Hydromodification Assessment

Prepared for

Oak Lodge Sanitary District

June 2015

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

BC	Brown and Caldwell
CIP	capital improvement plan
DEQ	Oregon Department of Environmental Quality
District	Oak Lodge Sanitary District (also OLSD)
EPA	U.S. Environmental Protection Agency
GIS	geographic information system
LID	low-impact development
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
ODOT	Oregon Department of Transportation
OLSD	Oak Lodge Sanitary District (also District)
SWCIP	*Surface Water Program Capital Improvement Plan*
SWMRR	*Surface Water Management Rules and Regulations for Oak Lodge Sanitary District,* May 2012
TMDL	total maximum daily load
UIC	underground injection control
WQRA	Water Quality Resource Area
ZDO	Clackamas County's Zoning and Development Ordinance

Section 1

Introduction and Key Findings

Brown and Caldwell (BC) completed a hydromodification assessment for the Oak Lodge Sanitary District (District, also referred to as OLSD). This study has been conducted in accordance with the District's National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit, in advance of the July 1, 2015, compliance deadline.

Hydromodification of stream channels is caused by both natural and man-made factors. This study is focused on hydromodification impacts associated with urbanization and MS4 discharges. As a highly urbanized area, development in the District has historically impacted stream conditions through alterations to natural channels and increases in stormwater discharge. In response, the District currently implements a number of programs to mitigate flow changes and projects to improve impacted channels.

This study shows that the District should continue implementing key programs and projects and consider modifications to existing design standards to address hydromodification impacts.

This hydromodification assessment includes a review of existing planning documents, a geographic information system (GIS) desktop evaluation of watershed conditions, and targeted field assessments to identify hydromodification indicators. Based on these evaluations, the hydromodification assessment revealed the following conclusions:

- Current land use and future development patterns in the District indicate limited potential for future flow increases.
- Existing stream channel problem areas indicate historical hydromodification impacts throughout the District.
- Current stormwater design standards may not offset all potential future flow impacts.
- Proposed capital improvement projects would address hydromodification impacts by improving stream channels and managing flows.

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

- implement key capital projects, such as the Boardman-Rinearson Wetland Complex project, to increase stream corridor storage and mitigate peak flows
- enhance existing stormwater design standards to prioritize infiltration and low-impact development (LID) approaches to stormwater management
- update the Surface Water Master Plan to enhance existing data and planning for capital projects continue to monitor known problem areas and capital project locations through annual inspections and documentation
- prioritize locations for future property acquisition along stream channel corridors

The conclusions and recommendations outlined in this hydromodification assessment may be used to inform District decisions related to land use and development policy, design standards, and the selection of capital projects.

Section 2

Hydromodification Background

The Oak Lodge Sanitary District is located in the greater Portland metro area, adjacent to the Willamette River. The District manages sanitary sewer and some stormwater services for an unincorporated service area of approximately 5.5 square miles.

As a highly urbanized area, stormwater discharges from the District have the potential to impact stream conditions through hydromodification. Increasing impervious area typically alters runoff conditions and increases flow to the stream channel, increasing stream energy. Increased stream energy can alter stream channels through flooding, bank erosion, bed incision, sediment production, and other impacts.

The District's NPDES MS4 permit requires the District to complete and submit a hydromodification assessment by July 1, 2015. The assessment must evaluate stream channels in the District to determine whether increased stream flows due to urbanization have impacted the stream channels and whether future land use development patterns are likely to contribute to additional impacts. The assessment must then identify strategies to address the hydromodification impacts.

2.1 What is Hydromodification?

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

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

When watersheds develop, the overall increase of flow and volume that occurs with increasing impervious surface translates to an increase in stream energy that can cause bank erosion, bed incision, sediment production, and other channel alterations. Small storm events tend to 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 and 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.

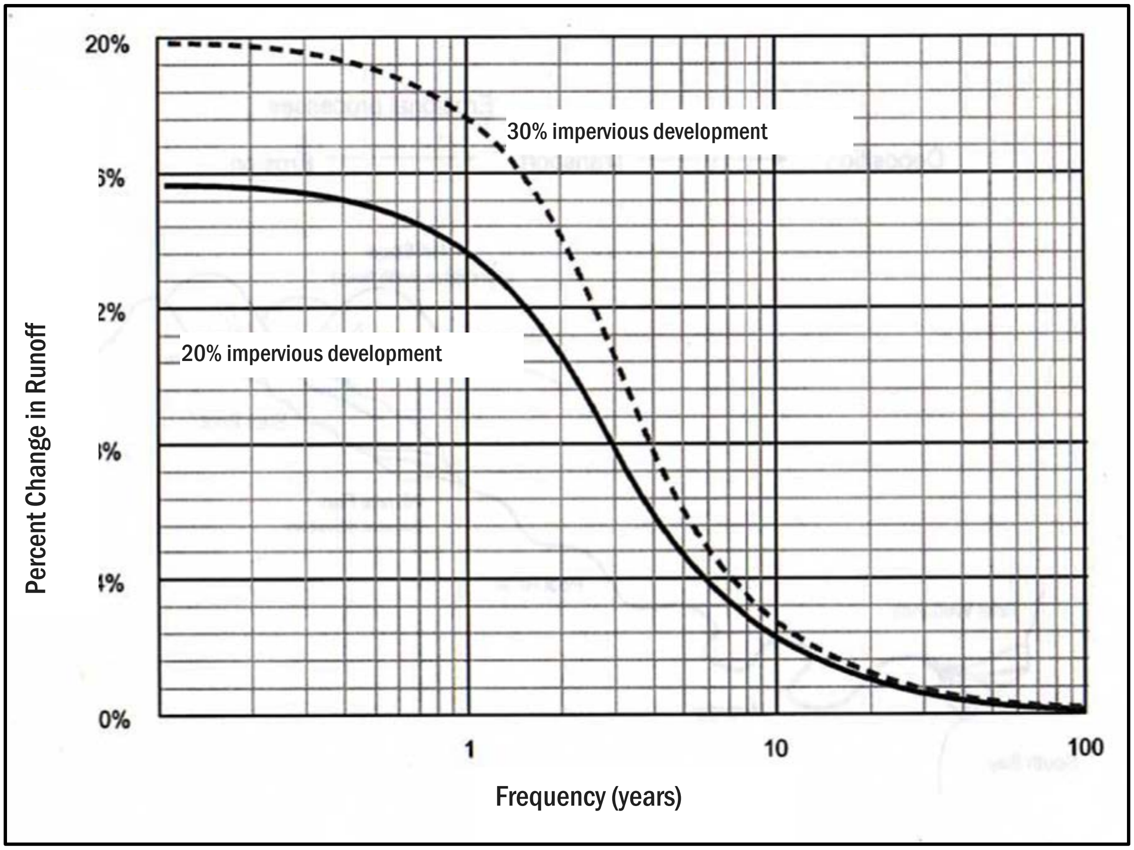

Figure 2-1. Effects of imperviousness and storm frequency on runoff (Hollis, 1975)

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

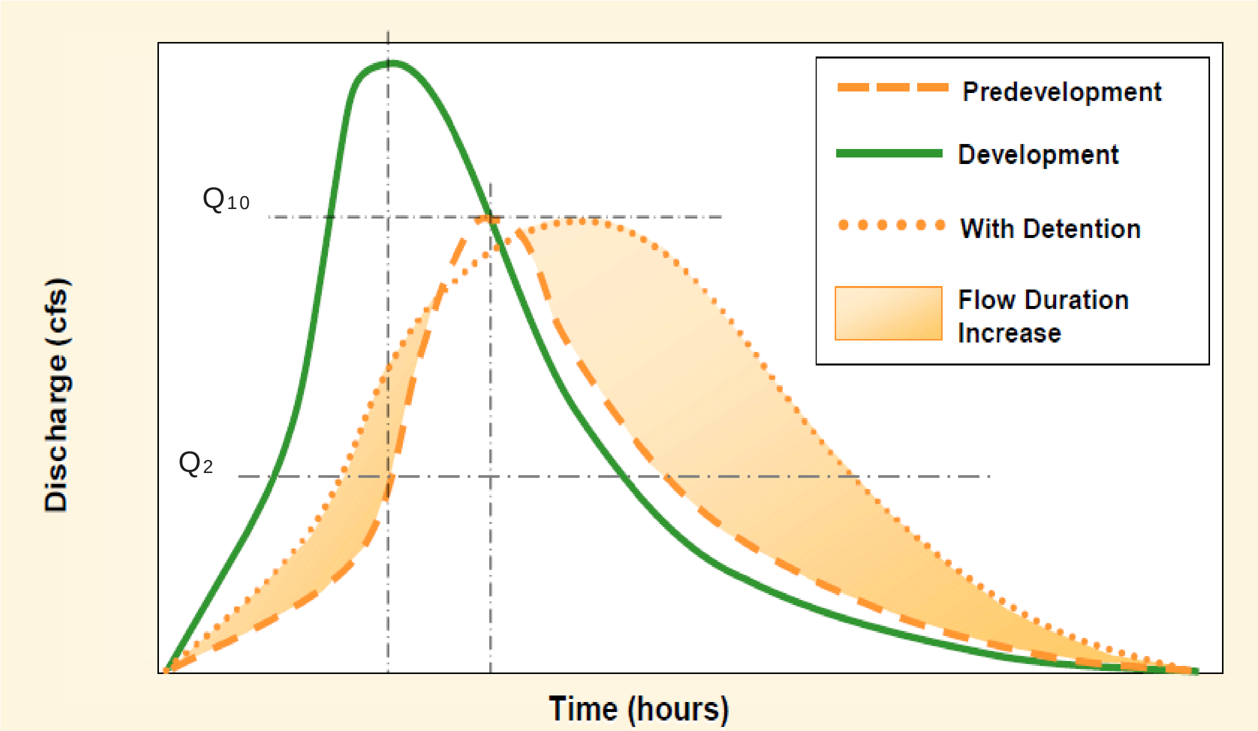

Figure 2-2. Schematic showing how peak flow matching can increase energy in creek systems

2.2 Regulatory Requirements

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

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

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

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

5. *The co-permittee must conduct an initial hydromodification assessment and submit a report by July 1, 2015 that examines the hydromodification impacts related to the co-permittee's MS4 discharges, including erosion, sedimentation, and alteration to stormwater flow, volume and duration that may cause or contribute to water quality degradation. The report shall describe existing efforts and proposed actions the co-permittee has identified to address the following objectives:*

    a. *Collect and maintain information that will inform future stormwater management decisions related to hydromodification based on local conditions and needs;*

    b. *Identify or develop strategies to address hydromodification information or data gaps related to water bodies within the co-permittee's jurisdiction;*

    c. *Identify strategies and priorities for preventing or reducing hydromodification impacts related to the co-permittee's MS4 discharges; and,*

    d. *Identify or develop effective tools to reduce hydromodification.*

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

2.3 Strategies to Address Hydromodification

This section describes potential strategies that jurisdictions might use to address hydromodification. Upland strategies manage flows from the contributing watershed. In-stream strategies 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 in the District.

2.3.1 Upland Strategies

Urbanization adds impervious surface, which reduces opportunities for stormwater runoff to infiltrate into the soil layer. As shown in Figure 2-1 in Section 2.1, this results in higher runoff rates and volumes. Typical upland strategies to combat this increase in stormwater flow rates and durations include the installation of stormwater management facilities to manage flows from the contributing watershed and/or site planning adjustments to reduce the impervious area 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, and infiltration trenches, and infiltrating storage tanks or vaults. Infiltration systems can be located throughout a watershed to infiltrate stormwater near the source or placed at the downstream end of a collection and conveyance system to infiltrate runoff before discharge to a natural channel. Below-ground infiltration systems, such as drywells, infiltrating storage tanks, or vaults, must be designed to comply with regulations governing underground injection control (UIC) systems.

DEQ's NPDES MS4 Phase I stormwater permits require Oregon communities to *prioritize LID* and other green infrastructure approaches to better mimic natural conditions. Communities including Salem, Wilsonville, and Oregon City have recently adopted new stormwater standards and/or design manuals that require the use of infiltration-based stormwater controls to the maximum extent practicable. As described in Section 6, the District's stormwater design standards encourage the use of infiltration to manage runoff from small storm events.

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

Detention. Flow detention 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 the state of 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 have a number of challenges. One challenge is that it requires use of more sophisticated modeling approaches than traditional approaches. Many jurisdictions adopting a flow-duration standard are also developing 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 driveways surfaces, narrowing streets, using porous pavements, and disconnecting residential downspouts to provide increased stormwater dispersion and infiltration opportunities. By applying these principles, impervious surfaces in developed areas are reduced, which reduces the need for other flow management strategies.

2.3.2 In-Stream Strategies

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

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

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

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

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

Piped bypass systems may be an effective solution to address specific problems in areas that are adjacent to large rivers that can accept increased local flows (Willamette River, Clackamas River, etc.). However, these projects sometimes require property acquisition or a series of easements to install the bypass systems, which can be 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 uses a GIS desktop assessment, targeted field assessment, and review of existing planning documents to develop strategies and approaches addressing hydromodification impacts. The results of this study show that the District should continue to implement key programs and projects to address hydromodification impacts.

This hydromodification assessment includes the following elements:

- *GIS assessment* of watershed conditions to evaluate drainage patterns, natural features, and the extent of urbanization and future development potential (Section 4)
- *field assessment* of known problem areas and other locations to identify hydromodification indicators (Section 5)
- *review of existing planning documents* to determine whether current land use policy and development standards are adequate to protect against further impacts (Section 6)
- *evaluation of planned capital projects* 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 provide buffering against stream channel impacts. In other cases, locations where the steam 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 condition and urbanization patterns in causing or resisting hydromodification impacts.

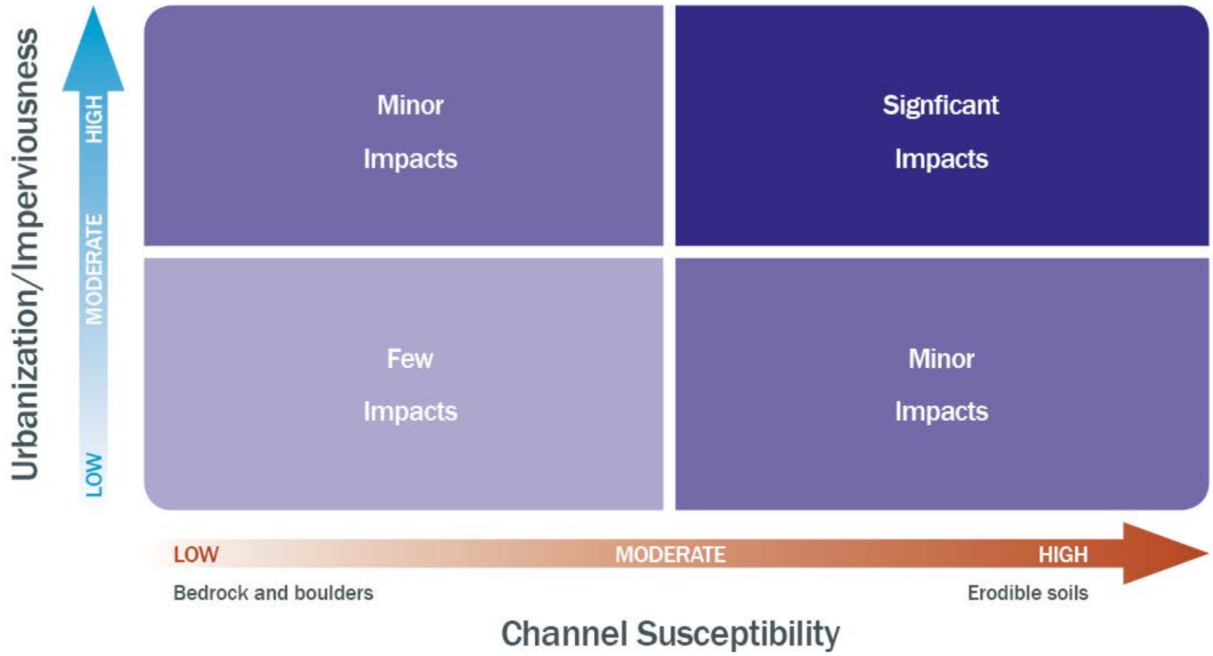

Figure 3-1. Relationship of urbanization and stream channel conditions on hydromodification potential

3.1 Future Use of This Assessment

This hydromodification assessment may be used to inform District decisions related to land use and development policy, design standards, and capital projects. Where specific projects are identified, they should be incorporated into the next Surface Water Master Plan update for inclusion in the District'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 and unreasonable cost and resources. 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 and analysis costs without significantly advancing the Districts understanding of conditions or enhancing recommendations. Instead, this hydromodification assessment uses typical characterizations, includes existing local knowledge and provides the background for future data collection efforts, if necessary.

Section 4

Desktop Assessment of Watershed Conditions

The goals of the GIS-based desktop assessment were to:

- evaluate watershed conditions to understand drainage patterns and locations of natural features, and
- 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 District were used to create the maps included in Appendix A. Second, the District's 1997 Surface Water Master Plan provided general watershed and drainage basin information that is referenced below.

While ongoing urbanization has caused hydromodification to the stream channels, based on the desktop assessment, there appears to be little potential for future impacts. As described in the following sections, past development has significantly impacted the District's streams by through channelization and piping of natural streams to support development. Natural open stream channels are limited in the District.

The land use and vacant land analysis assessment shows that there is little potential for future development in the District. The District is essentially built out and unlikely to expand its service boundary; future development is likely to be small infill redevelopment projects with incremental increases in impervious surface. The District's existing design standards require flow mitigation to offset the incremental increase in flows. Additional information regarding design standards is included in Section 6.

4.1 Watershed Summary

The District's drainage area covers more than 3,500 acres. The area is located adjacent to the Willamette River and is part of unincorporated Clackamas County.

Watersheds in the District include Kellogg Creek, River Forest Creek, North Boardman Creek, South Boardman Creek, and Willamette River Direct. A small basin on Wallace Road drains to the city of Gladstone.

River Forest Creek and Boardman Creek are the focus of this assessment, as they contain natural stream channels with drainage area isolated to the District. River Forest Creek runs from east to west in the northern portion of the District, through River Forest Lake and into the Willamette River. Boardman Creek also runs from east to west in the southern portion of the District, originating at the Boardman wetland complex, located near Boardman Avenue and McLoughlin Boulevard. North Boardman Creek is a primarily piped tributary that discharges to Boardman Creek near SW Blanton Street.

Figure 4-1 shows an overview of District watersheds.

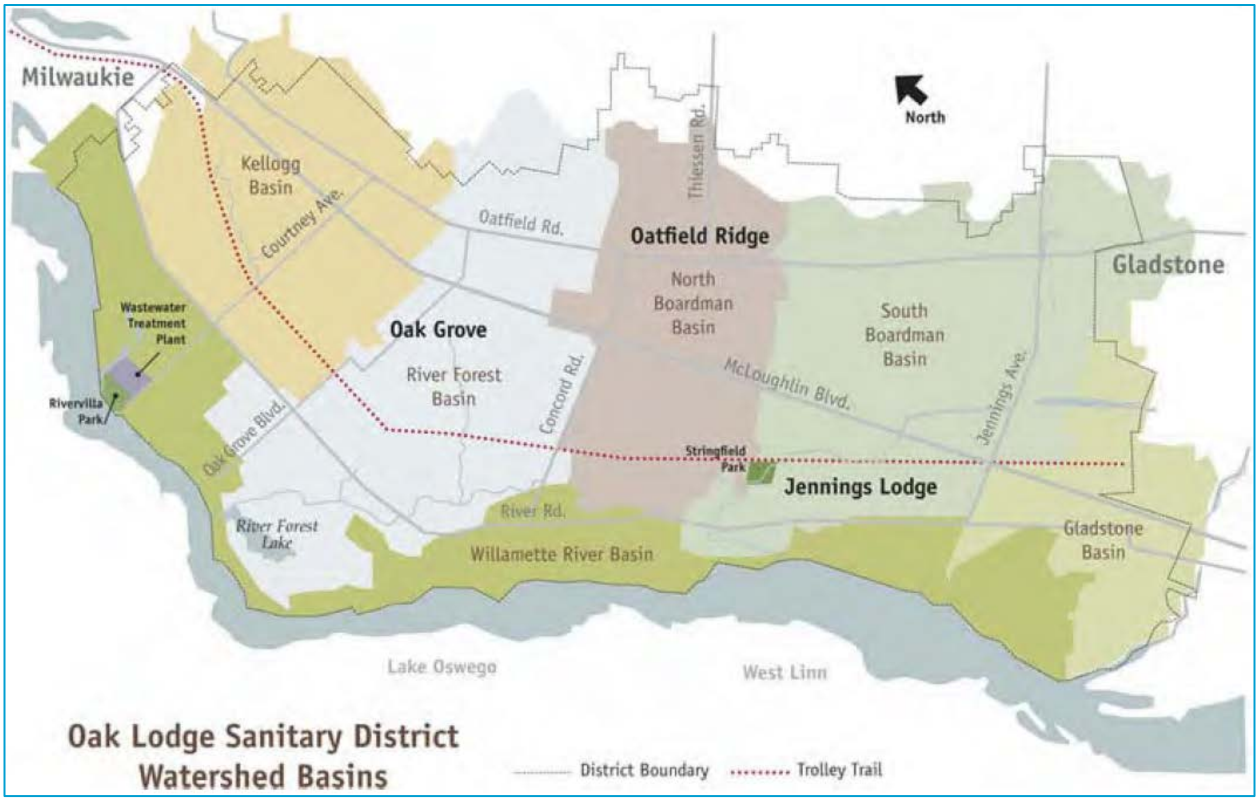

Figure 4-1. Overview of District watersheds

Source: OLSD Surface Water Strategic Plan, 2011

Table 4-1 lists the watersheds in the District and miles of drainage features in each watershed. These data show that the District has very few open-channel streams. Most natural drainage features have previously been channelized or piped to support development. Only nine percent of the District's drainage infrastructure is open stream channel. With this level of existing hydromodification, the first priority should be to focus surface water efforts on maintaining and enhancing the existing natural stream channels rather than trying to restore the piped/ channelized stream channels to their natural condition function. Opportunities to restore connections between natural systems, such as replacing culverts with bridges or reconnecting channels to wetland storage areas, may also have a positive impact on areas with limited natural systems.

Table 4-1. District Watershed Basins and Stormwater Features

Basin	Size (acres)	Pipe infrastructure (miles)	Drainage ditches (miles)	Stream channel (miles)
Kellogg Creek	533	11	1	1
River Forest Creek	796	16	1	2
North Boardman	525	11	1	1
South Boardman	802	10	1	1
Gladstone	321	3	0	1
Willamette River Direct	589	3	1	0

Source: OLSD Surface Water Management Strategic Plan

The District has relatively flat topography, with approximately 400 feet of elevation change between Oatfield Ridge to the east and the Willamette River. The McLoughlin Boulevard Commercial Corridor runs in a north-south direction through the center of the District and includes the area of most intense development and associated modification to the landscape. The Trolley Trail corridor provides a collection point for many drainage channels in the District. The 1997 Surface Water Master Plan identified seven natural groundwater springs that provide year-round flow to streams.

Soils in the District have moderate or poor surface water infiltration characteristics, as evidenced by the number of wetland features throughout the District. A majority of soils in the District are identified as hydrologic soil group C/D, which typically do not support infiltration of runoff. Small areas of the District along the Willamette River are identified as hydrologic soils A/B, which typically have greater infiltrating capability.

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

- Figure A-1. Soils and Topography
- Figure A-2. Zoning and Existing Detention Facilities
- Figure A-3. Hydromodification Data Compilation: River Forest Creek
- Figure A-4. Hydromodification Data Compilation: Boardman Creek

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 in the District and evaluate whether future development is likely to contribute significantly to additional hydromodification in the stream channels.

The District is highly urbanized with little potential for future development. Most commercial and residential development occurred from 1950 to 1990. As such, most development was installed without stormwater management facilities.

In addition to the physical changes to natural systems, such as channelization and piping of the stream channels, urbanization significantly increased the overall impervious surface in the District's watersheds. The 1997 Surface Water Master Plan estimated impervious surface coverage in the District to be between 40 and 75 percent, depending on land use. A more recent evaluation of impervious surface coverage, conducted in 2013, estimated that the impervious surface coverage may be upwards of 80 to 90 percent for some land use categories. As described in Section 2, this increase in impervious surface leads to increased stormwater runoff, particularly for the range of geomorphically significant flows.

During the desktop analysis, Metro-designated vacant lands were reviewed with aerial imagery and classified into three categories, as listed below and shown in Figures A-3 and A-4 in Appendix A:

- designated vacant lands that have already been developed to their maximum density
- designated vacant lands restricted from development because of sensitive-areas designations
- designated vacant lands with future development potential that are likely to increase impervious surface

Most vacant lands with future development potential appear to be single lots or tracts that could be subdivided into additional residential dwelling units or redeveloped to a higher impervious surface coverage.

Small redevelopment projects will not greatly increase in-channel flows because so much of the watershed is already urbanized and covered with impervious surface. Development projects with more than 5,000 square feet of impervious surface are currently required to implement stormwater management controls that restrict peak flows and provide water quality treatment. Reducing this area threshold below 5,000 square feet would result in more infill development and redevelopment projects installing stormwater management facilities. These controls would manage both the new impervious surface and the replaced impervious surface, providing a positive benefit to stream channel flows.

Additional information regarding the District's stormwater management design standards is included in Section 6.

Section 5

Field Assessment

The field assessment was conducted in April 2015, by both BC and District staff. Field observations indicate that past hydromodification impacts previously described seem to have re-stabilized to accommodate the current flow regime.

Because the District had 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, stormwater controls, etc.) may have been the primary contributor to the observed problem. Understanding the potential causes then informs the development of strategies to prevent future impacts (Section 8).

The results of the field assessment showed the following hydromodification indicators in the District:

- heavily modified open-channel areas
- bed incision in areas of bank armoring
- localized areas of bank erosion
- limited riparian areas

These observations indicate that past urbanization has altered the flow regime and reduced channel buffers and floodplain areas. These changes have increased stream energy, which causes bank erosion and bed incision.

However, most observed problems do not seem to be active across the District. Some specific locations are experiencing ongoing bank erosion or bed incision, but the majority of the stream channels look to be stable as they have adjusted over the years to the current flow regime. Ongoing monitoring is needed to keep records of specific problem areas.

The field assessment also shows that the District could address hydromodification impacts by focusing on preserving and improving existing stream channel function. This may include targeted restoration projects in focused areas, property acquisition along stream channels, and vegetation management to enhance riparian corridors.

5.1 Field Methodology

The field assessment was conducted on April 2, 2015, by Alissa Maxwell, P.E. and Angela Wieland, P.E., of BC, with support from District staff (Markus Mead and Rick Pauker).

The field assessment approach was qualitative in nature, and was focused on documenting existing channel conditions to locate hydromodification indicators. Field observations were focused on River Forest Creek and Boardman Creek, as those are the natural stream channels with large drainage areas in the District.

Prior to the field assessment, the District identified known and suspected problem areas where past flooding, citizen complaints or maintenance staff observations have indicated that the stream channel could be impacted by urbanization and/or changes in runoff from the MS4. These areas, shown on Figures A-3 and A-4 in Appendix A, represent key locations for field observations. The District should continue to monitor problem sites through annual inspections.

The majority of open channels in the District are located on private property which limits access. In response, observation locations were limited to public road crossings, parks, public corridors, and properties where owners were willing to allow stream access. 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.

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).

Table 5-1. District Field Observation Locations

Site number	Water body	Location	Description
001 to 004	River Forest Creek	15300/15320 SE Laurie Avenue	• District-identified problem area • Incised channel on private property
005 and 006	River Forest Creek	At Fair Oaks Drive	• Reference reach downstream of sites 001 to 004 • Current monitoring location
008	River Forest Lake	Outlet at River Forest Drive	• District-identified problem area • Perched culvert at lake outlet
009 and 010	River Forest Creek	At River Road	• Reference reach upstream of site 001 to site 008
011	River Forest Creek	Private property at SE Linden Avenue	• District-identified problem area • Headwaters of River Forest Creek • Man-made alterations of stream channel
012 and 013	North Fork Boardman Creek	3320 West View Avenue	• District-identified problem area • Incised channel on private property
014	Boardman Creek	4606 Boardman Avenue, downstream of Boardman wetlands	• District-identified problem area • Development encroachment on stream channel • District-identified capital project (SB-17)
015	Boardman Creek	4607 Boardman Avenue	• District-identified problem area • Incised channel on private property
016	Boardman Creek	At Arista Drive	• District-identified problem area • Beaver dams cause debris accumulation and localized flooding • Macroinvertebrate monitoring location
017	Boardman Creek	Trolley Trail corridor at Arista Drive, parallel to Paradise Creek	• District-identified problem area • Reports of localized flooding • District-identified capital project (SB-01)
018 and 019	Boardman Creek	At Stringfield Park	• Reference reach • Completed stream enhancement CIP (SB-03) • Macroinvertebrate monitoring location
020	Boardman Creek	Upstream of confluence with North Fork Boardman Creek	• District-identified problem area • Reports of localized flooding • District-identified capital project (SB-16)
021 and 022	Boardman Creek	SE River Road and SE Walter Vista	• District-identified capital project (SB-08) • Downstream reach of Boardman Creek

Note: See Section 7 for additional information on District-identified capital projects.

5.2 Stream Channel Characterization

Table 5-2 lists the hydromodification indicators observed in the District. The table includes both general observations and specific problem locations that show the impacts of hydromodification. The table was developed based on field observation, staff and citizen 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. District Hydromodification Indicators

Indicators	Current conditions based on available data		
	River Forest Creek	North Fork Boardman Creek	Boardman Creek (main stem)
Flooding	• Channel has been heavily altered by man-made bank protection on private properties, causing overtopping of banks during peak events. • Control structure at outlet of River Forest Lake collects debris, causing blockages and flooding in peak events.	Some areas of flooding during high flows in the limited open-channel areas.	• Historical flooding upstream of SE McLoughlin Boulevard due to complex series of culverts and development encroachment in historical floodplain. • Beaver dams in channels along SE Arista Drive and Trolley Trail are causing debris accumulation, high water, and flooding of local streets.
Degradation/ bed incision	• Channelized/armored banks on private property have led to bed incision. • Problem location at SE Laurie shows evidence of active channel incision.	Observed incised channel on private property at West View Avenue (with piped conveyance upstream and downstream).	• Channelized/armored banks and lack of floodplain connection upstream of SE McLoughlin Boulevard have led to bed incision. • Channel downstream of McLoughlin is very flat with low stream energy. No observed areas of incision.
Bank erosion/widening	• Channelized/armored sections of channel have continued erosion problems, due to increased stream energy. Problem location at SE Laurie Avenue shows increased bank erosion in recent years. • Channel sections with sufficient setbacks (i.e., Culvert at River Road) have maintained floodplain connection and do not show signs of ongoing erosion.	Observed active erosion on private property at West View Avenue. Bank protections are eroding in open-channel area.	• Erosion around culvert outlets and at channel bends upstream of SE McLoughlin Boulevard. • Channel downstream of McLoughlin is very flat with low stream energy. No observed areas of bank erosion. • Beaver dams in channels along SE Arista Drive and Trolley Trail are causing debris accumulation and channel widening.
Lack of riparian vegetation	• Observed channel areas have good vegetative cover. • Most channel areas are on private property, where District does not have control of vegetation. • Evidence of invasive species.	• Limited open-channel areas in this drainage basin. • Recent plantings on private property at West View Avenue.	• Development encroachment has reduced riparian vegetation in some areas. • Channels along SE Arista Drive and Trolley Trail have good riparian vegetation.

Table 5-2. District Hydromodification Indicators			
Indicators	Current conditions based on available data		
	River Forest Creek	North Fork Boardman Creek	Boardman Creek (main stem)
Aggradation/ sediment loads *(evidence of increasing sediment loads without capacity to transport)*	• Small areas of sediment deposition upstream of culvert at Laurie Avenue. • Sediment deposition and accumulation in River Forest Lake.	None observed or reported.	• Beaver dams in channels along SE Arista Drive and Trolley Trail are causing debris accumulation and sediment collection. • Overbank sediment accumulation and unconsolidated bed material in Stringfield Park.
Other observed problems	• Channel has been heavily altered (straightened, armored) with man-made features on several private properties. • Development encroachment of the channel has removed floodplain and resulted in increased flow velocities.	None observed or reported. Basin is primarily a piped system.	• Development encroachment and limited building setbacks have resulted in a lack of floodplain and significant flooding complaints. • Historical re-routing of the channel upstream of Trolley Trail (specifically along SE McLoughlin Boulevard) has resulted in fluctuating channel grade, causing additional flooding. • Beaver dams in channels along SE Arista Drive and Trolley Trail are causing debris accumulation, high water, and flooding of local streets. • Potential temperature concerns with shallow, slow moving water in channels along SE Arista Drive.
Unique features that may inform hydromodification strategies	• Headwater areas have very little flow, compared to upstream drainage area. Most upstream area has been collected in conveyance system that discharges to creek at Woodland Way. • Limited new and redevelopment potential in watershed due to existing build-out and access limitations (steep slopes, no access roads, etc.)	• Limited open-channel areas in this drainage basin. • Some locations of the piped conveyance system are located on or under existing structures and/or private property. Limited potential to daylight or increase conveyance capacity.	• Boardman-Rinearson Wetland Complex will provide increased flood storage and re-establish channel-wetland-floodplain connection upstream of Boardman Avenue. Project is in planning and land acquisition stages. • Channel downstream of Stringfield Park is in good condition with connected floodplain and riparian vegetation. • Channel downstream of Walta Vista is in good condition with connected floodplain. Condition likely varies as channel moves through private property.

The field observations indicate that the predominant hydromodification sources are channelization and piping of natural stream channels. Remaining open channels show evidence of bank erosion and bed incision, particularly in locations of restricted flow. Restricted flow occurs at road culverts and on private property where the channel banks have been armored to prevent widening. Most open channels are located on private property, which typically results in a reduced floodplain and riparian buffer. Some evidence of invasive plant species was observed, particularly in the areas of reduced riparian buffers.

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 District monitor specific problem areas on an annual basis to document changes in channel conditions. Key locations for future monitoring include:

- River Forest Creek at SE Laurie Avenue (Site Location 001 through 004)
- Outlet of River Forest Lake (Site Location 008)
- North Boardman Creek at West View Avenue (Site Location 012)
- Boardman Creek at Boardman Avenue (Site Location 015)

Monitoring should include photo documentation and channel measurements. Annual monitoring will show whether problem areas are actively changing or if the channel is stabilized in its current condition.

Where project funds are available, enhancement of channelized stream sections could reconnect the floodplain, providing additional stream corridor storage and energy dissipation. These types of projects may require additional easements or property acquisition along stream channel corridors. The District’s vegetation management activities should consider partnerships with private property owners to enhance vegetation in depleted riparian areas including removal of invasive species.

Section 6

Design Standards and Land Use Policy

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

- *Surface Water Management Rules and Regulations for Oak Lodge Sanitary District*, May 2012 (SWMRR)
- Clackamas County's Zoning and Development Ordinance (ZDO)

Review of these documents showed that the District has existing policies focused on stream protection and flow mitigation. Specifically, the District has existing policies to:

- require detention of stormwater runoff to mitigate peak flows from new development or redevelopment to or below pre-development rates
- require stormwater treatment facilities to offset pollutant discharge associated with new development or redevelopment activities
- require stream channel buffers and setbacks to protect existing natural corridors

Minor adjustments to the SWMRR would enhance the existing policies. Based on this evaluation, it is recommended that the District update the SWMRR to lower the area threshold for requiring the installation of stormwater management facilities and update the referenced stormwater facility design manual. The stormwater facility design manual should prioritize infiltration and emphasize the use of LID (i.e., green infrastructure) approaches in stormwater management. These practices provide better mitigation for increased runoff from future development. Emphasizing green infrastructure design approaches would also give the District flexibility in retrofitting existing areas.

Current land use policies include requirements for stream buffers that should provide riparian area protection when the land use restrictions are enforced. However, because much of the District was developed prior to the establishment of buffer zones and existing development does not have the required setback from the stream channels, acquisition of key properties with significant flooding and encroachment into the stream corridor is recommended as a long-term strategy to enhance stream channel function and preserve riparian areas.

6.1 Stormwater Design Standards

The District's stormwater design standards for new development and redevelopment are outlined in the SWMRR, which was last updated in 2012. Current standards require detention to mitigate flow from development projects. However, the standards would benefit from lower management thresholds, clearer guidance on infiltration and green infrastructure facility design, and specific flow control exemptions.

Key aspects of the SWMRR include the following policies and design requirements.

- **Thresholds:** The stormwater design standards require water quality treatment and flow control for projects that add more than 2 new residential lots or include 5,000 square feet or more of impervious surface. It is recommended that the District adjust the threshold down to 1,000 square feet of impervious area, consistent with the NPDES MS4 permit requirements. DEQ set the 1,000-square-foot standard for post-construction controls based on an analysis of regional impervious area thresholds being implemented. The District's current 5,000-square-foot threshold could result in infill projects being exempt from flow mitigation requirements.
- **Infiltration:** SWMRR 6.3.060 encourages infiltration where appropriate. When implemented, infiltration facilities reduce runoff volumes and help to reduce the flashiness of peak flows. The stormwater design standards would benefit by including or referencing design guidelines for infiltration facilities. (See facility design guidelines discussion below.)
- **Peak flow matching:** The flow control requirements in the stormwater design standards require development projects to install detention facilities to reduce post-development flows below pre-development levels. SWMRR 6.3.050 requires most projects to reduce the 2-year post-developed peak flow to half of the 2-year pre-development peak flow rate. In capacity-constrained areas, the detention facility must also reduce the 25-year post-developed peak flow below the 2-year pre-developed peak flow rate. This detention requirement provides significant and retroactive protection for downstream infrastructure (including stream channels). In highly urbanized areas, the best way to achieve this detention requirement may be to reduce the volume of runoff through infiltration systems.

  The District would benefit from defining and identifying the capacity-constrained areas during development of an updated Surface Water Master Plan.
- **Flow duration matching is not required:** As described in the hydromodification background discussion in Section 2, protection from hydromodification is achieved by controlling peak flow rates and the duration of flow from development. The flow control requirements in SWMRR 6.3.050 are aimed at reducing a range of post-development peak flows below pre-development rates, but do not require volume reduction or duration matching. These standards are not considered full mitigation in terms of addressing hydromodification impacts from geomorphically significant flows. However, given the limited potential for new development, little additional benefit is expected by requiring exact flow-duration matching for development and redevelopment projects within the District. Changes to the detention standard are not recommended at this time. However, if the District elects to adopt a reference manual for stormwater facility design manual that is based on flow-duration matching, the resulting facilities would continue to meet the District's hydromodification goals.
- **Facility design guidelines:** SWMRR Section 6.4 currently refers to the *Surface Water Quality Facilities Technical Guidance Handbook*, which is outdated and no longer in use. It is recommended that the District develop or adopt stormwater facility design guidelines that emphasize the use of green infrastructure. Green infrastructure uses dispersed systems of rain gardens, stormwater planters, and swales rather than large regional ponds. 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.

  Regional manuals that include green infrastructure guidelines include the City of Portland Stormwater Management Manual and the Oregon City Stormwater and Grading Design Standards. Wilsonville, Salem, Eugene, and Albany all have green infrastructure stormwater facility design guidelines written into their public works standards that may be good reference sources for the District.

- **Flow control exemptions:** The SWMRR currently requires the same flow control standards in all areas of the District. The District is considering a flow control exemption for areas adjacent to the Willamette River. A flow control exemption is appropriate in areas that drain directly to a large water body where hydromodification is not a concern. Further analysis of a flow control exemption is included in a prior memo developed by BC (BC, 2014), including sample code language for incorporation into the SWMRR.
- **Natural resource protection:** SWMRR Section 5.5.030 requires development to provide an undisturbed buffer adjacent to sensitive areas. Sensitive areas include stream channels, lakes, and wetlands. Table B-1 in the SWMRR defines a buffer width of 25 or 35 feet, which is less than the buffers required by Clackamas County's land use policies (see Section 6.2). It is recommended that the District update the vegetated buffer widths for consistency with Clackamas County. Vegetated buffers are further evaluated in Section 6.2.

6.2 Land Use and Zoning Code

The District's 1997 Surface Water Master Plan identified some key challenges related to land use management within the District. In particular, most stream channels are located on private property. With the exception of small sections of stream corridors through parks, the District currently does not have direct access to a majority of the stream corridors in order to clear debris and make channel improvements. Residents occasionally allow the District to access private property to clear debris, but that work occurs on an as-needed basis instead of a more proactive management frequency and schedule.

As an unincorporated area of Clackamas County, land use requirements in the District are dictated by Clackamas County's ZDO. The District does not have direct control over land use decisions; however, Clackamas County land use policies are applied consistently in the District and other urbanized unincorporated areas. Clackamas County engages the District to review development applications for projects that propose to connect to either the sanitary sewer system or the stormwater system.

Most stream corridors in the District are part of Clackamas County's defined Water Quality Resource Area (WQRA), which has specific land use restrictions defined in ZDO 709. Development projects in the WQRA are required to protect a vegetated setback of 50 feet, measured from top of bank or the top of a steep slope adjacent to a stream or creek corridor. Projects adjacent to the WQRA must install plantings to establish a good-quality stream buffer. ZDO 709 does allow specific project uses within the WQRA, provided that appropriate mitigation is provided.[1]

In undeveloped areas, these land use regulations would create a vegetated corridor to protect stream channels. However, the large majority of land area within the District was developed prior to the establishment of the WQRA- or SWMRR-defined riparian buffers. As a result, many open channels have buildings and/or pavement within the regulated setback.

[1] Note that ZDO 704 "Stream Buffers" does not apply to areas within the Urban Growth Boundary. However, the buffers and setbacks defined in ZDO 709 are nearly identical to those in ZDO 704, so the same protections apply in the District as in most other areas of the county.

The current land use review process allows the District to have influence on proposed development projects, within the constraints of adopted development standards. Because the District has little control over the County's ZDO, the District's best opportunity to influence stormwater management is through adoption of stormwater design standards in the SWMRR. The District can also affect land use change through the acquisition of problem properties that can be used to restore previously impacted riparian areas. As mentioned above, it is recommended that the District update the vegetated buffer widths defined in the SWMRR for consistency with Clackamas County ZDO 709.

Section 7

Review of Planned Projects

The District has previously identified capital improvement projects that are focused on stream enhancement and flood storage in natural systems. These improvements will address hydromodification impacts by restoring a more natural flow regime.

Capital projects related to stream channel enhancement are outlined in three documents:

- *Surface Water Management Program Master Plan,* 1997
- *OLSD Surface Water Strategic Plan*, February 2011
- *2014–2019 Surface Water Program Capital Improvement Plan* (SWCIP), January 2014

The following sections document District capital projects that have the potential to address hydromodification impacts.

Capital project implementation is limited by funding and property availability. By prioritizing projects and identifying property acquisition needs, the District is in a better position to apply for grants and other outside funding to support restoration projects.

7.1 Surface Water Master Plan

The primary source for existing data regarding the District's surface water infrastructure is the *Surface Water Management Program Master Plan* (OLSD, 1997), which was prepared by Montgomery Watson. The District's authority was expanded to include surface water management in 1993. As a result, a master plan was needed to provide a basis for managing stormwater. The Surface Water Master Plan included a comprehensive inventory of stormwater infrastructure and the development of a hydrologic and hydraulic model of the existing system to evaluate both existing and projected future flows. While the Surface Water Master Plan did not include a comprehensive evaluation of in-stream conditions, the modeling provided estimates of in-stream flow rates during various storm events.

The recommendations in the Surface Water Master Plan included more than 70 conveyance improvement projects and two detention projects, one at the Boardman wetland and one at Risley Park. The Boardman wetland project has been incorporated into the District's current Capital Improvement Plan (CIP), as described in Section 7.3 below.

7.2 Strategic Plan

The District's *Surface Water Management Strategic Plan* (February 2011) outlines the overall vision and priorities for the surface water program. The plan provides a solid framework for the District to address hydromodification.

The plan was developed by a Surface Water Community Advisory Committee, with input from District customers and community leaders. The plan affirmed the District's commitment to surface water management. Fixing localized flooding and improving water quality were identified as top priorities. Both of these objectives help to address hydromodification impacts.

The strategic plan highlighted one priority project—the Boardman Creek Basin Initiative—which is a collection of capital projects and other actions. The initiative aims to mitigate hydromodification impacts by replacing culverts and problem structures, improving water quality, attenuating flows, and restoring riparian areas in the Boardman Creek Basin. The initiative requires cooperation from multiple agencies including Clackamas County, Oregon Department of Transportation (ODOT), North Clackamas Parks and Recreation District, Watershed Council, and private property owners.

Recommendations from the strategic plan are focused on program and management initiatives. One management change highlighted in the strategic plan was to dedicate staff to the surface water program. This change was intended to prevent sanitary projects from consuming staff time needed to address stormwater issues. By dedicating staff to the surface water program, the District is better able to focus on implementation of surface water projects, including the capital projects identified in Section 7.3.

The strategic plan also identified the need to update the District's SWMRR. Some goals of the update were to minimize impervious surface, establish stormwater design standards that meet water quality goals, provide clear requirements for public facility design, and address erosion control. Several of these goals were incorporated into the 2012 SWMRR update. Additional updates to the SWMRR are recommended, as described in Sections 6.1 and 6.2.

7.3 Capital Improvement Plan

The District implements a 5-year surface water CIP that includes surface water improvement projects. The most recent plan, the SWCIP (January 2014), prioritizes a number of large-scale projects to address water quality improvement in the District. Most of the identified projects are complex and require multiple years to complete. Table 7-1 lists the capital projects in the current SWCIP along with an initial assessment of the hydromodification benefits.

Capital project implementation is limited by available funding and property availability. The District charges customers a monthly surface water fee, which covers both program operations and capital projects. The SWCIP identifies options for funding additional capital projects, including increasing revenue options and transfers between District funds. Regardless of the funding plan, the following actions are recommended:

- prioritize capital projects that mitigate hydromodification impacts through restoration of existing channels, increasing flood storage, reconnecting wetlands, and/or enhancing riparian buffers
- develop an updated Surface Water Master Plan to include new water quality and stream restoration projects
- identify property acquisition needs (ownership, easements, or other mechanism) and begin securing property to support capital projects

By taking these steps toward capital project implementation, the District will be in a better position to apply for grants and other outside funding to implement restoration projects.

Table 7-1. Surface Water Projects Identified in the 2014–2019 Surface Water CIP						
Watershed	Project number	Project name	Description	Lead agency	Status	Potential hydromodification benefits
Boardman Creek	BB-01	Boardman Basin Watershed Hydraulic Modeling	Develop hydraulic model of Boardman Basin to assess flow and CIP performance under variable design events	OLSD	Future (2016)	Basin modeling could inform upland and in-stream channel projects
	BB-02	McLoughlin Corridor Regional Facility	Install regional facility to treat 99E and Boardman Basin developments	OLSD	Concept (scoping and property acquisition)	Potential to adjust design to provide flow management in addition to water quality treatment
	SB-03	Boardman Watershed Initiative: Phase 1	Restore channel function and riparian zone in Stringfield Park	North Clackamas Parks and Recreation	Completed (2014)	Project addressed erosion, improved in-stream function, and enhanced riparian zone
	SB-01	Boardman Watershed Initiative: Paradise Subdivision Stormwater Retrofit	Retrofit existing stormwater facility to meet flow control and water quality standards	OLSD	Future (2018)	Addresses local flooding and provides flow control and water quality treatment
	SB-08	Boardman Watershed Initiative: Phase 2, Walter Vista and River Road Culvert Replacement	Replace undersized culverts with bridges; rebuild 520' of Boardman Creek for increased capacity and fish passage	Clackamas County	Concept (30% design)	Addresses channel erosion and enhances in-stream function Project is on hold, pending review of channel conditions
	SB-16	Boardman Watershed Initiative: Naef Road Culvert Replacement	Replace undersized 60" culvert with box culvert or bridge; daylight and restore 160' of piped stream channel	OLSD	Design (50% design)	Addresses channel erosion and enhances in-stream function
	SB-17	Boardman Watershed Initiative: Phase 3, Boardman Wetland Complex	Enhance wetland function and storage capacity through upsizing/increased footprint (purchase 4 parcels)	OLSD	Concept (10% design)	Major watershed project will address flooding, increase in-stream and off-channel storage, and provide flow management to address hydromodification in downstream areas
	SB-18	Jennings Avenue Sidewalk: Green Infrastructure Demonstration Project	Install LID with new sidewalk from Oatfield to River Road	Clackamas County	Concept (scoping)	LID facilities will provide flow attenuation and upland management
	SB-19	Boardman Watershed Initiative: Phase 6, Channel Reestablishment, Boardman Avenue to Roethe Road	Remove sediment and invasive species in Boardman Creek from Boardman Avenue to Roethe Road	OLSD	Right-of-way (easement acquisition)	Restores in-stream function and riparian zone
Willamette River direct	WR-16	Bluff Road Repaving and Stormwater Infrastructure	Install stormwater infrastructure with repaving project	Clackamas County	Completed: 2014	Not applicable

Table 7-1. Surface Water Projects Identified in the 2014–2019 Surface Water CIP						
Watershed	Project number	Project name	Description	Lead agency	Status	Potential hydromodification benefits
Linden Creek	CS-01	Courtney Springs Riparian Restoration and Regional Stormwater Facility	Re-establish riparian area on Courtney Springs Creek (behind Elks Lodge) Install regional stormwater facility to treat runoff from 99E	Tri-Met	Completed (2014)	Re-established riparian areas and will help address erosion
	RF-31	Kellogg Avenue Sidewalk/Stormwater Project	Construct new, partial porous pavement sidewalk and bioswale	Clackamas County	Completed (2013)	Porous pavement and bioswales provide increased upland management

Section 8

Strategies and Recommendations

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

- inform the District's prioritization of capital projects
- guide development of updated stormwater design standards
- support development of an updated Surface Water Master Plan
- prioritize locations for future property acquisition

Stream channels in the District show hydromodification impacts from past development. Likely sources of hydromodification include the channelization and piping of natural stream channels, development encroachment into riparian areas, and construction of culverts and other structures. These sources are largely the result of past development activity, and future development activity in the District is expected to be limited to small-scale redevelopment projects. Observed hydromodification impacts include areas of channel incision and bed/bank erosion, areas of stream channel widening, flooding, and stream channel aggradation.

The District's design standards should provide adequate mitigation for potential flow changes from future development. In addition, the District's surface water capital projects are focused on preserving and restoring natural stream channels.

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

8.1 Capital Projects

With little expected change to land use or development patterns, the District's best opportunity to address hydromodification is to construct projects that enhance existing stream channel conditions and/or mitigate peak flows. As outlined in Section 7 and Table 7-1, the District has previously identified the following key capital projects that can help address hydromodification impacts:

- **SB-17: Boardman Watershed Initiative.** Boardman-Rinearson Wetland Complex project to add stream corridor storage and enhance wetland areas.
- **SB-16: Boardman Watershed Initiative.** Naef Road Culvert Replacement project to return a piped corridor to a natural channel.
- **SB-08: Boardman Watershed Initiative.** Walta Vista and River Road Culvert replacement to stabilize existing channels.
- **SB-01: Paradise Stormwater Retrofit** to provide a stormwater system and restore stream flows adjacent to a residential area.
- **BB-02: McLoughlin Corridor Regional Facility** to increase water quality treatment and mitigate peak flows from a commercial area.

8.2 Enhance Design Standards and Land Use Policies

Enhancements to existing stormwater design standards are recommended to prioritize infiltration and LID approaches to stormwater management. This would include updating the SWMRR to reduce management thresholds, provide clearer guidance on infiltration and green infrastructure facility design, and specify flow control exemptions. The following enhancements are recommended:

- Reduce the area threshold that triggers stormwater management from 5,000 square feet of impervious area to 1,000 square feet of impervious area, consistent with NPDES MS4 permit requirements.
- Identify capacity-constrained areas where the District's increased flow control standard applies. These areas may best be identified during an update of the Surface Water Master Plan.
- Develop or adopt a new guidance document for stormwater facility design. The guidance document should include design standards for infiltration facilities and green infrastructure systems such as stormwater planters, rain gardens, and bioinfiltration swales. The current reference document (*Surface Water Quality Facilities Technical Guidance Handbook*) is outdated and no longer in use.
- Set clear flow control exemption standards for areas adjacent to the Willamette River.
- Update vegetated buffer requirements for consistency with Clackamas County ZDO. Continue to work with Clackamas County to enforce vegetated buffer requirements on stream corridors. These setbacks are needed to provide flood storage, reduce stream energy, and restore riparian areas.

8.3 Develop an Updated Surface Water Master Plan

The District's current Surface Water Master Plan was developed in 1997. The projects identified in the Surface Water Master Plan are largely conveyance improvements associated with piped infrastructure. With water quality and flood control as key District priorities, an updated Surface Water Master Plan is recommended that include capital projects that address hydromodification. Potential projects may include elements of stream restoration, flow mitigation, water quality retrofit, and riparian planting. The updated Surface Water Master Plan will provide the basis for long-term project prioritization and budgeting.

The Surface Water Master Plan update should 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.

It is also recommended that the Surface Water Master Plan identify capacity-constrained areas to apply to the flow control standards in SWMRR 6.3.050.

8.4 Monitor Problem Areas

Annual inspections are recommended to monitor known problem areas and proposed capital project locations. 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:

- River Forest Creek at SE Laurie Avenue (Site Location 001 through 004)
- Outlet of River Forest Lake (Site Location 008)
- North Boardman Creek at West View Avenue (Site Location 012)
- Boardman Creek at Boardman Avenue (Site Location 015)

- Locations of planned stream channel capital projects
- Locations of stream channel capital projects constructed in the 5 years prior

8.5 Prioritize Areas for Future Property Acquisition

The District is a largely urbanized area. Most stream channel corridors are located on private property, with the exception of small reaches on park property. This limits the District's ability to manage riparian areas, implement setbacks, and perform maintenance. It is recommended that the District prioritize locations for future property acquisition along stream channel corridors to remove channel encroachments and restore natural system function.

Property acquisition could occur when prioritized properties are subject to sale from willing owners. Proactive negotiations are not recommended at this time, unless stream channel problems begin impacting public infrastructure or public safety.

Section 9

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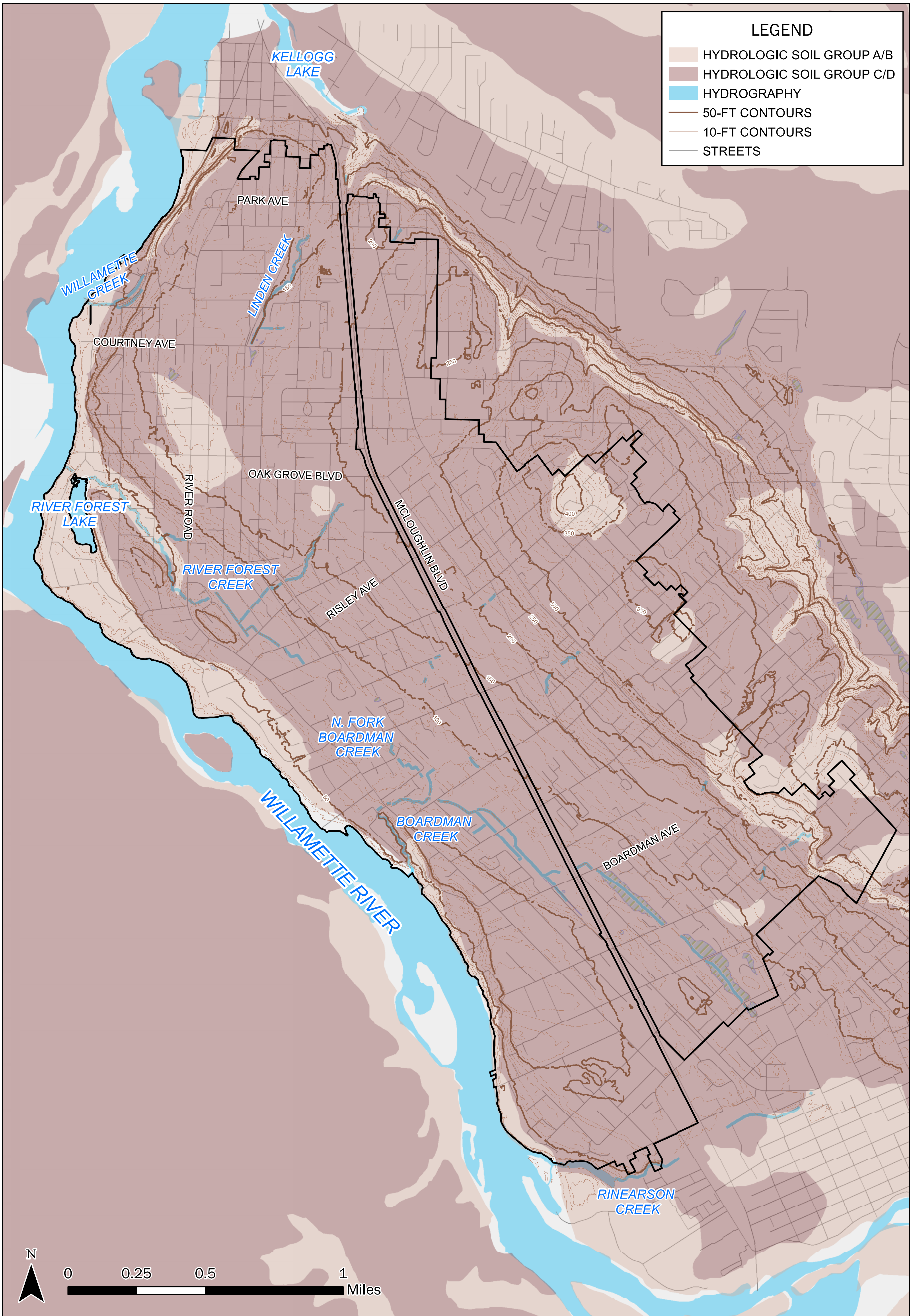
Limitations

This document was prepared solely for the Oak Lodge Sanitary District (District) in accordance with professional standards at the time the services were performed and in accordance with the contract between District and Brown and Caldwell dated March 21, 2014. This document is governed by the specific scope of work authorized by District; 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 District 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

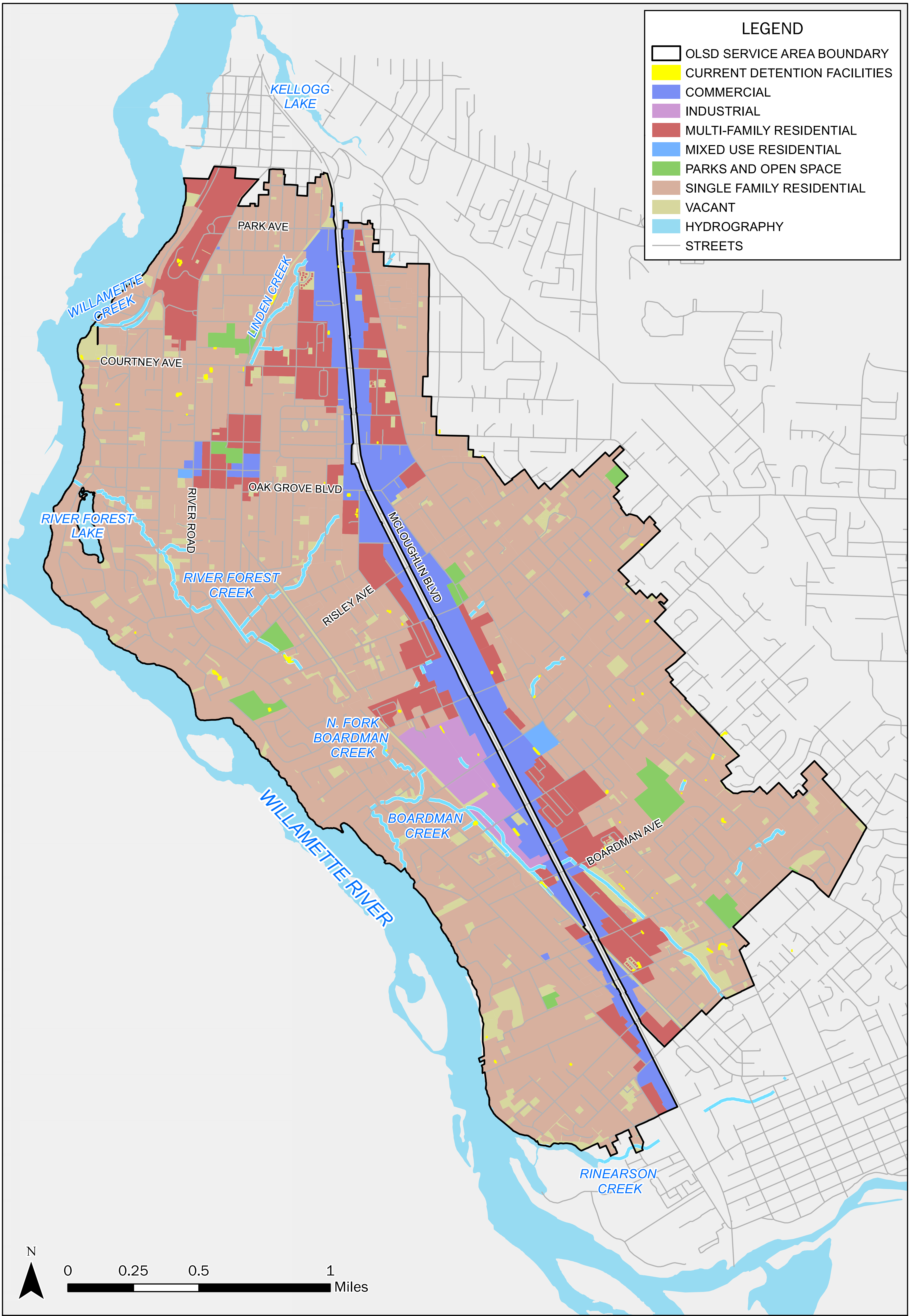


OAK LODGE SANITARY DISTRICT

MS4 HYDROMODIFICATION ASSESSMENT

FIGURE A-1: SOILS AND TOPOGRAPHY

JUNE 2015



OAK LODGE SANITARY DISTRICT

MS4 HYDROMODIFICATION ASSESSMENT

FIGURE A-2: ZONING AND EXISTING DETENTION FACILITIES

Brown AND Caldwell

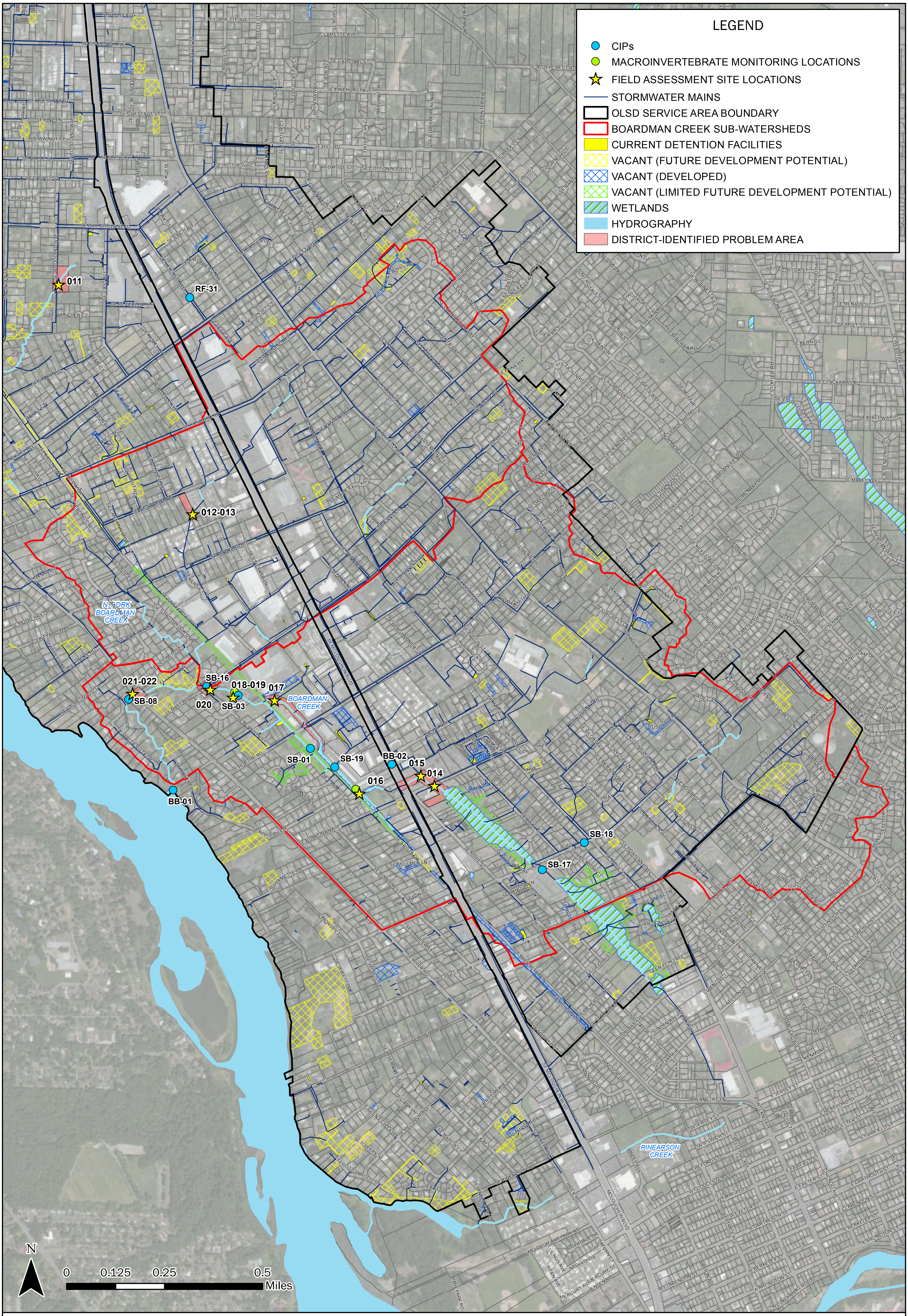
JUNE 2015

OAK LODGE SANITARY DISTRICT

MS4 HYDROMODIFICATION ASSESSMENT

FIGURE A-3: HYDROMODIFICATION DATA COMPILATION - RIVER FOREST CREEK

JUNE 2015



OAK LODGE SANITARY DISTRICT

MS4 HYDROMODIFICATION ASSESSMENT

FIGURE A-4: HYDROMODIFICATION DATA COMPILATION - BOARDMAN CREEK

Brown AND Caldwell

JUNE 2015

Appendix B: Photo Log

Appendix B

Field Assessment Photo Log

Photographs and observations during the field investigation (by site) are provided on the following pages.

Waterbody:	**River Forest Creek**
Reach description:	**At confluence with the River Forest Main channel at SE Laurie Ave (15300 and 15320 SE Laurie Ave). District identified problem area.**
Site locations:	**001 - 004**

Site location: 001
Photo number: SAM_1189
Description: Public ROW - Upstream of culvert under SE Laurie Ave (15300 SE Laurie Ave.)

Site location: 001
Photo number: SAM_1191
Description: Public ROW - Upstream of culvert under SE Laurie Ave (15300 SE Laurie Ave.)

		Site location: Photo number: Description:	001 SAM_1193 Downstream of culvert under SE Laurie Ave
		Site location: Photo number: Description:	001 SAM_1196 Downstream of culvert under SE Laurie Ave

Site location:	002
Photo number:	SAM_1201
Description:	Private Property (15320 SE Laurie Ave). Channel reinforcement on inner bank.

Site location:	002
Photo number:	SAM_1202
Description:	Private Property (15320 SE Laurie Ave). Exposed roots on eroding bank

Site location:	002
Photo number:	SAM_1203
Description:	Private Property (15320 SE Laurie Ave). From homeowners footbridge.

Site location:	004
Photo number:	SAM_1206
Description:	Private Property (15320 SE Laurie Ave). From homeowner's deck.

Site location: 004
Photo number: SAM_1208
Description: Private Property (15320 SE Laurie Ave). Exposed roots on eroding bank

Site location: 002
Photo number: SAM_1209
Description: Private Property (15320 SE Laurie Ave). Area drain showing extent of channel widening (1 foot+ over 1 year)

Waterbody:	River Forest Creek
Reach description:	At Fair Oaks Drive and current MS4 instream monitoring location (downstream of site locations 001-004)
Site locations:	005 - 007

Site location:	005
Photo number:	SAM_1210
Description:	Public ROW – Upstream of bridge at Fair Oaks Ave.

Site location:	006
Photo number:	002
Description:	Public ROW – Downstream of bridge at Fair Oaks Ave.

Site location:	006
Photo number:	006
Description:	River Forest Creek alignment across Fair Oaks Ave.

Waterbody:	River Forest Lake
Reach description:	At discharge channel from River Forest Lake to culvert under River Forest Dr. District identified problem area.
Site locations:	008

Site location: 008

Photo number: 008

Description: Discharge channel from River Forest Lake to culvert under River Forest Dr.

Site location: 008

Photo number: 010

Description: Observed beaver dam activity and private property setback at River Forest Lake.

Site location:	008
Photo number:	012
Description:	Perched culvert from River Forest Lake (under SE River Forest Dr.) to Willamette River

Waterbody:	**River Forest Creek**
Reach description:	**At River Road (stream reference condition).**
Site locations:	**009 - 010**

Site location: 009
Photo number: 014
Description: Upstream of culvert under River Road.

Site location: 009
Photo number: 016
Description: Upstream of culvert under River Road.

Site location: 010

Photo number: 019

Description: Downstream of culvert under River Road.

Waterbody:	**River Forest Creek**
Reach description:	**Headwaters at SE Linden Ave. District identified problem area.**
Site locations:	**011**

Site location: 011
Photo number: 024
Description: Private Property (SE Linden Ave) – Stepped pools along backyard.

Site location: 011
Photo number: 025
Description: Private Property (SE Linden Ave) – Stepped pools along backyard.

Site location: 011

Photo number: 027

Description: Private Property (SE Linden Ave) – Stepped pools along backyard.

Site location: 011

Photo number: 028

Description: Widened channel downstream of SE Linden Ave. Discharge to culvert under SE Linden Avenue.

Waterbody:	North Fork Boardman Creek
Reach description:	At 3320 West View Ave. District identified problem area.
Site locations:	012 - 013

Site location: 012
Photo number: 032
Description: Private Property (3320 West View Ave). Reflects limited daylighted channel in backyard.

Site location: 012
Photo number: 033
Description: Private Property (3320 West View Ave).

Site location: 012

Photo number: 034

Description: Private Property (3320 West View Ave).

Site location: 013

Photo number: 036

Description: Looking downstream to culvert under adjacent manufactured home park.

Site location: 013

Photo number: 037

Description: Private Property (3320 West View Ave).

Waterbody:	Boardman Creek Wetlands
Reach description:	At Eastside Athletic Club (EAC) (4606 Boardman Ave). District identified problem area.
Site locations:	014

Site location: 014
Photo number: 039
Description: Looking upstream from EAC to Boardman Creek Wetlands.

Site location: 014
Photo number: 041
Description: Looking downstream along Boardman Creek to culvert across Boardman Ave.

Site location: 014

Photo number: 042

Description: Beaver dam at outlet from Boardman Creek Wetlands.

Waterbody:	Boardman Creek
Reach description:	At 4607 Boardman Ave. Downstream of culvert across Boardman Ave. District identified problem area.
Site locations:	015

Site location: 015
Photo number: 044
Description: Incised channel and active eroding stream banks

Site location: 015
Photo number: 046
Description: Downstream end of culvert under Boardman Ave.

Site location: 015

Photo number: 047

Description: ODOT keyhole culvert under 99E.

Waterbody:	**Boardman Creek**
Reach description:	**At Arista Dr and macroinvertebrate monitoring location UBOCREEK**
Site locations:	**016**

Site location: 016

Photo number: 049

Waterbody:	**Boardman Creek**
Reach description:	**At Arista Dr. and parallel to Paradise Creek. District identified problem location.**
Site locations:	**017**

Site location: 017
Photo number: 051
Description: Paradise Creek upstream of confluence with Boardman Creek.

Site location: 017
Photo number: 052
Description: Boardman Creek upstream of confluence with Paradise Creek.

Site location: 017

Photo number: 053

Description: Downstream of confluence with Paradise Creek.

Site location: 017

Photo number: 054

Description: Downstream of confluence with Paradise Creek.

Waterbody:	**Boardman Creek**
Reach description:	**At Stringfield Park and macroinvertebrate monitoring location BOCREEK**
Site locations:	**018 - 019**

Site location: 018
Photo number: 056
Description: Recent stream restoration effort at Stringfield Park.

Site location: 019
Photo number: 058
Description: Pools and wetlands adjacent to picnic area at Stringfield Park.

Waterbody:	**Boardman Creek**
Reach description:	**Upstream of confluence with North Fork Boardman Creek. District identified problem location.**
Site locations:	**020**
	 **Site location:** 020 **Photo number:** 060

Waterbody:	**Boardman Creek**
Reach description:	**At SE River Road and SE Water Vista. Future CIP location.**
Site locations:	**021 - 022**

Site location: 021
Photo number: 062
Description: Public ROW – Boardman Creek discharge from culvert under River Rd.

Site location: 022
Photo number: 064
Description: Downstream reach of Boardman Creek prior to confluence with Willamette River.

Appendix C: Stream Channel Observation Form

Channel Stability Observation Form

Water Body:	Riverforest Creek	**Date:**	4/2/15
Site/Location:	15300 SE Laurie 15320 SE Laurie	**Time:**	10 Am
		Crew:	MM, RP, AM, AW
Photos:	site 001, 002, 003, 004	**Weather:**	Overcast
Channel Size:	width: 5-6ft / Depth: 5-8 ft	**Observed problems:**	A. Flooding
Channel Pattern:	Meandering		B. Degradation
	Straight		C. Bank Erosion
	Braided		D. Lack of Vegetation
	Channelized/Altered		E. Sediment Loads

A. Flooding	
Describe observed/known flooding problems:	Flooding during high intensity storms.
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% Armored banks restrict bed movement to only vertical
Exposed Roots	None Mild Moderate Severe few sources
Head cutting or nick points	Describe: N/A
C. Bank Erosion/Widening	
Primary Bank Materials	Bedrock Boulders Gravel/Sand Silt/Clay Armored - rock, planks, and other materials
Bank Protection	None Left Bank Right Bank
Streambank Erosion	Left Bank: None Fluvial Mass Wasting Right Bank: None Fluvial Mass Wasting washing out armoring in places
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% would be 100% w/out armoring
Vegetation Impacts	Exposed Roots Leaning Trees J-shaped Trees None present
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% Landscaped
E. Sediment Loads	
Aggradation	☒ Fresh sediment deposition: channel bar near structure overbank ☐ Unconsolidated bed ☐ Embedded Cobbles near SE Laurie causing channel movement
Turbidity/ Siltation	Describe: deposition upstream of culvert
Other	
Known or observed problems **Unique features** **Field notes**	• Active bank erosion over last 2+ years • Armored banks are sloughing; downcutting is restricted by bed materials, so greater erosive forces on armoring. • Side channel has better floodplain connection.

* 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:	River Forest Creek	**Date:**	4/2/15
Site/Location: 2D	Culvert crossing of River Road	**Time:**	11^{20} Am
		Crew:	MM, RP, AM, AW
Photos:	Site 009 + 010	**Weather:**	overcast
Channel Size:		**Observed problems:**	A. Flooding B. Degradation C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	Meandering Straight Braided Channelized/Altered		

A. Flooding

Describe observed/known flooding problems:	—

B. Degradation/Bed Incision

Primary Bed Material:	Bedrock Boulders Cobbles Gravel Sand Silt Clay unknown
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

C. Bank Erosion/Widening

Primary Bank Materials	Bedrock Boulders Gravel/Sand Silt/Clay unknown - no access
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 in floodplain

D. Lack of Vegetation

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

E. Sediment Loads

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

Other

Known or observed problems **Unique features** **Field notes**	• Stream has good floodplain connection and setbacks to allow overtopping during peak events. Invasive vegetation!

* 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:	Riverforest Creek	**Date:**	4/2/15
Site/Location: 2A	Headwaters at woodland Road	**Time:**	11 30 Am
		Crew:	Mm, RP, Am, AW
Photos:	011	**Weather:**	Sunny
Channel Size:	varies, heavily altered	**Observed problems:**	A. Flooding
Channel Pattern:	Meandering Series of "frog ponds"		B. Degradation
	Straight		C. Bank Erosion
	Braided		D. Lack of Vegetation
	Channelized/Altered		E. Sediment Loads

completely altered channel

A. Flooding	
Describe observed/known flooding problems:	overflow during high flows
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 N/A
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 old concrete banks removed and replaced w/ rock and cobbles
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 N/A
D. Lack of Vegetation	
Established riparian woody-vegetative cover	Left Bank: 0-25% 26-50% 51-75% 76-100% limited
	Right Bank: 0-25% 26-50% 51-75% 76-100%
E. Sediment Loads	
Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☐ Unconsolidated bed ☐ Embedded Cobbles N/A.
Turbidity/ Siltation	Describe:
Other	
Known or observed problems **Unique features** **Field notes**	channel has very limited flow compared to drainage area. Stormwater pipes are carrying runoff around this block & entering Creek downstream.

* 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:	N. fork Boardman creek	**Date:**	4/2/15
Site/Location:	coulter property	**Time:**	12 noon
		Crew:	mm, RP, Am, AW
Photos:	site 012 and 013	**Weather:**	Overcast
Channel Size:		**Observed problems:**	A. Flooding B. Degradation C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	Meandering Straight Braided Channelized/Altered		

A. Flooding	
Describe observed/known flooding problems:	High flow flooding
B. Degradation/Bed Incision	
Primary Bed Material:	Bedrock Boulders Cobbles Gravel Sand Silt Clay
Degree of incision*	0-25% 26-50% 51-75% 76-100% channelized.
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 No trees to erode
D. Lack of Vegetation	
Established riparian woody-vegetative cover	Left Bank: 0-25% 26-50% 51-75% 76-100% New plantings
	Right Bank: 0-25% 26-50% 51-75% 76-100%
E. Sediment Loads	
Aggradation No	☐ Fresh sediment deposition: channel bar near structure overbank ☐ Unconsolidated bed ☐ Embedded Cobbles flow too fast
Turbidity/ Siltation	Describe: N/A
Other	
Known or observed problems **Unique features** **Field notes**	• Small segment of exposed stream channel between piped segments • Recent Plantings to add Shade - well set back from channel.

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

Channel Stability Observation Form

Water Body:	Boardman Creek	**Date:**	4/2/15
Site/Location:	4607 Boardman Ave Site 1B	**Time:**	12 15 Pm
		Crew:	mm, RP, Am, AW
Photos:	015 - Site #	**Weather:**	Sunny
Channel Size:	6-8' wide / 6-8' 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:	Reports of flooding from nearby property owners
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
C. Bank Erosion/Widening	
Primary Bank Materials	Bedrock Boulders Gravel/Sand Silt/Clay
Bank Protection	None Left Bank Right Bank Gabions at culvert outlet
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%
E. Sediment Loads	
Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☒ Unconsolidated bed ☒ Embedded Cobbles accumulated sediment
Turbidity/ Siltation	Describe: turbid water
Other	
Known or observed problems **Unique features** **Field notes**	Constrained channel Narrow/No setbacks No floodplain - parking lots encroach on channel.

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

Channel Stability Observation Form

Water Body:	Boardman Creek	**Date:**	4/12/15
Site/Location:	@ Arista Dr. downstream of Boardman Rd.	**Time:**	12³⁰ PM
		Crew:	MM, RP, AM, AW
Photos:	site #06	**Weather:**	Sunny
Channel Size:	15-20+' wide / 12-18" deep	**Observed problems:**	A. Flooding
Channel Pattern:	Meandering		B. Degradation
	Straight		C. Bank Erosion
	Braided		D. Lack of Vegetation
	Channelized/Altered		E. Sediment Loads

A. Flooding

Describe observed/known flooding problems:	Flat and shallow channel, easily overtops banks.

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

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%
	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
Turbidity/ Siltation	Describe: silty bed - Deposition area

Other

Known or observed problems **Unique features** **Field notes**	- Possible WQ challenges with shallow channel + sediment accumulation. - Temperature issues?

* 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:	Boardman Creek	**Date:**	4/2/15
Site/Location:	@ Paradise ditch Location 1A	**Time:**	1:00 PM
		Crew:	MM, RP, AM, AW
Photos:	site 017	**Weather:**	Sunny
Channel Size:		**Observed problems:**	A. Flooding B. Degradation C. Bank Erosion D. Lack of Vegetation E. Sediment Loads
Channel Pattern:	Meandering Straight Braided Channelized/Altered		

A. Flooding	
Describe observed/known flooding problems:	upstream of Beaver dams. wide, flat channel with shallow/no banks; Easily overtops banks.
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
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 slow rate of erosion, if any.
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%
E. Sediment Loads	
Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☒ Unconsolidated bed ☒ Embedded Cobbles
Turbidity/ Siltation	Describe: Overbank silt accumulation in park
Other	
Known or observed problems **Unique features** **Field notes**	Beaver dams altering water flow paths.

* 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:	Boardman Creek	**Date:**	4/2/15
Site/Location: 3B	upstream of confluence w/ N. fork Boardman	**Time:**	1:30 pm
		Crew:	MM, RP, AM, AW
Photos:	Site #020	**Weather:**	Sunny
Channel Size:		**Observed problems:** good reference reach.	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
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
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% Large trees
	Right Bank: 0-25% 26-50% 51-75% 76-100% and shade
E. Sediment Loads	
Aggradation	☐ Fresh sediment deposition: channel bar near structure overbank ☒ Unconsolidated bed ☐ Embedded Cobbles sediment accumulation in bed.
Turbidity/ Siltation	Describe:
Other	
Known or observed problems **Unique features** **Field notes**	· minor influence of beaver dams · Some invasive vegetation · channel has good floodplain.

* 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