Hydromodification Assessment

Prepared for

City of Wilsonville

June 2015

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CITY OF WILSONVILLE

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)
HYDROMODIFICATION ASSESSMENT
JULY 1, 2015

The undersigned hereby submits this Hydromodification Assessment in accordance with NPDES Permit Number 101348. I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person, or persons, who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

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Natural Resources Program Manager

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List of Abbreviations

BC	Brown and Caldwell
CIP	capital improvement project
City	City of Wilsonville
DEQ	Oregon Department of Environmental Quality
EPA	U.S. Environmental Protection Agency
GIS	geographic information system
I-5	Interstate 5
LID	low-impact development
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
ODFW	Oregon Department of Fish and Wildlife
ODOT	Oregon Department of Transportation
RM	river mile
SMP	*City of Wilsonville Stormwater Master Plan* (March 2012)
SROZ	Significant Resource Overlay Zone
TMDL	total maximum daily load
UGB	urban growth boundary
UIC	underground injection control
WMC	*Wilsonville Municipal Code*

Section 1

Introduction and Key Findings

Brown and Caldwell (BC) completed a hydromodification assessment for the City of Wilsonville (City). This study was conducted in accordance with the City's National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit, in advance of the July 1, 2015, compliance deadline.

Hydromodification of stream channels is caused by both natural and man-made factors. This study is focused on hydromodification impacts associated with urbanization and MS4 discharges. As a highly urbanized area, stormwater discharges in the city have historically impacted stream corridors. Projected development patterns have the potential to continue to impact stream corridors by increasing stormwater runoff in the headwater areas of the city. Results of this study show that the City should continue to implement key programs and projects to address hydromodification impacts.

This hydromodification assessment includes a review of existing planning documents, a geographic information system (GIS) desktop evaluation of watershed conditions, and targeted field assessments to identify hydromodification indicators.

Based on these evaluations, the hydromodification assessment revealed the following conclusions:

- Observed stream channels indicate historical hydromodification impacts. Minor hydromodification impacts are currently observed in locations of concentrated flows and development encroachment.
- Current City programs and policies appear to be effective at addressing hydromodification indicators.
- Current land use and future development patterns in the city show that there is the potential for future flow increases.
- The City's current land use policies and updated stormwater design standards are in line with best practices to address hydromodification.
- The City has already identified and is implementing projects to address hydromodification.

In light of these conclusions, it is recommended that the City continue to invest in programs and projects to address hydromodification. The following recommendations are expanded on in Section 8:

- Implement key capital projects to address in-stream hydromodification problems, such as significant erosion at stormwater outfalls and historical channel modifications.
- Continue to monitor known problem areas through annual inspections and documentation.
- Continue to develop and implement master plans for new development areas that address natural resource issues and include channel restoration priorities.

The conclusions and recommendations outlined in this hydromodification assessment may be used to inform City priorities in refining policies and continuing development of projects to address hydromodification.

Section 2

Hydromodification Background

The city of Wilsonville is located in both Washington and Clackamas counties, approximately 20 miles south of the city of Portland. The city is located in the middle Willamette River watershed. Drainage from Wilsonville flows to the Willamette River via Coffee Lake Creek, Boeckman Creek, and other natural channels.

As an urbanized area, stormwater discharges generated in the city have the potential to impact stream conditions through hydromodification. Increasing impervious area through development and redevelopment activities alters runoff conditions and increases flow to them, typically increasing stream energy. Increased stream energy can alter stream channels through flooding, bank erosion, bed incision, sediment production, and other impacts.

The City's NPDES MS4 permit requires the City to complete and submit a hydromodification assessment by July 1, 2015. The assessment must evaluate stream channels in the city to determine whether discharges from the MS4 have impacted stream channels and whether future development patterns are likely to contribute to additional impacts. The assessment must then identify strategies to address the hydromodification impacts.

2.1 What is Hydromodification?

The U.S. Environmental Protection Agency (EPA) (1993) broadly defines hydromodification as the "alteration of the hydrologic characteristics of coastal and non-coastal waters, which in turn could cause degradation of water resources." This definition covers the range of changes to hydrologic characteristics, which are generally associated with changes in land use, construction or removal of dams, or other man-made or natural channel modifications. This study is focused on the aspects of hydromodification that are addressed by the NPDES MS4 permit: erosion; sedimentation; and alteration of stormwater flow, volume, and duration that may cause or contribute to water quality degradation.

While the concept of hydromodification is new to the NPDES MS4 permits in Oregon, the concept is not new in scientific literature, which suggests that the frequency and duration of *geomorphically significant flows* are the primary factors that control channel stability or instability. Geomorphically significant flows range from a lower threshold of flow where bed material begins to move to an upper limit where flood flows are no longer contained in the channel (Dunne and Leopold, 1978). Smaller, more frequent flow events tend to move the most sediment over time, dictating channel dimensions.

When watersheds develop, the overall increase of flow and volume that occurs with increasing impervious surface translates to an increase in stream energy that can cause bank erosion, bed incision, sediment production, and other channel alterations. Small storm events tend to result in the greatest change in runoff patterns when development occurs (Hollis, 1975).

Figure 2-1 shows the percent change in stormwater runoff from storm events when a watershed moves from 20 percent to 30 percent impervious coverage. During frequent events, such as the 1-year storm, pervious areas provide opportunity for infiltration. Significant differences in runoff are observed as impervious surfaces are added to the watershed.

For large storm events greater than the 10-year storm, the increasing impervious coverage does not significantly increase runoff. Large storm events typically occur during saturated soil conditions, effectively turning the whole watershed into an impervious surface. Efforts to reduce hydromodification and manage the geomorphically significant flows must pay particular attention to small storm events.

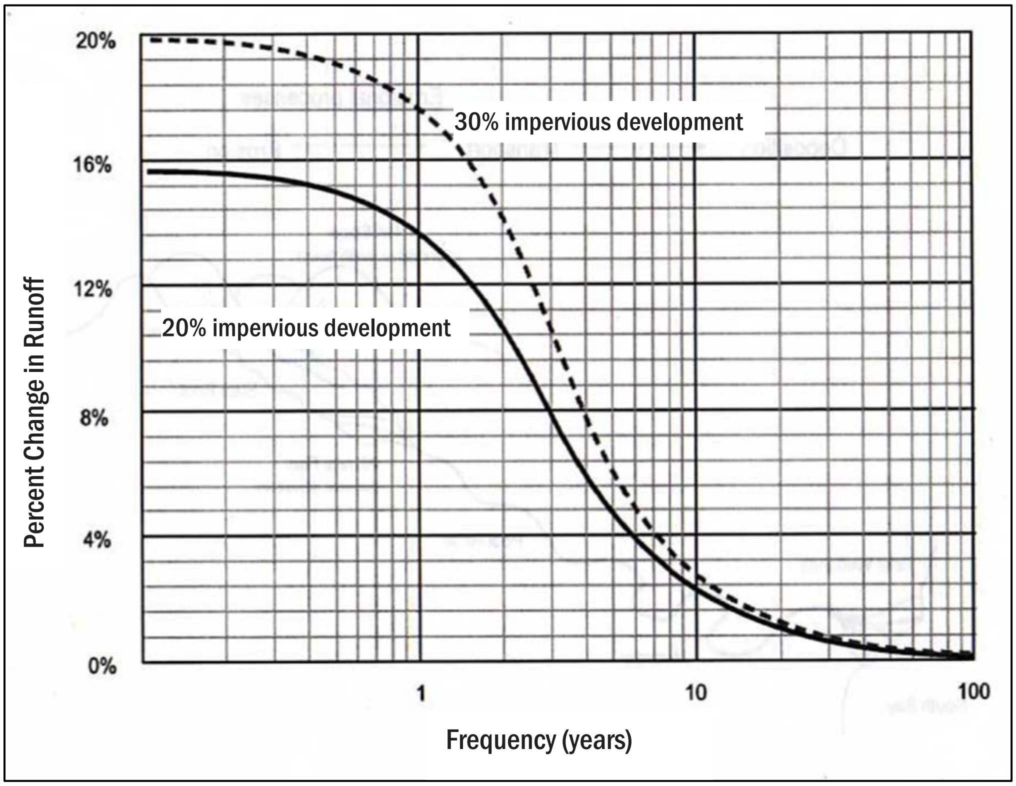

Figure 2-1. Effects of imperviousness and storm frequency on runoff

Source: Hollis, 1975

To control flooding, traditional flow control standards have required detention facilities that reduce peak flows to pre-development levels. These standards do not address the increase in flow volume or the duration of peak flows. Figure 2-2 shows how the traditional standards may have significant impacts on stream channel conditions. Development and urbanization increase peak flows above pre-development conditions (compare "Development" line to "Predevelopment" line in Figure 2-2). When detention facilities are installed to reduce peak flows to pre-development levels (see "With Detention" line in Figure 2-2), the result is an increase in the duration of controlled peak flows. Those controlled peaks are often in the range of flows that impact channel shape. Hydromodification control strategies must focus on volume control to reduce the duration and frequency of geomorphically significant flows.

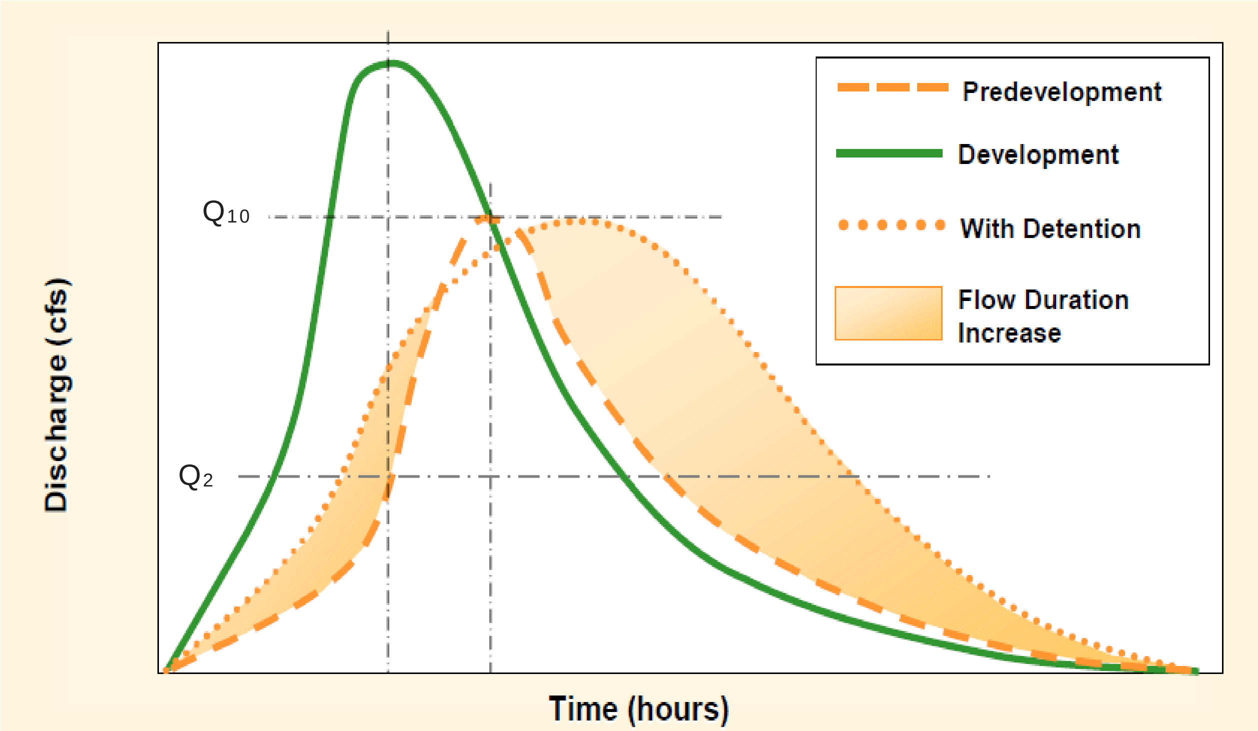

Figure 2-2. Schematic representation of how peak flow matching can increase energy in creek systems

2.2 Regulatory Requirements

As a surface water management agency, the City must comply with the federal Clean Water Act and the associated NPDES program. The City is a co-permittee on Clackamas County Phase I NPDES MS4 Permit 101348, which was issued by the Oregon Department of Environmental Quality (DEQ) on March 16, 2012.

Regionally, addressing hydromodification is considered to be the current best science in surface water management related to flows. Early stormwater management approaches focused on addressing flood control by upsizing conveyance systems or installing detention/retention facilities to prevent downstream flooding of private property and public infrastructure. In 1995, the first NPDES MS4 permits were issued to Phase I jurisdictions in Oregon, increasing the focus on water quality and the need to reduce pollutants in stormwater runoff. More recently, total maximum daily load (TMDL) requirements for municipal stormwater programs have further emphasized the need for pollutant reduction.

The current regulatory emphasis on hydromodification acknowledges that flow changes in stream channels are due in part to changes in stormwater runoff patterns, peak flow, and volume. Such flow changes in stream channels can result in flooding, water quality impacts, bank and bed erosion, channel instability, loss of aquatic and riparian habitat, and property impacts.

The City's NPDES MS4 permit, Schedule A.5 requires the development of the hydromodification assessment. The specific permit language is written as follows:

5. *The co-permittee must conduct an initial hydromodification assessment and submit a report by July 1, 2015 that examines the hydromodification impacts related to the co-permittee's MS4 discharges, including erosion, sedimentation, and alteration to stormwater flow, volume and duration that may cause or contribute to water quality degradation. The report shall describe existing efforts and proposed actions the co-permittee has identified to address the following objectives:*
   a. *Collect and maintain information that will inform future stormwater management decisions related to hydromodification based on local conditions and needs;*
   b. *Identify or develop strategies to address hydromodification information or data gaps related to water bodies within the co-permittee's jurisdiction;*
   c. *Identify strategies and priorities for preventing or reducing hydromodification impacts related to the co-permittee's MS4 discharges; and,*
   d. *Identify or develop effective tools to reduce hydromodification.*

This report is intended to meet the NPDES MS4 permit requirements for the hydromodification assessment.

2.3 Strategies to Address Hydromodification

This section describes potential strategies that jurisdictions might use to address hydromodification. Upland strategies manage flows from the contributing watershed. In-stream strategies address stream or creek conditions to accommodate higher flows and prevent ongoing channel alteration. Section 8 provides recommendations about which of these approaches, or combination of approaches, is recommended for use in Wilsonville.

2.3.1 Upland Strategies

Urbanization adds impervious surface, which reduces opportunities for stormwater runoff to infiltrate into the soil layer. As described in Section 2.1, this results in higher rates, volumes, and durations of stormwater flow. Typical upland strategies to combat the increase in stormwater flow include the installation of stormwater management facilities to manage flows from the contributing watershed and/or site planning adjustments to reduce the impervious areas in the watershed. Additional details are included below.

Infiltration. Infiltration reduces the overall volume of stormwater flowing into local waterways during storm events, better mimicking the pre-developed conditions.

Infiltration systems include green infrastructure (i.e., rain gardens, planters, swales), drywells, infiltration trenches, and infiltrating storage tanks or vaults. Infiltration systems can be located throughout a watershed to infiltrate stormwater near the source or placed at the downstream end of a collection and conveyance system to infiltrate runoff before discharge to a natural channel. Below-ground infiltration systems, such as drywells, infiltrating storage tanks, or vaults, must be designed to comply with regulations governing underground injection control (UIC) systems.

DEQ's Phase I NPDES MS4 permits require permittees to prioritize low-impact development (LID) and other green infrastructure approaches to better mimic natural conditions. Communities like Wilsonville, Salem, and Oregon City have recently adopted new stormwater standards that require the use of infiltration-based stormwater controls to the maximum extent practicable.

Nationally, some NPDES MS4 permits require a retention-based flow control standard that requires development projects to capture and retain a specified percentage of all stormwater runoff on the site. This can be accomplished only through the use of infiltration systems.

Detention. Detention of flow is a runoff management strategy that can be applied to new development areas, redevelopment areas, and regionally as a basin-wide control. Detention systems include ponds, storage wetlands, or underground tanks or vaults designed to capture runoff and release it at a lower rate.

Detention facilities can be designed based on a traditional peak flow matching standard or a flow-duration matching standard. As discussed in Section 2.1, a traditional peak flow matching standard can result in excess stream energy during the range of geomorphically significant flows. Flow-duration matching is the statewide standard in Washington, and several Oregon jurisdictions (including Wilsonville) are adopting or have adopted a flow-duration matching standard as a way to address hydromodification.

Sizing detention facilities to match peak flow and flow duration can present a number of challenges. One challenge is that it requires the use of more sophisticated modeling approaches than traditional approaches. Many jurisdictions that adopt a flow-duration standard also develop tools to aid developers and engineers with implementation. Another challenge is the difficulty in determining the appropriate range of geomorphically significant flows. Often the flows are quite variable and stream-specific. Jurisdictions may either directly analyze their stream channels through a complicated monitoring approach or rely on literature values and regional assumptions that may over- or under-predict the necessary level of protection.

Site Planning. LID site planning principles emphasize design features that minimize impervious surfaces and reduce the effective impervious area that is directly connected to the MS4. These site planning principles may be applied to new development or redevelopment activities in an effort to replicate pre-development hydrology. Typical site planning principles include clustering development to reduce road and driveway surfaces, narrowing streets, using porous pavements, and disconnecting residential downspouts to provide increased stormwater dispersion and infiltration opportunities. By applying these principles, impervious surfaces in developed areas are reduced, which reduces the need for other flow management strategies.

2.3.2 In-Stream Strategies

When upland strategies are not effective in reducing stream energy in the natural system, in-stream strategies may be required to accommodate higher flows and prevent ongoing channel alteration.

Stream Stability Projects. Stream stability projects include a variety of in-stream channel improvements to modify the stream channel to accommodate larger stream flows, while still providing desired habitat, riparian, and water quality features. Stream stability and restoration projects can be effective in addressing hydromodification in areas where the upstream development patterns are established and the stream corridor has adequate buffer areas to allow for the creation of a larger channel and floodplain. Existing culverts and other man-made structures may need to be upsized to accommodate higher flows and/or provide fish passage.

Stream stability and restoration projects typically require permits from natural resource agencies. These projects must be designed to account for both upstream and downstream impacts and are typically most effective when designed to address specific problems within a larger watershed context.

Riparian Zone and Floodplain Restoration. Near-channel restoration is a strategy to reconnect a stream channel to the natural floodplain. Stream channels in equilibrium will naturally overflow banks during peak flows. When the channel flows out of bank, stream energy is reduced. Urbanized systems often have limited riparian areas because of development encroachment. This reduces the floodplain area available, so excess stream energy is focused in the channel, which leads to bank erosion and bed incision. Maintaining stream buffers, restoring riparian planting, and reconnecting channels to floodplain areas are all strategies to reduce stream energy during peak flows.

Piped Bypass Systems. When channel conditions cannot be modified to accommodate a changed flow regime, a piped bypass system could be considered as a method to re-route stormwater flows away from the stream channel and toward reaches that can handle increased flows. To be effective at addressing hydromodification concerns, bypass systems should be designed to bypass excess stormwater flows during the full range of geomorphically significant flows.

Piped bypass systems may be an effective solution to address specific problems in areas that are adjacent to large rivers that can accept increased local flows (Willamette River, Clackamas River, etc.). However, these projects sometimes require property acquisition or a series of easements to install the bypass systems, which can be cost-prohibitive.

Section 3

Methodology and Approach

This report is intended to meet the NPDES MS4 permit requirements for the hydromodification assessment. This assessment included a GIS desktop assessment, targeted field assessment, and review of existing planning documents and policies to inform the development of strategies and approaches to address hydromodification. The results of this study show that the City should continue to invest in programs and projects to address hydromodification.

This hydromodification assessment includes the following elements:

- a *GIS assessment* of watershed conditions to evaluate drainage patterns, natural features, and the extent of urbanization and future development potential (Section 4)
- a *field assessment* of known problem areas and other locations to identify hydromodification indicators (Section 5)
- a *review of existing design standards and zoning code* to determine whether current standards are adequate to protect against further impacts (Section 6)
- an *evaluation of planning documents and watershed studies* to identify projects that will restore impacted channels or help manage stormwater runoff to better mimic historical conditions (Section 7)

The overall goal of this hydromodification assessment is to conduct a qualitative evaluation of stream channel conditions and to determine locations where past development patterns and controls (or lack of controls) have resulted in significant stream channel impacts. In some cases, the hydromodification assessment revealed locations where natural channel conditions have provided buffering against stream channel impacts. In other cases, locations where the stream channel may be more susceptible to incision and erosion were identified. At these locations, minor increases in flows can have significant impacts.

Figure 3-1 illustrates the relationship between natural stream channel conditions and urbanization patterns in causing or resisting hydromodification impacts.

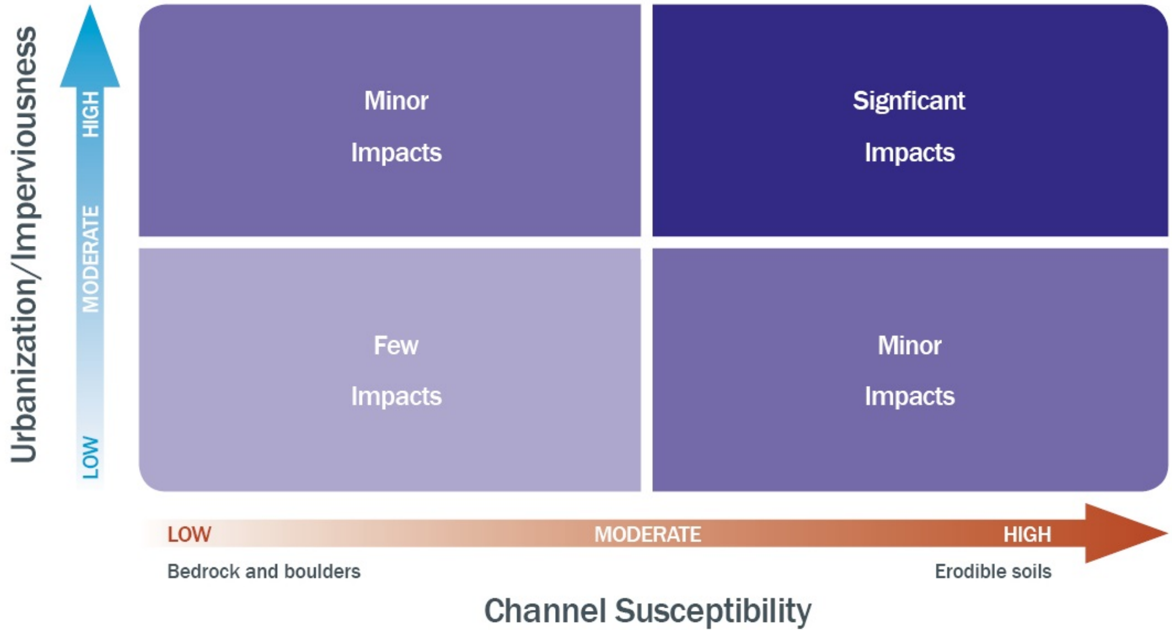

Figure 3-1. Relationship of urbanization and stream channel conditions on hydromodification potential

3.1 Future Use of This Assessment

This hydromodification assessment may be used to inform City decisions related to land use and development policy, design standards, and capital projects. Where specific project locations are identified, associated projects should be incorporated into the City's project prioritization and funding strategy as necessary.

In the past, DEQ has indicated that the results of this assessment may be considered in developing future NPDES MS4 permit requirements and post-construction performance standards.

3.2 Other Methods Considered

DEQ's NPDES MS4 Phase I permit evaluation report acknowledges that the sources and issues related to hydromodification vary among jurisdictions. The combination of geology, topography, hydrology, land use planning, stream channel configurations, and drainage system layout may collectively contribute to hydromodification. However, the same combination of factors, coupled with policies, design standards, and capital projects, may serve to reduce the potential impacts.

Methods to assess and evaluate each stream segment and each hydromodification factor individually would require significant cost and resources beyond what is available. Methods of data collection and analysis that were initially considered for this hydromodification assessment included conducting detailed stream surveys, cross-section mapping, and hydrologic/hydraulic modeling to inform shear stress analysis. Each of these methodologies would have required extensive additional data collection. Furthermore, such an effort would produce only a baseline assessment of current conditions. Future analyses would be required to evaluate change in the baseline stream channel conditions over time. Instead, this hydromodification assessment accounts for existing local knowledge and provides the background for future data collection efforts, if necessary.

Section 4

Desktop Assessment of Watershed Conditions

One element of the hydromodification assessment was to conduct a GIS-based desktop assessment. The goals of the desktop assessment were as follows:

- evaluate watershed conditions to understand drainage patterns and locations of natural features
- evaluate how current and future development patterns may contribute to hydromodification

Two primary sources of data were used for conducting this desktop assessment. First, GIS data layers provided by the City were used to prepare maps of watershed features, land use conditions, and future anticipated development areas. These maps are included in Appendix A. Second, relevant City planning documents including the *City of Wilsonville Stormwater Master Plan* (March 2012) (SMP), Survey of Fish Species and Habitat in Wilsonville Streams (ODFW, 2006), and macroinvertebrate assessment reports (2004 and 2013) were reviewed for information on drainage basins, observed habitat conditions, and water quality.

The city is located at the downstream portion of the Coffee Lake Creek and Boeckman Creek watersheds. A majority of stormwater runoff from the city enters those two tributaries. Historical development patterns have resulted in channelized wetland areas, the creation of low-gradient stream channels, and altered natural flow patterns.

The city's natural hydrogeology contains silty soils with limited infiltration capability and moderate erodibility potential, particularly in the headwater areas and upland areas. These conditions create the potential for hydromodification when changes in stream energy occur.

The City has experienced strong and steady growth over the last 30 years and future growth is expected to continue at a similar pace. New development is expected to add significant impervious surfaces in the Coffee Lake Creek and Boeckman Creek watersheds. Projected development patterns have the potential to impact stream channels, and the City will need proper infrastructure and land use policies to mitigate impacts.

4.1 Watershed Summary

Wilsonville's MS4 service area is approximately 4,600 acres, covering all area within the city limits. An additional 460 acres of area is located within the city's urban growth boundary (UGB) and is anticipated for development in the near future. Approximately 1,000 acres outside of the city's UGB is defined as a future planning area.

Wilsonville is located in the middle Willamette River watershed, along the Willamette River between river miles (RMs) 37 and 40. The Willamette River runs from west to east along the southern city boundary. The Interstate 5 (I-5) corridor runs north and south through the middle of the city.

The western portion of the city (west of the I-5 corridor) is primarily composed of the Coffee Lake Creek watershed. Tributaries to Coffee Lake Creek include Arrowhead Creek, Basalt Creek, the middle tributary to Coffee Lake Creek, and the southern tributary to Coffee Lake Creek. The Coffee

Lake wetland area is a large wetland complex that is one of the major restoration sites within the city.

The eastern portion of the city (east of the I-5 corridor) includes the headwaters of the middle and southern tributaries to Coffee Lake Creek, Boeckman Creek watershed, and Meridian Creek watershed. Areas directly along the Willamette River, including the Charbonneau development south of the Willamette River, discharge directly to the Willamette River.

Figure 4-1 shows an overview of the watersheds in the city. Table 4-1 documents the drainage areas associated with each watershed.

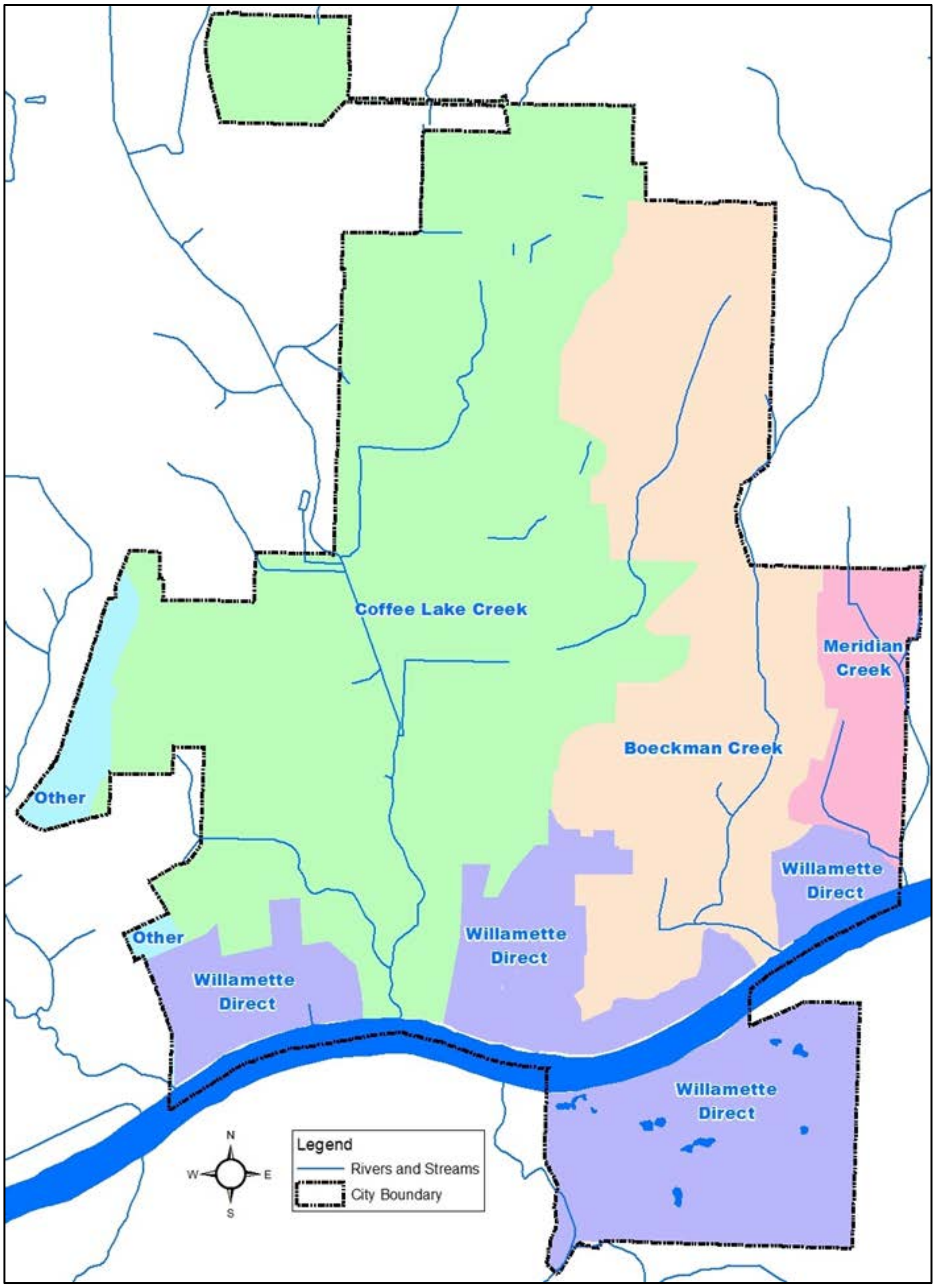

Figure 4-1. Overview of city watersheds

Data source: City of Wilsonville GIS

Table 4-1. Wilsonville Watershed Summary		
Watershed	Subbasins	Total area within city limits (acres)
Coffee Lake Creek	Arrowhead Creek	2,120
	Basalt Creek	
	Coffee Lake Creek (south tributary)	
	Coffee Lake Creek (middle tributary)	
Boeckman Creek	Boeckman Creek	1,100
Meridian Creek	Meridian Creek	190
Willamette River (direct)	Charbonneau development area	970
	Other	
Other	Villebois development area	210
	Other tributaries	

Source: City of Wilsonville 2012 Stormwater Master Plan. Acreage has been rounded.

Topography and soil characteristics within the city vary by watershed. The city consists of relatively flat topography, with the exception of the steep slopes along the Boeckman Creek corridor. Elevation within the city ranges from approximately 380 feet in the headwaters of Coffee Lake Creek to approximately 60 feet at the Willamette River.

Soils within the city are generally limited in infiltration capability (type C/D), although large areas of type B soils along the Willamette River and in the headwaters of Basalt Creek have better infiltration rates. Soils are generally silty or silty loam, except along the canyon portion of Boeckman Creek, which are combination silt and sand. The downstream reach of Coffee Lake Creek also has more gravel and cobble substrate materials (ODFW, 2006). This literature-reported soil composition breakdown was verified during field observations (see Appendix C).

A review of the soil erodibility factor (K factor), which represents the susceptibility of soil to erosion and rate of runoff, was also conducted. Although not a specific indicator of channel erosion, this can be used to help determine the susceptibility of soils to erosion. Soils with high silt content and K values greater than 0.4 are most susceptible to erosion. As shown in Figure A-2, Basalt Creek, Arrowhead Creek, the middle tributary to Coffee Lake Creek, and portions of the Boeckman Creek watershed may be more susceptible to erosion than other areas of the city, and thus may be more susceptible to hydromodification when changes in stream energy occur.

Stream geomorphology and habitat differs between the Coffee Lake Creek drainage system and the Boeckman Creek drainage system. The upstream portion of the Coffee Lake Creek drainage system has been historically modified and contains numerous beaver dams. Pools tend to dominate the habitat conditions, and the Coffee Lake Wetlands provide for storage and detention of flow. The downstream portion of the Coffee Lake Creek drainage system is fairly channelized. The Boeckman Creek drainage system is composed of more fast water units, and stream conditions are in general more susceptible to erosion (ODFW, 2006).

Most stream reaches throughout the city are heavily vegetated with good riparian buffers and tree canopy. Exceptions include Coffee Lake Creek upstream of Wilsonville Road and the middle tributary of Coffee Lake Creek, which flow through agricultural areas and grass fields, providing little shade.

This watershed summary is supported by the following maps, located in Appendix A:

- Figure A-1. Soils and Topography
- Figure A-2. Soil Erodibility
- Figure A-3. Land Use and Development Patterns
- Figure A-4. Hydromodification Data Compilation (field assessment locations)

4.2 Development Patterns

As part of the desktop assessment, an evaluation of land use, planned developments, and Metro-designated vacant lands was conducted to assess the current level of urbanization and impervious surface in the city and to evaluate whether future development is likely to significantly contribute to additional hydromodification of the stream channels.

Historical development activities have resulted in channelized wetland areas, which have created low gradient stream channels and altered natural flow patterns. Particularly in the western portion of the city, development during the 1950s, 1960s, and 1970s was accommodated by filling wetlands and redirecting contributing flow.

Flows in the city have also been re-routed to accommodate new development. For example, a historical flow diversion re-routed flow from Arrowhead Creek (in the Coffee Lake Creek watershed) to Legacy Creek (outside of the city limits), and a current flow diversion re-routes flow from the middle tributary of Coffee Lake Creek toward upstream Boeckman Creek at Canyon Creek Park. While recent efforts have been made to redirect flows back to their historical points of discharge, impacts can still be observed.

Current development includes large commercial and industrial areas along the I-5 corridor. Residential development is located in the Boeckman Creek basin, downstream portion of the Coffee Lake Creek basin, Charbonneau area south of the Willamette River, and new Villebois development at the west end of the city.

Because most development in the city has occurred in the last 20–30 years, many developments have installed stormwater facilities to address peak flows to receiving waters. The field assessment (Section 5) investigates the conditions of tributary streams to evaluate whether the required stormwater management facilities have been providing adequate mitigation against hydromodification in tributary areas.

Villebois is a newer master planned development area covering approximately 150 acres along the western city boundary in the Coffee Lake Creek watershed. Concept planning for this area placed strong emphasis on protection of natural resources and restoration of historical flow patterns. As such, the Villebois development included significant use of green infrastructure for stormwater management, well before current design standards and requirements were in place. The master plan also called for removal of a historical flow diversion to Legacy Creek and relocation of flow back to Arrowhead Creek.

Much of the future development is projected to occur within the Coffee Lake Creek and Boeckman Creek basins. The City has significant undeveloped and underdeveloped areas within its city limits; pending future commercial and industrial infill development areas are located throughout the central corridor of the city (see Figure A-4). Development is also projected to occur in designated future planning areas within the city UGB. These future planning areas include the Coffee Creek Planning Area (industrial development), Frog Pond Planning Area (residential development), and School/ Community Park Planning Area (public development). The City intends to use a similar master planning process to guide those developments, which would provide opportunity to mitigate natural resource impacts, including the protection and restoration of adjacent stream channels.

Section 5

Field Assessment

The field assessment was conducted over 2 days in May 2015, by both BC and City staff. Field observations identified hydromodification impacts throughout the tributaries included in the evaluation.

Because the City has not previously performed a comprehensive stream channel evaluation for comparison, the field assessment focused on using ***hydromodification indicators*** to identify locations where past events have already caused alteration to the stream channel. Where indicators were observed, the desktop assessment (Section 4) was used to infer what previous events (development patterns, flow restrictions, etc.) may have contributed to the observed problem. Understanding the potential causes then informs the development of hydromodification strategies and projects outlined in Section 8.

The results of the field assessment identified the following stream characteristics and hydromodification indicators in the city:

- Boeckman Creek is a well-protected stream channel with limited observed bank erosion or channel incision, especially considering the level of surrounding development. Active erosion is isolated to stormwater outfalls and headwater areas. Most observed problems at stormwater outfall locations are well upslope of channel.
- Arrowhead Creek appears to be managing the altered flow regime (after removal of the historical flow diversion), which indicates that the channel is sized accordingly for expected flows.
- Coffee Lake Creek and tributaries are significantly modified due to development, but flat grade and the Coffee Lake wetland system mitigate downstream flows. Channel bank and bed materials, particularly in headwater areas, appear to be susceptible to erosion and incision.
- Reported stream channel flooding in the Coffee Lake Creek watershed is generally isolated to areas where development has encroached on the stream channel.
- Implementation of wide setbacks and adherence to the Significant Resource Overlay Zone (SROZ) has resulted in limited development encroachment and an established riparian buffer along a majority of the evaluated reaches.

These observations indicate that while urbanization has increased flow to stream channels, the City has implemented measures to dissipate flow and reduce stream energy. Such measures appear to be effective and have minimized the potential for bank erosion and bed incision. Identified problem areas are generally associated with stormwater outfalls and other concentrated discharge locations. Ongoing visual monitoring may be used to document changes in specific problem areas.

The field assessment also shows the need for stabilization projects at key locations to address active erosion problems and reduce the potential for future impacts. A majority of such stabilization projects are currently reflected in the stormwater capital project list.

5.1 Field Methodology

Alissa Maxwell, P.E., and Angela Wieland, P.E., of BC conducted the field assessment on May 21 with support from City staff (Kerry Rappold, Luke Bushman, Arnie Gray, and Casey Peck).

The field assessment was qualitative in nature and was focused on documenting existing channel conditions. Priority locations for the field assessment were identified based on known and suspected problem areas where flooding, citizen complaints, or public works staff observations have indicated that the stream channel could be impacted by urbanization. Priority locations were also selected based on expected future upstream development and, in some cases, correlated to monitoring sites or locations of City restoration and enhancement projects.

Fieldwork included 12 locations across the Coffee Lake Creek and Boeckman Creek watersheds to establish a comprehensive understanding of stream channel conditions. A 2-mile walk was conducted along Boeckman Creek to evaluate the condition of the stream channel. The stream walk included evaluation of the condition of stormwater outfalls and effectiveness of stormwater management controls in the surrounding development area.

The field assessment did not emphasize areas with direct discharge to the Willamette River, as Wilsonville's MS4 discharge is insignificant compared to the total watershed area of this large river system.

Nearly all of the field observations were made from public property. Table 5-1 lists the specific locations of field observations. Field observation locations are also mapped on Figure A-4 in Appendix A.

Table 5-1. Hydromodification Assessment Field Observation Locations

Site number	Watershed	Water body	Location	Description
001	Coffee Lake Creek	Arrowhead Creek	At Jobsey Lane access from Brown Avenue	• City-identified problem area due to scour at existing 48" culvert outlet • Location of proposed CIP CLC-9 • Adjacent area with future development potential • Location visited in order to evaluate channel conditions following removal of flow diversion to Legacy Creek
002	Coffee Lake Creek	Arrowhead Creek	At bridge to Water Treatment Plan, approximately 1,000' upstream of confluence with Coffee Lake Creek	• Location visited in order to evaluate channel conditions following removal of flow diversion to Legacy Creek
003	Coffee Lake Creek	Coffee Lake Creek	At Industrial Way, between Wilsonville Road and Ore Pac Avenue	• Approximately 1,500' upstream of confluence with Arrowhead Creek • City-identified problem area due to incised channel with limited riparian canopy • Location of proposed CIP CLC-8
004	Coffee Lake Creek	South tributary	At Boberg Road	• City-identified problem area due to channel incision, invasives, and erosion at existing 42" culvert • Location of proposed CIP CLC-7
005	Coffee Lake Creek	Coffee Lake wetlands	At Boeckman Road	• City restoration and mitigation site • Site is also location of potential future Metro purchase to improve habitat and channel connectivity

Site number	Watershed	Water body	Location	Description
	Table 5-1. Hydromodification Assessment Field Observation Locations			
006	Coffee Lake Creek	Basalt Creek	Southwest of Commerce Circle and north of Ridder Road	• City-identified problem area due to reported flooding on private property • Location of proposed CIP CLC-3
007	Coffee Lake Creek	South Tributary	Approximately 1,000' upstream of site 004	• Baseline site for comparison with site 004
008	Boeckman Creek	Boeckman Creek	Canyon Creek Park	• City-identified problem area due to observed bank erosion • Flow diversion upstream results in increased flow to this location
009	Meridian Creek	Upland area	At Frog Pond development area	• Site of proposed future development area
010	Boeckman Creek	Boeckman Creek	2-mile reach from Boeckman Road to trail access at Meadows Loop	• Prominent natural channel location through east side of the city • Includes City-identified problem areas due to active erosion at outfall locations • Includes location of proposed CIP BC-2
011	Boeckman Creek	Boeckman Creek	Downstream of Gesellschaft Water Well	• Specific location during site 010 stream walk • City-identified problem area due to active erosion at stormwater outfall and water system flushing into the channel • Location of proposed CIP BC-4
012	Boeckman Creek	Boeckman Creek	At Rose Lane	• Location of past City capital project to replace constricting culvert with footbridge within Memorial Park • Macroinvertebrate monitoring location

The field assessment was used to document hydromodification indicators by taking photographs at each site (see Appendix B) and completing Stream Channel Observation Forms for major observed reaches (see Appendix C).

5.2 Stream Channel Characterization

The field observations indicate that stream channels in the city appear to be relatively stable, with little evidence of active bank erosion and channel incision or widening. There is some evidence of bank erosion and bed incision at locations of restricted or concentrated flow. Concentrated flows typically occur at stormwater outfalls, road culverts, and other areas where development encroachment has limited floodplain connectivity. Development encroachment also reduces the ability of stream channels to widen and restabilize to accommodate increased flow.

Generally, erosion associated with stormwater outfalls is isolated to the hillside or channel side slope where the stormwater flow has created a conveyance ditch (sites 010 and 011). Erosion is typically not occurring within the stream channel itself.

Table 5-2 lists the hydromodification indicators observed in the city. The table includes both general observations and specific problem locations that show the impacts of hydromodification. The table was developed based on field observations, staff reports, and review of existing documents. These indicators are intended to be representative, not comprehensive, in nature.

Detail related to specific field observations is provided in the sections below.

Table 5-2. Hydromodification Indicators in Wilsonville's Watersheds			
Indicators	**Coffee Lake Creek (includes Basalt Creek and southern tributary to Coffee Lake Creek)**	**Arrowhead Creek**	**Boeckman Creek**
Flooding	• Reported private property flooding along drainage ditch to Basalt Creek (site 006). Ditch setback from property < 10'. Development assumed use of private property for flood storage. • Localized conveyance system flooding reported in upstream, headwater area to Basalt Creek.	• None observed or reported.	• None observed or reported. Observed open-channel areas in canyon setting, limiting potential flooding.
Degradation/bed incision	• Channel incision and straightening identified in areas of development encroachment (sites 003, 004, and 006). • Channel bed composed of more silt and clay materials that can be susceptible to erosion.	• Observed locations show little incision because of cobble/gravel bed materials.	• Channel incision identified in headwater areas (site 008). Elevated tree roots and head cutting identified. • Channel bed composed of more silt and clay materials that can be susceptible to erosion.
Bank erosion/widening	• Head cutting, bank scour, and knick points observed in areas of development encroachment (site 004). No flow present during site visit.	• Erosion around culvert outlet and plunge pool (site 001). Current CIP CL-9 to address issue. • Minor evidence of bank erosion under bridge structure (Arrowhead Creek Lane), but vegetation patterns indicate no active erosion.	• Head cutting, bank scour, and leaning trees observed in headwater areas (site 008). • Localized areas of bank scour and head cutting along Boeckman Creek corridor in canyon (site 010).
Lack of riparian vegetation	• Established setbacks along downstream corridor provide riparian buffer and connectivity to floodplain (site 003). • Development encroachment has resulted in limited tree canopy and riparian vegetation (site 004).	• Observed channel areas have good vegetated cover and tree canopy. • Invasives along channel and riparian corridor.	• Established setbacks along entire corridor provide riparian buffer and connectivity to floodplain. • Excellent tree canopy and vegetative understory. • Minor invasives observed along channel and riparian corridor throughout watershed.
Aggradation/sediment loads (evidence of increasing sediment loads without capacity to transport)	• None observed or reported.	• None observed or reported.	• Unconsolidated bed material observed on select areas of channel meander. Appears to be deposition of eroded bank material. • Outfall erosion contributes to in-stream sediment deposition.
Other observations	• Some large trash and debris accumulation in channel, specifically the downstream reach (site 003). • No flow observed in the middle tributary to Coffee Lake Creek at site 004.	• Some large trash and debris accumulation in channel. • Transient population access also observed.	• Because of topography, a number of outfalls discharge to creek significantly above the stream channel bed, resulting in scour in the drainage channel, and sediment deposition in the creek. CIPs already identified at problem locations.
Unique features that may inform hydromodification strategies	• Heavily modified stream channel system; historical wetland area. • Coffee Lake wetlands comprise a majority of the watershed and provide flood storage. Beaver dams are common and cause backwater effects. • Providing for large setbacks and buffers associated with new development can help dissipate flow and mitigate downstream impacts (site 007).	• Re-introduced flows to the stream system (in 2007) from the Graham Oak diversion does not appear to have affected channel stability. • Observed channel areas have sufficient setbacks and connectivity with the floodplain. • Future upgrades at the WTP (site 002) may result in additional outfall to stream.	• Incision and bank erosion associated with site 008 may be due to flow routing and limited stormwater controls on contributing drainage area • Past projects to daylight stream channels and replace culverts have shown significant improvements to the channel (site 012)

Flow Diversions

Historical flow diversions have changed flow patterns and impacted stream conditions. In Arrowhead Creek, a recent project conducted in conjunction with the Villebois development removed the historical flow diversion at Graham Oaks Nature Park that diverted flow to Legacy Creek. In 2007, a project was initiated in conjunction with the Villebois development to return flow to Arrowhead Creek. Arrowhead Creek appears to have stabilized to the restored flow regime, with no evidence of active bank erosion or flooding.

In addition, prior industrial development in the northeastern portion of the city routed stormwater flow from the Coffee Lake Creek basin to the headwaters of Boeckman Creek. Peak flow and volumes have increased to Boeckman Creek and evidence of hydromodification was observed during the field assessment in the form of bed incision and bank erosion at site 008. Impacts of flow diversions can be exacerbated by soil conditions and soil erodibility, and Boeckman Creek soil conditions include more silt and sand substrate compared to other areas of the city.

Restoration Projects

The City's continued efforts to preserve and restore stream channel habitat appear to be an effective strategy at managing hydromodification impacts. The Coffee Lake wetlands restoration effort has provided for flow mitigation in the downstream reaches of Coffee Lake Creek. Although straightened and channelized, Coffee Lake Creek downstream of the wetlands (site 003) does not show evidence of active bank erosion, channel incision, or aggradation. Continued coordination with Metro to pursue property acquisition in this watershed is recommended to enhance habitat and provide for additional flow mitigation.

Protected Riparian Corridors

The City's land development code includes sensitive areas zoning districts (see Section 6). These districts include development restrictions that create wide riparian buffers and setbacks through which peak flow can be carried to overbank areas. Overbank flows reduce stream energy and riparian vegetation can slow down erosive flows. This condition was observed in the Boeckman Creek Canyon (site 010), where upstream development seems to have little impact on channel conditions. This condition was also observed at the Brenchley Estates development area (site 007).

5.3 Findings and Recommendations

It is difficult to document whether there is ongoing risk of hydromodification in stream channels without a record of channel changes over time. It is recommended that the City monitor problem areas on an annual basis to document changes in channel conditions. Monitoring should include photo documentation and channel measurements where applicable. Based on the results of the field assessment, potential hydromodification monitoring locations due to observed hydromodification indicators include the following:

- Arrowhead Creek at Jobsey Lane (site 001): degrading culvert with associated erosion
- Coffee Lake Creek at Industrial Way (site 003): straightened channel with limited riparian cover
- South tributary to Coffee Lake Creek at Boberg Road (site 004): channel incision and sloughing stream banks
- Boeckman Creek at Canyon Creek Park (site 008): active erosion and channel incision
- Boeckman Creek along Boeckman Creek Canyon (site 010): erosion at stormwater outfalls on hillside above the creek

- Boeckman Creek at Gesellschaft Water Well (site 011): active erosion in outfall channel on hillside above the creek

Results of this field assessment indicate the need for in-stream or upslope stabilization projects to address hydromodification issues at each of the above locations. Each of the sites listed above has been identified in the SMP as a potential capital improvement project (CIP) location. The City's stormwater Capital Improvement Plan includes in-stream strategies and upland strategies to address potential hydromodification impacts. Additional information related to CIPs is provided in Section 7.

Section 6

Design Standards and Land Use Policy

This hydromodification assessment included an evaluation of the City's stormwater design standards and land use policies to determine if existing policies are likely to provide adequate protection against ongoing hydromodification as development occurs in the city. The primary source documents for this evaluation were:

- Wilsonville Public Works Construction Standards, Section 3, September 2014 (2014 Standards)
- Wilsonville Municipal Code (WMC), Section 4 Planning and Development, July 2013

The City adopted updated stormwater design standards in 2014 to comply with NPDES MS4 permit requirements. These standards require development projects to address hydromodification by maximizing infiltration of stormwater and matching flow durations. The standards also require projects to mitigate pollutant discharge associated with new development or redevelopment activities. WMC requires projects to protect and restore vegetation in stream channel buffers.

The City's updated stormwater policies are in line with best practices to address hydromodification. It is recommended that the City continue to implement the new standards. Additional details are provided in the following sections.

6.1 Stormwater Design Standards

The City's 2014 Standards apply to new development, redevelopment, and public projects. The standards were adopted in September 2014 to replace the previous Section 3 of the Public Works Standards. The 2014 Standards apply best practices for mitigating flow to address hydromodification. Key aspects of the 2014 Standards include the following policies and design requirements:

- **Thresholds:** The 2014 Standards require water quality treatment and flow control for projects that add or replace 5,000 square feet or more of impervious surface. No changes are recommended to the stormwater management impervious area threshold. This threshold was dictated in the City's NPDES MS4 permit. DEQ set the threshold based on a previous analysis conducted by the City based on expected development patterns that showed that a threshold of 5,000 square feet would capture approximately 90 percent of all impervious surface added in the city.
- **Infiltration:** The 2014 Standards require projects to use infiltration and LID to the maximum extent practicable. When implemented, infiltration facilities reduce runoff volumes and help to reduce the flashiness of peak flows.
- **Flow duration matching:** The flow control requirements in the 2014 Standards require development projects to install detention facilities to match the pre-developed peak rate and duration of flow for the range of geomorphically significant flows. The range of flows for flow duration matching is from 42 percent of the 2-year through the 10-year flow frequency. As described in Section 2, flow duration matching is the best practice in managing geomorphically

significant flows. These standards will apply to developments across the city, including those in areas where potential hydromodification impacts have been observed.

- **Low-impact development**: The 2014 Standards prioritize the use of LID in both site planning and stormwater facility design. In site planning, LID principles reduce the impervious surfaces and maintain natural vegetation to promote infiltration. In facility design, LID principles promote dispersed systems of green infrastructure—rain gardens, stormwater planters, and swales—to manage stormwater runoff. Even in tight soils, green infrastructure facilities can be used to infiltrate, treat, and manage stormwater flows in a way that better mimics natural flow conditions. These facilities also integrate well with both commercial and residential areas and can become a visual amenity to the community.

6.2 Land Use and Zoning Code

The WMC outlines land use requirements that have the potential to impact stream channels, either by contributing to or mitigating hydromodification. The City's land use policies are protective of stream channels by requiring stormwater runoff mitigation, designating vegetated buffers around stream channels, and promoting landscaping and natural surfaces.

Section 8 of the WMC requires projects to comply with the stormwater requirements of the Public Works Construction Standards for stormwater management described in Section 6.1 above.

WMC Section 4.139 establishes the SROZ, which encompasses the locally significant Goal 5 resources, including lands protected under Metro Title 3 and 13, riparian corridors, wetlands, and significant wildlife habitat. The SROZ designates a buffer around the riparian corridor and riparian impact area. Buffer widths vary from 50 feet for all streams up to 300 feet for some riparian corridors.

Development within the SROZ is extremely limited. Provisions of the WMC allow for activities such as removal of invasive species, public improvements in conjunction with an approved master plan, and minor encroachments. The WMC requires an area of mitigation ranging from 1.5 to 5 times the original disturbance area.

Tree protection standards are referenced in the WMC (Section 4.600). These policies help to preserve or create vegetated canopy that provides opportunity for rainfall interception and evapotranspiration, reducing runoff to stream channels. The removal of any native tree with a diameter of 6 inches or more is allowed only with a City-issued permit. Any proposed tree cutting in the SROZ requires submittal of a significant resource impact report unless exempt from the requirements of the section (e.g., hazardous tree removal). The site planning guidance in the City's new stormwater design standards also emphasizes retention of natural surfaces.

Section 7

Review of Planned Projects

The City has previously identified CIPs that include elements of stream enhancement, flood storage in the natural system, and upland detention and infiltration of stormwater. These CIPs will address hydromodification impacts by helping to restore a more natural flow regime.

CIPs related to in-stream restoration and upland flow control are outlined in the following documents:

- *City of Wilsonville Stormwater Master Plan,* March 2012 (SMP)
- *2014–2015 Capital Improvement Plan*, December 2014 (2014–2015 Plan)
- *Stormwater Retrofit Plan,* June 2015

The following sections document the CIPs referenced in these planning documents that have the potential to address hydromodification impacts.

Ongoing implementation of capital projects is limited by funding and property availability. By prioritizing projects and identifying property needs, the City is in a better position to apply for grants and other outside funding to support restoration projects.

7.1 2012 Stormwater Master Plan

The primary source document for existing data regarding the City's stormwater and surface water infrastructure is the SMP. The SMP includes a comprehensive inventory of stormwater infrastructure and hydrologic and hydraulic model results to evaluate existing and projected stormwater flows in the system. While the SMP did not include a comprehensive evaluation of in-stream flow conditions, the modeling provided estimates of contributing flows to the stream systems during various storm events.

The SMP identifies CIPs to address flood control, water quality, temperature control, habitat restoration, and erosion control. Many of the CIPs also address hydromodification impacts through upland flow control, in-stream channel improvements and restoration, and upland erosion/ sedimentation control measures. CIPs were prioritized in accordance with City goals and objectives, and a general schedule for implementation was developed based on project priorities and anticipated funding.

Since 2012, a number of CIPs from the SMP have been constructed. Other CIPs are no longer on the CIP priority list because of complicating factors or changing conditions. Table 7-1 documents the completed and future CIPs from the SMP that have hydromodification benefit(s) for tributary streams within the city. Referenced CIPs are also shown on Figure A-4 (Appendix A).

7.2 2014–2015 Capital Improvement Plan

The City implements an annual Capital Improvement Plan that includes the priority stormwater and surface water improvement projects. The 2014–2015 Plan includes a number of the high-priority stormwater CIPs identified in the SMP. In addition, the City has added CIPs (not reflected in the SMP) to the 2014–2015 Plan based on immediate, identified needs. Table 7-1 and Figure A-4 also include those applicable CIPs that are on the current list.

Table 7-1. Current Capital Projects with Hydromodification Benefit							
Water-shed	Project number	Project name	Description	Source	Hydromodification strategy	Potential hydromodification benefits	Status[a]
Coffee Lake Creek	CLC-9	Jobsey Lane Culvert Replacement	Replace existing 48" culvert with a bridge to reduce scour	2012 SMP	In-stream: stream stability	• Reduces pipe constriction to minimize scour • Reduces stream energy to minimize erosion potential	Long-term
	SD4021 and SD4022	Boberg Road Culvert Replacement	Replace 42" culvert with 4' x 6' box culvert to reduce scour and sediment deposition	2012 SMP	In-stream: stream stability	• Reduces pipe constriction to minimize scour • Reduces stream energy to minimize erosion potential downstream and sediment deposition upstream • Potential to incorporate vegetation restoration to stabilize stream banks through riparian planting	Long-term
	CLC-1	Detention/Wetland Facility near Tributary to Basalt Creek	Construct wetland for stormwater detention and reduced downstream erosion potential	2012 SMP	Upland: flow control	• Reduces downstream flow to minimize erosion in channels and receiving waters	Long-term
	CLC-2	SW Parkway Avenue Stream Restoration	Excavate channel for flood storage capacity and enhance riparian vegetation	2012 SMP	In-stream: restoration	• Reduces stream energy to minimize erosion potential • Stabilizes stream banks through riparian planting	Long-term
	CLC-3	Commerce Circle Channel Restoration	Create a more naturalistic channel through meandering, widening, and planting	2012 SMP	In-stream: restoration	• Reduces stream energy to minimize erosion potential • Stabilizes stream banks through riparian planting	Long-term
	CLC-4	Ridder Road Wetland Restoration	Create new floodplain terrace and enhance vegetation	2012 SMP	In-stream: restoration	• Reduces stream energy to minimize erosion potential • Stabilizes stream banks through riparian planting	Long-term
	CLC-5	Coffee Lake Creek Stream and Riparian Enhancement	Excavate channel to increase meander and increase floodplain, enhance vegetation	2012 SMP	In-stream: restoration	• Reduces stream energy to minimize erosion potential • Stabilizes stream banks through riparian planting	Long-term
	CLC-6	Coffee Lake Creek South Tributary Wetland Enlargement	Enhance existing wetland and create new adjacent wetland	2012 SMP	In-stream: restoration	• Reduces stream energy to minimize erosion potential • Stabilizes stream banks through riparian planting	Long-term
	CLC-7	Coffee Lake Creek South Tributary Stream Restoration	Excavate channel to increase meander and increase floodplain, enhance vegetation	2012 SMP	In-stream: restoration	• Reduces stream energy to minimize erosion potential • Stabilizes stream banks through riparian planting	Long-term
	CLC-8	Coffee Lake Creek Restoration	Excavate channel to increase meander and increase floodplain	2012 SMP	In-stream: restoration	• Reduces stream energy to minimize erosion potential • Stabilize stream banks through riparian planting	Long-term
	LID-2	SW Hillman Green Street Stormwater Curb Extension	Install vegetated water quality treatment facilities	2012 SMP	Upland: flow control	• Reduces downstream flow to minimize erosion in channels and receiving waters • Promotes infiltration, reducing flows to channel	Long-term
	LID-3	SW Camelot Green Street Mid-block Curb Extension	Install vegetated water quality treatment facilities	2012 SMP	Upland: flow control	• Reduces downstream flow to minimize erosion in channels and receiving waters • Promotes infiltration, reducing flows to channel	Long-term
	LID-7	SW Wilsonville Road Stormwater Planters	Install vegetated water quality treatment facilities	2012 SMP	Upland: flow control	• Reduces downstream flow to minimize erosion in channels and receiving waters • Promotes infiltration, reducing flows to channel	Long-term
	CLC-10B	Coffee Creek Storm Projects	Install vegetated water quality treatment and detention facilities	2014–2015 Plan	Upland: flow control	• Reduces downstream flow to minimize erosion in channels and receiving waters	Long-term

Table 7-1. Current Capital Projects with Hydromodification Benefit							
Water-shed	Project number	Project name	Description	Source	Hydromodification strategy	Potential hydromodification benefits	Status[a]
						• Promotes infiltration, reducing flows to channel	
Boeckman Creek	BC-8	Canyon Creeks Estate Pipe Removal	Daylight piped channel to reduce scour potential and promote infiltration	2012 SMP	Upland: sediment control	• Reduces pipe constriction to minimize scour • Promote infiltration, reducing flows to channel	Short-term
	BC-2	Boeckman Creek Outfall Rehabilitation	Evaluate and rehab up to 5 outfalls to reduce scour potential	2012 SMP	Upland: sediment control	• Stabilizes hillside above channel • Reduces sediment load to receiving waters	Long-term
	BC-3	Cascade Loop Detention Pipe Install	Install additional detention at Cascade Loop to minimize erosive flows to Boeckman Creek	2012 SMP	Upland: flow control	• Reduces downstream flow to minimize erosion in channels and receiving waters • Facilities sized based on 2014 Standards can address geomorphically significant flows	Long-term
	BC-5	Boeckman Creek Outfall Realignment	Realign existing pipe and outfall structure to reduce scour potential and improve stability	2012 SMP	Upland: sediment control	• Reduces sediment load to receiving waters	Long-term
	BC-6	Multiple Detention Pipe Installation	Install detention upstream of four outfalls (referenced in CP BC-2) to minimize erosive flows to Boeckman Creek	2012 SMP	Upland: flow control	• Reduces downstream flow to minimize erosion in channels and receiving waters • Facilities sized based on 2014 Standards can address geomorphically significant flows	Long-term
	BC-4	Gesellschaft Water Well Channel Restoration	Pipe weekly water well discharge around Boeckman Creek to reduce scour, revegetate	2012 SMP	Upland: flow bypass	• Re-routes flow to minimize active erosion and sediment transport • Consider channel reconstruction to reduce hillside erosion	Short-term
	BC-7	Boeckman Creek Realignment	Remove berms and relocate channel away from existing bridge pilings to reduce scour potential	2012 SMP	In-stream: stream stability	• Stabilizes stream channel to reduce scour potential	Completed
	BC-10	Memorial Park Stream and Wetland Enhancement	Enhance vegetation on existing channel	2012 SMP	In-stream: restoration	• Stabilizes stream banks through riparian planting	Long-term
	LID-1	Memorial Park Parking Lot Vegetated Swales	Install vegetated water quality treatment facilities	2012 SMP	Upland: flow control	• Reduces downstream flow to minimize erosion in channels and receiving waters	Completed

a. *Status refers to the anticipated schedule for construction. Completed projects are identified. Short-term is construction in the next 5 years as per the 2014–2015 Plan; long-term is future (> 5 years) construction. Status is not currently reflective of CP prioritization as documented in the 2015 Stormwater Retrofit Plan.*

7.3 2015 Stormwater Retrofit Plan

To comply with requirements of the City's NPDES MS4 permit, the City recently completed a stormwater retrofit plan to aid in implementation of projects and programs that improve water quality in underserved areas of the city.

No new projects were identified in the 2015 Stormwater Retrofit Plan that are not already included in other planning documents. Instead, the Stormwater Retrofit Plan reprioritized CIPs with water quality benefit to focus on objectives related to TMDL pollutant removal, temperature management, habitat restoration, and erosion prevention and control. The updated project prioritization will be incorporated into future stormwater budget and implementation schedules.

Section 8

Strategies and Recommendations

The hydromodification assessment presented in Sections 4 through 7 identifies hydromodification impacts observed in the city and identifies potential strategies to offset or mitigate those impacts. The results of this hydromodification assessment should be used to:

- inform the City's development and prioritization of CIPs
- define areas for ongoing hydromodification monitoring

Stream channels in the city show hydromodification impacts from past development. These impacts include bed incision and bank erosion at locations where flow has been restricted or concentrated or in headwater areas where flow diversions occur. Given observed soil characteristics and the level of future development activity expected in the city, future development has the potential to exacerbate these impacts.

The City's new stormwater design standards are implementing best practices by requiring flow duration matching from new development and redevelopment areas. While these standards should provide adequate mitigation for potential flow changes from future development, it is recommended that the City continue to implement projects to address specific areas of existing hydromodification.

The following section provides additional detail about the key programs and projects recommended for implementation to protect stream channels and address hydromodification impacts.

Capital Improvement Projects

The City has an opportunity to address hydromodification impacts by constructing projects that enhance existing stream channel conditions and/or mitigate peak flows. As outlined in Section 7, the City has previously identified, prioritized, and in some cases scheduled CIP construction per its SMP and current Capital Improvement Plan that can help address hydromodification impacts. Of those CIPs, the ones listed below are located at an identified, potential problem area per the field assessment effort:

- **CLC-9: Jobsey Lane Culvert Replacement.** Associated with site 001. Project to replace existing 48-inch culvert with bridge to reduce scour.
- **CLC-8: Coffee Lake Creek Restoration.** Associated with site 003. Project to increase meander and condition of channel.
- **CLC-7 and SD4021–SD4022: Coffee Lake Creek South Tributary Stream Restoration and Boberg Road Culvert Replacement.** Associated with site 004. Projects to improve in-stream conditions and minimize erosive flows.
- **CLC-3 and CLC-10B: Commerce Circle Channel Restoration and Coffee Creek Storm Projects.** Associated with site 006. Projects to increase channel capacity, manage upstream contributing flow, and improve in-stream conditions.
- **BC-2 and BC-6: Boeckman Creek Outfall Rehabilitation and Detention Pipe Installation.** Associated with site 010. Projects to manage upstream contributing flow and stormwater outfall conveyance channels to receiving waters to manage sediment discharge.

- **BC-4: Gesellschaft Water Well Channel Restoration.** Associated with site 011. Projects to manage upstream contributing flow and stormwater outfall conveyance channel to receiving waters to manage sediment discharge.

It is important that the City continue to incorporate additionally identified CIPs to address hydromodification (not otherwise reflected in the SMP) on an as-needed basis into the Capital Improvement Plan. As part of the annual Capital Improvement Plan development, the City has incorporated a general "Early Planning – Future Stormwater Projects" and general "Project Design and Development" budget line item for unanticipated capital projects.

The City may also revisit projects described in the SMP that are not currently included in the current Capital Improvement Plan or funded and scheduled in accordance with long-term priorities. Projects that may have a hydromodification benefit should be considered for re-inclusion with future SMP and Capital Improvement Plan updates. One example is the Wiedeman Road Regional Detention and Stream Enhancement project that would address contributing flow associated with potential hydromodification problem area, site 008. This project was in the original SMP but is not currently funded or scheduled per future Capital Improvement Plans.

Finally, design modifications and adjustments should be considered in conjunction with construction of CIPs, to further address hydromodification indicators. This may include the construction of energy dissipation structures at stormwater outfalls and culverts where concentrated flows are contributing to localized erosion problems or in-stream/riparian vegetation enhancement associated with facility construction.

Data Collection/Monitoring

Annual inspections are recommended to monitor known problem areas, proposed CIP locations, and recently completed CIPs with a stream channel restoration component. For example, BC-7 (Boeckman Creek Realignment), was a recently completed project that involved in-stream work to remove berms and relocate the channel away from existing bridge pilings. Monitoring the condition of recently completed projects gives the City a mechanism to track the effectiveness of projects over time.

Because new development will be occurring in the city as large, planned development areas, monitoring of stream conditions in areas adjacent to or directly downstream of the planned development is recommended as well. This would allow the City to establish a baseline stream condition with which to evaluate any future impacts.

Photo documentation and the Stream Channel Observation Forms included in Appendices B and C, respectively, can be used to record stream conditions and compare them to the conditions observed during the annual inspections.

Finally, the City is also likely to conduct ongoing water quality and macroinvertebrate sampling as a result of future NPDES MS4 permit requirements. Physical condition data and observations may be collected in conjunction with these monitoring efforts, which could be used to inform hydromodification project priorities.

Policy Recommendations

The City's current design standards and land use policies are in line with best practices to address hydromodification. It is recommended that the City continue to implement the 2014 Standards and sizing tool and plan for occasional review of the standards to address any implementation challenges. As possible, the 2014 Standards and sizing tool should be used to design CIPs and other public projects and retrofits to address potential hydromodification indicators. Ongoing implementation and enforcement of stream channel buffers and setbacks with new development has proved to be an effective hydromodification strategy in the city.

It is also recommended that the City continue master planning for projected development areas in the UGB to consider natural resource implications, particularly the potential for changes in stormwater runoff that could impact stream channels.

Additional Strategies

In conjunction with the City's 2014 TMDL Implementation Plan and current stormwater public education and outreach strategy, the City conducts outreach with watershed groups and nonprofit organizations (i.e., Friends of Trees) to conduct planting and cleanup activities along stream corridors. Additionally, the City encourages stewardship and enhancement of riparian buffers and vegetated corridors on private property through a planting incentive program. The planting incentive program provides training and planting materials upon request to private property owners to encourage riparian restoration and vegetation management.

Such efforts provide for targeted and ongoing vegetation management throughout the city and are recommended to be continued.

Section 9

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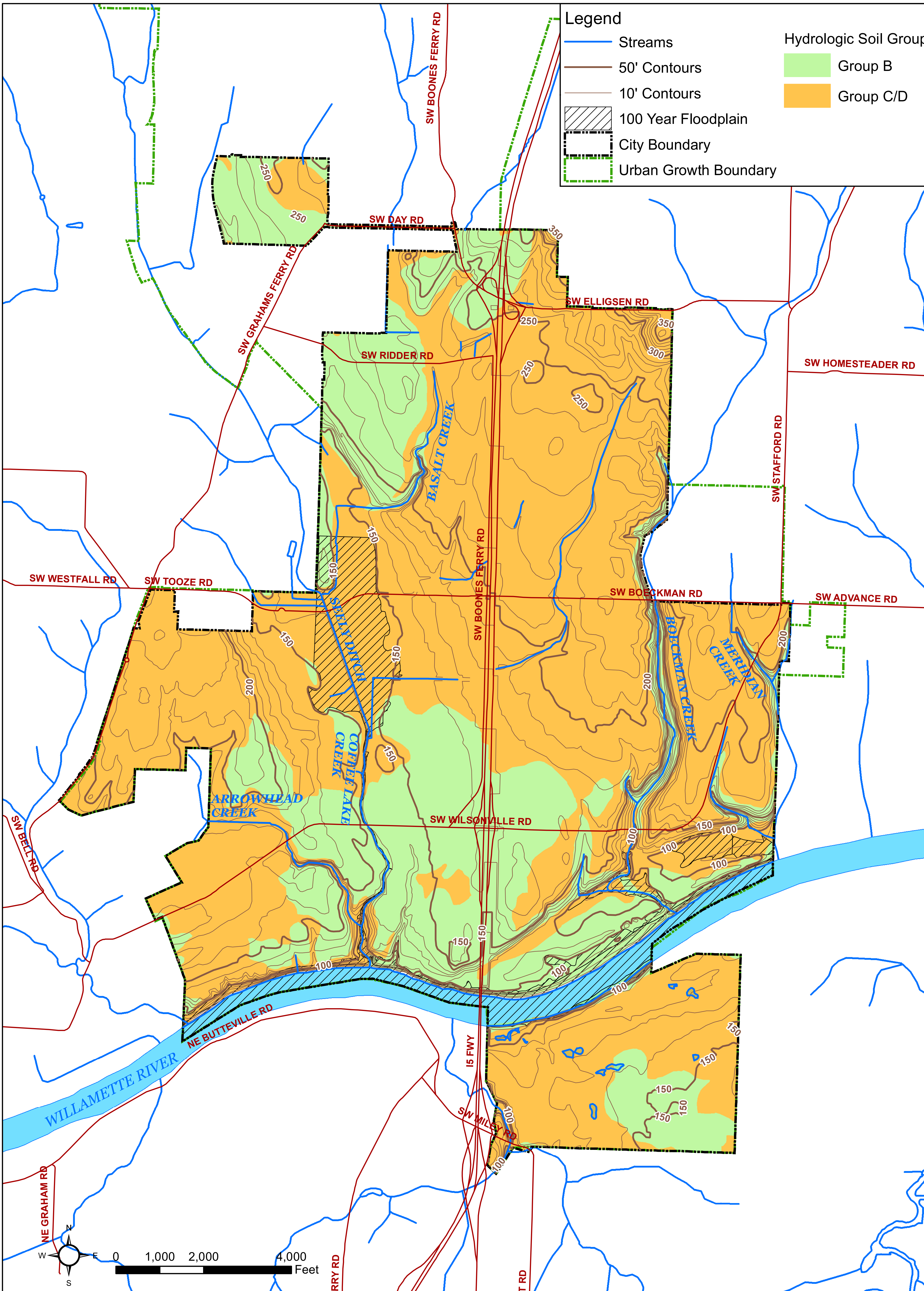
Limitations

This document was prepared solely for the City of Wilsonville in accordance with professional standards at the time the services were performed and in accordance with the contract between City and Brown and Caldwell dated April 19, 2012. This document is governed by the specific scope of work authorized by the City; 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 and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

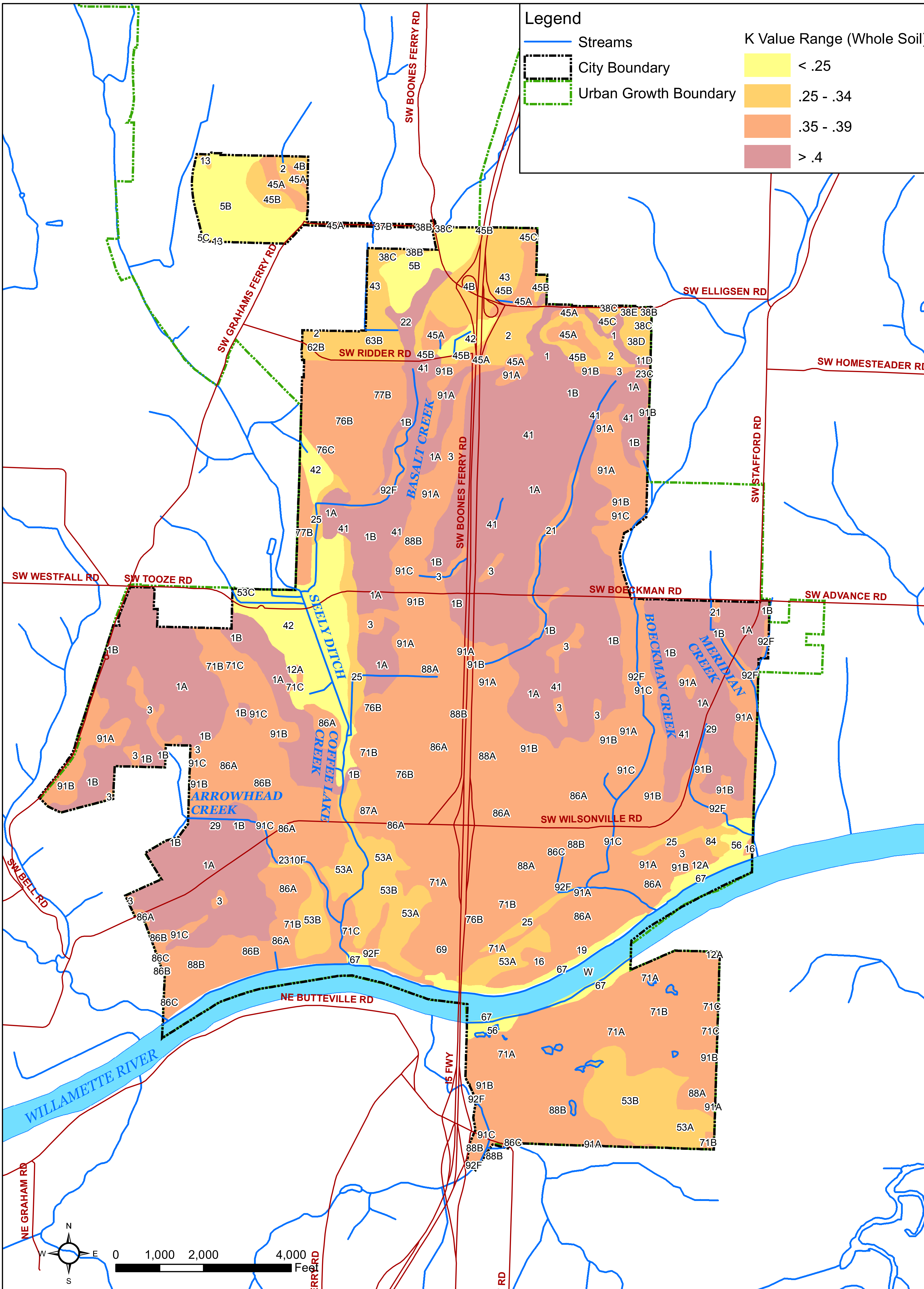
Appendix A: Figures



WILSONVILLE
POWERED BY PURPOSE

CITY OF WILSONVILLE
HYDROMODIFICATION ASSESSMENT
FIGURE A-1: SOILS & TOPOGRAPHY

Brown AND Caldwell
JUNE 2015



Brown AND Caldwell

WILSONVILLE
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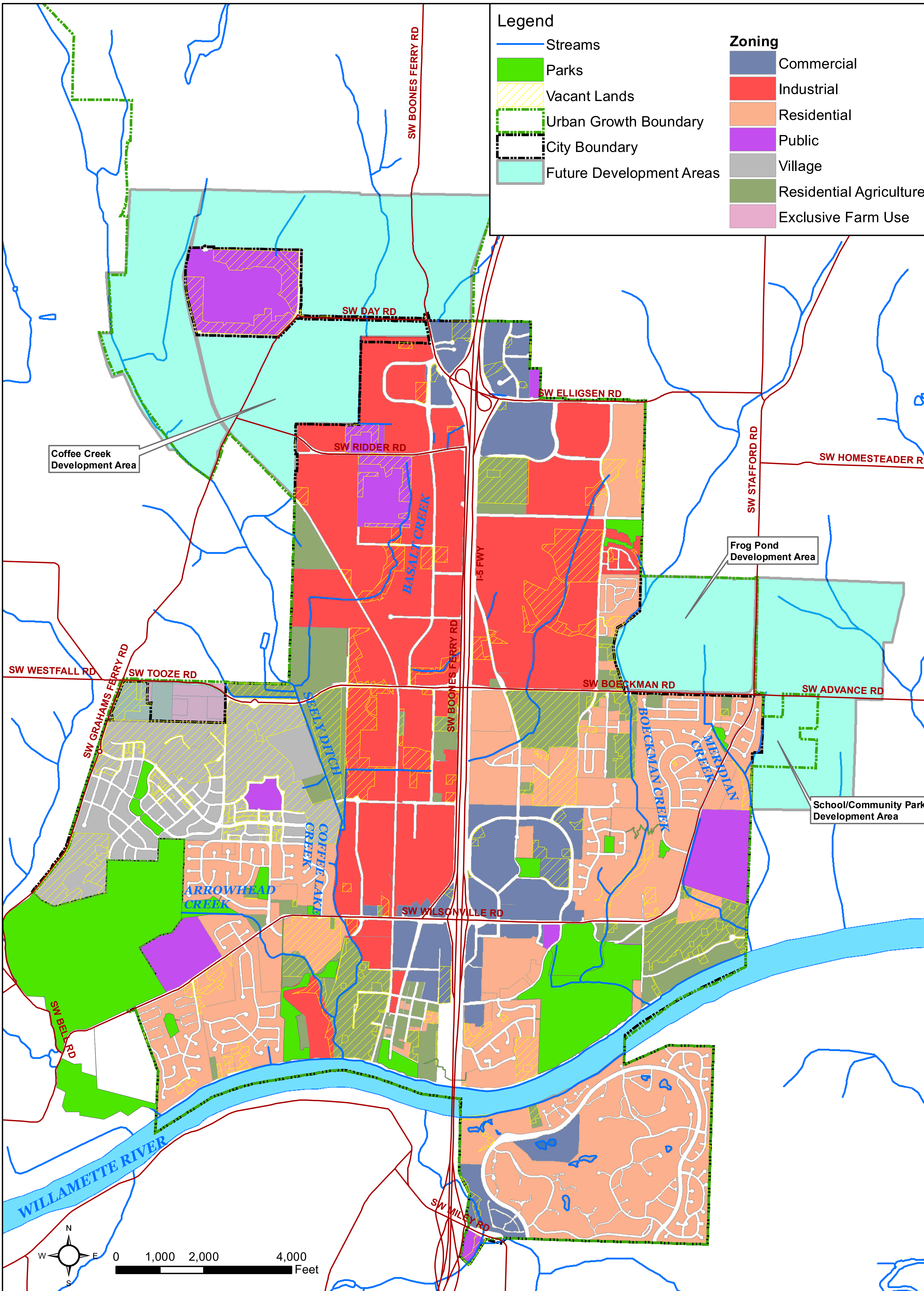
CITY OF WILSONVILLE
HYDROMODIFICATION ASSESSMENT
FIGURE A-2: SOIL ERODIBILITY

JUNE 2015

Note: Numbers shown on the map are associated with mapped soil types.



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HYDROMODIFICATION ASSESSMENT
FIGURE A-3: ZONING

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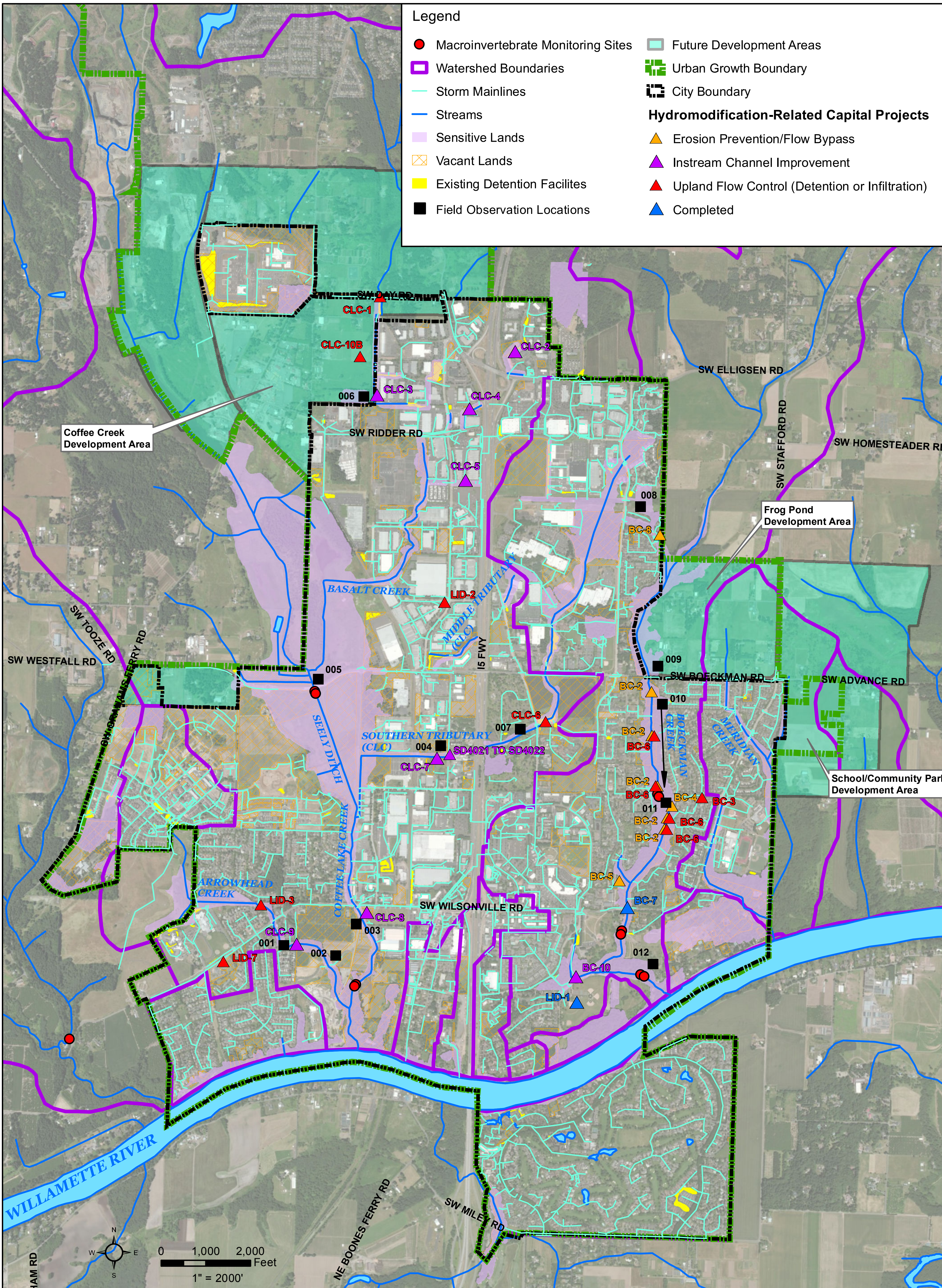

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CITY OF WILSONVILLE
HYDROMODIFICATION ASSESSMENT
FIGURE A-4: PRIORITY AREAS AND CURRENT CAPITAL PROJECTS

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JUNE 2015

Appendix B: Photo Log

Appendix B

Photo Log Documentation

Photographs and descriptions from the field assessment effort (by site location) are provided on the following pages.

Waterbody:	**Arrowhead Creek**
Reach description:	**Arrowhead Creek at Jobsey Lane (CIP CLC-9), accessed from Brown Avenue**
Site locations:	**001**

Site location: 001

Photo number: 005

Description: Scour hole at outlet of 48" culvert along Arrowhead Creek (CIP CLC-9 location)

Site location: 001

Photo number: 0006

Description: Looking downstream from 48" culvert. Observed invasives.

Site location: 001

Photo number: 009

Description: Hardpan bed material with small cobbles and gravel.

Site location: 001

Photo number: 008

Description: Limited flow observed during field assessment. Hardpan bed material. No observed incision or widening in channel.

Waterbody:	**Arrowhead Creek**
Reach description:	**Arrowhead Creek at Water Treatment Plant, upstream of confluence with Coffee Lake Creek (~1,000 ft. downstream from site location 001)**
Site locations:	**002**

Site location: 002

Photo number: 011

Description: Arrowhead Creek downstream of bridge on Arrowhead Creek Lane. Wide floodplain and dense vegetation.

Site location: 002

Photo number: 012

Description: Under bridge at Arrowhead Creek Lane. Observed hardpan and gravel/ cobbles. Limited observed channel incision and widening

Waterbody:	**Coffee Lake Creek**
Reach description:	**Coffee Lake Creek along Industrial Way, between Wilsonville Road and Ore Pac Avenue**
Site locations:	**003**

Site location: 003

Photo number: 020

Description: Looking upstream from Ore Pac Ave. Wide floodplain with proposed development area to the east. Straightened, incised channel with established vegetation.

Site location: 003

Photo number: 022

Description: Looking downstream from Ore Pac Ave. Wide floodplain. Nursery to the west. Straightened, incised channel with established vegetation.

Site location:	003
Photo number:	019
Description:	Pipe serving as a debris dam along Coffee Lake Creek.

Waterbody:	**Coffee Lake Creek (south tributary)**
Reach description:	**Channel crossing at Boberg Road.**
Site locations:	**004**

Site location: 004

Photo number: 025

Description: Looking upstream from Boberg Road toward 42” culvert. No oberved flow.

Site location: 004

Photo number: 026

Description: Channel crossing under Boberg Rd.

Site location:	004
Photo number:	028
Description:	Looking downstream toward Boberg Rd. Incised channel appears stabilized based on observed vegetation. Significant private property encroachment.

Site location:	004
Photo number:	029
Description:	Sloughing north bank of channel.

Site location: 004

Photo number: 032

Description: Approximately 300’ downstream from photos 025-029. Dense vegetation and invasives. No flow observed in channel.

Waterbody:	**Coffee Lake Wetlands**
Reach description:	**Coffee Lake Wetlands at Tooze Road**
Site locations:	**005**

Site location: 005

Photo number: 035

Description: Coffee Lake wetlands complex, looking downstream.

Site location: 005

Photo number: 037

Description: Looking downstream along Seely Ditch, which flows through the Coffee Lake wetlands. Observed beaver dam. Straightened channel with wide floodplain and dense vegetation.

Site location: 005

Photo number: 039

Description: Looking upstream along Seely Ditch at channel diversion around basalt humock island.

Waterbody:	Basalt Creek (north tributary to Coffee Lake Creek)
Reach description:	Basalt Creek southwest of Commerce Circle and north of Ridder Road
Site locations:	006

Site location: 006
Photo number: 042
Description: Looking upstream along channel. Industrial property owners report flooding in adjacent parking.

Site location: 006
Photo number: 043
Description: Looking downstream along channel. Channel straightened but signficant vegetation including invasives within flow path.

Waterbody:	**Coffee Lake Creek (south tributary)**
Reach description:	**Approximately 1,000 ft upstream from site location 004**
Site locations:	**007**

Site location: 007

Photo number: 045

Description: New development with channel restoration. Wide floodplain and boulder energy dissipation.

Site location: 007

Photo number: 047

Description: Looking downstream from photo 045.

Waterbody:	**Boeckman Creek**
Reach description:	**Upstream segment of Boeckman Creek at Canyon Creek Park**
Site locations:	**008**

Site location: 008
Photo number: 049
Description: Looking downstream from footbridge. Wide floodplain and vegetation (including invasives).

Site location: 008
Photo number: 050
Description: Observed channel downcutting and widening.

Site location: 008
Photo number: 051
Description: Observed nick points and scour holes and the footbridge (channel crossing).

Site location: 008
Photo number: 053
Description: Observed some exposed roots and exidence of channel widening. No observed aggradation.

Site location: 008

Photo number: 056

Description: Silty loam bed material with little/ no cobbles and gravel.

Waterbody:	**Meridian Creek Watershed**
Reach description:	**Drive-by at Frog Pond Development Area**
Site locations:	**009**

Site location: 009

Photo number: 059

Description: Proposed location of future school and City park.

Waterbody:	**Boeckman Creek**
Reach description:	**Stream walk from Boeckman Road to trail access point along Meadows Loop.**
Site locations:	**010**

Site location: 010
Photo number: 061
Description: Boeckman Creek from beginning of trail at public access (off Boeckman Rd.).Wide canyon with heavy vegetation and canopy.

Site location: 010
Photo number: 063
Description: Slight observed downcutting and incision along channel.

Site location: 010

Photo number: 066

Description: Existing outfall from Arbor Crossing Development area. Outfall structure appears to provide energy dissipation prior to discharge down canyon slope.

Site location: 010

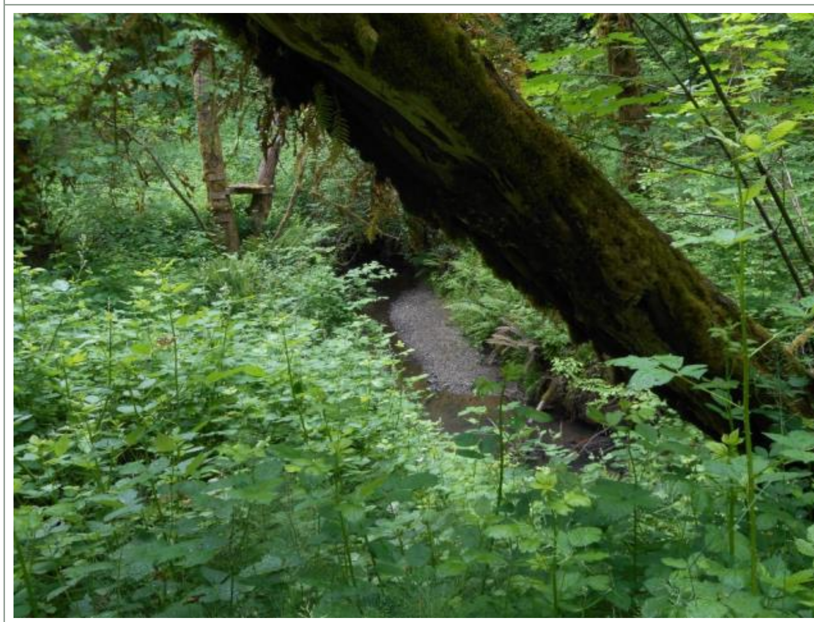
Photo number: 065

Description: Outfall across trail to Boeckman Creek (from photo 066)

Site location: 010

Photo number: 068

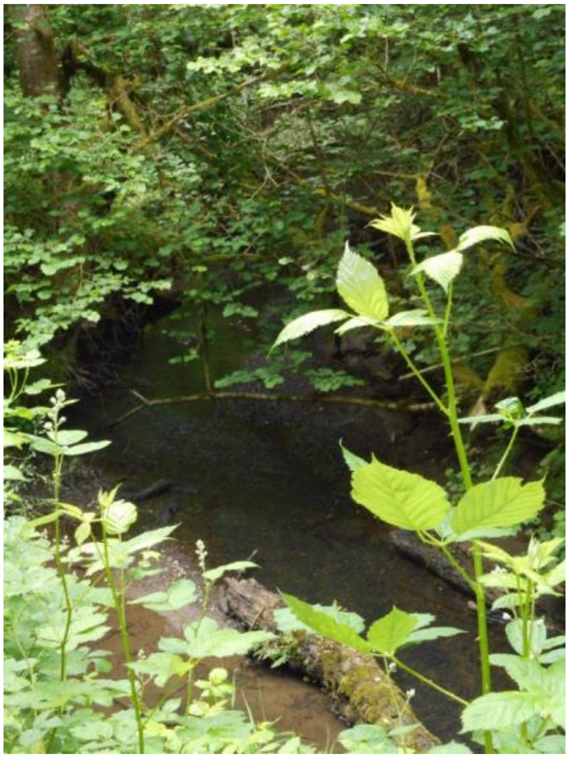
Description: Evidence of eroding stream banks.



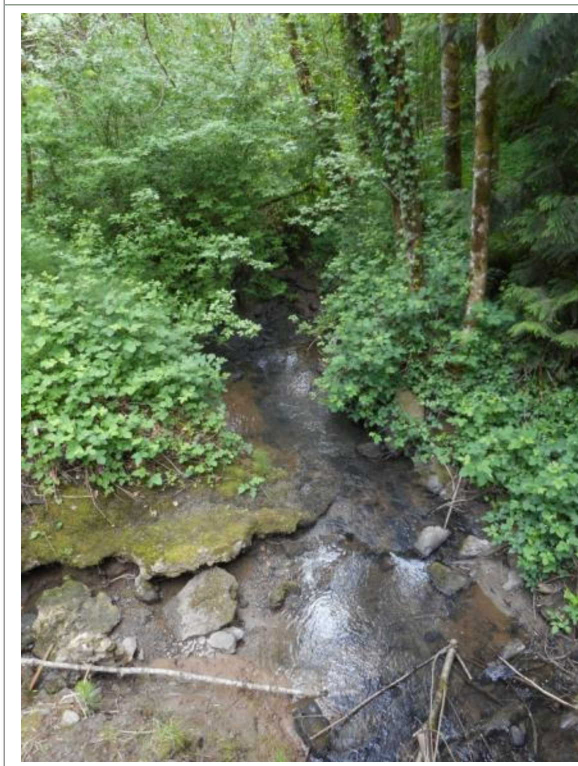
Site location: 010

Photo number: 070

Description: Point bar along Boeckman Creek.



Site location:	010
Photo number:	082
Description:	Bed material appears poorly sorted with evidence of aggradation.



Site location:	010
Photo number:	084
Description:	Outfall to Boeckman Creek with observed erosion (one of the CIP BC-2 locations) .

Site location:	010
Photo number:	086
Description:	Observed sinkhole associated with photo 084.

Waterbody:	Boeckman Creek
Reach description:	Tribuary from Gesellschaft Water Well
Site locations:	011

Site location: 011

Photo number: 089

Description: Outlet from Gessellscheft Water Well (CIP BC-4).

Site location: 011

Photo number: 091

Description: Observed channel incision and nick points along channel alignment.

Site location:	011
Photo number:	093
Description:	Observed silty loam bed material with limited gravel or cobbles toward middle/ downstream end of channel.

Site location:	011
Photo number:	094
Description:	Upstream end of channel, observed active bank erosion along right bank.

Site location: 011

Photo number: 074

Description: Looking upstream along Gessellscheft Water Well discharge channel from trail along Boeckman Creek.

Site location: 011

Photo number: 080

Description: Observed trail settling and erosion at outfall from Gessellscheft Water Well channel.

Waterbody:	**Boeckman Creek**
Reach description:	**Downstream portion of Boeckman Creek at Rose Lane macroinvertebrate monitoring locations**
Site locations:	**012**

Site location: 012

Photo number: 099

Description: Looking upstream along channel from footbridge. Channel alignment in canyon with dense vegetation and tree cover. Observed invasives.

Site location: 012

Photo number: 098

Description: Observed gravel and cobbles along channel bank.

Site location: 012
Photo number: 100
Description: Established vegetation along channel banks and observed point bar.

Site location: 012
Photo number: 102
Description: Point bar along channel alignment.

Appendix C: Stream Channel Observation Forms

Channel Stability Observation Form

Water Body:	Arrowhead Creek	Date:	5/21/15
Site/Location: ac-9	001 @ Jobsey Lane	Time:	~~Am~~ 945 Am
		Crew:	~~Am, Aco~~ all
Photos:		Weather:	overcast
Channel Size:	varies 2-5' wide No depth - flat/wide floodplain	Observed problems: N/A	A. Flooding
Channel Pattern:	Meandering		B. Degradation
	Straight		C. Bank Erosion
	Braided		D. Lack of Vegetation
	Channelized/Altered		E. Sediment Loads

A. Flooding

Describe observed/known flooding problems:	No - channel in ravine w/ setbacks

B. Degradation/Bed Incision

Primary Bed Material:	Bedrock	Boulders	Cobbles	Gravel	Sand	Silt	Clay
Degree of incision *	0-25%	26-50%	51-75%	76-100%			
Exposed Roots	None	Mild	Moderate	Severe			
Head cutting or nick points	Describe: No						

C. Bank Erosion/Widening

Primary Bank Materials		Bedrock	Boulders	Gravel/Sand	Silt/Clay
Bank Protection		None	Left Bank	Right Bank	
Streambank Erosion	Left Bank:	None	Fluvial	Mass Wasting	
	Right Bank:	None	Fluvial	Mass Wasting	
Streambank Instability (% each bank failing)	Left Bank:	0-25%	26-50%	51-75%	76-100%
	Right Bank:	0-25%	26-50%	51-75%	76-100%
Vegetation Impacts		Exposed Roots	Leaning Trees	J-shaped Trees	No

No evidence

Diversion back into this channel ≈ 2007 has not impacted channel

D. Lack of Vegetation

Established riparian woody-vegetative cover	Left Bank:	0-25%	26-50%	51-75%	76-100%
	Right Bank:	0-25%	26-50%	51-75%	76-100%

invasives

E. Sediment Loads

Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☐ Unconsolidated bed ☐ Embedded Cobbles N/A
Turbidity/ Siltation	Describe:

Other

Known or observed problems Unique features Field notes	Large culvert is degrading in bed - asphalt crumbling Dumping in riparian area - large debris potential WWTP expansion adjacent to d/s channel

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.

↳ How much more flow to arrowhead creek?

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Channel Stability Observation Form

Water Body:	Arrowhead	Date:	5/21/15
Site/Location:	002 - upstream of confluence w/ Coffee Lake Creek	Time:	10:00
		Crew:	all
Photos:		Weather:	overcast
Channel Size:		Observed problems:	A. Flooding B. Degradation C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	Meandering Straight Braided Channelized/Altered		

A. Flooding

Describe observed/known flooding problems:	~~Chan~~ flows stay in channel large bridge > no flooding

B. Degradation/Bed Incision

Primary Bed Material:	Bedrock	Boulders	Cobbles	Gravel	Sand	Silt	Clay	
Degree of incision *	0-25%	26-50%	51-75%	76-100%	has reached a stable spot			
Exposed Roots	None	Mild	Moderate	Severe				
Head cutting or nick points	Describe: None							

C. Bank Erosion/Widening

Bed + bank material is different

Primary Bank Materials	Bedrock	Boulders	Gravel/Sand	Silt/Clay	
Bank Protection	None	Left Bank	Right Bank		
Streambank Erosion	Left Bank:	None	Fluvial	Mass Wasting	minor, but consistent throughout
	Right Bank:	None	Fluvial	Mass Wasting	
Streambank Instability (% each bank failing)	Left Bank:	0-25%	26-50%	51-75%	76-100%
	Right Bank:	0-25%	26-50%	51-75%	76-100%
Vegetation Impacts	Exposed Roots	Leaning Trees	J-shaped Trees	No	

Little change over last 5 years

D. Lack of Vegetation

Established riparian woody-vegetative cover	Left Bank:	0-25%	26-50%	51-75%	76-100%	Blackberries
	Right Bank:	0-25%	26-50%	51-75%	76-100%	

E. Sediment Loads

Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☐ Unconsolidated bed ☐ Embedded Cobbles No
Turbidity/ Siltation	Describe: No

Other

Known or observed problems	None
Unique features	
Field notes	

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.

Channel Stability Observation Form

Water Body:	Coffee Lake Creek	Date:	~~10~~ 5/21/15
Site/Location:	003 upstream of confluence w/ Arrowhead (urban/industrial area)	Time:	10^15
Photos: CLC-8		Crew:	all
		Weather:	Overcast
Channel Size:	5' wide, 2-3' deep flowing. wide/flat floodplain	Observed problems:	A. Flooding
Channel Pattern:	Meandering		B. Degradation
	Straight		C. Bank Erosion
	Braided		D. Lack of Vegetation
	Channelized/Altered Previously channelized through urban industrial area		E. Sediment Loads

representative of d/s portion of Coffee Lake Creek

A. Flooding	
Describe observed/known flooding problems:	d/s culvert on private property floods in high events
B. Degradation/Bed Incision	
Primary Bed Material:	Bedrock Boulders Cobbles Gravel Sand Silt Clay
Degree of incision*	0-25% 26-50% 51-75% 76-100%
Exposed Roots	None Mild Moderate Severe
Head cutting or nick points	Describe: No
C. Bank Erosion/Widening	
Primary Bank Materials	Bedrock Boulders Gravel/Sand Silt/Clay silt + cobbles - stratified
Bank Protection	None Left Bank Right Bank
Streambank Erosion	Left Bank: None Fluvial Mass Wasting minor but stabilized
	Right Bank: None Fluvial Mass Wasting
Streambank Instability (% each bank failing)	Left Bank: 0-25% 26-50% 51-75% 76-100%
	Right Bank: 0-25% 26-50% 51-75% 76-100%
Vegetation Impacts	Exposed Roots Leaning Trees J-shaped Trees No
D. Lack of Vegetation	
Established riparian woody-vegetative cover	Left Bank: 0-25% 26-50% 51-75% 76-100% Open canopy w/ recent planting
	Right Bank: 0-25% 26-50% 51-75% 76-100%
E. Sediment Loads	good setbacks - channel can meander
Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank
	☐ Unconsolidated bed
	☐ Embedded Cobbles No.
Turbidity/ Siltation	Describe:
Other	
Known or observed problems	- recent nearby development was conditioned to replant streambanks
Unique features	
Field notes	- WWTP project will increase setbacks

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.

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Channel Stability Observation Form

Water Body:	South fork Coffee Lake Creek	Date:	5/21/15
Site/Location: CLC-7	004 @ Boberg Rd.	Time:	10^30
		Crew:	all
Photos:		Weather:	overcast
Channel Size:	Urbanized drainage ditch	Observed problems: N/A	A. Flooding
Channel Pattern:	Meandering 3' ~~4'~~ wide		B. Degradation
	Straight ~~[illegible]~~		C. Bank Erosion
	Braided 6'+ft deep		D. Lack of Vegetation
	Channelized/Altered		E. Sediment Loads

see site 007 for

A. Flooding

Describe observed/known flooding problems:	N/A – incised channel

B. Degradation/Bed Incision

Primary Bed Material:	Bedrock	Boulders	Cobbles	Gravel	Sand	Silt	Clay	tree Roots
Degree of incision*	0-25%	26-50%	51-75%	76-100%	heavily incised urban drainage ditch			
Exposed Roots	None	Mild	Moderate	Severe				
Head cutting or nick points	Describe:	• Historic – channel has						

C. Bank Erosion/Widening

Primary Bank Materials	Bedrock	Boulders	Gravel/Sand	Silt/Clay	+ Roots
Bank Protection	None	Left Bank	Right Bank		
Streambank Erosion	Left Bank:	None	Fluvial	Mass Wasting	
	Right Bank:	None	Fluvial	Mass Wasting	
Streambank Instability (% each bank failing)	Left Bank:	0-25%	26-50%	51-75%	76-100%
	Right Bank:	0-25%	26-50%	51-75%	76-100%
Vegetation Impacts	Exposed Roots	Leaning Trees	J-shaped Trees		

Historic incision is not increasing

D. Lack of Vegetation

Established riparian woody-vegetative cover	Left Bank:	0-25%	26-50%	51-75%	76-100%
	Right Bank:	0-25%	26-50%	51-75%	76-100%

E. Sediment Loads

Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☐ Unconsolidated bed ☐ Embedded Cobbles N/A
Turbidity/ Siltation	Describe:

Other

Known or observed problems	d/s adjacent to WA County property undeveloped No plans
Unique features	
Field notes	Historic records call the area "the black swamp"

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.

Channel Stability Observation Form

Water Body:	Coffee Lake Creek wetland	Date:	5/21/15
Site/Location:	005-Seely Ditch @ Villebois Rd	Time:	11 AM
		Crew:	all
Photos:		Weather:	Sunny
Channel Size:	6' wide - 2' deep	Observed problems:	A. Flooding
Channel Pattern:	Meandering man-created channel		B. Degradation
	Straight		C. Bank Erosion
	Braided		D. Lack of Vegetation
	Channelized/Altered + wetland historic		E. Sediment Loads

A. Flooding

Describe observed/known flooding problems:	-wetland complex. Upstream B mitigation site -Beaver dams have potential to move channel

B. Degradation/Bed Incision

Primary Bed Material:	Bedrock Boulders Cobbles Gravel Sand Silt Clay
Degree of incision*	N/A 0-25% 26-50% 51-75% 76-100% man-altered historically to create a wet ditch/channel
Exposed Roots	None Mild Moderate Severe
Head cutting or nick points	Describe: N/A Deep peat soils 10-15' deep

C. Bank Erosion/Widening

Primary Bank Materials	Bedrock Boulders Gravel/Sand Silt/Clay
Bank Protection	None Left Bank Right Bank
Streambank Erosion	Left Bank: None Fluvial Mass Wasting
	Right Bank: None Fluvial Mass Wasting None - wide floodplain
Streambank Instability (% each bank failing)	Left Bank: 0-25% 26-50% 51-75% 76-100%
	Right Bank: 0-25% 26-50% 51-75% 76-100%
Vegetation Impacts	Exposed Roots Leaning Trees J-shaped Trees No

D. Lack of Vegetation

Established riparian woody-vegetative cover	Left Bank: 0-25% 26-50% 51-75% 76-100% prairie-type wetland
	Right Bank: 0-25% 26-50% 51-75% 76-100%

E. Sediment Loads

Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☐ Unconsolidated bed ☐ Embedded Cobbles Not a problem
Turbidity/ Siltation	Describe:

Other

Known or observed problems	- all development in this area has had to show
Unique features	no impacts to Seeley Ditch
Field notes	-City bridge was channel needs to stay in place

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.

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Channel Stability Observation Form

Water Body:	Basalt creek	Date:	5/21/15
Site/Location:	006 behind commerce circle (CC-3)	Time:	11:15
		Crew:	all
Photos:		Weather:	overcast
Channel Size:	4' wide + 2' deep	Observed problems:	A. Flooding localized B. Degradation C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	Meandering Straight Braided Channelized/Altered		

A. Flooding	
Describe observed/known flooding problems:	d/s culvert backwater + causes parking lot flooding
B. Degradation/Bed Incision	
Primary Bed Material:	Bedrock Boulders Cobbles Gravel Sand Silt Clay
Degree of incision*	~~0-25% 26-50% 51-75% 76-100%~~ → man-made alteration
Exposed Roots	None Mild Moderate Severe
Head cutting or nick points	Describe: Stagnant ditch
C. Bank Erosion/Widening	
Primary Bank Materials	Bedrock Boulders Gravel/Sand Silt/Clay
Bank Protection	None Left Bank Right Bank encroachment of parking lot
Streambank Erosion	Left Bank: None Fluvial Mass Wasting Right Bank: None Fluvial Mass Wasting
Streambank Instability (% each bank failing)	Left Bank: 0-25% 26-50% 51-75% 76-100% Right Bank: 0-25% 26-50% 51-75% 76-100%
Vegetation Impacts	Exposed Roots Leaning Trees J-shaped Trees None
D. Lack of Vegetation	
Established riparian woody-vegetative cover	Left Bank: 0-25% 26-50% 51-75% 76-100% Right Bank: 0-25% 26-50% 51-75% 76-100%
E. Sediment Loads	
Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☐ Unconsolidated bed ☐ Embedded Cobbles N/A
Turbidity/ Siltation	Describe:
Other	
Known or observed problems	-extensive restoration project
Unique features	-failing culverts on private property
Field notes	

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.

Channel Stability Observation Form

Water Body:	Canyon Creek	Date:	5/21/15
Site/Location:	008 Canyon creek Park under BPA lines	Time:	12 40 pm
		Crew:	Am, AW, KR
Photos:		Weather:	Sunny/overcast
Channel Size:	2' wide 12" deep	Observed problems:	A. Flooding B. Degradation C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	Meandering Straight Braided Channelized/Altered		

A. Flooding

Describe observed/known flooding problems:	N/A - good protected area

B. Degradation/Bed Incision

Primary Bed Material:	Bedrock	Boulders	Cobbles	Gravel	Sand	Silt	Clay	Loamy
Degree of incision*	0-25%	26-50%	51-75%	76-100%				
Exposed Roots	None	Mild	Moderate	Severe				
Head cutting or nick points	Describe: minor nick points - 12-24" drops							

C. Bank Erosion/Widening

Primary Bank Materials	Bedrock	Boulders	Gravel/Sand	Silt/Clay		
Bank Protection	None	Left Bank	Right Bank			
Streambank Erosion	Left Bank:	None	Fluvial	Mass Wasting		eroding banks + undercuts on all banks
	Right Bank:	None	Fluvial	Mass Wasting		
Streambank Instability (% each bank failing)	Left Bank:	0-25%	26-50%	51-75%	76-100%	
	Right Bank:	0-25%	26-50%	51-75%	76-100%	
Vegetation Impacts	Exposed Roots	Leaning Trees	J-shaped Trees			

D. Lack of Vegetation

Established riparian woody-vegetative cover	Left Bank:	0-25%	26-50%	51-75%	76-100%	minor invasive
	Right Bank:	0-25%	26-50%	51-75%	76-100%	

E. Sediment Loads

Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☒ Unconsolidated bed - in areas - looks like eroding banks re-depositing ☐ Embedded Cobbles
Turbidity/ Siltation	Describe:

Other

Known or observed problems Unique features Field notes	Great riparian area - upstream development w/out stormwater control - Old basin transfer

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.

Channel Stability Observation Form

Water Body:	Boeckman Creek	Date:	5/21/15
Site/Location:	010 ~~B~~ d/s of Boeckman Road	Time:	1 15 Pm
		Crew:	Am, AW, KR, K
Photos:		Weather:	
Channel Size:	10' wide 2-3' deep	Observed problems:	A. Flooding B. Degradation C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	Meandering Straight Braided Channelized/Altered - significant meandering w/in channel		

A. Flooding

Describe observed/known flooding problems:	No - Canyon w/ wide riparian area wide floodplain w/ meanders

B. Degradation/Bed Incision

Primary Bed Material:	Bedrock Boulders Cobbles Gravel Sand Silt Clay
Degree of incision*	0-25% 26-50% 51-75% 76-100%
Exposed Roots	None Mild Moderate Severe — minor
Head cutting or nick points	Describe: ~~minor~~ minor in localized areas

C. Bank Erosion/Widening

Primary Bank Materials	Bedrock Boulders Gravel/Sand Silt/Clay
Bank Protection	None Left Bank Right Bank
Streambank Erosion	Left Bank: None Fluvial Mass Wasting Right Bank: None Fluvial Mass Wasting
Streambank Instability (% each bank failing)	Left Bank: 0-25% 26-50% 51-75% 76-100% — meandering Right Bank: 0-25% 26-50% 51-75% 76-100%
Vegetation Impacts	Exposed Roots Leaning Trees J-shaped Trees

D. Lack of Vegetation

Established riparian woody-vegetative cover	Left Bank: 0-25% 26-50% 51-75% 76-100% Right Bank: 0-25% 26-50% 51-75% 76-100% Beautiful Corridor

E. Sediment Loads

Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☒ Unconsolidated bed ☐ Embedded Cobbles ~~AB~~ Some areas of deposition on meanders
Turbidity/ Siltation	Describe:

Other

Known or observed problems	Sewer corridor provides trail access
Unique features	Side channels - Steep w/ some protection
Field notes	Trout + other fish in full length of Boeckman

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.

Brown AND Caldwell

+BC-2 outfall stabilization project
↳ Boeckman creek crossing
Sinkhole - High priority project

Problem area
BC-4 @ Gazelle Shaft

Channel Stability Observation Form

Water Body:	Boeckman Creek	Date:	5/21/15
Site/Location:	012 Lower @ Memorial Park	Time:	245 pm
		Crew:	AM, AW, KR
Photos:	Bridge installation 2005 Restoration area	Weather:	Overcast
Channel Size: 5-10' wide varying depth		Observed problems:	A. Flooding
Channel Pattern:	Meandering		B. Degradation
	Straight	No	C. Bank Erosion
	Braided		D. Lack of Vegetation
	Channelized/Altered		E. Sediment Loads

Macro site + reference reach

Reference Reach. No hydromod indicators.

A. Flooding

Describe observed/known flooding problems:	No → well established canyon w/ floodplain.

B. Degradation/Bed Incision

Primary Bed Material:	Bedrock Boulders Cobbles Gravel Sand Silt Clay
Degree of incision*	0-25% 26-50% 51-75% 76-100%
Exposed Roots	None Mild Moderate Severe
Head cutting or nick points	Describe:

Adjustments to new channel condition + now stabilizing. Old culvert was on heavy fill + causing significant backwater erosion

C. Bank Erosion/Widening

Primary Bank Materials	Bedrock Boulders Gravel/Sand Silt/Clay
Bank Protection	None Left Bank Right Bank
Streambank Erosion	Left Bank: None Fluvial Mass Wasting
	Right Bank: None Fluvial Mass Wasting
Streambank Instability (% each bank failing)	Left Bank: 0-25% 26-50% 51-75% 76-100%
	Right Bank: 0-25% 26-50% 51-75% 76-100%
Vegetation Impacts	Exposed Roots Leaning Trees J-shaped Trees No

D. Lack of Vegetation

Established riparian woody-vegetative cover	Left Bank: 0-25% 26-50% 51-75% 76-100%
	Right Bank: 0-25% 26-50% 51-75% 76-100%

Some Ivy also + replanting area.

E. Sediment Loads

Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☐ Unconsolidated bed ☐ Embedded Cobbles
Turbidity/ Siltation	Describe:

Well graded stream channel with erosion and aggradation looking balanced

Other

Known or observed problems	Chinook, Steelhead, Pacific Lamprey use this reach
Unique features	Restoration Site
Field notes	

* Degree of incision = relative elevation of the "normal" low water compared to the floodplain/terrace. Normal water equal to the floodplain/terrace represents 100%.