	Questionnaire-Bert City GIS	Capacity (pipe grade) Maintenance	Pipe inspection confirms existing 42" pipe full of sediment. Flat pipe. Per 6/29/16 mtg - not a MP issue, but per recent findings should be included.				N	
4		2	Venetia Water Quality Facility Failing WQF (Lee between 56th and 57th)	Saum Creek	City GIS	Maintenance	The existing access path is partially washed out. The swale is mostly overgrown with large bushes and trees that need to be removed. It is unclear what the swale looks like underneath. Likely some regrading, replanting of the entire swale will be needed. Highflow bypass outfall should be checked and repaired as needed.	6/29/16 - Facility appeared overgrown but functional. No gate access to inspect inlet and outlet configuration. Limited maintenance access. Steeper grade and observed high flow bypass.	Maintenance	Inclusion in larger water quality facility maintenance CIP.	N	
5		3	Recent outfall retrofit (Blake St at Saum Creek)	Saum Creek	City GIS	Maintenance (Debris accumulation) Erosion	Outfall installation approximately 2010. Problem area #1: Pipe under Blake (not replaced in 2010) has flat grade and high water in winter. Problem area #2: Outfall north of Blake (separate pipe system) experiences bank erosion (citizen complaints)	6/29/16 - Outfall south of Blake appears functional. Some invasives identified and two large rocks in flow path result in sediment accumulation (may be intentional to divert flow). Problem areas not specifically looked at. 12/7/16 - Significant bank erosion in the vicinity of the outfall(Problem area #2) and the creek appears to be down cutting though may be stable now due to observed clay/hard pan layer. • The bank is steep and appears to be reasonably unstable and erosive. Further erosion could impact the adjacent home. The upstream system inspected previously (6-29-16) and is in good order. • Culvert inlet under Blake may be undersized and cause some backwater upstream.	Direct Replacement	CIP needed to retrofit existing outfall into creek and minimize erosion of the channel, which is hanging out over the creek and exposed.	N	
6	X		Blue Lot (Boones Ferry Rd and Tualatin Rd)	Hedges Creek	City GIS Water Quality Eval	Capacity (bank overtopping)	Flooding of lot due to proximity to Hedges Creek and floodplain. Flooding due to stream capacity issue. Per 6/29/16 mtg - flooding not a MP issue	Not required	New Infrastructure/ WQ Retrofit	Use of LID onsite may qualify as a retrofit per CWS retrofit strategy.	N	
7	X		Green Lot (approx. 18725 SW Boones Ferry Rd)	Hedges Creek	City GIS Water Quality Eval	Capacity (bank overtopping)	Flooding of lot due to proximity to Hedges Creek and floodplain. Flooding due to stream capacity issue. Per 6/29/16 mtg - flooding not a MP issue	Not required	New Infrastructure/ WQ Retrofit	Use of LID onsite may qualify as a retrofit per CWS retrofit strategy.	N	
8			Jurgens City Park	Tualatin River	City GIS	Capacity (bank overtopping)	Path floods due to stream capacity issue. Per 6/29/16 mtg - flooding not a MP issue	Not required	N/A	Not required	N	
9	X	4	Manhasset Dr. (near10550 SW Manhasset Dr)	Hedges Creek	Questionnaire-Bert Storm Area Hot Spots City GIS Stormwater CIP Water Quality Eval	Capacity	Frequent flooding of drainage channel between private properties from T-S Rd to Manhasset. Photos and background data received from City. WQ Opportunity - adjacent undeveloped land that has transportation and warehouse land draining to it	6-29-16 - Private property flooding reported. Drainage channel has limited capacity, especially if private property or area south of T-S Road discharges to it. Observed debris accumulation. Ditch along Manhasset is unmapped and drainage area to the ditch is unclear.	Upsize Infrastructure WQ Retrofit	CIP needed to alleviate private property flooding. MP effort to conduct detailed study of contributing area and flow patterns.	Y	No asbuilts exist with collection information. Requires survey of private collection system inputs and open channel. Improvement possibly a closed system. Model from culvert under Tualatin-Sherwood Rd, through open channel between the private properties, to closed system discharge to Hedges Creek.

Table A-3: Stormwater Problem Areas and Project Opportunities

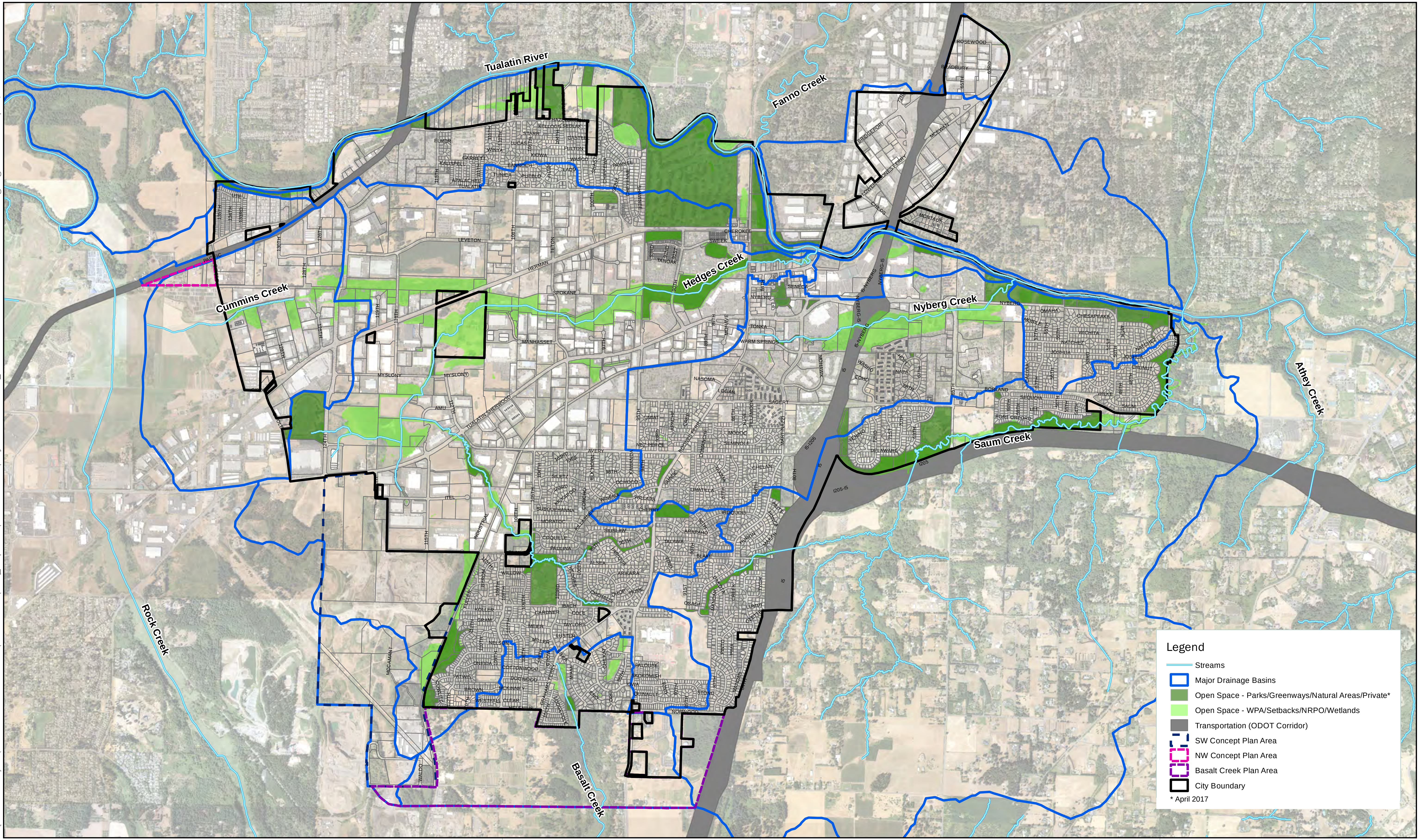
Preliminary Stormwater Problem Area ID	WQ Retrofit Opportunity	Stormwater Project Opportunity Area ID	Location Name	Basin/ Waterbody	Source	Problem Description	Problem/ Project Area Summary	Site Visit Summary (per 6-29-16 and 12-7-16 site visits)	Project Category	Preliminary Project Concept	Modeling (Y/N)	Modeling Data Needs
10		5	Boones Ferry Rd (19417 SW Boones Ferry Rd)	Nyberg Creek	Storm Area Hot Spots City GIS	Debris accumulation Capacity	Drainage ditch (behind Oil Can Henrys) and inlet frequently backed up due to debris accumulation. No system information currently in GIS. Unsure whether a maintenance issue or infrastructure issue. Per 10/31/16 call - Site visit required to confirm something can/ should be done here. Per 11/22/16 email - Low area along Boones Ferry has ponding, possibly due to inlet capacity. Nyberg Creek is piped behind the buildings to the west which may also be contributing to the issue behind Oil Can Henry's.	12/7/16 - This area may be the largest systematic problem area in the city. Problem area begins at the inlet along the railroad behind Oil Can Henry's and ends at the crossing of Martinazzi Ave. Some connectivity with Opportunity Area #12. • The inlet along the RR is a maintenance issue, gravel is transported and redeposited down the system. • StormFilter catchbasins along Boones are located at the sag, and clog due to filters being overwhelmed with sediment. • Channel from Boones to Tonka is small, incised and overwhelmed during large events. • The conveyance system in the vicinity of Tonka, Warm Springs and Boones does not appear to be efficient and well laid out. • Problem area #12 contributes to the flooding at Tonka and Warm Spring due to overland flow and carrying sediment down to the intersection. • The channel from Tonka to Martinazzi needs to be reviewed/optimized for conveyance IE: does the Izzy's weir need to come out and will that facilitate drainage? • Pipe system down Martinazzi from T-S road (Problem Area 1) accumulates sediment and discharges in vicinity.	New Infrastructure	CIP needed for source control and improved conveyance. Gravel barrier or netting at railroad ballast. Additional sediment control or more frequent maintenance may be needed to alleviate standing water of StormFilters. Rerouting SF to channel on E of Boones Ferry may improve conveyance. Inlets at the intersection of Tonka and Warm Springs should be rerouted for efficiency. Removal or reconfiguration of Izzy's Pond.	Y	Requires survey of select infrastructure and possible open channel conveyance. Model to include Opp Area #10. Extents of model to be determined with City as most infrastructure modeled will need to be surveyed. Model proposed from inlet along the RR tracks to Boones Ferry, then east where system becomes an open channel. The open channel will be modeled to the outfall at Martinazzi Ave and include drainage from Opp Area #10 to the south.
11			Cummings Creek (125th Ct).	Cummins Creek	Questionnaire-Bert	Capacity (bank overtopping)	Problematic flooding due to vegetation accumulation in stream channel and beaver activity.	12/7/16 - Reported flooding due to low lying property in floodplain. Flooding potentially due to beaver dam mitigation and installation of chain link fence on upstream and downstream ends of footbridge, resulting in backwater effects. Some questions remain with respect to drainage system, discharge locations along SW 125th Court, but no project proposed for this area.	N/A	Not required.	N	
12	X	6	Alsea/BF Rd 99th/Siuslaw Greenway	Hedges Creek	Questionnaire-Bert Retrofit Assessment	Infrastructure Replacement Water Quality	Corrugated Pipe has the bottom rusted out. Ditch inlet. No apparent capacity deficiency, just a pipe replacement. WQ Opportunity- This long linear greenway may provide an opportunity for enhancement and water quality treatment of outfalls along the alignment	12/7/16 - Pipe replacement due to condition. Scope may include replacement of parallel pipes (GIS indicates are concrete but are CMP) and downstream sediment trap/ water quality facility (swale). • Sedimentation is currently an issue at this location • May regrade grassy swale (concerns with WQ plantings due to maintenance) to be a water quality retrofit. • City input whether a water quality feature at downstream end of parallel pipe system would impede use of greenway.	Direct Replacement WQ Retrofit	CIP needed to replace pipe from Boones Ferry to manhole upstream of parallel pipes. Additional scope may include parallel pipes to outfall, outfall structure to capture sediment, and regrading of existing channel for water quality feature.	Hydrology only	
13			Borland Rd	Saum Creek	Questionnaire-Bert	Infrastructure Needs	Frequent flooding due to lack required drainage infrastructure. Inlet on south side of Borland does not discharge anywhere. Per 10/31/16 call - Area drains to a drywell and addressed as part of Sagert Farms project effort. Not an area to be addressed with MP.	Not required	N/A	Not required	N	
14	X	7	Herman Rd	Hedges Creek	Questionnaire-Bert Water Quality Eval	Infrastructure Needs Water Quality	Frequent flooding Lacks required drainage infrastructure Per 10/31/16 call - Recent traffic accident in proximity; desire to install piped/ below ground infrastructure. WQ Opportunity - Land SE corner of Herman Road and 95th may facilitate water quality treatment associated with Herman Road development	6-29-16 - Relatively flat grade. Half the road drains to roadside ditch and the other half to a ditch along railroad ROW. Stormwater improvements to be done in conjunction with roadway widening. City needs preliminary costs.	New Infrastructure WQ Retrofit	CIP needed to install additional conveyance infrastructure and possibly accommodate water quality.	Y	South side of road has no piped collection system or drainage facilities from 118th to Teton. From Teton east, the road needs full improvements. This area is very flat and there is no clear location to drain runoff. The model will extend from Teton to Tualatin Road and require verification of culvert elevations under railroad. Preferred discharge location(s) should be identified and coordinated with the City prior to modeling.
15			Grams Ferry/Victoria Woods	Seely Ditch	Questionnaire-Bert Stormwater CIP	Infrastructure Needs	Lacks required drainage infrastructure. Need water treatment for untreated areas. Per 11/22/16 email - Outfalls have WQFs and no ongoing maintenance. Not a problem.	Not required	N/A	Not required	N	

Table A-3: Stormwater Problem Areas and Project Opportunities												
Preliminary Stormwater Problem Area ID	WQ Retrofit Opportunity	Stormwater Project Opportunity Area ID	Location Name	Basin/ Waterbody	Source	Problem Description	Problem/ Project Area Summary	Site Visit Summary (per 6-29-16 and 12-7-16 site visits)	Project Category	Preliminary Project Concept	Modeling (Y/N)	Modeling Data Needs
16	X		93rd Ave	Nyberg Creek	Questionnaire-Bert Water Quality Eval	Infrastructure Needs	Unimproved roadway lacks required drainage infrastructure. Per 10/31/16 call - Outfall improvement may be needed.	12/7/16 - Reported need to install drainage system on unimproved roadway. • Street update could provide treatment in the form of roadside planters or green street for much of the street up to Avery Street. • Street needs sidewalk, curb/gutter, etc. Current conveyance is provided in street side ditch primarily on the west side of 93rd.	WQ Retrofit	GIS indicates collection system exists so no new infrastructure required. CIP to install green street or develop a green street program may be developed (see City-wide public infrastructure opportunity).	N	
17		8	Curves at Blake/105/108th	Hedges Creek	Questionnaire-Bert	Infrastructure Needs	Lacks required drainage infrastructure Per 10/31/16 call - Potential for two projects; one is to upsize culvert under Blake (fish passageable) and two is to add roadway drainage. City is currently in planning stages for roadway update but no budget for project yet. Culvert alignment may play a role in design and cost estimate.	12/7/16 - No collection system. Current drainage from Coquille and 105th is an open channel ditch to culvert inlet. • Stream channel experiences 90-degree bends on both sides of culvert. • Culvert replacement may need to be fish passable, culvert is undersized, currently a 36" or 42". Existing roadway embankments are steep and drainage updates are needed for the roadway. • City input related to culvert orientation and points of discharge needed.	New Infrastructure	CIP needed to address roadway drainage and culvert crossing. The roadway improvement extents to be verified by City (Moratoc to 108th). The culvert design will incorporate a sizing and length based on the hydrology and ideal alignment. Per 1/25/17 - ODFW feedback indicates culvert likely not need to be fish passageable.	Hydrology only	
18			Sagert Farms	Saum Creek	Questionnaire-Bert	Infrastructure Needs	Development is currently occurring and area not to be reflected with MP. Two water quality ponds installed. Downstream analysis conducted to verify no impacts.	Not required	N/A	Not required	N	
19			Nyberg Wetlands	Nyberg Creek	Questionnaire-Bert	Capacity (bank overtopping)	Current City-initiated modeling effort in conjunction with CWS and Wetlands Conservancy. Per 6/29/16 mtg - do not include in MP.	Not required	N/A	Not required	N	
20			Fred Meyer	Nyberg Creek	Questionnaire-Bert Storm Area Hot Spots	Capacity (bank overtopping)	Backwater and heavy sediment load reduces capacity in Nyberg Creek, causing it to overtop its banks. Current City-initialed modeling effort with CH. Per 6/29/16 mtg - do not include in MP.	Not required	N/A	Not required	N	
21	X	9	Sagert St. - Shenandoah Apts (Sandalwood)	Nyberg Creek	Storm Area Hot Spots Water Quality Eval	Erosion (Channel incision) Capacity	Reported flooding during Oct and Dec 2015 storms. Concerns over erosion and channel incision. No mapped drainage ditch.	6-29-16 - Limited pipe cover on inlet pipe. Channel is incised and sloughing observed. Flooding may be due to debris from above tree limiting capacity in ditch inlet. Possible opportunity for water quality project, water quality facility.	Upsize Infrastructure WQ Retrofit	CIP needed to address channel downcutting. WQ and detention should be incorporated into this project if possible (project location is upstream of Opp Area #10).	Y	Model will extend from Seminole to Sagert. This model may be incorporated into the models for Opp areas #5 and #10.
22			Marquis 100 acre regional facility	Nyberg Creek	Questionnaire-Staff	Water Quality	Water quality concerns related to stormwater Per 11/22/16 email - Not a problem area due to recent WQF install.	Not required	N/A	Not required	N	
23	X	City wide	Public infrastructure improvements	Citywide	Questionnaire-Staff	Infrastructure Needs Water Quality Maintenance	Storm lines and infrastructure throughout City.	Not required	Direct Replacement Maintenance/ Asset Management WQ Retrofit (Green streets)	Development of an asset management/ maintenance related project for infrastructure requiring increased maintenance frequency; proactive pipe replacement; and green street pilot program. Areas and scope to be defined during CIP workshop.	N	
24			Riverhouse bridge		Questionnaire-Staff	Infrastructure Needs	Outdated infrastructure that may require replacement. Also includes culvert on lot to the east in the floodplain. Per 11/22/16 email - Problem was washed out culvert on private lot. Not a problem area.	Not required	N/A	Not required	N	

Table A-3: Stormwater Problem Areas and Project Opportunities												
Preliminary Stormwater Problem Area ID	WQ Retrofit Opportunity	Stormwater Project Opportunity Area ID	Location Name	Basin/ Waterbody	Source	Problem Description	Problem/ Project Area Summary	Site Visit Summary (per 6-29-16 and 12-7-16 site visits)	Project Category	Preliminary Project Concept	Modeling (Y/N)	Modeling Data Needs
25		10	Mohawk Apts	Nyberg Creek	Storm Area Hot Spots	Capacity Maintenance	Field ditch inlet backs up and accumulates debris on public property. Close proximity to problem area #5.	12/7/16 - Conveyance capacity issue also affecting Opp area #5. • Inlet behind Mohawk Apts is overwhelmed and water flows overland through adjacent property and causes flooding at Tonka and Warm Springs. • Just a few feet of freeboard is currently available prior to overtopping at the inlet, and a grate structure is installed on top of the inlet. This may be an inlet capacity issue, a pipe capacity issue or the combination of the two. • City is unaware of any easements that are in place that may facilitate correcting the issue. Corrective action may include piping the current open channel, updating the inlet, or increasing downstream pipe capacity. • City to see whether existing easement continues upstream.	New Infrastructure	CIP needed to alleviate overland flow affecting surrounding properties. May include closed conveyance for open channel system through apartments.	Y	Include with Opp Area 5 modeling effort. Model to extend from
26			Lake Blake		Storm Area Hot Spots	Maintenance	Field ditch inlet. Per 11/22/16 email - Likely same location as problem area #3. Not a standalone problem area.	Not required	N/A	Not required	N	
27			124th Ave at Leventon Dr.	Cummins Creek	Storm Area Hot Spots	Maintenance	Field ditch inlet backs up and accumulates debris.	12/7/16 - Maintenance issues at existing inlet on private property. Inlet doesn't appear to receive road drainage. Invasive vegetation prevents drainage. May include as part of an ongoing maintenance CIP.	Maintenance/ Asset Management	Development of an asset management/ maintenance related CIP for increased maintenance frequency or proactive pipe replacement to be discussed during CIP workshop (see City-wide public infrastructure opportunity).	N	
28		11	Piute Ct	Saum Creek	Storm Area Hot Spots	Maintenance	Public water quality facility is failing. No adequate access road. Sediment accumulation. The location of discharge is unknown.	12/7/16 - WQ facility maintenance required and installation of access road. • Limited easement between homes to install access road but existing access along backside of facility and reported existing road overgrown. • City to verify whether existing road alignment (currently overgrown) can be used as an access road from Martinazzi.	New infrastructure Maintenance	CIP to include facility regrading with sediment removed and replantings. The outfall structure should be inspected. The discharge location is unknown but likely on ODOT ROW. Need to establish maintenance access. Existing easement available between two houses on Piute Ct.	N	
29	X		Facility next to C and E Rentals	Hedges Creek	Site Visit Water Quality Eval	Unknown	Ownership and functionality of existing stormwater facility is not known. Per 10/31/16 call - Not a City issue. Property belongs to Washington County. Remove from problem area list, but may be potential water quality opportunity area.	Not required. Per City, ownership is Washington County.	N/A	Do not consider at this time.	N	
30		12	Sequoia Ridge Water Quality Facility	Saum Creek	Stormwater CIP	Maintenance	Maintenance needed and malfunctioning outlet structure.	12/7/16 - This facility has had little to no maintenance over the years. • Large cottonwood trees need to be removed, full replanting, outfall structures need to be re-viewed and updated as needed. • Due to the standing water its assumed there is little to no beneficial vegetation • Outlet structure appears to have a capped low flow pipe so pond design may have included an underdrain.	Maintenance	Inclusion in larger water quality facility maintenance CIP.	N	
31		13	Sweek Dr. water quality pond	Hedges Creek	Stormwater CIP	Maintenance	Maintenance needed due to sediment accumulation and tree growth.	12/7/16 - This facility has had little to no maintenance over the years. • Large cottonwood trees need to be removed, full replanting, outfall structures need to be re-viewed and updated as needed.	Maintenance	Inclusion in larger water quality facility maintenance CIP.	N	
32	X	14	Waterford Water Quality Facility	Hedges Creek	Stormwater CIP Water Quality Eval	Maintenance Water Quality	Maintenance needed due to sediment build up and limited access to outlet structure. Original design had a WQ swale graded around the pond for preliminary treatment and then the swale discharged into the pond. The swale no longer exists and needs to be regraded into the facility, there is likely sediment build up in the pond that needs to be removed. The existing outlet structure in the pond needs to be removed and replaced along the side of the pond to facilitate access.	12/7/16 - This facility has had little to no maintenance over the years. • Original design reported to properly function 15+ years ago. • No vegetation is visible and the original design included a swale graded around the pond for pretreatment, prior to entering the pond. The swale currently does not receive any water and is not functional. • Full replanting of vegetation is needed. Outfall structures need to be relocated and reviewed so that maintenance can be performed during high water events as needed. The inlet riprap needs to be replaced.	Maintenance WQ Retrofit	Update system design to incorporate detention and water quality improvements. Redesign system to relocate outfall structure and replace inlet structure.	Hydrology only	

Table A-3: Stormwater Problem Areas and Project Opportunities													
Preliminary Stormwater Problem Area ID	WQ Retrofit Opportunity	Stormwater Project Opportunity Area ID	Location Name	Basin/ Waterbody	Source	Problem Description	Problem/ Project Area Summary	Site Visit Summary (per 6-29-16 and 12-7-16 site visits)	Project Category	Preliminary Project Concept	Modeling (Y/N)	Modeling Data Needs
	X	City wide	Public Water Quality Retrofit	Citywide	Water Quality Eval	Water Quality	City staff has been receiving complaints from homeowners unaware that a public water quality facility is located in close proximity to their residence. Re-engineering and/or retrofit of existing water quality facilities may be required.	Pending	Maintenance WQ Retrofit	Develop a program to review/ investigate existing system design and function. To be discussed during CIP workshop.	N	
	X	15	89th Ave/Tualatin-Sherwood Rd Stormwater Outfall	Hedges Creek	Stormwater CIP Water Quality Eval	Water Quality	Water quality manhole installation to prevent debris from discharging into wetlands. CWS retrofit program driver.	12/7/16 - Limited opportunity for green infrastructure or any facility with drop requirement. Water surface elevation in adjacent wetlands, which is the outfall for this system, prohibits use of any facility with large internal drop requirement.	New Infrastructure/ WQ Retrofit	Per review of CWS Permit and SWMP, appears to be viable as an outfall retrofit project.	N	
	X	16	125th to Herman Rd	Cummins Creek	Stormwater CIP Water Quality Eval	Water Quality	Water quality treatment facility/ manhole installation to treat 143 ac contributing area with no upstream treatment. CWS retrofit program driver.	12/7/16 - Limited opportunity for green infrastructure or any facility with drop requirement. Water surface elevation in adjacent wetlands, which is the outfall for this system, prohibits use of any facility with large internal drop requirement. • Identifying the catchment for a proposed vortex device sizing remains the challenge due to the railway along south side of SW Herman Road and its impact on the catchment areas. • City input needed on drainage patterns in proximity of railway.	New Infrastructure/ WQ Retrofit	Per review of CWS Permit and SWMP, appears to be viable as an outfall retrofit project.	N	
	X		City Operations Yard	Hedges Creek	Water Quality Eval	Water Quality	Potential water quality retrofit at City-owned, municipal property. Signinficant impervious surface area. No existing treatment.	Pending	New Infrastructure/ WQ Retrofit	Use of LID onsite may qualify as a retrofit per CWS retrofit strategy.	N	
	X		White Parking Lot	Hedges Creek	Water Quality Eval	Water Quality	Potential water quality retrofit at City-owned, parking lot. Signinficant impervious surface area. No existing treatment.	Pending	New Infrastructure/ WQ Retrofit	Use of LID onsite may qualify as a retrofit per CWS retrofit strategy.	N	

Attachment B: Maps



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Brown AND Caldwell

City of Tualatin

City of Tualatin

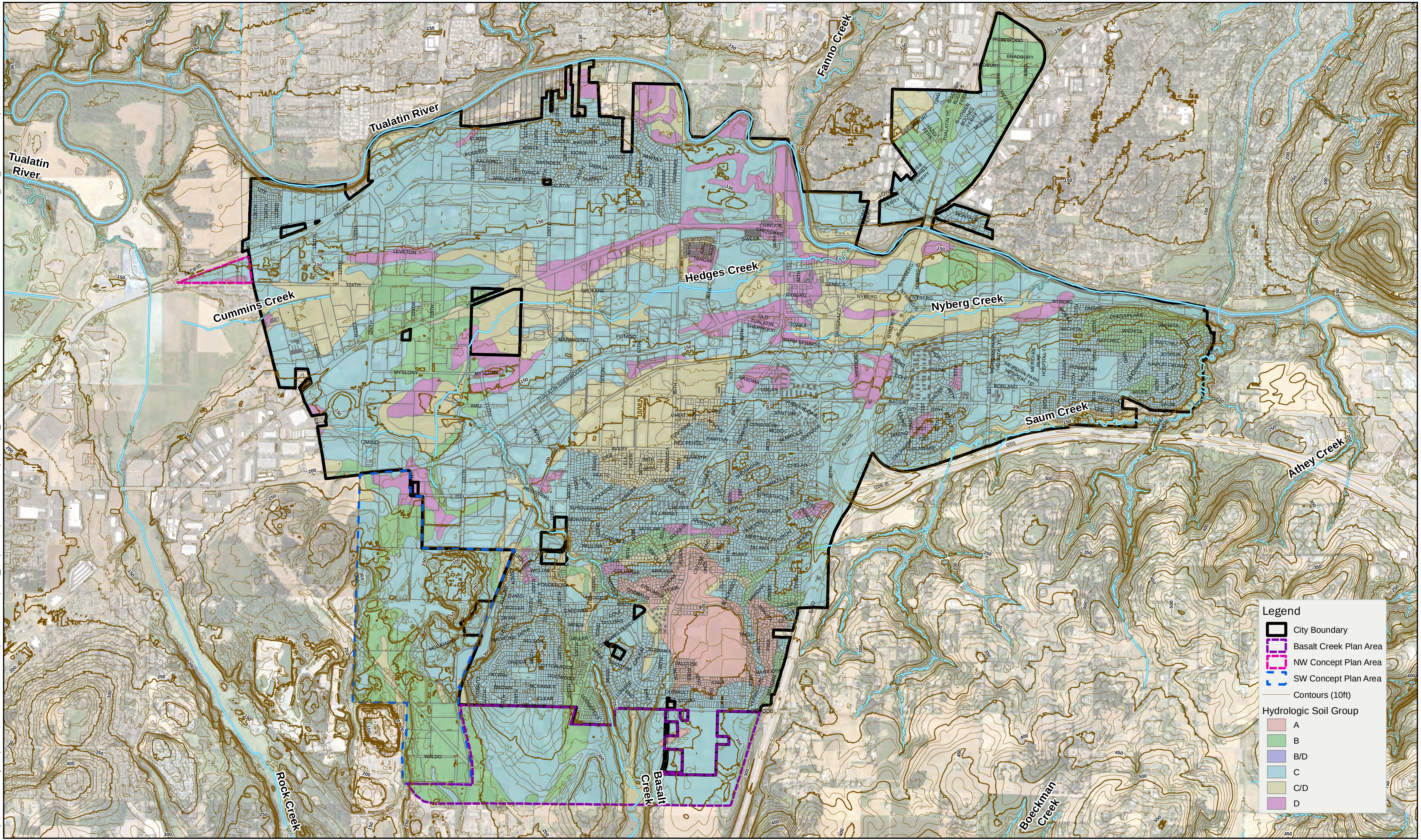
Stormwater Master Plan

Date: March 2017
Project: Project 149233

Notes:
1. Projection: NAD 1983 State Plane Oregon North (feet)

Figure 1

Project Area Overview



City of Tualatin
Stormwater Master Plan

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Project: Project 149233

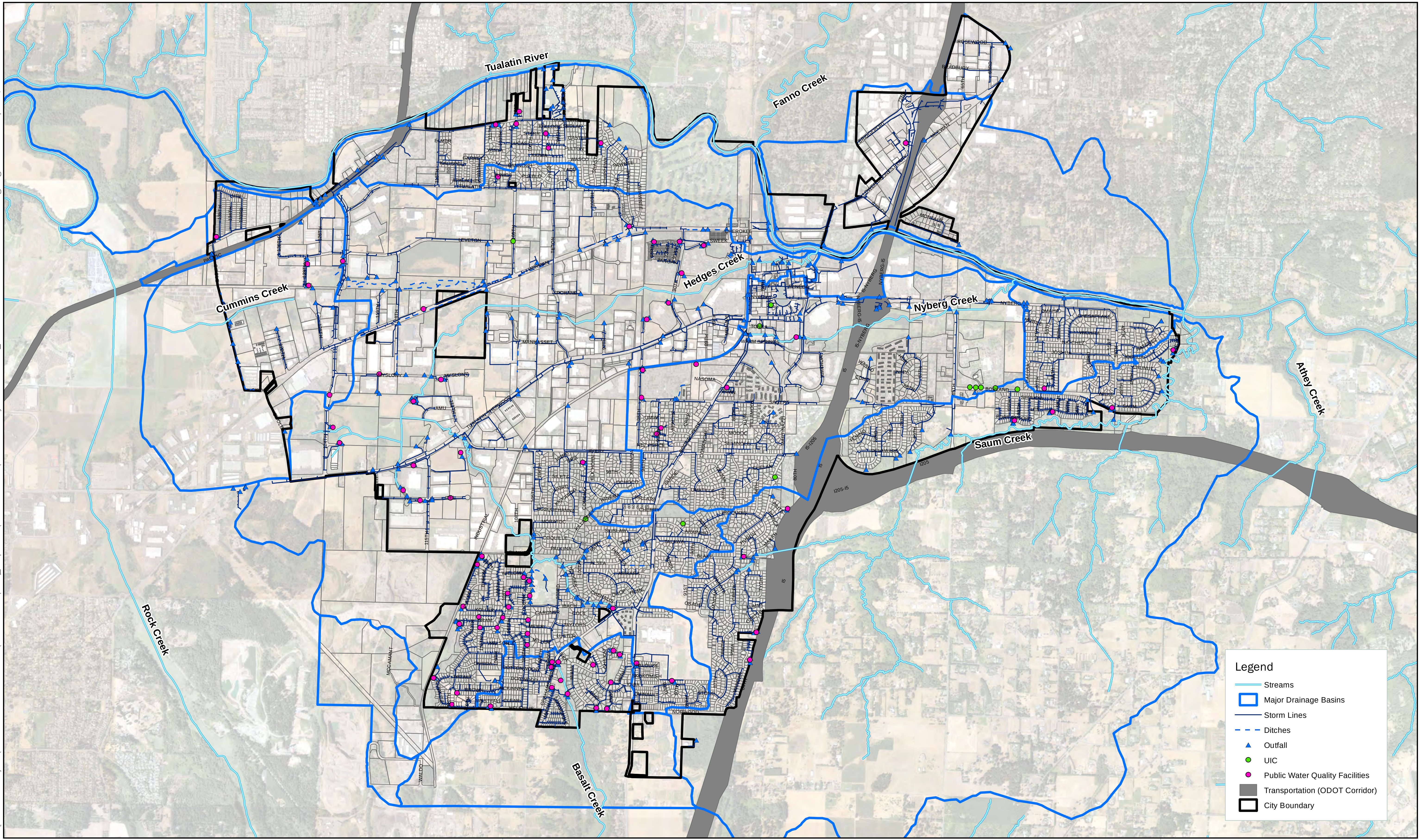
0 2,250 4,500 Feet

N

Notes:
1. Projection: NAD 1983 State Plane Oregon North (feet)

Figure 2

Topography and Soils



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City of Tualatin
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Notes:
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Figure 3

Stormwater System Overview

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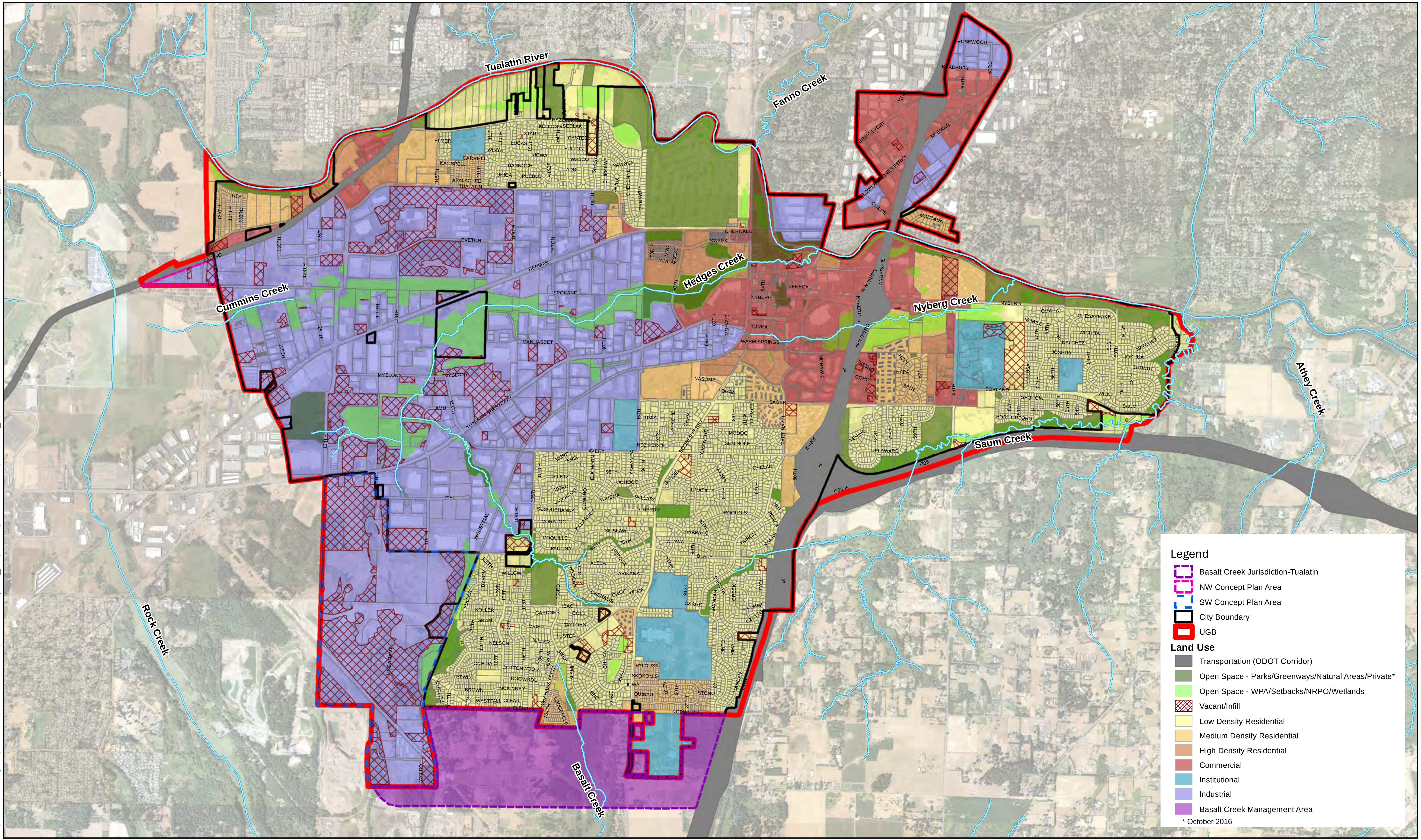
mgrzegorzewski

Apr 7, 2017



City of Tualatin

Stormwater Master Plan

Date: March 2017

Project: Project 149233

0 2,250 4,500 Feet

N

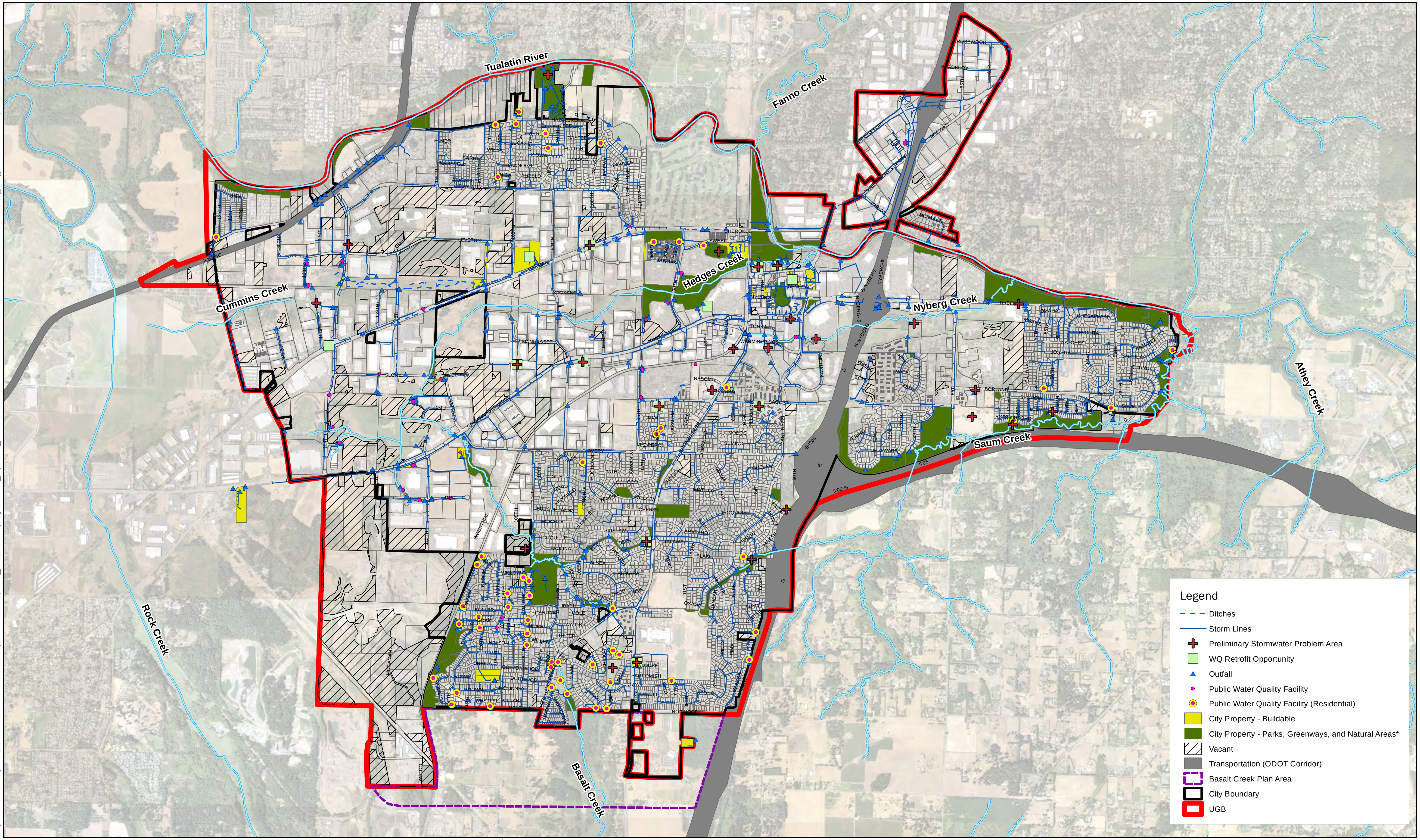
Notes:

1. Projection: NAD 1983 State Plane Oregon North (feet)

Figure 4

Land Use

[BCDENFP01]; P:\149233 Tualatin SW MP\07 CAD-GIS\GIS_MapDocs\WQRetrofit_Update_11x17.mxd mgrzegorzewski Apr 24, 2017



Brown AND Caldwell

City of Tualatin

City of Tualatin

Stormwater Master Plan

Date: March 2017
Project: Project 149233

0 2,250 4,500 Feet

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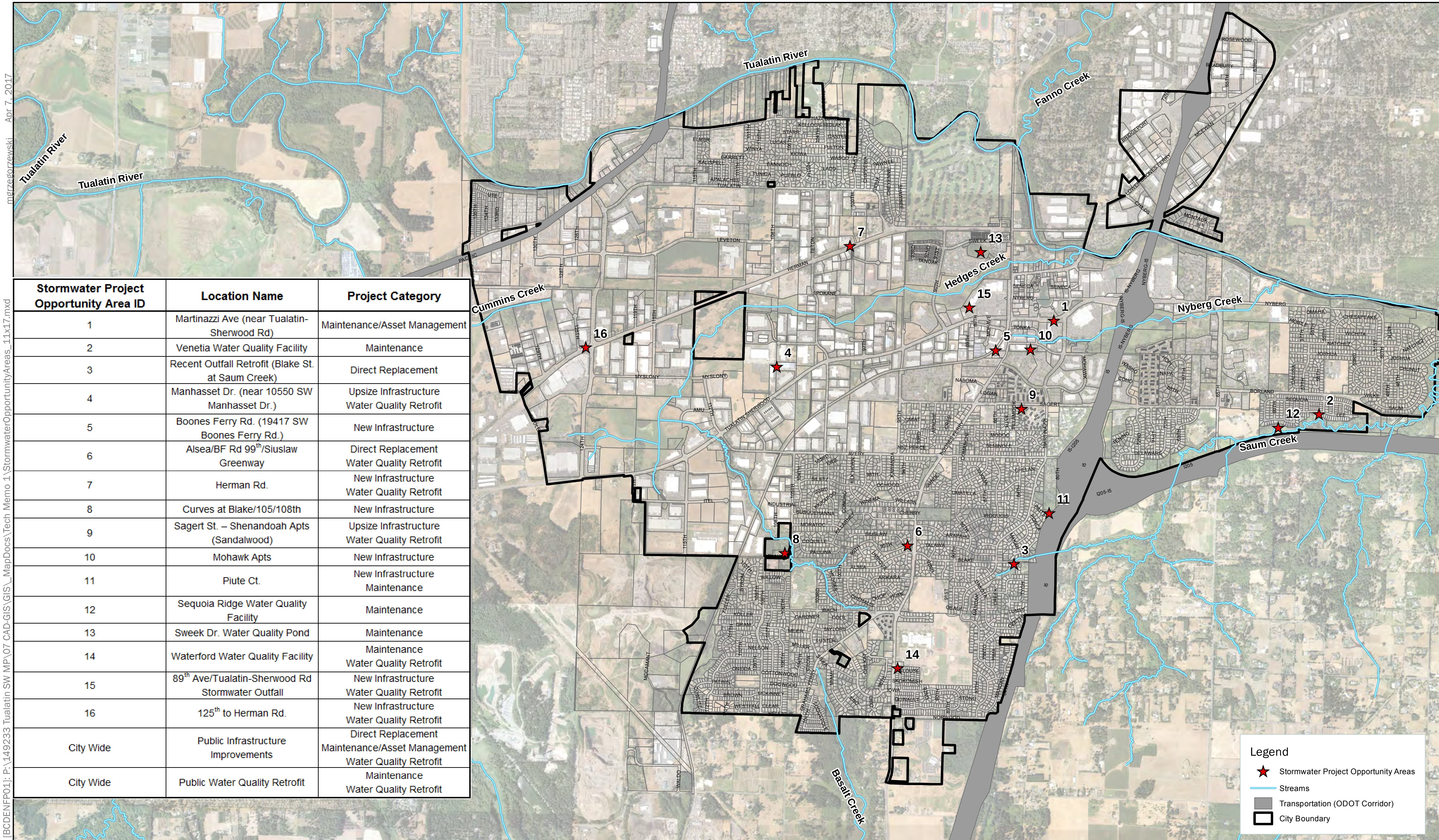
Notes:
1. Projection: NAD 1983 State Plane Oregon North (feet)

Figure 5

Water Quality Assessment



Stormwater Project Opportunity Area ID	Location Name	Project Category
1	Martinazzi Ave (near Tualatin-Sherwood Rd)	Maintenance/Asset Management
2	Venetia Water Quality Facility	Maintenance
3	Recent Outfall Retrofit (Blake St. at Saum Creek)	Direct Replacement
4	Manhasset Dr. (near 10550 SW Manhasset Dr.)	Upsize Infrastructure Water Quality Retrofit
5	Boones Ferry Rd. (19417 SW Boones Ferry Rd.)	New Infrastructure
6	Alsea/BF Rd 99th/Siuslaw Greenway	Direct Replacement Water Quality Retrofit
7	Herman Rd.	New Infrastructure Water Quality Retrofit
8	Curves at Blake/105/108th	New Infrastructure
9	Sagert St. – Shenandoah Apts (Sandalwood)	Upsize Infrastructure Water Quality Retrofit
10	Mohawk Apts	New Infrastructure
11	Piute Ct.	New Infrastructure Maintenance
12	Sequoia Ridge Water Quality Facility	Maintenance
13	Sweek Dr. Water Quality Pond	Maintenance
14	Waterford Water Quality Facility	Maintenance Water Quality Retrofit
15	89th Ave/Tualatin-Sherwood Rd Stormwater Outfall	New Infrastructure Water Quality Retrofit
16	125th to Herman Rd.	New Infrastructure Water Quality Retrofit
City Wide	Public Infrastructure Improvements	Direct Replacement Maintenance/Asset Management Water Quality Retrofit
City Wide	Public Water Quality Retrofit	Maintenance Water Quality Retrofit

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City of Tualatin
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Date: March 2017
Project: Project 149233

Notes:
1. Projection: NAD 1983 State Plane Oregon North (feet)

Figure 6

Stormwater Project Opportunity Areas

Appendix C: Hydrology and Hydraulic Modeling Methods and Results (TM2)

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Technical Memorandum

Prepared for: City of Tualatin

Project Title: Stormwater Master Plan

Project No.: 149233

Technical Memorandum 2 (updated)

Subject: Hydrology and Hydraulic Modeling Methods and Results

Date: Original: September 8, 2017

Updated: September 7, 2018

To: Kim McMillan, P.E., City Project Manager

From: Angela Wieland, P.E.,
Matt Grzegorzewski
Ryan Retzlaff

Prepared by: ______________________
Ryan Retzlaff

Reviewed by: ______________________
Angela Wieland, P.E.

Table of Contents

List of Tables

Section 1: Introduction

The City of Tualatin (City) is developing a stormwater master plan to guide future surface and stormwater program decisions. The master plan will address both water quantity and quality issues for the constructed and natural systems under the City's management. The master plan requires a clear understanding of existing and future runoff conditions across the city to identify long-term stormwater project needs.

This technical memorandum (TM2) has been developed to document the methodology used for modeling city-wide hydrology and hydraulics in specific areas of concern. Section 2 of TM2 outlines applicable stormwater design standards and criteria used to evaluate the performance of the storm drainage system. Section 3 outlines hydrologic model development. Section 4 outlines hydraulic model development, and Section 5 outlines results of the modeling efforts and proposed locations for the development of capital projects (CP).

The hydrology model was developed to evaluate peak flows generated by all subbasins within the city for existing and anticipated future development conditions. The hydrologic modeling results show that peak flows are expected to remain constant in watersheds such as Nyberg Creek and the Tualatin River where most land area is currently built to maximum zoning allowances. The most significant flow increases are anticipated in the Hedges Creek watershed due to significant vacant lands slated for future industrial development.

The hydraulic model results show flooding in several open channel and piped systems starting at a 2-year design storm event. Specific flooding locations include the open channel along the north side of Herman Road west of SW Tualatin Road, the railroad ditch behind Oil Can Henry's, and the open channel system along Manhasset Drive. Capital projects will be needed to address system flooding.

Section 2: Stormwater Design Standards and Criteria

Brown and Caldwell (BC) conducted a review of the City's Public Works (PW) Standards and the Clean Water Services (CWS) *Design and Construction Standards* (2007) and the CWS *Low Impact Development Approaches (LIDA) Handbook* (2009) to establish planning criteria relevant to the analysis of the City's stormwater system. Planning criteria were used to identify where the system has capacity limitations and as the basis for design of stormwater projects for water quality, condition improvements, and capacity.

Applicable planning criteria are referenced in Table 1.

Table 1. Drainage Standards and Design Criteria		
Criteria	**Source**	**Value**
Water Quality Facility Design	PW Standards (206.8)	Design to requirements of CWS *Design and Construction Standards* and CWS *LIDA Handbook*. Specific to the PW Standards, facilities are required to include 4 foot or 6 foot vinyl coated chain link fencing.
Water Quantity Facility Design	PW Standards (206.8) CWS *Design and Construction Standards*	Design to requirements of CWS *Design and Construction Standards*. Match pre- and post-development flow for the 2-, 10-, and 25-year, 24-hour storm events.
Pipe Design Storm	PW Standards (206.3)	Design to the 25-year storm event. Surcharge during the 25-year is not permissible.[a]
Pipe Size	PW Standards (206.4)	10-inch minimum diameter for pipe from catch basins to the main line in the public right-of-way. 12-inch minimum diameter for mains in the public right-of-way.
Manning's Roughness	PW Standards (Table 206-8)	Varies by material and shape.
Pipe Material	PW Standards (206.4)	Concrete, PVC, Ductile iron, and aluminum spiral rib pipe.
Pipe Cover	CWS *Design and Construction Standards*	Table 5-2, varies by pipe material.
Structure Spacing	PW Standards (206.4)	250 feet maximum for 10-inch pipe; 400 feet maximum for 12-inch pipe.
Manhole Size	PW Standards (206.6)	48-inch-diameter minimum.

a. The City's PW standards reference the rational method for conveyance design. Santa Barbara Urban Hydrograph (SBUH) was an approved equivalent as discussed with the City during the July 28, 2016 meeting.

For additional details on the City's design standards and criteria, see Section 2.2 of *TM #1: Data Compilation and Preliminary Stormwater Project Development* (TM1) dated April 24, 2017.

Section 3: Hydrologic Model Development

The hydrologic model was developed using XP-Storm Water Management Model (XPSWMM) version 2016.1. Within the model, the Santa Barbara Urban Hydrograph (SBUH) method was used to estimate hydrology. The necessary parameters for the SBUH method include subbasin areas, impervious percentages, pervious curve numbers, and times of concentration. The hydrology routine in XPSWMM converts rainfall into stormwater runoff based on design storm parameters (e.g., volume and intensity of rainfall) and subbasin characteristics such as topography, land use, vegetation, soil types and SBUH subbasin parameters described above.

This section includes detailed descriptions of the methodology used in determining each of the hydrology model input parameters.

3.1 Subbasin Delineation

The purpose of the subbasin boundary delineation is to refine major watershed boundaries into smaller subbasins to reflect specific catchment areas within the city.

Watershed boundaries for six major watersheds were provided by the City as a geographic information system (GIS) shapefile: Hedges Creek, Nyberg Creek, Saum Creek, Cummins Creek, Tualatin River, and Seely Ditch. These larger watershed boundaries are defined based on topography and conveyance system routing.

The watershed boundaries were refined in GIS based on outfall locations, with areas ranging between 56 and 2,918 acres. These watersheds were then divided up into smaller subbasins using a combination of contours, streets, tax lots, and conveyance infrastructure such as pipes, ditches, culverts, and open channels. Subbasins are generally smaller in the more densely urbanized areas where the pipe network is more complex. Smaller subbasins were also delineated in areas where hydraulic modeling was proposed (see Section 4.1). Subbasin boundary questions were addressed using as-built records, GIS invert data, and City staff knowledge of the existing drainage system. A total of 256 subbasins were defined, ranging in size from 0.4 to 777.7 acres with an average area of 38.1 acres. The watershed and subbasin boundaries are shown in Attachment C, Figure 1.

Each subbasin was assigned a name in conjunction with the City-provided watershed name (e.g., NY for Nyberg Creek) and numbering associated with location in the subbasin. The numbering begins at 0010 near the outfall and increase in increments of 10 moving upstream. Subbasin names are shown in Attachment A, Table A-1.

Larger subbasins were delineated in the outer areas of the city and in rural/agricultural areas that have not yet developed. Many of these larger subbasins drain away from City infrastructure and include: CU-0010, CU-0020, CU-0030, SA-0120, SA-0140, SA-Offsite1, SA-Offsite2, SA-Offsite3, SA-Offsite4, SA-Offsite5, TU-Offsite1, and TU-Offsite2. Additionally, portions of the transportation corridor along I-5 are isolated from City infrastructure by topography or physical features. Subbasins in these areas were delineated separately and named with the extension "-ODOT." Hydrologic model results from subbasins that are not contributing to city infrastructure are highlighted in gray in Attachment A, Table A-1.

Subbasin areas were calculated in GIS and are also provided in Attachment A, Table A-1.

3.2 Time of Concentration

Due to the number of subbasins, a modified, streamlined methodology was used to calculate time of concentration. The traditional approach of calculating time of concentration requires overland flow, shallow concentrated flow, and channel or pipe flow times to be calculated individually and added together, as shown in equation (1). The streamlined method is described below and includes application of general assumptions for the overland flow and shallow concentrated flow time components and calculating average pipe flow variables and applying them to all subbasins to determine the pipe flow times.

(1) Tc = Overland flow time (min) + Shallow concentrated flow (min) + Pipe/ channel flow (min)

The first step involves estimating the longest pipe flow path within each subbasin. Twenty subbasins were selected at random and the longest pipe flow path to the outlet was measured for each of them. A linear regression shown in equation (2), was developed based on the measured values and applied to the remaining subbasins to calculate an approximate pipe flow path. In the regression equation, subbasin area in acres is the independent variable (x), and longest pipe flow length is the dependent variable (y). This method was used to save time and is nearly as accurate as estimating the length of pipe flow within each subbasin.

(2) $Y = 43.411x + 413.91$ ($R^2 = 0.81$)

Average pipe slope was calculated for each subbasin based on LiDAR data. The maximum and minimum surface elevations within each subbasin were identified in GIS and used to approximate an average pipe slope for each subbasin. To check the validity of these values, pipe slope was manually calculated for 20 subbasins based on available invert data in GIS. The average of the manually calculated pipe slopes was found to be 40 percent less than the average of the slopes calculated using the maximum and minimum surface elevations. Thus, a 40 percent correction factor was applied to all calculated pipe slopes.

Pipe flow velocities were calculated using Manning's equation. Calculations assumed a 12-inch-diameter concrete pipe (n = 0.014) flowing at maximum discharge (93 percent full). Table 2 shows the calculated pipe flow velocities for slopes ranging from 0.5 percent to 6 percent. Average pipe slopes were rounded to the nearest 0.5 percent to estimate pipe flow velocities for calculating pipe flow times.

The channel or pipe flow times were directly calculated for each subbasin using the pipe flow velocities per Table 2 and the calculated longest flow path.

To account for the overland flow component of the time of concentration calculation, 5 minutes was assumed for sheet flow. No additional time was assumed for shallow concentrated flow due to the relatively large percentage of impervious surface in the City. From this information, the total time of concentration was calculated for all subbasins.

Table 2. Pipe Flow Velocities

Slope, percent	Velocity, feet per second
0.5	3.2
1	4.5
1.5	5.5
2	6.4
2.5	7.2
3	7.8
3.5	8.5
4	9.1
4.5	9.6
5	10.1
5.5	10.6
6	11.1

Fourteen subbasins were identified as having a substantial amount of open space or vacant lands and minimal pipe network so the streamlined methodology described above did not apply. For these subbasins, the traditional method of calculating time of concentration was used to more accurately estimate the overland flow and shallow concentrated flow times.

The traditional method required identifying the longest flow path lines in GIS and dividing the path into sheet flow, shallow concentrated flow, and pipe/ open channel flow lengths. The maximum sheet flow length was set to 150 feet. The shallow concentrated flow length was calculated based on the remaining flow path length needed to reach an open channel conveyance. The flow length and slope of the open channel conveyance was directly measured in GIS, and the average open channel velocity was estimated using the following equation (3) where k is the velocity factor dependent on the channel bottom, and s is the measured slope of the channel in ft/ft. Grassed waterways have a velocity factor k of 15.

(3) $v = k\sqrt{s}$

The time of concentration calculated for all subbasins ranged from 5.8 to 183 minutes with an average of 14.2 minutes. Attachment A, Table A-1 includes the calculated time of concentration values for each subbasin.

3.3 Existing Land Use Conditions

The City provided GIS data representing City planning districts, developable lands, parks, open spaces, and natural areas. Through coordination with the City, BC developed general land use classes by consolidating planning districts and merging the planning districts with developable lands and (undevelopable) open spaces.

Developable lands were categorized as vacant, infill, or re-developable. Upon analysis of aerial imagery, it was determined that areas classified as vacant and infill are currently undeveloped and development will lead to a significant increase in impervious coverage and associated runoff volume. Thus, vacant land use coverage consists of vacant and infill areas. Re-developable areas are already developed consistent with their planning district designation and were assigned land use based on their consolidated planning district designation. Undevelopable open space included City-owned parks, greenways, and natural areas, the Wetland Protection Area (WPA), wetlands, and the Natural Resource Protection Overlay (NRPO) District.

The Oregon Department of Transportation (ODOT) corridor along Interstate 5, Interstate 205, and Highway 99W was defined separately as a transportation land use coverage as these areas are fully developed and impervious coverage is not expected to change.

For additional detail on the development of land use coverage, refer to Section 2.3.1 of TM1. Existing land use coverage is shown in Attachment C, Figure 2.

3.4 Future Land Use Conditions

To represent future land use conditions, all vacant lands defined under existing condition land use was assumed to be developed in accordance with the City's underlying planning district designation. Future conditions land use is also reflected in Attachment C, Figure 2.

3.5 Impervious Coverage

Impervious coverage by land use was directly calculated using City-provided GIS coverage of impervious surface and supplemented with City-provided GIS coverage of building footprints and right-of-way. The calculated impervious percentages by land use were verified using aerial imagery and compared to impervious percentages used by surrounding communities.

Due to the potential for redevelopment and infill amongst the residential land use categories, a separate future condition impervious percentage was defined for the low density, medium density, and high density residential land use categories. Each calculated impervious percentage (reflecting existing development conditions) was increased by 10 percentage points to account for added impervious surface expected with redevelopment. This increase was made independent from the anticipated development of vacant land use.

Existing and future impervious percentages by land use are shown in Table 3. For additional detail on the impervious coverage calculations, refer to Section 2.3.2 of TM1.

Table 3. Modeled Land Use Categories and Impervious Percentages

Modeled Land Use	Existing Impervious Percentage	Future Impervious Percentage
Low-density residential	43	53
Medium-density residential	45	55
High-density residential	50	60
Institutional	35	35
Industrial	74	74
Commercial	78	78
ODOT Corridor	46	46
Basalt Creek/Rural Residential	7	7
Open Space (Parks/Greenways/Natural Areas)	5	5
Open Space (WPD/NRPO/Wetlands)	4	4
Vacant	5	Consistent with underlining planning district designation

An area-weighted average impervious coverage by subbasin was calculated for both existing and future conditions based on the contributing land use and associated impervious percentage. The existing and future impervious percentage for each subbasin is shown in Attachment A, Table A-1.

3.6 Curve Number

Curve numbers are dimensionless numbers defined by the hydrologic soil group and land cover and are required for use in the SBUH hydrology method.

Runoff curve numbers for pervious areas were estimated from typical runoff curve number tables provided in the Soil and Conservation Service (SCS) Technical Release 55, titled *Urban Hydrology for Small Watersheds* (SCS 1986). Curve number values are shown in Table 4 and were selected based on hydrologic soil group and associated land use description for the pervious portions of each subbasin.

Aerial imagery was used to select a representative pervious land use description. Fair condition open space was used for primarily developed subbasins and fair-condition woods-grass combination was used for primarily undeveloped subbasins. Hydrologic soil group coverage is shown in Attachment C, Figure 3. Area-weighted pervious curve numbers were then directly calculated for each subbasin.

A curve number of 98 was assumed for impervious areas.

Table 4. Runoff Curve Numbers for Urban Areas

Land use descriptions	Curve numbers for hydrologic soil group			
	A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, etc.)				
Good condition (grass cover >75%)	39	61	74	80
Fair condition (grass cover 50–75%)	49	69	79	84
Poor condition (grass cover <50%)	68	79	86	89
Paved parking lots, roofs, driveways, etc.	98	98	98	98
Woods-grass combination:				
Poor condition	57	73	82	86
Fair condition	43	65	76	82
Good condition	32	58	72	79

3.7 Design Storms

Design storms are precipitation patterns typically used to evaluate the capacity of storm drainage systems and design capital improvements for the desired level of service.

Design storms used for this study included the 2-, 10-, and 25-year recurrence interval 24-hour events. The rainfall depths were taken from CWS' *Design & Construction Standards*, Standard Detail Drawing No. 1280. The rainfall distribution for these design storms was based on a SCS Type IA, 24-hour distribution, which is applicable to western Oregon, Washington, and northwestern California.

Table 5 lists the design storm rainfall depths used in the hydrology model.

Table 5. Design Storm Depths	
Design storm event	Rainfall depth, inches
2-year, 24-hour	2.50
10-year, 24-hour	3.45
25-year, 24-hour	3.90

Section 4: Hydraulic Model Development

To evaluate flood hazards and capacity limitations of stormwater infrastructure, the XPSWMM computer model was used to simulate the hydraulic performance of select pipe and open-channel systems to calculate peak flow, water surface elevation, and velocities within the modeled infrastructure for select design storms.

This section includes a summary of the hydraulic modeled areas and input parameters used to characterize the hydraulic conditions of the modeled system.

4.1 Modeling Areas

As described in TM1, a total of five stormwater project opportunity areas were identified as those that would benefit from a hydraulic modeling assessment:

1. Stormwater Project Opportunity Area 4 – Manhasset
2. Stormwater Project Opportunity Area 5 – Boones Ferry Road at Oil Can Henry's
3. Stormwater Project Opportunity Area 7 – Herman Road
4. Stormwater Project Opportunity Area 9 – Sagert Street at the Shenandoah Apartments
5. Stormwater Project Opportunity Area 10 – Mohawk Apartments

These project opportunity areas were identified based on City and stakeholder reported flooding and the need for additional information to understand the potential cause of flooding. Hydraulic assessment of these areas will also help with development of project concepts and CIPs. The hydraulic model extents were discussed and verified with City staff on February 2, 2017. Due to proximity and connectivity of the proposed modeled system, three of the project opportunity areas (5, 9, and 10) were combined into one hydraulic model system. The specific model areas are described in detail below and an overview is provided in Attachment C, Figure 4.

4.1.1 Herman Road System

City staff identified this area during completion of the stormwater surveys (see TM1) as frequently flooding. The drainage system along the north side of Herman Road is characterized by ditches and culverts, which drain south under the road and adjacent railroad through two culverts. South of the railroad is an open channel that conveys all runoff to the east before discharging into Sweek Pond.

Based on field reconnaissance, feedback from City staff, and initial system review in GIS, the primary drainage issues include undersized drainage infrastructure and flat grade along Herman Road. The south side of Herman Road does not have a stormwater collection system, which results in standing water on the roadway.

The hydraulic model for the Herman Road system includes the piped and open channel conveyance along Herman Road between Southwest Teton Avenue and Southwest Tualatin Road, as well as the open channel/piped system between Herman Road and the outfall at Sweek Pond. Attachment C, Figure 5 shows the hydraulic modeling extents specific for the Herman Road system.

4.1.2 Manhasset Drive System

The City frequently responds to flooding of the open channel system, starting from Tualatin-Sherwood Road to Manhasset Drive. This area was also identified as having frequent flooding during completion of stormwater surveys. The Manhassat Drive system receives stormwater from the area south of Tualatin-Sherwood Road. A culvert under Tualatin-Sherwood Road discharges north to the open channel system, which runs between private industrial properties before entering a ditch inlet and pipe to Hedges Creek.

Based on field reconnaissance, feedback from City staff, and initial system review in GIS, the open channel system is capacity limited. The channel is larger and steeper in the southern (upstream) portion and becomes shallower flatter in the northern (downstream) portion. During a site visit on June 29, 2016, BC and City staff observed a large amount of debris and lawn clippings in the channel as well as portions of the curb and larger rocks, which further limit capacity and indicate the need for ongoing maintenance. The stormwater conveyance system downstream of the open channel system is very flat but appears to have adequate capacity as no flooding has been reported.

The hydraulic model for the Manhassat Drive system includes the culvert under Tualatin-Sherwood Road and the piped and open channel system running north to the outfall into Hedges Creek. Attachment C, Figure 6 shows the hydraulic modeling extents specific for the Manhassat Drive system.

4.1.3 Nyberg Creek System

The Nyberg Creek system includes stormwater project opportunity areas 5, 9, and 10. These areas were combined into a single hydraulic model to provide a more comprehensive assessment of the problem areas and downstream system impacts. All three of these stormwater project opportunity areas were identified due to frequent flooding issues and the need for further assessment.

Stormwater project opportunity area 5 is associated with the open channel system along the railroad tracks behind the former Oil Can Henry’s (19417 SW Boones Ferry Road). The open channel is adjacent to a railroad ballast, and gravel and rock from the ballast is dislodged and transported to a 36-inch pipe that daylights prior to discharge under Boones Ferry Road via a parallel culvert. The gravel and rock occlude the outlet and pipe under Boones Ferry Road, causing backwater conditions and flooding at Oil Can Henry’s. During a site visit on December 8, 2016, it was observed that the pipe under Boones Ferry Road was more than 50 percent filled with sediment. Attachment D includes photographs of the rocky open channel system and the transition to the piped system. Additionally, water quality along Boones Ferry Road is being managed with StormFilter catchbasins located at a sag in Boones Ferry Road. The StormFilter catchbasins do not appear to be functioning, possibly due to the high sediment and gravel loads, which result in standing water in the roadway.

Stormwater project opportunity areas 9 and 10 are associated with two open channel segments in Sandalwood (area 9) and in the Mohawk Apartments property (area 10), which experience significant erosion and flooding. The open channel at Sandalwood is experiencing severe incision, which prevents runoff from being effectively discharged to the downstream ditch inlet and pipe system. Water ponds in this area and is not adequately conveyed. The open channel at the Mohawk Apartments is also ineffective at discharging to the downstream ditch inlet, and thus, flow overtops the banks causing overland runoff through private property. Downstream from the Mohawk Apartments site, the piped conveyance system in Tonka Street and Warm Springs Street does not appear to be laid out in an efficient manner, which further contributes to the observed capacity deficiencies.

The hydraulic model includes the open channel associated with stormwater project opportunity area 5, the piped the drainage system on Boones Ferry Road, the culverts discharging east under Boones Ferry Road, and the open channel system flowing east from Boones Ferry Road to Martinazzi Avenue. The model terminates at the Martinazzi Avenue culvert where a free outfall has been included as the model’s boundary condition. The open channel system between Boones Ferry Road and Martinazzi Avenue is the upstream portion of Nyberg Creek. The open channel and piped systems associated with stormwater project opportunity areas 9 and 10 discharge north to Nyberg Creek and are also included. Attachment C, Figure 7 provides an overview of the Nyberg Creek system that was modeled.

4.2 Conveyance Naming Convention

Storm structures, including manholes, catch basins, ditch inlets, outfalls, tees, flow structures, and clean outs, are identified in the City's GIS database by their asset ID, a six-digit number ranging from 123539 to 335465. The storm conduits also use a similar naming convention. The six-digit asset IDs for conduits range from 164640 to 335463.

The names of nodes (storm structures, typically manholes) and links (pipes or open channel conduits) assigned in the hydraulic models are consistent with the City's naming convention. Based on field survey results, and to accommodate flow routing and other modeling needs, links or nodes were added that did not previously exist in the City's GIS database. For these added features, the default XPWMM naming convention was used (e.g., Link43, Node68).

4.3 Datum

To verify the vertical datum reflected in the City's GIS data, BC conducted a comparison of rim elevations from the GIS with rim elevations interpreted from LIDAR, which uses the North American Vertical Datum of 1988 (NAVD88). The average rim elevation interpreted from LiDAR was consistently 3.5 feet higher than the City-provided rim elevations. This is consistent with the datum correction of +3.52 feet between National Geodetic Vertical Datum of 1929 (NGVD29) and NAVD88. Based on this observation, it was assumed that most of the City's GIS data provided in their original June 2016 data package used the NGVD29 vertical datum.

In July 2016, the City corrected their system elevation data to match the NAVD88 vertical datum and provided updated stormwater system information in GIS to BC. The hydraulic modeling assumes consistent use of the NAVD88 vertical datum.

4.4 Survey Needs

After determining the extent of areas to be modeled for each stormwater project opportunity area (see Section 4.1), missing invert elevations and pipe diameters within these general extents were identified from GIS. A total of 77 structures required field survey.

CESNW performed the survey work in April, 2017 and obtained the missing data necessary for modeling. Survey results were delivered in the form of a computer-aided design (CAD) file and an Excel spreadsheet. After converting the data from CAD to GIS, BC staff incorporated the updated elevations into the GIS database. The updated GIS data were exported to XPSWMM for use in the hydraulic model.

4.5 Hydraulic Input Parameters

Hydraulic input parameters include conduit (pipe or open channel) name, upstream (US) and downstream (DS) node information (name, invert elevation, rim elevation), conduit length, conduit slope, conduit shape, and pipe diameter. The following sections describe the model input parameters that were required for development of the hydraulic models.

Attachment B, Table B-1 Hydraulic Model Results, includes all conduit and node data applicable to each system model.

4.5.1 Node Data

Model nodes include manholes, catch basins, outfalls, and other junction points as defined in the City's GIS or developed based on changes in conduit direction, slope, or cross section configuration (for open channels).

The upstream and downstream node names for each conduit were assigned based on the naming convention provided by the City's GIS. Nodes in the hydraulic model that also include model hydrologic input information were renamed with the nomenclature NodeName_SubbasinName (e.g. 261567_NY-0530).

The rim elevation at each node location was assigned based on the City's GIS. Several rim elevations were missing in the City's GIS database and values were estimated based on LiDAR data. Field survey included the collection of rim elevations for structures where rim elevations were inconclusive from LiDAR.

Upstream and downstream invert elevations were extracted from node and conduit data in GIS. If invert information was missing or conflicting between the node and conduit attribute data, the invert data were collected via field survey as described in Section 4.4.

4.5.2 Conduit Data

Modeled conduits include pipes, culverts, and open channels. The length of each modeled conduit was originally provided in the City's GIS. Because conduits were extended or combined with other segments as necessary to ensure continuity in the system, revised conduit lengths were directly calculated using GIS.

Conduit slopes were calculated in XPSWMM using the upstream and downstream node invert elevations and refined segment lengths.

Pipe diameters were obtained from the City's GIS or collected during field survey. For pipes where pipe diameters were not provided in GIS or could not be field-verified during the survey work, the diameter was assumed to be the same size as the pipe segment immediately upstream. This assumption provides a conservative estimate of hydraulic system capacity. Pipes were assumed to be circular in shape.

Most open channel cross-sections were obtained by field survey. Open channels segments not surveyed or used for flow routing purposes were assumed to be trapezoidal in shape with dimensions approximated based on measurements obtained during field visits or via aerial imagery.

Manning's roughness coefficient "n" is dependent on the surface material of pipes and open channels. All modeled pipes were concrete and assigned a roughness coefficient of 0.014. A roughness coefficient range of 0.027 to 0.045 was assigned to open-channel conduits based on field observations from aerial imagery. Open channels lined with shorter vegetation and dirt had lower roughness while open channels lined with large rocks and thick vegetation had values of Manning's "n" up to 0.045.

4.5.3 System Routing

Only select portions of the City's conveyance system were hydraulically modeled to evaluate system flooding. To account for upstream subbasins that do not directly enter the modeled conveyance system but still contribute runoff to the modeled system, a simplified system routing was used. A simple pipe network was incorporated into the hydraulic model to mimic the upstream conveyance system and route flow downstream to the modeled system.

This approach was used for the Nyberg Creek model area (see Attachment C, Figure 4). The simple pipe network geometry is based on available GIS information and invert elevations as available and assumes a constant pipe slope based on surface elevations. The hydraulic model results for the simple pipe networks and simplified routing are included in Attachment B, Table B-1 for reference only. These results should not be considered in the assessment of system flooding or CP development.

Section 5: Model Refinement and Results

XP-SWMM was used to simulate the 2-year, 10-year, and 25-year, 24-hour design events for current and future development conditions. Results of the hydrologic and hydraulic model simulations are tabulated in Attachment A, Table A-1 (for hydrology) and Attachment B, Table B-1 (for hydraulics).

5.1 Model Refinement

The hydrologic and hydraulic models were developed and initial model results were compared to City-reported flooding locations, field observations, and City photographs taken during the December 2015 storm events (for the Manhasset Drive system). Model validation information was anecdotal and general in nature, and did not include specific flows or water surface elevations at structures within each of the hydraulic model areas. Therefore, model refinements instead of a model validation were performed by comparing initial model results with reported flooding areas and adjusting hydraulic input parameters based on field observations to match reported flooding.

The Herman Road system was refined following site visits by BC staff and additional feedback from City staff. The geometry of culverts under the rail road and select ditches and culverts on the north side of the road were refined. In addition, the contributing drainage area for subbasin HE-0090 was decreased from 19.04 acres to 5.00 acres based on discussion of drainage patterns with City staff (Attachment C, Figure 5). Subbasin HE-0900 is primarily composed of the Tualatin Country Club golf course and does not contribute to the Herman Road system. Please note the subbasin delineation was not adjusted, only the area contributing to the Herman Road system from subbasin HE-0900.

For the Manhasset Drive system, to better match reported flooding and photo documentation, several adjustments were made to the hydraulic model. The Manning's roughness coefficient of the open channels was refined to more closely align with the observed conditions. Values vary from 0.03 to 0.08 based on field observations. A short link was added (Link13) with a roughness value of 0.08 to represent a highly-obstructed portion of the open channel system where debris and lawn clippings were observed during the site visit. The addition of Link13 also extended the steeper upstream segment to reflect existing topography, as surveyed cross sections are often extrapolated and do not always align with specific grade break locations. Finally, the contributing drainage area for subbasin HE-0500 (Attachment C, Figure 6) was decreased from 4.93 acres to 1.54 acres based on as-built drawings provided by the City. Please note the subbasin delineation was not adjusted, only the area contributing to the Manhasset Drive system from subbasin HE-0500.

For the Nyberg Creek system, to better match reported flooding in the proximity of Oil Can Henry's (area 5) and Mohawk Apartments (area 10), the entrance and exit loss coefficients at ditch inlets in both locations were set to 1.0 to reflect reduced hydraulic efficiency in the transition from open channel to piped system. Link84 was added to the downstream end of the open channel by Oil Can Henry's to represent the steep concrete chute before the system daylights west of Boones Ferry Road. The Manning's roughness coefficients of the open channels were refined based on observed condition to represent the gravel and rock subgrade, with values ranging from 0.04 and 0.05. Sediment, as a hydraulic model parameter, was added to the downstream piped system to mimic observed conditions where rock and gravel have filled the pipe and outlet.

5.2 Hydrologic Model Results

The hydrologic model results show minimal to no increases in future flows for subbasins that are fully developed, such as in the Nyberg Creek and Tualatin River watersheds. The largest increases in flow were in subbasins with large amounts of vacant land, such as in the Hedges Creek watershed.

Results of the hydrologic simulations for all events and subbasins are tabulated in Attachment A (Table A-1). Results are displayed as maximum flows within each subbasin for each design storm. Attachment A, Table A-1 also provides the change in peak flow and percent increase between the existing and future conditions flows for each subbasin.

5.3 Hydraulic Model Results

The hydraulic model results show minimal to no increases in future flows for the modeled areas that are fully developed. As expected, the largest projected flow increases were seen in areas with existing vacant land. The model results confirm the flooding problem areas/ capacity limited areas as reported by City staff, and they provided additional information about potential sources of the problems.

Hydraulic modeling results are tabulated in Attachment B, Table B-1. Results are displayed as the maximum water surface elevation and maximum peak flows for existing and future conditions for each modeled conduit.

5.3.1 Initial Identification of Flooding Problems

Based on the hydraulic model results summarized in Attachment B, Table B-2, flooding in the piped system was identified when the theoretical maximum capacity of the conduit was exceeded and surcharging occurred. In the open channel system, flooding was identified when the maximum water surface elevation at any modeled node was equal to or greater than the ground elevation of the node, which implies that flow is overtopping the bank.

In areas where flooding occurs and stormwater would exit a pipe or overtop an open channel, the model was configured to ensure no system losses, and that all water exiting the system would be routed back into the system immediately downstream of the flooded location. This modeling approach more accurately simulates real-world channel and pipe conditions and eliminates water loss from the system. Links used to model this process are highlighted in gray in Attachment B, Table B-1, as they are not actual system conduits and instead were used to inform the identification of flooded areas.

The design storm and scenario where the model indicates flooding is identified in Attachment B, Table B-1.

5.3.2 Summary of Flooding Problems

Table 6 summarizes the general modeled flooding locations, the potential source of the capacity deficiencies, and preliminary CIP recommendations. A summary of the hydraulic model results by system is described below.

5.3.2.1 Herman Road System

The hydraulic model shows extensive flooding in the open channel/culvert system along Herman Road between SW Teton Avenue and SW Tualatin Road. Attachment C, Figures 8 and 9 show the extent of system flooding by modeled conduit. The stormwater conveyance system is very flat and the open channel system and culverts appear to be undersized.

The open channel system north of Herman Road is further restricted by the two culverts across Herman Road. These culverts have a non-traditional layout, likely due to the ground clearance required beneath the railroad, and have a negative or backslope. To reduce flooding along the north side of Herman Road, the open channel system from conduit 322603 and 268054 could be piped. The culverts across Herman Road could be replaced to more freely discharge. Piping the open channel segments also provides flexibility for future road improvements and roadway widening.

To the east, the parallel culverts south of the intersection of Tualatin Road and Herman Road (conduit 322619 and 322618) begin surcharging at the 2-year event. While the model does not indicate flooding, these pipes do not meet City design standards.

5.3.2.2 Manhasset Drive System

The hydraulic model shows extensive flooding during the 2-year design storm in the stormwater system along Manhasset Drive, especially along the open channel portion. Attachment C, Figure 10 shows the extent of modeled flooding by conduit.

Channel velocity is high in the upstream portion of the open channel system where the slope is steeper and the channel is grassy (lower Manning's n). As the channel flattens and becomes rockier in the downstream portion of the system, the channel velocity decreases and water begins to pond. The open channel cross sections are also unsymmetrical and limited in capacity. Proper maintenance of the open channel, including removal of debris and regular mowing of vegetation in the channel, may alleviate some flooding; however, the channel is still undersized for the contributing flow. Due to limited easement within the surrounding areas, replacement of the open channel system with an adequately-sized piped system may reduce flooding.

Pipes further downstream (north of Manhassat Drive) experience surcharging and therefore do not meet City design standards; however, the maximum water elevations are not above rim elevations.

5.3.2.3 Nyberg Creek System

The hydraulic model shows widespread system flooding during the 2-year design storm. Attachment C, Figure 11 and 12 show the extent of modeled flooding by modeled conduit.

One prevalent location of flooding is the open channel behind Oil Can Henry's (19417 SW Boones Ferry Road). The open channel is overtopping and the downstream pipes (Link 36, Link 80) are surcharging, resulting in flooding of nearby businesses. In the hydraulic model, flooding is being routed to the system on Boones Ferry Road via links Overflow1 and Overflow2, consistent with the flow patterns reported by city staff. The ditch inlet at the end of the open channel also restricts flow. Based on field observations, sediment discharges to the inlet and is deposited in the downstream pipes, further restricting flow. Sediment is also deposited into the parallel culvert across Boones Ferry Road, which limits capacity beginning at the 10-year storm (see Attachment B, Table B-1). Modification of this inlet structure to increase hydraulic efficiency and conducting regular maintenance to remove accumulated sediment are needed to reduce flooding.

Additional system surcharging and minor flooding is also occurring in the pipes north of Seminole Trail between Tillamook Court and Martinazzi Avenue starting at the 10-year event. These pipes appear to be undersized for the 25-year design event and do not meet the City's design standard. This system is upstream of the reported flooding at Sandalwood (area 9). Although modeling did not indicate flooding of the open channel system, upsizing of the upstream pipes would impact the open channel so a comprehensive review of project needs in this area will be needed.

Additionally, the pipes near the intersection of SW Boones Ferry Road and SW Warm Springs Street and the intersection of SW Warm Springs Street and SW Tonka Street are surcharging beginning at the 10-year event. System rerouting, particularly the catch basins at the corner of SW Tonka St and SW Warm Springs Street directly north to Nyberg Creek and the catchbasins along SW Boones Ferry Road, may help alleviate the capacity issues.

Table 6. Initial Flood Control Capital Improvement Projects					
Modeled System	General Location	Conduit	Flooding Scenario	Source of Capacity Deficiency	CIP Recommended?
Herman Road System	Open channel/culvert system on north side of Herman Road	Link32.1	Existing 10-yr	Existing culverts are undersized and have minimal slope. Multiple transitions from open channel to a piped system lead to high energy losses.	Y
		Link34.1	Existing 10-yr		
		322603	Existing 2-yr		
		322638.1	Existing 2-yr		
		333704.1	Existing 2-yr		
		333705.1	Existing 2-yr		
		333706.1	Existing 2-yr		
		333707.1	Existing 2-yr		
		334080.1	Existing 2-yr		
		Link33.1	Future 2-yr		
	Culvert across Herman Road	322643	Existing 2-yr	Existing pipe has minimal slope and nearby pipes show unusual change in inverts. Follow up survey recommended.	Y
	Dual culvert south of intersection of Tualatin Road and Herman Road	322618	Existing 2-yr	Pipe has minimal slope. Culvert is surcharging but not flooding.	Y
	Stormwater system at intersection of Tualatin Road and Herman Road	268371	Future 25-yr	Pipe is surcharging but not flooding. Refined hydrology during CP development may adjust project need.	Possibly
Manhasset Drive System	Open channel along Manhasset Drive	Link9	Existing 2-yr	Open channel is undersized and not properly maintained.	Y
		Link10.1	Existing 2-yr		
		Link11.1	Existing 2-yr		
		Link12.1	Existing 2-yr		
		Link13.1	Existing 2-yr		
		Link14.1	Existing 2-yr		
	Piped system downstream of open channel on Manhasset Drive	266695	Existing 2-yr	Existing pipes are surcharging but not flooding due to minimal slope.	Y
		266697	Existing 2-yr		
		268265	Existing 2-yr		

Table 6. Initial Flood Control Capital Improvement Projects					
Modeled System	General Location	Conduit	Flooding Scenario	Source of Capacity Deficiency	CIP Recommended?
Nyberg Creek System	Open channel and pipe system behind Oil Can Henry's including junction of outfalls directly west of Boones Ferry Road	Link36	Existing 2-yr	Rock/gravel accumulation is limiting capacity. Project needs may include source control and maintenance.	Y
		Link43.1	Existing 2-yr		
		Link80	Existing 2-yr		
		277225	Future 2-yr		
	Piped system on Boones Ferry Road near Warm Springs Street	268293	Existing 10-yr	Existing open channels and pipes are undersized for the contributing drainage area. This system receives overland flow from the open channel behind Oil Can Henrys. System rerouting may help alleviate flooding.	Y
		322832	Existing 10-yr		
		268296.1	Existing 25-yr		
		267215	Future 10-yr		
		268297.1	Future 25-yr		
	Piped system at intersection of Warm Springs Street and Tonka Street	264286	Existing 10-yr	Existing pipes have minimal slope and are undersized. System rerouting may alleviate flooding.	Y
		265109	Existing 2-yr		
	Piped system between Seminole Trail and Sagert Street	267910	Existing 10-yr	Existing pipes are undersized for contributing drainage area. Pipes are surcharged but not flooding. System is upstream of reported Sandalwood project opportunity area.	Y
		267951	Existing 10-yr		
		264521	Future 10-yr		
	Sandalwood open channel	Link31	-	No flooding in model; however, flooding was reported during the December 2015 storm event. Channel is incised.	Y
	Open channel behind Mohawk Apartments	Link32	-	Open channel is not flooding in the model; however, flow is being restricted at the downstream ditch inlet, which has large hydraulic losses.	Y
		Link 33	-		

Section 6: References

City of Tualatin. 2013. Public Works Standards, Section 206.

Clean Water Services. 2007. Storm*water and Grading Design Standards*. March 2017.

Soil Conservation Service (SCS). 1986. *Urban Hydrology for Small Watersheds*, Technical Release 55. June.

Attachment A: Hydrology Model Results

Table A-1: Hydrology Model Results

Basin ID	Area (acres)	Time of Concentration (minutes)	Existing Impervious Percentage	Future Impervious Percentage	Pervious CN	Existing Land Use Maximum Flow (cfs)			Future Land Use Maximum Flow (cfs)			Existing Land Use Increase in Maximum Flow (cfs)			Future Land Use Percent Increase in Maximum Flow (%)		
						2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr
Basalt Creek																	
BA-0010	226.9	63.6	10	12	73	10.68	26.88	36.14	11.22	27.80	37.26	0.54	0.92	1.12	5.1	3.4	3.1
BA-0020	127.4	62.7	15	15	76	9.23	20.44	26.64	9.23	20.44	26.64	0.00	0.00	0.00	0.0	0.0	0.0
BA-0030	32.1	8.5	41	51	79	9.15	16.03	19.42	10.44	17.54	21.00	1.29	1.51	1.57	14.1	9.4	8.1
BA-0040	20.3	8.9	34	47	78	4.90	9.05	11.13	5.99	10.37	12.52	1.09	1.32	1.40	22.1	14.6	12.5
BA-0050	22.0	7.5	37	49	72	4.26	8.49	10.65	5.48	10.04	12.32	1.22	1.56	1.67	28.7	18.4	15.7
BA-0060	21.2	7.6	34	44	78	5.33	9.73	11.94	6.12	10.70	12.95	0.79	0.96	1.02	14.8	9.9	8.5
BA-0070	39.9	46.8	43	52	75	5.58	10.56	13.10	6.76	12.06	14.71	1.18	1.50	1.61	21.1	14.2	12.3
Cummins Creek																	
CU-0010	175.4	46.8	5	5	79	14.78	33.24	43.12	14.78	33.24	43.12	0.00	0.00	0.00	0.0	0.0	0.0
CU-0020	123.3	35.0	22	25	78	15.69	31.98	40.41	16.46	33.00	41.52	0.77	1.02	1.11	4.9	3.2	2.8
CU-0030	57.4	15.8	16	21	81	11.10	21.44	26.70	11.87	22.43	27.76	0.76	0.98	1.06	6.9	4.6	4.0
CU-0040	73.5	23.8	58	63	80	21.55	35.23	41.81	22.93	36.74	43.34	1.38	1.51	1.54	6.4	4.3	3.7
CU-0050	16.2	8.4	61	70	79	6.00	9.68	11.45	6.72	10.45	12.22	0.72	0.77	0.77	12.0	7.9	6.7
CU-0060	57.1	13.8	65	72	80	20.97	33.29	39.17	22.72	35.12	40.99	1.74	1.83	1.83	8.3	5.5	4.7
CU-0070	34.8	10.8	47	59	80	10.85	18.35	22.00	12.58	20.30	24.01	1.73	1.95	2.00	16.0	10.6	9.1
CU-0080	28.5	9.3	73	73	79	12.20	18.70	21.78	12.20	18.70	21.78	0.00	0.00	0.00	0.0	0.0	0.0
CU-0090	21.4	8.1	68	74	79	8.68	13.59	15.92	9.33	14.25	16.58	0.65	0.66	0.66	7.4	4.9	4.2
CU-0100	33.9	12.0	64	66	75	11.32	18.66	22.20	11.76	19.15	22.70	0.44	0.49	0.50	3.9	2.6	2.3
CU-0110	10.5	8.2	68	74	77	4.12	6.53	7.67	4.46	6.88	8.02	0.34	0.35	0.35	8.2	5.4	4.6
CU-0120	10.3	7.2	28	74	79	2.49	4.61	5.68	4.52	6.94	8.09	2.03	2.33	2.41	81.4	50.4	42.5

Table A-1: Hydrology Model Results																	
Basin ID	Area (acres)	Time of Concentration (minutes)	Existing Impervious Percentage	Future Impervious Percentage	Pervious CN	Existing Land Use Maximum Flow (cfs)			Future Land Use Maximum Flow (cfs)			Existing Land Use Increase in Maximum Flow (cfs)			Future Land Use Percent Increase in Maximum Flow (%)		
						2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr
Hedges Creek																	
HE-0010	4.2	6.2	75	75	82	1.96	2.97	3.44	1.97	2.97	3.45	0.01	0.01	0.01	0.4	0.2	0.2
HE-0020	6.8	6.6	8	14	80	1.31	2.62	3.29	1.44	2.78	3.47	0.13	0.16	0.18	9.5	6.2	5.3
HE-0030	10.1	7.6	65	74	82	4.27	6.61	7.73	4.61	6.98	8.09	0.34	0.37	0.36	8.0	5.5	4.7
HE-0040	3.7	6.7	65	70	80	1.51	2.39	2.80	1.60	2.48	2.90	0.09	0.10	0.10	5.8	4.1	3.4
HE-0050	8.7	7.4	25	29	78	1.85	3.57	4.44	1.99	3.75	4.63	0.14	0.18	0.19	7.6	5.0	4.3
HE-0060	35.5	30.6	41	50	80	7.27	12.93	15.73	8.27	14.12	16.98	1.00	1.19	1.25	13.7	9.2	7.9
HE-0070	6.5	7.6	41	49	81	2.08	3.52	4.23	2.28	3.75	4.46	0.20	0.23	0.23	9.5	6.4	5.5
HE-0080	12.5	7.9	43	47	81	4.03	6.81	8.16	4.24	7.04	8.40	0.20	0.23	0.24	5.0	3.4	2.9
HE-0090	19.0	39.4	43	53	80	3.66	6.43	7.79	4.21	7.07	8.46	0.54	0.64	0.67	14.8	10.0	8.6
HE-0100	7.4	7.2	43	53	79	2.21	3.82	4.61	2.52	4.18	4.99	0.32	0.37	0.38	14.3	9.6	8.2
HE-0110	11.3	7.4	48	57	79	3.58	6.07	7.28	4.02	6.57	7.80	0.44	0.50	0.52	12.4	8.3	7.1
HE-0120	5.4	7.0	47	57	80	1.79	2.99	3.58	2.02	3.26	3.86	0.23	0.26	0.28	13.1	8.8	7.7
HE-0130	9.6	8.1	74	74	83	4.46	6.69	7.74	4.46	6.69	7.74	0.00	0.00	0.00	0.0	0.0	0.0
HE-0140	10.5	7.6	27	74	79	2.52	4.66	5.74	4.59	7.02	8.18	2.08	2.36	2.45	82.4	50.7	42.6
HE-0150	3.3	7.1	74	74	84	1.58	2.36	2.73	1.58	2.36	2.73	0.00	0.00	0.00	0.0	0.0	0.0
HE-0160	22.0	10.1	68	73	79	8.80	13.77	16.13	9.27	14.25	16.61	0.47	0.48	0.48	5.3	3.5	3.0
HE-0170	23.9	10.4	61	62	81	9.13	14.49	17.05	9.20	14.57	17.13	0.07	0.08	0.08	0.8	0.5	0.5
HE-0180	22.2	12.2	31	37	78	4.85	9.14	11.31	5.35	9.76	11.97	0.50	0.62	0.66	10.2	6.8	5.8
HE-0190	10.6	8.2	37	37	79	2.81	5.04	6.15	2.81	5.04	6.15	0.00	0.00	0.00	0.0	0.0	0.0
HE-0200	19.6	8.8	76	76	81	8.88	13.36	15.47	8.88	13.36	15.48	0.00	0.00	0.00	0.0	0.0	0.0
HE-0210	9.3	7.1	74	74	80	4.12	6.31	7.34	4.12	6.31	7.34	0.00	0.00	0.00	0.0	0.0	0.0
HE-0220	19.1	8.8	39	46	81	5.67	9.81	11.83	6.23	10.45	12.50	0.55	0.65	0.67	9.8	6.6	5.7
HE-0230	8.4	7.4	55	64	81	3.11	5.03	5.95	3.40	5.34	6.28	0.30	0.32	0.33	9.5	6.3	5.6
HE-0240	22.8	9.2	73	74	80	9.85	15.06	17.52	9.98	15.19	17.65	0.13	0.13	0.13	1.3	0.9	0.7
HE-0250	15.4	7.8	71	71	81	6.69	10.25	11.95	6.69	10.25	11.95	0.00	0.00	0.00	0.0	0.0	0.0

Table A-1: Hydrology Model Results

Basin ID	Area (acres)	Time of Concentration (minutes)	Existing Impervious Percentage	Future Impervious Percentage	Pervious CN	Existing Land Use Maximum Flow (cfs)			Future Land Use Maximum Flow (cfs)			Existing Land Use Increase in Maximum Flow (cfs)			Future Land Use Percent Increase in Maximum Flow (%)		
						2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr
HE-0260	15.4	7.3	49	49	82	5.42	8.90	10.58	5.44	8.92	10.60	0.02	0.02	0.02	0.4	0.2	0.2
HE-0270	24.9	8.9	69	74	82	10.66	16.36	19.06	11.11	16.82	19.51	0.46	0.46	0.45	4.3	2.8	2.4
HE-0280	15.8	7.9	74	74	82	7.13	10.79	12.53	7.13	10.79	12.53	0.00	0.00	0.00	0.0	0.0	0.0
HE-0290	16.9	8.5	74	74	81	7.54	11.43	13.26	7.54	11.43	13.26	0.00	0.00	0.00	0.0	0.0	0.0
HE-0300	17.2	7.7	43	53	79	5.17	8.92	10.75	5.89	9.75	11.62	0.72	0.83	0.86	14.0	9.3	8.0
HE-0310	14.8	7.1	43	53	80	4.63	7.89	9.49	5.24	8.58	10.20	0.60	0.69	0.71	13.0	8.7	7.5
HE-0320	25.8	10.7	45	54	81	8.35	13.97	16.70	9.27	15.00	17.75	0.92	1.03	1.05	11.0	7.3	6.3
HE-0330	22.0	8.2	41	51	80	6.58	11.36	13.70	7.44	12.36	14.73	0.86	0.99	1.03	13.1	8.7	7.5
HE-0340	16.4	7.9	48	57	79	5.26	8.88	10.65	5.85	9.55	11.33	0.59	0.67	0.69	11.2	7.5	6.4
HE-0350	21.2	9.0	71	74	80	9.03	13.89	16.18	9.27	14.12	16.42	0.24	0.24	0.24	2.6	1.7	1.5
HE-0360	39.0	12.8	35	46	78	9.05	16.69	20.51	10.70	18.71	22.65	1.65	2.02	2.14	18.3	12.1	10.4
HE-0370	52.1	18.9	59	60	79	16.32	26.69	31.68	16.48	26.87	31.86	0.16	0.17	0.18	1.0	0.7	0.6
HE-0380	20.1	9.8	74	74	81	8.85	13.42	15.58	8.85	13.42	15.58	0.00	0.00	0.00	0.0	0.0	0.0
HE-0390	40.4	13.0	74	74	80	16.74	25.62	29.81	16.74	25.62	29.81	0.00	0.00	0.00	0.0	0.0	0.0
HE-0400	42.1	13.3	48	58	79	12.31	21.06	25.34	14.03	23.03	27.37	1.72	1.97	2.03	14.0	9.3	8.0
HE-0410	30.4	14.0	51	52	82	9.97	16.40	19.50	10.17	16.62	19.72	0.19	0.22	0.22	2.0	1.3	1.1
HE-0420	29.0	10.1	52	56	79	9.44	15.78	18.86	9.89	16.29	19.38	0.45	0.51	0.53	4.8	3.2	2.8
HE-0430	10.4	8.2	24	24	80	2.42	4.53	5.58	2.42	4.53	5.58	0.00	0.00	0.00	0.0	0.0	0.0
HE-0440	11.5	7.4	56	72	80	4.15	6.77	8.03	4.97	7.65	8.94	0.82	0.89	0.91	19.7	13.1	11.3
HE-0450	44.0	12.0	58	73	80	15.45	25.07	29.69	18.37	28.16	32.79	2.92	3.09	3.10	18.9	12.3	10.4
HE-0460	19.3	8.3	60	60	80	7.33	11.73	13.83	7.33	11.73	13.83	0.00	0.00	0.00	0.0	0.0	0.0
HE-0470	6.4	7.6	70	70	81	2.78	4.28	4.99	2.78	4.28	4.99	0.00	0.00	0.00	0.0	0.0	0.0
HE-0480	2.6	6.9	74	74	80	1.14	1.75	2.03	1.14	1.75	2.03	0.00	0.00	0.00	0.0	0.0	0.0
HE-0490	4.8	6.9	68	74	79	1.98	3.10	3.63	2.10	3.23	3.77	0.13	0.14	0.14	6.5	4.5	3.8
HE-0500	4.9	6.6	74	74	79	2.17	3.34	3.89	2.17	3.34	3.89	0.00	0.00	0.00	0.0	0.0	0.0
HE-0510	22.7	9.2	58	74	79	8.13	13.22	15.66	9.80	14.98	17.43	1.67	1.77	1.77	20.5	13.4	11.3

Table A-1: Hydrology Model Results																	
Basin ID	Area (acres)	Time of Concentration (minutes)	Existing Impervious Percentage	Future Impervious Percentage	Pervious CN	Existing Land Use Maximum Flow (cfs)			Future Land Use Maximum Flow (cfs)			Existing Land Use Increase in Maximum Flow (cfs)			Future Land Use Percent Increase in Maximum Flow (%)		
						2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr
HE-0520	30.9	10.3	47	71	80	9.83	16.55	19.81	13.00	19.99	23.30	3.18	3.45	3.49	32.3	20.8	17.6
HE-0530	23.9	73.1	31	31	78	2.52	4.87	6.10	2.52	4.87	6.10	0.00	0.00	0.00	0.0	0.0	0.0
HE-0540	70.6	17.9	45	62	76	16.30	29.44	36.00	21.50	35.61	42.44	5.20	6.17	6.44	31.9	21.0	17.9
HE-0550	64.8	16.9	56	73	79	20.22	33.38	39.74	24.87	38.38	44.78	4.65	5.00	5.05	23.0	15.0	12.7
HE-0560	39.7	96.0	15	61	77	2.52	5.40	6.96	5.80	9.80	11.77	3.29	4.40	4.81	130.7	81.3	69.2
HE-0570	12.9	10.1	58	58	69	3.37	6.04	7.37	3.37	6.04	7.37	0.00	0.00	0.00	0.0	0.0	0.0
HE-0580	46.2	42.3	30	74	79	6.56	12.54	15.59	12.61	19.66	23.00	6.05	7.12	7.41	92.1	56.7	47.5
HE-0590	19.9	8.3	56	74	78	6.84	11.31	13.47	8.54	13.13	15.30	1.70	1.82	1.83	24.8	16.1	13.6
HE-0600	12.6	7.1	65	74	79	4.97	7.88	9.28	5.53	8.50	9.90	0.56	0.62	0.62	11.3	7.9	6.7
HE-0610	42.7	11.9	50	56	75	11.32	20.07	24.41	12.40	21.37	25.77	1.09	1.30	1.36	9.6	6.5	5.6
HE-0620	37.6	62.1	12	27	80	3.65	7.48	9.47	4.67	8.83	10.96	1.02	1.36	1.49	27.8	18.1	15.8
HE-0630	30.1	14.0	71	71	73	10.48	16.90	19.99	10.48	16.91	19.99	0.00	0.00	0.00	0.0	0.0	0.0
HE-0640	25.0	10.6	74	74	72	9.51	15.11	17.79	9.51	15.11	17.79	0.00	0.00	0.00	0.0	0.0	0.0
HE-0650	24.0	9.4	22	72	81	5.70	10.55	12.99	10.39	15.87	18.45	4.70	5.32	5.47	82.5	50.4	42.1
HE-0660	14.5	45.0	26	46	79	1.84	3.62	4.53	2.59	4.57	5.56	0.74	0.96	1.03	40.3	26.4	22.7
HE-0670	11.0	7.7	73	74	76	4.50	7.03	8.24	4.53	7.06	8.27	0.03	0.03	0.03	0.7	0.5	0.4
HE-0680	32.5	11.8	53	68	77	9.90	16.82	20.20	12.20	19.39	22.82	2.30	2.57	2.62	23.2	15.3	13.0
HE-0690	18.9	8.7	34	46	76	4.21	7.98	9.88	5.20	9.20	11.18	0.99	1.23	1.30	23.5	15.4	13.2
HE-0700	34.6	12.1	10	30	80	6.26	12.58	15.82	8.55	15.49	18.95	2.29	2.91	3.13	36.5	23.2	19.8
HE-0710	23.0	31.1	29	66	79	3.74	7.12	8.85	6.53	10.45	12.32	2.78	3.33	3.48	74.4	46.7	39.3
HE-0720	63.4	16.7	61	72	78	20.64	33.65	39.90	23.76	36.99	43.27	3.12	3.35	3.37	15.1	10.0	8.5
HE-0730	18.4	7.8	61	63	79	6.88	11.07	13.08	7.07	11.27	13.28	0.19	0.20	0.21	2.7	1.9	1.6
HE-0740	141.9	29.4	11	39	76	12.91	30.39	39.79	23.88	45.54	56.52	10.97	15.15	16.74	85.0	49.9	42.1
HE-0750	145.8	22.6	59	73	78	41.19	68.44	81.64	49.77	77.82	91.14	8.59	9.38	9.51	20.9	13.7	11.6
HE-0760	21.9	8.6	73	73	78	9.18	14.21	16.59	9.20	14.22	16.61	0.02	0.02	0.02	0.2	0.1	0.1
HE-0770	64.6	13.4	59	73	78	20.99	34.72	41.36	25.45	39.56	46.25	4.47	4.84	4.89	21.3	13.9	11.8

Table A-1: Hydrology Model Results

Basin ID	Area (acres)	Time of Concentration (minutes)	Existing Impervious Percentage	Future Impervious Percentage	Pervious CN	Existing Land Use Maximum Flow (cfs)			Future Land Use Maximum Flow (cfs)			Existing Land Use Increase in Maximum Flow (cfs)			Future Land Use Percent Increase in Maximum Flow (%)		
						2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr
HE-0780	35.0	10.9	66	66	79	13.31	21.13	24.87	13.31	21.13	24.87	0.00	0.00	0.00	0.0	0.0	0.0
HE-0790	40.8	11.6	66	68	79	15.46	24.51	28.82	15.81	24.87	29.18	0.34	0.36	0.37	2.2	1.5	1.3
HE-0800	38.4	10.4	58	63	79	13.38	21.87	25.96	14.36	22.94	27.05	0.98	1.07	1.09	7.3	4.9	4.2
HE-0810	10.1	6.8	44	49	79	3.03	5.24	6.33	3.26	5.51	6.60	0.23	0.27	0.27	7.4	5.1	4.3
HE-0820	26.0	9.0	41	50	80	7.59	13.18	15.93	8.58	14.34	17.13	0.99	1.16	1.20	13.1	8.8	7.5
HE-0830	72.0	13.2	22	42	77	12.70	25.63	32.28	17.98	32.35	39.49	5.28	6.72	7.21	41.6	26.2	22.3
HE-0840	15.3	8.3	43	53	79	4.51	7.82	9.45	5.16	8.58	10.23	0.65	0.76	0.78	14.4	9.7	8.3
HE-0850	17.8	8.6	43	53	79	5.22	9.06	10.95	5.98	9.94	11.86	0.76	0.88	0.91	14.5	9.7	8.3
HE-0860	14.3	6.5	38	47	79	3.94	7.00	8.51	4.45	7.61	9.15	0.52	0.62	0.64	13.1	8.8	7.6
HE-0870	51.4	11.1	32	50	72	8.24	17.36	22.10	12.34	22.67	27.83	4.10	5.31	5.73	49.8	30.6	25.9
HE-0880	16.7	7.0	38	47	79	4.68	8.26	10.03	5.27	8.96	10.76	0.59	0.70	0.73	12.6	8.5	7.3
HE-0890	4.4	5.9	41	50	79	1.31	2.26	2.73	1.48	2.46	2.95	0.17	0.20	0.22	13.1	9.0	8.0
HE-0900	36.4	9.3	24	29	77	6.70	13.52	17.02	7.50	14.55	18.14	0.79	1.03	1.12	11.8	7.6	6.6
HE-0910	16.1	7.0	36	44	77	4.01	7.35	9.02	4.57	8.03	9.74	0.56	0.68	0.72	13.8	9.2	7.9
HE-0920	25.1	8.5	43	53	64	3.38	7.67	9.94	4.77	9.54	11.99	1.39	1.87	2.05	41.2	24.4	20.7
HE-0930	7.7	7.0	39	48	72	1.55	3.05	3.82	1.89	3.48	4.28	0.34	0.43	0.46	21.8	14.1	12.1
HE-0940	9.1	6.7	41	50	77	2.43	4.35	5.31	2.80	4.80	5.78	0.38	0.45	0.47	15.5	10.4	8.9
HE-0950	9.6	8.1	40	50	75	2.25	4.20	5.18	2.67	4.71	5.72	0.42	0.51	0.54	18.5	12.2	10.5
HE-0960	16.1	7.6	42	52	71	3.25	6.38	7.98	4.06	7.41	9.09	0.81	1.03	1.10	25.0	16.1	13.8
HE-0970	2.8	6.0	39	48	65	0.38	0.86	1.11	0.51	1.04	1.31	0.13	0.18	0.20	35.4	21.0	17.9
HE-0980	17.7	29.8	31	37	78	2.87	5.50	6.84	3.21	5.95	7.33	0.35	0.46	0.49	12.1	8.3	7.1
HE-0990	18.2	7.8	42	51	64	2.42	5.52	7.16	3.35	6.78	8.54	0.93	1.26	1.38	38.6	22.8	19.3
HE-1000	15.5	7.8	43	53	75	3.91	7.13	8.74	4.64	8.01	9.67	0.73	0.88	0.93	18.6	12.4	10.6
HE-1010	16.1	7.6	43	53	80	4.90	8.43	10.16	5.57	9.20	10.96	0.67	0.77	0.80	13.6	9.1	7.8
HE-1020	23.3	7.8	42	51	78	6.57	11.57	14.04	7.55	12.72	15.24	0.98	1.15	1.20	14.9	9.9	8.5
HE-1030	25.8	7.8	43	53	75	6.48	11.82	14.49	7.73	13.34	16.09	1.26	1.52	1.60	19.4	12.9	11.0

Table A-1: Hydrology Model Results

Basin ID	Area (acres)	Time of Concentration (minutes)	Existing Impervious Percentage	Future Impervious Percentage	Pervious CN	Existing Land Use Maximum Flow (cfs)			Future Land Use Maximum Flow (cfs)			Existing Land Use Increase in Maximum Flow (cfs)			Future Land Use Percent Increase in Maximum Flow (%)		
						2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr
HE-1040	11.0	6.5	37	47	72	2.05	4.14	5.21	2.58	4.83	5.96	0.54	0.69	0.75	26.2	16.7	14.3
HE-1050	14.2	6.9	36	48	78	3.68	6.66	8.15	4.41	7.54	9.07	0.73	0.88	0.92	19.9	13.2	11.3
HE-1060	17.1	7.3	40	47	53	0.64	2.81	4.05	1.26	3.76	5.14	0.63	0.95	1.09	98.4	34.0	26.8
HE-1070	89.0	18.0	38	44	59	5.01	15.84	21.97	7.49	19.74	26.38	2.48	3.91	4.41	49.4	24.7	20.1
HE-1080	19.4	7.5	45	55	66	3.29	6.86	8.71	4.37	8.27	10.24	1.08	1.41	1.53	32.9	20.6	17.6
Nyberg Creek																	
NY-0010	7.1	6.9	5	5	76	0.87	2.06	2.69	0.88	2.06	2.69	0.00	0.00	0.00	0.2	0.1	0.1
NY-0020	1.1	6.2	6	6	77	0.15	0.34	0.44	0.15	0.34	0.44	0.00	0.00	0.00	0.0	0.0	0.2
NY-0030	30.3	40.2	13	46	80	3.63	7.38	9.33	6.06	10.49	12.66	2.43	3.11	3.33	67.0	42.1	35.7
NY-0040	18.8	8.7	37	58	75	4.21	7.97	9.87	6.06	10.22	12.24	1.85	2.25	2.37	44.0	28.2	24.0
NY-0050	49.1	10.4	30	32	79	11.66	21.53	26.48	11.91	21.85	26.82	0.25	0.32	0.34	2.2	1.5	1.3
NY-0060	2.8	6.2	78	78	79	1.29	1.95	2.26	1.29	1.95	2.26	0.00	0.00	0.00	0.1	0.0	0.0
NY-0070	7.4	6.7	50	58	79	2.45	4.10	4.91	2.72	4.42	5.24	0.27	0.31	0.33	11.2	7.6	6.8
NY-0080	47.1	10.3	24	29	79	10.14	19.35	24.00	11.03	20.48	25.22	0.89	1.13	1.21	8.8	5.8	5.0
NY-0090	39.9	9.2	52	61	79	13.22	22.05	26.33	14.74	23.74	28.06	1.51	1.69	1.73	11.5	7.7	6.6
NY-0100	10.4	6.4	45	52	73	2.49	4.61	5.68	2.87	5.09	6.19	0.39	0.48	0.51	15.6	10.4	8.9
NY-0110	18.5	7.8	70	71	76	7.38	11.63	13.65	7.46	11.71	13.73	0.08	0.09	0.09	1.1	0.7	0.6
NY-0120	23.3	7.4	44	54	80	7.23	12.36	14.86	8.20	13.46	16.00	0.97	1.10	1.14	13.3	8.9	7.7
NY-0130-ODOT	9.7	6.8	46	46	79	3.09	5.24	6.29	3.09	5.24	6.29	0.00	0.00	0.00	0.0	0.0	0.0
NY-0140	20.3	7.4	60	75	79	7.62	12.25	14.47	9.03	13.78	16.02	1.41	1.52	1.56	18.5	12.4	10.7
NY-0150	11.0	7.0	43	49	80	6.96	11.94	14.37	7.50	12.57	15.03	0.54	0.63	0.65	7.8	5.3	4.5
NY-0150-ODOT	11.7	7.0	46	46	80	3.74	6.34	7.60	3.74	6.34	7.60	0.00	0.00	0.00	0.0	0.0	0.0
NY-0160	24.1	9.9	66	66	82	11.51	17.86	20.87	11.51	17.86	20.87	0.00	0.00	0.00	0.0	0.0	0.0
NY-0160-ODOT	3.9	9.9	46	46	82	1.28	2.13	2.55	1.28	2.13	2.55	0.00	0.00	0.00	0.0	0.0	0.0
NY-0170-ODOT	30.4	11.4	46	46	80	9.27	15.77	18.93	9.27	15.77	18.93	0.00	0.00	0.00	0.0	0.0	0.0
NY-0180	26.5	9.1	44	54	79	7.84	13.55	16.35	8.97	14.86	17.70	1.13	1.31	1.35	14.4	9.6	8.3

Table A-1: Hydrology Model Results

Basin ID	Area (acres)	Time of Concentration (minutes)	Existing Impervious Percentage	Future Impervious Percentage	Pervious CN	Existing Land Use Maximum Flow (cfs)			Future Land Use Maximum Flow (cfs)			Existing Land Use Increase in Maximum Flow (cfs)			Future Land Use Percent Increase in Maximum Flow (%)		
						2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr
NY-0190	20.1	8.0	43	53	79	5.93	10.28	12.41	6.78	11.27	13.44	0.85	0.99	1.03	14.4	9.6	8.3
NY-0200	11.5	8.4	72	72	81	5.01	7.66	8.90	5.01	7.66	8.90	0.00	0.00	0.00	0.0	0.0	0.0
NY-0210	22.1	12.2	70	70	82	9.21	14.12	16.44	9.21	14.13	16.45	0.00	0.00	0.00	0.0	0.0	0.0
NY-0220	20.1	11.7	67	70	82	8.19	12.68	14.80	8.42	12.91	15.03	0.23	0.23	0.23	2.8	1.8	1.6
NY-0230	29.6	8.1	78	78	80	13.54	20.36	23.60	13.55	20.37	23.61	0.01	0.01	0.01	0.1	0.1	0.0
NY-0240	2.8	6.0	57	57	80	1.04	1.68	1.99	1.04	1.68	1.99	0.00	0.00	0.00	0.0	0.0	0.0
NY-0250	2.2	6.9	71	71	82	0.99	1.51	1.75	0.99	1.51	1.75	0.00	0.00	0.00	0.0	0.0	0.0
NY-0260	2.8	6.1	71	72	81	1.27	1.94	2.26	1.28	1.95	2.27	0.01	0.01	0.01	1.0	0.7	0.6
NY-0270	2.9	5.9	75	76	79	1.30	1.99	2.31	1.31	2.00	2.33	0.02	0.02	0.02	1.2	0.9	0.7
NY-0280	6.5	6.4	59	66	80	2.46	3.97	4.70	2.66	4.20	4.93	0.20	0.23	0.23	8.1	5.7	4.9
NY-0290	8.9	6.6	49	59	79	2.90	4.89	5.85	3.29	5.33	6.32	0.39	0.44	0.47	13.3	9.0	8.0
NY-0300	4.1	6.4	47	56	79	1.30	2.21	2.66	1.47	2.41	2.87	0.17	0.20	0.21	13.0	8.9	7.9
NY-0310	9.4	6.5	39	57	79	2.67	4.71	5.71	3.41	5.56	6.62	0.74	0.86	0.91	27.5	18.2	15.9
NY-0320	2.5	6.1	45	55	79	0.76	1.31	1.57	0.87	1.43	1.71	0.11	0.13	0.13	13.9	9.6	8.4
NY-0330	2.3	6.0	45	55	79	0.72	1.24	1.49	0.82	1.36	1.62	0.10	0.12	0.13	13.9	9.7	8.5
NY-0340	4.1	6.3	44	54	79	1.24	2.14	2.57	1.42	2.34	2.79	0.18	0.20	0.22	14.1	9.5	8.5
NY-0350	15.6	7.8	43	53	79	4.62	8.00	9.66	5.28	8.77	10.46	0.66	0.77	0.80	14.3	9.6	8.3
NY-0360	13.1	7.6	43	53	79	3.89	6.74	8.14	4.44	7.39	8.81	0.56	0.65	0.67	14.3	9.6	8.2
NY-0370	1.0	6.2	76	76	83	0.49	0.74	0.86	0.49	0.74	0.86	0.00	0.00	0.00	0.0	0.0	0.0
NY-0380	0.6	6.3	76	76	82	0.29	0.43	0.50	0.29	0.43	0.50	0.00	0.00	0.00	0.0	0.0	0.0
NY-0390	0.4	7.2	75	75	83	0.19	0.29	0.33	0.19	0.29	0.33	0.00	0.00	0.00	0.0	0.0	0.0
NY-0400	1.5	6.5	78	78	83	0.73	1.09	1.26	0.73	1.09	1.26	0.00	0.00	0.00	0.0	0.0	0.0
NY-0410	1.6	5.8	48	58	82	0.56	0.91	1.09	0.62	0.99	1.16	0.06	0.07	0.07	11.0	7.8	6.6
NY-0420	22.0	8.2	45	55	81	7.10	11.96	14.33	7.98	12.96	15.35	0.89	1.00	1.03	12.5	8.4	7.2
NY-0430	40.6	11.6	42	53	79	11.24	19.69	23.85	13.09	21.86	26.11	1.85	2.17	2.26	16.5	11.0	9.5
NY-0440	32.9	10.6	39	52	79	9.01	15.90	19.30	10.72	17.91	21.39	1.71	2.01	2.09	19.0	12.6	10.8

Table A-1: Hydrology Model Results																		
Basin ID	Area (acres)	Time of Concentration (minutes)	Existing Impervious Percentage	Future Impervious Percentage	Pervious CN	Existing Land Use Maximum Flow (cfs)			Future Land Use Maximum Flow (cfs)			Existing Land Use Increase in Maximum Flow (cfs)			Future Land Use Percent Increase in Maximum Flow (%)			
						2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	
NY-0450	22.3	8.0	48	58	81	7.44	12.42	14.83	8.35	13.43	15.86	0.91	1.01	1.03	12.2	8.1	7.0	
NY-0460	26.1	9.0	43	53	80	8.10	13.80	16.57	9.15	14.99	17.81	1.05	1.20	1.24	13.0	8.7	7.5	
NY-0470	15.9	7.9	42	52	80	4.86	8.34	10.04	5.50	9.07	10.80	0.64	0.73	0.76	13.1	8.8	7.5	
NY-0480	14.7	7.7	40	49	79	4.20	7.37	8.93	4.75	8.02	9.60	0.55	0.65	0.67	13.1	8.8	7.6	
NY-0490	15.6	7.8	41	51	79	4.47	7.82	9.47	5.11	8.57	10.25	0.64	0.75	0.78	14.3	9.6	8.2	
NY-0500	25.5	9.0	40	51	79	7.13	12.55	15.22	8.28	13.90	16.64	1.15	1.36	1.41	16.2	10.8	9.3	
NY-0510	21.3	8.5	45	55	82	7.11	11.85	14.15	7.93	12.77	15.09	0.82	0.92	0.94	11.6	7.8	6.6	
NY-0520	18.6	7.6	52	54	81	6.75	10.97	13.00	6.89	11.13	13.16	0.14	0.16	0.16	2.1	1.4	1.2	
Oswego Creek																		
OS-Offsite1	56.1	19.8	74.6	74.6	70.2	17.97	29.04	34.36	17.97	29.04	34.36	0.00	0.00	0.00	0.0	0.0	0.0	
Rock Creek																		
RO-0010	76.5	18.8	52	63	79	21.50	36.37	43.63	24.85	40.17	47.52	3.35	3.79	3.89	15.6	10.4	8.9	
RO-0020	147.4	25.6	27	72	72	14.61	34.08	44.56	42.28	69.10	82.01	27.67	35.02	37.45	189.4	102.8	84.0	
Saum Creek																		
SA-0010	11.6	6.4	28	34	75	2.17	4.38	5.51	2.46	4.76	5.92	0.29	0.38	0.41	13.4	8.7	7.5	
SA-0020	7.2	5.9	38	46	78	1.96	3.50	4.26	2.22	3.81	4.60	0.26	0.31	0.34	13.1	8.8	7.9	
SA-0030	12.7	6.7	18	22	79	2.62	5.12	6.39	2.79	5.34	6.63	0.17	0.22	0.24	6.6	4.3	3.7	
SA-0040	3.8	5.8	42	52	79	1.13	1.95	2.36	1.28	2.14	2.56	0.16	0.19	0.20	13.9	9.8	8.5	
SA-0050	22.2	7.4	43	53	79	6.49	11.30	13.66	7.45	12.41	14.81	0.95	1.11	1.15	14.7	9.8	8.4	
SA-0060	11.0	6.3	26	35	79	2.58	4.81	5.94	2.94	5.27	6.42	0.36	0.45	0.48	14.1	9.4	8.1	
SA-0070	19.8	7.7	39	50	77	5.04	9.17	11.22	6.07	10.40	12.52	1.02	1.23	1.29	20.3	13.4	11.5	
SA-0080	30.9	8.7	31	37	79	7.69	14.05	17.23	8.35	14.86	18.09	0.67	0.82	0.86	8.7	5.8	5.0	
SA-0090	6.5	6.2	42	52	79	1.92	3.33	4.03	2.19	3.65	4.37	0.27	0.32	0.34	14.0	9.5	8.5	
SA-0100	9.5	6.8	43	53	79	2.84	4.91	5.92	3.25	5.39	6.42	0.41	0.48	0.49	14.5	9.7	8.4	
SA-0110	21.7	7.9	37	51	79	5.90	10.50	12.78	7.11	11.93	14.28	1.22	1.44	1.50	20.6	13.7	11.7	
SA-0120	41.7	10.8	23	28	78	8.17	16.06	20.09	8.88	16.98	21.09	0.72	0.93	1.00	8.8	5.8	5.0	

Table A-1: Hydrology Model Results																	
Basin ID	Area (acres)	Time of Concentration (minutes)	Existing Impervious Percentage	Future Impervious Percentage	Pervious CN	Existing Land Use Maximum Flow (cfs)			Future Land Use Maximum Flow (cfs)			Existing Land Use Increase in Maximum Flow (cfs)			Future Land Use Percent Increase in Maximum Flow (%)		
						2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr
SA-0130	17.3	7.1	24	28	78	3.63	7.04	8.77	3.88	7.36	9.11	0.25	0.32	0.34	6.8	4.5	3.9
SA-0140	19.5	8.3	23	29	78	4.02	7.82	9.76	4.52	8.46	10.44	0.50	0.64	0.69	12.4	8.2	7.1
SA-0150	23.1	8.0	30	36	78	5.37	10.05	12.41	5.93	10.75	13.15	0.56	0.70	0.74	10.4	7.0	6.0
SA-0160	51.0	10.5	37	45	79	11.99	21.39	26.06	13.51	23.22	27.97	1.52	1.82	1.91	12.7	8.5	7.3
SA-0170-ODOT	54.8	14.2	46	46	78	14.66	25.70	31.13	14.66	25.70	31.13	0.00	0.00	0.00	0.0	0.0	0.0
SA-0180	10.4	6.4	38	46	79	2.92	5.15	6.25	3.27	5.57	6.70	0.36	0.42	0.44	12.2	8.2	7.1
SA-0190	7.9	6.6	42	52	81	2.57	4.33	5.18	2.87	4.67	5.55	0.30	0.34	0.37	11.6	7.9	7.1
SA-0200	20.7	8.4	43	53	79	6.10	10.57	12.77	6.98	11.59	13.82	0.88	1.02	1.05	14.4	9.6	8.2
SA-0210	11.7	6.8	39	48	76	2.90	5.33	6.54	3.37	5.91	7.15	0.48	0.58	0.61	16.4	10.9	9.4
SA-0220	26.7	9.1	38	47	74	5.67	10.90	13.55	6.73	12.24	14.98	1.06	1.34	1.43	18.7	12.3	10.5
SA-0230	22.3	7.5	37	42	55	0.83	3.67	5.29	1.37	4.50	6.24	0.54	0.84	0.95	65.4	22.8	18.0
SA-0240	28.4	9.3	37	40	60	2.08	6.17	8.43	2.51	6.81	9.15	0.43	0.64	0.72	20.9	10.3	8.5
SA-0250	14.5	6.7	42	53	59	1.38	3.64	4.87	2.25	4.86	6.22	0.88	1.22	1.35	63.7	33.4	27.7
SA-0260	21.7	7.5	42	51	73	4.81	9.15	11.34	5.86	10.46	12.74	1.05	1.31	1.40	21.9	14.3	12.3
SA-0270	8.8	6.8	36	53	69	1.34	2.92	3.75	2.11	3.92	4.83	0.77	1.00	1.08	57.0	34.2	28.9
SA-0280	26.0	8.6	42	51	61	2.77	6.93	9.17	4.09	8.76	11.19	1.32	1.82	2.02	47.7	26.3	22.0
SA-0290	47.0	36.9	15	16	76	4.22	9.57	12.45	4.35	9.76	12.66	0.13	0.19	0.21	3.1	2.0	1.7
SA-Offsite1	115.3	21.4	7	7	76	10.49	26.06	34.48	10.49	26.06	34.48	0.00	0.00	0.00	0.0	0.0	0.0
SA-Offsite2	21.0	7.1	8	8	76	2.79	6.39	8.30	2.81	6.42	8.33	0.02	0.03	0.03	0.8	0.5	0.4
SA-Offsite3	718.9	122.1	7	7	70	21.84	50.21	68.45	21.84	50.21	68.45	0.00	0.00	0.00	0.0	0.0	0.0
SA-Offsite4	777.7	183.0	7	7	73	27.14	57.12	74.84	27.14	57.12	74.84	0.00	0.00	0.00	0.0	0.0	0.0
SA-Offsite5	576.2	159.7	8	9	76	30.51	64.30	83.28	30.51	64.30	83.28	0.00	0.00	0.00	0.0	0.0	0.0
SA-Offsite5-ODOT	98.6	159.7	46	46	76	8.67	15.72	19.30	8.67	15.72	19.30	0.00	0.00	0.00	0.0	0.0	0.0

Table A-1: Hydrology Model Results																		
Basin ID	Area (acres)	Time of Concentration (minutes)	Existing Impervious Percentage	Future Impervious Percentage	Pervious CN	Existing Land Use Maximum Flow (cfs)			Future Land Use Maximum Flow (cfs)			Existing Land Use Increase in Maximum Flow (cfs)			Future Land Use Percent Increase in Maximum Flow (%)			
						2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	
Tualatin River																		
TU-0010	18.2	7.0	10	11	73	1.70	4.53	6.06	1.78	4.64	6.19	0.08	0.12	0.13	4.8	2.5	2.1	
TU-0020	23.9	7.5	40	50	73	5.25	10.02	12.43	6.32	11.35	13.85	1.07	1.34	1.43	20.4	13.4	11.5	
TU-0030	45.1	10.1	41	50	77	11.70	21.03	25.67	13.33	23.00	27.73	1.63	1.96	2.06	13.9	9.3	8.0	
TU-0040	9.8	7.5	41	50	79	2.86	4.98	6.02	3.19	5.37	6.43	0.33	0.39	0.41	11.6	7.8	6.7	
TU-0050	41.2	9.7	43	53	71	8.28	16.19	20.22	10.37	18.83	23.05	2.08	2.64	2.82	25.2	16.3	14.0	
TU-0060	9.4	7.5	5	5	77	1.24	2.85	3.71	1.24	2.85	3.71	0.00	0.00	0.00	0.0	0.0	0.0	
TU-0070	5.3	5.9	40	50	80	1.59	2.75	3.33	1.81	3.01	3.60	0.22	0.26	0.28	13.7	9.5	8.3	
TU-0080	34.6	9.4	39	49	74	7.51	14.33	17.78	9.11	16.33	19.91	1.60	2.00	2.13	21.3	13.9	12.0	
TU-0090-ODOT	12.7	7.1	46	46	80	4.11	6.94	8.31	4.11	6.94	8.31	0.00	0.00	0.00	0.0	0.0	0.0	
TU-0100	38.3	11.3	71	72	80	15.85	24.43	28.48	16.05	24.62	28.68	0.19	0.20	0.19	1.2	0.8	0.7	
TU-0110	2.2	6.3	23	28	77	0.44	0.87	1.09	0.48	0.92	1.14	0.04	0.05	0.05	8.6	5.6	4.9	
TU-0120	19.9	7.7	33	40	78	4.95	9.08	11.14	5.48	9.73	11.83	0.53	0.65	0.69	10.7	7.2	6.2	
TU-0130	11.8	6.6	76	76	79	5.26	8.05	9.37	5.26	8.05	9.37	0.00	0.00	0.00	0.0	0.0	0.0	
TU-0140	51.9	18.9	64	66	75	15.63	25.87	30.82	16.11	26.42	31.38	0.48	0.55	0.56	3.1	2.1	1.8	
TU-0150	6.4	7.1	78	78	79	2.91	4.41	5.12	2.91	4.41	5.12	0.00	0.00	0.00	0.0	0.0	0.0	
TU-0160	22.0	10.1	78	78	74	9.12	14.10	16.45	9.12	14.10	16.45	0.00	0.00	0.00	0.0	0.0	0.0	
TU-0170	6.8	6.8	56	56	76	2.20	3.71	4.45	2.20	3.71	4.45	0.00	0.00	0.00	0.0	0.0	0.0	
TU-0180	21.8	10.0	63	63	73	7.13	11.91	14.23	7.13	11.91	14.23	0.00	0.00	0.00	0.0	0.0	0.0	
TU-0190	50.0	18.5	60	61	77	14.74	24.61	29.39	15.02	24.92	29.71	0.27	0.31	0.32	1.9	1.3	1.1	
TU-0200	39.3	9.9	6	6	76	4.25	10.51	13.87	4.25	10.51	13.87	0.00	0.00	0.00	0.0	0.0	0.0	
TU-0210	39.2	9.9	67	67	79	15.40	24.27	28.48	15.40	24.27	28.48	0.00	0.00	0.00	0.0	0.0	0.0	
TU-0220	56.9	12.5	5	5	76	5.61	14.23	18.89	5.61	14.23	18.89	0.00	0.00	0.00	0.0	0.0	0.0	
TU-0230	25.6	9.6	73	73	79	10.88	16.72	19.49	10.88	16.72	19.49	0.00	0.00	0.00	0.0	0.0	0.0	
TU-0240	8.3	6.7	78	78	78	3.79	5.76	6.69	3.79	5.76	6.69	0.00	0.00	0.00	0.0	0.0	0.0	
TU-0250	123.1	35.0	37	44	81	23.87	42.46	51.76	26.42	45.61	55.08	2.55	3.15	3.32	10.7	7.4	6.4	

Table A-1: Hydrology Model Results																		
Basin ID	Area (acres)	Time of Concentration (minutes)	Existing Impervious Percentage	Future Impervious Percentage	Pervious CN	Existing Land Use Maximum Flow (cfs)			Future Land Use Maximum Flow (cfs)			Existing Land Use Increase in Maximum Flow (cfs)			Future Land Use Percent Increase in Maximum Flow (%)			
						2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	2-yr	10-yr	25-yr	
TU-0260	72.6	23.6	31	38	82	16.23	28.92	35.20	17.74	30.73	37.11	1.51	1.82	1.91	9.3	6.3	5.4	
TU-0270	23.1	9.3	43	53	79	6.71	11.65	14.08	7.68	12.78	15.25	0.97	1.13	1.17	14.5	9.7	8.3	
TU-0280	20.5	8.0	43	53	79	6.06	10.51	12.69	6.93	11.52	13.74	0.87	1.01	1.04	14.3	9.6	8.2	
TU-0290	3.8	6.3	42	53	81	1.23	2.07	2.49	1.39	2.26	2.68	0.16	0.18	0.19	12.7	8.8	7.7	
TU-0300	15.7	7.9	15	17	80	3.28	6.35	7.92	3.41	6.52	8.10	0.13	0.17	0.18	4.0	2.7	2.3	
TU-0310	64.5	14.7	39	52	79	16.25	28.98	35.29	19.40	32.71	39.18	3.15	3.73	3.90	19.4	12.9	11.0	
TU-0320	36.8	12.4	28	34	79	8.22	15.36	18.96	9.01	16.35	20.02	0.79	0.99	1.05	9.7	6.4	5.6	
TU-0330	35.4	9.5	40	46	79	9.87	17.36	21.06	10.75	18.41	22.15	0.88	1.05	1.09	8.9	6.0	5.2	
TU-0340	27.7	9.9	39	48	79	7.66	13.49	16.36	8.65	14.66	17.59	0.99	1.17	1.22	12.9	8.7	7.5	
TU-0350	42.9	10.9	44	57	79	12.36	21.43	25.89	14.75	24.19	28.74	2.39	2.76	2.85	19.3	12.9	11.0	
TU-0360	26.7	8.6	48	58	79	8.37	14.21	17.07	9.52	15.53	18.41	1.16	1.31	1.35	13.8	9.2	7.9	
TU-0370	40.5	10.0	48	54	79	12.39	21.15	25.43	13.41	22.32	26.64	1.01	1.17	1.21	8.2	5.5	4.7	
TU-0380	9.0	7.4	65	69	79	3.52	5.59	6.58	3.72	5.79	6.79	0.19	0.21	0.22	5.5	3.7	3.3	
TU-Offsite1	400.6	97.7	5	5	68	10.54	24.79	34.90	10.54	24.79	34.90	0.00	0.00	0.00	0.0	0.0	0.0	
TU-Offsite2	307.6	76.7	6	6	79	21.09	45.82	59.17	21.18	45.96	59.33	0.09	0.14	0.16	0.4	0.3	0.3	

Note: Subbasins that do not drain to city infrastructure are highlighted in gray.

Attachment B: Hydraulic Model Results

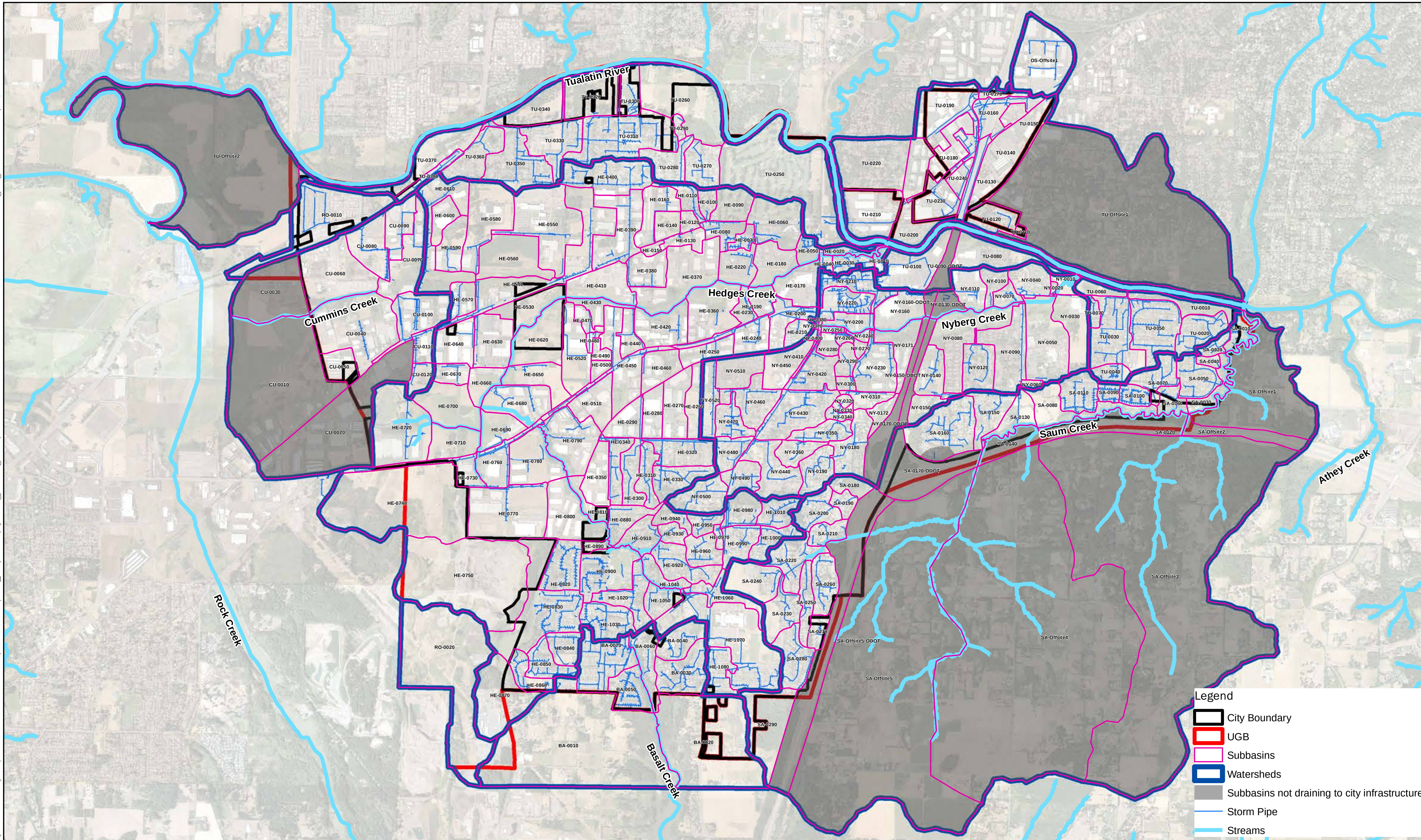
Table B-1. Hydraulic Model Parameters and Results

						Node Name		Invert Elevation (ft)		Ground Elevation (ft)		Existing 2 yr Max Water Surface Elevation (ft)		Future 2 yr Max Water Surface Elevation (ft)		Existing 10 yr Max Water Surface Elevation (ft)		Future 10 yr Max Water Surface Elevation (ft)		Existing 25 yr Max Water Surface Elevation (ft)		Future 25 yr Max Water Surface Elevation (ft)		2 yr Max Flow (cfs)		10 yr Max Flow (cfs)		25 yr Max Flow (cfs)		
Link ID	Length (ft)	Shape	Diameter/Height (ft)	Slope (%)	Design Flow (cfs)	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	Existing	Future	Existing	Future	Existing	Future	When Hydraulically Deficient
Herman Road System																														
267853	105.1	Circular	2.0	0.6	15.9	262914	322610_HE-0080	123.72	123.12	131.59	127.16	124.84	124.05	124.94	124.11	125.35	124.39	125.47	124.44	125.63	124.52	125.80	124.57	6.7	7.6	11.5	12.6	13.9	14.9	
268054	60.5	Circular	1.0	2.5	5.0	262138_HE-0120	270931	127.44	125.90	129.44	129.14	127.99	126.15	128.04	126.19	128.24	126.99	128.34	127.09	128.56	127.17	129.01	127.25	1.8	2.0	3.0	3.3	3.7	3.9	
268371	55.7	Circular	2.0	0.4	12.6	262922	262914	124.12	123.92	130.53	131.59	125.29	124.84	125.39	124.94	125.83	125.35	125.96	125.47	126.18	125.63	126.38	125.80	5.8	6.5	9.8	10.7	11.8	12.8	Future 25-yr
268372	131.0	Circular	1.0	0.9	3.2	262918_HE-0090	262914	126.13	124.92	128.62	131.59	126.51	125.30	126.54	125.33	126.65	125.44	126.68	125.47	126.71	125.63	126.75	125.80	1.0	1.1	1.7	1.9	2.0	2.2	
268384	174.9	Circular	2.0	0.4	13.3	262545	262922	124.92	124.22	128.65	130.53	125.98	125.29	126.08	125.39	126.54	125.83	126.69	125.96	127.04	126.18	127.33	126.38	5.8	6.5	9.9	10.7	11.9	12.8	
322603	108.8	Circular	1.5	0.3	5.6	322601_HE-0160	HE-0150	127.31	126.95	131.06	129.95	130.36	128.91	130.54	128.93	132.61	129.10	132.87	129.12	133.94	129.17	134.23	129.19	8.8	9.3	13.8	14.2	16.1	16.6	Existing 2-yr
322618	380.4	Circular	2.5	0.2	8.5	322608	322610_HE-0080	123.37	122.66	127.87	127.16	125.94	124.05	126.21	124.11	126.52	124.39	126.52	124.44	126.53	124.52	126.53	124.57	12.0	13.3	14.1	14.1	14.1	14.1	Existing 2-yr
322620	51.1	Circular	2.0	1.7	27.8	322615	322613	124.99	124.10	127.99	128.23	125.99	125.98	126.27	126.26	126.71	126.64	126.78	126.69	126.83	126.72	126.90	126.77	2.9	3.2	5.1	5.7	6.1	6.6	
322621	40.9	Circular	2.0	-3.1	36.7	322613	322614	122.95	124.20	128.23	128.14	125.98	125.97	126.26	126.24	126.64	126.56	126.69	126.58	126.72	126.60	126.77	126.62	2.9	3.1	5.0	5.7	6.1	6.5	
322638.1	49.5	Circular	1.0	0.3	1.9	322625	322630	125.26	125.09	128.26	128.09	127.63	126.46	127.69	126.67	127.82	127.29	127.87	127.51	127.89	127.59	127.97	127.75	4.5	4.5	4.5	4.5	4.5	4.5	Existing 2-yr
322638_flood	49.5	Trapezoidal	1.0	0.3		322625	322630	127.26	127.09	128.26	128.09	127.63	127.36	127.69	127.42	127.82	127.54	127.87	127.59	127.89	127.61	127.97	127.75	8.3	11.0	17.5	20.8	22.0	25.4	
322639	76.9	Circular	1.0	0.1	0.9	322626	322631	124.80	124.74	127.80	127.74	126.00	126.14	126.27	126.47	126.71	127.24	126.78	127.47	126.81	127.56	126.89	127.72	-1.6	-1.9	-2.3	-2.6	-2.7	-2.9	
322641	43.5	Circular	2.0	2.2	61.8	322627	322634	124.72	123.78	127.72	128.15	126.14	126.09	126.47	126.38	127.24	126.97	127.47	127.13	127.56	127.18	127.72	127.29	11.0	13.0	17.7	20.4	21.3	22.8	
322642	52.4	Circular	2.0	0.6	33.8	322634	322637	123.00	122.66	128.15	127.86	126.09	126.03	126.38	126.29	126.97	126.70	127.13	126.76	127.18	126.79	127.29	126.83	11.0	13.0	17.7	20.4	21.3	22.8	
322643	12.3	Circular	2.0	0.6	31.7	322637	322632_HE-0130	124.06	123.99	127.86	126.49	126.03	125.99	126.29	126.25	126.70	126.49	126.76	126.49	126.79	126.49	126.83	126.49	10.9	13.0	17.7	20.4	21.3	22.8	Existing 2-yr
3333707_flood	46.9	Trapezoidal	1.0	0.4		333702	333701_HE-0140	128.16	127.99	129.16	128.99	128.58	128.45	128.61	128.51	128.73	128.61	128.76	128.66	128.79	128.68	128.82	128.73	9.5	10.1	15.3	15.8	18.0	18.6	
333704.1	12.6	Circular	0.8	0.3	1.1	333700	333699	125.88	125.84	128.88	128.84	128.33	128.27	128.38	128.32	128.48	128.42	128.53	128.47	128.55	128.49	128.59	128.53	2.2	2.2	2.2	2.2	2.2	2.2	Existing 2-yr
333704_flood	12.6	Trapezoidal	1.0	0.3		333700	333699	127.88	127.84	128.88	128.84	128.33	128.27	128.38	128.32	128.48	128.42	128.53	128.47	128.55	128.49	128.59	128.53	12.1	14.6	19.9	22.8	23.7	26.6	
333705.1	34.5	Circular	0.8	0.3	1.1	333701_HE-0140	333700	125.99	125.88	128.99	128.88	128.45	128.33	128.51	128.38	128.61	128.48	128.66	128.53	128.68	128.55	128.73	128.59	1.9	1.9	1.9	1.9	1.9	1.9	Existing 2-yr
333705_flood	34.5	Trapezoidal	1.0	0.3		333701_HE-0140	333700	127.99	127.88	128.99	128.88	128.45	128.33	128.51	128.38	128.61	128.48	128.66	128.53	128.68	128.55	128.73	128.59	11.9	14.4	19.8	22.6	23.6	26.5	
333706.1	46.9	Circular	0.8	0.4	1.2	333702	333701_HE-0140	126.16	125.99	129.16	128.99	128.58	128.45	128.61	128.51	128.73	128.61	128.76	128.66	128.79	128.68	128.82	128.73	1.5	1.3	1.5	1.2	1.5	1.2	Existing 2-yr
333707.1	49.2	Circular	0.8	0.0	1.2	333703	333702	126.32	126.16	129.32	129.16	128.73	128.58	128.75	128.61	128.87	128.73	128.89	128.76	128.93	128.79	128.95	128.82	1.4	1.3	1.4	1.2	1.5	1.1	Existing 2-yr
333707_flood	49.2	Trapezoidal	1.0	0.3		333703	333702	128.32	128.16	129.32	129.16	128.73	128.58	128.75	128.61	128.87	128.73	128.89	128.76	128.93	128.79	128.95	128.82	9.3	9.8	15.1	15.6	17.8	18.3	
334080.1	52.0	Circular	0.8	0.3	1.2	333699	334081	125.84	125.66	128.84	128.66	128.27	127.67	128.32	127.74	128.42	127.87	128.47	127.94	128.49	127.96	128.53	128.03	2.6	2.6	2.6	2.6	2.6	2.6	Existing 2-yr
334080_flood	52.0	Trapezoidal	1.0	0.3		333699	334081	127.84	127.66	128.84	128.66	128.27	127.99	128.32	128.04	128.42	128.14	128.47	128.18	128.49	128.20	128.53	128.24	11.1	13.6	19.0	21.9	22.8	25.8	
335317	21.7	Circular	2.0	-6.5	53.6	322614	322612	122.70	124.10	128.14	127.10	125.97	125.96	126.24	126.23	126.56	126.51	126.58	126.52	126.60	126.52	126.62	126.52	2.8	3.1	5.0	5.7	6.1	6.5	
Link32.1	185.2	Trapezoidal	1.5	0.3		HE-0150	333703	126.95	126.32	129.95	129.32	128.91	128.73	128.93	128.75	129.10	128.87	129.12	128.89	129.17	128.93	129.19	128.95	10.4	10.8	14.3	14.5	15.7	15.8	Existing 10-yr
Link32_flood	185.2	Trapezoidal	1.0	0.3		HE-0150	333703	128.95	128.32	129.95	129.32	128.91	128.73	128.93	128.75	129.10	128.87	129.12	128.89	129.17	128.93	129.19	128.95	0.0	0.0	1.8	2.1	3.1	3.5	
Link33.1	119.5	Trapezoidal	2.0	0.0		334081	322625	125.66	125.26	128.66	128.26	127.67	127.63	127.74	127.69	127.87	127.82	127.94	127.87	127.96	127.89	128.03	127.97	12.8	14.9	18.8	20.7	21.3	22.9	Future 2-yr
Link33_flood	119.5	Trapezoidal	1.0	0.3		334081	322625	127.66	127.26	128.66	128.26	127.67	127.63	127.74	127.69	127.87	127.82	127.94	127.87	127.96	127.89	128.03	127.97	0.0	0.5	1.9	2.8	3.2	4.5	
Link34.1	110.5	Trapezoidal	2.0	0.3		322630	322627	125.09	124.72	128.09	127.72	126.46	126.14	126.67	126.47	127.29	127.24	127.51	127.47	127.59	127.56	127.75	127.72	12.7	15.2	19.7	21.1	21.0	21.7	Existing 10-yr
Link34_flood	110.5	Trapezoidal	1.0	0.3		322630	322627	127.09	126.72	128.09	127.72	---	---	---	---	127.289	127.235	127.509	127.474	127.588	127.56	127.748	127.72	0.0	0.0	1.6	4.2	5.2	7.5	
Link35	10.7	Trapezoidal	2.0	0.2		322631	322627	124.74	124.72	127.74	127.72	126.14	126.14	126.47	126.47	127.24	127.24	127.47	127.47	127.56	127.56	127.72	127.72	-1.6	-1.9	-2.4	-2.6	-2.7	-2.9	
Link36	12.6	Trapezoidal	2.0	7.2		270931	322615	125.90	124.99	129.14	127.99	126.15	125.99	126.19	126.27	126.99	126.71	127.13	126.78	127.17	126.83	127.25	126.90	1.8	2.0	-11.4	11.2	10.5	-15.3	
Link37	230.8	Trapezoidal	2.0	0.1		322615	322626	124.99	124.80	127.99	127.80	125.99	126.00	126.27	126.27	126.71	126.71	126.78	126.78	126.83	126.81	126.90	126.89	-1.4	-1.5	-2.6	-3.4	-3.3	-3.7	
Link38	316.7	Natural	2.0	0.0		322632_HE-0130	322612	123.99	124.10	126.49	127.10	125.99	125.96	126.25	126.23	126.49	126.51	126.49	126.52	126.49	126.52	126.49	126.52	14.5	16.2	21.3	22.3	23.0	23.7	
Link39.1	358.0	Natural	2.0	0.2		322612	322608	124.10	123.37	127.10	127.87	125.96	125.94	126.23	126.21	126.51	126.52	126.52	126.52	126.52	126.53	126.52	126.53	14.8	16.2	19.2	19.9	20.1	20.5	Future 2-yr
Link39_flood	358.0	Trapezoidal	1.0	0.5		322612	322608	126.10	124.37	127.10	127.87	125.96	125.94	126.23	126.21	126.51	126.52	126.52	126.52	126.52	126.53	126.52	126.53	0.0	0.4	1.2	1.2	1.2	1.2	
Link40	425.0	Natural	3.5	0.1		322610_HE-0080	Node567	122.66	121.99	127.16	126.43	124.05	123.60	124.11	123.68	124.39	124.03	124.44	124.09	124.52	124.19	124.57	124.25	21.7	23.3	31.8	33.1	35.4	36.6	
Link41	425.0	Natural	4.0	0.1		Node567	Node568	121.99	121.39	126.43	126.39	123.60	123.15	123.68	123.25	124.03	123.67	124.09	123.75	124.19	123.87	124.25	123.95	21.1	22.8	30.8	32.2	34.4	35.7	
Link42	112.4	Circular	4.0	0.1	87.2	262143_HE-0070	270939_HE-0060	121.32	121.20	127.32	129.12	123.14	123.07	123.24	123.17	123.66	123.59	123.75	123.67	123.87	123.79	123.94	123.87	22.5	24.5	33.5	35.1	37.8	39.3	
Link43	414.9	Circular	4.0	0.0	8.4	270939_HE-0060	260389	121.10	121.10	129.12	127.86	123.07	122.52	123.17	122.60	123.59	122.94	123.67	123.01	123.79	123.10	123.87	123.16	29.7	32.6	46.2	49.0	53.3	56.0	
Link44	156.4	Circular	4.0	0.2	126.2	260389	271095	121.00	120.65	127.86	124.65	122.52	121.78	122.60	121.83	122.94	122.07	123.01	122.11	123.10	122.18	123.16	122.22	29.6	32.6	46.2	49.0	53.3	56.0	
Link45	50.0	Natural	5.0	0.1		Node568	262143_HE-0070	121.39	121.32	126.39	127.32	123.15	123.14	123.25	123.24	123.67	123.66	123.75	123.75	123.87	123.87	123.95	123.94	20.9	22.8	30.6	32.0	34.2	35.5	
Link46	170.3	Circular	1.5	2.9	16.5	263295_HE-0110	262910_HE-0100	130.92	126.02	136.52	132.57	131.42	126.58	131.45	126.67	131.59	127.11	131.62	127.26	131.69	127.66	131.76	128.04	3.6	4.0	6.1	6.6	7.3	7.8	
Link47	99.5	Circular	2.0	0.5	14.9	262910_HE-0100	262545	125.52	125.02	132.57	128.65	126.58	125.98	126.67	126.08	127.11	126.54	127.26	126.69	127.66	127.04	128.04	127.33	5.8	6.5	9.9	10.7	11.9	12.8	
Manhasset Drive System																														
266695	132.0	Circular	1.8	-0.5	10.4	259248	262763_HE-0480	132.70	133.40	139.25	138.78	136.12	134.99	136.72	135.17	138.48	135.92	136.72	135.17	138.67	136.16	138.76	136.22	10.6	12.5	16.0	16.4	16.6	16.8	Existing 2-yr
266696	47.4	Circular	1.8	4.0	29.0	262001	259248	134.65	132.75	139.76	139.25	136.80	136.12	137.67	136.72	140.10	138.48	137.67	136.72	140.29	138.67	140.43	138.76	10.6	12.5	10.6	12.5	16.6	16.8	
266697	194.1	Circular	2.3	0.2	11.6	262765_HE-0470	271161	129.88	129.56	135.43	132.06	131.93	130.87	132.22	130.97	133.09	131.20	132.22	130.97	133.23	131.22	133.26	131.23	14.3	16.3	21.7	21.8	22.6	22.8	Existing 2-yr
267387	102.0	Circular	2.5	1.1	40.5	261974_HE-0510	262060_HE-0500	157.90	156.75	160.40	159.25	159.22	157.63	159.40	157.72	159.95	158.99	159.40	157.72	160.02	159.25	160.20	159.25	8.1	9.8	14.3	16.3	15.7	17.4	
268265	149.3	Circular	2.3	0.1	10.5	262763_HE-0480	262764	133.20	133.00	138.78	137.99	134.99	134.18	135.17	134.28	135.92	134.93	135.17	134.28	136.16	135.18	136.22	135.22	11.7	13.6	17.5	17.6	17.8	18.0	Existing 2-yr
268266	407.7	Circular	2.3	0.7	23.7	262764	262765_HE-0470	132.80	129.98	137.99	135.43	134.02	131.93	134.19	132.22	134.93	133.09	134.19	132.22	135.18	133.23	135.22	133.26	11.6	13.6	17.5	17.7	18.0	18.1	
Link10.1	200.0	Natural	0.6	3.1		Node278	Node280	153.54	147.30	155.66	149.00	154.76	148.17	154.79	148.21	154.87	148.30	154.79	148.21	154.87	148.31	154.87	148.31	5.5	5.5	11.6	13.6	5.5	5.5	Existing 2-yr
Link10_flood	200.0	Trapezoidal	1.0	3.3		Node278	Node280	154.66	148.00	155.66	149.00	154.76	148.17	154.79	148.21	154.87	148.30	154.79	148.21	154.87	148.31	154.87	148.31	3.3	4.9	8.5	10.2	10.7	10.7	
Link11.1	160.0	Natural	0.8	2.1		HE-0490	262001	141.34	137.96	143.14	139.76	142.29	138.63	142.32	138.64	142.43	140.10	142.32	138.64	142.44	140.29	142.44	140.43	6.2	6.2	6.7	6.7	6.7	6.6	Existing 2-yr
Link11_flood	160.0	Trapezoidal	1.0	2.1		HE-0490	262001	142.14	138.76	143.14	139.76	142.29	138.91	142.32	138.94	142.43	140.10	142.32	138.94	142.44	140.29	142.44	140.43	4.4	6.2	6.2	6.2	14.2	14.6	
Link12.1	130.0	Natural	0.7	1.2		Node280	Node281	147.30	145.75	149.00	147.45	148.17	146.68	148.21	146.71	148.30	146.80	148.21	146.71	148.31	146.80	148.31	146.80	4.3	4.3	4.3	4.3	4.4	4.4	Existing 2-yr
Link12_flood	130.0	Trapezoidal	1.0	1.2		Node280	Node281	148.00	146.45	149.00	147.45	148.17	146.68	148.21	146.71	148.30	146.80	148.21	146.71	148.31	146.80	148.31	146.80	4.4	6.1	9.7	11.3	11.8	11.8	
Link13.1	20.0	Natural	0.7	1.2		Node281	Node282	145.75	145.51	147.45	147.21	146.68	146.40	146.71	146.44	146.80	146.53	146.71	146.44	146.80	146.54	146.80	146.54	2.0	2.0	4.4	6.1	2.0	2.0	Existing 2-yr
Link13_flood	20.0	Trapezoidal	1.0	1.2		Node281	Node282	146.45	146.21	147.45	147.21	146.68	146.44	146.71	146.47	146.80	146.56	146.71	146.47	146.80	146.57	146.80	146.57	7.0	8.7	12.2	13.9	14.4	14.4	
Link14.1	330.0	Natural	0.7	1.3		Node282	HE-0490	145.51	141.34	147.21	143.14	146.40	142.29	146.44	142.32	146.53	142.43	146.44	142.32	146.54	142.44	146.54	142.44	3.5	3.5	7.0	8.7	3.5	3.5	Existing 2-yr
Link14_flood	330.0	Trapezoidal	1.0	1.2		Node282	HE-0490	146.21	142.14	147.21	143.14	146.40	142.33	146.44	142.37	146.53	142.46	146.44	142.37	146.54	142.47	146.54	142.47	5.2	6.9	10.5	12.2	12.7	12.7	
Link9	200.0	Natural	1.1	1.6		262060_HE-0500	Node278	156.75	153.54	159.25	155.66	157.63	154.76	157.72	154.79	158.99	154.87	157.72	154.79	159.25	154.87	159.25	154.87	8.8	10.5	5.2	6.9	16.2	16.2	Existing 2-yr
Nyberg Creek System																														
264286	237.6	Circular	1.5	0.2	4.5	262213	NY-0250	120.20	119.70	125.08	126.15	124.18	124.06	124.69	124.58	125.08	125.75	125.08	125.93	125.08	126.08	125.08	126.15	2.5	2.5	-4.6	-5.2	-5.7	-5.9	Existing 10-yr
264288	268.3	Circular	1.0	2.8	5.5	262214_NY-0270	262213	127.82	120.30	134.82	125.08	128.17	124.18	128.19	124.69	128.34	125.08	128.34	125.08	128.40	125.08	128.40	125.08	1.3	1.3	2.0	2.0	2.3	2.3	
264517	120.0	Circular	1.8	1.5	18.0	263083_NY-0340	263084_NY-0330	211.00	209.19	215.65	214.60	212.14	210.10	212.25	210.20	214.57	211.94	215.65	212.79	215.65	212.82	215.65	212.84	9.7	11.1	16.7	17.5	17.5	17.6	
264521	238.9	Circular	1.8	1.6	18.6	263084_NY-0330	263085	209.09	205.28	214.60	208.46	210.10	206.28	210.20	206.38	211.94	207.60	212.79	208.00	212.82	208.02	212.84	208.03	10.4	11.9	17.9	18.8	18.9	18.9	Future 10-yr
264912	177.1	Circular	2.5	5.7	91.1	262947_NY-0310	262948_NY-0300	193.30	183.20	206.92	191.71	193.97	184.44	194.03	184.60	194.22	185.14	194.27	185.35	194.28	185.41	194.32	185.61	13.7	16.1	23.3	25.6	26.1	27.1	
264913	74.7	Circular	2.5	1.5	46.2	262948_NY-0300	262949	183.10	182.00	191.71	192.66	184.44	183.23	184.60	183.38	185.14	183.89	185.35	184.07	185.41	184.13	185.61	184.24	15.0	17.6	25.5	28.0	28.7	30.0	
264914	124.5	Circular	2.5	1.1	40.4	262949	262950	181.90	180.50	192.66	189.27	183.23	181.68	183.38	181.83	183.89	182.27	184.07	182.41	184.13	182.45	184.24	182.53	15.0	17.6	25.5	28.0	28.7	30.0	
264915	29.5	Circular	2.5	2.0	54.2	262950	263397_NY-0290	180.30	179.70	189.27	187.40	181.68	180.52	181.83	180.59	182.27	180.83	182.41	180.91	182.45	180.94	182.53	180.98	15.0	17.6	25.5	28.0	28.7	30.0	
265109	16.3	Circular	1.0	0.0	0.1	262208_NY-0260	262213	120.20	120.20	124.78	125.08	124.20	124.18	124.71	124.69	125.18	125.08	125.18	125.08	125.21	125.08	125.21	125.08	1.3	1.3	1.9	2.0	2.3	2.3	Existing 2-yr

Table B-1. Hydraulic Model Parameters and Results

						Node Name		Invert Elevation (ft)		Ground Elevation (ft)		Existing 2 yr Max Water Surface Elevation (ft)		Future 2 yr Max Water Surface Elevation (ft)		Existing 10 yr Max Water Surface Elevation (ft)		Future 10 yr Max Water Surface Elevation (ft)		Existing 25 yr Max Water Surface Elevation (ft)		Future 25 yr Max Water Surface Elevation (ft)		2 yr Max Flow (cfs)		10 yr Max Flow (cfs)		25 yr Max Flow (cfs)		
Link ID	Length (ft)	Shape	Diameter/Height (ft)	Slope (%)	Design Flow (cfs)	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	US	DS	Existing	Future	Existing	Future	Existing	Future	When Hydraulically Deficient
265110	24.9	Circular	3.0	16.5	251.0	262210_NY-0280	262209	130.60	126.50	136.53	133.15	131.46	127.49	131.54	127.68	131.83	128.50	131.97	129.10	132.12	129.72	132.29	130.17	20.3	23.4	34.2	37.4	39.2	41.1	
265111	207.7	Circular	2.5	3.1	67.4	262209	NY-0250	126.30	119.80	133.15	126.15	127.49	124.06	127.68	124.58	128.50	125.75	129.10	125.93	129.72	126.08	130.17	126.15	20.2	23.4	34.1	37.3	39.1	41.1	
266998	142.0	Circular	3.0	3.0	106.5	260409	262210_NY-0280	135.09	130.90	140.51	136.53	136.11	131.73	136.21	131.80	136.51	132.00	136.60	132.05	136.63	132.12	136.65	132.29	17.9	20.8	30.3	33.3	34.5	36.3	
267215	83.8	Circular	3.0	0.7	52.1	262844	270971	125.20	124.61	132.63	127.61	127.20	125.52	127.40	125.73	128.60	127.01	129.04	127.07	129.43	127.14	129.97	127.20	27.5	32.0	47.8	53.1	57.9	63.3	Future 10-yr
267573_1	52.0	Circular	5.3	0.9	265.1	260399	Node588	114.33	113.88	123.85	123.85	116.51	116.10	116.62	116.21	116.85	116.47	116.88	116.49	116.92	116.55	116.93	116.57	88.9	97.6	113.9	115.2	116.6	117.4	
267573_2	45.0	Circular	5.3	0.9	265.4	Node588	Node589	113.88	113.50	123.85	123.15	116.10	115.74	116.21	115.84	116.47	116.11	116.49	116.14	116.55	116.21	116.57	116.23	93.3	101.7	120.6	122.3	125.5	126.7	
267573_3	15.0	Circular	5.3	0.9	265.2	Node589	270963	113.50	113.37	123.15	123.15	115.74	115.61	115.84	115.72	116.11	115.98	116.14	116.01	116.21	116.08	116.23	116.10	97.8	106.1	128.2	130.6	136.3	138.2	
267910	126.6	Circular	1.8	0.9	14.3	262152_NY-0350	263083_NY-0340	212.30	211.10	216.42	215.65	213.49	212.14	213.63	212.25	216.63	214.57	218.16	215.65	218.69	215.65	219.20	215.65	8.4	9.7	14.7	16.1	17.8	19.3	Existing 10-yr
267951	199.0	Circular	1.8	1.4	17.3	263085	271340_NY-0320	205.20	202.44	208.46	205.44	206.28	203.09	206.38	203.12	207.60	203.25	208.00	203.27	208.02	203.28	208.03	203.28	10.4	11.9	17.8	18.8	18.9	18.9	Existing 10-yr
267953	84.5	Circular	2.5	7.2	102.3	260393	262947_NY-0310	200.00	193.90	203.34	206.92	200.64	194.46	200.69	194.50	202.36	194.63	202.49	194.65	202.52	194.66	202.53	194.66	11.1	12.7	18.8	20.1	20.4	20.6	
268293	21.4	Circular	2.5	1.4	45.1	262846	262844	126.70	126.40	135.44	132.63	129.06	127.81	129.37	127.96	131.22	128.63	132.11	129.04	133.06	129.43	134.34	129.97	27.5	32.0	47.8	53.1	57.9	63.3	Existing 10-yr
268295.1	119.7	Circular	2.5	5.5	89.7	262856	262847_NY-0370	138.10	131.46	147.25	138.76	139.24	132.77	139.36	132.95	139.88	134.24	140.78	136.10	143.52	137.76	144.74	137.87	27.1	31.5	47.2	52.4	57.1	62.5	
268295_flood	119.7	Trapezoidal	1.0	7.1		262856	262847_NY-0370	146.3	137.8	147.3	138.8	---	---	---	---	---	---	---	---	---	---	---	---	0.0	0.0	0.0	0.0	0.0	0.0	
268296.1	67.6	Circular	2.5	4.4	79.6	262847_NY-0370	262846	131.26	128.30	138.76	135.44	132.77	129.31	132.95	129.40	134.24	131.22	136.10	132.11	137.76	133.06	137.87	134.34	27.5	32.0	47.9	53.1	57.8	58.0	Existing 25-yr
268296_flood	67.6	Trapezoidal	1.0	4.9		262847_NY-0370	262846	137.8	134.4	138.8	135.4	---	---	---	---	---	---	---	---	---	---	---	134.55	0.0	0.0	0.0	0.0	0.0	13.1	
268297.1	41.3	Circular	2.5	10.4	122.8	262848	262856	142.50	138.20	148.93	147.25	143.71	139.24	143.85	139.36	144.35	139.88	144.63	140.78	147.55	143.52	148.04	144.74	27.1	31.5	47.2	52.4	57.1	58.2	Future 25-yr
268297_flood	41.3	Trapezoidal	1.0	4.1		262848	262856	147.9	146.3	148.9	147.3	---	---	---	---	---	---	---	---	---	---	---	146.36	0.0	0.0	0.0	0.0	0.0	10.7	
277225	110.2	Circular	3.0	1.2	48.1	277227_NY-0380	277232	124.00	122.72	127.95	126.72	127.47	125.40	128.36	125.65	129.66	126.72	129.67	126.72	129.69	126.72	129.70	126.72	46.6	51.7	53.9	54.0	54.2	54.3	Future 2-yr
312461	52.4	Circular	1.0	6.1	8.2	312444_NY-0410	312445_NY-0400	143.10	139.90	147.23	143.47	143.29	140.10	143.30	140.10	143.34	140.16	143.35	140.17	143.37	140.20	143.38	140.20	0.6	0.6	0.9	1.0	1.1	1.2	
322832	62.1	Circular	1.3	2.4	9.3	312443	322831	125.60	124.11	129.32	126.11	125.95	125.21	125.97	125.70	130.39	126.96	129.32	127.00	131.01	127.05	129.32	127.10	1.3	1.3	10.9	9.1	12.4	9.0	Existing 10-yr
333171	653.3	Circular	2.5	4.6	81.2	263397_NY-0290	333170	179.70	149.92	187.40	152.92	180.52	150.82	180.59	150.86	180.83	150.99	180.91	151.03	180.94	151.04	180.98	151.07	17.9	20.8	30.3	33.3	34.5	36.3	
Link31	127.0	Natural	2.5	1.9		271340_NY-0320	260393	202.44	200.06	205.44	203.34	203.09	200.71	203.12	200.74	203.25	202.36	203.27	202.49	203.28	202.52	203.28	202.53	11.1	12.7	19.0	20.2	20.4	20.6	
Link32	93.0	Natural	2.5	8.0		333170	Node561	149.92	142.51	152.92	145.10	150.82	143.64	150.86	143.68	150.99	143.80	151.03	143.83	151.04	143.84	151.07	143.86	17.9	20.8	30.3	33.3	34.5	36.3	
Link33	93.0	Natural	2.0	4.3		Node561	260409	142.51	138.51	145.10	140.51	143.64	139.63	143.68	139.67	143.80	139.77	143.83	139.80	143.84	139.82	143.86	139.83	17.9	20.8	30.3	33.3	34.5	36.3	
Link34	186.3	Circular	3.5	0.2	42.8	NY-0250	270982_NY-0200	119.40	119.01	126.15	126.00	124.06	123.90	124.58	124.39	125.75	125.38	125.93	125.46	126.08	125.54	126.15	125.59	23.7	26.8	33.7	35.1	35.7	37.0	
Link35	303.0	Circular	1.0	4.7	7.1	312445_NY-0400	312443	139.80	125.70	143.47	129.32	140.10	125.99	140.10	125.99	140.16	130.39	140.17	129.32	140.20	131.01	140.20	129.32	1.3	1.3	2.0	2.1	2.3	2.4	
Link36	456.0	Circular	3.0	2.7	102.2	335464	Node591	136.18	123.77	142.50	127.95	139.70	127.93	139.94	128.93	140.04	130.27	140.05	130.28	140.06	130.30	140.06	130.31	46.3	51.4	53.3	53.4	53.5	53.6	Existing 2-yr
Link37	40.0	Natural	2.0	1.3		270971	322831	124.61	124.11	127.61	126.11	125.52	125.21	125.73	125.70	127.01	126.96	127.07	127.00	127.14	127.05	127.20	127.10	27.5	31.9	47.7	53.0	57.8	63.3	
Link38	120.0	Natural	2.0	1.2		322831	277232	124.11	122.72	126.11	126.72	125.21	125.13	125.70	125.65	126.96	126.72	127.00	126.72	127.05	126.72	127.10	126.72	28.5	32.7	56.0	61.1	66.8	71.0	
Link43.1	1125.0	Natural	0.5	1.3		NY-0450	Node595	151.99	137.68	154.39	142.50	153.96	140.13	154.08	140.51	154.82	140.66	155.18	140.67	155.78	140.68	156.22	140.69	4.5	4.5	4.5	4.5	4.6	4.6	Existing 2-yr
Link43_flood	1125.0	Trapezoidal	2.0	1.1		NY-0450	Node595	152.39	140.50	154.39	142.50	153.96	141.69	154.08	141.79	154.82	142.08	155.18	142.10	155.78	142.13	156.22	142.15	41.9	47.9	66.7	67.9	70.0	71.5	
Link49	115.0	Circular	5.0	1.3	208.2	NEW1	Node570	117.18	115.68	127.68	127.68	122.81	121.87	123.08	121.93	123.64	122.01	123.68	122.02	123.73	122.02	123.76	122.03	90.3	99.1	115.3	116.6	118.0	118.8	
Link60	280.0	Trapezoidal	1.5	1.0		NY-0520	NY-0510	165.05	162.19	166.55	163.70	165.52	162.90	165.53	162.93	165.68	163.14	165.68	163.16	165.74	163.25	165.75	163.28	6.7	6.9	11.0	11.1	13.0	13.1	
Link61	1000.0	Trapezoidal	1.5	1.0		NY-0510	NY-0450	162.19	151.99	163.70	154.39	162.90	153.96	162.93	154.08	163.14	154.82	163.16	155.18	163.25	155.78	163.28	156.22	13.6	14.6	22.6	23.7	26.6	27.7	
Link62	1200.0	Circular	3.0	1.5	74.9	NY-0470	NY-0460	182.73	165.16	187.73	170.16	184.02	165.55	184.12	165.58	184.51	165.69	184.62	165.72	184.75	165.76	184.88	165.78	20.3	23.3	35.7	39.2	43.3	47.0	
Link63	900.0	Trapezoidal	2.0	1.5		NY-0460	NY-0450	165.16	151.99	170.16	154.39	165.55	153.96	165.58	154.08	165.69	154.82	165.72	155.18	165.76	155.78	165.78	156.22	28.1	32.1	49.1	53.9	59.4	64.4	
Link67	1500.0	Circular	3.0	2.6	99.1	NY-0430	NY-0420	210.40	171.97	215.40	176.97	211.32	173.04	211.40	173.13	211.64	173.43	211.72	173.52	211.78	173.60	211.86	173.71	20.1	23.7	35.4	39.5	42.9	47.2	
Link68	1150.0	Circular	3.0	2.6	99.1	NY-0420	262848	171.97	142.50	176.97	148.93	173.04	143.71	173.13	143.85	173.43	144.35	173.52	144.63	173.60	147.55	173.71	148.04	27.1	31.5	47.2	52.4	57.1	62.5	
Link69	1600.0	Circular	1.8	1.5	18.9	NY-0360	262152_NY-0350	239.07	212.50	244.07	216.42	239.61	213.49	239.64	213.63	239.79	216.63	239.83	218.16	239.87	218.69	239.92	219.20	3.8	4.4	6.7	7.4	8.1	8.8	
Link70	750.0	Circular	3.0	2.6	99.2	NY-0440	NY-0430	229.62	210.40	234.62	215.40	230.23	211.32	230.29	211.40	230.43	211.64	230.48	211.72	230.52	211.78	230.57	211.86	9.0	10.7	15.8	17.9	19.2	21.3	
Link71	1300.0	Circular	3.0	1.5	75.0	NY-0500	NY-0490	232.50	213.47	237.50	218.47	233.12	214.26	233.17	214.33	233.33	214.54	233.37	214.59	233.42	214.65	233.46	214.71	7.1	8.2	12.5	13.8	15.2	16.6	
Link72	600.0	Circular	3.0	1.5	74.9	NY-0490	NY-0480	213.47	204.69	218.47	209.69	214.26	205.62	214.33	205.69	214.54	205.95	214.59	206.02	214.65	206.09	214.71	206.16	11.5	13.3	20.2	22.4	24.6	26.8	
Link73	1500.0	Circular	3.0	1.5	74.9	NY-0480	NY-0470	204.69	182.73	209.69	187.73	205.62	184.02	205.69	184.12	205.95	184.51	206.02	184.62	206.09	184.75	206.16	184.88	15.6	17.9	27.5	30.3	33.4	36.3	
Link74	400.0	Circular	1.0	0.0	0.6	NY-0220	260399	114.68	114.54	123.72	123.85	115.78	116.51	115.85	116.62	116.16	116.85	116.20	116.88	116.29	116.92	116.31	116.93	-1.5	-1.5	-1.5	-1.5	-1.5	-1.5	Existing 2-yr
Link78	375.0	Circular	1.5	6.6	25.0	NY-0230	Node588	138.51	113.88	146.05	123.85	139.04	116.10	139.04	116.21	139.18	116.47	139.18	116.49	139.23	116.55	139.23	116.57	6.7	6.7	10.1	10.1	11.8	11.8	
Link79	375.0	Circular	1.5	6.7	25.2	NY-0230	Node589	138.51	113.50	146.05	123.15	139.04	115.74	139.04	115.84	139.18	116.11	139.18	116.14	139.23	116.21	139.23	116.23	6.8	6.8	10.2	10.2	11.8	11.8	
Link80	30.0	Circular	3.0	2.7	61.3	Node591	277227_NY-0380	123.77	122.95	127.95	127.95	127.93	127.47	128.93	128.36	130.27	129.66	130.28	129.67	130.30	129.69	130.31	129.70	46.3	51.4	53.3	53.4	53.5	53.6	Existing 2-yr
Link84	5.0	Trapezoidal	3.0	30.0		Node595	335464	137.68	136.18	142.50	142.50	140.13	139.70	140.51	139.94	140.66	140.04	140.67	140.05	140.68	140.06	140.69	140.06	46.3	51.4	53.3	53.4	53.5	53.6	
Link86	400.0	Circular	4.0	0.3	76.2	NY-0220	270963	114.68	113.37	123.72	123.15	115.78	115.61	115.85	115.72	116.16	115.98	116.20	116.01	116.29	116.08	116.31	116.10	9.3	9.6	13.9	14.1	16.0	16.3	
Nyberg1	360.0	Natural	3.0	1.0		277232	270982_NY-0200	122.72	119.01	126.72	126.00	125.13	123.90	125.65	124.39	126.72	125.38	126.72	125.46	126.72	125.54	126.72	125.59	72.8	80.0	90.5	90.4	91.1	90.6	
Nyberg2	140.0	Natural	3.5	0.0		270982_NY-0200	Node592	119.01	119.00	126.00	126.27	123.90	123.59	124.39	124.02	125.38	124.89	125.46	124.96	125.54	125.03	125.59	125.08	96.0	105.9	122.9	124.5	125.7	126.5	
Nyberg2.1	140.0	Natural	3.5	0.0		Node593	Node569	119.00	119.00	126.27	125.27	123.28	122.99	123.65	123.30	124.40	123.93	124.46	123.98	124.52	124.03	124.56	124.06	93.2	102.2	118.6	119.8	120.7	121.3	
Nyberg3	280.0	Natural	4.0	0.4		Node569	NY-0240	119.00	117.99	125.27	129.75	122.99	122.86	123.30	123.15	123.93	123.73	123.98	123.77	124.03	123.82	124.06	123.85	90.6	99.3	114.8	116.0	117.1	117.8	
Nyberg4	65.0	Natural	4.0	1.2		NY-0240	NEW1	117.99	117.18	129.75	127.68	122.86	122.81	123.15	123.08	123.73	123.64	123.77	123.68	123.82	123.73	123.85	123.76	90.4	99.1	115.3	116.6	118.0	118.8	
Nyberg5	83.0	Natural	5.0	0.0		Node570	Node571	116.85	116.85	127.68	122.70	121.87	121.85	121.93	121.91	122.01	121.98	122.02	121.99	122.02	121.99	122.03	122.00	90.3	99.1	115.3	116.6	118.0	118.8	
Nyberg6	33.0	Natural	5.0	0.1		Node571	Node574	116.85	116.83	122.70	123.20	121.85	121.85	121.91	121.90	121.98	121.98	121.99	121.98	121.99	121.99	122.00	121.99	90.4	99.1	115.3	116.6	118.0	118.8	
Nyberg8	30.0	Natural	6.0	1.2		Node575	260399	114.69	114.33	123.20	123.85	116.72	116.51	116.83	116.62	117.05	116.85	117.07	116.88	117.10	116.92	117.11	116.93	90.4	99.1	115.3	116.6	118.0	118.8	
Overflow1	470.0	Trapezoidal	1.5	2.8		335464	312443	141.0	127.8	142.5	129.3	---	---	---	---	140.043	130.385	140.048	129.316	140.06	131.01	140.06	129.32	0.0	0.0	0.0	0.0	0.0	0.0	
Overflow2	470.0	Trapezoidal	1.5	2.7		Node595	312443	140.5	127.8	142.5	129.3	---	---	140.512	127.803	140.663	130.385	140.67	129.316	140.68	131.01	140.69	129.32	0.0	0.2	17.8	19.0	21.0	22.5	
Weir	2.0	Natural	3.5	0.0		Node574	Node575	119.35	119.35	123.20	123.20	121.85	121.83	121.90	121.88	121.98	121.96	121.98	121.96	121.99	121.97	121.99	121.97	90.4	99.1	115.3	116.6	118.0	118.8	

Attachment C: Figures



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City of Tualatin

Stormwater Master Plan

Date: August 2017

Project: Project 149233

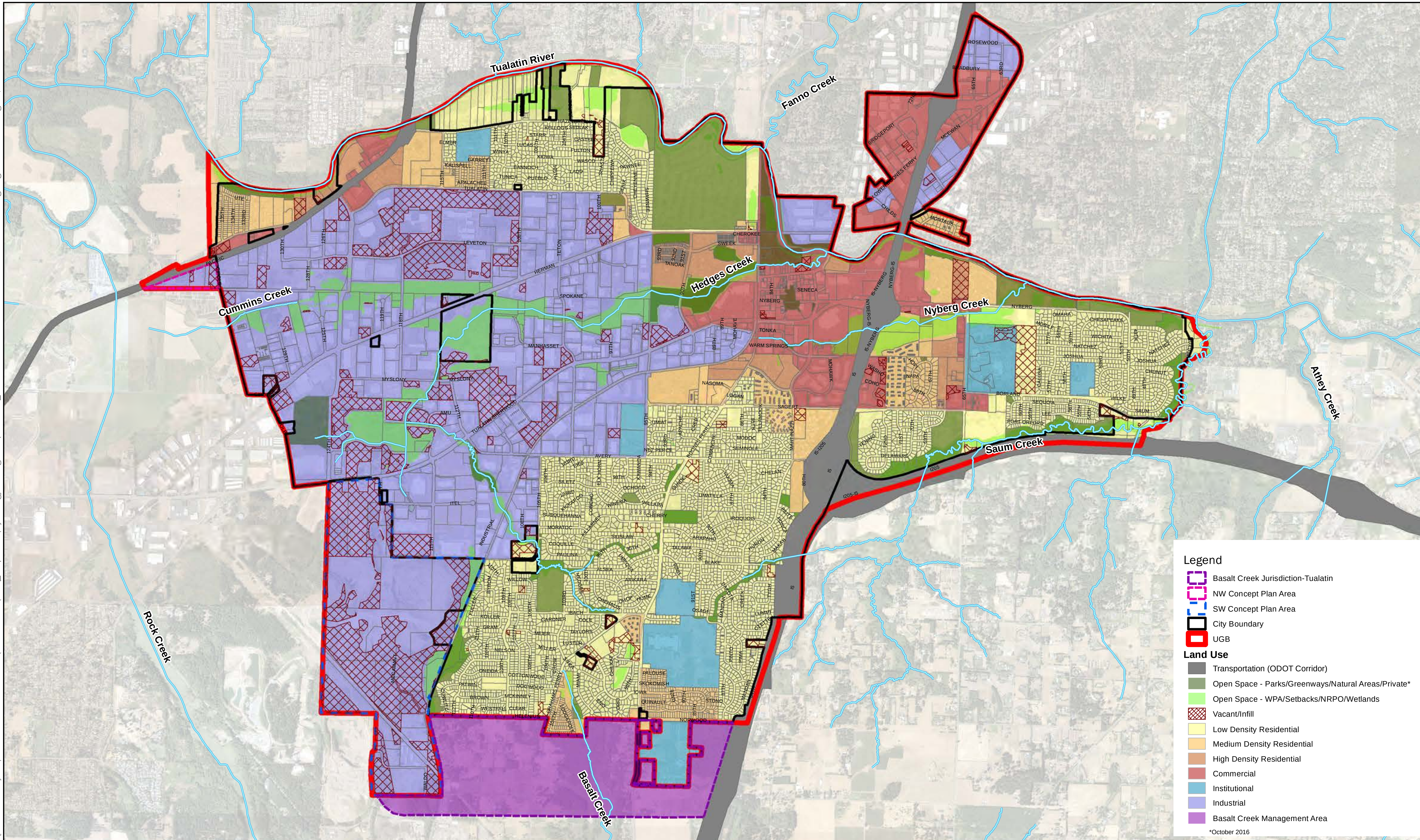
0 2,300 4,600 Feet

N

Notes:
1. Projection: NAD 1983 State Plane Oregon North (feet)

Figure 1

Subbasin Boundaries



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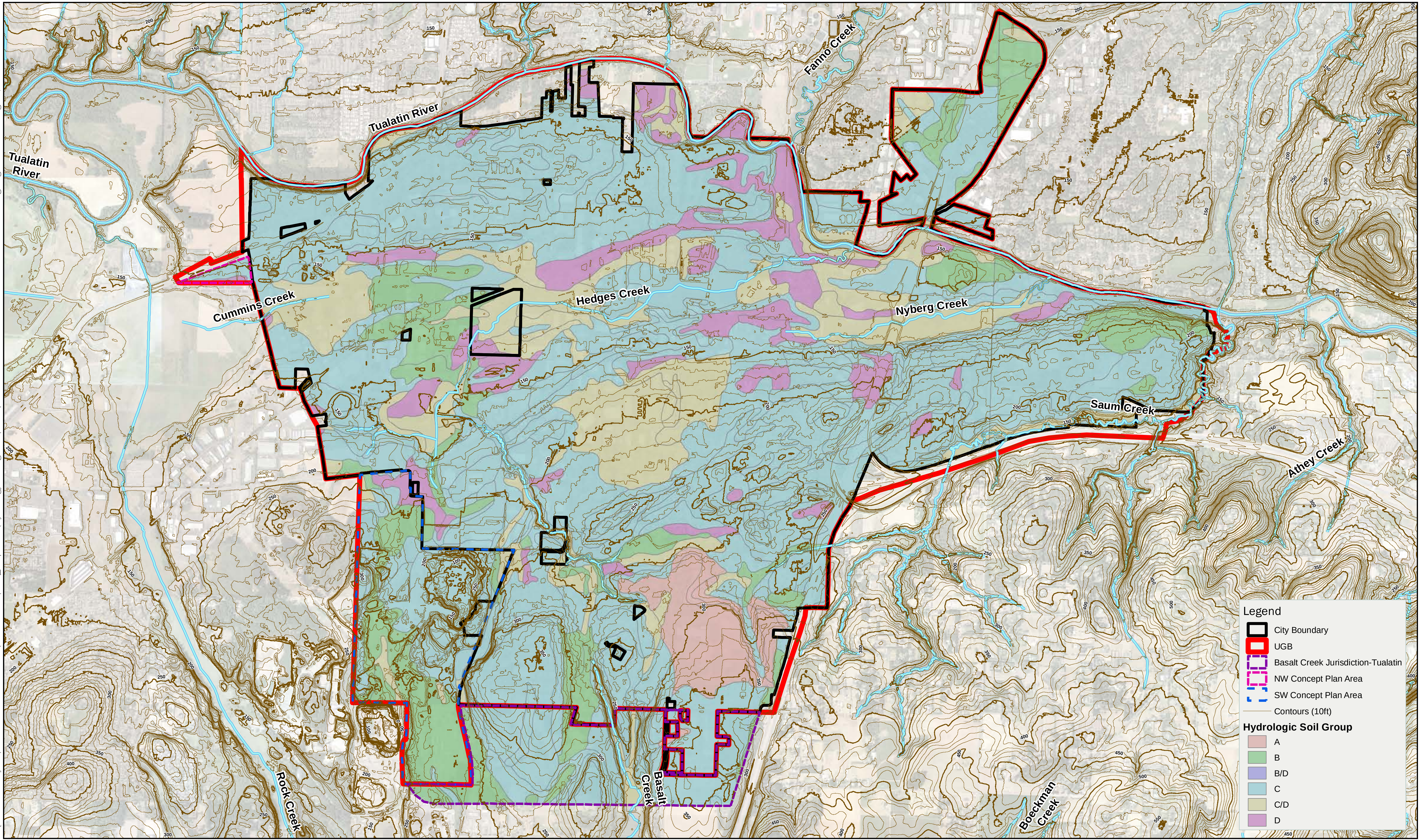
Notes:
1. Projection: NAD 1983 State Plane Oregon North (feet)

Figure 2

Land Use



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Aug 31, 2017

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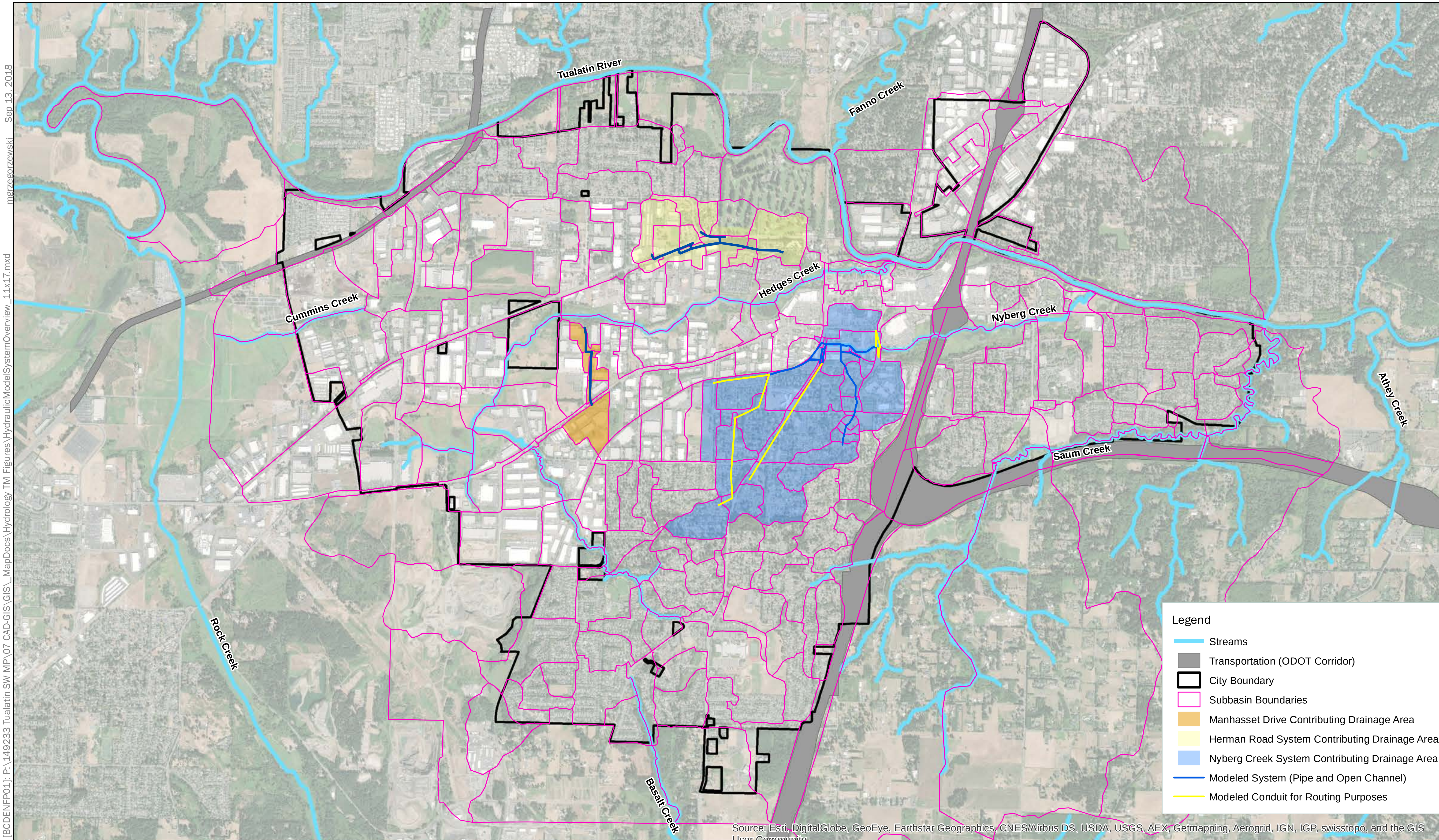
0 2,250 4,500 Feet

N

Notes:
1. Projection: NAD 1983 State Plane Oregon North (feet)

Figure 3

Topography and Hydrologic Soil Group



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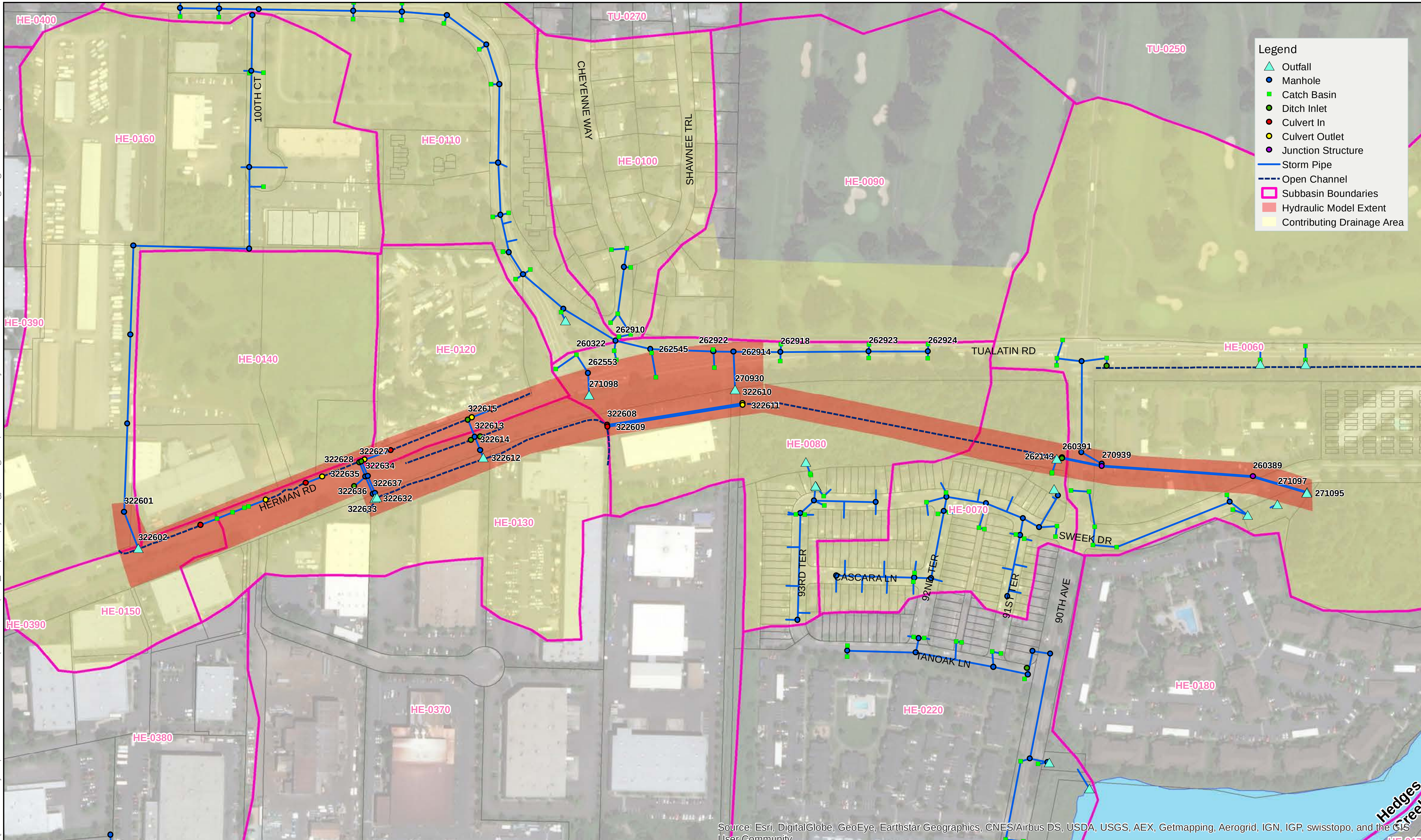
Notes:
1. Projection: NAD 1983 State Plane Oregon North (feet)

Figure 4

Hydraulic Model System Overview



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Notes:
1. Projection: NAD 1983 State Plane Oregon North (feet)

Figure 5
Hydraulic Modeling Extents

Herman Road System

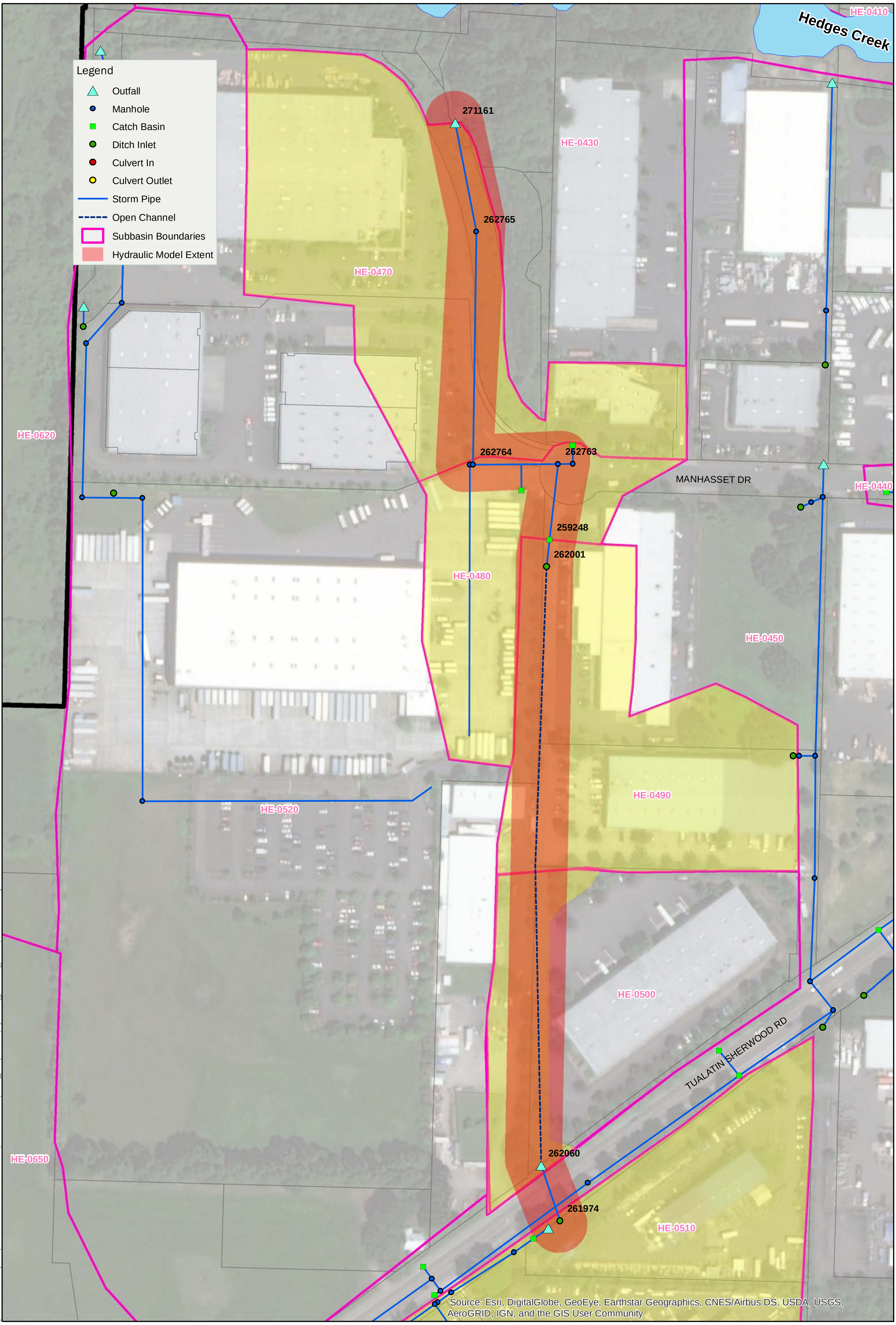

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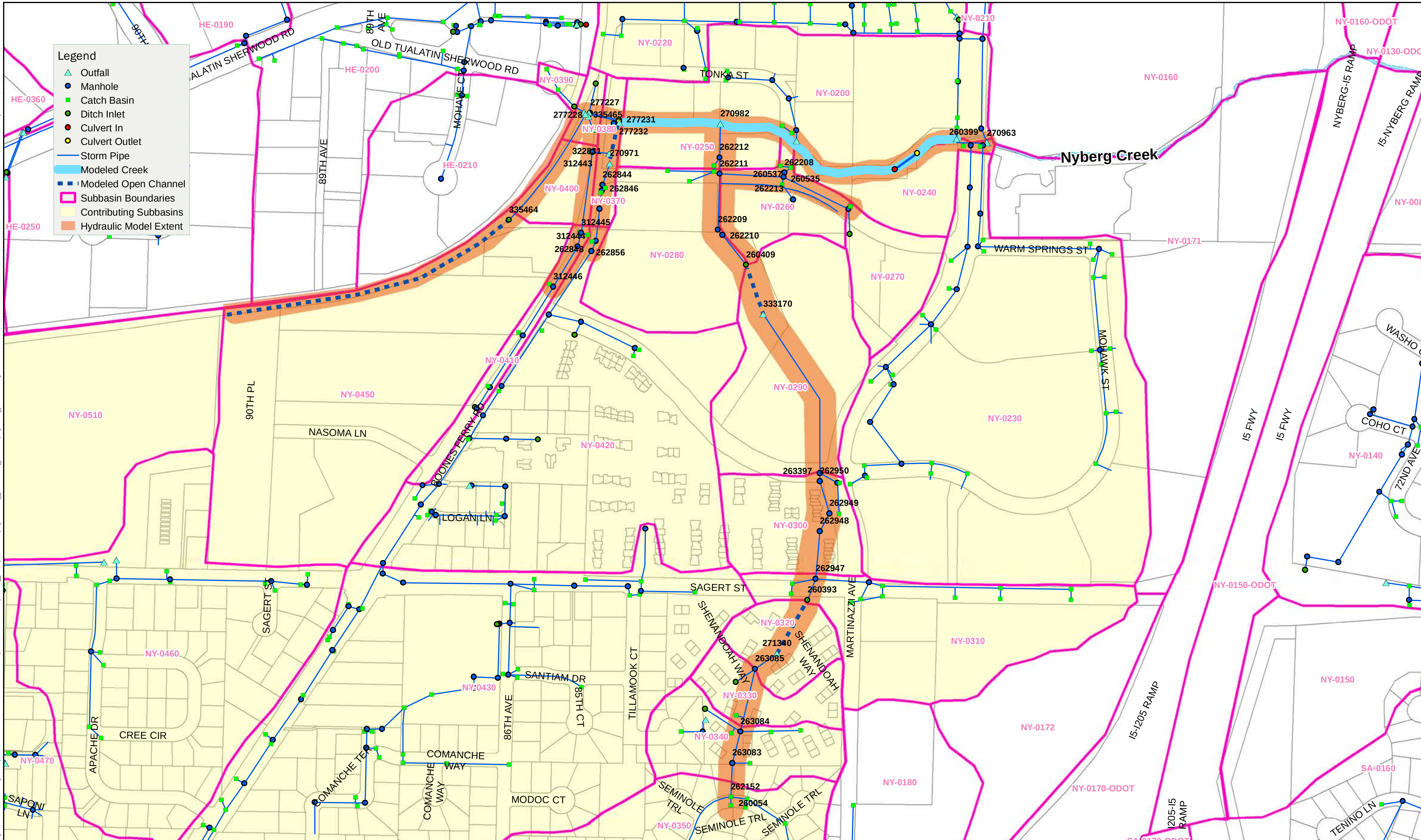
Figure 6
Hydraulic Modeling Extents

Manhasset Drive System



Apr 15, 2019 MGlass [BCDENFP01]: P:\149233 Tualatin SW MP\07 CAD-GIS\GIS_MapDocs\Hydrology TM Figures\NybergCreekSystemOverview.mxd

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0 300 600 Feet

N

Notes:
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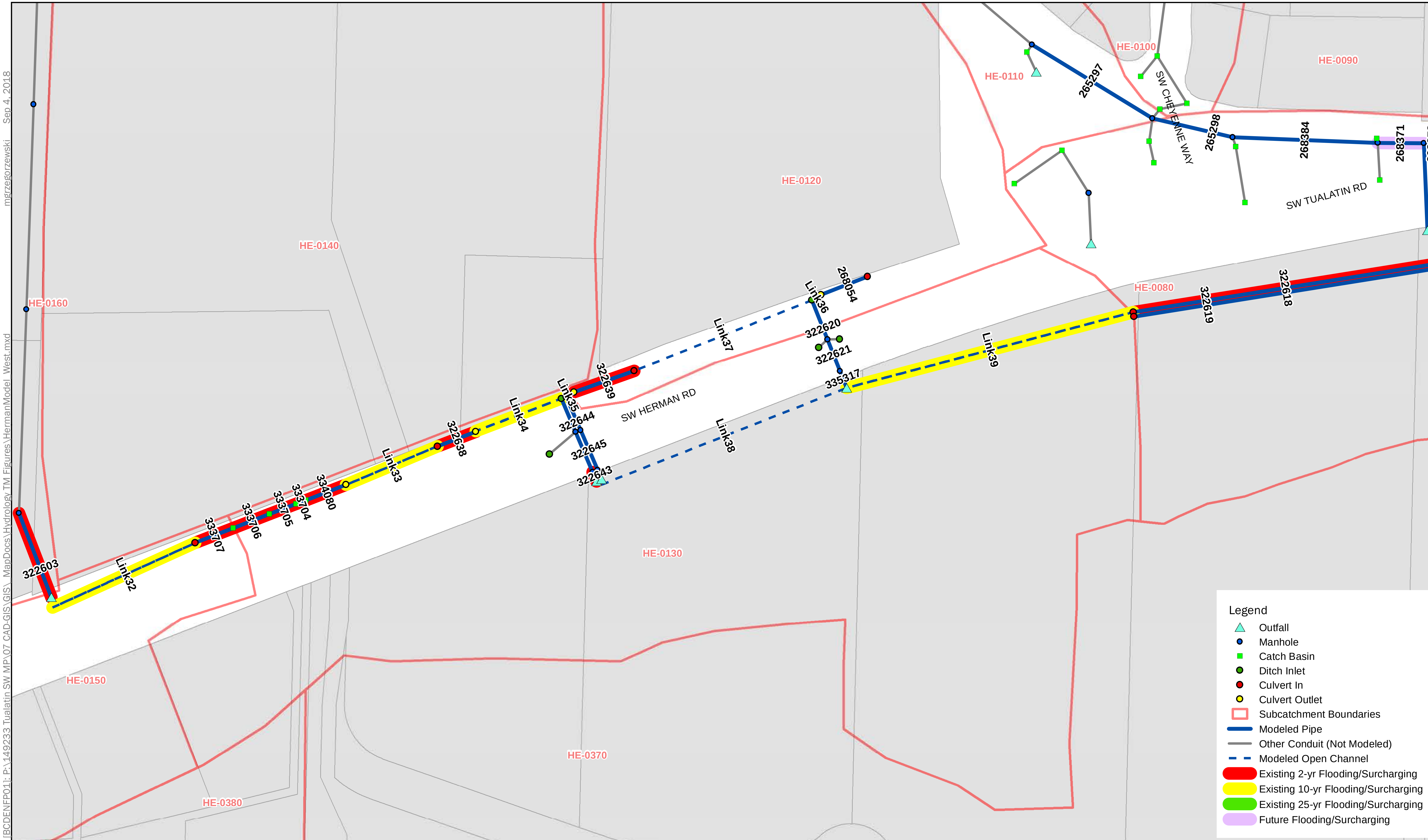
Figure 7
Hydraulic Modeling Extents
Nyberg Creek System



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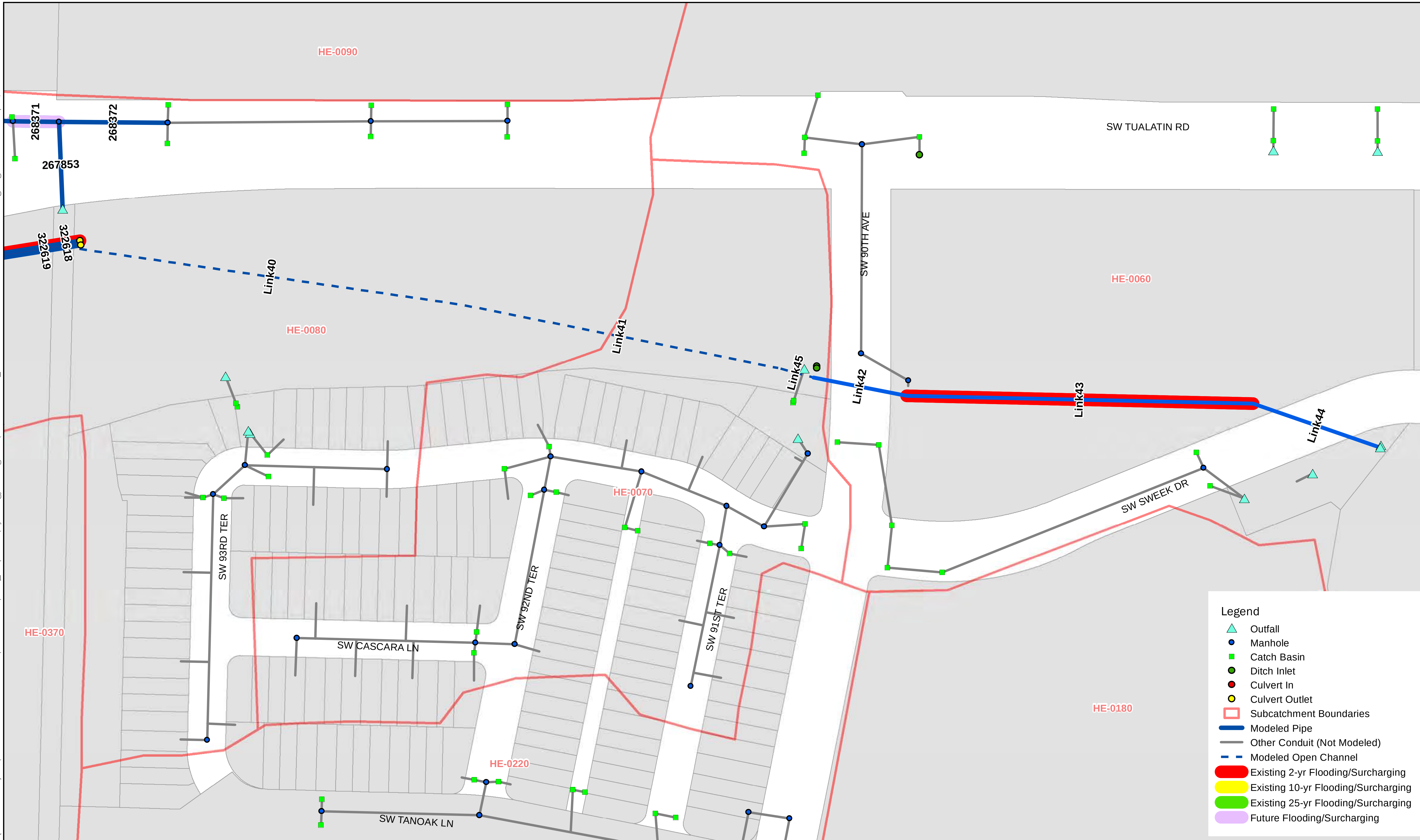
N

0 150 300 Feet

Notes:
1. Projection: NAD 1983 State Plane Oregon North (feet)

Figure 8
Hydraulic Modeling Results

Herman Road System-West



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Notes:
1. Projection: NAD 1983 State Plane Oregon North (feet)
2. Due to the very low slope of Link43, the calculated design flow is artificially low. No surcharging is occurring in this pipe despite maximum flow surpassing design flow beginning at the 2-year event.

Figure 9
Hydraulic Modeling Results

Herman Road System-East

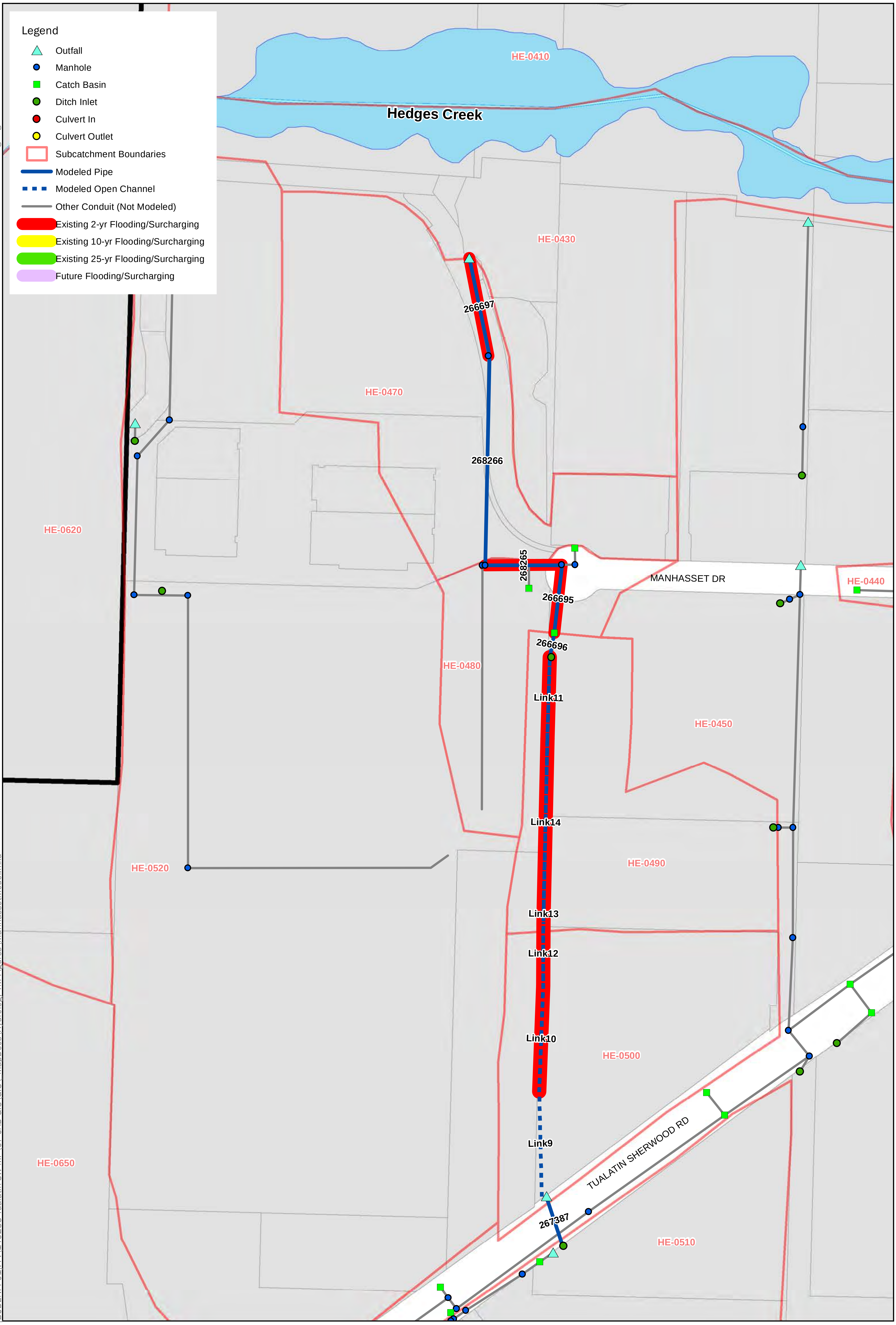

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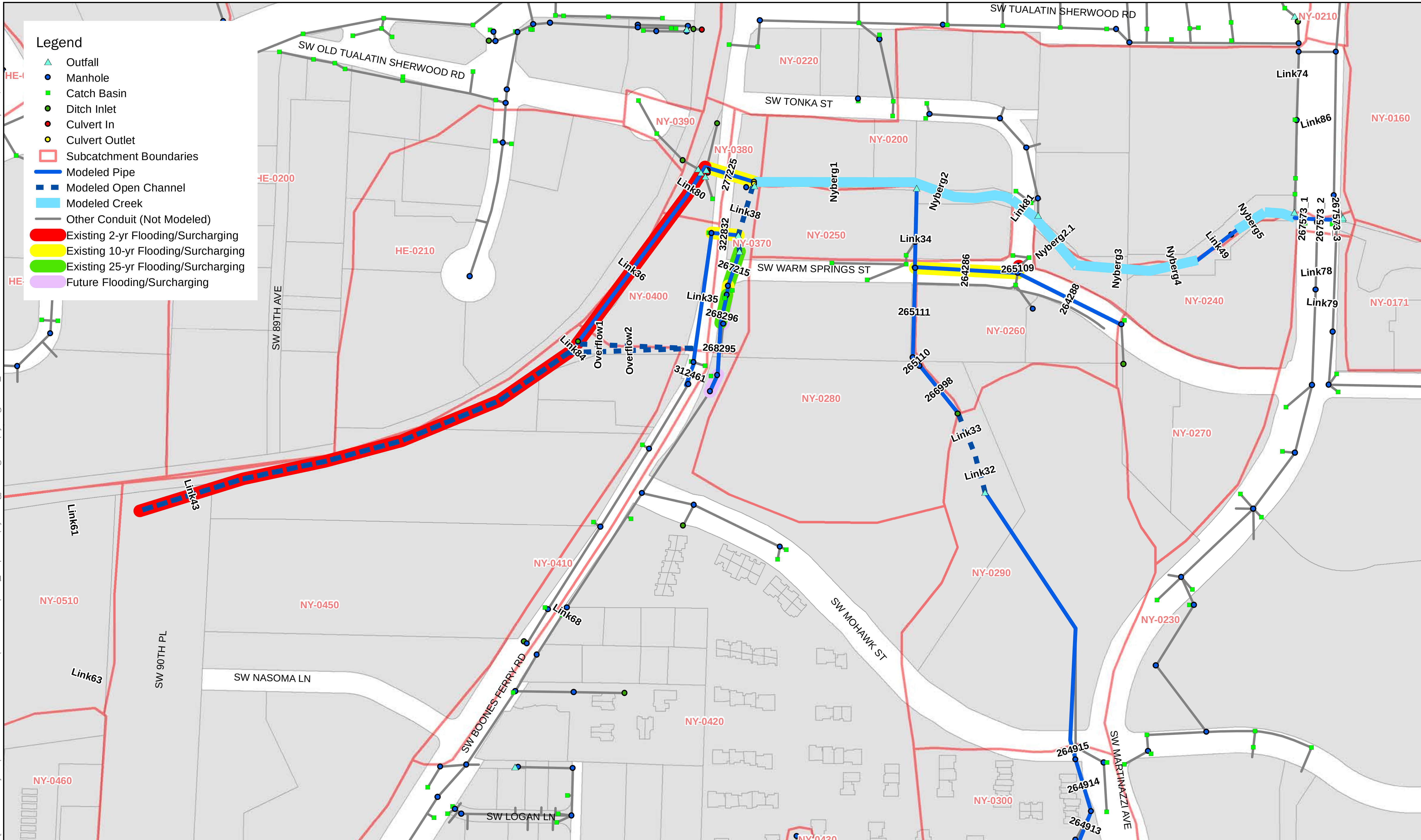
Figure 10
Hydraulic Modeling Results

Manhasset Drive System



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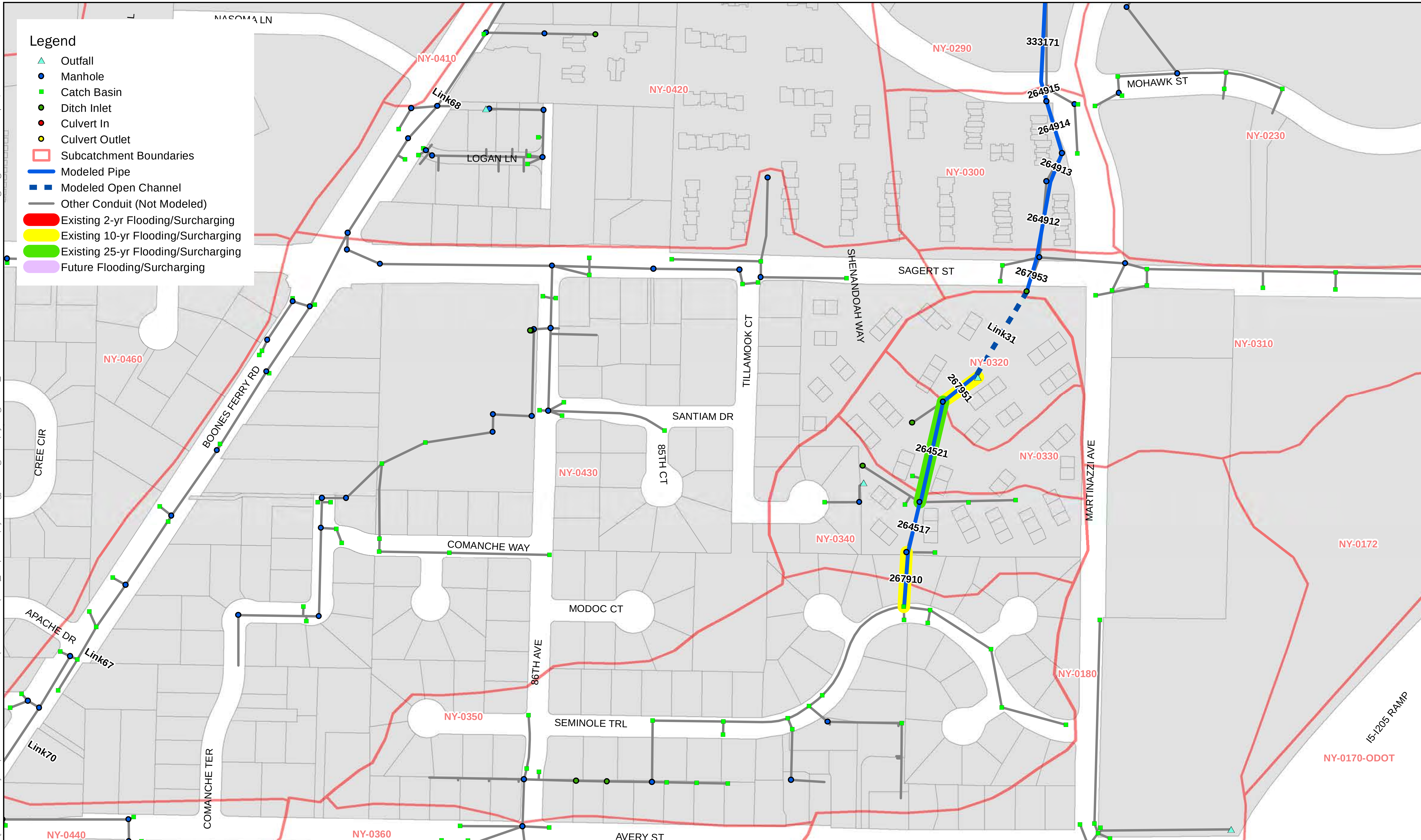
Date: August 2017
Project: Project 149233

Notes:
1. Projection: NAD 1983 State Plane Oregon North (feet)

Figure 11
Hydraulic Modeling Results

Nyberg Creek System-North



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0 300 600
Feet

N

Notes:
1. Projection: NAD 1983 State Plane Oregon North (feet)

Figure 12
Hydraulic Modeling Results

Nyberg Creek System-South

Attachment D: Photo Log

Attachment D

Modeled System Photo Log

Photographs and descriptions from the June 29, 2016 and December 8, 2016 field investigations are provided on the following pages by modeled system. Photos were used to verify existing system conditions and refine the hydraulic model.

Hydraulic Model System	Manhasset Drive	
		
	Location:	Manhasset Drive Open Channel
	Photo number:	1
	Description:	Flooding of open channel along Manhasset Drive during December 2015 storm event. Photo provided by City.
		
	Location:	Manhasset Drive Open Channel
	Photo number:	2

Hydraulic Model System	Manhasset Drive	
	Description:	Open channel upstream of ditch inlet at Manhassat Drive. Channel bottom is rocky and has high roughness.
		
	Location:	Manhasset Drive Open Channel
	Photo number:	3
	Description:	Debris in open channel is a restriction during rain events.
		
	Location:	Manhasset Drive Open Channel
	Photo number:	4
	Description:	Grated inlet at end of open channel segment along Manhassat Drive.

Hydraulic Model System	Nyberg Creek
	 **Location:** Behind Oil Can Henry's (19417 SW Boones Ferry Road) **Photo number:** 1 **Description:** Grated inlet at the end of railroad ditch where sediment enters the piped system
	 **Location:** Behind Oil Can Henry's (19417 SW Boones Ferry Road) **Photo number:** 2 **Description:** Alternate view of grated inlet

Hydraulic Model System	Nyberg Creek
	 **Location:** Boones Ferry Road and SW Tonka Street **Photo number:** 3 **Description:** Heavy sedimentation in dual culvert across Boones Ferry Road
	 **Location:** Mohawk Apartments **Photo number:** 4 **Description:** Downstream inlet causing flooding issues at the Mohawk Apartments

Appendix D: Nyberg Creek Flood Reduction Modeling (TM3)

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Portland, OR 97239

T: 503.977.6607

Technical Memorandum

Prepared for: City of Tualatin

Project title: Stormwater Master Plan

Project no.: 149233

Technical Memorandum #3

Subject: Nyberg Creek Flood Reduction Modeling

Date: February 15, 2019

To: Kim McMillan, P.E., City Engineer

From: Ryan Retzlaff and Angela Wieland, P.E.

Overview

This technical memorandum (TM) summarizes development and results related to the one-dimensional (1D) and two-dimensional (2D) hydraulic modeling of Nyberg Creek from Martinazzi Avenue to Nyberg Lane. Brown and Caldwell (BC) conducted modeling to evaluate the type and extent of conveyance system modifications necessary to reduce or eliminate localized nuisance flooding along Tualatin-Sherwood (TS) Road and Martinazzi Avenue. The nuisance flooding is primarily related to the capacity and geometry of Nyberg Creek and the associated stormwater collection system in the proximity of Martinazzi Avenue and TS Road.

Various types of system modifications including channel widening, channel deepening, and removal of culverts and flow impediments have been evaluated to assess the reduction in water surface elevation at key locations where flooding is experienced.

This TM presents model results (i.e., associated reduction in water surface elevation) for eight system modification alternatives. Three of those alternatives provide significant reduction in water surface elevation along TS Road and Martinazzi Avenue for a 5-year, 24-hour storm event, which was the storm event selected to represent nuisance flooding of the system. These alternatives may be considered by the City of Tualatin (City) as a future capital improvement project (CIP).

Model Development

BC performed modeling using the platform XP-SWMM. Both 1D and 2D modeling approaches were employed to comprehensively identify flooding extents, potential causes of flooding, and how potential changes to Nyberg Creek and the stormwater collection system can reduce flooding (inundation) at five key locations in the Nyberg Creek basin, specifically those locations along Martinazzi Ave and TS Road.

The 1D model includes Nyberg Creek channel cross sections that extend to the top of bank, the double 48-inch culverts behind Fred Meyer, and the narrow channel associated with the embankment east of I-5. The 2D model represents the floodplain or area above the top of bank. This approach allows full representation of the flooded area.

BC used the 1D XP-SWMM Nyberg Creek system model that was developed as part of the City's stormwater master plan (SMP) effort for this evaluation. BC extended the existing model from Martinazzi Avenue to the culvert outfall at Nyberg Lane to capture the full system that influences localized flooding. Additional portions of the stormwater collection system north of TS Road along Martinazzi Avenue, as well as conveyance infrastructure along TS Road, were added to reflect low points in the roadway where water has the potential to exit the closed conveyance system (i.e., catch basins).

BC built the 2D model for Nyberg Creek, extending downstream of Martinazzi Ave to Nyberg Lane, to accurately illustrate surface inundation above the top of bank of the channel and flooding out of the closed conduit collection system. The 1D and 2D models are linked in XP-SWMM and simulated as a single model of the channel and floodplain. Using a 1D and 2D modeling approach, stormwater moves in and out of the channel, flood plain, and structures, simulating the relationship and movement of water as it occurs in nature. BC used light detecting and ranging (LiDAR), field observations from stream walks, aerial photos, and topographic survey to develop the 2D model.

System Hydrology

BC used city-wide hydrology based on the Santa Barbara Urban Hydrograph (SBUH) method, previously developed as part of the SMP, for this modeling effort (see *TM2: Hydrology and Hydraulic Modeling Methods and Results, September 7, 2018*). Future land use conditions were simulated to establish the boundary condition and evaluate alternatives.

Contributing subbasins to Nyberg Creek, downstream of Martinazzi Avenue, were included in the model update to accurately reflect all contributing drainage area. See Attachment A, Figure 1 for contributing subbasins and routing used for this effort.

BC selected the Clean Water Services (CWS) 5-year (3.1 inches), 24-hour Soil Conservation Service (SCS) Type 1A storm event for evaluation based on feedback from City staff and the objective to address more frequent nuisance flooding. All results in this TM are specific for this rainfall event.

System Survey

The BC team surveyed the Nyberg Creek channel from Martinazzi Avenue to Nyberg Lane to inform the geometry for the 1D model extension. This section of the creek had not been surveyed previously as part of the stormwater master plan effort. Accurate data is important because of the shallow grade and significant wetlands.

The survey effort included eight stream cross sections to the top of bank, 10 channel invert elevations to establish the long stream profile, and inverts for the culverts behind Fred Meyer, located approximately 900 feet east of Martinazzi Avenue. Staff also surveyed additional ground, rim, and invert elevations at specific locations and infrastructure along Martinazzi Avenue and TS Road. Finally, staff conducted field and topographic surveys to verify the elevation of the roadway embankment, orientated north and south in the Nyberg wetland complex, approximately 1,000 feet east of I-5. As mentioned, BC used LiDAR to develop the geometry to inform the 2D model.

Boundary Condition

Nyberg Creek discharges to the Tualatin River approximately 5,700 feet downstream of Martinazzi Avenue. During large, regional storm events, the Tualatin River can backwater and influence Nyberg Creek conveyance capacity, which results in flooding along TS Road and Martinazzi Avenue. BC reviewed the potential influence of the Tualatin River on system hydraulics to establish an appropriate boundary condition for the hydraulic model.

To determine the influence of the Tualatin River on Nyberg Creek during smaller storm events, BC modeled the existing channel geometry for the 5-year, 24-hour storm event with future land use hydrology, assuming both a free outfall and using a 10-year flood elevation for the Tualatin River as a downstream boundary condition. The 10-year Federal Emergency Management Agency (FEMA) flood elevation is 119.50 feet for the Tualatin River. For reference, the low point along Martinazzi Ave is at an elevation of 119.70 feet, and the low point along TS Road is at an elevation of 120.65 feet. Both low point elevations are above the 10-year flood elevation for the Tualatin River.

Surface flooding at key (5) locations in the system did not change significantly depending on the boundary condition used. The water surface elevations at key locations along Martinazzi Avenue and TS Road increased by less than 0.10 foot with application of a 10-year flood elevation in the Tualatin as the boundary condition. Additionally, with smaller, more frequent storm events, the timing of the peak discharge for Nyberg Creek and associated water surface elevation in the City's system has a low probability of occurrence with the timing of a 10-year flood elevation for the Tualatin River. This is primarily due to the size of the Tualatin River watershed versus the much smaller local flow contribution from the City. Based on these results, BC did not use a boundary condition to evaluate the 5-year, 24-hour nuisance storm event as part of this analysis.

Model Validation

There were no recent model validation or calibration data available. In leu of a model validation, the City provided flooding photos of Martinazzi Avenue and TS Road during February 1996, which is reflective of a 100-year storm event. BC compared documented flooding in the images provided to the modeled flooding extents along Martinazzi Avenue and TS Road for the existing channel geometry and the 5-year, 24-hour storm event. The flooding extents for the 5-year, 24-hour storm event is not as extensive and is shallower than the extents in the photos; however, flooding locations are consistent.

Baseline Condition Model

BC established the baseline condition model using future land use conditions with a free outfall (Attachment A, Figure 2).

BC modeled and evaluated system alternatives based on the water surface elevations at five key locations in the Nyberg Creek basin (see Figures 2, 3, 4 and 5). These five locations experience regular flooding and are in the proximity of Martinazzi Avenue and TS Road. Flooding readily occurs along TS Road, Martinazzi Avenue, and the southwest corner of the Fred Meyer Parking lot.

Model Alternative Summary

BC developed and simulated eight alternatives to determine how modifications to the Nyberg Creek system would change the extent of surface flooding and the water surface elevation at key locations in the Nyberg Creek basin. The focus was on reducing the water surface elevation at Martinazzi Avenue and TS Road, so the alternatives emphasized system modifications to move water downstream. Table 1 summarizes the alternatives based on the simulated modifications to Nyberg Creek and associated infrastructure (e.g., channel widening, removal of culvert, removal of embankment, channel slope modification, and channel deepening).

Alternatives 1 and 2 reflect the proposed system modifications suggested by the City for evaluation.

Table 1. Alternative Descriptions

Alternative	Channel Modification (width)	Channel Modification (depth)	Infrastructure Modification
1	Maintain existing channel width	Reduction of channel bed elevation by 1 foot from Martinazzi Ave. to Nyberg Lane (length = 5,000 feet)	Removal of 300 feet of berm (located 1,000 feet east of I-5) Removal of 2–48-inch diameter culverts (Key Location ID #5)
2	Maintain existing channel width	Reduction of channel bed elevation by 1 foot from Martinazzi Ave. to I-5 (length = 1,500 feet)	Removal of 300 feet of berm (located 1,000 feet east of I-5) Removal of 2–48-inch diameter culverts (Key Location ID #5)
3	Channel width to 15 feet with 3:1 side slope from Martinazzi Ave to I-5 (length = 1,500 feet)	Maintain existing slopes	Removal of 300 feet of berm (located 1,000 feet east of I-5) Removal of 2–48-inch diameter culverts (Key Location ID #5)
4	Channel width to 15 feet with 3:1 side slope from Martinazzi Ave to Nyberg Lane (length = 5,000 feet)	Maintain existing slopes	Removal of 300 feet of berm (located 1,000 feet east of I-5) Removal of 2–48-inch diameter culverts (Key Location ID #5)
5	Channel width to 20 feet with 3:1 side slope and a low flow channel from Martinazzi Ave to Nyberg Lane (length = 5,000 feet)	Maintain existing slopes	Removal of 300 feet of berm (located 1,000 feet east of I-5) Removal of 2–48-inch diameter culverts (Key Location ID #5)
6	Maintain existing channel width	Maintain existing slopes	Removal of 300 feet of berm (located 1,000 feet east of I-5)
7	No width modification, channel slope modified to be consistent from Martinazzi Ave to Nyberg Lane (length = 5,000 feet)	Minor modification of channel depth	Removal of 300 feet of berm (located 1,000 feet east of I-5) Removal of 2–48-inch diameter culverts (Key Location ID #5)
8	Maintain existing channel width	Maintain existing slopes	Removal of 2–48-inch diameter culverts (Key Location ID #5)

Results and Recommendations

Table 2 summarizes the model results for each alternative to inform actions that may reduce the extent, depth, and frequency of localized flooding at Martinazzi Avenue and TS Road. The model results represent the difference in water surface elevation from the baseline condition model at the five key locations.

Alternatives 3, 4, and 5 show the most significant reduction in water surface elevations when compared to the baseline condition (see Table 2). Alternative 5 provides the greatest reduction and shows no flooding at the key locations yet represents the most significant changes to the Nyberg Creek channel and associated infrastructure. Figures 3, 4, and 5 (see Attachment A) show the anticipated flooding (surface inundation) associated with each of these three alternatives.

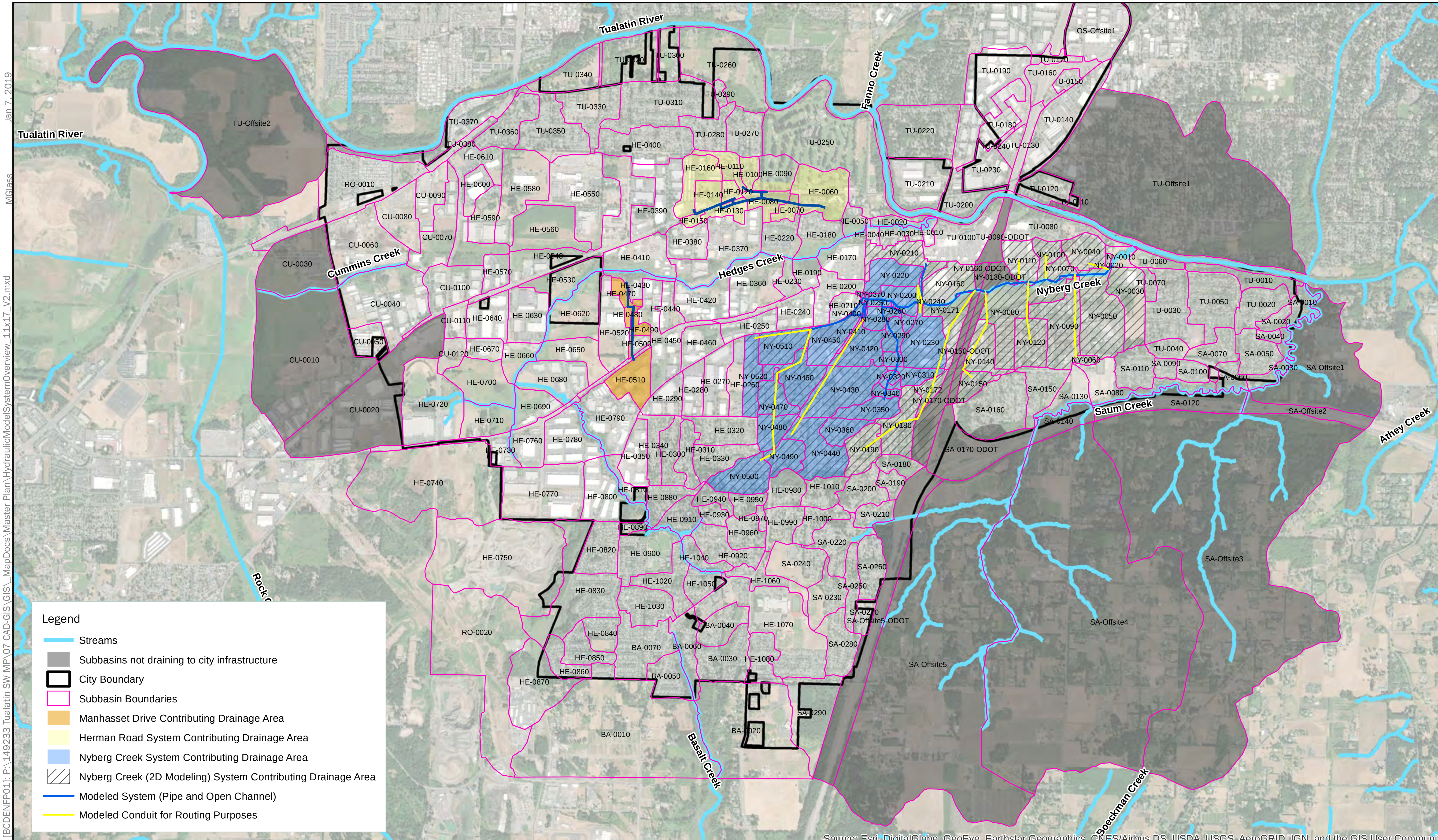
Future actions to mitigate flooding along Martinazzi Avenue and TS Road should be coordinated with future actions currently being explored by CWS and The Wetland Conservancy in the areas east of I-5 owned by The Wetland Conservancy.

Table 2. Water Surface Elevation Change Compared to Baseline Conditions

Key Location ID	Key Location Description	Alternatives							
		1	2	3	4	5[a]	6	7	8
1	TS Road, 300' west of Martinazzi Avenue	0.02	0.01	-1.47	NA	NA	0.00	0.00	0.01
2	Martinazzi Road, west of Fred Meyer	0.01	0.00	-1.26	-1.36	NA	-0.02	-0.02	0.00
3	SW Corner of Fred Meyer	0.03	0.02	-1.23	-1.33	NA	0.00	0.00	0.02
4	Martinazzi Avenue Outfall	0.03	0.02	-5.5	-5.51	NA	-0.01	-0.01	0.02
5	2 - 48" culverts south of Fred Meyer	0.03	0.03	-3.37	-3.37	NA	0.00	0.01	0.03

a. NA = no flooding occurs at key locations, so no comparison can be made to the baseline condition model.

Attachment A: Figures



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Stormwater Master Plan

Date: December 2018
Project: Project 149233

0 2,250 4,500 Feet

N

Notes:
1. Projection: NAD 1983 State Plane Oregon North (feet)

Figure 1

Model System Overview

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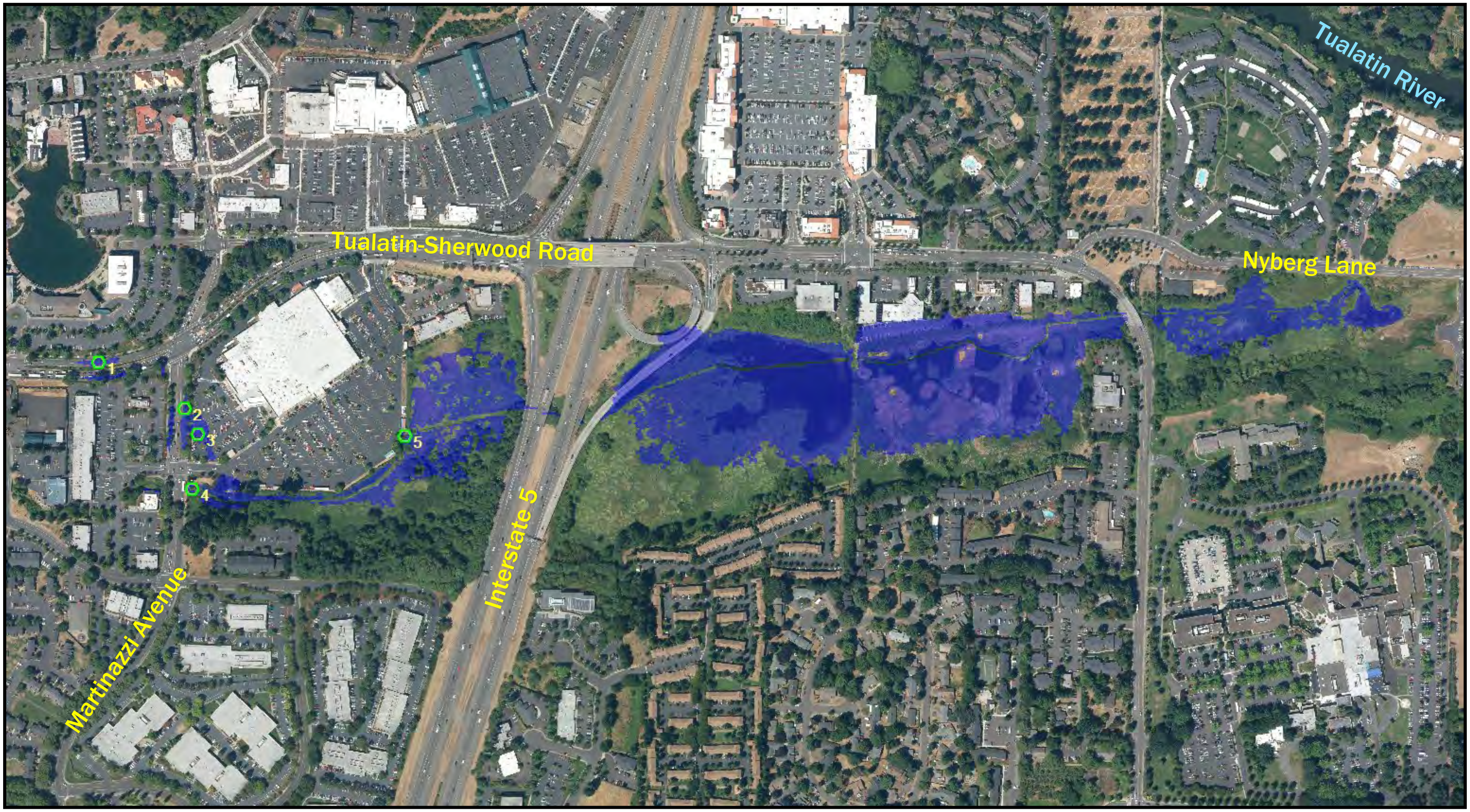
Figure 2.
Base Case 2D Model Results

City of Tualatin



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Project No.: 149233
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Figure 3.
Alternative 3 2D Model Results

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Project No.: 149233
Client: City of Tualatin

Figure 4.
Alternative 4 2D Model Results

City of Tualatin

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Date: February 15, 2019
Project No.: 149233
Client: City of Tualatin

Figure 5.
Alternative 5 2D Model Results

City of Tualatin

Appendix E: Capital Project Modeling Results

Table E-1. CIP Hydraulic Model Parameters and Results																	
					Node Name		Invert Elevation (ft)		Ground Elevation (ft)		Future 10 yr CIP Max Water Surface		Future 25 yr CIP Max Water Surface		Future CIP Max Flow (cfs)		
Link ID	Length (ft)	Shape	Diameter/ Height (ft)	Slope (%)	US	DS	US	DS	US	DS	US	DS	US	DS	10-yr	25-yr	CIP Project Number
Herman Road System																	
322603	108.8	Circular	2.0	2.2	322601_HE-0160	HE-0150	127.3	125.0	131.1	130.0	129.3	128.4	130.37	129.05	14.24	16.61	CIP #5
Link48	200.0	Circular	3.0	0.1	HE-0150	HE-0140	124.5	124.2	130.0	129.0	128.4	128.1	129.05	128.68	16.58	19.31	CIP #5
Link49	200.0	Circular	3.0	0.1	HE-0140	Node571	124.0	123.7	129.0	128.6	128.1	127.6	128.68	127.94	23.59	27.46	CIP #5
Link50	200.0	Circular	3.0	0.1	Node571	322634.0	123.5	123.2	128.6	128.2	127.6	127.0	127.94	127.20	23.59	27.46	CIP #5
Link52	200.0	Circular	3.0	0.1	HE-0120	322634.0	123.3	123.2	128.3	128.2	127.0	127.0	127.17	127.20	-5.42	-6.14	CIP #5
Link51	160.0	Circular	3.0	0.1	HE-0120	322613.0	123.3	123.2	128.3	128.2	127.0	126.9	127.17	127.09	8.68	9.99	CIP #5
Manhasset Drive System																	
267387	102.0	Circular	2.5	4.1	261974_HE-0510	262060_HE-0500	157.90	153.75	160.40	160.40	158.65	154.70	160.16	154.80	15.0	17.4	CIP #1
Link9	200.0	Circular	2.5	3.4	262060_HE-0500	Node280	153.75	147.00	160.40	153.00	154.70	147.81	154.80	147.88	16.0	18.6	CIP #1
Link12	200.0	Circular	2.5	3.2	Node280	Node283	146.80	140.40	153.00	146.40	147.70	141.47	147.78	141.60	16.0	18.6	CIP #1
Link15	200.0	Circular	2.5	1.2	Node283	HE-0490	140.20	137.90	146.40	143.40	141.47	139.17	141.60	139.37	16.0	18.6	CIP #1
Link11	350.0	Circular	2.5	0.9	HE-0490	262001	137.70	134.65	143.40	139.76	139.17	136.70	139.37	137.02	19.2	22.3	CIP #1
266696	47.4	Circular	2.5	0.6	262001	259248	134.65	134.37	139.76	139.25	136.70	136.19	137.02	136.50	19.2	22.3	CIP #1
266695	132.0	Circular	2.5	0.6	259248	262763_HE-0480	134.17	133.40	139.25	138.78	136.19	135.34	136.50	135.55	19.2	22.3	CIP #1
268265	149.3	Circular	3.0	0.1	262763_HE-0480	262764	133.20	133.00	138.78	137.99	135.34	134.47	135.55	134.59	20.9	24.3	CIP #1
268266	407.7	Circular	3.0	0.7	262764	262765_HE-0470	132.80	129.98	137.99	135.43	134.29	132.26	134.48	132.52	20.9	24.3	CIP #1
266697	194.1	Circular	3.0	0.2	262765_HE-0470	271161	129.88	129.56	135.43	132.56	132.26	131.18	132.52	131.31	25.1	29.3	CIP #1
Nyberg Creek System																	
Link90	80.0	Circular	2.0	3.0	263397_NY-0290	Node597	179.70	177.30	187.40	186.35	181.24	179.00	182.73	180.36	33.3	36.3	CIP #2.1
Link91	180.0	Circular	2.0	2.4	Node597	Node598	177.30	173.02	186.35	182.52	179.00	174.72	180.36	175.02	33.3	36.3	CIP #2.1
Link95	190.0	Circular	2.0	2.6	Node598	Node599	172.82	167.92	182.52	173.78	174.44	169.54	174.70	169.76	33.3	36.2	CIP #2.1
Link92	230.0	Circular	2.0	3.4	Node599	Node600	167.72	159.79	173.78	166.36	169.14	161.21	169.24	161.31	33.3	36.2	CIP #2.1
Link93	161.0	Circular	2.0	5.6	Node600	Node602	159.63	150.56	166.36	157.22	160.83	151.76	160.90	151.83	33.3	36.2	CIP #2.1
Link94	162.0	Circular	2.0	7.2	Node602	Node603	150.51	138.77	157.22	146.89	151.61	139.87	151.67	139.93	33.3	36.2	CIP #2.1
Link78	220.0	Circular	2.0	6.6	Node603	NY-0230	138.51	123.97	146.89	130.70	139.65	125.32	139.71	125.58	33.3	36.2	CIP #2.1
Link96	120.0	Circular	2.0	8.6	NY-0230	270963	123.86	113.50	130.70	123.15	125.32	116.00	125.58	116.10	53.5	59.7	CIP #2.1
Link89	400.0	Circular	4.0	1.3	270971	NY-0250	125.30	120.00	130.80	126.15	127.24	125.46	127.55	126.06	52.9	63.3	CIP #2.2
264286	237.6	Circular	4.0	0.4	NY-0250	262213	119.80	118.80	126.15	125.08	125.46	124.81	126.06	125.08	51.2	59.3	CIP #2.2
Link97	150.0	Circular	4.0	0.5	262213	Node569	118.80	118.00	125.08	125.27	124.81	124.61	125.08	124.92	54.6	63.4	CIP #2.2
268297	41.3	Circular	3.0	5.8	262848	262856	142.50	140.10	148.93	147.25	144.70	141.60	145.05	141.82	52.4	62.5	CIP #2.3
268295	119.7	Circular	3.0	5.8	262856	262847_NY-0370	140.00	133.00	147.25	138.76	141.60	134.70	141.82	135.04	52.4	62.5	CIP #2.3
268296	67.6	Circular	3.0	5.9	262847_NY-0370	262846	132.80	128.80	138.76	135.44	134.70	131.06	135.04	131.46	53.1	63.3	CIP #2.3
268293	21.4	Circular	3.5	5.6	262846	262844	128.60	127.40	135.44	132.63	131.06	129.50	131.46	129.82	53.1	63.3	CIP #2.3
267215	50.0	Circular	3.5	4.2	262844	270971	127.40	125.30	132.63	130.80	129.51	127.24	129.83	127.55	53.1	63.3	CIP #2.3
322832	62.1	Circular	2.0	2.4	312443	322831	125.60	124.11	129.32	129.11	126.25	126.29	126.86	126.86	2.1	2.4	CIP #2.3
Link36	484.0	Circular	3.5	2.7	335464	277227_NY-0380	136.18	122.95	141.50	128.95	138.39	127.68	138.91	129.03	89.8	107.5	CIP #7
Blake Street System																	
Link31	120.0	Circular	7.0	1.2	Node1557	Node1566	196.2	194.8	203.5	203.5	201.11	201.88	198.09	199.76	155.5	194.1	CIP #6

Figure E-1. CIP #1 Manhasset Storm System Improvements – Proposed System Node Numbering

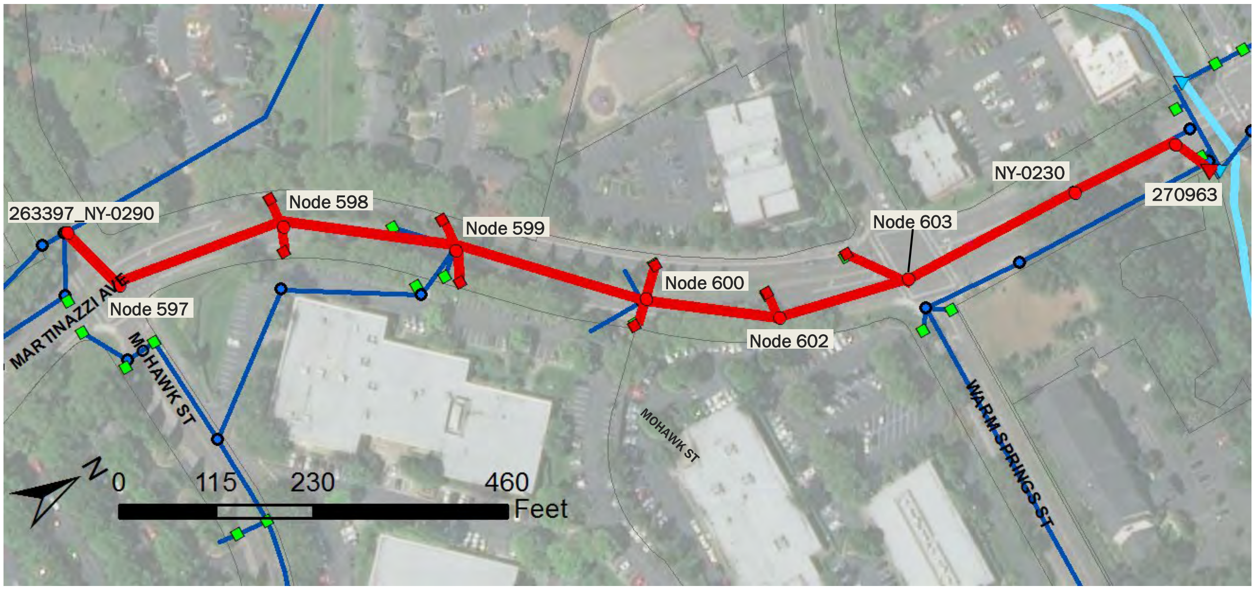

Figure E-2A. CIP #2 Nyberg Creek Stormwater Improvements (Phase 1)– Proposed System Node Numbering

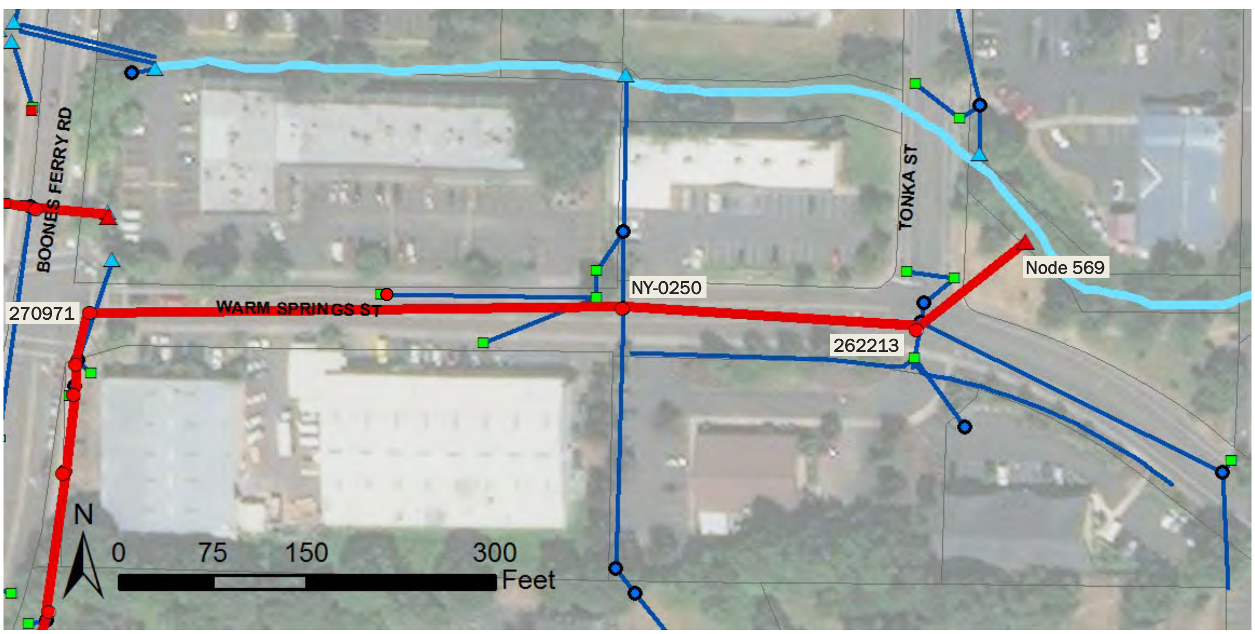

Figure E-2B. CIP #2 Nyberg Creek Stormwater Improvements (Phase 2) – Proposed System Node Numbering

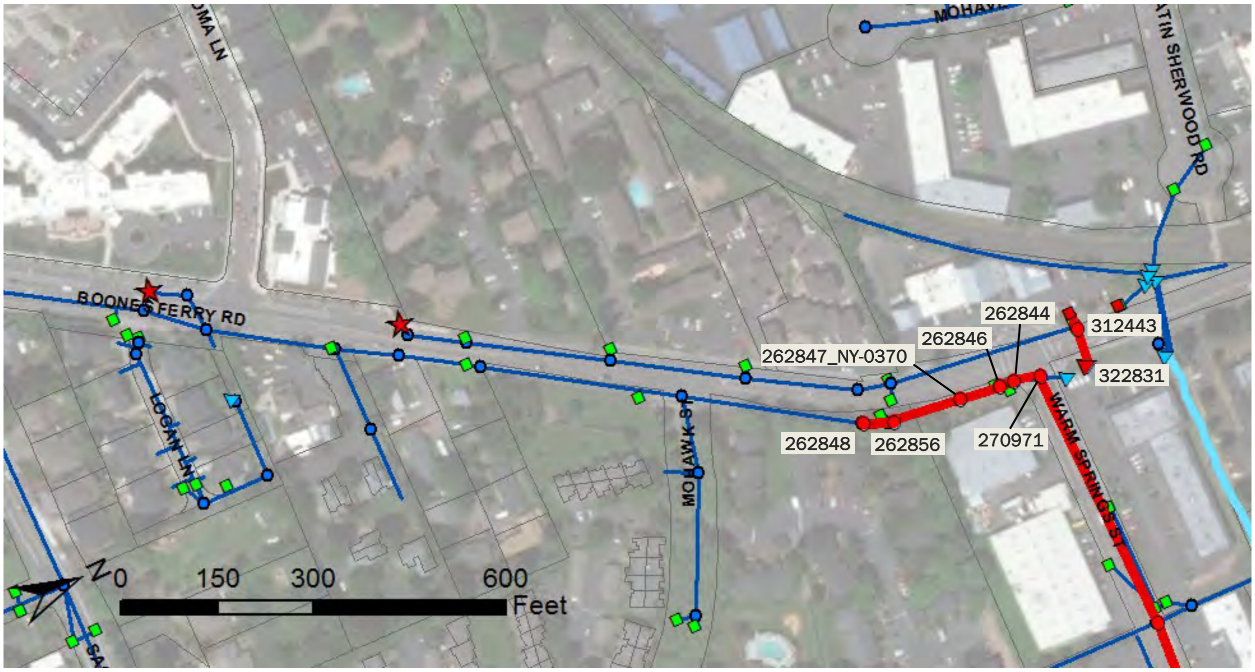

Figure E-2C. CIP #2 Nyberg Creek Stormwater Improvements (Phase 3) – Proposed System Node Numbering

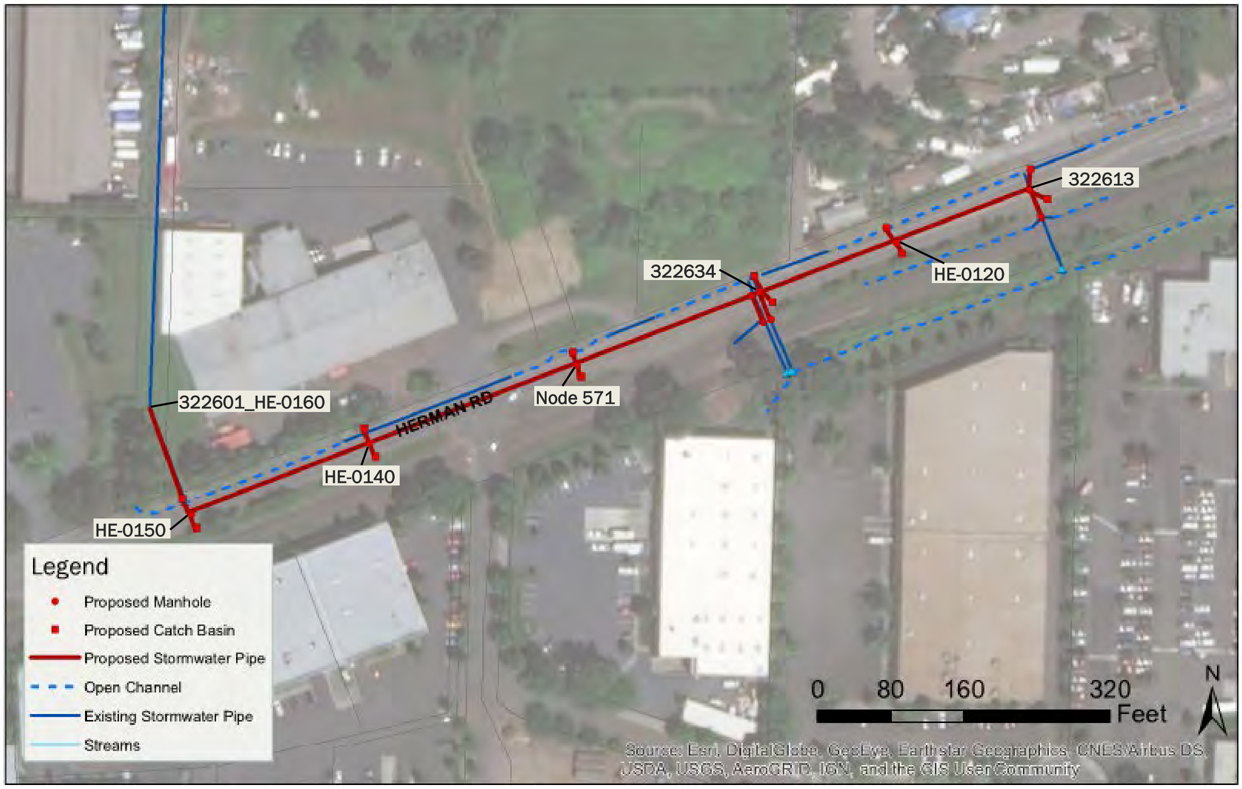

Figure E-3. CIP #5 Herman Road Storm System – Proposed System Node Numbering

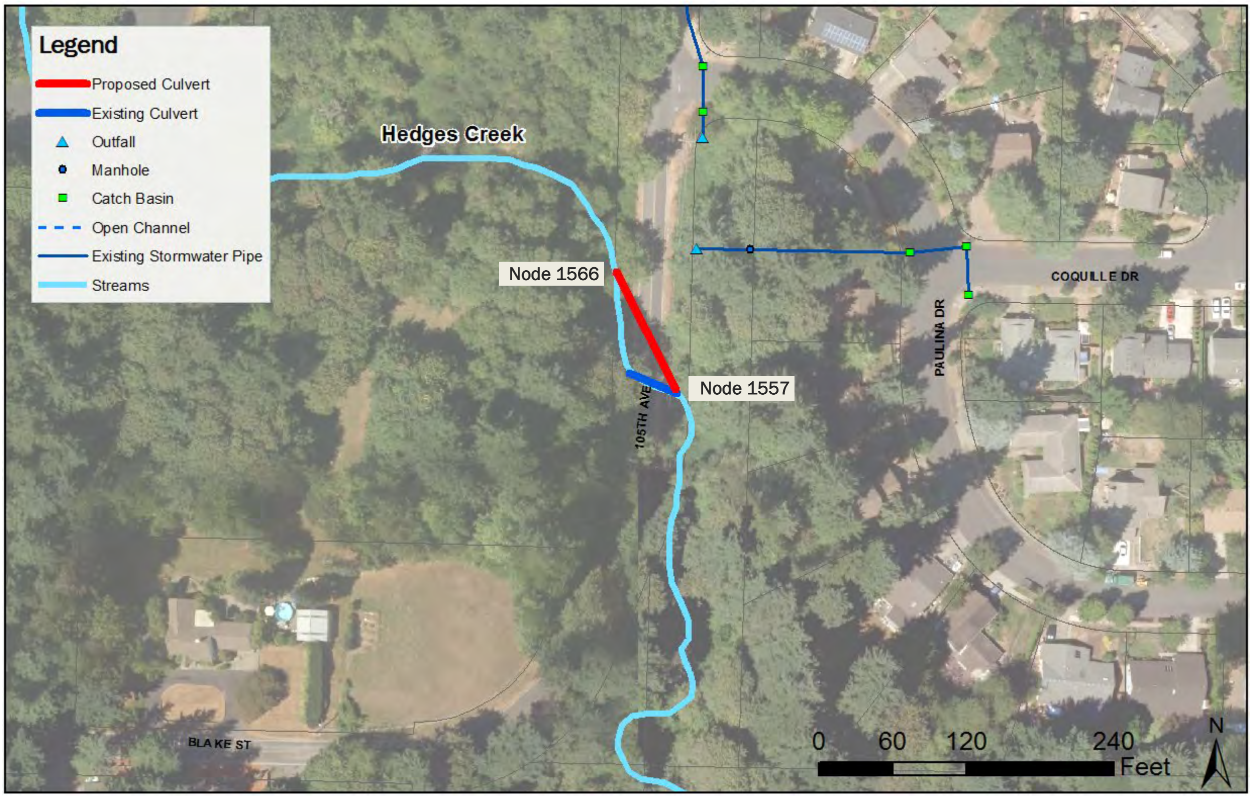

Figure E-4. CIP #6 Blake Street Culvert Replacement – Proposed System Node Numbering

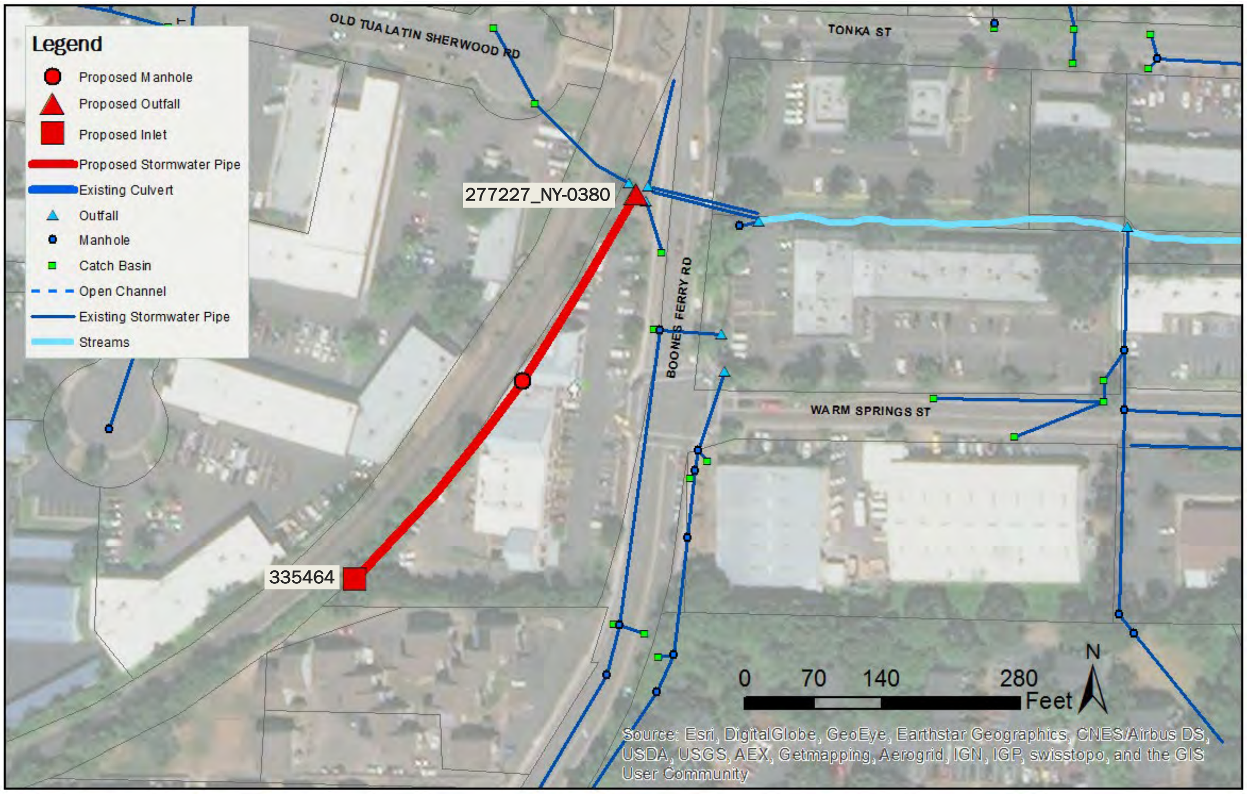

Figure E-5. CIP #7 Boones Ferry Railroad Conveyance Improvements – Proposed System Node Numbering

Appendix F: Stream Assessment TM (TM4)

AltaTerra

Stream Assessment

Technical Memorandum

City of Tualatin

Prepared for:
Brown and Caldwell
6500 SW Macadam Avenue #200
Portland, Oregon

January 30, 2018

Finalized: February 17, 2019

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Glossary

Aggradation	The process of building up a surface by deposition (as in sediment in a stream channel).
Bankfull Depth	The depth of the channel when discharges are at full channel capacity. Discharges above the bankfull depth would overflow onto the floodplain. Evidence of bankfull depth includes breaks in slope on channel banks, vegetation changes,
Bankfull Width	The width of the channel when discharges are at full channel capacity, measured at the elevation of bankfull depth.
Channel	The deepest part of a stream or water body.
Channel Capacity	The maximum flow a given channel can transmit without overtopping its banks.
Downcutting	Streambed erosion that results in deep, narrow, channels.
Downstream	In the direction that flow is headed, generally to a lower elevation in the case of stream channels.
Erosion	The wearing away of soil and rock by the action of streams, mass wasting, and weathering.
Gradient	The steepness of the channel slope, referred to in percent or feet of drop in elevation per foot length of channel.
Hillslope	The flanks that form the valley walls adjacent to stream channels. Hillslopes are the zones where soil and rock are loosened by weathering processes and transported downgradient.
Incision	Downward erosion, as in a streambed. Synonymous with downcutting.
Reach	A length of stream channel with similar physical characteristics, or length of stream channel between two arbitrarily chosen landmarks, such as road crossings or other logical breaks in open channel flow.
Tributary	Any stream that contributes water to another stream.
Upstream	In the direction that flow originates, generally from a higher elevation in the case of stream channels.

1.0 Introduction and Summary

The Tualatin River is the major surface water feature in the City of Tualatin (City), located north of the City Center. The City manages the surface and stormwater that flows into the Tualatin River through pipes and tributary creeks, as well as flood flows from the river that backwater into tributary channels and stormwater pipes.

The City contracted with Brown and Caldwell for development of their Stormwater Master Plan to evaluate hydrology and stormwater flows, identify system deficiencies, and develop and prioritize capital improvement projects to facilitate long-term economic, social and environmental benefit of residents and businesses in Tualatin. As part of the Stormwater Master Plan, the City wanted to incorporate a stream channel assessment into the overall stormwater system evaluation. Tributary streams to the Tualatin River are an important component of the surface water network in the City. They provide conveyance and storage (both in channel and on floodplains) of water and sediment, and habitat to aquatic and terrestrial species.

This stream assessment technical memorandum (TM) provides supporting documentation for Tualatin's Stormwater Master Plan. A field assessment was conducted on priority reaches along tributary streams in September 2017. Figure 1 shows the locations of the tributary stream reaches assessed. The overall goals of the stream assessment were to:

- Provide a baseline assessment of existing physical stream conditions;
- Identify existing problem areas such as locations of channel instability or excessive erosion that may impact private or public infrastructure;
- Assess the potential for changes and impacts to the stream channel; and
- Recommend capital, operational, maintenance or other solutions for issues identified.

Results of the field assessment include recommendations for strategies that address erosion, invasive vegetation, and hillslope instability. Specific recommendations include:

- Development of policies to encourage onsite retention of stormwater and flow mitigation in neighborhoods where stream channels are susceptible to flashy runoff conditions.
- Development of vegetation management plans for stream reaches that are teeming with invasive vegetation.
- Regular inspection of infrastructure that is being impacted by erosion to monitor for further deterioration in advance of future planned capital projects.

AltaTerra

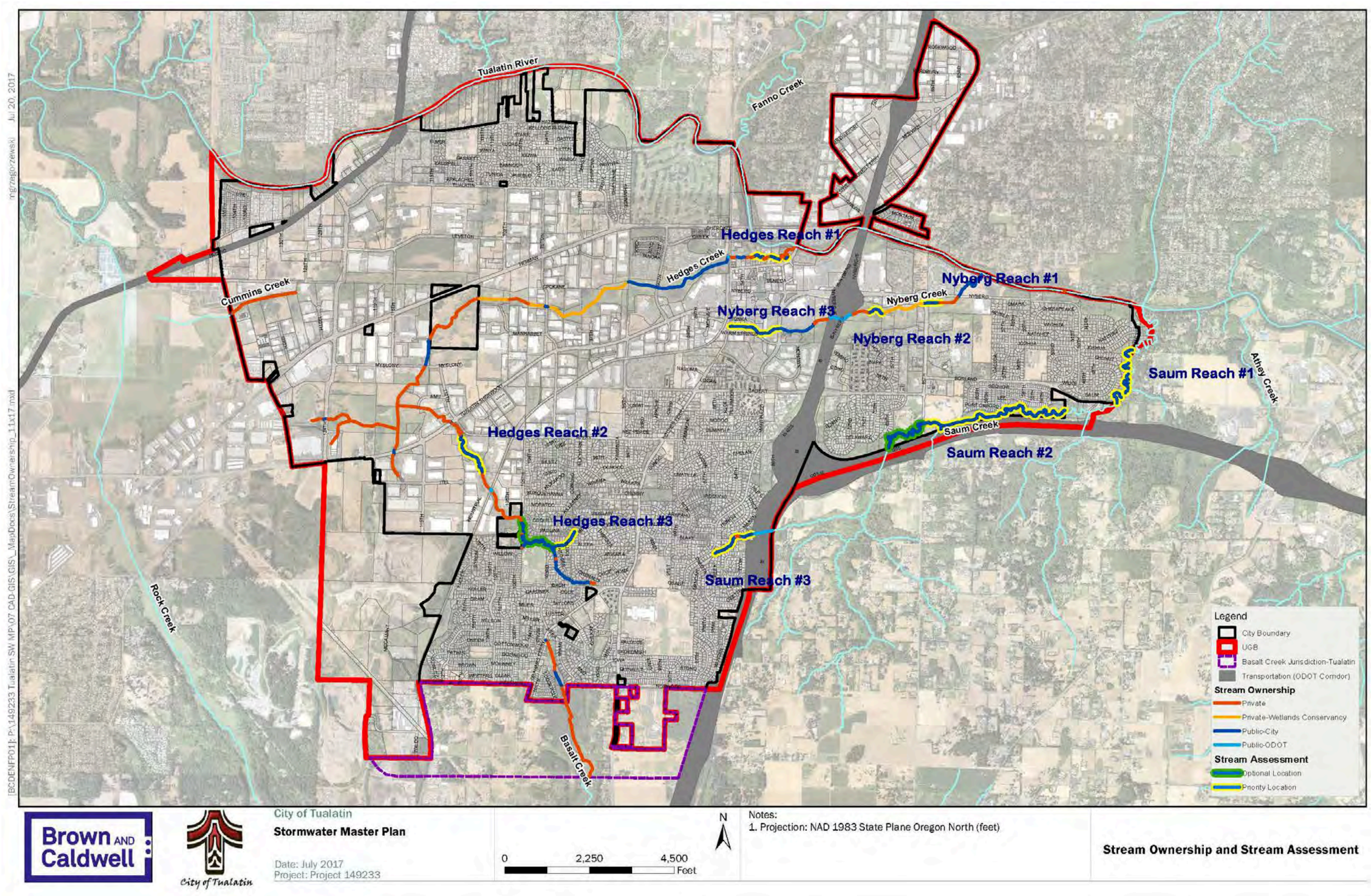


Figure 1. Vicinity Map and Location of Priority Stream Reaches Walked during Stream Assessment

2.0 Methodology

The stream assessment was primarily focused on direct observations gained from conducting stream walks on priority stream reaches along Saum, Nyberg, and Hedges Creeks. Priority stream reaches were identified by City staff based on ownership and a history of staff or citizen complaints/ concerns, and potential for additional stream flows due to new or redevelopment.

Prior to stream walks, maps were generated from geographic information system (GIS) coverages provided by the City. Available GIS data including major roads, City parcels, streams, and wetlands were reviewed and incorporated into field maps. Additionally, regional geologic map information was obtained online (Hart and Newcomb 1965).

The stream walks were conducted by Erin Nelson, Altaterra Consulting and Ryan Retzlaff, Brown and Caldwell between September 11, 2017 and September 15, 2017. Streams were walked in the upstream direction from the lowest point in the reach to the highest point in the reach. Photographs were taken to document conditions (generally in the upstream direction). Physical and biological conditions were noted in a field notebook and mapped with geographic references (such as road crossings) and approximate distances upstream from the starting point. The following stream characteristics were documented:

- General vegetation condition, including presence of native and non-native vegetation
- In-stream and hillslope erosion processes (incision, aggradation and hillslope failures)
- Approximate bankfull stream channel widths and depths, measured at appropriate intervals when conditions change
- General aquatic habitat conditions (pools, riffles, large woody debris, flow)
- Location of stormwater outfalls, pipes and groundwater seeps
- Potential pollution sources
- General in-stream sediment distribution throughout stream channel
- Wildlife activity (presence of beaver dams)

These characteristics were noted because they provide evidence of current aquatic health and physical channel conditions, as well as documentation that can be used to compare future stream assessment results.

Observations made during the stream walks were used to qualitatively identify current stream channel deficiencies and potential strategies for improvement. Hydrologic and hydraulic data, including historic, current or predicted stream discharges was not reviewed relative to the physical channel conditions. Analysis of this data compared to physical channel dimensions could potentially be used to predict future changes.

Table 1 provides a list of the reaches included in the assessment and the approximate reach lengths that were walked. Stream reaches were evaluated from downstream starting point to upstream end point.

Table 1. List of Stream Reaches Walked

Stream	Reach	Starting Point	End Point	Approximate Distance (ft)
Saum Creek	#1	Tualatin River	SW Prosperity Park Road	6,775
	#2	SW Lee Street (east end)	SW 65th Ave	4,950
	#3	SW Blake Street	Upstream 530', downstream vicinity 90'	600
Nyberg Creek	#1	SW Nyberg Lane	SW 65th Avenue	950
	#2	SW 65th Ave	I-5	2,100
	#3	SW Martinazzi Ave	Boones Ferry Road	1,400
Hedges Creek	#1	SW Boones Ferry Road/Tualatin River	SW Tualatin Rd	2,250
	#2	Tualatin-Sherwood Rd	SW Industrial Way	1,900
	#3A	Blake St/SW 105th Ave	Confluence with S. Tributary	1,740
	#3B	Confluence with S. Tributary	SW 99th Ave	560

3.0 Stream Assessment Results

Stream channel characteristics observed during the stream walk and field investigations are described below for each reach. Additional detail is provided in the reach summary sheets included in Attachment A. Physical reach characteristics are summarized in Table 2. This information can be compared to discharge data, if available, to compare physical channel dimensions (channel capacities) to flow.

Table 2. Summary of physical stream channel characteristics by reach.

Stream	Reach	Avg. Gradient (%)	Avg. Valley Width (ft)	Avg. Bankfull Width (feet)	Avg. Bankfull Depth (feet)	Width:Depth Ratio
Saum Creek	#1	0.59	100-200	13.2	5.9	2.2
	#2	0.36	150-175	10.5	4.7	2.2
	#3 (us of Blake)	1.12	75-100	6	2	3.0
	#3 (ds of Blake)	3.0	75-100	nm	nm	nm
Nyberg Creek	#1	<0.001	300-400	nm	nm	nm
	#2	0.09	500-650	nm	nm	nm
	#3	0.3	30-60	6.5	2.5	2.6
Hedges Creek	#1	0.8	75 - 125	11.5	4.2	2.7
	#2	0.2	125-250	11.5	4.3	2.7
	#3A	0.009	~150	10.6	3.7	2.9
	#3B	3.7	~50	5.7	2.8	2.0

Notes: us = upstream, ds = downstream, nm = not measured

3.1 Overall Summary

Some of the notable positive characteristics observed in the stream reaches investigated include:

- wide riparian corridors surround many of the stream channels, which is noteworthy given the otherwise urban/suburban setting of the City
- a distinct lack of trash in and around the channels

Preservation of riparian corridors and floodplains is especially important in low-gradient stream systems, where streams typically have a meandering characteristic and require space to maintain this stable channel form. Moderate and steep gradient streams are usually more confined by narrow valleys and narrower floodplains, and stable channel forms do not necessarily need as much lateral space for movement. However, wide swaths of riparian vegetation in these areas is also very beneficial to channel stability. Healthy riparian corridors in moderate and steep gradient systems supply large wood to channels as trees fall in (providing channel structure), and slope stability benefits through water interception, water uptake, and soil reinforcement from roots.

Negative characteristics observed in many of the stream reaches investigated include the presence of invasive non-native vegetation such as reed canary grass, Himalayan blackberry, jewel weed, and English Ivy. Invasive vegetation was observed in almost every stream reach, although some reaches were heavily impacted.

Physical stream channel conditions generally correlate to the reaches position in the watershed and factors such as riparian width, stream channel gradient, and channel confinement (from development or topographic conditions). Bank and bed erosion was most prevalent in the headwater reaches of the stream channels assessed (e.g., Saum Creek Reach #3 and Hedges Creek Reach #3B), where stream channel gradients were steeper, and channels were confined. These headwater reaches are also exposed to the first effects of high flows during rain events, conveyed from surrounding residential neighborhoods. There is very little in-channel or floodplain storage capacity to dissipate flows. The lower or downstream reaches of the streams generally have wide riparian corridors and floodplains to effectively dissipate peak flows from the channel to the floodplain, reducing the power to erode. Localized bank erosion was mostly observed in the lower reaches on the outside of meanders, where erosion would be expected to occur.

3.1 Saum Creek

Approximately 2 ¼ miles of Saum Creek were assessed between its confluence with the Tualatin River to its headwaters, upstream of I-205, near SW Blake Street. Most of the Saum Creek stream corridor within Tualatin is surrounded by a wide riparian protected greenway (the Saum Creek Greenway downstream of I-5 in Reaches #1 and #2 and the Chieftan/Dakota Greenway upstream of I-5 in Reach #3). Highlights of stream channel characteristics, and problems notes are described below and reach description summary sheets for Saum Creek Reaches #1, #2, and #3 are provided in Attachment A. Photo logs of the stream walks for Saum Creek Reaches #1, #2, and #3 are provided in Attachments B-1 through B-3.

3.1.1 Saum Creek Reaches #1 and #2

The lower reaches (Saum Creek Reach #1 and Reach #2) have the benefit of a wide floodplain to accommodate high flows during flood events. There were no outstanding issues observed in either reach that stood out as needing attention. Minor erosion was observed in both reaches, but there was no indication that the erosion is currently impacting City or private property or infrastructure or that remedies are needed at this time for these minor issues. Non-native invasive vegetation was present along many portions of both reaches, intermixed with native vegetation. The City may wish to develop a vegetation management plan for the Saum Creek Greenway to ensure the success of native vegetation and reduce the proliferation of the non-native invasive species in the corridor.

3.1.2 Saum Creek Reach #3

Saum Creek Reach #3 is divided by SW Blake Street. Downstream of SW Blake Street, a hillslope failure on the north side of the channel has caused the outfall that discharges stormwater piped from SW Makah Ct. to hang several feet above the stream bed (Photo 1). The hillslope failure caused several large trees to fall, resulting in a large number of branches, logs and debris in this reach. The entire north slope was saturated at the time of the site visit. Soil saturation could be a contributing factor to the slope instability in this location. The mechanisms of slope failure were not investigated in detail during the site investigation. Further investigation of the geologic condition along this slope is recommended in order to determine cause of failure and need for hillslope reinforcement.

Photo 1. Hanging culvert on north side of Saum Creek Reach #3 in location of hillslope failure (September 2017)

The channel upstream of SW Blake Street was restored in 2014 with a series of rock check dams and pools. This project was constructed in conjunction with a neighborhood water quality project. Prior to the restoration, the channel in this reach was significantly incised and banks were being eroded from high rates and volumes of stormwater runoff emanating from the surrounding residential development (Otak, 2013). A new stream channel gradient was established through the reach using rock weirs and splash pools to dissipate the energy (Photo 2) and the entire corridor was revegetated with native vegetation. A current view of the restoration area is shown in Photo 3. The channel structure (boulders and drop pools) is intact and erosion does not appear to be a current problem in this reach. However, the lower portion of the reach immediately upstream of SW Blake Street is very flat, and the ground is saturated (Photo 4). Saturated conditions, as well as the presence of invasive vegetation appear to be impacting native plants that have been planted in this corridor. There is a need for ongoing vegetation maintenance in the entire reach, but particularly in this area where an investment has already been made on the stream restoration project. Plant selection and/or locations may need some adjustment for the best chance of success.

Photo 2. Otak photo of newly constructed Saum Creek channel in Chieftan/Dakota Greenway (c. 2013)

Photo 3. Saum Creek restoration in Chieftan/Dakota Greenway (September 2017)

Photo 4. Saum Creek immediately upstream of SW Blake Street. Channel is obscured by reed canary grass. This area is very flat, and wet.

3.2 Nyberg Creek

Three reaches (approximately 0.84 miles) of Nyberg Creek between SW Nyberg Lane and SW Boones Ferry Road were assessed and/or walked as part of the stream assessment. Highlights of stream channel characteristics and problems noted are described below and reach description summary sheets for Nyberg Creek Reaches #1, #2, and #3 are provided in Attachment A. Photo logs of the stream walks for Nyberg Creek Reaches #1, #2, and #3 are provided in Attachments B-4 through B-6.

3.2.1 Nyberg Creek Reaches #1 and #2

Nyberg Reach #1 and Nyberg Reach #2 were mostly lacking stream channel characteristics at the time of the stream assessment. These reaches are wetland complexes with significant open water components (Photos 5 and 6). Beaver activity is prevalent, and is likely the reason for the extensive open water in these two reaches. There was evidence of past efforts to address the beaver activity in Nyberg Creek Reaches #1 and #2. However, the beaver activity observed did not appear to be in areas of concern with regard to infrastructure or flooding. Vegetation in Nyberg Creek Reaches #1 and #2 consisted of wetland vegetation. Due to the on-going beaver activity and the changing nature of the flooded areas that currently have wetland characteristics, there is no recommendation for vegetation management.

Photo 5. Nyberg Creek Reach #1 downstream of SW 65th Avenue

Photo 6. Nyberg Creek Reach #2 downstream of I-5, with beaver swimming in foreground.

3.2.2 Nyberg Creek Reach #3

Nyberg Creek Reach #3, between SW Martinazzi Avenue and Boones Ferry Rd has much different physical characteristics than Nyberg Creek Reach #1 and Reach #2. This reach is primarily confined to a narrow swath of open space between commercial development. Immediately upstream of SW Martinazzi Avenue, a notched concrete dam is present, creating a pond (known by City staff as Izzy's Pond) on the upstream side. Upstream of the pond, the channel is piped for approximately 100 feet in a strip mall parking lot. The remainder of the reach consists of open channel that is straight, narrow, and dominated by reed canary grass (Photo 7). Vegetation management is needed in this entire reach, including removal of invasive reed canary grass and replacement with other appropriate native vegetation.

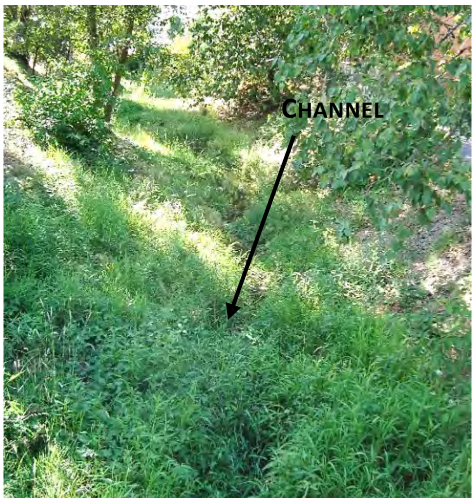


Photo 7. Nyberg Creek Reach #3 upstream of SW Martinazzi Avenue.

3.3 Hedges Creek

Approximately 1 ¼ miles of Hedges Creek was assessed between the Tualatin River and the headwaters near SW 99th Ave. in the Ibach Park neighborhood. Hedges Creek is almost entirely within the City of Tualatin jurisdictional boundary, but much of it is under private ownership. Only a small portion of the stream was walked, at the mouth and at the headwaters. Three independent reaches (Reach #1, #2, and #3) were selected for investigation because of known issues and/or City property ownership. Reach #3 was further divided into two sub-reaches, Reach #3A and Reach #3B, because there were distinctly different characteristics observed in the downstream (#3A) and upstream (#3B) portions of the reach. Highlights of stream channel characteristics and problems notes are described below and reach description summary sheets for Hedges Creek Reaches #1, #2, #3A, and #3B are provided in Attachment A. Photo logs of the stream walks for Hedges Creek Reaches #1, #2, #3A, and #3B are provided in Attachments B-7 through B-10.

3.3.1 Hedges Reach #1

Hedges Reach #1 extends from the Tualatin River to SW Tualatin Road. This reach reflects a mix of public and private ownership and is partially located within Tualatin Community Park property. The lower 1,200 feet of the channel includes meandering characteristics, except for a few straight sections. In general, the straight sections correspond with sections where the channel bed consists of hard silt. The channel bed otherwise consisted of loose sediment (fine silt and sand, with occasional gravel) in Hedges Reach #1.

Bank erosion was observed in Hedges Reach #1 at a few locations on the outside of meander bends in the first 500 feet upstream of the Tualatin River. Rip-rap armoring was observed at one location on private property approximately 450' upstream from the Tualatin River, and a concrete apron was observed on private property at another location 200' upstream from the Tualatin River. It appears that these materials were used to stabilize the stream banks, prevent erosion, and protect private property. The bank stabilization efforts appear to be locally effective in protecting property in the immediate vicinity of the stabilization.

The channel gradient is steeper in the lower (downstream) portion of the reach, flattening out in the upstream portion towards Tualatin Road.

A channel-spanning debris jam was present approximately 300 feet upstream from the mouth of the channel. This debris jam may be associated the event that washed out a private bridge approximately 500 feet upstream from the mouth. The debris and gravel deposited downstream of the bridge wash-out is still present in the channel and the culvert (Photo 8) that conveys water through the debris, directs water toward the opposite bank, due to its orientation. It is not clear whether the culvert was placed in the channel pre- or post- bridge wash out, but the culvert is undersized for the volume of flow received in the channel. The area of the culvert is smaller than the bankfull channel capacity upstream and downstream. High flows would back up at this location and eventually overtop the road and result in erosion. The channel makes a 90 degree turn against a vertical bank, 30 feet downstream of the culvert. Due to the orientation of the stream channel and the culvert which concentrates and directs flow in this location, this bank is at risk of erosion, and may be a potential threat to a private structure located on the top of the bank.

Approximately 200 feet downstream, another private structure is located on the top of the bank on the outside bend of a meander. This structure may have similar risks due to proximity to the edge of the bank. Both of these structures are east of SW Martinazzi Ave and north of SW Boones Ferry Road.

Photo 8. Culvert placed in debris from washed out bridge to convey Hedges Creek.

Approximately 1,200 feet upstream of the mouth, an 18-inch diameter stormwater outfall enters Hedges Creek from the south. Stormwater inputs at this location could account for some of the differences in stream characteristics upstream. Upstream of this location, in the Tualatin Community Park, the channel is mostly straight, with a wider floodplain, and a flatter gradient, and based on the channel conditions, erosive flows appear to be less frequent. No channel erosion was observed in this part of the reach. The channel is also largely overgrown with reed canary grass through this portion of the reach (Photo 9), and beaver dams were also observed. Vegetation management is needed to control reed canary grass in the Tualatin Community Park.

Photo 9. Hedges Creek Reach #1. Reed canary grass-choked channel downstream of Tualatin Road.

3.3.2 Hedges Reach #2

Hedges Creek Reach #2 is located between SW Tualatin-Sherwood Road and SW Industrial Way. It is surrounded by the Hedges Creek Greenway open space, a wide riparian floodplain area. Hedges Creek is relatively stable through this reach, with only minor erosion observed on the outside of meanders. The adjacent floodplain provides ample room for the channel to naturally meander and migrate. However, the entire reach needs extensive vegetation management due to observed, dense invasive plants including Himalayan blackberry and reed canary grass, as shown in Photo 10.

Photo 10. Hedges Creek Reach #2.

3.3.3 Hedges Reach #3A

Hedges Creek Reach #3A is located between SW 105th Avenue/Blake Street and a tributary that enters Hedges Creek from the South downstream of SW Alsea Ct. A pedestrian bridge crosses the stream channel in this location.

Hedges Reach #3A has a meandering characteristic and a relatively low gradient. Channel substrate consists of loose silt, hard silt, and an outcrop of bedrock present for about 100 feet of stream channel starting approximately 500 feet upstream of 105th Avenue. A rock wall protecting the bank (and presumably road embankment) 175 feet upstream and on the east side of 105th Avenue/Blake Street has been compromised, as it has been eroded by the stream (Photo 11). At this location, Hedges Creek makes a 90-degree turn, which is a point of maximum velocity and energy on the outside bend. It is recommended to reinforce/ rebuild the rock wall to ensure the road embankment is not compromised and/or reorient the culvert under 105th Avenue/ Blake Street to minimize flow velocity directed at the road embankment and wall. It is assumed that design and construction would be conducted in conjunction with the scheduled road widening project for 105th Avenue.

Another issue observed in Reach #3A is channel incision in a side channel entering the main channel from the south, approximately 700 feet upstream of SW 105th Avenue. The neighborhood west of Ibach Park contributes drainage to this side channel and it appears that this channel receives a large volume of water from the upstream catchment. The extreme erosion in this side channel has exposed a sanitary sewer manhole (Photo 12). This exposure, over time, may compromise the structural integrity of the manhole.

Evidence of a recent stream restoration project was observed upstream of Ibach Park (Photo 13), starting approximately 950 feet upstream of SW 105th Avenue. Large wood, bed protection matting and tiles, and root wads were placed and cabled at several different locations in the channel. It is unclear based on the locations of the restoration efforts what the goals might have been. Bank erosion and hillslope slumps were observed throughout the reach, however, property or infrastructure did not appear to be impacted or immediately threatened by the erosion. Invasive vegetation, including English ivy, and Himalayan blackberry were present throughout the reach as well.

It is recommended that locations of active channel erosion, in the vicinity of the rock wall and the sanitary sewer pipe, in this reach be monitored by the City to ensure that site conditions do not deteriorate. Additionally, the side channel entering Hedges Creek in Reach #3A has experienced erosion due to the flashiness of stormwater runoff from upstream. Flow control and onsite retention standards and policies are recommended for the City's consideration in Hedges Reach #3A, in the vicinity of the area west of Ibach Park, to mitigate for areas of active erosion and preserve the integrity of small streams such as this side channel.

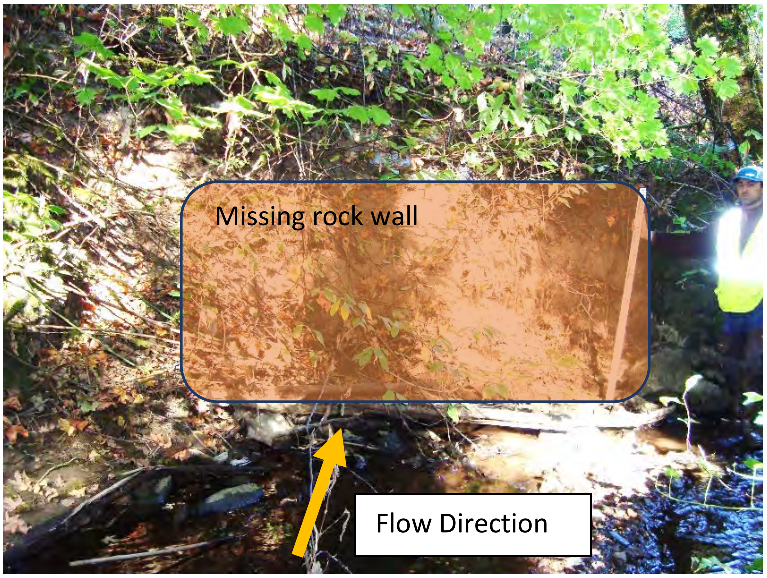


Photo 11. Hedges Creek Reach #3A, showing rock wall location and missing rocks.

Photo 12. Side channel incision and erosion around sanitary sewer manhole.

Photo 13. Restoration area showing cabled logs and root wads. Approximately 950 feet upstream of SW 105th Avenue.

3.3.4 Hedges Reach #3B

Hedges Creek Reach #3B is located between a tributary that enters Hedges Creek from the South downstream of SW Alsea Ct and SW 99th Avenue.

Hedges Reach #3B has a much steeper gradient that Reach #3A and the channel is incised with the width to depth ratio decreasing upstream along the reach. The channel is not stable in this reach. Adjacent slopes have failed on both banks (Photo 14) and the culvert under SW Alsea Ct. is perched resulting from erosion and downcutting at the base (Photo 15).

Photo 14. Left bank slump upstream of confluence.

Photo 15. Perched culvert on downstream side of SW Alsea Ct.

Further upstream of SW Alsea Ct. to SW 99th Ave, there is more evidence of erosion and downcutting. A culvert delivering water to the head of the channel near 9999 SW Alsea Ct. is perched approximately 6 feet above the current channel. The culvert is actively eroding the channel. It appears the channel receives a large volume of water from the upstream catchment. BC estimates approximately 140 acres of residential development is collected and conveyed undetained to this stream reach. Given the susceptibility to headwater channels to experience erosion due to the flashiness of stormwater runoff, flow control and onsite retention standards and policies are recommended for the City's consideration in Hedges Reach #3B to mitigate for areas of active erosion and preserve the integrity of the headwater channels.

4.0 Findings and Recommendations

As part of the City's stormwater master plan development, the City is defining projects and strategies to enhance or protect City resources and address stormwater-related problems occurring on City property. This stream assessment was focused on publicly owned land and resources. Findings and recommendations have been identified and developed specific to reaches observed, and do not reflect all stream conditions in the City.

The following is a summary of findings from the stream assessment and recommendations of strategies, including programmatic, projects, and policies to improve stream channel conditions in the reaches evaluated, and/or solve site specific problems.

4.1 Channel Erosion and Incision

Channel erosion and incision was primarily observed in Hedges Creek, and particularly in the headwaters in Reaches #3A and #3B. Table 3 summarizes the locations of channel erosion that were considered problematic from the standpoint of being a risk to property or infrastructure, and recommended strategies for addressing the situation.

Table 3. Summary of Channel Erosion Observations and Recommended Strategies

Stream	Reach	Approximate Location and Issue	Ownership	Recommended Strategy
Hedges Creek	#1	~500 ft. upstream of Tualatin River (washed out bridge)	Private	1. As of the writing of this report, the City is currently working with the property owner and other resource agencies to address permit compliance.
	#3A	~175 ft. upstream of SW 105th Ave. (rock wall)	City	1. Inspect rock wall for ongoing deterioration. 2. Repair rock wall in conjunction with road project. 3. Reorient the downstream culvert to minimize flow velocity directed at embankment.
	#3A	~700 ft. upstream of SW 105th Ave. (side channel and exposed sanitary	City	1. Consider policies to encourage onsite retention and flow mitigation. 2. Inspect sanitary sewer manhole for ongoing exposure or deterioration.

		sewer manhole)		
	#3B	Entire stream reach (erosion and instability)	City/ Private	Consider policies to encourage onsite retention and flow mitigation.
	#3B	Culvert at 9999 SW Alsea Ct. (extreme downcutting)	City	1. Consider policies to encourage onsite retention and flow mitigation. 2. Implement channel reconstruction/stabilization project to protect private property (private property owner).

4.1.1 Flow Control

The physical conditions of Hedges Creek Reach #3 indicate that the stream channel is subjected to high flow volumes on a regular basis. There is significant erosion and downcutting at the base of two culverts and in the channel (adjacent to house 9999 SW Alsea Ct, and downstream of SW Alsea Ct) as well as bank and hillslope failures in this reach. Additionally, a side channel entering Hedges Creek near Ibach Park has experienced extreme incision, likely due to altered hydrology upstream. This side channels exposed a sanitary sewer manhole, and if the channel continues to downcut, it may further threaten the integrity of the sewer structure. Altered hydrology (from forested/ undeveloped conditions to residential development) has impacted this reach. These observed locations (see Table 3) may benefit from implementation of flow control design standards aimed at reducing both the peak flow and the duration of channel forming flows entering this reach. The City does not currently require stormwater detention or flow mitigation in conjunction with new and redevelopment and coordinates with Clean Water Services on stormwater management and stormwater design standards. The City may consider updates to their stormwater management policy to encourage onsite retention and flow mitigation in areas susceptible to hydromodification impacts, such as Hedges Reach #3.

It should be noted that flow control may not be as effective in the downstream reaches (i.e., Hedges Reach #1) because of wide floodplains and wetlands are effective at dissipating flow and reducing erosivity. It is recommended that hydrologic and hydraulic modeling be conducted to model the potential effects of flow control standards on downstream reaches.

4.1.2 Road Embankment Erosion

The rock wall protecting the road embankment on 105th Avenue/Blake Street from Hedges Creek in Reach #3A was observed to be failing. Rocks have fallen into the stream, and only a few pieces of the wall remain in place. It is understood that the City plans to widen SW 105th Avenue, which will require a detailed evaluation and updated design of the road embankment and culvert crossings in relationship to the stream channel. A potential design option is to reorient the culvert in conjunction with the roadway widening project to mimic the direction of the natural stream channel and minimize flow velocity directed at the road embankment. Alternatively, reinforcement/ replacement of the existing rock wall would be needed.

4.2 Vegetation Management

Nearly all the reaches assessed were impacted by invasive vegetation, with the most common species being reed canary grass, Himalayan blackberry and English Ivy. Specific locations where intense vegetation management is recommended is detailed in Table 4.

Table 4. List of Locations Recommended for Vegetation Management

Stream	Reach	Location	Ownership	Invasive Vegetation	Approximate Distance (ft)
Saum Creek	#3	Upstream of SW Blake Street in vicinity of existing restoration project (maintenance is needed).	City	Reed canary grass, Himalayan Blackberry	Approximately 200
Nyberg Creek	#3	Entire reach	Mostly City, approximately 300 feet private	Reed canary grass	1,400
Hedges Creek	#1	Tualatin Community Park	City	Reed canary grass	~500
	#2	Entire reach	City	Reed canary grass, Himalayan Blackberry	1,900

Hedges Reach #2 has the most potential for improvement. This area is within the Hedges Creek Greenway and there are established deciduous and conifer trees in the riparian corridor that provide significant shade and would aid in the establishment of newly planted vegetation if a revegetation effort was initiated. Invasive plants are successful because they thrive in environments where native plants struggle, such as areas that lack shade. Providing a hospitable environment for new plant growth, including shade from established trees, will make restoration efforts more successful.

Vegetation management efforts should include a plan for removal of invasive vegetation, replacement with native vegetation of appropriate type and quantities to be successful, irrigation (initially, until plants are established), follow-up monitoring, and on-going maintenance to continue invasive plant removal. Any efforts to remove invasive vegetation and replant with native riparian plants will require a long-term commitment to maintaining the restored areas to ensure success. At a minimum, annual inspections and potential maintenance (depending on the results of inspection) should occur following re-vegetation efforts. If annual inspections indicate no maintenance is needed, the frequency of inspections can be decreased.

4.3 Slope Stability

Results of the stream assessment identified one location where a capital project may be developed to address City infrastructure potentially susceptible to failure. A perched stormwater pipe above the stream channel in Saum Creek Reach #3 was identified during the stream assessment. Stormwater discharge from this pipe will cause further erosion of the slope around it if left in its current position. A capital project is recommended to replace the pipe and repair the hillslope failure in the vicinity in conjunction with the pipe replacement. The new pipe should be placed on the hillside (i.e., thick-walled flexible pipe or similar) to the bottom of the slope, with energy dissipation provided. A geotechnical evaluation is recommended in order to determine the cause of the slope failure in the vicinity of the perched pipe, and provide input to the slope repair design.

5.0 References

D.H. Hart and R.C. Newcomb. USGS. Geology and Ground Water of the Tualatin Valley, Oregon. Water Supply Paper 1697. 1965. Accessed online. https://pubs.er.usgs.gov/publication/wsp1697

Otak 2013. Saum Creek Hydromodification and Water Quality Retrofit. Accessed online. http://www.otak.com/news/media/saumcreekhydromodificationandwaterqualityretrofittualatinoregon/

AltaTerra

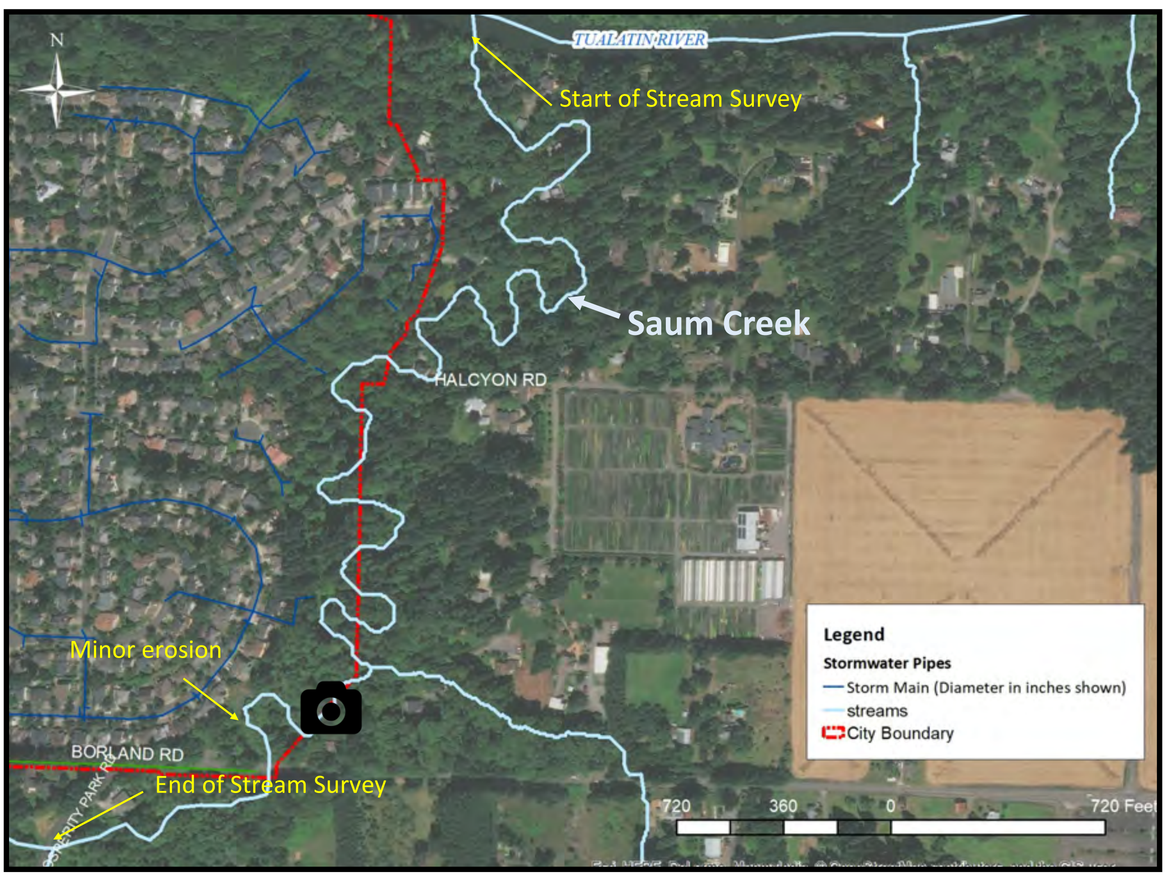
Attachment A

Stream Reach Summary Sheets

City of Tualatin
Stream Channel Condition Survey
Stream Reach Descriptions

Beaver dam ~ 700 ft. downstream of Borland Rd (photo location shown below with camera icon)

Stream	Saum Creek
Reach	#1 (Tualatin River to SW Prosperity Park Rd)
General Characteristics	
Reach Length:	~6,775 ft.
Gradient:	~0.6%
Valley Width:	~100—200 ft
Planform:	Meandering
Average BFW:	~13’ (range 12’ to 15’)
Average BFD:	~6’ (range 4’ to 7’)
Substrate:	Predominantly silt, some small gravel
Vegetation:	Invasive vegetation (reed canary grass, blackberries, ivy), Douglas fir
Beaver Activity:	Yes. Four beaver dams observed.
Issues:	Minor erosion downstream of Borland Rd.

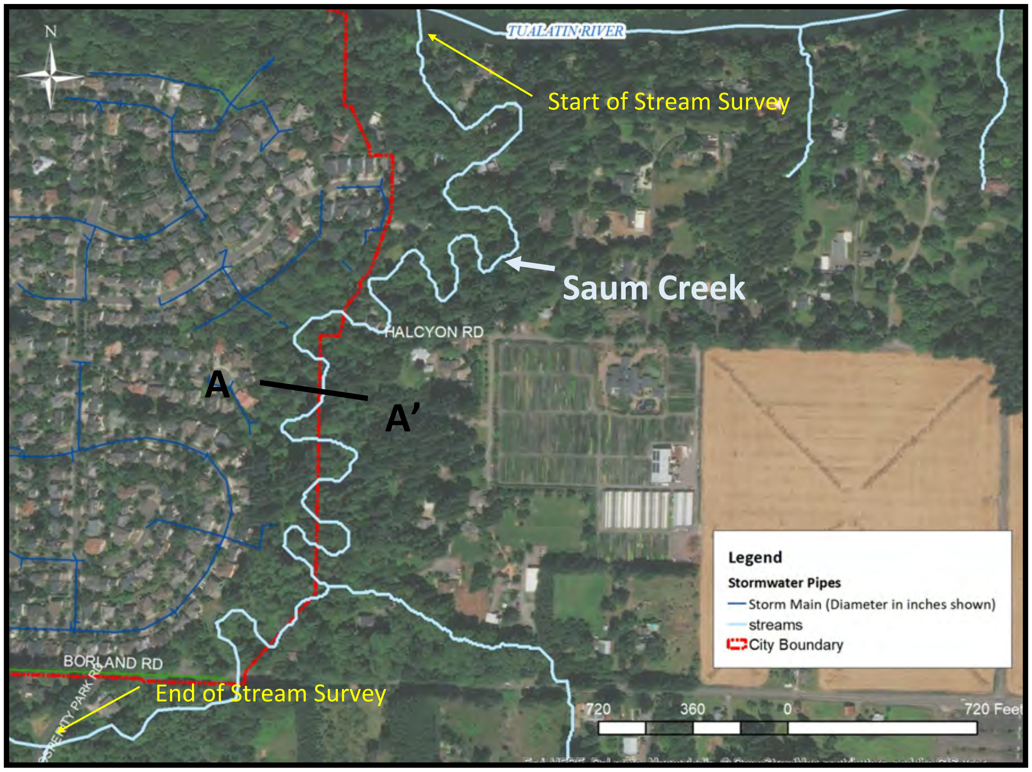


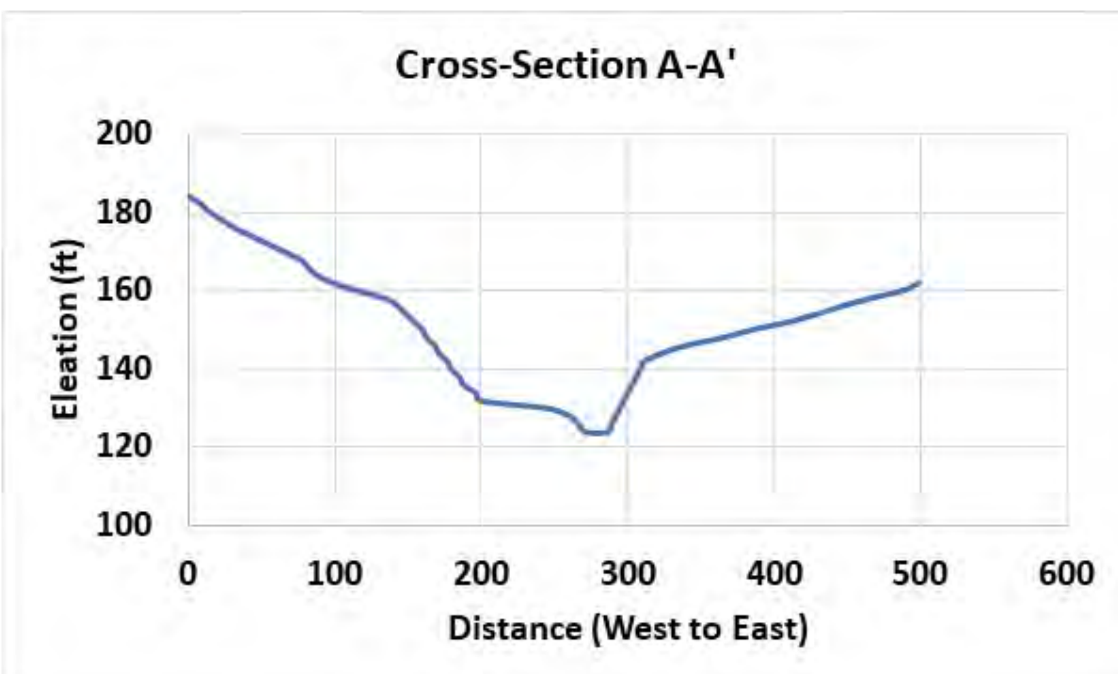
Aerial view of Saum Creek Reach #1 (Tualatin River to Prosperity Park Road)

City of Tualatin

Stream Channel Condition Survey

Stream Reach Descriptions



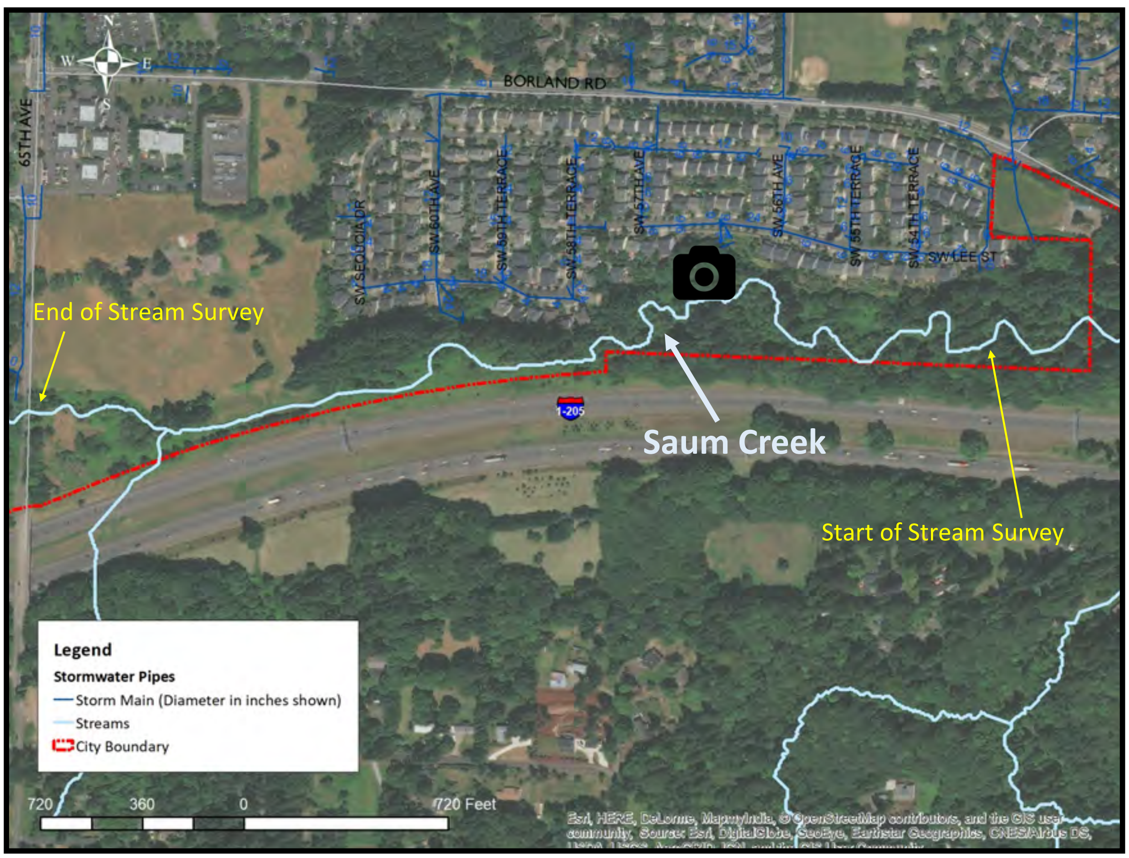


Generalized topographic cross section of Saum Creek Valley in Reach #1.

City of Tualatin
Stream Channel Condition Survey
Stream Reach Descriptions

Hard clay forming pools within channel bed in Saum Creek Reach #2 (photo location shown below with camera icon)

Stream	Saum Creek
Reach	#2 (Lee St. to 65 Ave.)
General Characteristics	
Reach Length:	~4,950 ft.
Gradient:	~0.4 %
Floodplain Width:	~150' - 175'
Planform:	Meandering (Lee St. to SW 60th, straight (SW 60th to 65th Ave)
Average BFW:	~10' (range 8' to 15')
Average BFD:	~5' (range 3' to 6')
Substrate:	Silt, hard clay, occasional gravel
Vegetation:	Mixed floodplain forest (maples, alders, firs), reed canary grass, jewel weed, blackberries, ferns, willows, sedges
Beaver Activity:	None observed.
Issues:	No critical issues.

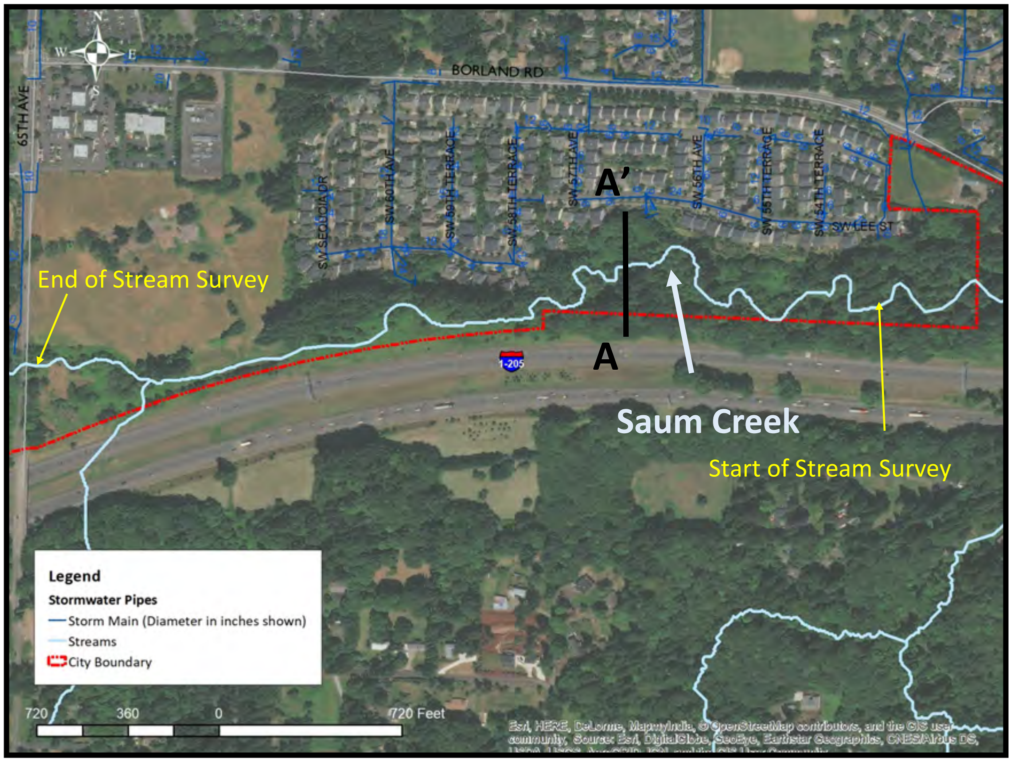


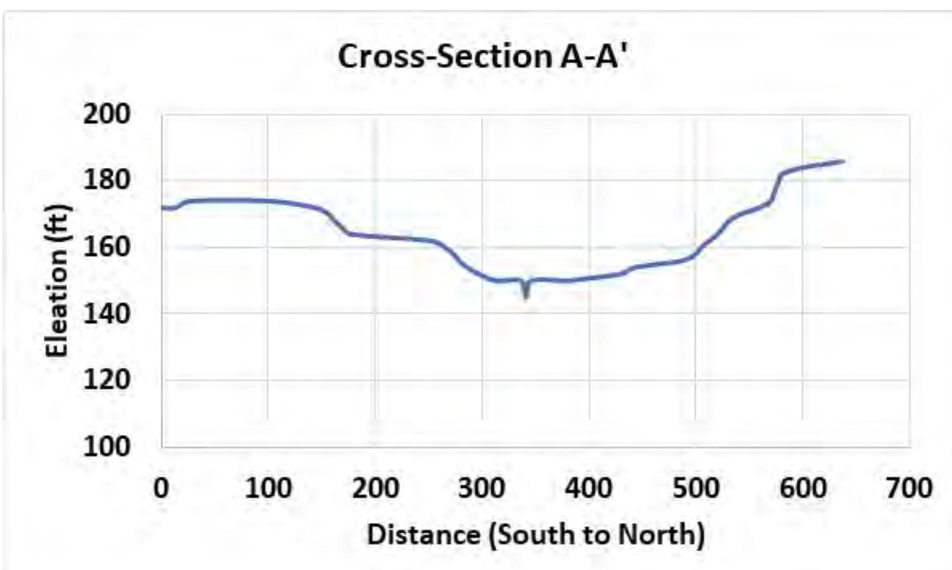
Aerial view of Saum Creek Reach #2 (SW Lee Street to 65th Avenue)

City of Tualatin

Stream Channel Condition Survey

Stream Reach Descriptions



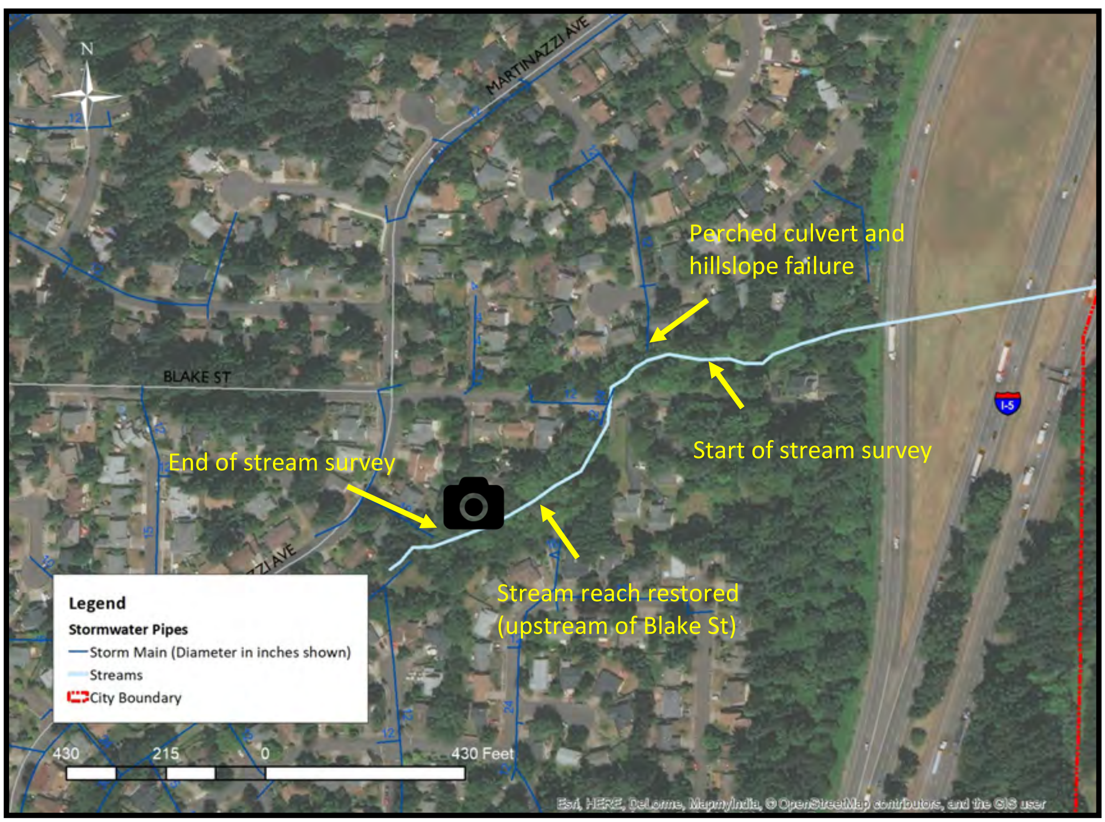


Generalized topographic cross section of Saum Creek floodplain in Reach #2.

City of Tualatin
Stream Channel Condition Survey
Stream Reach Descriptions

Rock check dam and pool in restored section upstream of Blake Street (photo location shown below with camera icon)

Stream	Saum Creek
Reach	#3 (Vicinity of Blake Street)
General Characteristics	
Reach Length:	~600 ft.
Gradient:	~1.1 % (ds of Blake), ~3% (us of Blake)
Valley Width:	~75' to 100' (confined)
Planform:	Straight
Average BFW:	~6'
Average BFD:	~2'
Substrate:	Fine sediment
Vegetation:	Conifer and deciduous trees (many down in channel), reed canary grass, ivy
Beaver Activity:	None observed.
Issues:	Unstable hillslope and perched culvert, invasive vegetation.

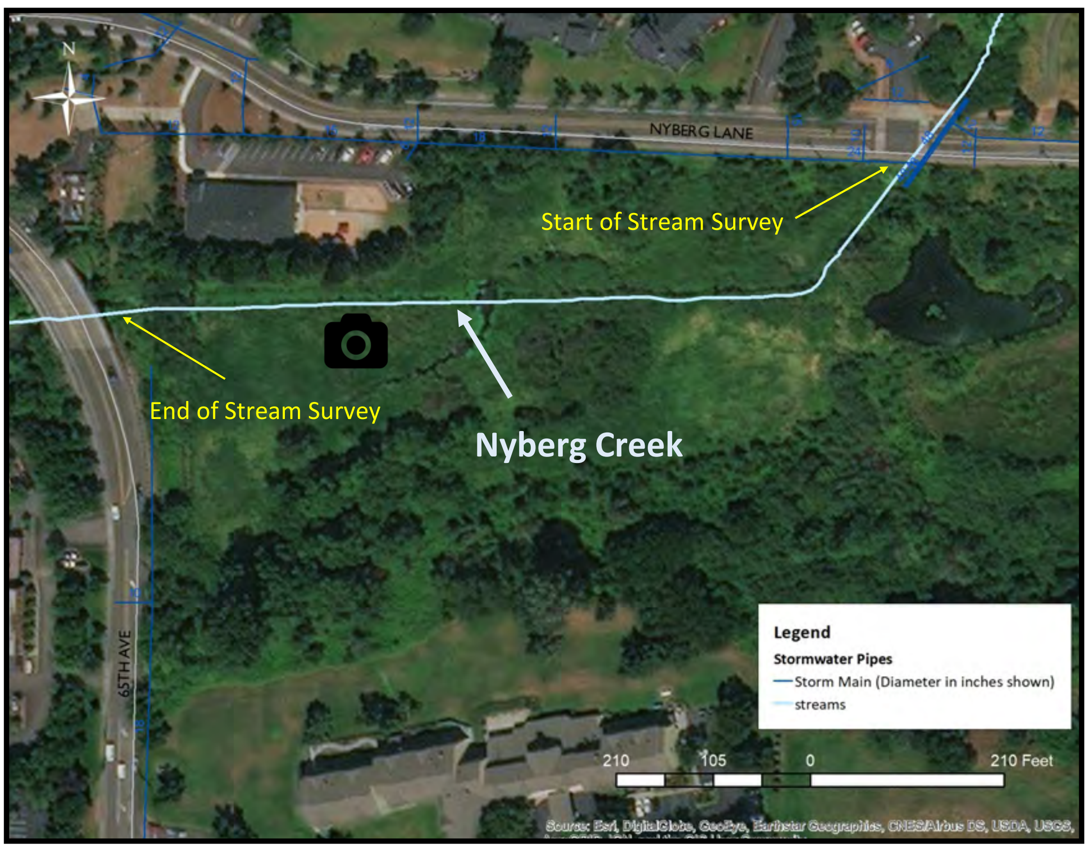


Aerial view of Saum Creek Reach #3 (Vicinity of Blake Street)

City of Tualatin
Stream Channel Condition Survey
Stream Reach Descriptions

Ponded area in Nyberg Creek Reach #1 downstream of 65th Avenue (photo location shown below with camera icon)

Stream	Nyberg Creek
Reach	#1 (Nyberg Lane to 65 Ave.)
General Characteristics	
Reach Length:	~950 ft.
Gradient:	~0.001% (almost flat)
Floodplain Width:	~300 –400'
Planform:	Straight, ditch-like or undefined channel (wetland, floodplain)
Average BFW:	Not measured. Mostly no single-thread channel. Multiple flow pathways.
Average BFD:	Not measured.
Substrate:	Loose silt and decaying vegetation.
Vegetation:	Wetland plants, reed canary grass, duckweed, spiraea, jewel weed
Beaver Activity:	Yes, at least two beaver dams in reach.
Issues:	No critical issues.

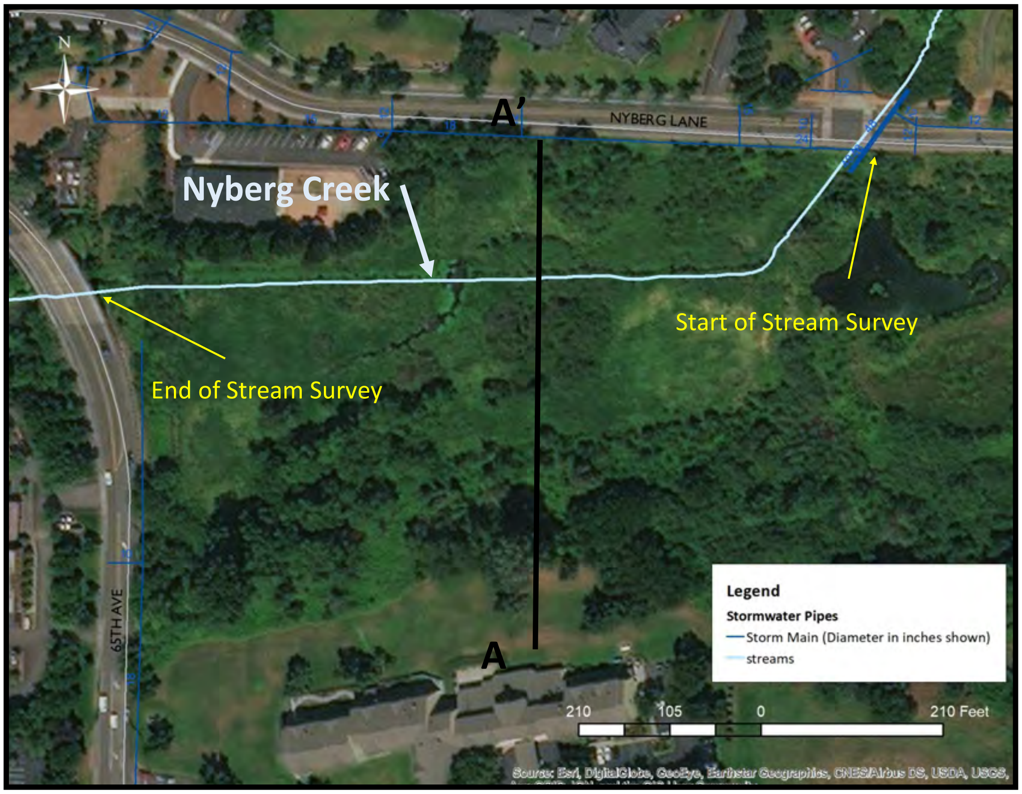


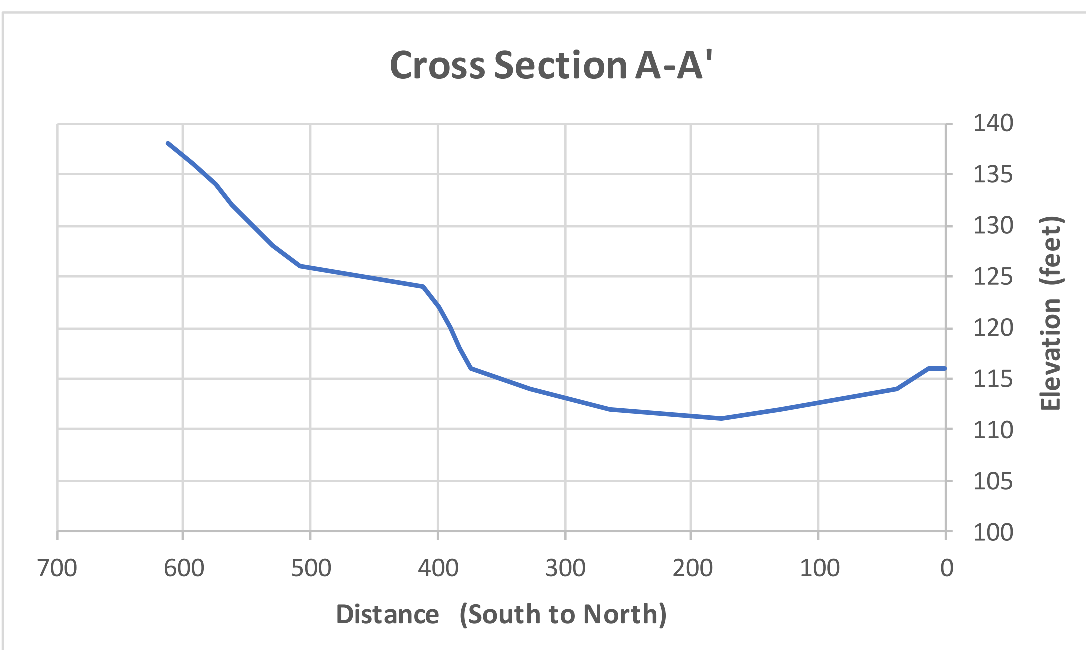
Aerial view of Nyberg Creek Reach #1 (Nyberg Lane to 65th Avenue)

City of Tualatin

Stream Channel Condition Survey

Stream Reach Descriptions





Generalized topographic valley cross section of Nyberg Creek floodplain.

City of Tualatin
Stream Channel Condition Survey
Stream Reach Descriptions

Nyberg wetlands between 65th Avenue and I-5
(photo location shown below with camera icon)

Stream	Nyberg Creek
Reach	#2 (65 Avenue to I-5)
General Characteristics	
Reach Length:	~2,100 ft.
Gradient:	~0.095%
Floodplain Width:	~500-650'
Planform:	Flooded, no channel.
Average BFW:	No channel. Not measured.
Average BFD:	No channel. Not measured.
Substrate:	Not evaluated. Flooded.
Vegetation:	Wetland plants, reed canary grass, duck-weed, spiraea, jewel weed
Beaver Activity:	Extensive. Major beaver dam, and beavers observed during field visit.
Issues:	No critical issues.

Aerial view of Nyberg Creek Reach #2 (65th Avenue to I-5)

City of Tualatin
Stream Channel Condition Survey
Stream Reach Descriptions

Nyberg Creek between Tonka Rd and Boones Ferry Rd. (photo location shown below with camera icon)

Stream Nyberg Creek

Reach #3 (Martinazzi Road to Boones Ferry Rd)

General Characteristics

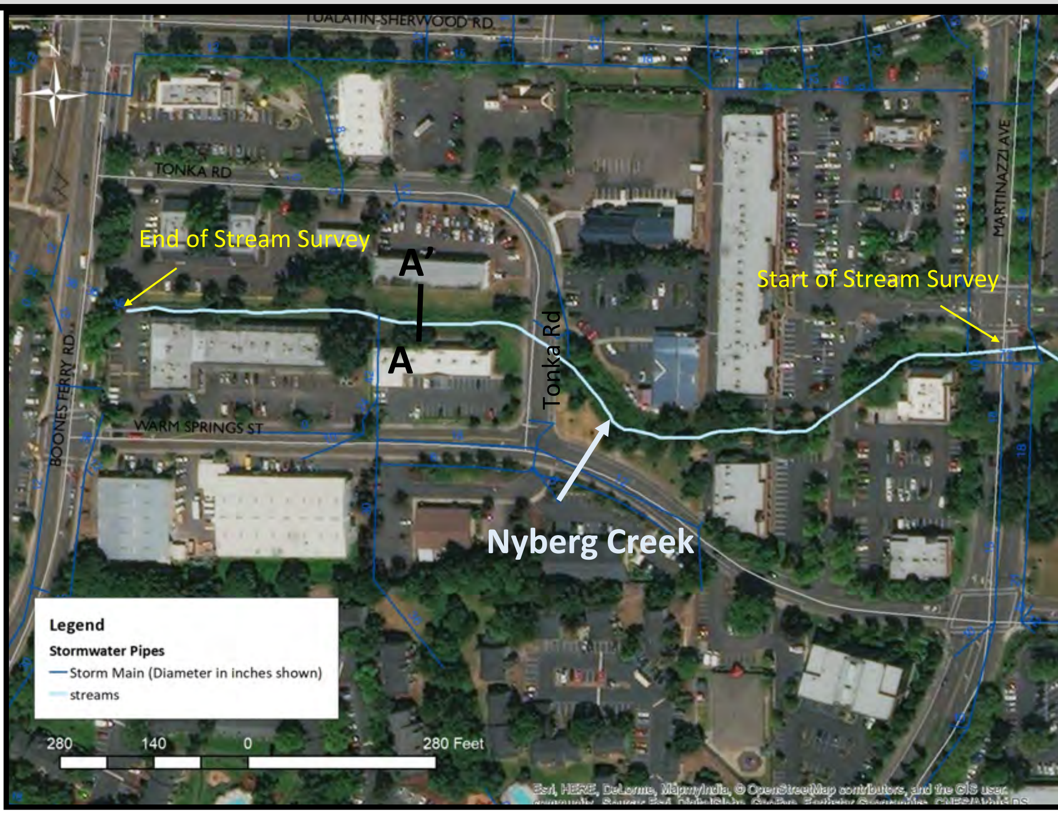
Reach Length:	~1,400 ft.
Gradient:	~0.29%
Valley Width:	~30-60’ (channel is confined by development)
Planform:	Straight, confined by development
Average BFW:	~6.5’
Average BFD:	~2.5’
Substrate:	Fine silt.
Vegetation:	Dominated by reed canary grass, few deciduous trees.
Beaver Activity:	No.
Issues:	No critical issues.

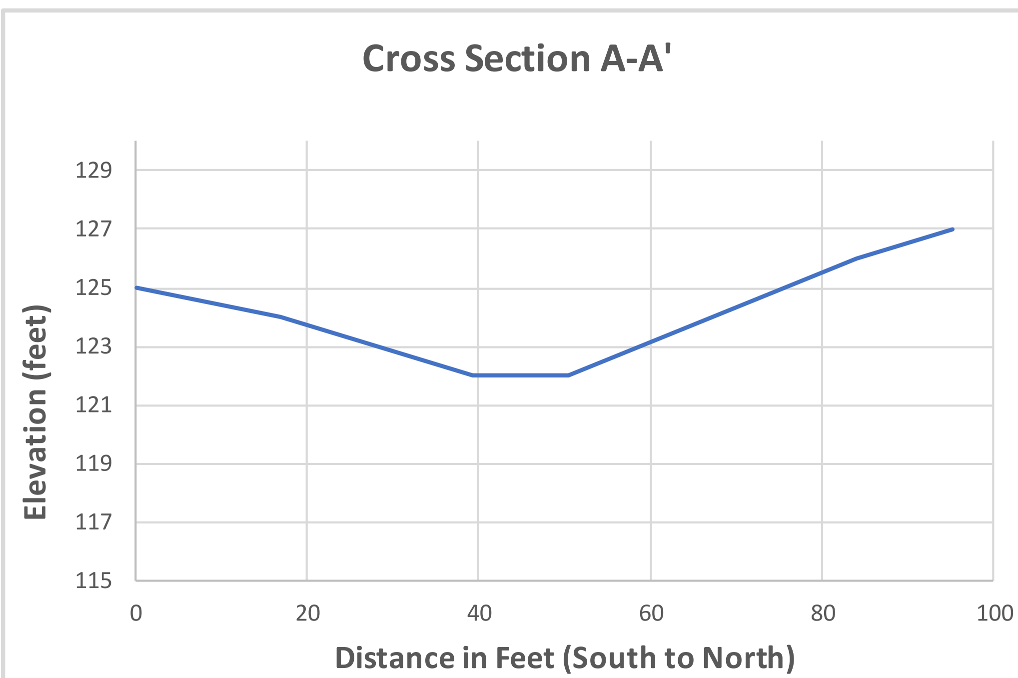
Aerial view of Nyberg Creek Reach #3 (Martinazzi Avenue to Boones Ferry Rd)

City of Tualatin

Stream Channel Condition Survey

Stream Reach Descriptions





Generalized topographic valley cross section of Nyberg Creek between Tonka Rd. and Boones Ferry Rd.

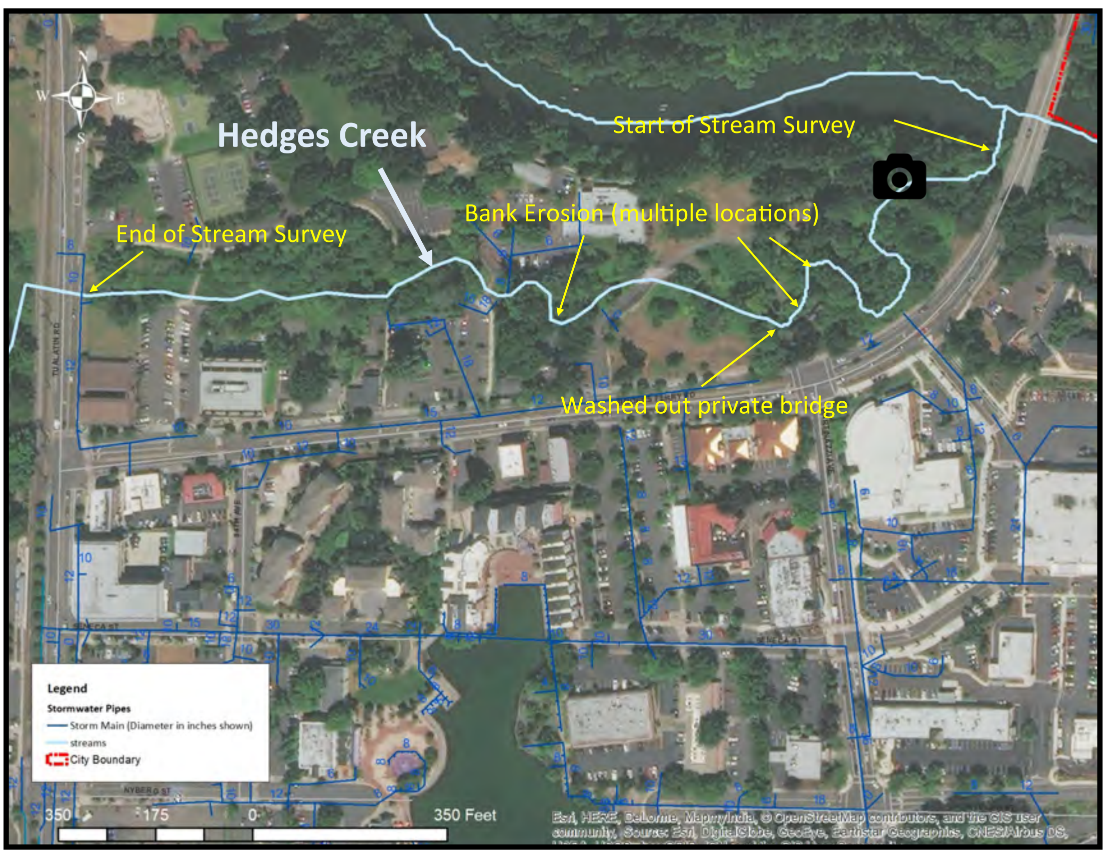
City of Tualatin
Stream Channel Condition Survey
Stream Reach Descriptions

Channel-spanning debris jam in Hedges Creek Reach #1 approx. 300’ upstream of Tualatin River (photo location shown below with camera icon)

Stream	Hedges Creek
Reach	#1 (Tualatin River to Tualatin Rd)

General Characteristics

Reach Length:	~2,250 ft.
Gradient:	~0.8%
Valley Width:	~75-125’
Planform:	Meandering and straight, where confined
Average BFW:	~11.5’ (wider near Tualatin, channel narrows upstream)
Average BFD:	~4.2’
Substrate:	Varies. Gravel and large rocks near mouth, hard silt in straight sections.
Vegetation:	Conifer and deciduous trees in lower section, reed canary grass, nettles, blackberries.
Beaver Activity:	Yes, upper half of reach.
Issues:	Bank erosion near private property. Washed out private bridge. No City issues.

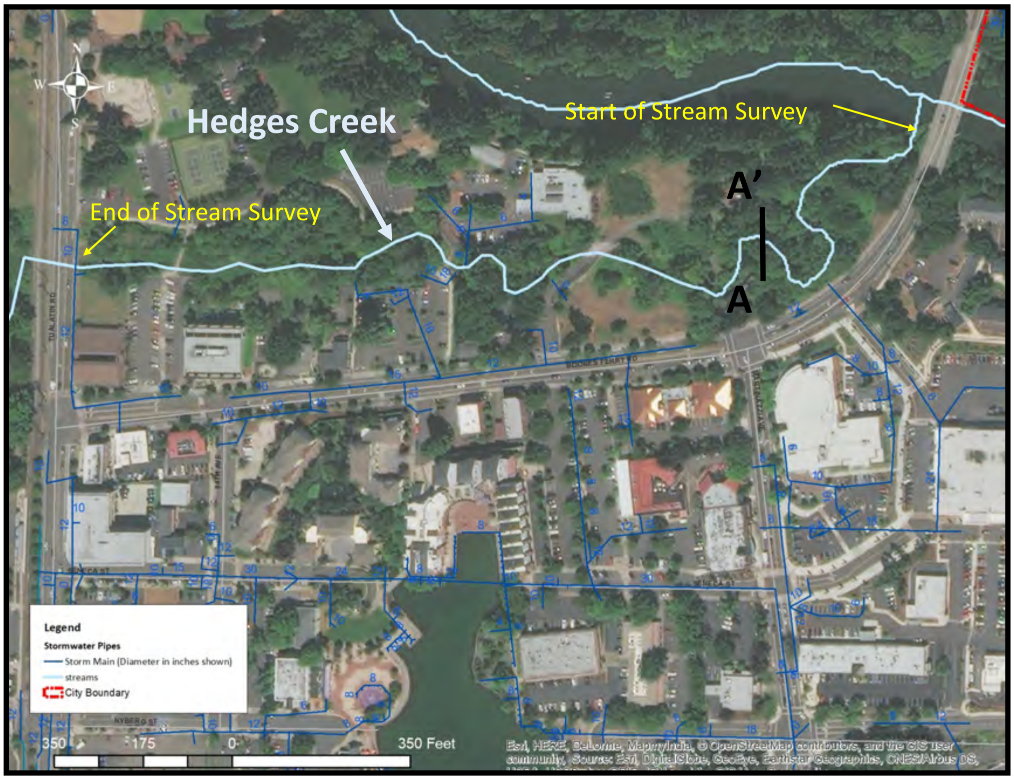


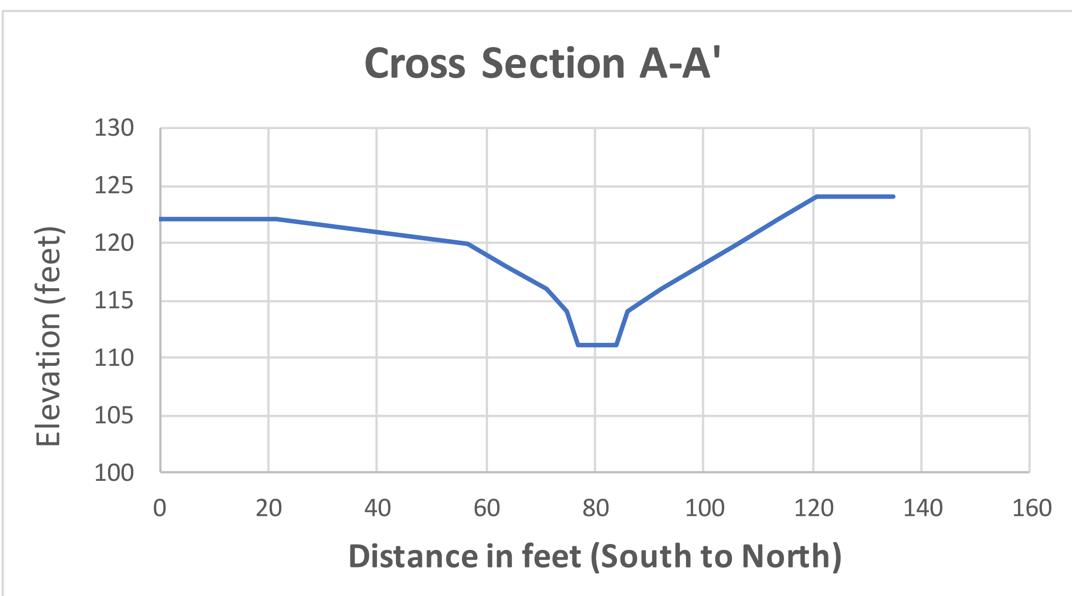
Aerial view of Hedges Creek Reach #1 (Tualatin River to Tualatin Rd.)

City of Tualatin

Stream Channel Condition Survey

Stream Reach Descriptions





Generalized topographic valley cross section of Hedges Creek Reach #1.

City of Tualatin
Stream Channel Condition Survey
Stream Reach Descriptions

Typical photo of Hedges Creek Reach #2. Stream channel is overgrown with invasive vegetation. Channel is to the right and 4’ below Ryan (standing on the bank). Photo location shown below with camera icon.

Stream Hedges Creek

Reach #2 (Tualatin-Sherwood Rd. to Industrial Way)

General Characteristics

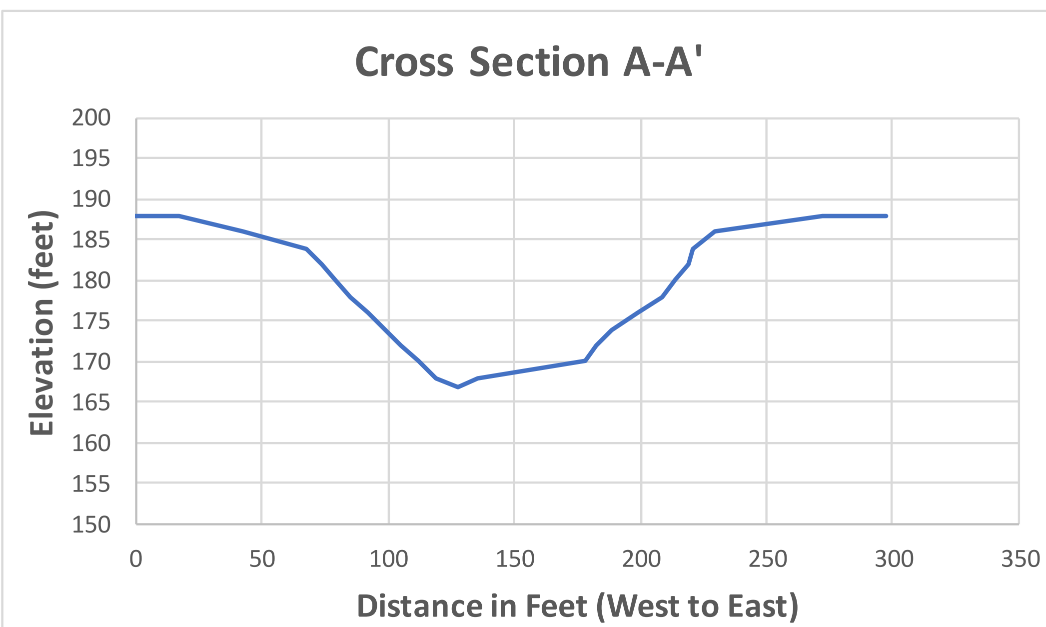
Reach Length:	~1,900 ft.
Gradient:	~0.2%
Valley Width:	~125-250’
Planform:	Meandering
Average BFW:	~11.5’
Average BFD:	~4.3’
Substrate:	Clay, hard silt.
Vegetation:	Reed canary, blackberries, nightshade, jewel weed, some deciduous and conifer trees.
Beaver Activity:	Yes, one beaver dam noted.
Issues:	Invasive vegetation.

Aerial view of Hedges Creek Reach #2 (Tualatin-Sherwood Rd to Industrial Way)

City of Tualatin

Stream Channel Condition Survey

Stream Reach Descriptions



Generalized topographic valley cross section of Hedges Creek Reach #2.

City of Tualatin
Stream Channel Condition Survey
Stream Reach Descriptions

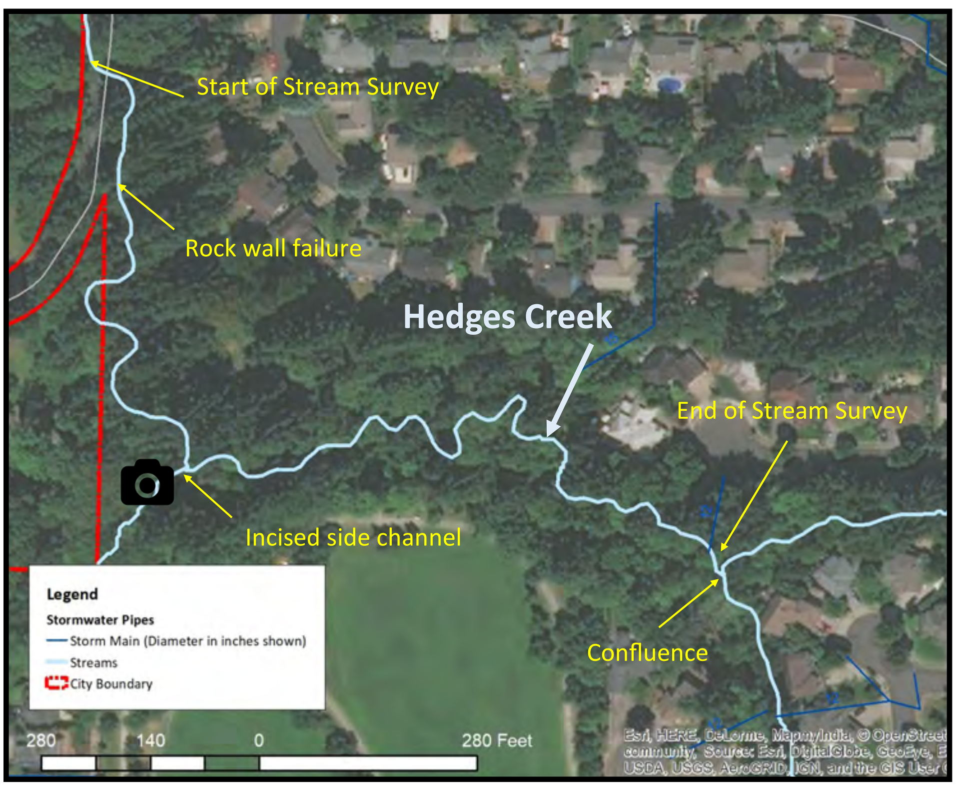
Incised side channel of Hedges Creek. Photo location shown below with camera icon.

Stream Hedges Creek

Reach #3A (Blake St/105th St to Confluence with S. Tributary)

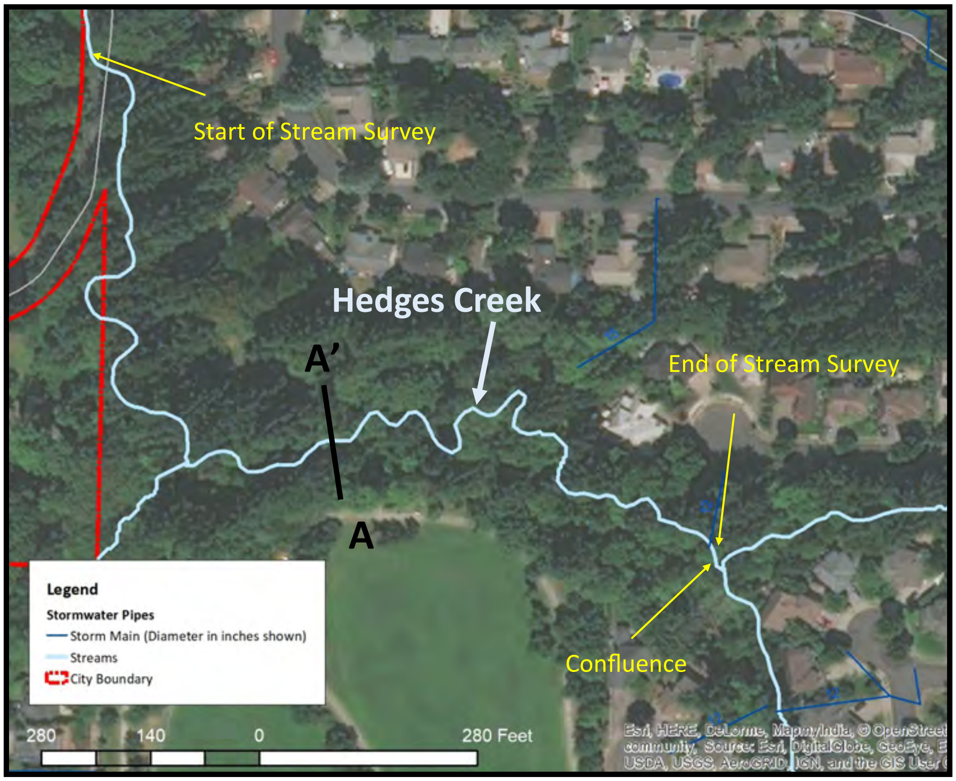
General Characteristics

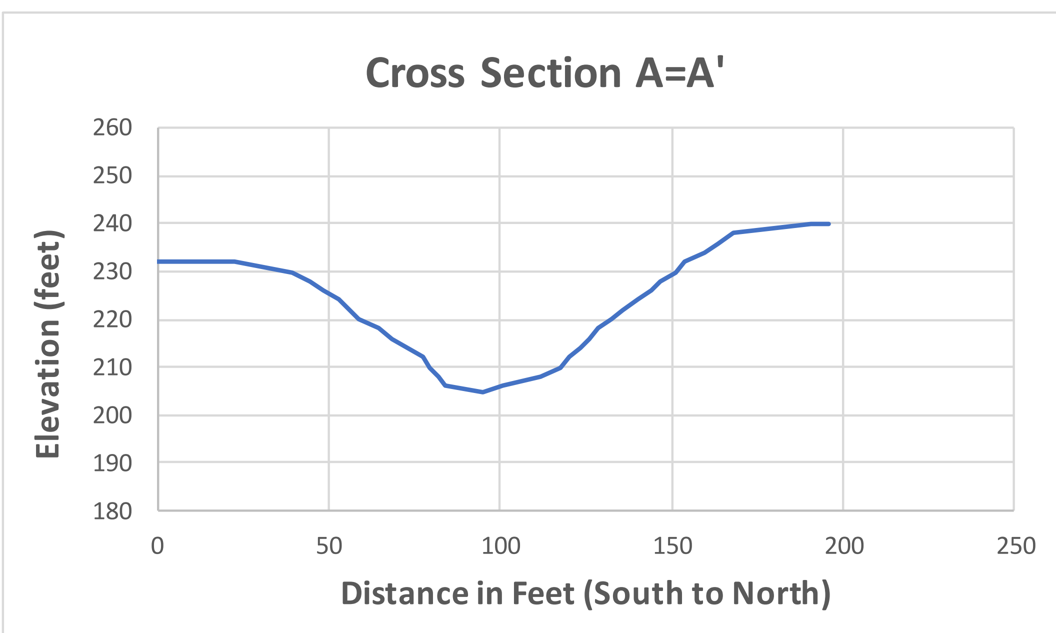
Reach Length:	~1,740 ft.
Gradient:	~0.9 %
Valley Width:	~50-150’
Planform:	Meandering and straight (where steep and confined)
Average BFW:	~10.5’
Average BFD:	~3.6’
Substrate:	Varies. Hard silt, bedrock, gravel, and loose silt.
Vegetation:	Conifer and deciduous trees, reed canary grass, nettles, blackberries.
Beaver Activity:	None observed.
Issues:	Channel incision adjacent to sanitary sewer manhole, and bank erosion and rock wall failure adjacent to Blake St./105th St.



Aerial view of Hedges Creek Reach #3 (Blake St/105th St to Confluence with S. Tributary)

City of Tualatin
Stream Channel Condition Survey
Stream Reach Descriptions





Generalized topographic valley cross section of Hedges Creek Reach #3 downstream of confluence.

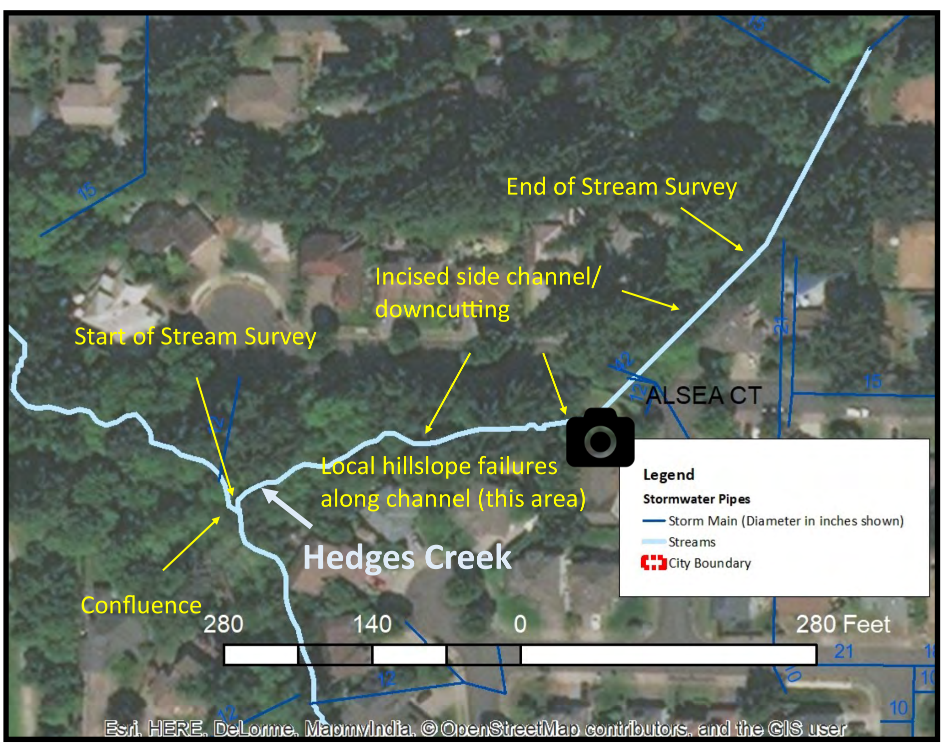
City of Tualatin
Stream Channel Condition Survey
Stream Reach Descriptions

Unstable hillslope and debris in channel. Photo Location shown below with camera icon.

Stream	Hedges Creek
Reach	#3B (Confluence with S. Tributary to SW 99th Ave)

General Characteristics

Reach Length:	~560 ft.
Gradient:	~3.7%
Valley Width:	~50-150’
Planform:	Straight
Average BFW:	5.5’
Average BFD:	2.8’
Substrate:	Varies. Hard silt, gravel, and loose silt.
Vegetation:	Conifer and deciduous trees, reed canary grass, nettles, blackberries.
Beaver Activity:	None observed.
Issues:	Extreme erosion/channel downcutting in proximity to private property, and hillslope failures.

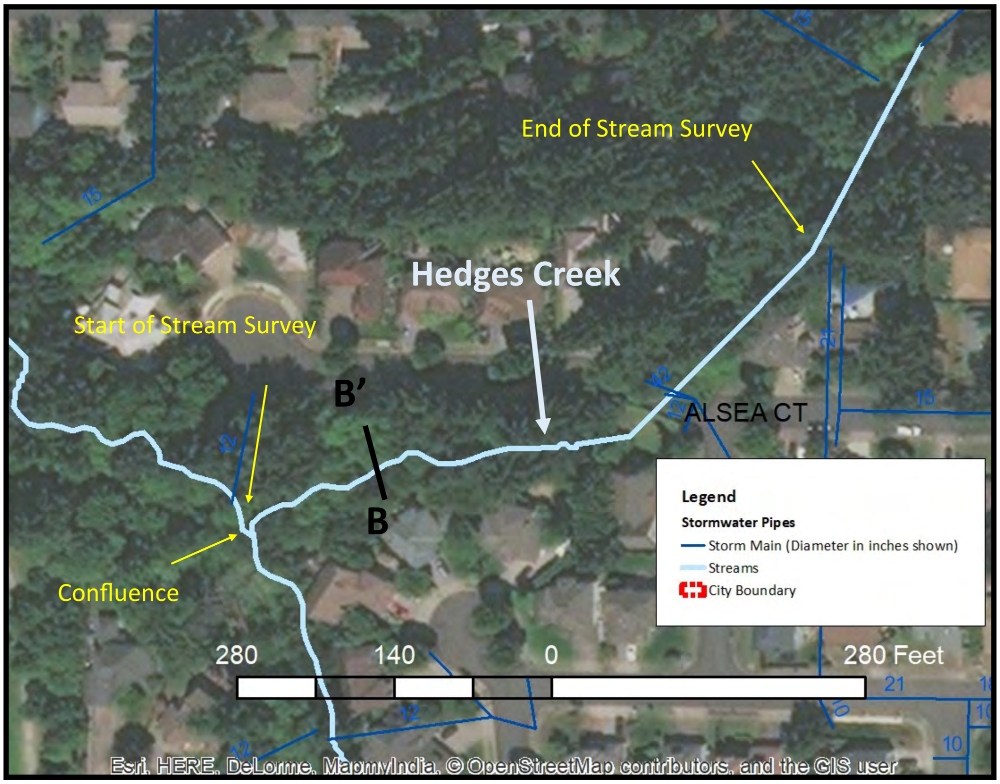


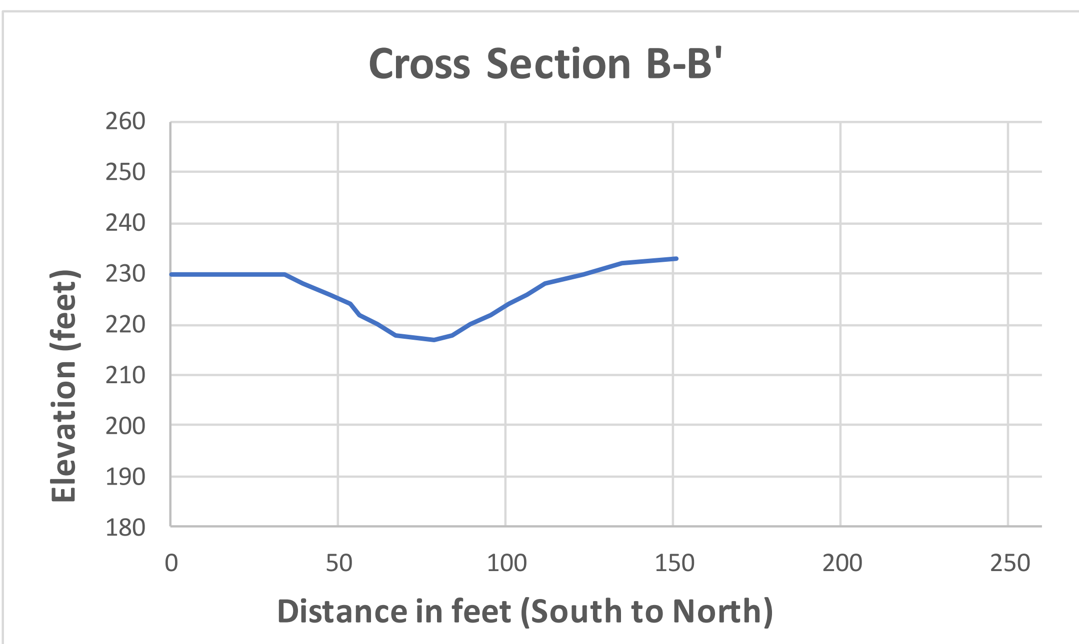
Aerial view of Hedges Creek Reach #3B (Confluence with S. Tributary to SW 99th Avenue)

City of Tualatin

Stream Channel Condition Survey

Stream Reach Descriptions





Generalized topographic valley cross section of Hedges Creek Reach #3 upstream of confluence.

AltaTerra

Attachment B-1

Saum Creek Reach #1 Photo Log

Attachment B-1

Photo Documentation

Saum Creek Reach #1 (Tualatin River from mouth to SW Prosperity Park Rd.)

Photographs and descriptions of the field investigation (by site) are provided on the following pages. Photographs are shown in the order that the stream survey was conducted, from the most downstream point in the reach to the most upstream point in the reach. In general, photos were taken in the upstream direction, except where noted. Photographs are labeled with a unique identifier that includes photograph number and stream reach identification. Photographs in Saum Creek Reach #1 are identified as S1-X, with X being the number of the photograph. Photo locations are shown in Figure 1.

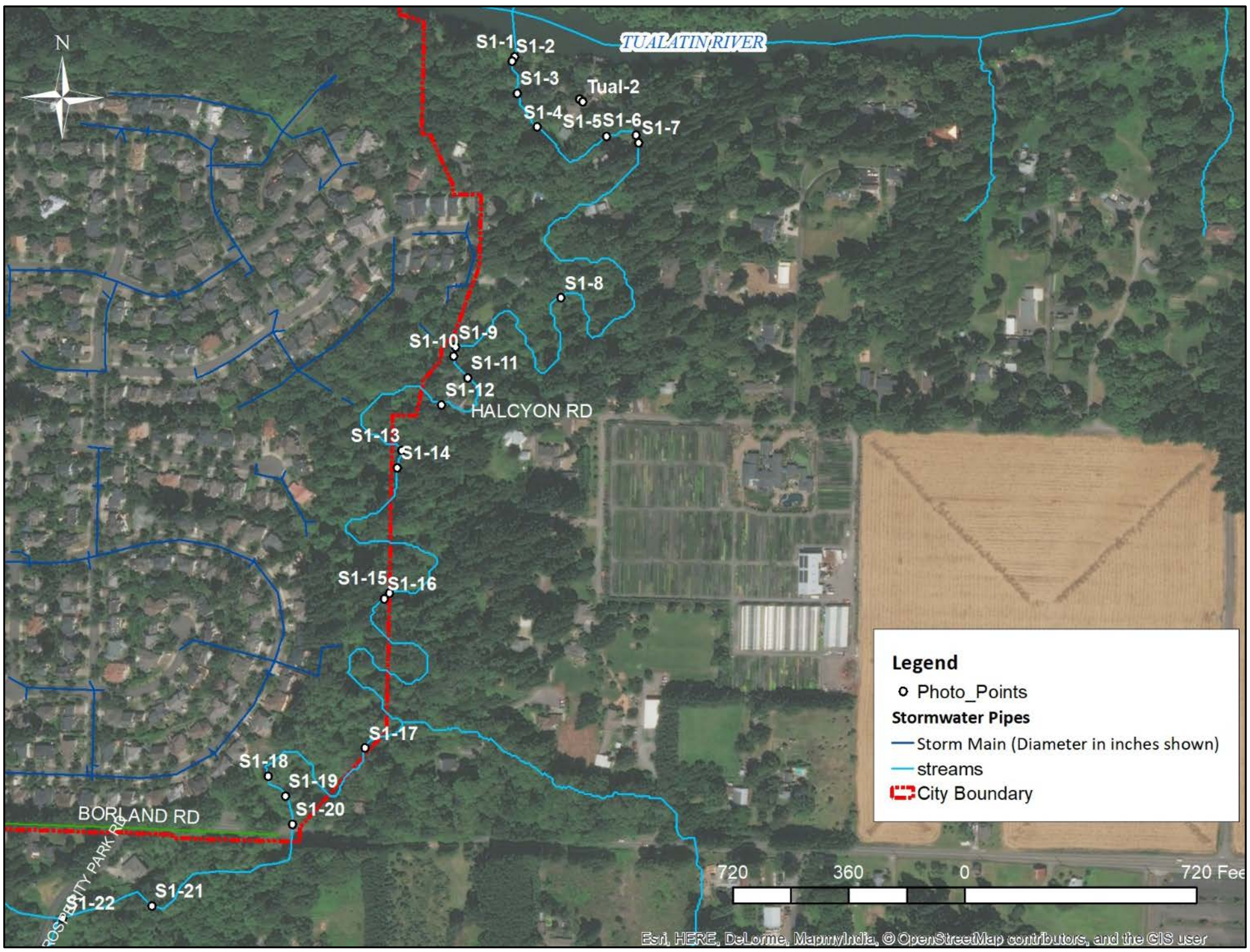


Figure 1. Saum Creek Reach #1 Photo Location Points

AltaTerra

Site location: Near Tualatin River

Photo number: Tual-1

Description: Flood marker on utility pole (1996 flood). Red arrow shows marker location.

Site location: Near Tualatin

Photo number: Tual-2

Description: View of utility pole with flood marker (1996 flood). Red arrow shows marker location.

Site location:	Tualatin River
Photo number:	S1-1
Description:	Tualatin River from mouth of Saum Creek- looking north

Site location:	30' upstream
Photo number:	S1-2
Description:	7' high vertical bank (right bank) unstable, bamboo

Site location: ~200’ upstream from Tualatin

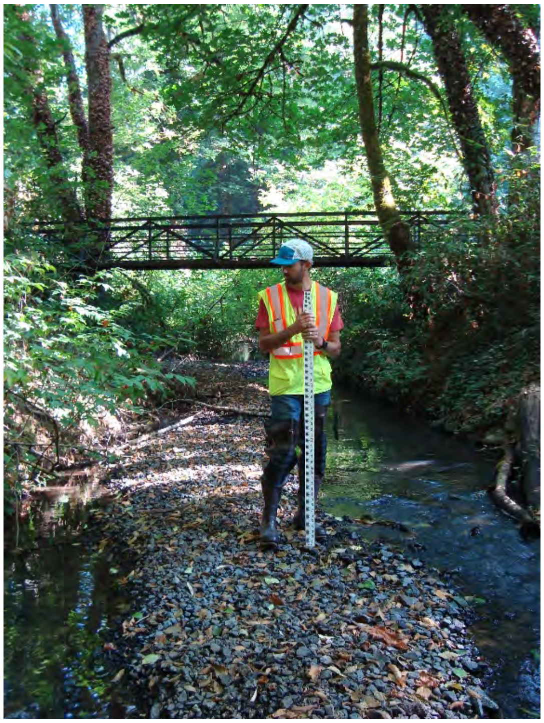
Photo number: S1-3

Description: Former bridge abutment, looking upstream at left bank

Site location: ~400’ upstream from Tualatin River

Photo number: S1-4

Description: Corrugated steel pipe (former water intake?) on left bank



Site location: ~750' upstream from Tualatin

Photo number: S1-5

Description: Gravel deposition in bed (angular rock, construction debris?), pedestrian bridge in background, looking upstream

Site location: ~800' upstream of Tualatin

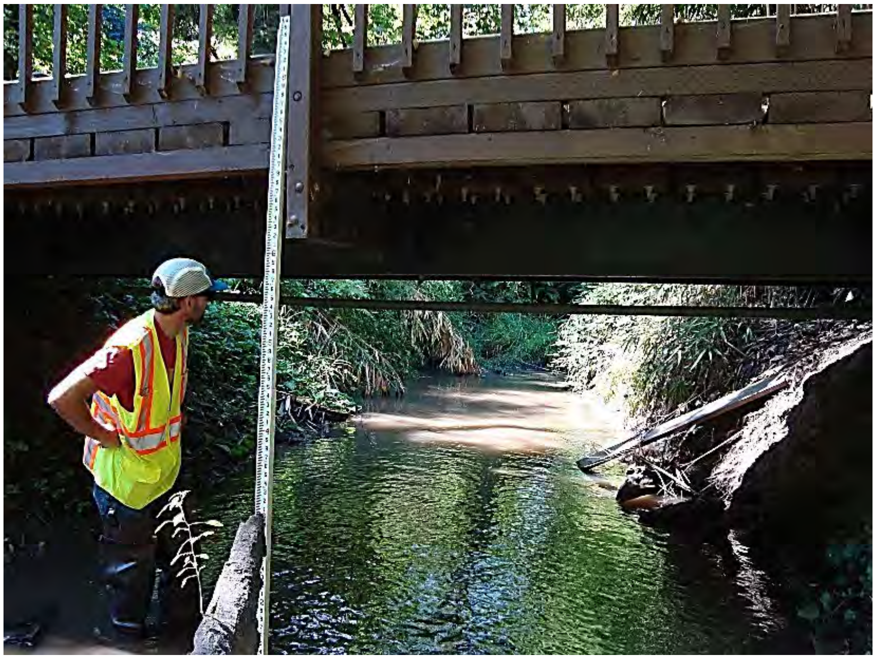
Photo number: S1-6

Description: Private driveway culvert crossing (6'), looking upstream

	
Site location:	~850' upstream of Tualatin, 20' upstream of culvert
Photo number:	S1-7
Description:	Old 3' high concrete weir wall (2 ½' wide opening) with pool on downstream end. Weir is leaning downstream and sediment has deposited behind it on upstream side.
	
Site location:	~800' downstream of SW Halcyon Rd. culvert crossing
Photo number:	S1-8
Description:	Silty bottom, water depth 1 ½' – 2', bankfull width ~ 12', bankfull depth ~ 6'

Site location:	SW Halcyon Rd. culvert crossing
Photo number:	S1-9
Description:	Looking upstream- twin 6' culverts, plunge pool on downstream end

Site location:	20' upstream of SW Halycon Rd. crossing
Photo number:	S1-10
Description:	Channel looking downstream



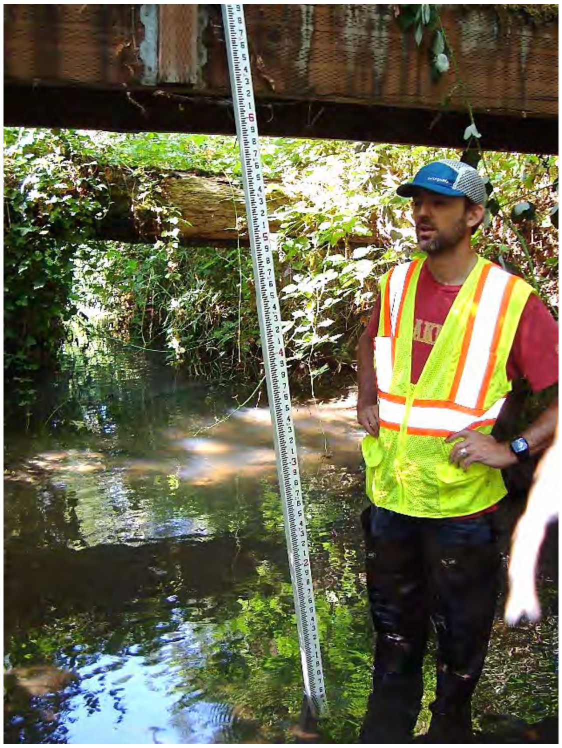
Site location:	Driveway bridge ~150' upstream of SW Halcyon Rd.
Photo number:	S1-11
Description:	Looking downstream

Site location:	~300' upstream of SW Halycon Rd.
Photo number:	S1-12
Description:	Looking upstream at pedestrian bridge, large wood in channel in distance

Site location:	800' upstream from SW Halcyon Rd.
Photo number:	S1-13
Description:	Slightly more gravel in channel in this reach

Site location:	850' upstream from SW Halcyon Rd.
Photo number:	S1-14
Description:	Looking upstream at beaver dam, debris on branches (high water mark near Ryan's right hand ~4.5 feet above channel bed)

Site location:	~1,200' downstream from SW Borland Rd.
Photo number:	S1-15
Description:	Pedestrian bridge looking upstream, silty bed



Site location:	~1,200' downstream from SW Borland Rd.
Photo number:	S1-16
Description:	Pedestrian bridge looking downstream, large tree down across channel in distance

		Site location: Photo number: Description:	~700' downstream of SW Borland Rd. S1-17 Beaver dam, ivy-covered trees in distance, looking upstream
		Site location: Photo number: Description:	300' downstream of SW Borland Rd. S1-18 Riprap left bank outside bend

Site location: 150' downstream of SW Borland Rd.
Photo number: S1-19
Description: Left bank slump, seepage, wetland plants observed in vicinity

Site location: SW Borland Rd. culvert
Photo number: S1-20
Description: Looking upstream (10 1/2 'high, 10' wide)

Site location: 600' upstream of SW Borland Rd.
Photo number: S1-21
Description: Broken pipe (right side of photo) on left bank, looking upstream

Site location: SW Prosperity Park Rd culverts
Photo number: S1-22
Description: Looking upstream at twin 36" culverts

AltaTerra

Attachment B-2

Saum Creek Reach #2 Photo Log

Attachment B-2

Photo Documentation

Saum Creek Reach #2 (SW Lee Street to SW 65th Avenue)

Photographs and descriptions of the field investigation (by site) are provided on the following pages. Photographs are shown in the order that the stream survey was conducted, from the most downstream point in the reach to the most upstream point in the reach. In general, photos were taken in the upstream direction, except where noted. Photographs are labeled with a unique identifier that includes photograph number and stream reach identification. Photographs in Saum Creek Reach #2 are identified as S2-X, with X being the number of the photograph. Photo locations are shown in Figure 1.

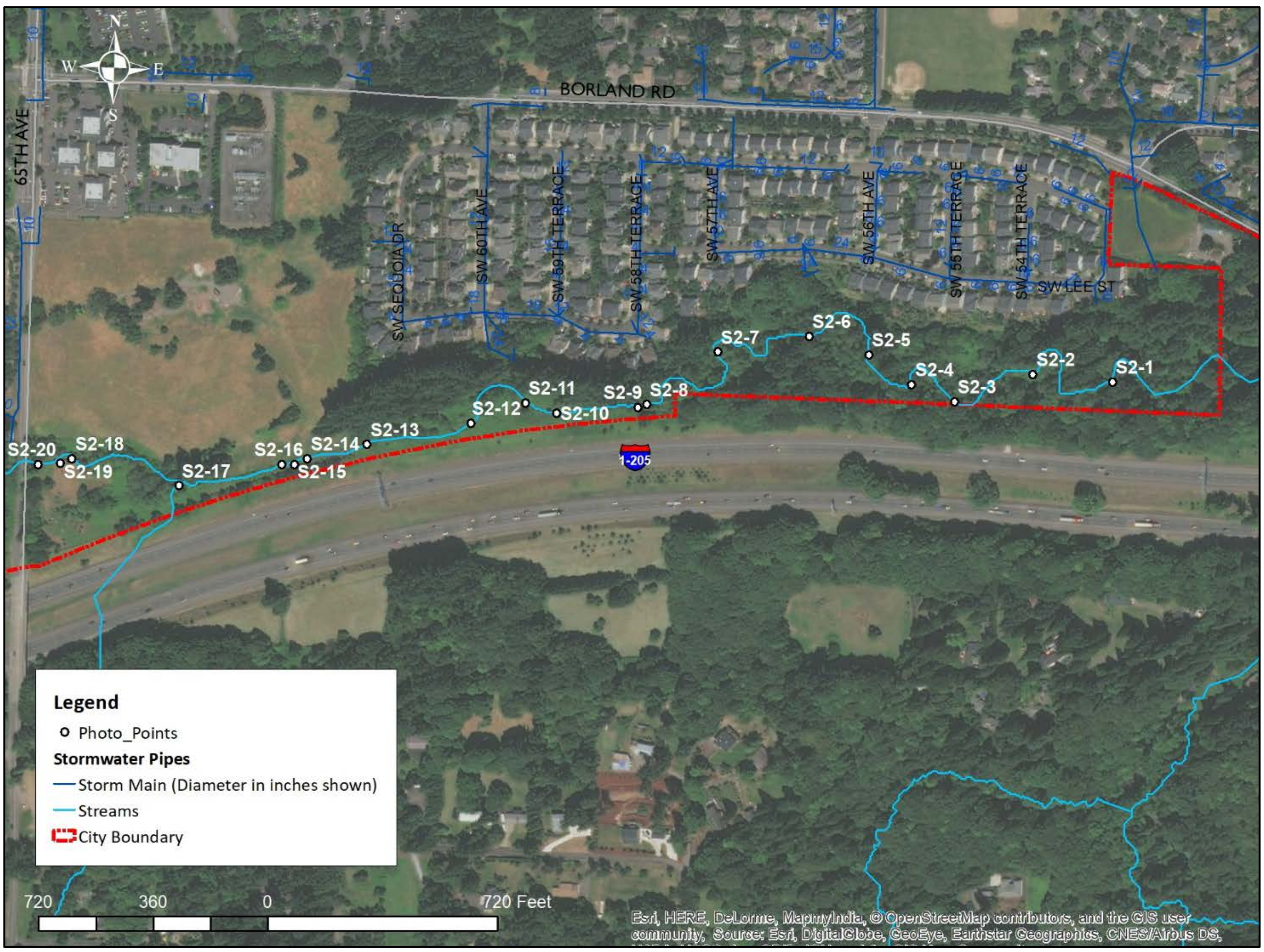


Figure 1. Saum Creek Reach #2 Photo Location Points

Site location: 50' upstream of SW Lee St. (starting location)

Photo number: S2-1

Description: Hard silt on bottom of channel, creates riffles, looking upstream

Site location: South of SW 45th Terrace

Photo number: S2-2

Description: Looking upstream

Site location:	South of SW 55th Terrace
Photo number:	S2-3
Description:	Wide floodplain bench left bank (right side of photo)

Site location:	Between SW 55th and SW 56th, near I-205
Photo number:	S2-4
Description:	Channel spanning debris blockage, ~4' above channel bed, looking south and upstream

Site location: South of SW 56th

Photo number: S2-5

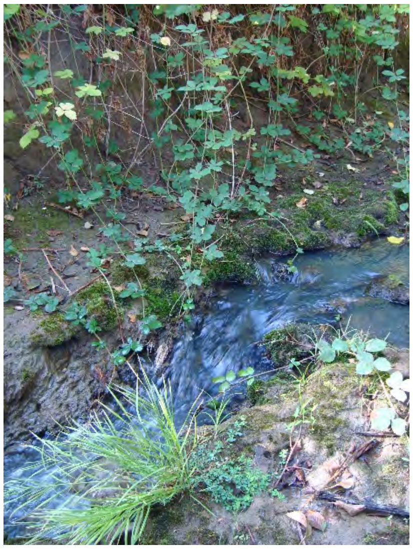
Description: Looking upstream, facing north, cedar tree on left bank appears to shade out invasive plants

Site location: Between SW 56th and SW 57th

Photo number: S2-6

Description: Hard silt creates pool/drop sequence in channel, small riffles

Site location:	South of SW 57th
Photo number:	S2-7
Description:	Looking upstream at debris in channel and associated bank erosion on edges



Site location:	South of SW 58th, near trail project under construction
Photo number:	S2-8
Description:	Looking downstream, hard clay unit in bed, slight knick point in channel, minor incision just upstream of debris jam

Site location:	South of SW 58th, near trail project under construction
Photo number:	S2-9
Description:	Looking upstream- same location as Photo S2-8

Site location:	South of SW 59th
Photo number:	S2-10
Description:	Location of 12” steel pipe in channel disconnected from vertical segment. Some gravel in channel at this location.

Site location:	Upstream of Photo S2-10
Photo number:	S2-11
Description:	Groundwater seepage on right bank

Site location:	South of Sequoia Drive
Photo number:	S2-12
Description:	Debris jam

Site location: 1200' east of SW 65th Ave.

Photo number: S2-13

Description: Fence, looking west

Site location: 1000' east of SW 65th Ave.

Photo number: S2-14

Description: Mitigation site on right bank (I-205 side), left side of photo. Red arrow shows channel location.

Site location: 1000' east of SW 65th Ave.

Photo number: S2-15

Description: Looking east (downstream) at mitigation site. Red arrow shows channel location.

Site location: 1000' east of SW 65th Ave.

Photo number: S2-16

Description: Looking north at construction site across channel

Site location: 600' east of SW 65th Ave.

Photo number: S2-17

Description: Right bank swale on west side of mitigation area.

Site location: 100' east of SW 65th Ave.

Photo number: S2-18

Description: Debris jam looking downstream

Site location: 100’ east of SW 65th Ave

Photo number: S2-19

Description: Looking upstream from same location as Photo S2-18. Gravel in channel at this point.

Site location: SW 65th Ave. crossing

Photo number: S2-20

Description: Looking upstream at pool on downstream side of SW 65th Ave.

Attachment B-3

Saum Creek Reach #3 Photo Log

Attachment B-3

Photo Documentation

Saum Creek Reach #3 (Vicinity of SW Blake St.)

Photographs and descriptions of the field investigation (by site) are provided on the following pages. Photographs are shown in the order that the stream survey was conducted, from the most downstream point in the reach to the most upstream point in the reach. In general, photos were taken in the upstream direction, except where noted. Photographs are labeled with a unique identifier that includes photograph number and stream reach identification. Photographs in Saum Creek Reach #3 are identified as S3-X, with X being the number of the photograph. Photo locations are shown in Figure 1.

Figure 1. Saum Creek Reach #3 Photo Location Points

Site location:	Downstream of SW Blake St.
Photo number:	S3-1
Description:	Looking down at valley bottom from above. Red arrow indicates location of channel.

Site location:	Downstream of SW Blake St.
Photo number:	S3-2
Description:	Hillslope failure and perched culvert

Site location: Downstream of SW Blake St.

Photo number: S3-3

Description: Perched culvert- hillslope failure on left bank

Site location: Upstream of SW Blake St. crossing

Photo number: S3-4

Description: Beginning of restoration area, very wet

Site location:	~80' upstream of SW Blake St.
Photo number:	S3-5
Description:	Looking upstream, mucky conditions

Site location:	~130' upstream of SW Blake St.
Photo number:	S3-6
Description:	Looking downstream, swale on right bank, rock on outside bend (near stadia- obscured by vegetation)

Site location: ~300' upstream of SW Blake St.

Photo number: S3-7

Description: Constructed rock drop pool (restoration)

Site location: ~350' upstream of SW Blake St.

Photo number: S3-8

Description: Constructed rock pool

AltaTerra

Attachment B-4

Nyberg Creek Reach #1 Photo Log

Attachment B-4

Photo Documentation

Nyberg Creek Reach #1 (SW Nyberg Lane to SW 65th Ave.)

Photographs and descriptions of the field investigation (by site) are provided on the following pages. Photographs are shown in the order that the stream survey was conducted, from the most downstream point in the reach to the most upstream point in the reach. In general, photos were taken in the upstream direction, except where noted. Photographs are labeled with a unique identifier that includes photograph number and stream reach identification. Photographs in Nyberg Creek Reach #1 are identified as N1-X, with X being the number of the photograph. Photo locations are shown in Figure 1.

Figure 1. Nyberg Creek Reach #1 Photo Location Points

Site location: South side of SW Nyberg Lane
Photo number: N1-1
Description: Ponded area adjacent to Nyberg Creek upstream of SW Nyberg Lane

Site location: Upstream side of SW Nyberg Lane
Photo number: N1-2
Description: Nyberg Creek where it flows under SW Nyberg Lane through three 48” culverts

Site location: Upstream side of SW Nyberg Lane

Photo number: N1-3

Description: Looking downstream at culverts, same location as Photo N1-2

Site location: 200' upstream from SW Nyberg Lane

Photo number: N1-4

Description: Old roadbed. Stream is in 30" CMP culvert under road.

Site location: 250' upstream of SW Nyberg Lane

Photo number: N1-5

Description: Deep, narrow main channel, flow is spread-out in multiple paths across wetland area

Site location: 400' upstream of SW Nyberg Lane

Photo number: N1-6

Description: Looking downstream at top of beaver dam. Red arrow points to top of dam. Drop is approximately 3 feet.

Site location:	450’ upstream of SW Nyberg Lane
Photo number:	N1-7
Description:	Recently removed beaver debris

Site location:	300’ downstream of SW 65th Ave.
Photo number:	N1-8
Description:	Looking upstream at ponded area. Red arrow shows location of SW 65th Ave.

Site location: 100’ downstream of SW 65th Ave.
Photo number: N1-9
Description: Upstream end of ponded area

Site location: Nyberg Creek on downstream side of SW 65th Ave.
Photo number: N1-10
Description: Same view as Photo N1-9

Site location: Nyberg Creek on downstream side of SW 65th Ave.

Photo number: N1-11

Description: Photo taken from left bank (north side) on 9/12. Additional debris was removed between 9/11 and 9/12. See photo N1-12 for comparison.

Site location: Nyberg Creek on downstream side of SW 65th Ave (east side)

Photo number: N1-12

Description: Photo taken from south side on 9/11. Red arrow shows debris removed from beaver activity.

Attachment B-5

Nyberg Creek Reach #2 Photo Log

Attachment B-5

Photo Documentation

Nyberg Creek Reach #2 (Downstream of I-5, wetland area)

Photographs and descriptions of the field investigation (by site) are provided on the following pages. Photographs are shown in the order that the stream survey was conducted, from the most downstream point in the reach to the most upstream point in the reach. In general, photos were taken in the upstream direction, except where noted. Photographs are labeled with a unique identifier that includes photograph number and stream reach identification. Photographs in Nyberg Creek Reach #2 are identified as N2-X, with X being the number of the photograph. Photo locations are shown in Figure 1.

Figure 1. Nyberg Creek Reach #2 Photo Location Points

Site location:	South of 7-11, West of SW 65th Ave.
Photo number:	N2-1
Description:	Nyberg Creek Wetlands

Site location:	Business park between Nyberg wetlands and SW Nyberg St.
Photo number:	N2-2
Description:	Ponded area shown indicated by red arrow.

Site location:	Nyberg Wetlands, downstream side of beaver dam
Photo number:	N2-3
Description:	Staff gauge in ponded area

Site location:	South of business park
Photo number:	N2-4
Description:	Constructed channel opening on north side of beaver dam (shown by red dashed lines)

Site location:	Downstream side of beaver dam
Photo number:	N2-5
Description:	Dam extends the entire length of valley bottom, creating a ~3 – 4' drop

Site location:	Ponded area downstream of I-5
Photo number:	N2-6
Description:	Baby beaver in foreground

Attachment B-6

Nyberg Creek Reach #3 Photo Log

Attachment B-6

Photo Documentation

Nyberg Creek Reach #3 (SW SW Martinazzi Ave. Ave. to SW Boones Ferry Rd.)

Photographs and descriptions of the field investigation (by site) are provided on the following pages. Photographs are shown in the order that the stream survey was conducted, from the most downstream point in the reach to the most upstream point in the reach. In general, photos were taken in the upstream direction, except where noted. Photographs are labeled with a unique identifier that includes photograph number and stream reach identification. Photographs in Nyberg Creek Reach #3 are identified as N3-X, with X being the number of the photograph. Photo locations are shown in Figure 1.

Figure 1. Nyberg Creek Reach #3 Photo Location Points

Site location:	East side of SW SW Martinazzi Ave.
Photo number:	N3-1
Description:	Looking downstream of SW Martinazzi Ave. where 48-inch diameter stormwater pipe enters Nyberg Creek (approximately where red arrow is pointing)

Site location:	Upstream of SW Martinazzi Ave. by Shari's restaurant
Photo number:	N3-2
Description:	Nyberg Creek, concrete dam with notch

Site location: ~200' upstream of SW Martinazzi Ave.

Photo number: N3-3

Description: Culvert next to Shari's restaurant in parking lot (indicated by red arrow)

Site location: ~300' upstream from SW Martinazzi Ave.

Photo number: N3-4

Description: Looking at the upstream end of the culvert next to Shari's restaurant (shown by red arrow)

Site location:	~350' upstream from SW Martinazzi Ave.
Photo number:	N3-5
Description:	Looking downstream from footbridge at upstream end of parking lot culvert (obscured by reed canary grass)

Site location:	SW Tonka Rd. bridge
Photo number:	N3-6
Description:	Looking in downstream direction

Site location:	~400' downstream of SW Boones Ferry Rd.
Photo number:	N3-7
Description:	Looking upstream, narrow channel

Site location:	~200' downstream of SW Boones Ferry Rd.
Photo number:	N3-8
Description:	42" outfall on south side of channel (1/2 full)

Site location: 100’ downstream of SW Boones Ferry Rd.

Photo number: N3-9

Description: Looking upstream at narrow channel. Grass has been cut on north side.

Site location: SW Boones Ferry Rd.

Photo number: N3-10

Description: Culverts entering Nyberg Creek from SW Boones Ferry Rd.

Attachment B-7

Hedges Creek Reach #1 Photo Log

Attachment B-7

Photo Documentation

Hedges Creek Reach #1 (Tualatin River to SW Tualatin Rd.)

Photographs and descriptions of the field investigation (by site) are provided on the following pages. Photographs are shown in the order that the stream survey was conducted, from the most downstream point in the reach to the most upstream point in the reach. In general, photos were taken in the upstream direction, except where noted. Photographs are labeled with a unique identifier that includes photograph number and stream reach identification. Photographs in Hedges Creek Reach #1 are identified as H1-X, with X being the number of the photograph. Photo locations are shown in Figure 1

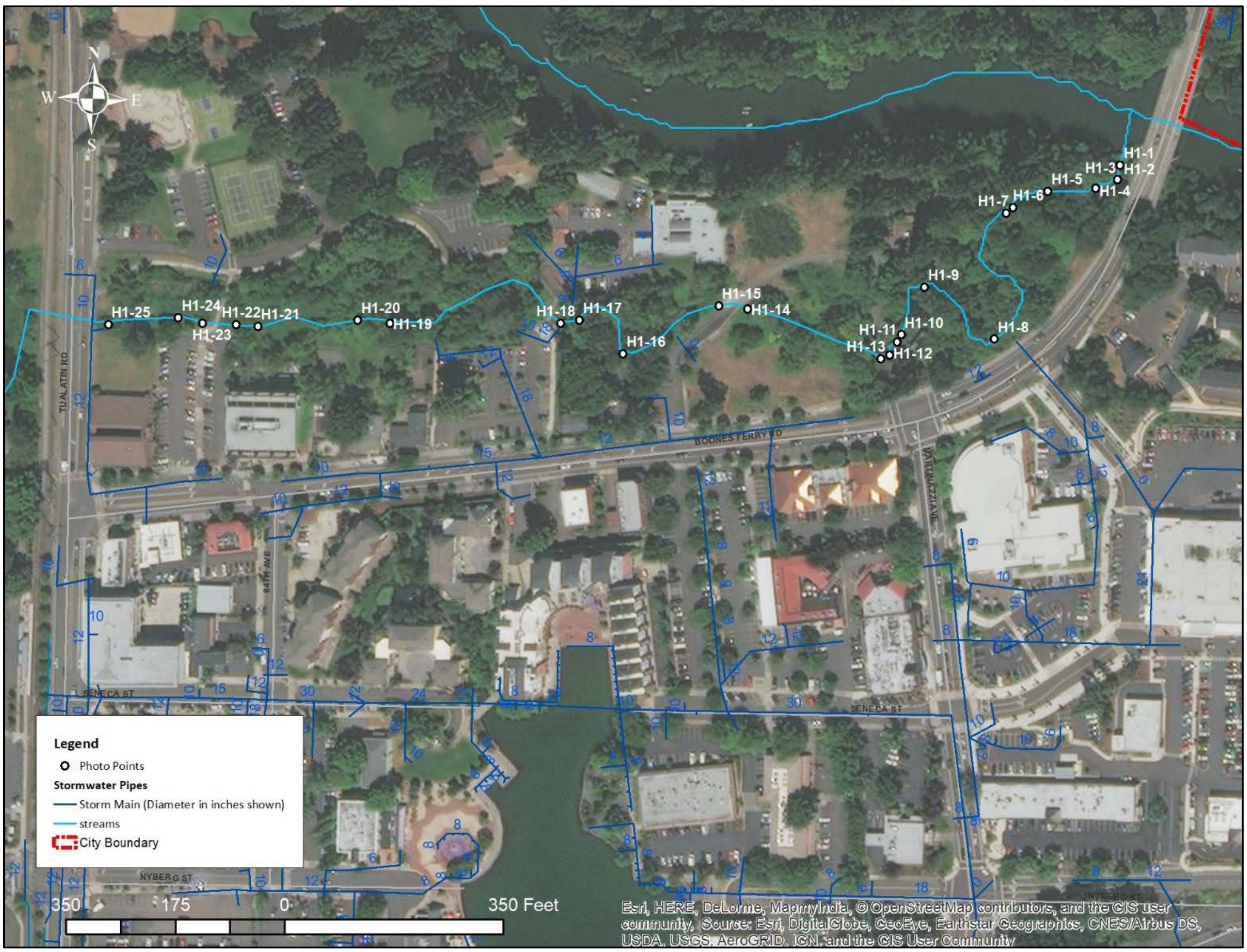


Figure 1. Hedges Creek Reach #1 Photo Location Points

Waterbody:	**Hedges Creek Reach #1**
Reach description:	
Site locations:	**Tualatin River to Tualatin Road**

Site location: Mouth of Hedges Creek below Boones Ferry Road bridge at Tualatin River

Photo number: H1-1

Description: 3" to 1.5' rocks in channel (rip-rap stabilization)

Site location: 30' upstream of Tualatin River

Photo number: H1-2

Description: 1' – 2' rocks in channel, high water mark on bridge abutment corresponds to about 6' above channel bed in this location, steep gradient to mouth

Site location:	100' upstream of Tualatin River
Photo number:	H1-3
Description:	Lots of silt in channel, gradient flattens

Site location:	150' upstream of Tualatin River
Photo number:	H1-4
Description:	Looking upstream, right bank erosion, downed trees, slumping on right bank

Site location:	200' upstream of Tualatin River
Photo number:	H1-5
Description:	Concrete poured in channel from left bank

Site location:	300' upstream of Tualatin River
Photo number:	H1-6
Description:	Looking upstream, gravel deposit in center of channel below channel-spanning debris jam

Site location: 300' upstream of Tualatin River

Photo number: H1-7

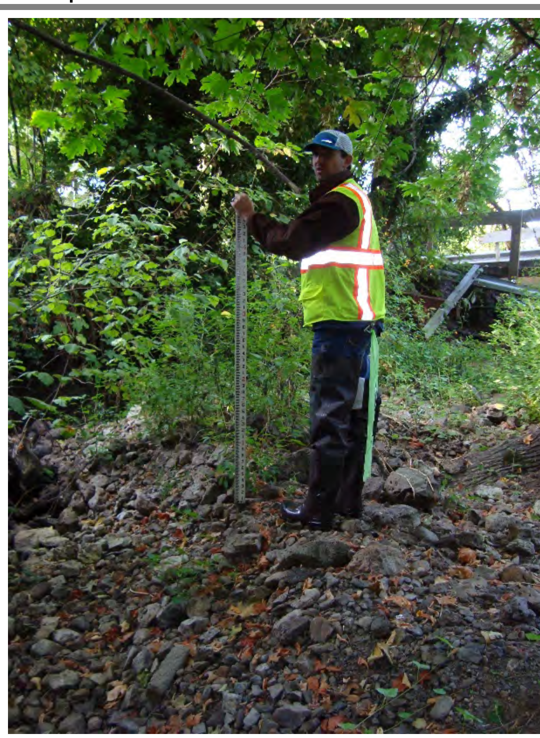
Description: Looking downstream at debris jam, Ryan is touching water line (?) pipe across debris

Site location: 350' upstream of Tualatin River

Photo number: H1-8

Description: Looking upstream at outside bend (adjacent to SW Boones Ferry Road)

Site location: 450' upstream of Tualatin River
Photo number: H1-9
Description: Looking upstream, bank armoring on left bank (right side of photo)



Site location: 500' upstream of Tualatin River (near SW Martinazzi Avenue)
Photo number: H1-10
Description: Debris deposited downstream of washed out driveway bridge

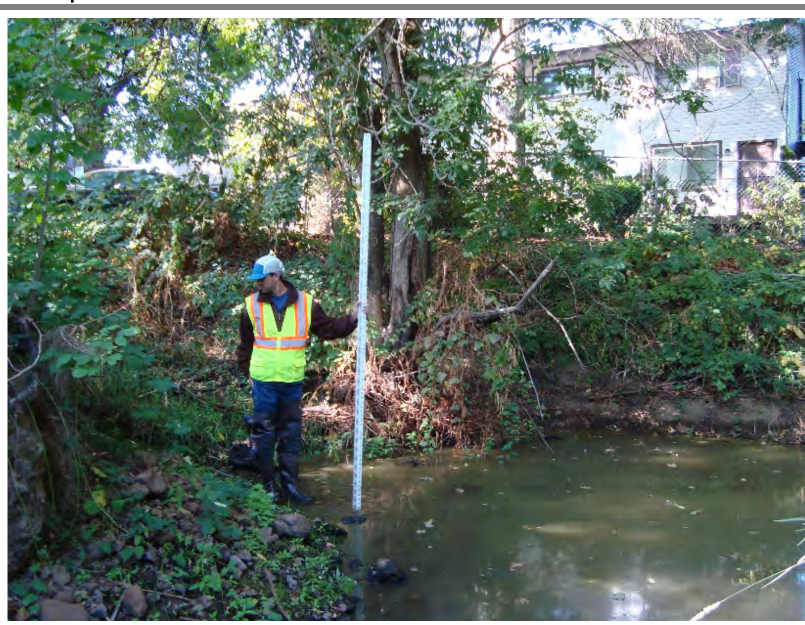
Site location:	500' upstream of Tualatin River
Photo number:	H1-11
Description:	Looking downstream at debris and creek, right bank (outside bend) is downstream of culvert constriction (washed out) where flow is concentrated. This area is vulnerable to erosion.

Site location:	500' upstream of Tualatin River
Photo number:	H1-12
Description:	Looking upstream at culvert under washed out bridge amongst debris that has not been removed

Site location:	500' upstream of Tualatin River
Photo number:	H1-13
Description:	Channel upstream of washed out bridge, stagnant water. Flow is restricted by debris and washed out culvert.

Site location:	800' upstream of Tualatin River
Photo number:	H1-14
Description:	Looking east (downstream) from new bridge.

Site location:	800' east of Tualatin River
Photo number:	H1-15
Description:	Looking west (upstream) from new bridge.



Site location:	1,000' upstream of Tualatin River
Photo number:	H1-16
Description:	Old culvert (where Ryan is standing), photo is looking upstream at outside bend where stream takes a sharp turn to the north

Site location: 1,200' upstream of Tualatin River

Photo number: H1-17

Description: Tualatin-Greenway bridge, channel choked with reed canary grass

Site location: 1,200' upstream of Tualatin River

Photo number: H1-18

Description: Same location as photo H1-17. 18" diameter stormwater pipe enters channel on right bank where stadia rod is pointed.

Site location: 1400' upstream of Tualatin River

Photo number: H1-19

Description: Looking upstream at reed canary grass choked channel.

Site location: 1450' upstream of Tualatin River

Photo number: H1-20

Description: Beaver dam looking upstream, wider floodplain west of this location (open space).

Site location: 1,500’ upstream of Tualatin River

Photo number: H1-21

Description: Looking downstream in open space area.

Site location: 200’ downstream of SW Tualatin Road

Photo number: H1-22

Description: Pedestrian bridge in wetland area downstream of SW Tualatin Road.

Site location:	200' downstream of SW Tualatin Road
Photo number:	H1-23
Description:	Looking upstream from pedestrian bridge at pooled water in wetland area east of SW Tualatin Road.

Site location:	200' downstream of SW Tualatin Road
Photo number:	H1-24
Description:	Wetland area from pedestrian bridge

Site location:	SW Boones Ferry Road
Photo number:	H1-25
Description:	Looking upstream at culvert under SW Boones Ferry Road

Attachment B-8

Hedges Creek Reach #2 Photo Log

Attachment B-8

Photo Documentation

Hedges Creek Reach #2 (SW Tualatin-Sherwood Rd. to SW Industrial Way)

Photographs and descriptions of the field investigation (by site) are provided on the following pages. Photographs are shown in the order that the stream survey was conducted, from the most downstream point in the reach to the most upstream point in the reach. In general, photos were taken in the upstream direction, except where noted. Photographs are labeled with a unique identifier that includes photograph number and stream reach identification. Photographs in Hedges Creek Reach #2 are identified as H2-X, with X being the number of the photograph. Photo locations are shown in Figure 1.

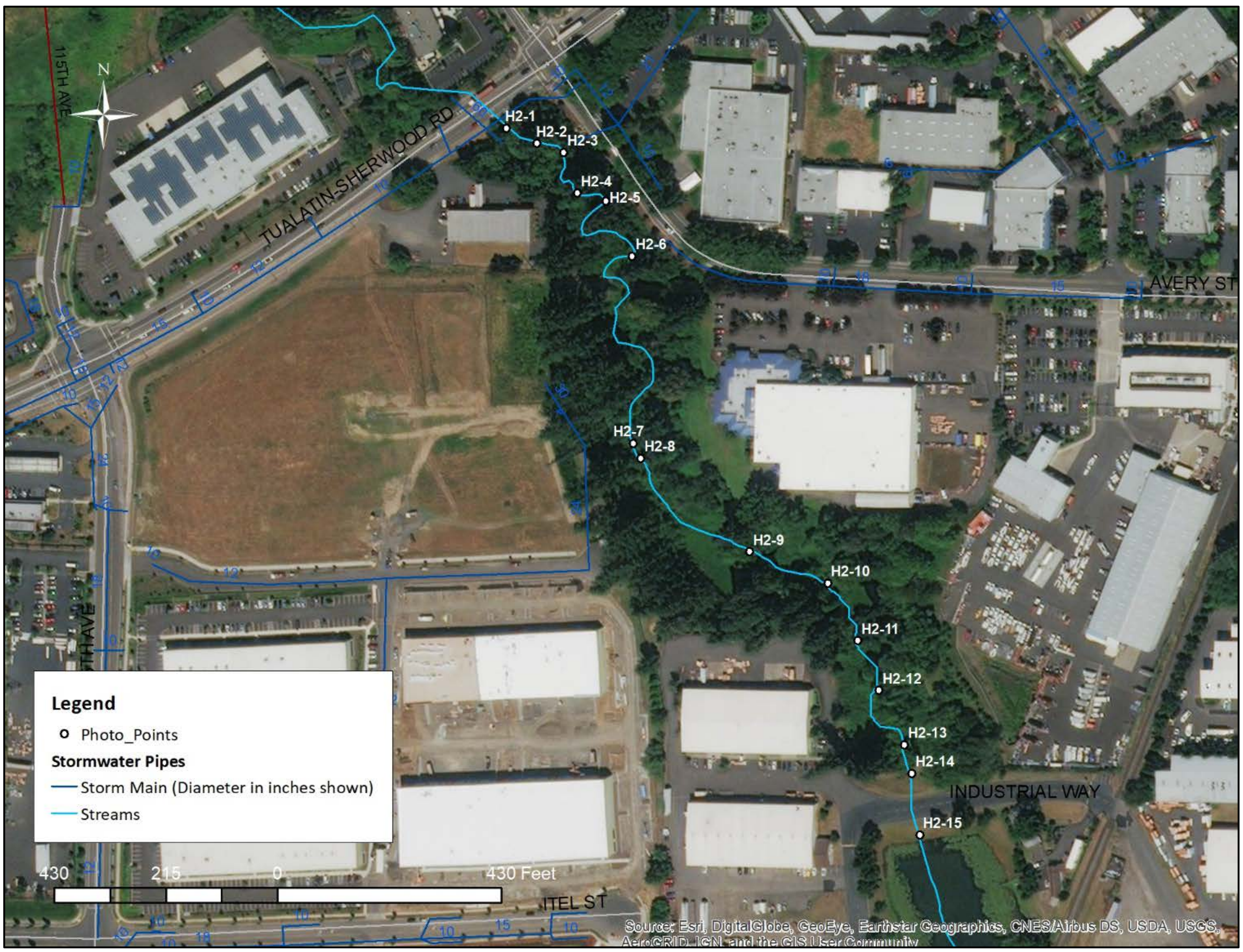


Figure 1. Hedges Creek Reach #2 Photo Location Points

Site location:	Culvert at SW Tualatin-Sherwood Road
Photo number:	H2-1
Description:	Armored channel with rip-rap, looking downstream

Site location:	100' upstream of SW Tualatin-Sherwood Road
Photo number:	H2-2
Description:	Staff gauge in channel

Site location: 200' upstream of SW Tualatin-Sherwood Road

Photo number: H2-3

Description: Right bank outfall

Site location: 400' upstream of SW Tualatin-Sherwood Rd.

Photo number: H2-4

Description: Looking upstream, wide floodplain, banks 4- 5' high, width ~ 8 – 10 ', hard silt bed

Site location:	500' upstream of SW Tualatin-Sherwood Road
Photo number:	H2-5
Description:	Debris on branches above channel (~4') indicating high water mark (red arrow)

Site location:	600' upstream of SW Tualatin-Sherwood Road
Photo number:	H2-6
Description:	Erosion on outside bend (right bank)

Site location: 650' upstream of SW Tualatin-Sherwood Road

Photo number: H2-7

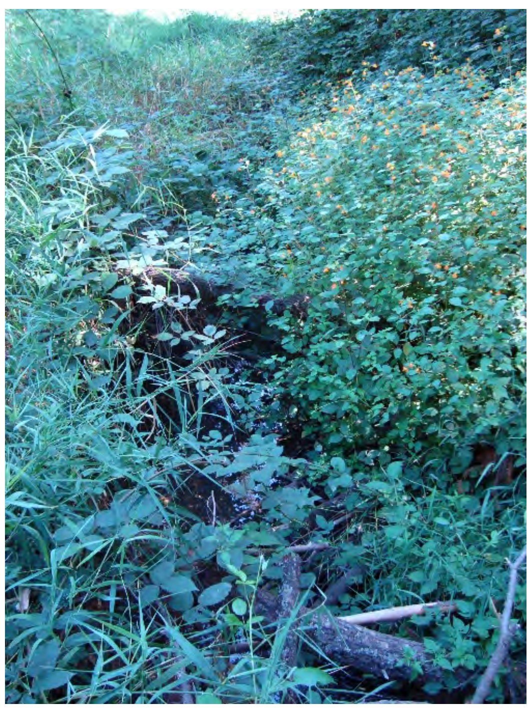
Description: Channel location from top of bank (4' depth). Enveloped with blackberries and reed canary grass.

Site location: 700' upstream of SW Tualatin-Sherwood Road

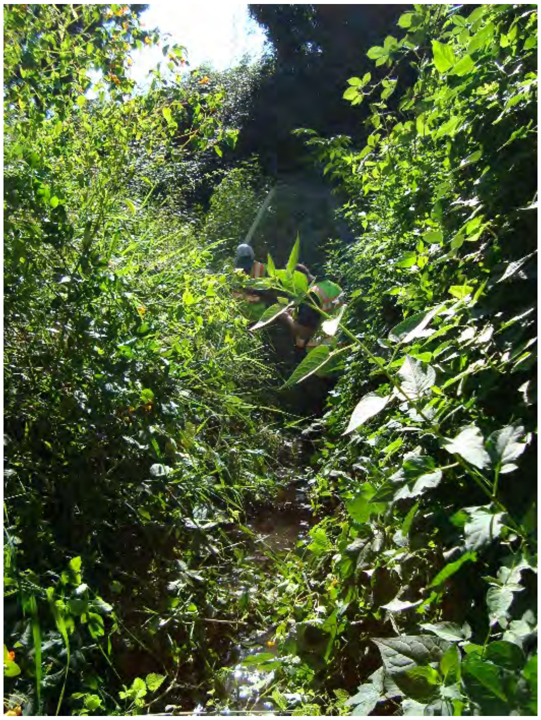
Photo number: H2-8

Description: Looking upstream

Site location:	900' upstream of SW Tualatin-Sherwood Road
Photo number:	H2-9
Description:	Looking upstream, exposed roots in channel. Left bank debris (high water ~4')



Site location:	1000' upstream of SW Tualatin-Sherwood Road
Photo number:	H2-10
Description:	Looking upstream, wide floodplain



Site location:	1200' upstream of SW Tualatin-Sherwood Road
Photo number:	H2-11
Description:	Hard silt layer in channel

Site location:	1300' upstream of SW Tualatin-Sherwood
Photo number:	H2-12
Description:	Right bank erosion (red arrow)

Site location:	100' downstream from SW Industrial Way
Photo number:	H2-13
Description:	Rock drop pool formed by rip-rap energy dissipation at culvert outfall

Site location:	Culvert at SW Industrial Way
Photo number:	H2-14
Description:	Looking down from right bank

Site location: Upstream side of SW Industrial Way

Photo number: H2-15

Description: Fire pond #1 in-line with Hedges Creek

Attachment B-9

Hedges Creek Reach #3A Photo Log

Attachment B-9

Photo Documentation

Hedges Creek Reach #3A (SW 105th Avenue/SW Blake St. to Confluence with S. Tributary)

Photographs and descriptions of the field investigation (by site) are provided on the following pages. Photographs are shown in the order that the stream survey was conducted, from the most downstream point in the reach to the most upstream point in the reach. In general, photos were taken in the upstream direction, except where noted. Photographs are labeled with a unique identifier that includes photograph number and stream reach identification. Photographs in Hedges Creek Reach #3 are identified as H3-X, with X being the number of the photograph. Photo locations are shown in Figure 1.

Hedges Creek Reach #3 was broken into two sub-reaches, #3A and #3B, to more effectively describe the unique characteristics that occur upstream and downstream of the confluence of a tributary that enters the main channel from the south downstream of SW Alsea Ct. The photos do not have a sub-reach qualifier in their name, but rather are labeled sequentially from the most downstream location to upstream location, in a similar manner to the other stream reaches assessed.

Figure 1. Hedges Creek Reach #3A Photo Location Points

Site location:	Culvert under SW 105th Ave (downstream side)
Photo number:	H3-1
Description:	Looking upstream at SW 105th Ave. culvert crossing from west side of SW 105th Ave.

Site location:	Culvert at SW 105th Ave. (upstream side)
Photo number:	H3-2
Description:	Looking downstream at SW 105th Ave. culvert crossing from east side of SW 105th Ave.

Site location:	30' upstream of SW 105th Ave.
Photo number:	H3-3
Description:	Right bank hillslope failures, wetland plants growing on slope (wet)

Site location:	150' upstream of SW 105th Ave.
Photo number:	H3-4
Description:	Rock wall on left bank adjacent to roadway fill

Site location: 175' upstream of SW 105th Ave.

Photo number: H3-5

Description: Left bank failure, missing wall segment adjacent to SW 105th Ave., outside bend

Site location: 500' upstream of SW 105th Ave.

Photo number: H3-6

Description: Bedrock outcrop in channel

Site location:	550' upstream of SW 105th Ave.
Photo number:	H3-7
Description:	Looking upstream, bedrock channel

Site location:	600' upstream of SW 105th Ave.
Photo number:	H3-8
Description:	Seepage on left bank, 2' above channel

Site location: 700' upstream of SW 105th Ave.

Photo number: H3-9

Description: Incised side channel on left bank, looking upstream from confluence

Site location: 750' upstream of SW 105th Ave.

Photo number: H3-10

Description: Side channel, left bank, deep incision, looking downstream

Site location: 750' upstream of SW 105th Ave.

Photo number: H3-11

Description: Side channel, adjacent to sewer manhole being eroded by channel. Manhole is 15' from start of headcut (erosion)

Site location: 750' upstream of SW 105th Ave.

Photo number: H3-12

Description: Main channel, looking upstream

Site location: 800' upstream of SW 105th Ave.
Photo number: H3-13
Description: Looking downstream at outside bend, eroding left bank

Site location: 900' upstream of SW 105th Ave.
Photo number: H3-14
Description: Outside bend erosion

Site location: 950' upstream of SW 105th Ave.

Photo number: H3-15

Description: Restoration area, looking downstream. Left bank root wads, right bank anchored log

Site location: 1100' upstream of SW 105th Ave.

Photo number: H3-16

Description: Right bank slope failure, very wet

Site location:	1300' upstream of SW 105th Ave.
Photo number:	H3-17
Description:	Rock in channel, moved downstream from upstream restoration project

Site location:	1350' upstream of SW 105th Ave.
Photo number:	H3-18
Description:	Bed protection and erosion fabric (restoration area)

Site location:	1350' upstream of SW 105th Ave.
Photo number:	H3-19
Description:	Looking downstream at restoration area

Site location:	400' downstream from confluence with S. Tributary
Photo number:	H3-20
Description:	Looking upstream, flow is coming in from right bank (very small channel not visible from left side of photo), stagnant water in this location

Site location:	Immediately downstream from confluence with S. Tributary
Photo number:	H3-21
Description:	Looking upstream, riprap

Site location:	Culvert crossing under trail
Photo number:	H3-22
Description:	Looking downstream, confluence with tributary from the south

Site location:	Confluence of mainstem with S. Tributary
Photo number:	H3-23
Description:	Looking upstream at south tributary

AltaTerra

Attachment B-10

Hedges Creek Reach #3B Photo Log

Attachment B-10

Photo Documentation

Hedges Creek Reach #3B (Confluence with S. Tributary to SW 99th Ave.)

Photographs and descriptions of the field investigation (by site) are provided on the following pages. Photographs are shown in the order that the stream survey was conducted, from the most downstream point in the reach to the most upstream point in the reach. In general, photos were taken in the upstream direction, except where noted. Photographs are labeled with a unique identifier that includes photograph number and stream reach identification. Photographs in Hedges Creek Reach #3 are identified as H3-X, with X being the number of the photograph. Photo locations are shown in Figure 1.

Hedges Creek Reach #3 was broken into two sub-reaches, #3A and #3B, to more effectively describe the unique characteristics that occur upstream and downstream of the confluence of a tributary that enters the main channel from the south downstream of SW Alsea Ct. The photos do not have a sub-reach qualifier in their name, but rather are labeled sequentially from the most downstream location to upstream location, in a similar manner to the other stream reaches assessed.

Figure 1. Hedges Creek Reach #3B Photo Location Points

Site location:	Immediately downstream from confluence with S. tributary
Photo number:	H3-21
Description:	Looking upstream, riprap

Site location:	Culvert crossing under trail
Photo number:	H3-22
Description:	Looking downstream, confluence with tributary from the south

Site location:	Confluence with S. tributary
Photo number:	H3-23
Description:	Looking upstream at south tributary

Site location:	300' upstream of confluence with S. tributary
Photo number:	H3-24
Description:	Looking upstream, hard silt in channel, incised

Site location:	500' upstream of confluence with S. tributary
Photo number:	H3-25
Description:	Left bank failure, incised channel, unstable

Site location:	600' upstream of confluence with S. tributary
Photo number:	H3-26
Description:	Left bank slumping

Site location:	650' upstream of confluence with S. tributary
Photo number:	H3-27
Description:	Left bank instability with concrete

Site location:	Culvert at SW Alsea Ct.
Photo number:	H3-28
Description:	Looking upstream, downstream of SW Alsea Ct.. Culvert is perched. No water.

Site location:	Culvert at SW Alsea Ct.
Photo number:	H3-29
Description:	Looking downstream, upstream of SW Alsea Ct. Dry channel.

Site location:	200' upstream of SW Alsea Ct.
Photo number:	H3-30
Description:	Looking upstream, narrow defined channel, dry

Site location: Culvert at 9999 SW Alsea Ct.

Photo number: H3-31

Description: Head cut below culvert, culvert is 6' above channel bottom (red arrow points to culvert)

Site location: Culvert at 9999 SW Alsea Ct.

Photo number: H3-32

Description: Plunge pool below culvert. Concrete apron below culvert indicated with red arrow.

Site location:	Culvert at 9999 SW Alsea Ct in the vicinity of SW 99th Ave.
Photo number:	H3-33
Description:	Looking downstream from upstream end of culvert. 18-inch culvert to left of 36-inch culvert.

Appendix G: CIP Detailed Cost Estimates

CIP Cost Summary

CIP ID	Project Title	Capital Expense Total (including contingency)	Engineering and Permitting	Administration	Other fees (studies, mitigation)	Capital Project Implementation Cost Total	Priority Projects (per City)		SDC Eligability[b]	SDC Percentage	SDC Eligible Cost
1	Manhassat Storm System Improvements	$1,171,000	$293,000	$117,000		$1,581,000		$0	100%	15%	$ 237,000.00
2	Nyberg Creek Stormwater Improvements - Phase I	$1,051,000	$368,000	$105,000		$1,523,000	X	$1,523,000	100%	19%	$ 289,000.00
2	Nyberg Creek Stormwater Improvements - Phase 2	$863,000	$302,000	$86,000		$1,252,000		$0	100%	19%	$ 238,000.00
2	Nyberg Creek Stormwater Improvements - Phase 3	$472,000	$118,000	$47,000		$637,000		$0	100%	19%	$ 121,000.00
3	Sandalwood Water Quality Retrofit	$79,000	$20,000	$8,000		$107,000		$0	100%	23%	$ 25,000.00
4	Mohawk Apartments Stormwater Improvements	$218,000	$55,000	$22,000		$295,000		$0	100%	20%	$ 59,000.00
5	Herman Road Storm System	$758,000	$189,000	$76,000		$1,023,000	X	$1,023,000	100%	27%	$ 276,000.00
6	Blake St Culvert Replacement	$381,000	$133,000	$38,000		$552,000	X	$552,000	100%	22%	$ 121,000.00
7	Boones Ferry Railroad Conveyance Improvements	$356,000	$124,000	$36,000		$515,000		$0	100%	21%	$ 108,000.00
8	89th Avenue Water Quality Retrofit	$209,000	$31,000	$21,000		$262,000		$0	100%	0%	$ -
9	125th Court Water Quality Retrofit	$165,000	$25,000	$16,000		$206,000		$0	100%	36%	$ 74,000.00
10	93rd Avenue Green Street	$166,000	$42,000	$17,000		$224,000		$0	100%	0%	$ -
11	Juanita Pohl Water Quality Retrofit	$116,000	$29,000	$12,000		$156,000	X	$156,000	100%	0%	$ -
12	Community Park Water Quality Retrofit	$117,000	$29,000	$12,000		$158,000	X	$158,000	100%	0%	$ -
13	Water Quality Facility Restoration - Venetia	$52,000	$8,000	$5,000		$65,000	X	$65,000	0%	23%	$ -
14	Water Quality Facility Restoration - Piute Court	$83,000	$12,000	$8,000		$104,000	X	$104,000	0%	23%	$ -
15	Water Quality Facility Restoration - Sequoia Ridge	$67,000	$10,000	$7,000		$83,000	X	$83,000	0%	36%	$ -
16	Water Quality Facility Restoration - Sweek Drive Pond	$83,000	$12,000	$8,000		$103,000	X	$103,000	0%	21%	$ -
17	Siuslaw Water Quality Facility Retrofit	$336,000	$84,000	$34,000		$454,000		$0	100%	23%	$ 104,000.00
18	Water Quality Facility Restoration - Waterford	$144,000	$22,000	$14,000		$180,000	X	$180,000	0%	22%	$ -
19	Saum Creek Hillslope Repair	$104,000	$37,000	$10,000	$20,000	$171,000	X	$171,000	0%	19%	$ -
20	Hedges Creek Stream Repair[a]	---	---	---		$327,000	X	$327,000	0%	24%	$ -
21	Nyberg Water Quality Retrofit	$1,234,000	$432,000	$123,000	$248,000	$2,037,000	X	$2,037,000	100%	13%	$ 265,000.00

a. Detailed costs provided in Hedges Creek (SW Ibach Road to SW 105th Avenue) Stream Assessment, CIP Opinion of Construction Costs for Identified Sites (February 2018)

b. SDC Eligibility applies to projects that increase capacity or treatment coverage. Maintenance-related projects to correct an existing deficiency are not eligible

TOTAL	$12,015,000	$ 6,482,000	$ 1,917,000

Unit Cost Table

Costs based on RS Means, collected bid tabs, and recent master planning efforts, adjusted to 2018 prices.

Item	Unit	Unit Cost (2018)
Inspection		
Mainline Video Inspection	FT	3.50
Earthwork		
General Earthwork/Excavation	CY	20
Embankment	CY	9
Clear and Grub brush including stumps	AC	8,200
Amended Soils and Mulch	CY	45
Jute Matting, Biodegradeable	SY	6
Tree removal	EA	300
Geomembrane	SY	30
Geotextile	SY	3
Energy dissapation pad - Rip-Rap, Class 50	CY	66
Energy dissapation pad - Rip-Rap, Class 100	CY	81
Energy dissapation pad - Rip-Rap, Class 200	CY	96
Drain Rock	CY	101
Water Quality Facility Installation		
Pond Outflow Control Structure	EA	6,100
Pond Inlet Structure	EA	4,500
Water Quality Facility Plantings with Trees	SF	6
Rain Garden	SF	27
Stormwater Planter	SF	40
Gravel Access Road	SF	5
Beehive Overflow	EA	1,500
Structure Installation		
Field Ditch Inlet	EA	4,000
Precast Concrete Manhole (48", 0-8' deep)	EA	5,600
Precast Concrete Manhole (48", 9-12' deep)	EA	6,600
Precast Concrete Manhole (48", 13-20' deep)	EA	10,200
Precast Concrete Manhole (60", 0-8' deep)	EA	7,600
Precast Concrete Manhole (60", 9-12' deep)	EA	9,700
Precast Concrete Manhole (72", 0-8' deep)	EA	9,700
Precast Concrete Manhole (72", 9-12' deep)	EA	12,200
Flow Splitter/WQ Manhole (72", all depths)	EA	12,300
Contech CDS (Model CDS3025, 72")	EA	28,800
StormFilter (2-cartridge catch basin unit, 18" cartridges)	EA	10,100
Drywell (48", 20-25' deep)	EA	12,200
Curb Inlet	EA	1,300
Catch Basin, all types	EA	2,000
Concrete Fill - UIC Decomissioning	EA	10,200
Connection to Existing Lateral	EA	1,200
Connection to Existing Structure, standard	EA	2,000
Abandon Existing Pipe, no excavation (12")	FT	10
Abandon Existing Pipe, no excavation (15"-18")	FT	20
Abandon Existing Pipe, no excavation (21"-24")	FT	25
Abandon Existing Pipe, no excavation (27"-36")	FT	35
Abandon Existing Structure	EA	1,000
Demo pipe	LF	71
Remove existing pavement	SY	10
Remove Manhole Structure	EA	1,000
Plug Existing Pipe	EA	505
Check dams	EA	505
Stem wall check dam	LF	66
Headwall with wingwalls, 84" pipe	EA	14,000
Outfall Improvements	EA	3,000-10,000

Unit Cost Table

Costs based on RS Means, collected bid tabs, and recent master planning efforts, adjusted to 2018 prices.

Item	Unit	Unit Cost (2018)
Restoration/Resurfacing		
Non-Water Quality Facility Landscaping	AC	15,300
Riparian/Wetland Planting (Non-irrigated)	AC	20,300
Riparian/Wetland Planting (w/temporary irrigation)	AC	32,500
Planting and Bioengineered Restoration	SY	40
4-foot Chain Link Fence	LF	22
Split Rail Fence	LF	25
Hydroseed, large quantities	AC	2500
Seeding, small quantities (< 5,000 sf)	SF	6
Sidewalk Installation	SF	7
Trench resurfacing, Permanent ACP, 6-Inch Depth	SY	71
Concrete Curbs	FT	40
Pipe Unit Cost		
Underdrain Pipe, 4"	LF	29
Underdrain, 6" perforated HDPE	LF	56
HDPE Inlet Lead (12", 2-5' deep)	FT	91
HDPE Pipeline w/asphalt resurfacing (12", 5-10' deep)	FT	140
HDPE Pipeline w/asphalt resurfacing (12", 10-15' deep)	FT	160
HDPE Pipeline w/asphalt resurfacing (18", 5-10' deep)	FT	200
HDPE Pipeline w/asphalt resurfacing (24", 5-10' deep)	FT	275
HDPE Pipeline w/asphalt resurfacing (30", 5-10' deep)	FT	325
HDPE Pipeline (30", 5-10' deep)	FT	240
HDPE Pipeline w/asphalt resurfacing (36", 5-10' deep)	FT	405
HDPE Pipeline (36", 5-10' deep)	FT	265
HDPE Pipeline w/asphalt resurfacing (42", 5-10' deep)	FT	485
HDPE Pipeline (42", 5-10' deep)	FT	345
HDPE Pipeline w/asphalt resurfacing (48", 5-10' deep)	FT	570
HDPE Pipeline (48", 5-10' deep)	FT	430
HDPE Pipeline w/asphalt resurfacing (60", 5-10' deep)	FT	820
HDPE Pipeline (60", 5-10' deep)	FT	680
CMP Pipeline w/asphalt resurfacing (84", 5-10' deep)	FT	1145
CMP Pipeline (84", 5-10' deep)	FT	935
Extra depth pipe	FT	51
Contingencies and Multipliers (applied to construction subtotals)		
Mobilization/Demobilization	LS	10%
Traffic Control/Utility Relocation	LS	5-10%
Erosion Control	LS	2%
Construction Contingency	LS	30%
Engineering and Permitting (%)	LS	15-35%
Administration (%)	LS	10%

CIP #: 1

Manhassat Storm System Improvements

DESIGN ASSUMPTIONS

1,230 LF of 30" diameter and 750 LF of 36" diameter pipe to replace existing open channel/ditch conveyance system
Replace the existing outfall to Hedges Creek

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	400	$8,000
Clear and Grub brush including stumps	AC	8,200	0.25	$2,050
Structure Installation				
Precast Concrete Manhole (60", 0-8' deep)	EA	7,600	9	$68,400
Connection to Existing Lateral	EA	1,200	2	$2,400
Connection to Existing Structure, standard	EA	2,000	1	$2,000
Demo Pipe	LF	71	900	$63,900
Outfall Improvements	EA	5,000	1	$5,000
Restoration/Resurfacing				
Non-Water Quality Facility Landscaping	AC	15,300	0.25	$3,825
Pipe Unit Cost				
HDPE Pipeline w/asphalt resurfacing (30", 5-10' deep)	FT	325	180	$58,500
HDPE Pipeline (30", 5-10' deep)	FT	240	1050	$252,000
HDPE Pipeline w/asphalt resurfacing (36", 5-10' deep)	FT	405	750	$303,750
Project Sub-Total				$769,825
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$76,983
Traffic Control/Utility Relocation	LS	5%		$38,491
Erosion Control	LS	2%		$15,397
Construction Cost Subtotal				$900,695
Construction Contingency	LS	30%		$270,209
Capital Expense Total				$1,170,904
Engineering and Permitting (%)	LS	25%		$292,726
Administration (%)	LS	10%		$117,090
			TOTAL	$1,580,720

CIP #: 2A

Nyberg Creek Stormwater Improvements - Phase I

DESIGN ASSUMPTIONS

Disconnect storm system at Mohawk Dr.

Install new storm trunkline down Martinazzi to new outfall at Nyberg Creek

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	40	$800
Energy dissipation pad - Rip-Rap, Class 100	CY	81	15	$1,215
Structure Installation				
Precast Concrete Manhole (60", 0-8' deep)	EA	7,600	9	$68,400
Catch Basin, all types	EA	2,000	8	$16,000
Demo Pipe	LF	71	900	$63,900
Remove Manhole Structure	EA	1,000	6	$6,000
Outfall Improvements	EA	10,000	1	$10,000
Restoration/Resurfacing				
Non-Water Quality Facility Landscaping	AC	15,300	0.1	$1,530
Riparian/Wetland Planting (Non-irrigated)	AC	20,300	0.1	$2,030
Concrete Curbs	FT	40	1000	$40,000
Pipe Unit Cost				
HDPE Inlet Lead (12", 2-5' deep)	FT	91	440	$40,040
HDPE Pipeline w/asphalt resurfacing (24", 5-10' deep)	FT	275	1500	$412,500
Project Sub-Total				$662,415
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$66,242
Traffic Control/Utility Relocation	LS	10%		$66,242
Erosion Control	LS	2%		$13,248
Construction Cost Subtotal				$808,146
Construction Contingency	LS	30%		$242,444
Capital Expense Total				$1,050,590
Engineering and Permitting (%)	LS	35%		$367,707
Administration (%)	LS	10%		$105,059
			TOTAL	$1,523,356

CIP #: 2B

Nyberg Creek Stormwater Improvements - Phase 2

DESIGN ASSUMPTIONS

Upsize storm pipe along Warm Springs Drive

Install new outfall to Nyberg Creek at Tonka and Warm Springs

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	50	$1,000
Energy dissipation pad - Rip-Rap, Class 100	CY	66	15	$990
Structure Installation				
Precast Concrete Manhole (72", 0-8' deep)	EA	9,700	4	$38,800
Connection to Existing Lateral	EA	1,200	5	$6,000
Demo Pipe	LF	71	250	$17,750
Remove Manhole Structure	EA	1,000	2	$2,000
Outfall Improvements	EA	10,000	1	$10,000
Restoration/Resurfacing				
Non-Water Quality Facility Landscaping	AC	15,300	0.5	$7,650
Riparian/Wetland Planting (Non-irrigated)	AC	20,300	0.1	$2,030
Concrete Curbs	FT	40	50	$2,000
Pipe Unit Cost				
HDPE Pipeline w/asphalt resurfacing (48", 5-10' deep)	FT	570	800	$456,000
Project Sub-Total				$544,220
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$54,422
Traffic Control/Utility Relocation	LS	10%		$54,422
Erosion Control	LS	2%		$10,884
Construction Cost Subtotal				$663,948
Construction Contingency	LS	30%		$199,185
Capital Expense Total				$863,133
Engineering and Permitting (%)	LS	35%		$302,097
Administration (%)	LS	10%		$86,313
			TOTAL	$1,251,543

CIP #: 2C

Nyberg Creek Stormwater Improvements - Phase 3

DESIGN ASSUMPTIONS

Upsize storm pipe along Boones Ferry Road

Install new StormFilter systems for increased treatment to Nasoma Ln.

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	30	$600
Water Quality Facility Installation				
StormFilter (2-cartridge catch basin unit, 18" cartridges)	EA	10,100	2	$20,200
Structure Installation				
Precast Concrete Manhole (60", 0-8' deep)	EA	7,600	6	$45,600
Catch Basin, all types	EA	2,000	2	$4,000
Connection to Existing Lateral	EA	1,200	5	$6,000
Remove existing pavement	SY	10	100	$1,000
Demo Pipe	LF	71	450	$31,950
Remove Manhole Structure	EA	1,000	7	$7,000
Outfall Improvements	EA	5,000	2	$10,000
Restoration/Resurfacing				
Non-Water Quality Facility Landscaping	AC	15,300	0.1	$1,530
Riparian/Wetland Planting (Non-irrigated)	AC	20,300	0.1	$2,030
Pipe Unit Cost				
HDPE Inlet Lead (12", 2-5' deep)	FT	91	150	$13,650
HDPE Pipeline w/asphalt resurfacing (24", 5-10' deep)	FT	275	60	$16,500
HDPE Pipeline w/asphalt resurfacing (36", 5-10' deep)	FT	405	250	$101,250
HDPE Pipeline w/asphalt resurfacing (42", 5-10' deep)	FT	485	75	$36,375
Project Sub-Total				$297,685
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$29,769
Traffic Control/Utility Relocation	LS	10%		$29,769
Erosion Control	LS	2%		$5,954
Construction Cost Subtotal				$363,176
Construction Contingency	LS	30%		$108,953
Capital Expense Total				$472,128
Engineering and Permitting (%)	LS	25%		$118,032
Administration (%)	LS	10%		$47,213
			TOTAL	$637,373

CIP #: 3

Sandalwood Water Quality Retrofit

DESIGN ASSUMPTIONS

220 LF bioswale with temporary irrigation

Relocated ditch inlet structure

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	250	$5,000
Embankment	CY	9	70	$630
Amended Soils and Mulch	CY	45	165	$7,425
Energy dissipation pad - Rip-Rap, Class 50	CY	66	20	$1,320
Drain Rock	CY	101	85	$8,585
Structure Installation				
Field Ditch Inlet	EA	4,000	1	$4,000
Precast Concrete Manhole (60", 0-8' deep)	EA	7,600	1	$7,600
Connection to Existing Structure, standard	EA	2,000	1	$2,000
Check dams	EA	505	3	$1,515
Restoration/Resurfacing				
Non-Water Quality Facility Landscaping	AC	15,300	0.4	$6,120
Riparian/Wetland Planting (w/temporary irrigation)	AC	32,500	0.1	$3,250
Pipe Unit Cost				
HDPE Pipeline (30", 5-10' deep)	FT	240	20	$4,800
Project Sub-Total				$52,245
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$5,225
Traffic Control/Utility Relocation	LS	5%		$2,612
Erosion Control	LS	2%		$1,045
Construction Cost Subtotal				$61,127
Construction Contingency	LS	30%		$18,338
Capital Expense Total				$79,465
Engineering and Permitting (%)	LS	25%		$19,866
Administration (%)	LS	10%		$7,946
			TOTAL	$107,277

CIP #: 4

Mohawk Apartments Stormwater Improvements

DESIGN ASSUMPTIONS
CCTV 1,000 LF of pipe with unknown alignment and condition
Install 4 72" diameter manholes for maintenance access
Replace ditch inlet and 170 LF of 36" CMP

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Inspection				
Mainline Video Inspection	FT	3.50	1000	$3,500
Earthwork				
General Earthwork/Excavation	CY	20	75	$1,500
Clear and Grub brush including stumps	AC	8,200	1	$8,200
Structure Installation				
Field Ditch Inlet	EA	4,000	1	$4,000
Precast Concrete Manhole (72", 9-12' deep)	EA	12,200	4	$48,800
Connection to Existing Structure, standard	EA	2,000	9	$18,000
Demo Pipe	LF	71	170	$12,070
Remove Manhole Structure	EA	1,000	1	$1,000
Restoration/Resurfacing				
Non-Water Quality Facility Landscaping	AC	15,300	0.1	$1,530
Pipe Unit Cost				
HDPE Pipeline (36", 5-10' deep)	FT	265	170	$45,050
Project Sub-Total				$143,650
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$14,365
Traffic Control/Utility Relocation	LS	5%		$7,183
Erosion Control	LS	2%		$2,873
Construction Cost Subtotal				$168,071
Construction Contingency	LS	30%		$50,421
Capital Expense Total				$218,492
Engineering and Permitting (%)	LS	25%		$54,623
Administration (%)	LS	10%		$21,849
			TOTAL	$294,964

CIP #: 5

Herman Road Storm System

DESIGN ASSUMPTIONS

New 36" diameter trunkline to replace existing open channel/ditch conveyance system
Water quality treatment is not included and will be reflected with roadway design
Asphalt resurfacing over pipe is not included and will be reflected with roadway design

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	250	$5,000
Structure Installation				
Precast Concrete Manhole (60", 0-8' deep)	EA	7,600	10	$76,000
Catch Basin, all types	EA	2,000	12	$24,000
Connection to Existing Structure, standard	EA	2,000	4	$8,000
Demo Pipe	LF	71	600	$42,600
Remove Manhole Structure	EA	1,000	3	$3,000
Pipe Unit Cost				
HDPE Inlet Lead (12", 2-5' deep)	FT	91	420	$38,220
HDPE Pipeline (30", 5-10' Deep)	FT	240	110	$26,400
HDPE Pipeline (36", 5-10' deep)	FT	265	960	$254,400
Project Sub-Total				$477,620
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$47,762
Traffic Control/Utility Relocation	LS	10%		$47,762
Erosion Control	LS	2%		$9,552
Construction Cost Subtotal				$582,696
Construction Contingency	LS	30%		$174,809
Capital Expense Total				$757,505
Engineering and Permitting (%)	LS	25%		$189,376
Administration (%)	LS	10%		$75,751
			TOTAL	$1,022,632

CIP #: 6

Blake Street Culvert Replacement

DESIGN ASSUMPTIONS

84" diameter culvert replacement
Construction to occur in conjunction with roadway widening project
Asphalt resurfacing over culvert not reelected in cost estimate.

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	900	$18,000
Embankment	CY	9	60	$540
Clear and Grub brush including stumps	AC	8,200	0.1	$820
Jute Matting, Biodegradable	SY	6	60	$360
Structure Installation				
Headwall with wingwalls, 84" pipe	EA	14,000	2	$28,000
Dewatering	EA	50,000	1	$50,000
Outfall Improvements	EA	10,000	1	$10,000
Restoration/Resurfacing				
Riparian/Wetland Planting (Non-irrigated)	AC	20,300	1	$20,300
Pipe Unit Cost				
CMP Pipeline (84", 5-10' deep)	FT	935	120	$112,200
Project Sub-Total				$240,220
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$24,022
Traffic Control/Utility Relocation	LS	10%		$24,022
Erosion Control	LS	2%		$4,804
Construction Cost Subtotal				$293,068
Construction Contingency	LS	30%		$87,921
Capital Expense Total				$380,989
Engineering and Permitting (%)	LS	35%		$133,346
Administration (%)	LS	10%		$38,099
			TOTAL	$552,434

CIP #: 7

Boones Ferry Railroad Conveyance Improvements

DESIGN ASSUMPTIONS

Remove existing ballast/accumulated sediment and replace with rip rap.

Install new field ditch inlet and 400 LF of 42-inch pipe.

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	165	$3,300
Energy dissipation pad - Rip-Rap, Class 100	CY	81	200	$16,200
Structure Installation				
Field Ditch Inlet	EA	4,000	1	$4,000
Precast Concrete Manhole (72", 0-8' deep)	EA	9,700	1	$9,700
Demo pipe	LF	71	400	$28,400
Outfall Improvements	EA	5,000	1	$5,000
Restoration/Resurfacing				
Non-Water Quality Facility Landscaping	AC	15,300	0.1	$1,530
Pipe Unit Cost				
HDPE Pipeline (42", 5-10' deep)	FT	345	480	$165,600
Project Sub-Total				$233,730
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$23,373
Traffic Control/Utility Relocation	LS	5%		$11,687
Erosion Control	LS	2%		$4,675
Construction Cost Subtotal				$273,464
Construction Contingency	LS	30%		$82,039
Capital Expense Total				$355,503
Engineering and Permitting (%)	LS	35%		$124,426
Administration (%)	LS	10%		$35,550
			TOTAL	$515,480

CIP #: 8

89th Avenue Water Quality Retrofit

DESIGN ASSUMPTIONS

Contech CDS (Model CDS 3025) hydrodynamic separator with 150 LF of piping

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	50	$1,000
Energy dissipation pad - Rip-Rap, Class 50	CY	66	25	$1,650
Water Quality Facility Installation				
Contech CDS (Model CDS3025, 72")	EA	28,800	1	$28,800
Structure Installation				
Precast Concrete Manhole (72", 0-8' deep)	EA	9,700	1	$9,700
Flow Splitter/WQ Manhole (72", all depths)	EA	12,300	1	$12,300
Demo pipe	LF	71	100	$7,100
Remove existing pavement	SY	1,000	13	$13,000
Outfall Improvements	EA	5,000	1	$5,000
Restoration/Resurfacing				
Non-Water Quality Facility Landscaping	AC	15,300	0.1	$1,530
Concrete Curbs	FT	40	20	$800
Pipe Unit Cost				
HDPE Pipeline w/asphalt resurfacing (24", 5-10' deep)	FT	275	50	$13,750
HDPE Pipeline (48", 5-10' deep)	FT	430	100	$43,000
Project Sub-Total				$137,630
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$13,763
Traffic Control/Utility Relocation	LS	5%		$6,882
Erosion Control	LS	2%		$2,753
Construction Cost Subtotal				$161,027
Construction Contingency	LS	30%		$48,308
Capital Expense Total				$209,335
Engineering and Permitting (%)	LS	15%		$31,400
Administration (%)	LS	10%		$20,934
			TOTAL	$261,669

CIP #: 9

125th Court Water Quality Retrofit

DESIGN ASSUMPTIONS

Contech CDS (Model CDS 3025) hydrodynamic separator with 100 LF of piping

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	50	$1,000
Water Quality Facility Installation				
Contech CDS (Model CDS3025, 72")	EA	28,800	1	$28,800
Structure Installation				
Precast Concrete Manhole (72", 0-8' deep)	EA	9,700	1	$9,700
Flow Splitter/WQ Manhole (72", all depths)	EA	12,300	1	$12,300
Connection to Existing Structure, standard	EA	2,000	3	$6,000
Demo pipe	LF	71	50	$3,550
Remove existing pavement	SY	1,000	13	$13,000
Pipe Unit Cost				
HDPE Pipeline w/asphalt resurfacing (24", 5-10' deep)	FT	275	50	$13,750
HDPE Pipeline w/asphalt resurfacing (36", 5-10' deep)	FT	405	50	$20,250
Project Sub-Total				$108,350
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$10,835
Traffic Control/Utility Relocation	LS	5%		$5,418
Erosion Control	LS	2%		$2,167
Construction Cost Subtotal				$126,770
Construction Contingency	LS	30%		$38,031
Capital Expense Total				$164,800
Engineering and Permitting (%)	LS	15%		$24,720
Administration (%)	LS	10%		$16,480
			TOTAL	$206,000

CIP #: 10

93rd Avenue Green Street

DESIGN ASSUMPTIONS

950 sf of flow-through stormwater planter

Curb and gutter along 550' of unimproved roadway

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	100	$2,000
Water Quality Facility Installation				
Stormwater Planter	SF	40	950	$38,000
Beehive Overflow	EA	1,500	2	$3,000
Structure Installation				
Curb Inlet	EA	1,300	4	$5,200
Connection to Existing Structure, standard	EA	2,000	2	$4,000
Abandon Existing Pipe, no excavation (12")	FT	10	30	$300
Remove Manhole Structure	EA	1,000	2	$2,000
Restoration/Resurfacing				
Trench resurfacing, Permanent ACP, 6-Inch Depth	SY	71	300	$21,300
Concrete Curbs	FT	40	550	$22,000
Pipe Unit Cost				
HDPE Pipeline w/asphalt resurfacing (12", 5-10' deep)	FT	140	50	$7,000
Project Sub-Total				$104,800
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$10,480
Traffic Control/Utility Relocation	LS	10%		$10,480
Erosion Control	LS	2%		$2,096
Construction Cost Subtotal				$127,856
Construction Contingency	LS	30%		$38,357
Capital Expense Total				$166,213
Engineering and Permitting (%)	LS	25%		$41,553
Administration (%)	LS	10%		$16,621
			TOTAL	$224,387

CIP #: 11

Juanita Pohl Water Quality Retrofit

DESIGN ASSUMPTIONS

1300 sf of flow through raingarden

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	180	$3,600
Water Quality Facility Installation				
Rain Garden	SF	27	1300	$35,100
Beehive Overflow	EA	1,500	2	$3,000
Structure Installation				
Precast Concrete Manhole (48", 0-8' deep)	EA	5,600	2	$11,200
Connection to Existing Structure, standard	EA	2,000	2	$4,000
Check dams	EA	505	2	$1,010
Stem wall check dams	LF	66	90	$5,940
Restoration/Resurfacing				
Trench resurfacing, Permanent ACP, 6-Inch Depth	SY	71	50	$3,550
Concrete Curbs	FT	40	100	$4,000
Pipe Unit Cost				
HDPE Inlet Lead (12", 2-5' deep)	FT	91	50	$4,550
Project Sub-Total				$75,950
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$7,595
Traffic Control/Utility Relocation	LS	5%		$3,798
Erosion Control	LS	2%		$1,519
Construction Cost Subtotal				$88,862
Construction Contingency	LS	30%		$26,658
Capital Expense Total				$115,520
Engineering and Permitting (%)	LS	25%		$28,880
Administration (%)	LS	10%		$11,552
			TOTAL	$155,952

CIP #: 12

Community Park Water Quality Retrofit

DESIGN ASSUMPTIONS

1550 sf of raingarden/swale

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	175	$3,500
Water Quality Facility Installation				
Rain Garden	SF	27	1550	$41,850
Beehive Overflow	EA	1,500	2	$3,000
Structure Installation				
Precast Concrete Manhole (48", 0-8' deep)	EA	5,600	2	$11,200
Connection to Existing Structure, standard	EA	2,000	2	$4,000
Abandon Existing Pipe, no excavation (12")	FT	10	60	$600
Remove Manhole Structure	EA	1,000	3	$3,000
Restoration/Resurfacing				
Trench resurfacing, Permanent ACP, 6-Inch Depth	SY	71	20	$1,420
Concrete Curbs	FT	40	150	$6,000
Pipe Unit Cost				
HDPE Inlet Lead (12", 2-5' deep)	FT	91	25	$2,275
Project Sub-Total				$76,845
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$7,685
Traffic Control/Utility Relocation	LS	5%		$3,842
Erosion Control	LS	2%		$1,537
Construction Cost Subtotal				$89,909
Construction Contingency	LS	30%		$26,973
Capital Expense Total				$116,881
Engineering and Permitting (%)	LS	25%		$29,220
Administration (%)	LS	10%		$11,688
			TOTAL	$157,790

CIP #: 13

Water Quality Facility Restoration - Venetia

DESIGN ASSUMPTIONS

Water quality swale is approx. 15' wide, 200' long, 1.5' deep, with 4' bottom width.

2' of excavation and installation of 1' of amended soils and temporary irrigated vegetation

Refurbish maintenance access road from Lee Street

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	225	$4,500
Clear and Grub brush including stumps	AC	8,200	0.3	$2,460
Amended Soils and Mulch	CY	45	100	$4,500
Energy dissipation pad - Rip-Rap, Class 50	CY	66	5	$330
Water Quality Facility Installation				
Water Quality Facility Plantings with Trees	SF	6	2580	$15,480
Gravel Access Road	SF	5	750	$3,750
Restoration/Resurfacing				
Non-Water Quality Facility Landscaping	AC	15,300	0.2	$3,060
Project Sub-Total				$34,080
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$3,408
Traffic Control/Utility Relocation	LS	5%		$1,704
Erosion Control	LS	2%		$682
Construction Cost Subtotal				$39,874
Construction Contingency	LS	30%		$11,962
Capital Expense Total				$51,836
Engineering and Permitting (%)	LS	15%		$7,775
Administration (%)	LS	10%		$5,184
			TOTAL	$64,795

CIP #: 14

Water Quality Facility Restoration - Piute Court

DESIGN ASSUMPTIONS

4,000 sf facility with a 7 ft design depth

3' of excavation and installation of 1' of amended soils and temporary irrigated vegetation

Install a maintenance access road from Piute Court

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	450	$9,000
Clear and Grub brush including stumps	AC	8,200	0.2	$1,640
Amended Soils and Mulch	CY	45	150	$6,750
Energy dissipation pad - Rip-Rap, Class 50	CY	66	10	$660
Water Quality Facility Installation				
Pond Outflow Control Structure	EA	6,100	1	$6,100
Gravel Access Road	SF	5	1000	$5,000
Structure Installation				
Flow Splitter/WQ Manhole (72", all depths)	EA	12,300	1	$12,300
Connection to Existing Lateral	EA	1,200	2	$2,400
Restoration/Resurfacing				
Non-Water Quality Facility Landscaping	AC	15,300	0.5	$7,650
Riparian/Wetland Planting (w/temporary irrigation)	AC	32,500	0.1	$3,250
Project Sub-Total				$54,750
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$5,475
Traffic Control/Utility Relocation	LS	5%		$2,738
Erosion Control	LS	2%		$1,095
Construction Cost Subtotal				$64,058
Construction Contingency	LS	30%		$19,217
Capital Expense Total				$83,275
Engineering and Permitting (%)	LS	15%		$12,491
Administration (%)	LS	10%		$8,327
			TOTAL	$104,093

CIP #: 15

Water Quality Facility Restoration - Sequoia Ridge

DESIGN ASSUMPTIONS

4,000 sf facility with a 5 ft design depth

3' of excavation and installation of 1' of amended soils and temporary irrigated vegetation

Install upstream water quality/flow control manhole for offline configuration

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	450	$9,000
Clear and Grub brush including stumps	AC	8,200	0.4	$3,280
Amended Soils and Mulch	CY	45	150	$6,750
Tree removal	EA	300	30	$9,000
Energy dissipation pad - Rip-Rap, Class 50	CY	66	2	$132
Water Quality Facility Installation				
Pond Outflow Control Structure	EA	6,100	1	$6,100
Restoration/Resurfacing				
Non-Water Quality Facility Landscaping	AC	15,300	0.2	$3,060
Riparian/Wetland Planting (w/temporary irrigation)	AC	32,500	0.2	$6,500
Project Sub-Total				$43,822
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$4,382
Traffic Control/Utility Relocation	LS	5%		$2,191
Erosion Control	LS	2%		$876
Construction Cost Subtotal				$51,272
Construction Contingency	LS	30%		$15,382
Capital Expense Total				$66,653
Engineering and Permitting (%)	LS	15%		$9,998
Administration (%)	LS	10%		$6,665
			TOTAL	$83,317

CIP #: 16

Water Quality Facility Restoration - Sweek Drive Pond

DESIGN ASSUMPTIONS

3,000 sf facility adjacent to larger Sweek Pond

3' of excavation and installation of 1' of amended soils and temporary irrigated vegetation

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	350	$7,000
Clear and Grub brush including stumps	AC	8,200	0.2	$1,640
Amended Soils and Mulch	CY	45	110	$4,950
Tree Removal	EA	300	30	$9,000
Energy dissipation pad - Rip-Rap, Class 50	CY	66	4	$264
Water Quality Facility Installation				
Pond Outflow Control Structure	EA	6,100	1	$6,100
Structure Installation				
Flow Splitter/WQ Manhole (72", all depths)	EA	12,200	1	$12,200
Connection to Existing Lateral	EA	1,200	3	$3,600
Restoration/Resurfacing				
Non-Water Quality Facility Landscaping	AC	15,300	0.2	$3,060
Riparian/Wetland Planting (w/temporary irrigation)	AC	32,500	0.2	$6,500
Project Sub-Total				$54,314
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$5,431
Traffic Control/Utility Relocation	LS	5%		$2,716
Erosion Control	LS	2%		$1,086
Construction Cost Subtotal				$63,547
Construction Contingency	LS	30%		$19,064
Capital Expense Total				$82,612
Engineering and Permitting (%)	LS	15%		$12,392
Administration (%)	LS	10%		$8,261
			TOTAL	$103,264

CIP #17

Siuslaw Water Quality Retrofit

DESIGN ASSUMPTIONS

Replace stormwater pipe from Boones Ferry Rd to Siuslaw Lane due to condition
Regrade/amend soils in existing greenway for enhanced water quality treatment
Install sedimentation manhole upstream of swale

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	560	$11,200
Amended Soils and Mulch	CY	45	420	$18,900
Energy dissipation pad - Rip-Rap, Class 100	CY	81	15	$1,215
Structure Installation				
Precast Concrete Manhole (60", 0-8' deep)	EA	7,600	2	$15,200
Flow Splitter/WQ Manhole (72", all depths)	EA	12,300	1	$12,300
Catch Basin, all types	EA	2,000	3	$6,000
Connection to Existing Lateral	EA	1,200	1	$1,200
Connection to Existing Structure, standard	EA	2,000	1	$2,000
Abandon Existing Pipe, no excavation (27"-36")	FT	35	70	$2,450
Check dams	EA	505	5	$2,525
Outfall Improvements	EA	3,000	2	$6,000
Restoration/Resurfacing				
Riparian/Wetland Planting (w/temporary irrigation)	AC	32,500	0.2	$6,500
Pipe Unit Cost				
HDPE Pipeline w/asphalt resurfacing (30", 5-10' deep)	FT	325	100	$32,500
HDPE Pipeline (30", 5-10' deep)	FT	240	250	$60,000
HDPE Pipeline (48", 5-10' deep)	FT	430	100	$43,000
Project Sub-Total				$220,990
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$22,099
Traffic Control/Utility Relocation	LS	5%		$11,050
Erosion Control	LS	2%		$4,420
Construction Cost Subtotal				$258,558
Construction Contingency	LS	30%		$77,567
Capital Expense Total				$336,126
Engineering and Permitting (%)	LS	25%		$84,031
Administration (%)	LS	10%		$33,613
			TOTAL	$453,770

CIP #: 18

Water Quality Facility Restoration - Waterford

DESIGN ASSUMPTIONS

2,500 sf facility, approx. 4' deep

3' of excavation and installation of 1' of amended soils and temporary irrigated vegetation

Relocation and replacement of outlet control structure with new 24" pipe

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	560	$11,200
Clear and Grub brush including stumps	AC	8,200	0.3	$2,460
Amended Soils and Mulch	CY	45	100	$4,500
Energy dissipation pad - Rip-Rap, Class 50	CY	66	12	$792
Water Quality Facility Installation				
Pond Outflow Control Structure	EA	6,100	1	$6,100
Water Quality Facility Plantings with Trees	SF	6	1200	$7,200
Structure Installation				
Flow Splitter/WQ Manhole (72", all depths)	EA	12,300	2	$24,600
Connection to Existing Lateral	EA	1,200	8	$9,600
Abandon Existing Pipe, no excavation (21"-24")	FT	25	80	$2,000
Abandon Existing Structure	EA	1,000	1	$1,000
Remove Manhole Structure	EA	1,000	2	$2,000
Restoration/Resurfacing				
Non-Water Quality Facility Landscaping	AC	15,300	0.2	$3,060
Riparian/Wetland Planting (w/temporary irrigation)	AC	32,500	0.2	$6,500
Pipe Unit Cost				
HDPE Pipeline w/asphalt resurfacing (24", 5-10' deep)	FT	275	50	$13,750
Project Sub-Total				$94,762
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$9,476
Traffic Control/Utility Relocation	LS	5%		$4,738
Erosion Control	LS	2%		$1,895
Construction Cost Subtotal				$110,872
Construction Contingency	LS	30%		$33,261
Capital Expense Total				$144,133
Engineering and Permitting (%)	LS	15%		$21,620
Administration (%)	LS	10%		$14,413
			TOTAL	$180,166

CIP #: 19

Saum Creek Hillslope Repair

DESIGN ASSUMPTIONS

Replace existing 18-inch pipe to outfall

Install bank reinforcement to prevent further erosion

Conduct geotechnical evaluation of bank slope conditions

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
Clear and Grub brush including stumps	AC	8,200	0.1	$820
Geotextile	SY	3	140	$420
Energy dissipation pad - Rip-Rap, Class 200	CY	96	60	$5,760
Structure Installation				
Precast Concrete Manhole (60", 0-8' deep)	EA	7,600	1	$7,600
Catch Basin, all types	EA	2,000	1	$2,000
Demo pipe	LF	71	100	$7,100
Outfall Improvements	EA	10,000	1	$10,000
Restoration/Resurfacing				
Riparian/Wetland Planting (Non-irrigated)	AC	20,300	0.4	$8,120
Pipe Unit Cost				
Underdrain, 6" perforated HDPE	LF	56	50	$2,800
HDPE Pipeline w/asphalt resurfacing (18", 5-10' deep)	FT	200	120	$24,000
Project Sub-Total				$68,620
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$6,862
Traffic Control/Utility Relocation	LS	5%		$3,431
Erosion Control	LS	2%		$1,372
Construction Cost Subtotal				$80,285
Construction Contingency	LS	30%		$24,086
Capital Expense Total				$104,371
Geotechnical Evaluation	LS	20000	1	$20,000
Engineering and Permitting (%)	LS	35%		$36,530
Administration (%)	LS	10%		$10,437
			TOTAL	$171,338

CIP #: 20

Hedges Creek Stream Repair

DESIGN ASSUMPTIONS

Costs directly from the Hedges Creek (SW Ibach Road to SW 105th Avenue) Stream Assessment, CIP Opinion of Construction Costs for Identified Sites, February 2018, GreenWorks PC and OTAK, INC. Refer to report for detailed cost information.

Stream rehabilitation

Sanitary infrastructure protection

Outfall Improvements

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Location "M"				
Capital Project Implementation Cost Total				$146,874
Location "N"				
Capital Project Implementation Cost Total				$179,793
			TOTAL	$326,667

CIP #: 21

Nyberg Water Quality Retrofit

DESIGN ASSUMPTIONS

1.5 acres water quality facility with additional site improvements

3' of excavation and installation of 1.5' of amended soils and temporary irrigated vegetation

Excavated outflow channel from facility to Nyberg Creek

Installation of low flow bypass from Martinazzi and Warm Springs to proposed facility

ITEM	UNIT	Unit Cost (2018)	Quantity	Total Cost
Earthwork				
General Earthwork/Excavation	CY	20	5362	$107,244
Clear and Grub brush including stumps	AC	8,200	1.54	$12,639
Amended Soils and Mulch	CY	45	2823	$127,050
Jute Matting, Biodegradable	SY	6	1083	$6,500
Tree removal	EA	300	20	$6,000
Energy dissipation pad - Rip-Rap, Class 50	CY	66	59	$3,911
Water Quality Facility Installation				
Pond Outflow Control Structure	EA	6,100	1	$6,100
Pond Inlet Structure	EA	4,500	1	$4,500
Water Quality Facility Plantings with Trees	SF	6	43560	$261,360
Gravel Access Road	SF	5	1800	$9,000
Beehive Overflow	EA	1,500	3	$4,500
Structure Installation				
Precast Concrete Manhole (48", 0-8' deep)	EA	5,600	2	$11,200
Precast Concrete Manhole (48", 13-20' deep)	EA	10,200	1	$10,200
Precast Concrete Manhole (60", 0-8' deep)	EA	7,600	1	$7,600
Precast Concrete Manhole (60", 9-12' deep)	EA	9,700	1	$9,700
Flow Splitter/WQ Manhole (72", all depths)	EA	12,300	2	$24,600
Catch Basin, all types	EA	2,000	3	$6,000
Connection to Existing Lateral	EA	1,200	5	$6,000
Abandon Existing Pipe, no excavation (12")	FT	10	490	$4,900
Abandon Existing Structure	EA	1,000	3	$3,000
Remove Manhole Structure	EA	1,000	2	$2,000
Outfall Improvements	EA	7,500	1	$7,500
Restoration/Resurfacing				
Riparian/Wetland Planting (Non-irrigated)	AC	20,300	0.5	$10,150
Hydroseed, large quantities	AC	2,500	0.5	$1,250
Pipe Unit Cost				
HDPE Inlet Lead (12", 2-5' Deep)	FT	91	100	$9,100
HDPE Overflow from Beehive Overflows (12", 2-5' Deep)	FT	76	75	$5,700
HDPE Pipeline w/asphalt resurfacing (12", 5-10' Deep)	FT	140	485	$67,900
HDPE Pipeline w/asphalt resurfacing (24", 5-10' deep)	FT	275	275	$75,625
Project Sub-Total				$811,229
Contingencies and Multipliers				
Mobilization/Demobilization	LS	10%		$81,123
Traffic Control/Utility Relocation	LS	5%		$40,561
Erosion Control	LS	2%		$16,225
Construction Cost Subtotal				$949,138
Construction Contingency	LS	30%		$284,742
Capital Expense Total				$1,233,880
Engineering and Permitting (%)	LS	35%		$431,858
Administration (%)	LS	10%		$123,388
Wetland Delineation	LS	15,000	1	$15,000
Wetland Mitigation	LS	232,500	1	$232,500
			TOTAL	$2,036,626

Appendix H: Staffing Analysis

Table H-1. Staffing Analysis Summary by CIP ID#							
CIP ID	Project Description	Project Information	Priority Project (Y/N)	Engineering Responsibility	Maintenance Details [a]	Estimated Annual Maintenance Resource Needs (FTE) [b]	Estimated Staff Resource Needs ($ and FTE) [c]
CIP #1 Manhasset Storm System Improvements	Replace existing conveyance open channel with pipe	• Engineering and permitting costs estimated at 25% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • New infrastructure will require more frequent maintenance due to anticipated sediment accumulation (annual pipe cleaning). • Project cost (total): $1,581,000.	N	Staff/consultant	• 1,980 linear feet (LF) of new pipe • Annual pipe cleaning (20'/hr)	Approximately 100 hours of annual maintenance (0.05 FTE)	Construction administration (total): $117,000 (or 0.78 FTE)
CIP #2a Phase 1 Nyberg Creek Stormwater Improvements	Install upsized and new storm lines in Martinazzi Avenue and construct new outfall to Nyberg Creek	• Engineering and permitting costs estimated at 35% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • New infrastructure will require more frequent maintenance due to anticipated sediment accumulation (annual pipe cleaning, outfall debris removal). • Project cost (total): $1,523,000.	Y	Staff/consultant	• 1,940 LF of new pipe, 1 new outfall • Annual pipe cleaning (20'/hr) • Outfall debris removal (4 hrs)	Approximately 100 hours of annual maintenance (0.05 FTE)	Construction administration (total): $105,000 (or 0.70 FTE)
CIP #2b Phase 2 Nyberg Creek Stormwater Improvements	Install upsized and new storm lines along Warm Springs Drive and construct new outfall to Nyberg Creek	• Engineering and permitting costs estimated at 35% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • New infrastructure will require more frequent maintenance due to anticipated sediment accumulation (annual pipe cleaning, outfall debris removal). • Project cost (total): $1,208,000.	N	Staff/consultant	• 800 LF of new pipe, 1 new outfall • Annual pipe cleaning (20'/hr) • Outfall debris removal (4 hrs)	Approximately 44 hours of annual maintenance (0.03 FTE)	Construction administration (total): $86,000 (or 0.57 FTE)
CIP #2c Phase 3 Nyberg Creek Stormwater Improvements	Install upsized and new storm lines along Boones Ferry and install new WQ treatment facilities (StormFilter cbs)	• Engineering and permitting costs estimated at 25% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • New infrastructure will require more frequent maintenance due to anticipated sediment accumulation (annual pipe cleaning, StormFilter cbs maintenance). • Project cost (total): $637,000.	N	Staff/consultant	• 535 LF of new pipe, 2 new StormFilters • Annual pipe cleaning (20'/hr) • StormFilter maintenance (6 hr/facility - assumed)	Approximately 40 hours of annual maintenance (0.02 FTE)	Construction administration (total): $47,000 (or 0.31 FTE)
CIP #3 Sandalwood Water Quality Retrofit	Retrofit existing open channel to WQ facility	• Engineering and permitting costs estimated at 25% of the construction cost. Assume consultant to complete. • Construction administration estimated at 10% of the construction cost. • New WQ facility will require annual inspections and maintenance to ensure plant viability and system functionality. • Project cost (total): $107,000.	N	Staff/consultant	• 220' water quality swale • Inspection four times/year (4 hrs total) • Annual swale maintenance (20'/hr)	Approximately 15 hours of annual maintenance (0.01 FTE)	Construction administration (total): $8,000 (or 0.06 FTE)
CIP #4 Mohawk Apartments Stormwater Improvements	CCTV pipe, replace pipe, install four new manholes and restore open channel	• Engineering and permitting costs estimated at 25% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • CCTV effort to be conducted by City staff. New manholes will require annual maintenance (previously unaccounted). • Project cost (total): $295,000.	N	Staff/consultant	• 1,000 LF of CCTV, 4 new manholes • CCTV (200'/hr) • Annual WQ manhole maintenance (1 hr/MH with biannual frequency)	Approximately 13 hours of annual maintenance (0.01 FTE)	Construction administration (total): $22,000 (or 0.15 FTE)
CIP #5 Herman Road Storm System	Construct new storm conveyance associated with roadway improvements	• Engineering and permitting costs estimated at 25% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • New infrastructure will require more frequent maintenance due to anticipated sediment accumulation (annual pipe cleaning). • Project cost (total): $1,023,000.	Y	Staff/consultant	• 1,490 LF of new pipe, 12 new catch basins • Annual pipe cleaning (20'/hr) • Annual cb maintenance (1hr/cb)	Approximately 87 hours of annual maintenance (0.05 FTE)	Construction administration (total): $76,000 (or 0.51 FTE)
CIP #6 Blake Street Culvert Replacement	Replace culvert at Hedges Creek associated with roadway improvements	• Engineering and permitting costs estimated at 35% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • No additional maintenance requirements. • Project cost (total): $552,000.	Y	Staff/consultant	• 120 LF of new culvert • No increased maintenance obligation or frequency expected.	N/A	Construction administration (total): $38,000 (or 0.25 FTE)
CIP #7 Boones Ferry Railroad Conveyance Improvements	Replace 400 LF of undersized pipe, ditch inlet, install a WQ manhole and mitigate gravel migration downstream	• Engineering and permitting costs estimated at 35% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • New and replaced infrastructure will require more frequent maintenance due to anticipated sediment accumulation (annual pipe cleaning, open channel maintenance) • Project cost (total): $515,000.	N	Staff/consultant	• 480 LF of replaced pipe, 150' open channel, 1 new manhole • Annual pipe cleaning (20'/hr) • Annual open channel cleaning (20'/hr) • Annual WQ manhole maintenance (1 hr/MH with biannual frequency)	Approximately 32 hours of annual maintenance (0.02 FTE)	Construction administration (total): $36,000 (or 0.24 FTE)

Table H-1. Staffing Analysis Summary by CIP ID#							
CIP ID	Project Description	Project Information	Priority Project (Y/N)	Engineering Responsibility	Maintenance Details [a]	Estimated Annual Maintenance Resource Needs (FTE) [b]	Estimated Staff Resource Needs ($ and FTE) [c]
CIP #8 89th Ave Water Quality Retrofit	Install WQ CDS unit and associated piping	• Engineering and permitting costs estimated at 15% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • New infrastructure will require more frequent maintenance due to anticipated sediment accumulation (annual pipe cleaning, CDS maintenance) • Project cost (total): $262,000.	N	Staff/consultant	• 150 LF of new pipe, new CDS WQ facility • Annual pipe cleaning (20'/hr) • CDS maintenance (6 hr/facility - assumed)	Approximately 14 hours of annual maintenance (0.01 FTE)	Construction administration (total): $21,000 (or 0.14 FTE)
CIP #9 125th Ct Water Quality Retrofit	Install WQ CDS unit and associated piping	• Engineering and permitting costs estimated at 15% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • New infrastructure will require more frequent maintenance due to anticipated sediment accumulation (annual pipe cleaning, CDS maintenance) • Project cost (total): $206,000.	N	Staff/consultant	• 100 LF of new pipe, new CDS WQ facility • Annual pipe cleaning (20'/hr) • CDS maintenance (6 hr/facility - assumed)	Approximately 11 hours of annual maintenance (0.01 FTE)	Construction administration (total): $16,000 (or 0.11 FTE)
CIP #10 93rd Ave Green Street	Add WQ planters	• Engineering and permitting costs estimated at 25% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • New WQ facility will require annual inspections and maintenance to ensure plant viability and system functionality. • Project cost (total): $224,000.	N	Staff/consultant	• 950 sf of WQ planters • Inspection four times/year (4 hrs total) • Annual planter maintenance (50 sf/hr)	Approximately 23 hours of annual maintenance (0.02 FTE)	Construction administration (total): $17,000 (or 0.11 FTE)
CIP #11 Juanita Pohl Water Quality Retrofit	Retrofit parking lot with WQ planters	• Engineering and permitting costs estimated at 25% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • New WQ facility will require annual inspections and maintenance to ensure plant viability and system functionality. • Project cost (total): $156,000.	Y	Staff/consultant	• 1,300 sf of WQ planters • Inspection four times/year (4 hrs total) • Annual planter maintenance (50 sf/hr)	Approximately 30 hours of annual maintenance (0.02 FTE)	Construction administration (total): $12,000 (or 0.08 FTE)
CIP #12 Community Park Water Quality Retrofit	Retrofit parking lot with WQ planters	• Engineering and permitting costs estimated at 25% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • New WQ facility will require annual inspections and maintenance to ensure plant viability and system functionality. • Project cost (total): $158,000.	Y	Staff/consultant	• 1,550 sf of WQ planters • Inspection four times/year (4 hrs total) • Annual planter maintenance (50 sf/hr)	Approximately 35 hours of annual maintenance (0.02 FTE)	Construction administration (total): $12,000 (or 0.08 FTE)
CIP #13 Water Quality Facility Maintenance - Venetia	Maintain existing WQ facility to restore function	• Engineering and permitting costs estimated at 15% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • Ongoing facility maintenance reflected in programmatic project. • Project cost (total): $65,000.	Y	Staff/consultant	• WQ facility maintenance • Project to be performed by hired contractor • Increased maintenance obligation or frequency to be accounted for in programmatic project	N/A	Construction administration (total): $5,000 (or 0.03 FTE)
CIP #14 Water Quality Facility Maintenance – Piute Ct	Maintain existing WQ facility to restore function	• Engineering and permitting costs estimated at 15% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • Ongoing WQ facility maintenance reflected in programmatic project. • Project cost (total): $104,000.	Y	Staff/consultant	• WQ facility maintenance • Project to be performed by hired contractor • Increased maintenance obligation or frequency to be accounted for in programmatic project	N/A	Construction administration (total): $8,000 (or 0.05 FTE)
CIP #15 Water Quality Facility Maintenance - Sequoia Ridge	Maintain existing WQ facility to restore function	• Engineering and permitting costs estimated at 15% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • Ongoing WQ facility maintenance reflected in programmatic project. • Project cost (total): $83,000.	Y	Staff/consultant	• WQ facility maintenance • Project to be performed by hired contractor • Increased maintenance obligation or frequency to be accounted for in programmatic project	N/A	Construction administration (total): $7,000 (or 0.05 FTE)
CIP #16 Water Quality Facility Maintenance - Sweek Pond	Maintain existing WQ facility to restore function	• Engineering and permitting costs estimated at 15% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • Ongoing WQ facility maintenance reflected in programmatic project. • Project cost (total): $103,000.	Y	Staff/consultant	• WQ facility maintenance • Project to be performed by hired contractor • Increased maintenance obligation or frequency to be accounted for in programmatic project	N/A	Construction administration (total): $8,000 (or 0.05 FTE)

Table H-1. Staffing Analysis Summary by CIP ID#							
CIP ID	Project Description	Project Information	Priority Project (Y/N)	Engineering Responsibility	Maintenance Details [a]	Estimated Annual Maintenance Resource Needs (FTE) [b]	Estimated Staff Resource Needs ($ and FTE) [c]
CIP #17 Alsea/BF Rd 99th/Siuslaw Greenway	Replace failing pipes, add pretreatment and enhance water quality along greenway path with WQ swale	• Engineering and permitting costs estimated at 25% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • New WQ facility will require annual inspections and maintenance to ensure plant viability and system functionality. • Project cost (total): $454,000.	N	Staff/consultant	• One new WQ manhole • Annual WQ manhole maintenance (1 hr/MH with biannual frequency) • 500' WQ swale • Inspection four times/year (4 hrs total) • Annual swale maintenance (20'/hr)	Approximately 30 hours of annual maintenance (0.02 FTE)	Construction administration (total): $34,000 (or 0.23 FTE)
CIP #18 Water Quality Facility Maintenance - Waterford	Maintain existing WQ facility to restore function	• Engineering and permitting costs estimated at 15% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • Ongoing WQ facility maintenance reflected in programmatic project. • Project cost (total): $180,000.	Y	Staff/consultant	• WQ facility maintenance • Project to be performed by hired contractor • Increased maintenance obligation or frequency to be accounted for in programmatic project.	N/A	Construction administration (total): $14,000 (or 0.09 FTE)
CIP #19 Saum Creek Slope Repair	Replace existing outfall and repair hillslope failure	• Engineering and permitting costs estimated at 35% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • Project cost includes additional geotechnical evaluation. • No additional maintenance requirements. • Project cost (total): $171,000.	Y	Staff/consultant	• Replace outfall and bank slope repair • No increased maintenance obligation or frequency expected.	N/A	Construction administration (total): $10,000 (or 0.07 FTE)
CIP #20 Hedges Creek Stream Repair	Bank slope stabilization, infrastructure protection, and vegetation management	• Project information and costs are included in the "Hedges Creek Stream Assessment, SW Ibach St. to SW 105th Ave.", February 2018, GreenWorks PC and OTAK, INC. • Ongoing vegetation management reflected in programmatic project. • Project cost (total): $327,000.	Y	Staff/consultant	• Increased maintenance obligation or frequency due to be accounted for in programmatic project	N/A	No related staffing cost estimate
CIP #21 Nyberg Water Quality Facility	Install regional WQ treatment facility at newly acquired City property	• Engineering and permitting costs estimated at 35% of the construction cost. Assume consultant to complete. • Construction administration (City staff) estimated at 10% of the construction cost. • Project cost includes additional estimate for fees and mitigation. • Project cost (total): $2,037,000.	Y	Staff/consultant	• WQ facility maintenance • Project to be performed by hired contractor • Increased maintenance obligation or frequency to be accounted for in programmatic project	N/A	Construction administration (total): $123,000 (or 0.82 FTE)
					Capital Project Total Staffing Estimate (FTE)	5.5 (total) or 0.6 (annual)[d]	
					Priority Capital Project Staffing Estimate (FTE)	2.8 (total) or 0.3 (annual)[d]	
					Annual Program Total (FTE), see Table 8-2	0.4	
					Annual TOTAL (FTE), All Projects and Programs	**1.0**	
					Annual TOTAL (FTE), Priority Projects and Programs	**0.7**	

a. Annual maintenance activities are estimated based on new assets added as part of the capital project scope.

b. Hour estimate for maintenance is based on average time/task provided by city staff and is provided for reference only. For purposes of calculating an equivalent FTE per cost estimate, an annual FTE works 2080 hrs; 0.02 FTE is 40 hrs. Costs are rounded to the 0.01 FTE.

c. Estimated combined resource needs are based directly on the construction administration cost. It reflects staff time (engineering, administration, and operations) to support design, construction and annual maintenance activities. For purposes of calculating an equivalent FTE per cost estimate, an annual FTE salary was assumed at $150,000/year. Costs are rounded to the 0.01 FTE.

d. Annualized over a 10-year planning period.

Appendix I: Clean Water Services Review Comments

Appendix I

Clean Water Services' Review Comments on the Draft Tualatin Stormwater Master Plan

Clean Water Services (CWS) reviewed the April 2019 Draft Stormwater Master Plan for the City of Tualatin. Review comments were received in September 2019 and primarily included comments related to City-identified water quality project opportunity locations (Table 3-1) and the resulting water quality retrofit projects.

Through this review process, CWS identified four additional water quality opportunity locations. Two locations (Location ID 27 and 28 as identified in Table I-1 below) are proposed as alternative locations for CIPs #8 and #9. Two locations are newly identified water quality opportunity locations.

Feedback from CWS did not result in direct changes to proposed CIPs, but these additional water quality opportunity areas can be considered with implementation of the City's new Public Water Quality Facility Retrofit Program. Table I-1 summarizes the CWS-identified water quality opportunity locations.

Figure I-1 below, was provided by CWS. The figure shows proposed water quality opportunity locations compared with City-identified water quality opportunity areas.

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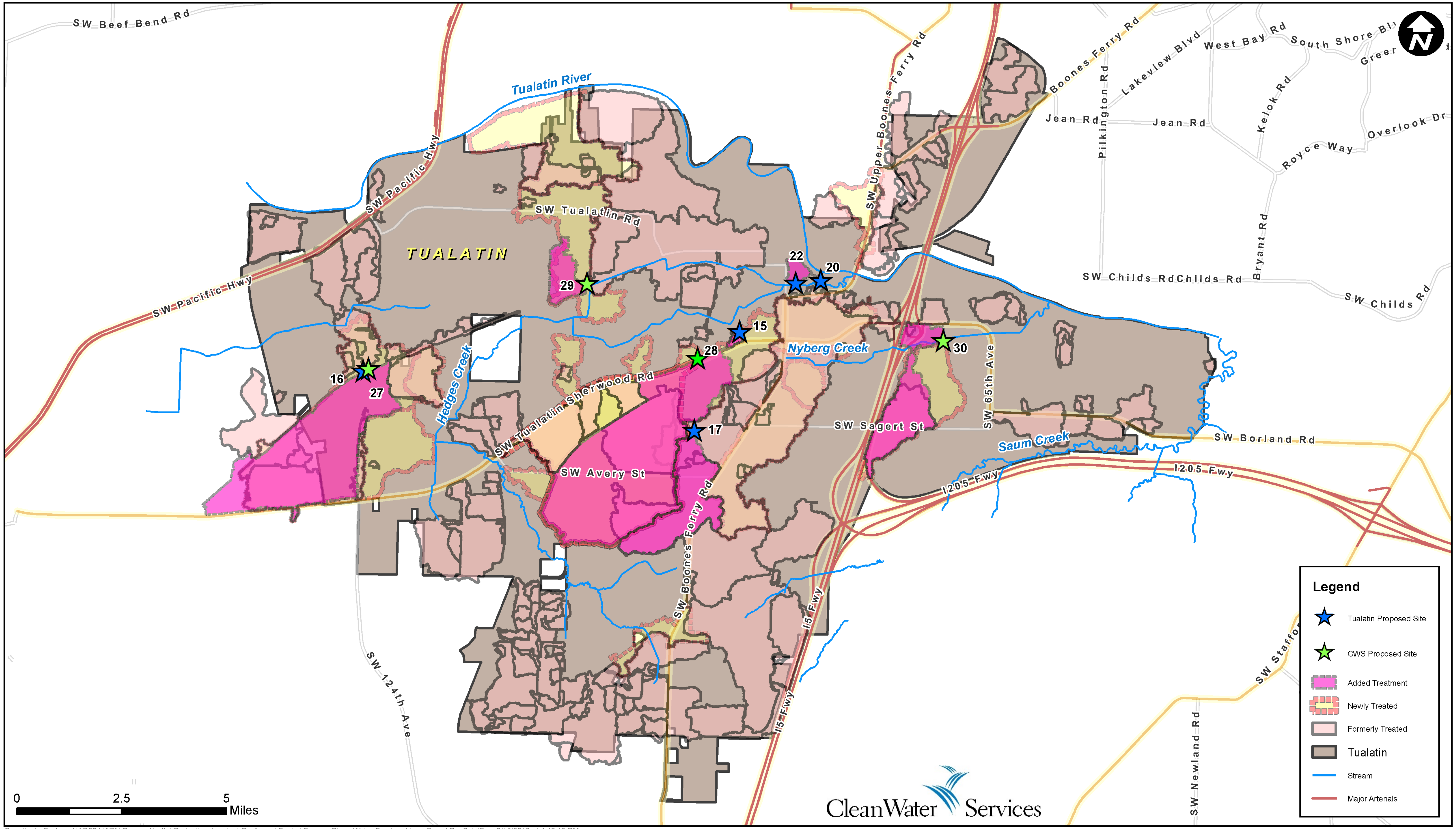
Table I-1. CWS Additional Stormwater Project Opportunities (with CWS comments)									
SW Project Opportunity Area ID	Location	Basin/ Waterbody	Problem/ Project Category	Source	WQ Retrofit Opportunity	Problem/Project Area Description	Preliminary Project Concepts and Observations (per site visits)	Additional Data Collection/City Input (following Project Development Workshop)	CWS Comments
27* (alternative to Location 16)	125th to Herman Rd	Cummins Creek	Water Quality (WQ)	Stormwater CIP WQ retrofit evaluation	X	• Project identified through GIS drainage basin analysis, integrating use of archydro basin delineation and storm flow. • Large untreated area has the potential for WQ treatment (~150 acres)	• Partnership with property owners needed to provide LIDA capable of treating the flows to this location. • Installation of WQMH (sumped) will enable periodic sediment removal before natural area. • Conveyance pipe/outfall replacement due to low slope.	Flow splitter and WQMH to meet flow and sizing criteria designated by CWS standards.	Difficult location, so consider Public-Private Partnership (3P) to construct WQ facility during redevelopment.
28* (alternative to Location 15)	SW 95th Ave- SW Tualatin Sherwood Rd	Hedges Creek	WQ Infrastructure need	Stormwater CIP WQ retrofit evaluation	X	• Project identified through drainage basin analysis, integrating use of archydro basin delineation and storm flow. • Potential to treat 304 acres, of which 147 acres are currently untreated. • Potential for WQ treatment areas to be identified as upstream areas redevelop. • Ideal for WQ/green facility in adjacent open area. Consider constructed wetlands.	• Current conveyance is provided through dual 24" culverts that cross SW Tualatin-Sherwood Rd and flow into 36" CSP alongside the major arterial. • The goal would be to split flows between the current conveyance (36" CSP) and a constructed facility (low flow), which would then reconnect into the 36" pipe. • The project would require coordination with Washington County, City of Tualatin, CWS, and the developer, (as well as additional upstream property owners potentially) to advance WQ treatment opportunities. • Needs further evaluation by consultant of upstream partial WQ treatment.	• Open conveyance between culverts that cross the road and the 36" pipe can be used to place the flow splitter structure, alleviating need of pipe removal. • Facility sizing would be included in scope of project.	• Land is owned by Zidell Companies who is looking to develop it for commercial use. Consider Public-Private Partnership (3P) to construct WQ facility during redevelopment. • Opportunity for partial treatment of large untreated basin with City partnership with smaller WQF construction as upstream development occurs. • WQ project(s) could be coordinated with an expansion of the ROW by Washington County . • Reference map Site 29 additional for basin detail.
29*	SW Teton Ave & SW Herman Rd Intersection	Hedges Creek	WQ	Stormwater CIP WQ retrofit evaluation	X	• Project identified through drainage basin analysis, integrating use of archydro basin delineation and storm flow. • Large untreated area has the potential for WQ treatment (~80 acres).	Needs further evaluation by consultant of upstream partial WQ treatment .	Flow splitter and WQMH to meet flow and sizing criteria designated by CWS standards.	Opportunity for partial treatment of large untreated basin with City partnership with smaller WQF construction as upstream development occurs.
30*	SW Nyberg St/65th Ave	Nyberg St	WQ	Stormwater CIP WQ retrofit evaluation	X	• Project identified through drainage basin analysis, integrating use of archydro basin delineation and storm flow. • Large untreated area has the potential for WQ treatment (xx acres). • Expanded constructed wetland complex to provide WQ treatment before discharging into wetlands surrounding Nyberg Creek, south of SW Nyberg St.	• Potential for WQ facility near convergence of multiple open conveyance ditches, behind site with large businesses. • Expected high level of solids removal and additional treatment area. • Needs further evaluation by consultant of upstream partial WQ treatment.	Facility sizing would be included in scope of project.	• Land owned by the Nyberg Creek Foundation. • Opportunity for partial treatment of large untreated basin with City partnership with smaller WQF construction as upstream development occurs.

**Indicates that the SW Project Opportunity Area ID created by CWS as an arbitrary value to continue using the City of Tualatin format.*



Coordinate System: NAD83 HARN Oregon North | Projection: Lambert Conformal Conic | Source: Clean Water Services | Last Saved By: SahliF on 9/16/2019 at 4:43:15 PM

Figure I-1. Proposed Storm Projects for the Tualatin SMP

Source: Clean Water Services

MEMORANDUM
CITY OF TUALATIN

DATE: **August 2, 2024**

TO: Erin Engman, Senior Planner
Steve Koper, Assistant Community Development Director

FROM: Mike McCarthy, PE, City Engineer
Hayden Ausland, PE, Principal Engineer

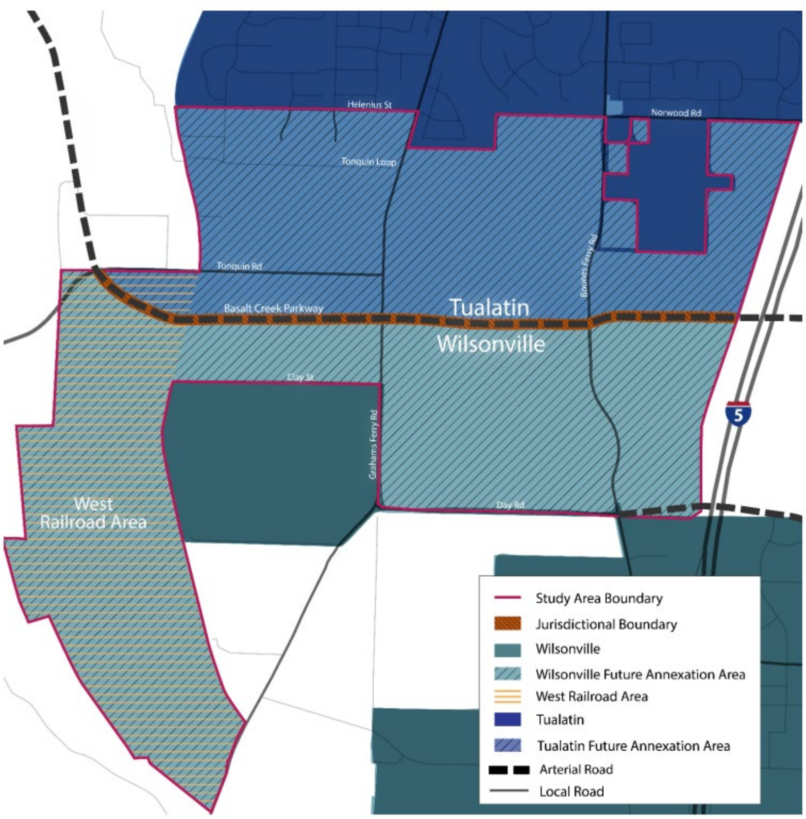
SUBJECT: Stormwater Master Plan Addendum

REGISTERED PROFESSIONAL ENGINEER
84903PE
OREGON
JULY 12, 2022
HAYDEN AUSLAND
EXPIRES: Dec 31, 2025

Stormwater Master Plan Addendum

The purpose of this addendum is to provide an analysis of the stormwater basin within the Basalt Creek Planning Area (Figure 1) and to recommend a regulatory approach to stormwater management that would apply to property development in this area.

Figure 1 Basalt Creek Planning Area and jurisdictional boundaries.



In April of 2022, city staff conducted field observation of two representative properties in the Basalt Creek area (Alvstead and Mast). At both properties, erosion issues were noted adjacent to the Basalt Creek canyon. At the Alvstead property some sedimentation along the creek due to erosion was also observed. The observed conditions were consistent with conditions shown in aerial photography as well as the existing semi-rural development patterns combined with a lack of existing stormwater infrastructure. Further, as noted in the City of Wilsonville's Stormwater Master Plan, downstream capacity issues exist with the Tapman Creek drainage basin, the upstream portion of which is the Basalt Creek Planning Area. Due to the existing erosion concerns and known downstream capacity issues within the Basalt Creek Planning Area and Tapman Creek drainage basin, city staff have drafted this Stormwater Master Plan Addendum and have proposed a "subbasin" approach for the area.

Therefore, development on all properties in the Basalt Creek Planning Area (Exhibit 1) must meet the following enhanced stormwater management standards:

- Hydromodification, subject to conformance with Clean Water Services' Design & Construction Standards; and
- Construction of permanent on-site stormwater quantity detention facilities designed to meet the 2-year, 10-year, and 25-year storm events.

Further, these requirements are proposed to be added to Section 3-5-220 of the Tualatin Municipal Code (TMC), excerpted below (deleted language in ~~strikethrough~~ and added language in **bold underline**).

TMC 3-5-220 - Criteria for Requiring On-Site Detention to be Constructed.
[…]
On-site facilities shall be constructed when any of the following conditions exist:
[…]
(3) There is a site within the boundary of the development which would qualify as a regional detention site under criteria or capital plan adopted by **Clean Water Services** ~~the Unified Sewerage Agency~~.
(4) The site is located in the Hedges Creek Subbasin as identified in the Tualatin ~~Drainage~~ **Stormwater Master** Plan and surface water runoff from the site flows directly or indirectly into the Wetland Protected Area (WPA) as defined in TDC 71.020. Properties located within the Wetland Protection District as described in TDC 71.010, or within the portion of the subbasin east of SW Tualatin Road are excepted from the on-site detention facility requirement.
(5) The site is located in the Basalt Creek Subbasin, as identified in the Tualatin Stormwater Master Plan. Properties located in the Basalt Creek Subbasin must meet hydromodification, subject to conformance with Clean Water Services' Design & Construction (D&C) Standards and must provide permanent on-site stormwater quantity detention facilities designed to meet the 2-year, 10-year, and 25-year storm events.