Hydromodification Assessment

Prepared for
The City of West Linn
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City of West Linn

Hydromodification Assessment

July 1st, 2015

We, the undersigned, hereby submit this Hydromodification Assessment under the NPDES (MS4) Discharge Permit #101348, Schedule A.5. We 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.

Date 6-26-2015

Signature Michael Cardwell

Mike Cardwell, Environmental Services Division Supervisor

Date 6/29/15

Signature

Lance Calvert, West Linn Public Works Director

Table of Contents

1. Introduction and Key Findings....1-1
2. Hydromodification Background....2-1
   - 2.1 What is Hydromodification?....2-1
   - 2.2 Regulatory Requirements....2-3
   - 2.3 Strategies to Address Hydromodification....2-4
     - 2.3.1 Upland Strategies....2-4
     - 2.3.2 In-Stream Strategies....2-5
3. Methodology and Approach....3-1
   - 3.1 Future Use of This Assessment....3-2
   - 3.2 Other Methods Considered....3-2
4. Desktop Assessment of Watershed Conditions....4-1
   - 4.1 Watershed Summary....4-1
   - 4.2 Development Patterns....4-2
5. Field Assessment....5-1
   - 5.1 Field Methodology....5-1
   - 5.2 Stream Channel Characterization....5-3
6. Design Standards and Land Use Policy....6-1
   - 6.1 Stormwater Design Standards....6-1
   - 6.2 Land Use and Zoning Code....6-2
7. Review of Planned Projects....7-1
8. Strategies and Recommendations....8-1
9. References....9-1

Appendix A: Figures....A-1

Appendix B: Photo Log....B-1

Appendix C: Stream Channel Observation Forms....C-1

List of Figures

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

Figure 2-2. Schematic representation of how peak flow matching can increase energy in creek systems 2-3

Figure 3-1. Relationship of urbanization and stream channel conditions on hydromodification potential 3-2

Figure 4-1. Overview of city watersheds 4-2

List of Tables

Table 4-1. West Linn Watershed Summary 4-1

Table 5-1. Hydromodification Assessment Field Observation Locations 5-2

Table 5-2. Hydromodification Indicators in West Linn Watersheds 5-4

Table 8-1. Potential In-stream Capital Project Locations 8-3

List of Abbreviations

BC	Brown and Caldwell
City	City of West Linn
DEQ	Oregon Department of Environmental Quality
EPA	U.S. Environmental Protection Agency
FTE	full-time equivalent
GIS	geographic information system
HCA	habitat conservation area
I-205	Interstate 205
LID	low-impact development
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
SWMM	Stormwater Management Manual
TMDL	total maximum daily load
UGB	urban growth boundary
UIC	underground injection control
WLCDC	*West Linn Community Development Code*
WLMC	*West Linn Municipal Code*

Section 1

Introduction and Key Findings

Brown and Caldwell (BC) completed a hydromodification assessment for the City of West Linn (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 is one of the leading sources of impairment in streams, lakes, estuaries, aquifers, and other water bodies in the United States. The three major types of hydromodification processes are channelization and channel modification, dams, and stream bank or shoreline erosion. Each of these processes changes a water body's physical structure as well as its natural function (EPA 2007). In West Linn, the primary concern is bank erosion. 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. The results of this study show that the City's stream channels may be naturally resistant to hydromodification

This hydromodification assessment includes a review of existing planning documents, a geographic information system (GIS) desktop evaluation of watershed conditions, and field assessments to identify hydromodification indicators. Field assessments were targeted at the Arbor Creek, Trillium Creek, and Tanner Creek watersheds.

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

- Stream bank and bed materials in many watersheds provide a natural resistance to hydromodification.
- Observed stream channels show minor hydromodification impacts in locations where there are concentrated flows, such as around culverts and at discharges from stormwater outfalls.
- Limited future development opportunities in the city have minor potential to increase flows to stream channels.
- Current stormwater design standards could be enhanced to increase areas managed by stormwater facilities.
- The City's current capital projects list includes culvert improvements, which could include opportunities to incorporate stream enhancement elements to reduce hydromodification impacts and provide additional benefits to the natural system.

In light of these conclusions, it is recommended that the City consider the following recommendations as expanded on in Section 8:

- update the City's master plan to incorporate capital projects with stream enhancement and vegetation management elements to protect stream channels where appropriate
- incorporate the City's stormwater retrofit plan (*Stormwater Retrofit Plan for the City of West Linn,* July 1, 2015) to improve stormwater mitigation in previously developed areas into the City's master plan update
- continue to monitor channel conditions and identify potential capital projects through regular inspections

Section 2

Hydromodification Background

The city of West Linn is located in the greater Portland metro area, adjacent to the Willamette and Tualatin rivers. The city's boundary encompasses approximately 8 square miles.

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 can alter runoff conditions and may increase flow and energy to stream channels. 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 potential 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. Primarily, alteration of stormwater flow, volume, and duration that may contribute to bank erosion or bed incision.

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 see 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.

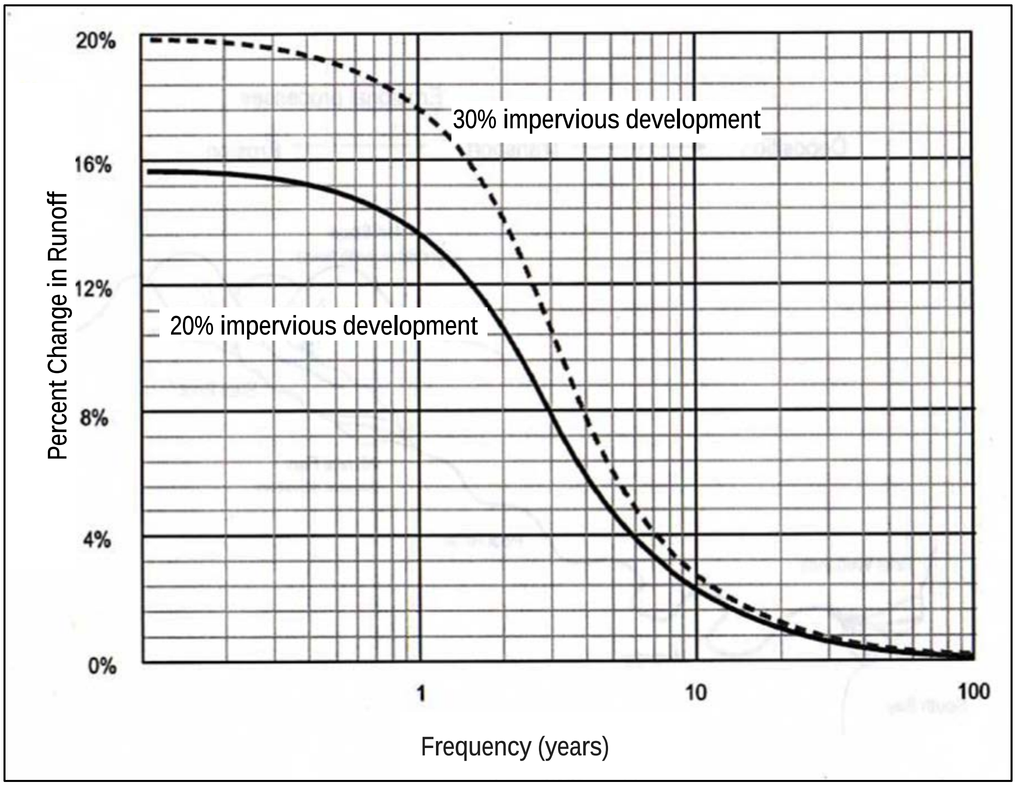

Figure 2-1. Effects of imperviousness and storm frequency on runoff

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 impacts on stream channel conditions. 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 may be in the range of flows that impact channel shape. Hydromodification control strategies focus on volume control to reduce the duration and frequency of geomorphically significant flows.

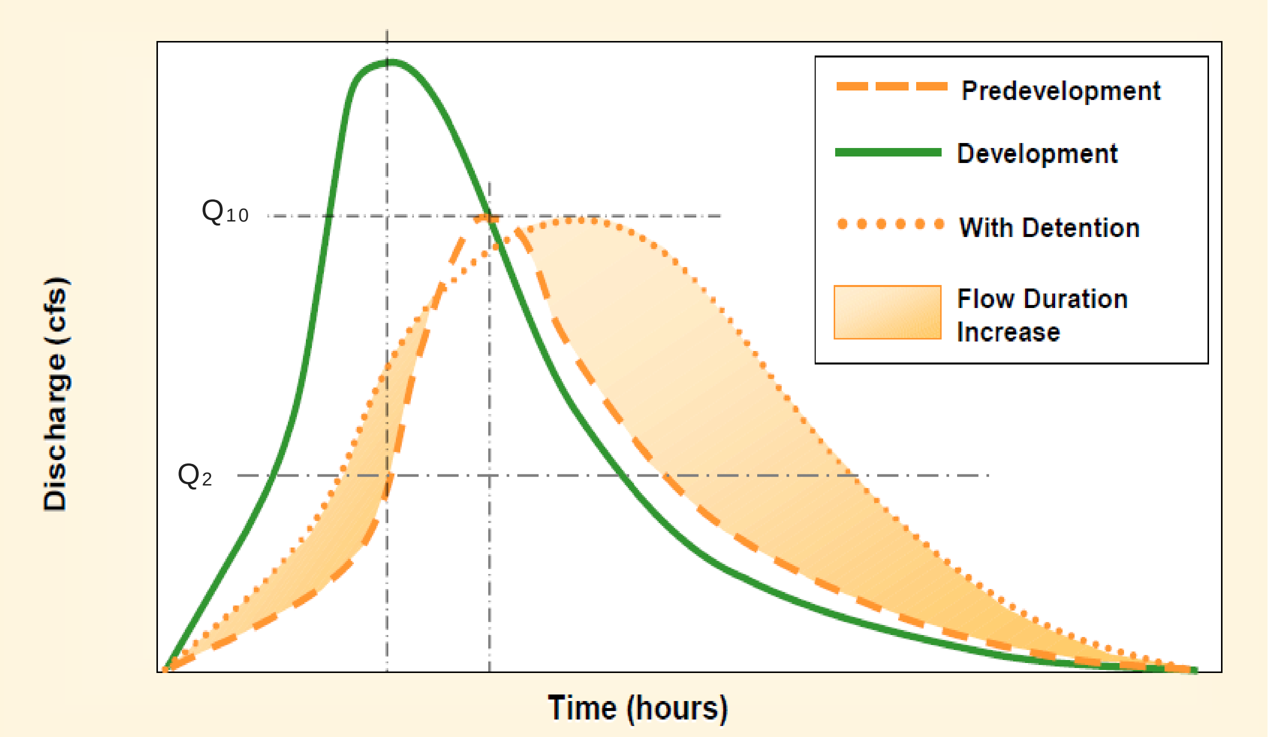

Figure 2-2. Schematic representation of how peak flow matching can increase energy in creek systems

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. 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.

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

> *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:*
>
> – *Collect and maintain information that will inform future stormwater management decisions related to hydromodification based on local conditions and needs;*
>
> – *Identify or develop strategies to address hydromodification information or data gaps related to water bodies within the co-permittee's jurisdiction;*

- *Identify strategies and priorities for preventing or reducing hydromodification impacts related to the co-permittee's MS4 discharges; and,*
- *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 the City might use to address hydromodification. Upland strategies manage flows from the contributing watershed. In-stream strategies adjust 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 West Linn.

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 can result 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 applicable 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. Several Phase I communities in Oregon have recently adopted new stormwater standards that require the use of infiltration-based stormwater controls to the maximum extent practicable.

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 are adopting 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.

Vegetative Bank Stabilization. Vegetative practices include the installation of plant materials as a structural component in controlling problems of land instability where erosion and sedimentation are occurring. Vegetative bank stabilization (“soil bioengineering”) can be effective at sites with limited exposure to strong flow velocities. In addition to controlling the sources of sediment contributed to surface waters, these techniques can halt the destruction of wetlands and riparian areas located along the stream bank. Stream bank vegetation can serve as a filter for surface water runoff from upland areas, or as a temporary sink for nutrients, contaminants, or sediment already present in surface waters. Additionally, vegetative approaches have the advantage of providing food, cover, and in-stream and riparian habitat for fish and wildlife and result in a more aesthetically appealing environment than traditional engineering approaches (EPA, 2007).

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 politically or 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's stream channels are naturally resistant to hydromodification, but could still benefit from stream enhancement and restoration.

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.

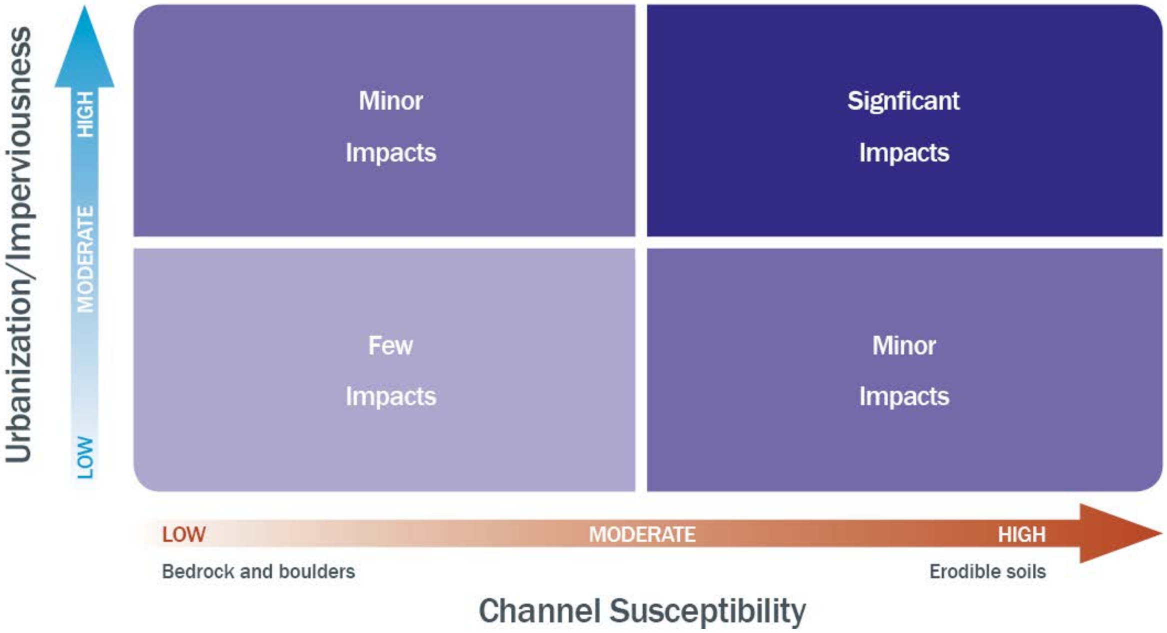

Figure 3-1. Relationship of urbanization and stream channel conditions on hydromodification potential

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 a surface water management plan, which will guide the City's project prioritization and funding strategy.

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 create the maps included in Appendix A. Second, the 2006 *West Linn Surface Water Management Plan* (2006 Plan) provided the general watershed and drainage basin information that is referenced below. Additional information was compiled from a natural resources assessment conducted by Fishman Environmental in 2002 and macroinvertebrate sampling from 2014. Taken together, these reports show relatively stable channel conditions across the city.

The city's natural hydrogeology contains steep canyons and numerous tributaries that drain to the Willamette and Tualatin rivers. The watersheds have seen significant development and urbanization over the last 30 years. While these conditions create the potential for hydromodification when changes in stream energy occur, the city's stream channels have natural features that buffer against hydromodification impacts.

4.1 Watershed Summary

West Linn's MS4 service area covers approximately 8 square miles. The area is located adjacent to the Willamette River in Clackamas County, Oregon. Most of the City's service area comprises steep hillsides that drain to small creeks with direct discharge to the Willamette River. A smaller area on the west side of the city drains to tributaries to the Tualatin River. The 2006 Plan identified 21 watershed areas within the city. Figure 4-1 shows an overview of watershed areas in the city and Table 4-1 documents the city's drainage basin areas.

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

- Figure A-1. Soils and Topography
- Figure A-2. Land Use
- Figure A-3. Soil Erodibility
- Figure A-4. Data Compilation, North
- Figure A-5. Data Compilation, South

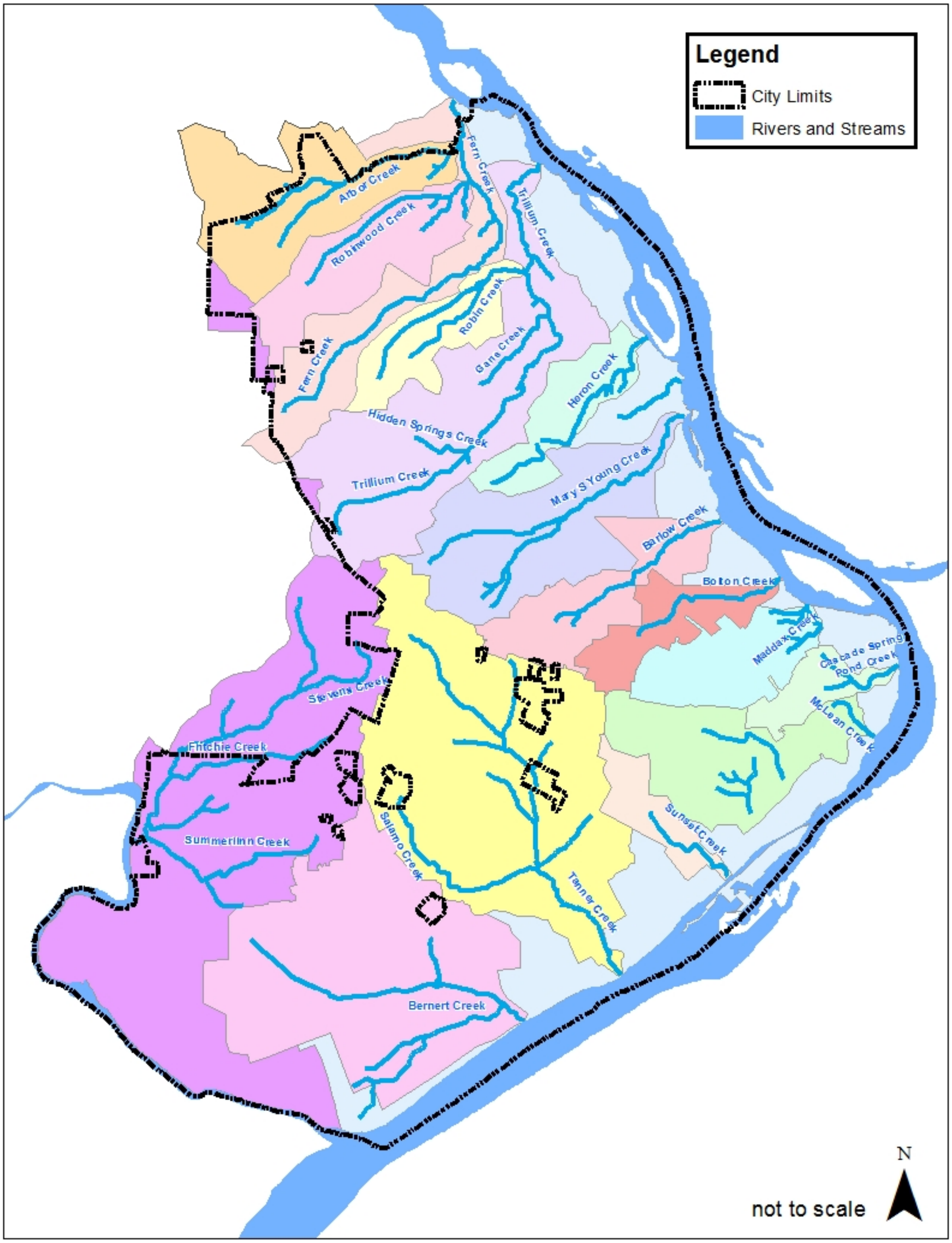

Figure 4-1. Overview of city watersheds

Source: City of West Linn GIS

Table 4-1. West Linn Watershed Summary

Watershed	Drainage basin	Drainage area (acres)
Willamette River	Arbor Creek	265
	Robinwood Creek	176
	Fern Creek	556
	Robin Creek	115
	Trillium Creek, including Gans Creek and Hidden Springs Creek Tributaries	452
	Heron Creek	114
	Mary S Young Creek	312
	Barlow Creek	166
	Bolton Creek	113
	Maddax Creek	138
	Cascade Pond Springs Creek	57
	McLean Creek	227
	Sunset Creek	76
	Tanner Creek, including Salamo Creek Tributary	700
	Bernert Creek	577
	Willamette Direct (multiple areas)	Undefined
Tualatin River	Dollar Creek	78
	Summerlinn Creek	318
	Fritchie Creek	389
	Tualatin Direct	Undefined

Source: West Linn Surface Water Management Plan, 2006.

The natural topography is similar across the many tributaries that drain to the Willamette River. Steep hillsides to the west drain down to a flat floodplain area between Highway 43 and the river. In the Willamette River watershed, the topography drops 700 feet from west to east. Tributaries in the Tualatin basin are much flatter, with only 200 feet of elevation change across the city. Nearly 50 percent of the city has slopes in excess of 10 percent, and 11 percent of the city has slopes in excess of 25 percent (2006 Plan, Table 3.1).

Soils in the city are predominantly silt loams with moderate to poor infiltration characteristics. Slow infiltration rates have the potential to exacerbate the impacts of high-magnitude rainfall events by favoring rapid surface runoff over infiltration, which would result in slower runoff into streams. Soil types adjacent to the Willamette River tend have higher infiltration capacity.

Figure A-3 in Appendix A includes an analysis of the soil erodibility factor (K factor), which shows that the majority of the soils in the city have a strong resistance to erosion. The K factor is not a specific indicator of channel erosion but reflects susceptibility of soil to erosion and rate of runoff. Soils with high silt content and K values greater than 0.4 are most susceptible to erosion. Most soils in West

Linn have K factors of less than 0.4 and many stream channels contain a high portion of larger soil material such as sand, cobbles, and bedrock.

The 2006 Master Plan references a natural resources evaluation prepared by Fishman Environmental based on riparian corridor field assessment information collected in July 2002. The evaluation indicated that observed stream channels were generally stable, with some areas of incision and invasive species. The macroinvertebrate monitoring report from 2014 also reported stream channels to have coarse substrate materials with relatively low levels of eroding channel banks and some non-native vegetation in riparian areas. These observations are consistent with the field observations conducted for this assessment, as documented in Section 5.

4.2 Development Patterns

As part of the desktop assessment, an evaluation of land use 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.

West Linn includes some of the oldest settlements in the state of Oregon, dating back to lumber mills constructed in the 1840s. Current development patterns include older residential areas adjacent to the Willamette River and newer residential areas in the hillsides above the river. The city has small commercial corridors along Highway 43 and Interstate 205 (I-205), as well as an area zoned for industrial use at the south end of the city, adjacent to the Willamette River.

Despite the steep topography, many residential developments have been constructed in tributary areas over the last 30 years. These developments typically have stormwater systems that discharge directly into tributary streams.

The City's current stormwater design standards were adopted in 2010. The current standards refer to the latest edition of the City of Portland Stormwater Management Manual (Portland SWMM) for stormwater facility design guidance. Developments are required to include stormwater facilities intended to manage flow from increasing impervious surfaces. The 2006 Plan identified 26 detention facilities in the City. Detention facilities are typically offline systems, controlling flow for a single development before discharging to the stream channel. Several developments in the Tanner Creek and Salamo Creek watersheds include in-line stormwater facilities that provide flow control directly in the stream channel. The field assessment (Section 5) included an investigation of the conditions of tributary streams to evaluate whether the stormwater management facilities have been providing adequate mitigation against hydromodification in tributary areas.

The City maintains a residential developable lands database that reflects refinement of the Metro RLIS vacant lands layer and includes residential lots that could be subdivided based on zoning. Many properties designated for potential residential development are restricted by sensitive area buffers and steep slopes.

The vacant lands analysis presented in Figures A-4 and A-5 in Appendix A shows that future development is expected to be primarily residential infill with limited areas of new commercial or industrial at the south end of the city. Unincorporated areas in the Tanner Creek and Tualatin River watersheds are the largest potential sources of new impervious area.

Section 5

Field Assessment

The field assessment was conducted over two 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:

- steep channel gradients in tributary streams
- channel bank and bed materials with natural resistance to erosion and incision
- localized erosion at stormwater outfalls and culverts
- past culvert replacement projects accommodating current flow patterns
- newer development areas that include stormwater controls
- invasive species that are pervasive in riparian areas and around stormwater facilities

These observations indicate that the natural channel conditions are resistant to increased stream energy from urbanization and impervious surfaces. The few identified problem areas are generally associated with stormwater outfalls and other concentrated discharges. Ongoing monitoring is recommended to continue observations of specific problem areas.

This field assessment was limited to investigations in several targeted watersheds. Additional fieldwork may be needed to look for hydromodification indicators and investigate problem areas in other areas of the city.

5.1 Field Methodology

Alissa Maxwell, P.E., and Angela Wieland, P.E., of BC, conducted the field assessment on May 11 and 14, with support from City staff (Beth Randolph and Mike Cardwell).

The field assessment was qualitative in nature, and was focused on documenting existing channel conditions. Priority locations for the field assessment were selected based on known problem areas and locations in subbasins that are expected to see future upstream development. Headwater streams are of particular interest, as upstream impacts tend to accumulate through the watershed.

Prior to the field assessment, the City identified 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 and/or changes in runoff patterns from the MS4. Field assessment locations also correlate with City's water quality monitoring sites.

The assessment targeted watersheds where multiple observations could be made along the channel alignment. Particular focus was given to the Tanner Creek watershed, which includes the Salamo Creek tributary. This watershed has had significant recent development and several areas pending for future development and annexation. As such, Tanner Creek was judged to be an area that would provide a representative indication of urbanized development impacts on the natural channel.

The desktop assessment showed similar watershed conditions and development patterns between most subbasins that drain to the Willamette River. These conditions include residential development in steep headwater areas, commercial areas at the base of the hillside along Highway 43, and additional flat residential areas adjacent to the Willamette River. Thus, the tributaries in the north portion of the city are expected to show similar hydromodification impacts. This hydromodification assessment prioritized field investigations in the urbanized areas of the Tanner Creek, Arbor Creek, and Trillium Creek subbasins.

Limited observations were also conducted in the Fritchie Creek subbasin, which is a tributary to the Tualatin River.

Nearly all of the field observations were made from public property. City staff identified field assessment locations with public access to the stream channel, including locations of road culverts, easements, and public facility tracts. Table 5-1 lists the specific locations of field observations. Field observation locations are also mapped on Figures A-3 and A-4 in Appendix A. Field visits to sites 001 through 008 were conducted during the first day of observations. Sites 009 through 020 were evaluated during the second day of observations.

This hydromodification assessment did not include observations of areas with direct discharge to the Willamette and Tualatin rivers, as West Linn's MS4 discharges are insignificant compared to the total watershed areas of those large river systems.

Table 5-1. Hydromodification Assessment Field Observation Locations

Site number	Water body	Location	Description
001	Tanner Creek	Channel downstream of Stonegate culvert	• Long stream reach with adjacent pedestrian access • Site selected to evaluate impacts from significant upstream development
002	Tanner Creek	Culvert and stormwater pond and Beacon Hill Court	• Adjacent to potential future annexation area • Offline stormwater pond serving residential development
003-004	Tanner Creek	Channel upstream of Beacon Hill Court	• Long stream reach with adjacent pedestrian access • Site selected to evaluate impacts from significant upstream development • Offline stormwater ponds serving residential developments
005	Tanner Creek	Channel downstream of Imperial Drive	• Long stream reach with adjacent access • Site of macroinvertebrate monitoring • Downstream point in Tanner Creek watershed
006	Salamo Creek	Bland Circle detention pond	• In-line stormwater pond at headwaters of Salamo Creek • Site of proposed stormwater pond retrofit to serve additional upstream development
007	Salamo Creek	In-line stormwater facility upstream of Remington Drive	• In-line stormwater facility in Salamo Creek • City-identified problem area due to silt accumulation and incision

Table 5-1. Hydromodification Assessment Field Observation Locations

Site number	Water body	Location	Description
008	Salamo Creek	Culvert at Theresa's Vineyard	• City-identified problem area due to poorly designed bridge/culvert • Adjacent offline stormwater facility
009	Arbor Creek	North tributary at Hillside Court near Skye Parkway	• City-identified evaluation area due to culvert crossing steep channel
010	Arbor Creek	Main stem at Hillside Court	• Location of City-constructed channel stabilization project
011	Arbor Creek	North tributary and main stem convergence at Upper Midhill Road	• City-identified evaluation area due to culvert crossing steep channel
012	Fern Creek	Robinwood Park	• City-identified problem area due to beaver ponds
013	Trillium Creek	Trillium Creek at Calaroga Drive	• Downstream watershed location to evaluate cumulative impacts • Site of macroinvertebrate monitoring
014	Trillium Creek	Trillium Creek at Elmran Drive	• Culvert crossing in flat portion of the watershed
015	Trillium Creek	Trillium Creek at Trillium Avenue	• Culvert crossing in flat portion of the watershed • Location of pervious City culvert replacement project
016-017	Trillium Creek	Trillium Creek at Cedar Oak Drive and Kenthorpe Way	• City-identified potential problem area due to private property channel modifications and upstream incision • Location of City property acquisition (downstream of Cedar Oak Drive)
018	Trillium Creek	Trillium Creek at Highway 43	• Culvert crossing in flat portion of the watershed
019	Cascade Springs Creek	Cascade Springs Creek at Sinclair Court	• City-identified problem area due to channel incision
020	Fritchie Creek	Fritchie Creek at Johnson Road	• Downstream end of watershed identified as potential future development area

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

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. The hydromodification indicators documented in Table 5-2 correspond to the Stream Channel Observation Forms included in Appendix C. These indicators are intended to be representative, not comprehensive, in nature.

Table 5-2. Hydromodification Indicators in West Linn Watersheds

Indicators	Tanner Creek and Salamo Creek Tributary	Willamette River Tributaries (Arbor Creek, Fern Creek, Trillium Creek, Cascade Springs Creek)	Fritchie Creek
Flooding	• None observed or reported associated with stream channel discharges. • Localized flooding problems are associated with capacity constraints in the conveyance system (Salamo Creek at Theresa's Vineyard).	• Reported flooding associated with beaver dam activity in lower portions of watersheds. Flooding is generally contained to open space and park areas. • Beaver dam wash-out occasionally results in temporary high flow conditions. • Observed open-channel areas are typically in small canyons, limiting potential flooding.	• Roadway flooding reported during peak storm events (flow overtops banks).
Degradation/bed incision	• Channel beds contain more cobbles and larger material, providing natural resistance to incision. • Observed some segments of minor bed incision at site 004 on Tanner Creek. • Incision along long reach of channel at site 007 on Salamo Creek. Channel is incising upstream of in-stream bed controls. • Downstream segments appear to be more stabilized with higher prevalence of cobbles and bedrock.	• Channel beds contain more cobbles and larger material, providing natural resistance to incision. • Channelized/armored banks on private property have led to downcutting and bed incision in downstream (sites 016 and 017). • Incised channel on Cascade Springs Creek (site 019) is reported to be caused by upstream beaver dams that washed out, creating major flow during peak storm event.	• Limited observation locations show little incision.
Bank erosion/widening	• Channel sections with sufficient setbacks have maintained their floodplain connection and do not show signs of ongoing erosion. • Large boulders and cobbles observed along stream bank appear to help stabilize the bank and dissipate high-velocity flow. • Some erosion around culvert outlets.	• Channel sections with sufficient setbacks have maintained floodplain connection and do not show signs of ongoing erosion. • Private property encroachment has resulted in localized areas of bank erosion (sites 017 and 020). • Some erosion around culvert outlets and channel bends. • Roadway crossings with replaced fish passage culverts appear stable over many years of upstream development.	• Some erosion around culvert outlets. • Minor levels of exposed roots observed.
Lack of riparian vegetation	• Significant tree canopy and understory vegetation along observed reaches. • Invasive species observed in urbanized areas.	• Development encroachment has reduced riparian vegetation in some areas, particularly in Trillium Creek basin. • Private property owners have participated in invasive removal and localized planting efforts. • Invasive species (ivy) observed.	• Observed reach is located along roadway corridor with grass meadow comprising floodplain. • Limited large trees/ shade potential. • Invasive species (ivy) observed.
Aggradation/sediment loads (evidence of increasing sediment loads without capacity to transport)	• Observed silty bed material and deposition at site 007 on Salamo Creek. Silt accumulation could be due to recent construction activity in surrounding neighborhood or potential upstream channel source.	• Heavy suspended sediment loads observed at sites 009 and 011, possibly due to upstream construction activities.	• Stream channel observations show some siltation and accumulation.

Table 5-2. Hydromodification Indicators in West Linn Watersheds

Indicators	Tanner Creek and Salamo Creek Tributary	Willamette River Tributaries (Arbor Creek, Fern Creek, Trillium Creek, Cascade Springs Creek)	Fritchie Creek
Other observations	• Culvert/bridge at site 008 on Salamo Creek was designed to fish passage standards, but installed at an elevation that causes material accumulation. • Generally appears to be a stabilized stream channel system due to substrate material and established riparian vegetation/buffers.	• Culverts in steep headwater areas have significant elevation drop, creating potential for bed incision and erosion at outfalls (site 009). • Concrete splash pads and channel bed weirs have been installed on select reaches. Bed control measures appear to be effective in limiting incision and dissipating stream energy at culvert outlets. • Generally good floodplain connectivity along Trillium Creek.	• Relatively flat corridor compared to other field observation locations in the city.
Unique features that may inform hydromodification strategies	• Unincorporated areas of the city with direct stream access have significant invasive species and livestock encroachment into the channel (may contribute to bank erosion). • Natural and man-made retention features online and directly offline help to dissipate high flows and provide sediment storage. • City staff indicates performance and maintenance challenges with existing stormwater management facilities.	• Steep slopes and more limited upstream development potential in these basins. • Previously completed stream enhancement project at site 010 is functioning as designed after 10+ years. This site may be a template for in-channel projects in other steep gradient tributaries.	• Undeveloped areas with annexation and development potential along headwaters of Fritchie Creek. • Important to maintain stream setbacks on future development areas. • Design standards for detention/ retention may be important here due to reported flooding, flatter topography, and stream erosion potential.

Representative conditions identified based on available data. Additional field assessments could be needed to investigate impacts in other creeks and tributaries, including Robinwood Creek, Fern Creek, Mary S Young Creek, and Bernert Creek.

General Observations

The field observations indicate little evidence of bank erosion and bed incision. In the observed locations, bed materials tend to consist of larger materials such as cobbles and boulders. Some locations show areas of bedrock. These materials stabilize the channel bed, limiting incision. Most observed reaches have protected floodplain areas, allowing the channels to overtop banks and dissipate energy during peak flows.

Observed locations with silty channel bed materials, such as site 007 on Salamo Creek and site 019 on Cascade Springs Creek, show more evidence of incision. These two sites may need in-stream projects to stabilize the channel from further incision.

Downstream areas, such as site 005 on Tanner Creek and sites 013 through 018 on Trillium Creek, do not show hydromodification indicators. These sites both showed stable bed and materials, connected floodplains, well-graded channel bed materials, and mature riparian vegetation. Upstream development has been significant in these watersheds. While developments in the Tanner Creek watershed have included a number of stormwater controls, the facilities were designed for only peak flow control, not flow-duration matching. The Trillium Creek watershed has few stormwater facilities to mitigate flows. However, in both cases, the channels are not showing significant hydromodification indicators. These observations indicate that the stream channels have natural resistance to hydromodification.

Observed problems are minor and typically located in areas of restricted or concentrated flow. Restricted flow occurs at road culverts. Concentrated flow occurs primarily at stormwater outfalls. Some evidence of invasive species was observed, particularly in the areas of reduced riparian buffers and in stormwater facilities.

Data Needs

It is difficult to document the severity and ongoing risk of identified problem areas without a record of channel changes over time. It is recommended that the City conduct regular observations to document changes in channel conditions. Observations should include photo documentation and channel measurements where applicable. Problem sites that are recommended for ongoing observations include:

- Salamo Creek at Remington (site 007): in-line stormwater control facility may not be functioning as designed; accumulated sediment could be indicator of adjacent construction activity or ongoing deposition problem
- Salamo Creek culvert at Theresa’s Vineyard (site 008): existing bridge/culvert is causing bed accumulation and shows potential to block channel flow
- Arbor Creek culvert at Hillside and Skye Parkway (site 009): elevation drop at culvert outlet has potential to create erosion problems
- Trillium Creek at Cedar Oak Drive and Kenthorpe Way (sites 016 and 017): channel erosion and incision upstream of private property channel alterations
- Cascade Springs Creek at Sinclair Court (site 019): channel incision on private property

This hydromodification assessment prioritized field investigations in the urbanized areas of the Tanner Creek, Arbor Creek, and Trillium Creek subbasins. Future hydromodification evaluations could investigate potential impacts in the Robinwood, Barlow, Sunset, and Bernert subbasins. If additional field investigations identify problem areas in other city subbasins, those problem areas should be added to the list of locations for observation.

Potential Project Locations

Problem sites that show active changes could present an opportunity for the City to develop stream stabilization capital projects to address ongoing hydromodification impacts. Stabilization projects could include outfall protection, energy dissipation, channel bed grade control measures, floodplain reconnection, and vegetation management. Capital projects developed to address hydromodification impacts would need to be incorporated into the City's next surface water master plan.

Site 010 on Arbor Creek is a template of a successful in-stream stabilization project. The project functions as designed, protecting the channel from ongoing modifications. The City may consider implementing similar projects at other steep channel culverts.

Problem areas that could benefit from in-stream stabilization projects include:

- Arbor Creek culvert at Hillside and Skye Parkway (site 009)
- Trillium Creek at Kenthorpe Way (site 017)
- Cascade Springs Creek at Sinclair Court (site 019)

The City may also consider upland projects to reduce stormwater flows to these active problem areas. The City has indicated that some stormwater management facilities are no longer functioning as designed. Examples include two in-line stormwater facilities on Salamo Creek (sites 006 and 007) that could be reconstructed to increase stormwater detention while adding additional water quality treatment elements. The City may identify additional stormwater ponds for retrofit efforts.

With hydromodification indicators limited to areas of channel constrictions, the City could further address hydromodification through the upgrade and replacement of degrading or undersized culverts. The field assessments identified the Salamo Creek culvert at the Theresa's Vineyard development (site 008) as a potential project site. As documented in Section 7, the City's 2006 Master Plan also includes a long list of culverts that need additional capacity to carry expected future flows. Continuing these culvert replacement efforts could address hydromodification by increasing channel capacity and reducing stream energy at road crossings.

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:

- City of West Linn, Public Works Standards, Section 2: Storm Drain Requirements, 2010 (PW Standards)
- West Linn Community Development Code (WLCDC)
- West Linn Municipal Code (WLMC)

Review of these documents showed that the City has existing policies that require detention and treatment facilities to mitigate peak flows and offset pollutant discharges associated with development activities. However, the PW Standards prohibit the use of infiltration facilities, which limits the types of stormwater management facilities that can be designed to meet the detention and treatment standards.

Based on the evaluation described below, it is recommended that the City update the PW Standards to adjust the stormwater management threshold and allow infiltration facilities for stormwater management when conditions allow. These changes would provide better mitigation for increased runoff from future development. Allowing infiltration increases opportunities for using green infrastructure design approaches, which give the City greater flexibility in retrofitting existing areas.

Current land use policies require developments to maintain stream buffers and setbacks to protect existing natural corridors. These standards provide protection for riparian areas and help maintain connectivity to the floodplain to support natural channel function.

6.1 Stormwater Design Standards

The City's stormwater design standards for new development and redevelopment are outlined in the PW Standards. Key aspects of the PW Standards include the following policies and design requirements.

Infiltration

When conditions allow, infiltration facilities reduce runoff volumes and help to reduce the flashiness of peak flows. PW Standards Section 2.0046 currently prohibits the use of infiltration such as storm sumps and drywells. . The current wording seems to prohibit all infiltration systems, but the City approves green infrastructure facilities, such as rain gardens and stormwater planters, to manage stormwater on individual lots and in the right of way in accordance with the City of Portland Stormwater Management Manual (Portland SWMM).

The facility design guidance in the Portland SWMM emphasizes the use of infiltration. It is recommended that PW Standards Section 2.0046 be amended to provide clarification that stormwater facilities that use surface infiltration are allowed when site conditions support infiltration.

Detention Standards

The detention requirements in the PW Standards require development projects to install detention facilities to reduce post-development flows to pre-development levels. PW Standards Section 2.0013 requires detention facilities to provide storage up to the 25-year storm event. Post-development flows from the 2-, 5-, 10-, and 25-year events shall be reduced to pre-development levels for the same storms. The current standards do not require volume reduction or duration matching.

As described in the hydromodification background discussion in Section 2, protection from hydromodification is achieved by controlling peak flow rates and the duration of flows from development. The peak flow matching requirements in PW Standards Section 2.0013 are not considered full mitigation in terms of addressing hydromodification impacts from geomorphically significant flows. However, given the limited number of hydromodification indicators observed in West Linn stream channels, there is little justification for adopting a more stringent flow duration standard on a citywide basis.

Facility Design Guidelines

The PW Standards currently reference the Portland SWMM for water quality facility design. PW Standards Section 2.0045 includes some limited guidance for detention facility design but an equivalent design manual is not referenced for detention facility design.

It is recommended that the City consider refining the existing PW Standards language to clarify which portions of the Portland SWMM are applicable in West Linn. The Portland SWMM may be appropriate for both water quality treatment and detention facilities, provided that PW Standards Section 2.0046 is revised to allow infiltration when site conditions allow. The Portland SWMM places a high emphasis on infiltration and green infrastructure facilities. 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.

Thresholds

In Section 2.0041, the PW Standards require water quality treatment for all development projects that create 500 square feet or more of impervious area. Detention is required for projects that create more than 5,000 square feet of new impervious area. It is recommended that the City adjust the detention threshold down to 1,000 square feet of impervious area, consistent with the City’s NPDES MS4 permit requirements.

6.2 Land Use and Zoning Code

The WLCDC designates several overlay zones that protect stream channels by requiring vegetated buffers around stream channels. The Willamette and Tualatin River Protection Area (WLCDC Chapter 28) sets habitat conservation areas (HCAs) adjacent to the major rivers, with associated building restrictions and setback requirements. Chapter 28 also includes provisions to protect riparian areas or mitigate for impacts to riparian vegetation.

The majority of the city’s tributary streams are covered by the Water Resource Protection Area (WLCDC Chapter 32). The City requires a vegetated buffer to be maintained adjacent to stream channels in the Water Resource Protection Area. WLCDC Table 32-2 defines the required setback distances, taking into account the steep ravines and topography in the city. In ephemeral streams and drainage ditches, the buffer may be as little as 15 feet on each side of the channel. Fish-bearing streams and riparian corridors may have a protected area of 100–200 feet on each side of the channel.

The City does allow specific land uses, such as minor utility lines, pervious surface trails, and replacement of existing structures, to encroach in the vegetated buffer. Other limited uses are allowed to encroach in the buffer, provided that the projects mitigate impacts by creating additional vegetated areas in the same corridor.

Planting requirements for the Water Resource Protection Area are focused on the goal of reestablishing a forested canopy and enhancing vegetation in riparian areas. A vegetated canopy provides opportunity for rainfall interception and evapotranspiration, reducing runoff to stream channels. The field observations documented in Section 5 of this assessment show that the vegetation goals are being met in most observed reaches.

Section 7

Review of Planned Projects

The *West Linn Surface Water Management Plan* (December 11, 2006) (2006 Plan) was developed prior to the adoption of the hydromodification goals in the NPDES MS4 permit and does not include specific capital projects to address in-stream problems or hydromodification. The capital projects identified in the 2006 Plan are focused on conveyance system needs, though culvert replacement projects could address hydromodification impacts by reducing flow restrictions and restoring a more natural flow regime.

The 2006 Plan identifies 79 potential pipe and culvert replacement projects. Nearly half of the identified projects relate to culvert replacements on either drainage ditches or natural channels. Culvert replacement projects on natural channels are potential sites for additional stream enhancement or restoration activities. Culvert replacement projects have the potential to improve stream conditions and address past hydromodification impacts by restoring stream connectivity and dissipating concentrated flows at undersized culverts.

These projects should be reviewed during development of the next master plan to determine the ongoing need and priority. Projects from the 2006 Master Plan should also be evaluated against current capacity and water quality needs. Where possible, to leverage City resources, multiple-objective projects should be developed to jointly address water quality, flow control, and drainage system capacity needs.

The City plans to develop a new surface water master plan and has budgeted for the work in the current fiscal cycle (2015/2016). The new master plan will define and prioritize projects for conveyance, water quality, and natural resources protection, including hydromodification. The new master plan should consider incorporating the following types of projects:

- pipe capacity projects identified through the 2006 Plan or updated modeling information
- culvert replacement projects identified in the 2006 Plan that show ongoing capacity problems or that are associated with in-stream problem areas
- in-stream problem locations identified in this hydromodification assessment (see Section 5)
- upland water quality retrofit projects identified through the *Stormwater Retrofit Plan for the City of West Linn* (June 1, 2015), developed as required by the NPDES MS4 permit
- sites of ongoing maintenance concerns

Potential projects may include elements of stream enhancement, flow mitigation, water quality retrofit, and vegetation management to provide comprehensive watershed solutions.

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 capital projects
- support development of a surface water master plan
- define areas for ongoing hydromodification monitoring
- prioritize locations for future property acquisition

Stream channels in the city show few hydromodification impacts from past development. In many observed locations, the stream channel is composed of large bed material that provides natural resistance to incision and erosion.

The City's future development areas are likely to include infill developments in headwaters areas that will include stormwater controls to limit peak flows. In areas of naturally resistant channels, peak flow controls may be effective in limiting hydromodification impacts. In areas where the stream channel is more susceptible to erosion, more stringent flow controls may be needed to mitigate the impacts of increasing impervious surface.

Observed problem areas were limited to areas of concentrated flow at stormwater outfalls or culvert restrictions. It is recommended that the City monitor problem areas on an annual basis to document changes in channel conditions. Active problem sites may be candidates for stream stabilization capital projects.

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

Data Collection and Data Gaps

The field assessment for this hydromodification assessment prioritized urbanized areas of the Tanner Creek, Trillium Creek, and Arbor Creek watersheds. Future hydromodification evaluations could investigate other city watersheds in both the Willamette and Tualatin river watersheds to look for hydromodification indicators and identify potential in-stream capital project locations.

The City is also likely to conduct ongoing water quality sampling as a result of future NPDES MS4 permit requirements. Data collected from these monitoring efforts could be used to inform hydromodification project priorities.

Develop an Updated Surface Water Master Plan

The City's 2006 Master Plan is focused on conveyance system needs and does not propose capital projects that address water quality or hydromodification goals. The City is planning to develop a new surface water master plan to include capital projects that address hydromodification. Potential projects may include elements of stream restoration, flow mitigation, water quality retrofit, and riparian planting. A new surface water master plan will provide the basis for long-term project prioritization and budgeting.

The new master plan may also consider the previously identified conveyance system improvement projects, and integrate outstanding capacity deficiency or conveyance projects with the restoration and water quality projects so that the comprehensive projects can be designed and constructed together for efficiencies.

Regular Inspections of Stream Conditions

Regular inspections are recommended to monitor known problem areas and proposed or completed capital project locations. The frequency of inspections should be determined based on observed conditions. 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 this assessment. Key locations for future monitoring include:

- Salamo Creek at Remington (site 007)
- Salamo Creek culvert at Theresa's Vineyard (site 008)
- Arbor Creek culvert at Hillside and Skye Parkway (site 009)
- Trillium Creek at Cedar Oak Drive and Kenthorpe Way (sites 016 and 017)
- Cascade Springs Creek at Sinclair Court (site 019)
- locations of planned stream channel capital projects
- locations of stream channel capital projects constructed in the 5 years prior

These identified sites are located only within the Tanner Creek, Trillium Creek, Arbor Creek, and Cascade Springs Creek watersheds. Additional fieldwork may identify additional areas requiring inspections in other city watersheds.

Capital Projects

The City has an opportunity to address hydromodification impacts by constructing projects that enhance existing stream channel conditions and/or mitigate peak flows. The City may also consider constructing energy dissipation structures at stormwater outfalls and culverts where concentrated flows are contributing to localized erosion problems.

Based on the results of this hydromodification assessment, Table 8-1 outlines potential capital projects identified during this assessment. These projects should be evaluated further during the development of the City's new surface water master plan. Where possible, capital projects could be incorporated into the surface water master plan to enhance existing stream channels and address ongoing hydromodification impacts.

These identified projects are located only within the drainage basins evaluated with this assessment. Additional fieldwork may be needed to identify potential projects in the other city watersheds. City staff may also conduct an evaluation of existing stormwater management facilities to identify additional locations for stormwater retrofit and reconstruction projects.

Table 8-1. Potential In-stream Capital Project Locations

Basin	Site visit location	Project location	Description	Potential hydromodification benefits
Arbor Creek	009	Downstream of Arbor Creek culvert at Hillside Drive near Skye Parkway	• Stream stabilization project to reduce channel drop at culvert outlet and prevent ongoing bank erosion due to high velocity flows	• Reduces stream energy and dissipates concentrated flows • Improves in-stream function • Addresses minor bank erosion problem
Trillium Creek	017	Trillium Creek at Kenthorpe Way	• Replace existing culvert to increase channel capacity • Stabilize stream channel upstream of road culvert • Restore natural stream channel on private property downstream of Kenthorpe Way	• Reduces stream energy and dissipates concentrated flows • Increases channel capacity for peak flows • Addresses moderate bank erosion problem • Improves in-stream function • Restores altered channel
Cascade Springs Creek	019	Cascade Springs Creek on private property at Sinclair Court	• Restore and stabilize stream channel on private property • Provide in-channel bed control to reduce potential future impacts	• Addresses active incision site • Restores altered channel
Salamo Creek	006	In-line stormwater pond at Bland Circle	• Reconstruct existing stormwater pond to provide increased storage and flow control, and enhanced water quality treatment • Evaluate potential to add infiltration function to existing pond	• Provides upland flow control for current and future development
Salamo Creek	007	In-line stormwater facility upstream of Remington Drive	• Evaluate opportunities to existing stormwater facility to provide increased storage and flow control, and enhanced water quality treatment • Consider opportunity to move stormwater offline from in-stream flows	• Provides flow control for current and future development • Removes in-stream flow barriers
Salamo Creek	008	Culvert at Theresa's Vineyard development	• Reconstruct existing channel to match current flow regime • Adjust flow path through existing culvert to increase stream energy to prevent aggradation of channel bed	• Adjusts stream channel to accommodate current flow regime • Increases stream energy through aggrading channel section

Refine Design Standards

Enhancements to existing PW Standards are recommended to comply with NPDES MS4 Permit requirements and to incorporate stormwater facility design guidelines that better mimic natural runoff patterns. The following enhancements are recommended:

- Adjust the threshold for projects to install detention facilities from 5,000 square feet to 1,000 square feet of impervious surface. This will allow the City to capture small infill developments, so that the cumulative impact of small projects is mitigated through detention facilities.
- Clarify PW Standards Section 2.0046 to indicate that infiltration is restricted with respect to drywells and other UIC systems. Infiltration through surface facilities, such as rain gardens, planters, and swales, should be encouraged when site conditions allow.
- Refine the existing language in PW Standards Section 2.0045 to clarify which portions of the Portland SWMM are applicable in West Linn. The Portland SWMM may be appropriate for both water quality treatment and detention facilities, provided that PW Standards Section 2.0046 is revised to allow infiltration when site conditions allow.

Watershed Planning

The City's current flow detention standards require only peak flow matching. This standard seems to have been effective in managing flows to Willamette River tributaries that are naturally resistant to hydromodification. Soils in the Tualatin River tributaries do not appear to have the high cobble and boulder content that is found in Willamette River tributaries. A more detailed evaluation may be needed to determine if Tualatin River tributary channels could be more susceptible to hydromodification, which could justify implementing a more stringent flow duration matching standard. If justified, the flow duration standard could be adopted as a basin-specific requirement or as part of a master plan for development in particular watersheds.

Retrofit Programs

The City is currently conducting a stormwater retrofit assessment and developing a retrofit strategy to improve stormwater quality in urbanized areas. Water quality retrofit projects also have the potential to address hydromodification by increasing infiltration and reducing peak flows and flow durations. Projects from the retrofit plan should be evaluated for hydromodification benefits and incorporated for consideration into the new surface water master plan.

Vegetation Management

Many field observations indicated a strong presence of invasive species in riparian areas. While all vegetation has the potential to provide bank stabilization and reduce erosion, invasive species have the potential to overtake riparian areas, choking out native plants and eventually diminishing the tree canopy and riparian vegetation diversity. It is recommended that the City explore opportunities to increase vegetation management in riparian areas.

Maintain Adequate Program Funding

Recommended programs and projects require oversight and management by City staff along with capital funding. The City currently funds 3.5 full-time equivalents (FTE) to implement the requirements of the City's NPDES MS4 permit and TMDL Implementation Plans. The current level of funding may need to be increased to address any additional program elements. The recommendations of this assessment will require additional resources to:

- conduct inspections of known problem areas
- conduct additional field investigations of city watersheds
- assess existing stormwater management facilities to identify retrofit opportunities
- review and revise the PW Standards related to stormwater management
- implement stormwater-related capital projects
- coordinate invasive species management

Staffing levels in stormwater program management, maintenance, and engineering should be evaluated during the development of the new stormwater master plan.

Additional Strategies

The city of West Linn is a largely urbanized area. Most stream channel corridors have sufficient setbacks and vegetated buffer restrictions, with the exception of small reaches adjacent to roads and other older development. In the past, the City has initiated property acquisition and developer contribution to support natural resource protection. In addition, development regulations require extensive buffering and setbacks of new development adjacent to stream channels. It is recommended that the City continue appropriate development regulation and potential future property acquisition along stream channel corridors to remove channel encroachments and restore natural system function.

Section 9

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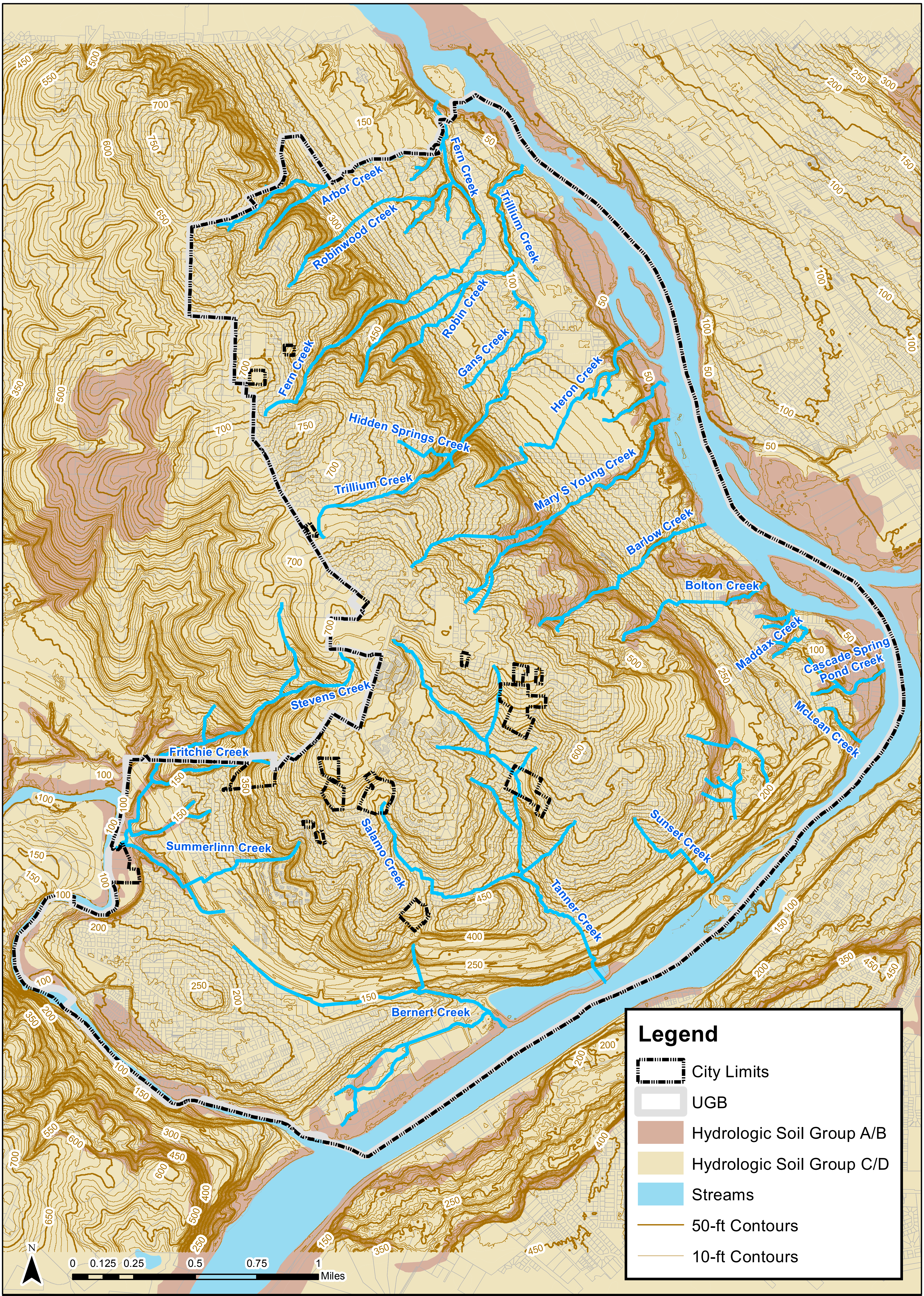
Limitations

This document was prepared solely for the City of West Linn 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 October 29, 2014. 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



CITY OF WEST LINN, OREGON

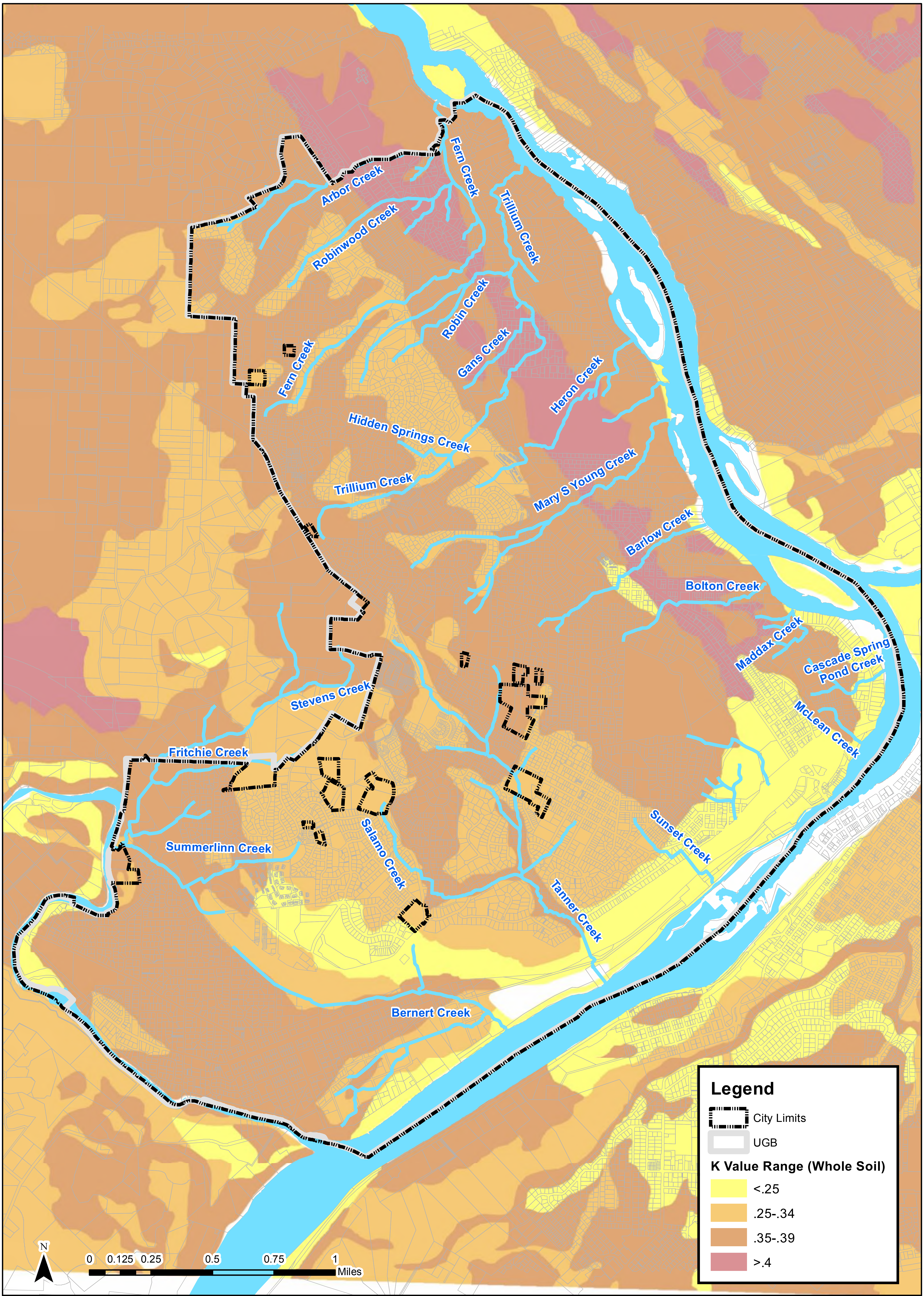
HYDROMODIFICATION ASSESSMENT

Soils and Topography - Figure A-1

Data Source: City of West Linn GIS, Metro RLIS, and USDA NRCS.

The Hydrologic Soils Group Layers reflect information provided by the U.S. Department of Agriculture Natural Resources Conservation Services Web Soil Survey.

Map Publication/Print Date: June 18 2015



CITY OF WEST LINN, OREGON

HYDROMODIFICATION ASSESSMENT

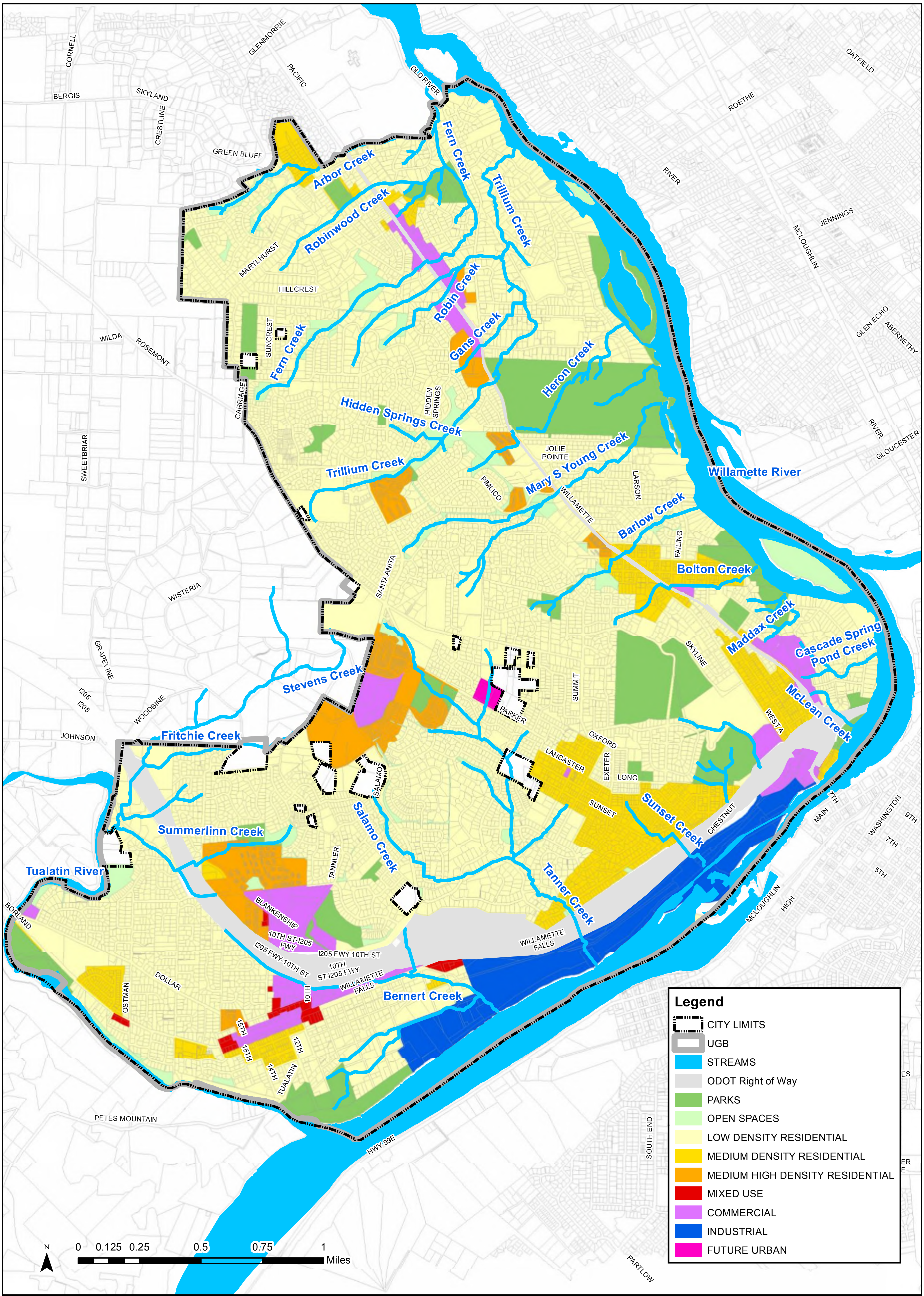
Soil Erodibility - Figure A-2

Brown AND Caldwell

Data Source: City of West Linn GIS, Metro RLIS, and USDA NRCS.

The K Values Range (Whole Soil) Layer reflects information provided by the U.S. Department of Agriculture Natural Resources Conservation Services Web Soil Survey.

Map Publication/Print Date: June 18, 2015



West Linn

CITY OF WEST LINN, OREGON

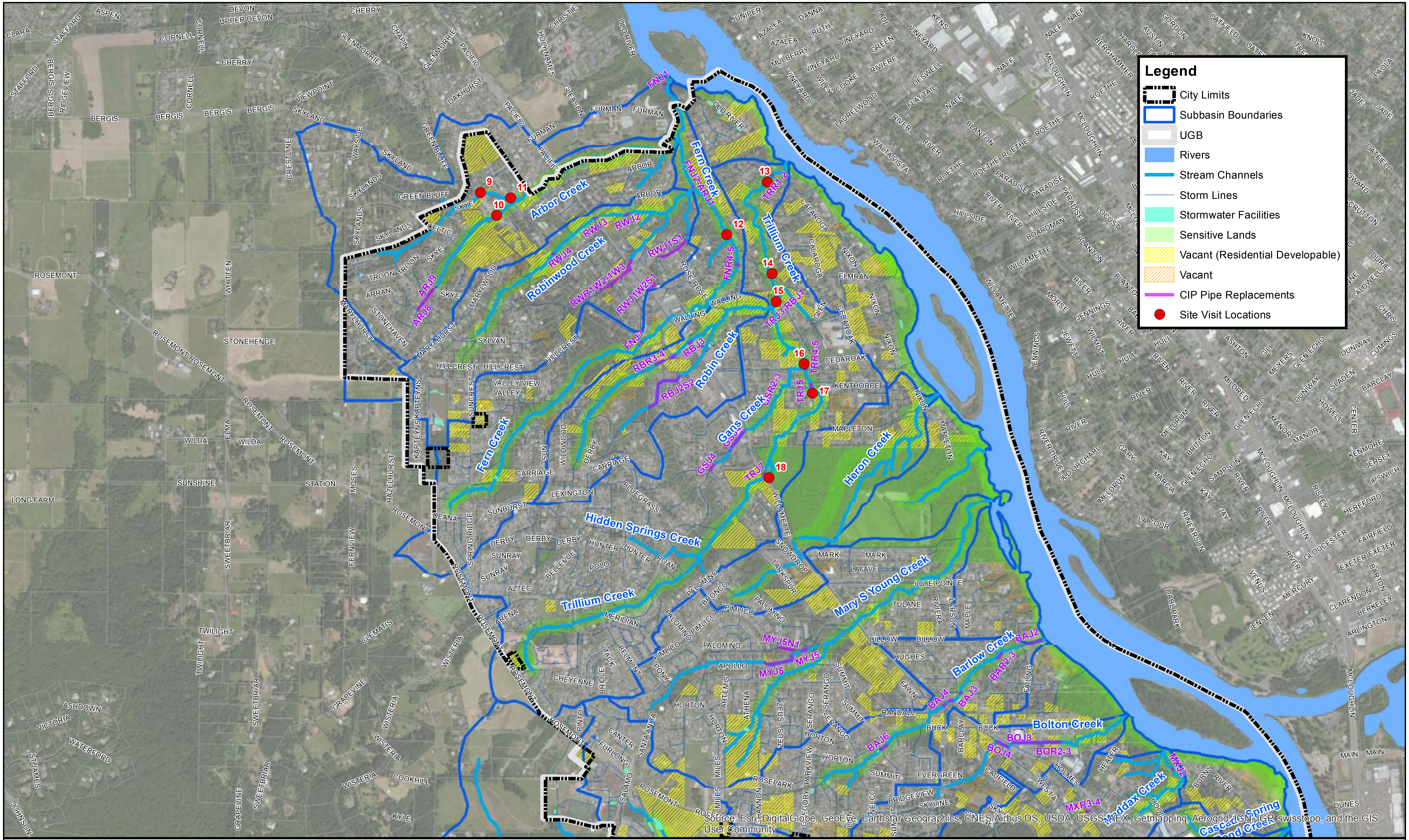
HYDROMODIFICATION ASSESSMENT

Zoning - Figure A-3

Brown and Caldwell

Data Source: City of West Linn GIS and Metro RLIS

Map Publication/Print Date: June 18, 2015



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

CITY OF WEST LINN, OREGON
HYDROMODIFICATION ASSESSMENT
Data Compilation - North - Figure A-4

Brown AND Caldwell

Data Source: City of West Linn GIS and Metro RLIS

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information.

Information shown on this map is for planning purposes only and wetland information is subject to change. There may be unmapped wetlands subject to regulation and all wetland boundary mapping is approximate. In all cases, actual field condition determine wetland boundaries. You are advised to contact the Oregon Division of State Lands and the U.S. Army Corps of Engineers with any regulatory questions.

The Sensitive Lands layer includes Riparian Buffer Zones, Wetlands, Tualatin River Protection Area, and Willamette River Greenway which were provided by the City of West Linn GIS.

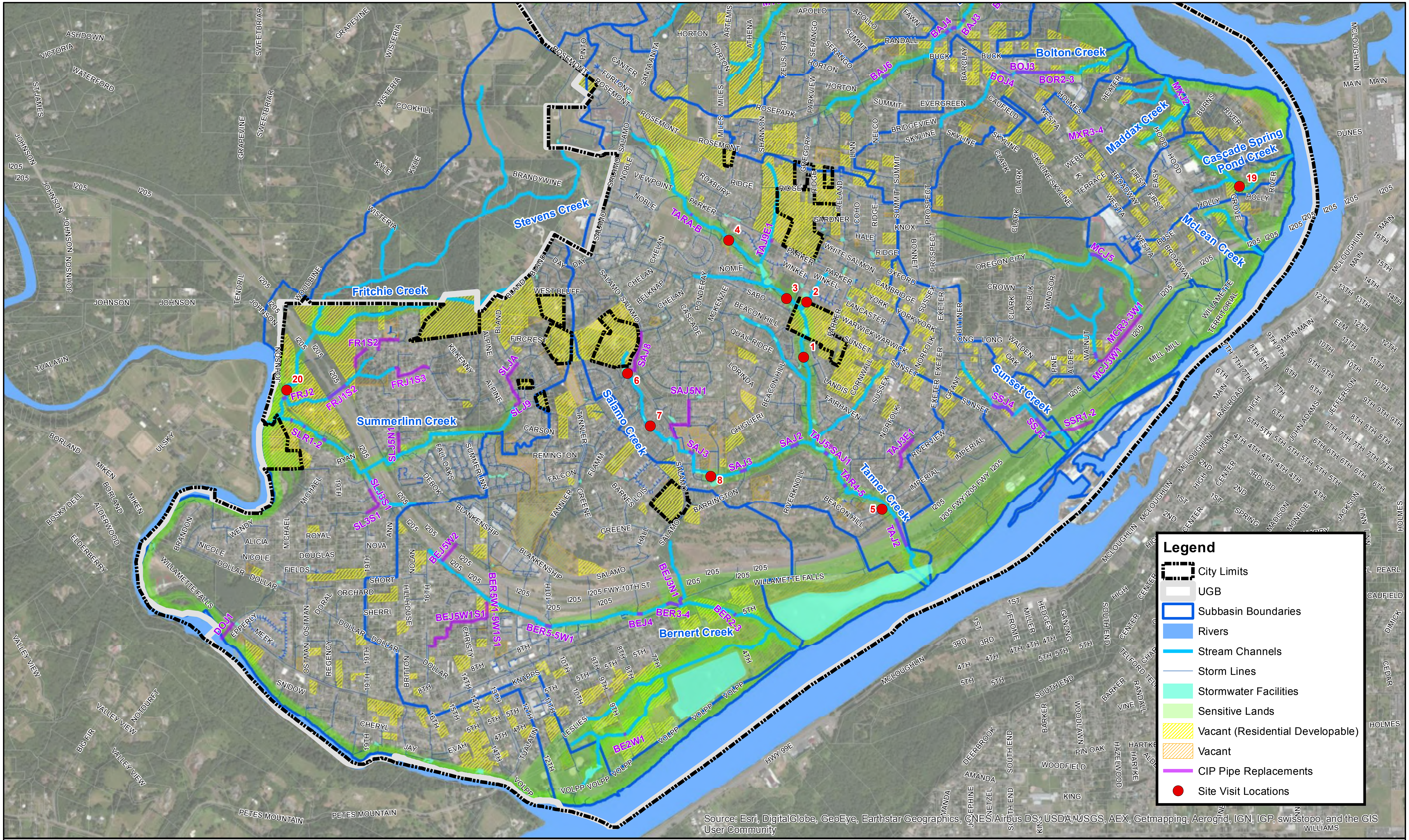
The 'Vacant (Residential)' layer reflects the residential buildable lands provided by the Cityof West Linn and the 'Vacant' layer reflects the vacant lands coverage provided by METRO RLIS

Map Publication/Print Date: June, 18 2015

0 1,000 2,000 4,000 Feet

1 inch = 2,000 feet

N



Legend

- City Limits
- UGB
- Subbasin Boundaries
- Rivers
- Stream Channels
- Storm Lines
- Stormwater Facilities
- Sensitive Lands
- Vacant (Residential Developable)
- Vacant
- CIP Pipe Replacements
- ● Site Visit Locations

West Linn

CITY OF WEST LINN, OREGON
HYDROMODIFICATION ASSESSMENT
Data Compilation- South - Figure A-5

Brown AND Caldwell

Data Source: City of West Linn GIS and Metro RLIS

Disclaimer: This product is for informational purposes and may not have been prepared for or be suitable for legal, engineering, or surveying purposes. Users of this information should review or consult the primary data and information sources to ascertain the usability of the information.

Information shown on this map is for planning purposes only and wetland information is subject to change. There may be unmapped wetlands subject to regulation and all wetland boundary mapping is approximate. In all cases, actual field condition determine wetland boundaries. You are advised to contact the Oregon Division of State Lands and the U.S. Army Corps of Engineers with any regulatory questions.

The Sensitive Lands layer includes Riparian Buffer Zones, Wetlands, Tualatin River Protection Area, and Willamette River Greenway which were provided by the City of West Linn GIS.
The 'Vacant (Residential)' layer reflects the residential buildable lands provided by the Cityof West Linn and the 'Vacant' layer reflects the vacant lands coverage provided by METRO RLIS
Map Publication/Print Date: June, 18 2015

0 1,000 2,000 4,000 Feet
1 inch = 2,000 feet
N

Appendix B: Photo Log

Appendix B

Photo Log

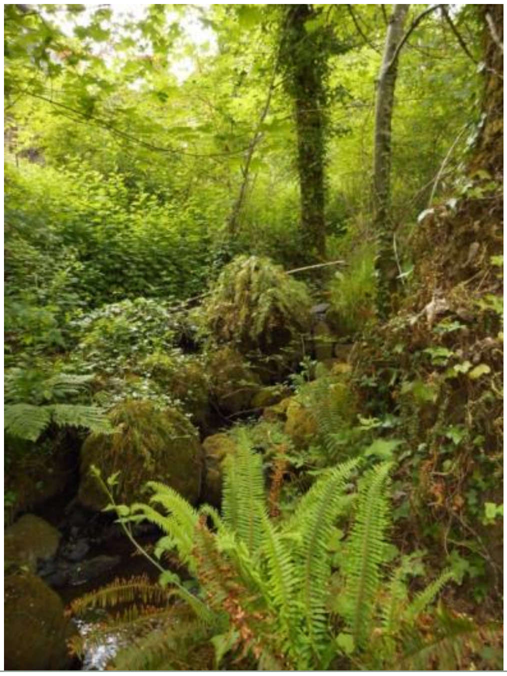
Photographs and descriptions of the field investigation (by site) are provided on the following pages.

Waterbody:	Tanner Creek
Reach description:	Tanner Creek at Stonegate and Landis, channel walk downstream in residential area
Site location:	001

Site location:	001
Photo number:	201
Description:	Looking downstream from Landis, heavy vegetation and wide riparian buffer.

Site location:	001
Photo number:	207
Description:	Large woody debris. No observed channel erosion.

Waterbody:	Tanner Creek
Reach description:	Tanner Creek at Stonegate and Landis, channel walk downstream in residential area
Site location:	001



Site location:	001
Photo number:	205
Description:	Heavy vegetation and established moss.

Site location:	001
Photo number:	212
Description:	Large boulders and cobbles in channel, bedrock substrate material.

Waterbody:	Tanner Creek
Reach description:	Tanner Creek at Stonegate and Landis, channel walk downstream in residential area
Site location:	001

Site location:	001
Photo number:	215
Description:	Looking downstream, wide floodplain with adjacent residential areas.

Site location:	001
Photo number:	217
Description:	Looking upstream along channel at Stonegate. Proposed future annexation area.

Waterbody:	**Tanner Creek**
Reach description:	**Tanner Creek at Beacon Hill Court, upstream from site location 001**
Site location:	**002**

Site location:	002
Photo number:	300
Description:	Looking downstream toward future annexation area. Observed invasive and livestock adjacent to channel.

Site location:	002
Photo number:	296
Description:	Offline detention pond for residential neighborhood.

Waterbody:	**Tanner Creek**
Reach description:	**Tanner Creek at Beacon Hill Court, upstream from site location 001**
Site location:	**002**

Site location:	002
Photo number:	220
Description:	Cobble and gravel bed material in Tanner Creek at Beacon Hill culvert.

Waterbody:	**Tanner Creek**
Reach description:	**Tanner Creek at Beacon Hill Court, channel walk upstream in residential area**
Site location:	**003**

Site location: 003

Photo number: 303

Description: Observed channel incision. Dense, established vegetation indicates limited active erosion.

Site location: 003

Photo number: 307

Description: Areas of channel incision. Silty loam substrate material.

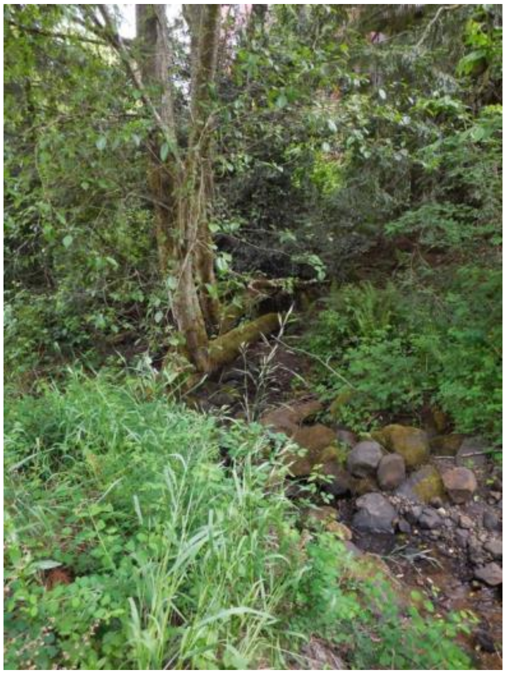
Waterbody:	**Tanner Creek**
Reach description:	**Tanner Creek at Beacon Hill Court, channel walk upstream in residential area**
Site location:	**003**

Site location:	003
Photo number:	312
Description:	Offline, manmade detention facility for residential neighborhood.

Site location:	003
Photo number:	315
Description:	Offline, natural retention pond/ wetland area.

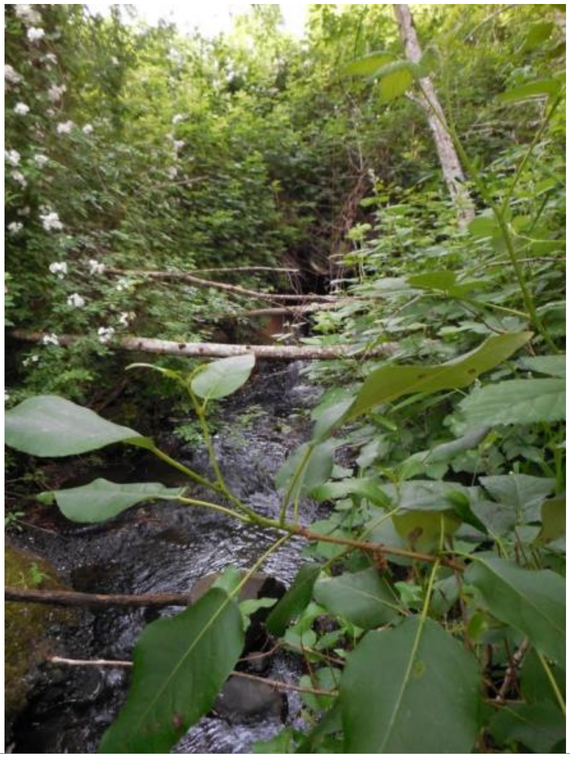
Waterbody:	Tanner Creek
Reach description:	Tanner Creek upstream of Beacon Hill Court, approximately 200’ upstream from site location 003
Site location:	004

Site location:	004
Photo number:	323
Description:	Gravel and cobbles in channel. Exposed roots.



Site location:	004
Photo number:	322
Description:	Wide floodplain. Limited observed channel incision.

Waterbody:	**Tanner Creek**
Reach description:	**Tanner Creek at Imperial Drive (and macroinvertebrate monitoring site), approximately 1,000 feet downstream of confluence with Salamo Creek.**
Site location:	**005**



Site location: 005

Photo number: 330

Description: Dense vegetation and LWD in channel.

Site location: 005

Photo number: 331

Description: Bedrock substrate with large cobbles and boulders in channel.

Waterbody:	**Tanner Creek**
Reach description:	**Tanner Creek at Imperial Drive (and macroinvertebrate monitoring site), approximately 1,000 feet downstream of confluence with Salamo Creek.**
Site location:	**005**

Site location: 005

Photo number: 332

Description: At inlet to 48" ODOT culvert under I-205

Site location: 005

Photo number: 336

Description: Looking upstream from photo 332, large cobbles and boulders and bedrock substrate.

Waterbody:	**Salamo Creek**
Reach description:	**Bland Circle detention pond**
Site location:	**006**

Site location:	006
Photo number:	338
Description:	Future detention pond retrofit with upstream development. Original design of perforated underdrain is not operational. Pond operates as a retention pond/ wetland.

Waterbody:	**Salamo Creek**
Reach description:	**Salamo Creek at Remington Drive, approximately 750' downstream from site location 006. Recent 3 lot partition adjacent to creek.**
Site location:	**007**

Site location:	007
Photo number:	340
Description:	Limited areas of channel incision and downcutting

Site location:	007
Photo number:	344
Description:	Silty bank materials but bedrock substrate.

Waterbody:	Salamo Creek
Reach description:	Salamo Creek at Remington Drive, approximately 750' downstream from site location 006. Recent 3 lot partition adjacent to creek.
Site location:	007

Site location: 007

Photo number: 346

Description: Areas of channel aggradation and sediment deposition.

Site location: 007

Photo number: 349

Description: Incised channel. Some locations of unconsolidated material.

Waterbody:	**Salamo Creek**
Reach description:	**Salamo Creek at Theresa's Vineyard property**
Site location:	**008**

Site location: 008

Photo number: 355

Description: Salamo Creek directly upstream from Theresa's Vineyard culvert shown in photo number 354.

Site location: 008

Photo number: 354

Description: Culvert installation over Salamo Creek. Culvert installed too low causing sediment and gravel to accumulate and redirect the channel.

Waterbody:	**Salamo Creek**
Reach description:	**Salamo Creek at Theresa's Vineyard property**
Site location:	**008**

Site location: 008

Photo number: 357

Description: Downstream end of Theresa's Vineyard culvert.

Site location: 008

Photo number: 358

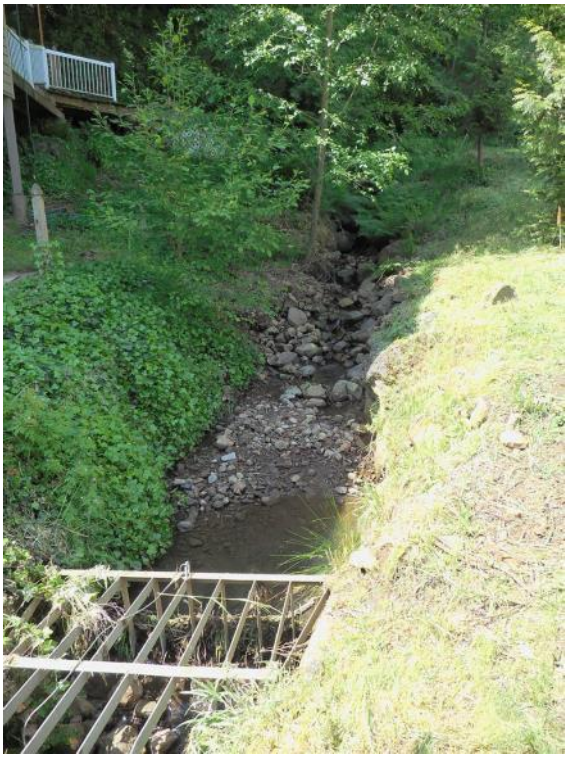
Description: Offline stormwater treatment/ detention facility.

Waterbody:	**Arbor Creek**
Reach description:	**Arbor Creek (north tributary) at Hillside Court near Skye Parkway**
Site location:	**009**

Site location:	009
Photo number:	002
Description:	Outlet of culvert under Skye Parkway. Heavy vegetation and canopy. Invasive species present.

Site location:	009
Photo number:	004
Description:	Scour hole at outlet of culvert. Some exposed roots along banks.

Waterbody:	**Arbor Creek**
Reach description:	**Arbor Creek mainstem at Hillside Court**
Site location:	**010**



Site location:	010
Photo number:	010
Description:	Stream restoration project from 10+ years ago. Cobbles and boulders along channel alignment.

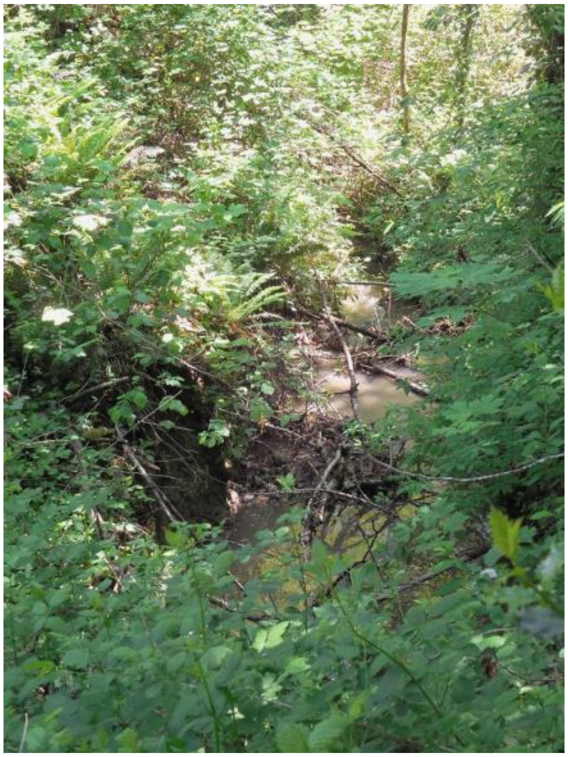
Site location:	010
Photo number:	012
Description:	Step pools with cobbles and boulders. Some invasives.

Waterbody:	Arbor Creek (north tributary)
Reach description:	Junction of Arbor Creek north tributary and main stem at Upper Midhill Road, approximately 500' downstream from site location 009
Site location:	011

Site location: 011

Photo number: 020

Description: Dense vegetation and wide floodplain.



Site location: 011

Photo number: 021

Description: Observed locations of historic bank erosion. Evidence of turbid discharge continuing downstream from site location 009.

Waterbody:	**Fern Creek**
Reach description:	**Beaver ponds at Robinwood Park**
Site location:	**012**

Site location:	012
Photo number:	023
Description:	Beaver dams created pond, which builds up and washes out with storm events. Significant vegetation including invasives, but relatively undisturbed natural habitat condition.

Waterbody:	**Trillium Creek**
Reach description:	**Trillium Creek at Calaroga Drive, water quality and macroinvertebrate monitoring site**
Site location:	**013**

Site location: 013

Photo number: 032

Description: Boulders and cobbles in channel; bedrock substrate. No observed bank erosion or evidence of active channel widening.

Site location: 013

Photo number: 035

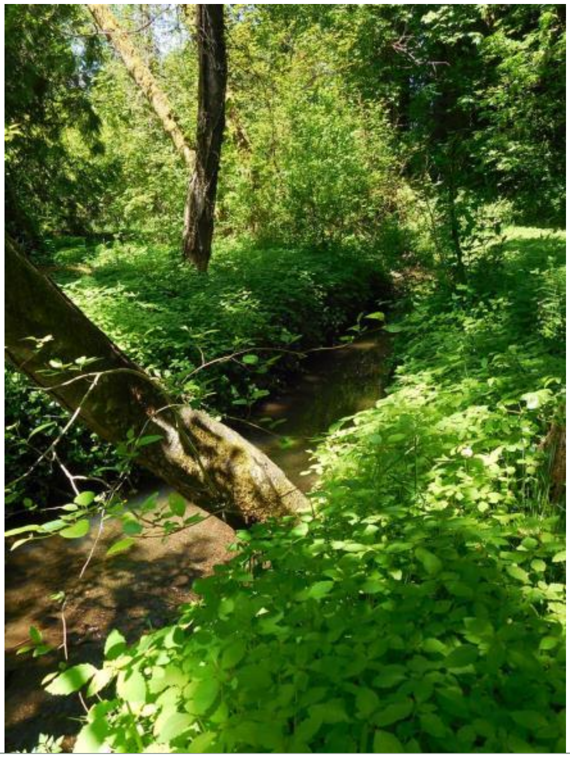
Description: Well graded stream sediments at downstream end of watershed.

Waterbody:	**Trillium Creek**
Reach description:	**Trillium Creek at Calaroga Drive, water quality and macroinvertebrate monitoring site**
Site location:	**013**

Site location:	013
Photo number:	029
Description:	Looking downstream from photo 032

Site location:	013
Photo number:	027
Description:	Manmade concrete channel bed grade control to dissipate stream energy and limit incision.

Waterbody:	**Trillium Creek**
Reach description:	**Trillium Creek at Elmran Drive**
Site location:	**014**



Site location: 014

Photo number: 038

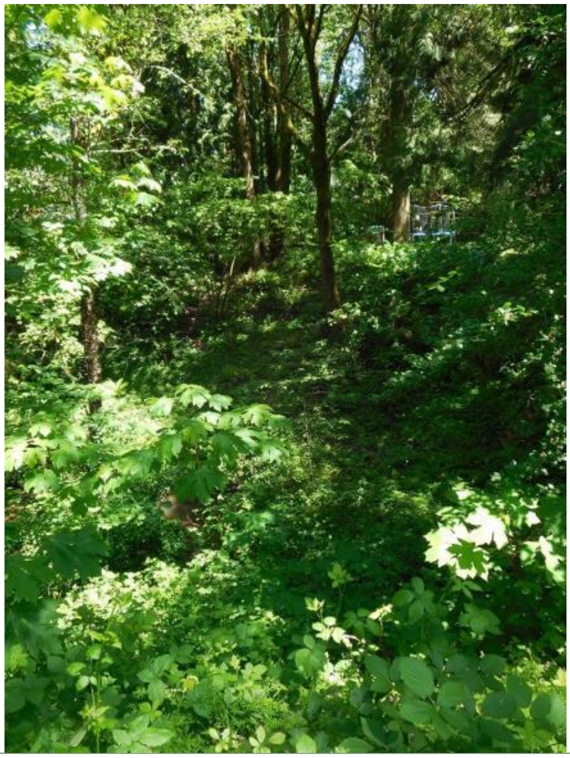
Description: Looking downstream from culvert at Elmran. Wide floodplain and established vegetation.

Site location: 014

Photo number: 040

Description: Gravel and silty bed material. Embedded cobbles.

Waterbody:	Trillium Creek
Reach description:	Trillium Creek at Trillium Avenue (approximately 300' upstream of site location 014)
Site location:	015



Site location: 015
Photo number: 043
Description: Wide active floodplain.

Site location: 015
Photo number: 045
Description: Dense vegetation. Could not access stream channel to observe bed conditions.

Waterbody:	**Trillium Creek**
Reach description:	**Trillium Creek at Cedar Oak Drive (City purchased property at northern end)**
Site location:	**016**

Site location: 016

Photo number: 050

Description: Dense vegetation. Wide floodplain

Site location: 016

Photo number: 047

Description: Gravel and sandy bed material.

Waterbody:	**Trillium Creek**
Reach description:	**Trillium Creek at Kanthorpe Way (approximately 100' upstream of site location 016)**
Site location:	**017**

Site location:	017
Photo number:	054
Description:	Point bars with observed sediment deposition shows stream channel has room for movement.

Site location:	017
Photo number:	055
Description:	Exposed roots and some locations of bank erosion,

Waterbody:	**Trillium Creek**
Reach description:	**Trillium Creek at Kanthorpe Way (approximately 100' upstream of site location 016)**
Site location:	**017**

Site location:	017
Photo number:	060
Description:	Private property along channel between site location 016 and site location 017 (photos 054 and 055). Channel heavily modifies and armored.

Waterbody:	**Trillium Creek**
Reach description:	**Trillium Creek at Highway 43 (upstream of site locations 013 to 017)**
Site location:	**018**

Site location:	018
Photo number:	064
Description:	Dense vegetation and cobble substrate. Potential development area to the west.

Waterbody:	**Cascade Springs Creek**
Reach description:	**Cascade Springs Creek at 5547 Sinclair Court (private property access)**
Site location:	**019**

Site location: 009

Photo number: 071

Description: Active downcutting and stream widening. Recently planted vegetation to stabilize stream banks.

Site location: 019

Photo number: 068

Description: Channel incision and widening within backyard.

Waterbody:	**Fritchie Creek**
Reach description:	**Fritchie Creek at Johnson Road**
Site location:	**020**

Site location: 020

Photo number: 074

Description: Straightened channel with established vegetation.

Site location: 020

Photo number: 079

Description: Cobble and gravel substrate

Appendix C: Stream Channel Observation Forms

Channel Stability Observation Form

Water Body:	Tanner Creek	**Date:**	5/11/15
Site/Location:	001 D/s of Stone Gate	**Time:**	1¹⁵ pm
		Crew:	all - AM, AW, BR, MC, KA, KL, E
Photos:		**Weather:**	Overcast
Channel Size:	4' wide / flow 6" deep	**Observed problems:**	A. Flooding B. Degradation C. Bank Erosion only invasives D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	[✓ Meandering] areas of wider 6-8' wide Straight Braided Channelized/Altered		

A. Flooding

Describe observed/known flooding problems:	No - good buffer

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: None

mass growing indicates established bed materials

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 - In channel vegetation is natural roughness

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 Ivy + Blackberry morning glory buttercup

E. Sediment Loads

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

Other

Known or observed problems **Unique features** **Field notes**	well connected floodplain with natural roughness Upstream development area

* 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:	Tamo-Creek	**Date:**	5/11/15
Site/Location:	003 upstream Of Sabo/Bacon Hill	**Time:**	145
		Crew:	all
Photos:		**Weather:**	Overcast
Channel Size:	4' wide - 2-3' deep	**Observed problems:**	A. Flooding B. Degradation C. Bank Erosion D. Lack of Vegetation only invasives E. Sediment Loads
Channel Pattern:	[✓ Meandering] Straight Braided Channelized/Altered		

A. Flooding

Describe observed/known flooding problems:	none - good stream corridor w/oaks

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~~: minor incision - possibly restabilized

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 possibly restablized
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 minor

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%] invasive ivy + blackberry

E. Sediment Loads

Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☒ Unconsolidated bed ☒ Embedded Cobbles silty bed - where is it coming from?
Turbidity/ Siltation	Describe:

Other

Known or observed problems **Unique features** **Field notes**	local drains discharging to creek upstream natural pond - year around water retention

* 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:	Tanner	**Date:**	5/11/15
Site/Location:	005 - Imperial	**Time:**	2⁰⁰
		Crew:	all
Photos:		**Weather:**	overcast
Channel Size:	4' wide 6-12" deep	**Observed problems:**	A. Flooding B. Degradation C. Bank Erosion D. Lack of Vegetation E. Sediment Loads None, only invasives
Channel Pattern:	[✓ Meandering] Straight Braided Channelized/Altered n[illegible]est pools wider in places w/ large cobble bed		

A. Flooding

Describe observed/known flooding problems:	none - good corridor + 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: None

C. Bank Erosion/Widening

Primary Bank Materials	Bedrock Boulders [✓ Gravel/Sand] Silt/Clay cobbles
Bank Protection	None [✓ Left Bank] Right Bank minor at private property
Streambank Erosion	Left Bank: None [✓ Fluvial] Mass Wasting Right Bank: None [✓ Fluvial] Mass Wasting minor
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 minor

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 invasives

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 **Unique features** **Field notes**	well preserved channel at d/s end of urbanized watershed. Good bed materia fewer invasives than upstream reaches.

* 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:	Salamocat	**Date:**	5/11/15
Site/Location:	007- Salamo Creek u/s of Remington	**Time:**	230
		Crew:	all
Photos:		**Weather:**	overcast
Channel Size:	2-3' 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		

A. Flooding

Describe observed/known flooding problems:	N/a - channel buffer is present

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: N/A - Concrete bed control						

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	minor	

D. Lack of Vegetation

Established riparian woody-vegetative cover	Left Bank:	0-25%	26-50%	51-75%	[✓ 76-100%]	invasives have been removed
	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 Silty bed & unconsolidated banks
Turbidity/ Siltation	Describe:

Other

Known or observed problems	recent adjacent development uses LID. Downspout rain garden + pervious pavement
Unique features	upstream projected for future subdivisions
Field notes	Revisit site in 2-5 years

* 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:	Arbor creek	**Date:**	5/14/15
Site/Location:	009- Hillside Road d/s of culvert	**Time:**	11^{00}
		Crew:	Am, AW, BR, MC
Photos:	009 - 011	**Weather:**	Sunny
Channel Size:	5' wide, rock + boulders banks at 3+ feet	**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:	None, unless road culverts are clogged

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% possibly restabilized
Exposed Roots	None Mild [✓ Moderate] Severe
Head cutting or nick points	Describe: Erosion at culvert crossings

C. Bank Erosion/Widening

Primary Bank Materials	Bedrock Boulders Gravel/Sand Silt/Clay
Bank Protection	[✓ None] Left Bank Right Bank Natural protection, large boulders
Streambank Erosion	Left Bank: None [✓ Fluvial] Mass Wasting Right Bank: None [✓ Fluvial] Mass Wasting possibly restabilized by natural features
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%] Right Bank: 0-25% 26-50% 51-75% [✓ 76-100%] Invasive Ivy + blackberry

E. Sediment Loads

Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☐ Unconsolidated bed ☐ Embedded Cobbles None
Turbidity/ Siltation	Describe: Yes! Heavy sediment at culvert outlet - possibly upstream contributors

Other

Known or observed problems **Unique features** **Field notes**	010 - City project 10+ years ago is well stabilized (west of previous culvert)

* 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:	Fern Creek Beaver Ponds	Date:	5/14/15
Site/Location:	Robinwood Park	Time:	12^{00} pm
		Crew:	AM, AW, BE, MC
Photos:	012	Weather:	Sunny
Channel Size:	Varied	Observed problems:	A. Flooding – natural flooding B. Degradation C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	[✓ Meandering] Straight Beaver Ponds Braided Channelized/Altered		

N/A - Beaver Dams

A. Flooding	
Describe observed/known flooding problems:	occassional flooding near arbor pumpstation
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:
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
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%] invasive ivy
E. Sediment Loads	
Aggradation unknown	☐ Fresh sediment deposition: channel bar near structure overbank ☐ Unconsolidated bed ☐ Embedded Cobbles
Turbidity/ Siltation	Describe: clear water
Other	
Known or observed problems Unique features Field notes	Beaver dams changing habitat Allowed to build & wash-out w/ natural Storms

* 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:	Millium	Date:	5/14/15
Site/Location:	013 Downstream Reach at Sampling site	Time:	1^{00} pm
		Crew:	AM, AW, BR, MC
Photos:	013	Weather:	Sunny
Channel Size:	8' wide, 4' deep	Observed problems:	A. Flooding B. Degradation None C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	[✓ Meandering] Straight Braided Channelized/Altered		

A. Flooding

Describe observed/known flooding problems:	No

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%	restabilized by bedrock and concrete bed weirs
Exposed Roots	None Mild Moderate Severe	
Head cutting or nick points	Describe: N/a	

C. Bank Erosion/Widening

Primary Bank Materials	Bedrock [✓ Boulders] Gravel/Sand Silt/Clay	
Bank Protection	[✓ None] Left Bank Right Bank	some on upper hillside w/ adjacent
Streambank Erosion	Left Bank: None [✓ Fluvial] Mass Wasting	very minor for
	Right Bank: None [✓ Fluvial] Mass Wasting	~~[illegible]~~ size of watershed
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]	minor

D. Lack of Vegetation

Established riparian woody-vegetative cover	Left Bank: 0-25% 26-50% 51-75% [✓ 76-100%]	good coverage.
	Right Bank: 0-25% 26-50% 51-75% [✓ 76-100%]	not many invasive

E. Sediment Loads

Aggradation	☒ Fresh sediment deposition: channel bar near structure overbank upstream ☐ Unconsolidated bed ☒ Embedded Cobbles at downstream end of culvert
Turbidity/ Siltation	Describe:

Other

Known or observed problems Unique features Field notes	Good looking channel at downstream end of watershed – little development potential

* 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:	Trillium	Date:	5/14/15
Site/Location:	014 Trillium creek at Elmran - Newer culvert 10-12 years	Time:	115 pm
		Crew:	Aw, Am, BR
Photos:	014 + 015	Weather:	Sunny
Channel Size:	6' wide / 3' deep	Observed problems:	A. Flooding B. Degradation minor impacts C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	[✓ Meandering] Straight Braided Channelized/Altered		

A. Flooding

Describe observed/known flooding problems:	None - floodplain has wide area good setbacks from stream channel

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

minor and looks to be restabilized, sediment + silt accumulation

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

Looks minor

minor

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 invasives

Some open meadow area

E. Sediment Loads

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

Other

Known or observed problems Unique features Field notes	no problems - Culvert is holding up well 015 at Trillium has had beaver accumulation - culvert was replaced in last 20 years

* 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:	Trillium mainstem	Date:	5/14/15
Site/Location:	016 - Culvert at & 017 Cedar oak & Kathrope	Time:	~~2~~ 145/200
		Crew:	AM, AW, BR, MC
Photos:		Weather:	Sunny
Channel Size:	3-4' wide/ ~~3-4' deep~~ 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] on private property		

A. Flooding

Describe observed/known flooding problems:	Not observed

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: None

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 - some areas at bends
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% meadow areas Right Bank: 0-25% 26-50% [✓ 51-75%] 76-100% private owner has removed invasives

E. Sediment Loads

Aggradation	☒ Fresh sediment deposition: [✓ channel bar] [✓ near structure] overbank Cobbles & gravel ☐ Unconsolidated bed ☐ Embedded Cobbles
Turbidity/ Siltation	Describe:

Other

Known or observed problems Unique features Field notes	City purchases property at downstream end of cedar oak preserves setbacks Private property has significant channel impacts between Cedar oak and Kathrope → placing stones in channel to create pools

* 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

Channel Stability Observation Form

Water Body:	Cascade Springs	**Date:**	3/14/15
Site/Location:	019 Pond Creek 5547 Sinclair Ct	**Time:**	230
		Crew:	Am, Aw, Be, MC
Photos:	019	**Weather:**	Sunny
Channel Size:	2-3' wide / 3-5' deep	**Observed problems:**	[✓ A. Flooding] – specific incidents 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:	yes – during peak flows after beaver Dam washout

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: Significant downcutting on private property eroding around boulders

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

more incision than bank erosion

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%]

property owner have plants

E. Sediment Loads

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

Other

Known or observed problems **Unique features** **Field notes**	upstream beaver dams have washed out, causing peak flow wash-out.

* 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

Channel Stability Observation Form

Water Body:	Fritchie Creek	**Date:**	5/14/15
Site/Location:	020 Fritchie channel at Johnson ~~Creek~~ road	**Time:**	2^{30}pm
		Crew:	Am/AW/BR/mc
Photos:		**Weather:**	Sunny
Channel Size:	2-3' wide 2' deep	**Observed problems:**	A. Flooding B. Degradation C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	Meandering [✓ Straight] Flat Braided Channelized/Altered		

A. Flooding

Describe observed/known flooding problems:	Road flooding during peak events ↳ connects 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% downstream has more gravel/sand
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 minor 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 minor

D. Lack of Vegetation

Established riparian woody-vegetative cover	Left Bank: 0-25% 26-50% [✓ 51-75%] 76-100% good for meadow valley Right Bank: 0-25% 26-50% [✓ 51-75%] 76-100%

E. Sediment Loads

Ivy downstream of Johnson Rd

Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☒ Unconsolidated bed ☐ Embedded Cobbles
Turbidity/ Siltation	Describe: flat areas have silt accumulation

Other

Known or observed problems	
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%.