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Title: Low Impact Development in the Ash Creek Watershed, Oregon: Feasibility Study and Implementation Tool Design

Abstract approved:

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William Todd Jarvis

This study presents potential Low Impact Development (LID) solutions for the Ash Creek watershed and designs several tools to assist localities in implementing the solutions they may choose. Ash Creek is a tributary of the Willamette River flowing through Dallas, Monmouth, and Independence in Polk County, Oregon. Currently, Ash Creek exists in a highly altered state due to historical channelization and urban development. As a result, frequent flooding threatens local roads and properties while excess nutrient and sediment levels threaten fish health and classify Ash Creek as "Impaired" by the EPA. LID is proposed as a solution because it can simultaneously address both water quantity and quality concerns, but has not yet been widely utilized in the watershed due to limited regulatory requirements of smaller municipalities. To learn more about the feasibility of LID implementation, this study details the findings from a series of interviews conducted with stormwater management stakeholders and a public focus group with local residents in the Ash Creek watershed. These findings, originally produced through an internship with the Luckiamute Watershed Council, were used to guide the selection of potential LID solutions to explore and LID implementation tools to design. This project is largely a preliminary study, meant to guide more formal investigations and site design in the future of any LID projects supported by the community.

Low Impact Development in the Ash Creek Watershed, Oregon: Feasibility Study and Implementation Tool Design

by
Douglas Chalmers

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APPROVED:

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Douglas Chalmers, Author

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CHAPTER 1- INTROUDCTION

This chapter provides background information on this project, including information on the Ash Creek watershed, motivation behind the project, and outline of this paper.

1.1: Nature of the Problem

As a suburban waterway, Ash Creek can enrich the local community. Ash Creek can protect properties from floodwaters, provide beauty and recreation opportunities, and support habitat for fish, birds, and other wildlife. However, dredging, channelization, and development have deterred many of these potential benefits, leaving the surrounding ecosystem and properties vulnerable. (Teller, 2015). A past Oregon State University study also indicates an issue of groundwater flooding around Polk County (Kemper, 2016).

1.1.1: Overview of the Ash Creek Watershed

Ash Creek is a tributary of the Willamette River with a 36-square mile watershed (LWC, 2013) (Figure 1.1) within Polk County, Oregon, approximately 15 miles southwest of Salem. Ash Creek flows from its source in the Oregon Coast Range through the small cities of Dallas, Monmouth, and Independence to its confluence with the Willamette River in downtown Independence. Land cover in the Ash Creek watershed (Figure 2) is 57% agricultural, 25% forested, and 18% developed (Homer et al., 2015).

Figure 1.1- Location of Ash Creek Watershed (National Geographic et al., 2011) (USDA-NRCS et al., 2016).

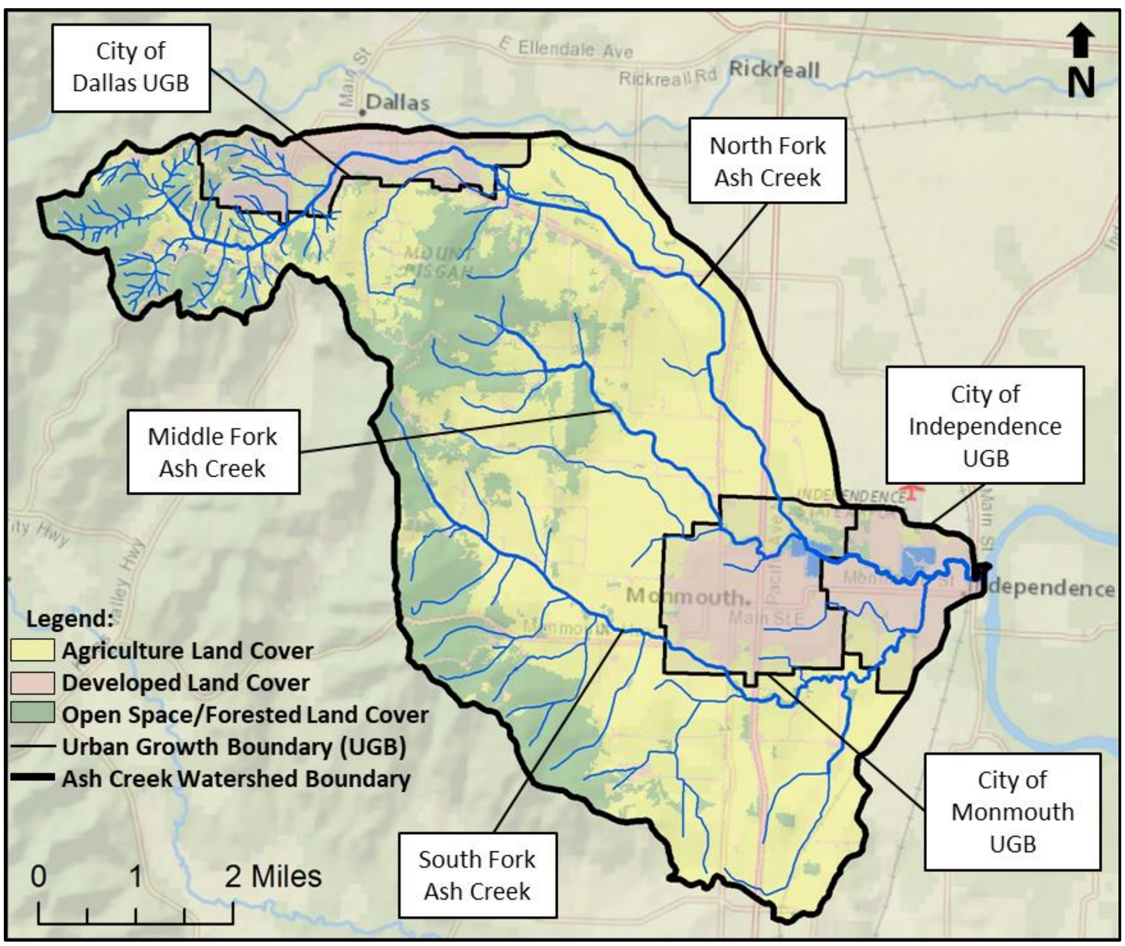


Figure 1.2- Overview of Ash Creek Watershed. Includes land cover and Urban Growth Boundaries (UGB) of municipalities (National Geographic et al., 2011) (Homer et al., 2015) (USDA-NRCS et al., 2016) (Polk County, 2018).

1.1.2: History of the Ash Creek Watershed

Prior to Euro-American development, the Ash Creek watershed resembled a boggy, “braided” marsh (LWC, 2013). Since then, many wetland and riparian areas have been drained and leveled for agriculture, logging, and development. During urban development, portions of the North Fork Ash Creek were culverted and redirected from the original banks. Although no longer performed today, historically the Ash Creek Water Control District (ACWCD) (see section 1.2 for more information on the ACWCD) would bulldoze Ash Creek each summer to clear it of obstructions. As a result of this historical development, Ash Creek is now largely channelized, incised, and disconnected from the floodplain (Figure 1.3) (Garono, et al., 2004). With many of Ash Creek’s natural bends and barriers removed, surges from large storm storms are able to move unimpeded down the creek.

Figure 1.3- Photo of Ash Creek during LWC Restoration Project. Note the straightened channel, lack of vegetation, and incised banks.

1.1.3: Development in the Ash Creek Watershed

Ongoing today is the continued rapid development of the cities of Dallas, Monmouth, and Independence (2010 Census populations of 14,600, 9,500, and 8,600 respectively).

Each city has more than tripled its current population since 1960 (US Census, 2017). Although only 20% of the Ash Creek watershed currently lies within Urban Growth Boundaries (Polk County, 2018), these cities will play an increasingly large role to the health of Ash Creek in the future. As urban hardscape areas increase in the watershed, pollutants are washed into Ash Creek without natural filtration. Runoff from storms will rapidly drain into storm sewers from hardscape roads, parking lots, and roofs, creating flash flood surges and enhancing erosion in Ash Creek.

1.1.4: Ash Creek Flooding and Water Quality Impairment Issues

The Luckiamute Watershed Council suspects that this human alteration contributes to flooding problems along Ash Creek. Past flood events have caused road closures in 2006, 2011, and 2012 (Figure 1.4) as well as periods of city staff overtime to keep roads open (Polk Itemizer-Observer, 2006) (Polk County Itemizer-Observer, 2011) (Mattson, 2012). In addition, many properties lie within the 100-year floodplain of Ash Creek, with the threat of property flooding damages exacerbated by continued urban development. A past Oregon State University study documents groundwater flooding issues in this area (Kemper, 2016).

Figure 1.4- Flooded Ash Creek (Mattson, 2012).

Furthermore, water quality in Ash Creek is currently classified by the EPA as "Impaired" due to excess nutrients and sediment, threatening fish and shellfish health in Ash Creek and the Willamette River (EPA, 2006). This impairment also runs the risk of EPA or Oregon DEQ enforcement.

1.2: Relevant Local Organizations

The Luckiamute Watershed Council (LWC) is a non-profit entity with a mission to engage and assist landowners and communities in the voluntary protection, restoration, and enhancement of the Luckiamute River and Ash Creek watersheds. The LWC, based in Independence, was formed in 2001 and is a member of the Oregon Network of Watershed Councils (LWC, 2016).

The Ash Creek Water Control District (ACWCD) is a special district formed to protect properties and agriculture from flooding damage along Ash Creek. The ACWCD, based in Monmouth, was formed in 1951 and has the authority to conduct activities in and near Ash Creek to accomplish its purpose (ACWCD, 2015).

Within the Ash Creek watershed, there are 3 incorporated cities of Dallas, Monmouth, and Independence along with some unincorporated areas under the jurisdiction of Polk County. The Oregon Department of Environmental Quality (DEQ) is responsible for permitting these municipalities and the county for water quality.

Western Oregon University is located in Monmouth with a campus footprint of 157 acres. The University is a public institution and enrolls over 5,000 undergraduate and graduate students (WOU, 2017).

The Oregon State University Extension Service (OSU Extension) is part of the Division of University Outreach and Engagement. Formed in 1911, OSU Extension has an office in each county of Oregon, with a mission to convey research-based knowledge in a useful way to improve the local communities across the state of Oregon (OSU Extension, 2018).

1.3: Low Impact Development (LID) as a Solution

The LWC and ACWCD are interested in exploring Low Impact Development (LID) as a potential flood mitigation and water quality protection strategy in the Ash Creek watershed.

1.3.1: Defining LID

LID can be defined as any set of systems or practices that mimic natural processes to manage rainfall at the source (EPA, 2017) (Contech, 2012). LID is a broad term encompassing a wide range of development techniques, including land-use practices, landscaping, structural or vegetated best management practices (BMPs) (e.g. rain gardens, bioswales, vegetated roofs, etc.), or local code requirements. The terms green infrastructure (GI), stormwater solutions, or sustainable drainage systems (SuDS) are similar in meaning and are largely interchangeable with LID.

1.3.2: How LID Can Address Ash Creek Problems

LID is proposed as a solution because it has the potential to simultaneously address both the water quality impairment and frequent flooding problems facing Ash Creek. Under conventional development, many hardscape surfaces (including roofs, roads, parking lots, sidewalks, gravel, etc.) directly discharge rainfall into the storm sewer system or waterways via surface runoff (OSU Extension, 2009) (EPA, 2017). Under LID, sites are designed to convey rainfall to pervious surfaces, generating relatively higher volumes of groundwater infiltration versus surface runoff (Figure 1.5) (OSU Extension, 2009).

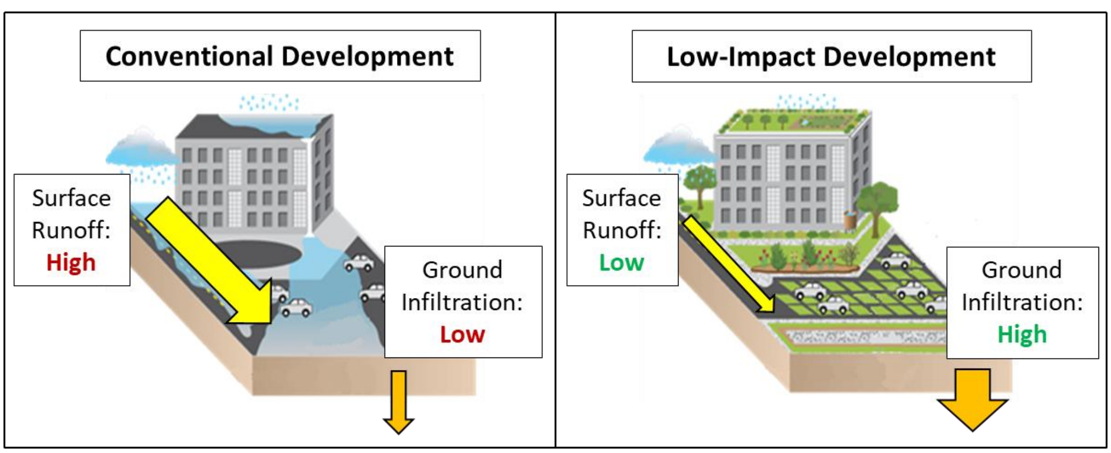


Figure 1.5- Benefits of LID (adapted from Chesapeake, 2013).

When stormwater infiltrates into the ground, the soil media acts as a natural filter, removing waterborne pollutants, sediment, and nutrients. Groundwater is then released into waterways in a more gradual time frame and at a slower discharge velocity compared to surface runoff. This gradual release rate increases base flows into waterways during dry summer months. (EPA, 2012).

As a result of these processes, LID can decrease sharp surges of peak flows in waterways during storm events, in turn reducing flooding and erosion. During dry summer periods, LID can also promote cooler streams for fish habitat and increased availability of water for residential landscaping. Finally, LID can reduce pollutant, sediment, and nutrient loads from developed areas. This improves water quality for fish and shellfish health and works towards removing the "Impaired" EPA designation (OSU Extension, 2009) (EPA, 2012).

Since the small cities of Dallas, Monmouth, and Independence have fewer LID regulatory requirements compared to larger urban areas, there has been limited use of such systems in these communities so far. As a result, the most cost-efficient LID solutions are likely still untapped. As the Luckiamute Watershed Council continues to complete the most cost-efficient riparian revegetation projects, its scope will need to expand into alternative project types encompassed under LID.

1.4: Project Background

1.4.1: Luckiamute Watershed Council (LWC) Internship

The work detailed in this project began as an internship with the LWC from June to October 2017, funded by the ACWCD, City of Independence, and City of Monmouth. As an intern, I first conducted a series of interviews and a local resident focus group, which were used to guide the rest of the internship. In October 2017, I presented my final report, titled "Low Impact Development: Findings & Recommendations for the Ash Creek Watershed") to the ACWCD and LWC and sent the report to all the local entities involved in the interviews. The original proposed deliverables and completed products of the internship report are shown below in Table 1.1.

Table 1.1- Proposed Internship Deliverables. Each proposed deliverable from the original LWC proposal is listed alongside the location of the completed products in this project that address it.

Activity	Objective	Prop. Deliverables	Completed Products
Interviews with Key Stakeholders	**1.** Determine current status, objectives, barriers, and opportunities of Ash Creek LID implementation **2.** Build partnerships between key local organizations **3.** Collect data on site specific problem areas (storm drains, intersections, bridges, etc.)	**1.** Interview Summaries **2.** Proposed priority zones within Ash Creek drainage	**1.** Chapter 2.4 summarizes findings from 13 interviews. **2.** Created Appendix J: Locations of Reported Flooding and Appendix G: Ideas for Potential LID Project Sites
Focus Group with Local Residents	**1.** Learn property owner perspectives on LID **2.** Assess local concerns on Ash Creek flooding and private citizen interest and willingness to voluntarily implement and maintain LID structures **3.** Educate property owners on stormwater BMP's and cost sharing programs **4.** Build rapport between the public and local stormwater organizations	Focus Group Summaries	Chapter 3.3 summarizes findings from focus group held with 9 local homeowners.
LID Case Study Review	Select most effective LID infrastructure types and implementation methods for Ash Creek	**1.** Summary of LID recommendations **2.** LID brochure for homeowners	**1.** Research and recommendations found in Chapter 4: Potential LID Solutions for Ash Creek **2.** Distributed LID guides for homeowners at focus group and reference other brochures in Appendix K: LID Resource Guide
Inventory of LID Implementation Areas	Categorize the following within Ash Creek watershed: **(a)** Undeveloped lands with development potential **(b)** Impervious surfaces built prior to current standards **(c)** Developed properties built under current standards	**1.** Map of Surface Types **2.** Area calculations and summary	ArcGIS used to produce maps of Inventory of Existing LID (Appendix J), Ideas for Potential LID Project Sites (Appendix G), and Locations of Reported Flooding (Appendix K)
Recommendations for Ash Creek LID Program	Select recommended projects and resource allocation for potential Ash Creek LID program	Recommended Projects Summaries: **a.** Public Opinions **b.** Barriers/Opportunities **c.** Cost/benefit analysis **d.** Engineering feasability	**a, b:** Found in Chapters 2.4 and 3.3 **c.** Found in Chapter 4: Potential LID Solutions for Ash Creek **d.** Discussed in Chapter 4 and Appendix G: Ideas for Potential LID Project Sites

1.4.2: Oregon State University Extension Service (OSU Extension) Research

Upon completion of the LWC internship, I continued this project by assisting research with OSU Extension to help create the Green Infrastructure Implementation Forms (discussed in section 5.1). I worked on the team from October 2017 – March 2018, during which time I modified the hydrology calculations, improved the user-interface for the spreadsheet on Microsoft Excel, and developed a user tutorial accompaniment.

The Green Infrastructure Implementation Forms were released at the end of 2017 and are available to the public at: (http://extension.oregonstate.edu/stormwater/gi-implementation-forms-and-tutorial).

1.5: Project Goals and Outline

The goals of this project are to present potential LID solutions for Ash Creek to address the local flooding and water quality impairment issues and to design a set of tools to help enable local stakeholders to implement any of the potential LID solutions they may choose in the future. The solutions and tools are chosen based on the constraints and suggestions from the stakeholder interviews (Chapter 2) and the public focus group (Chapter 3).

The potential LID solutions presented in Chapter 4 are chosen to address the:

(1) Benefits sought from LID (stakeholder interviews)

(2) Barriers to LID implementation (stakeholder interviews)

(3) Desired solutions for Ash Creek (public focus group)

The LID tools presented in Chapter 5 are chosen to address the:

(1) Desired outcomes from internship (stakeholder interviews)

(2) Helpful resources (public focus group)

This project is an initial scoping assessment to investigate, assess, and strategize for LID implementation in the Ash Creek watershed. The results are meant to guide any future formal LID site design project. However, site design, regional management plans, and site-specific quantitative cost-benefits are outside the scope of this preliminary project.

1.6: Chapter Summary

This chapter provides the background information necessary to understand the context and relevance of Low Impact Development (LID) implementation in the Ash Creek watershed. Ash Creek faces flooding and water quality impairment issues, both of which may be exacerbated in the future by continued growth in the cities of Dallas, Monmouth, and Independence. LID is introduced as a solution to manage Ash Creek with future development. This project investigates the feasibility of LID implementation in the Ash Creek watershed and designs a set of tools to help local organizations implement these solutions.

CHAPTER 2- STAKEHOLDER INTERVIEWS

This chapter discusses the series of 13 interviews I conducted with local stormwater stakeholders around the Ash Creek watershed in summer 2017. I explain my motivation behind the interviews, describe the methodology used, and present the results.

2.1: Interview Motivation

Stakeholder interviews were my first task to complete under the LWC internship proposal. Conducting the interviews early in the process allowed the feedback from stakeholders to guide the rest of the internship. I spoke with stakeholders about their level of interest in LID expansion, as well as what types of tools or projects would be most helpful to them. Doing so enabled me to prioritize my effort towards the areas most useful to local stakeholders.

The interviews were also meant to be a fact-finding mission, helping me learn more about the watershed and generate ideas for potential tools, possible LID project locations, and areas of past flooding. Finally, the interviews themselves served as outreach for the watershed council, helping to build awareness of LID and introduce the idea of a collaborative LID program for the Ash Creek watershed.

2.2: Interview Methodology

Stakeholders are defined in this project as individuals active in organizations that fund, conduct, or govern projects related to stormwater management, water quality protection, or flood mitigation in the Ash Creek watershed. The Luckiamute Watershed Council provided an initial list of local stakeholders at the start of the internship. I asked a total of 25 individuals if they were willing to interview with me about LID for Ash Creek. Many individuals provided alternate contacts to speak on their behalf (e.g. a Public Works Director speaking in place of a City Manager) or additional contacts during this process. In total, I interviewed 13 stakeholders representing the following organizations in Table 2.1. The total number of representatives is greater than the number of total interviewees because some individuals represented multiple organizations.

Table 2.1- Organizations Represented by Interviewees.

Ash Creek Water Control District	3	Western Oregon University	2
City of Independence	3	City of Dallas	1
City of Monmouth	2	Oregon DEQ	1*
Polk County	2	OSU Extension	1*

* Interview used for reference only. Responses not included in results

To align this project to the will of the local community, the results in section 2.4 include responses only from the representatives of organizations with interests residing primarily inside the Ash Creek basin. This excluded responses from DEQ and OSU Extension representatives, which were used for reference information only.

Leading up to the interview, I informed the stakeholders that the interviews are completely voluntary and would be related to discussing the "status, barriers, and objectives" of LID in the watershed. At the beginning of each interview, I reminded stakeholders of the topics, that the interview is voluntary, and that they may stop the conversation at any time. I asked the individuals for verbal consent if I could use a voice recorder and explained that I would be transcribing the recordings to generate the results of this project, but that their identity would remain anonymous and no quotations that could be tied to their name would be used. I informed them that at any point they may stop the recorder or request that I leave anything off the transcript.

The interviews were conducted according to a semi-structured general interview guide approach (Patton, 2015). In this approach, I followed the general set of topics contained in the guide, but did not read the guide as a script. Instead, I used the guide as needed to begin the conversation, transition topics during lulls in conversation, and to check that all desired topics were covered before completing the interview. I produced interview guides for each stakeholder, with the general template shown in Table 2.2 (full version found in Appendix A). Each individual guide closely followed this general template but contained tailored details and names, which are withheld to protect the identity of the individuals.

Table 2.2- Interview Guide Questions.

1.	What do you want from this internship? How can I help?
2.	What benefits from LID would you be interested in?
3.	What barriers would prevent you from pursuing LID?
4.	Where are Ash Creek stormwater problems or past flooding issues?
5.	What LID exists already in the watershed?
6.	Where are some possible pilot locations for a LID project? What types of LID would work best? What projects would you not want?
7.	How do you envision a succesful/unsuccesful LID program?
8.	Are there any requirements related to LID in current development standards?
9.	Where would you envision the resources coming from to implement LID?
10.	Who else would be useful to speak with?

Each interview revolved around the same general set of topics listed in the guide, but the order and time spent on each topic varied according to the natural flow of conversation. This semi-structured interview style allowed me to focus on those topics most relevant to each stakeholder and investigate any new topics that came up. Furthermore, this method tends to evoke more natural conversations compared to a survey or scripted interview (Patton, 2015), with the hope that the participants would provide more candid and earnest responses.

While the semi-structured interview style allows for significant freedom and natural conversation flow, it also brings a high degree of reflexivity to the process (Patton, 2015). My own individual biases, personality, identity, interests, and ideas all likely impacted the results of the interviews. I suspect that my role as an intern with LWC and choice to focus on the topic of LID likely influenced the stakeholders to be more supportive of LID in my presence. Additionally, the earlier interviews shaped the latter ones, as I would often bring up ideas suggested by previous interviewees. Thus, the results in section 2.4 are presented simply as feasibility information to guide this project. They should not be considered definitive survey results or official designations of the organizations represented by the stakeholders.

2.3: Interview Transcription and Coding Methodology

I manually transcribed the interview audio recordings into text files of the dialogue. During the transcription process, I developed the following codes (labels to help categorize qualitative data) (Bradley et al., 2007) in Table 2.3 to organize the dialogue.

Table 2.3- Interview Codes.

Code	Information Captured under Code
1. Benefits Sought from LID	Goals of the organization, how LID could help the organization, or reasons why the organization would pursue LID implementation.
2. Barriers Against LID Implementation	How LID could hinder the goals of the organization or why the organization would not choose to pursue LID implementation.
3. Desired Outcomes from Internship	Tasks or products that the representatives wish they had, wish for me to complete during my internship, or that they believe would be helpful.
4. Location of Existing LID	Examples of LID features currently in the Ash Creek watershed.
5. Reported Flooding Locations	Reported areas of past flooding in the Ash Creek watershed.
6. Future Ideas for LID Implementation	Locations or types of LID projects that the representatives would/would not like to see, believe are likely in the future, or that have had past interest.

I employed an integrated coding approach, using both pre-set coding (created ahead of time based on the interview guide questions) and open coding (created after the interview process based on the data collected) (Bradley et al., 2007). I initially created codes corresponding to the questions contained in the interview guide. However, I modified the codes to capture additional responses discovered during the transcription process. I chose the codes in Table 2.3 because they capture the overall dialogue and provide a clear path towards developing useful solutions and tools.

I created subcodes for each distinct idea that fit within these codes from the interview responses. Similar ideas (e.g. preventing pollution and improving water quality) were lumped together within the same subcode. Each interview could only count a maximum of one response for any single given subcode. However, there was no limit on how many different subcodes a single interview may count towards. The responses from codes #1-3 are presented in section 2.4 and those from codes #4-6 are used to construct the LID tools in Chapter 5.

2.4: Interview Results

Figure 2.1 presents the benefits from implementing LID that stakeholders would be interested in. As expected, minimizing flooding damage was one of the top benefits sought (64%). The other top benefit sought was complying with regulations (64%), which in this context referred to the Total Maximum Daily Load (TMDL) permits of the cities and Polk County. Although protecting water quality (45%) was one of the next most common benefits sought, many stakeholders distinctly expressed that they prioritized this benefit as secondary compared to flood mitigation and regulations. Based on this feedback, I frame the potential LID solutions in Chapter 4 based on their ability to work towards both flood mitigation and TMDL compliance. See section 4.1 for further discussion on how these responses guided the potential LID solutions.

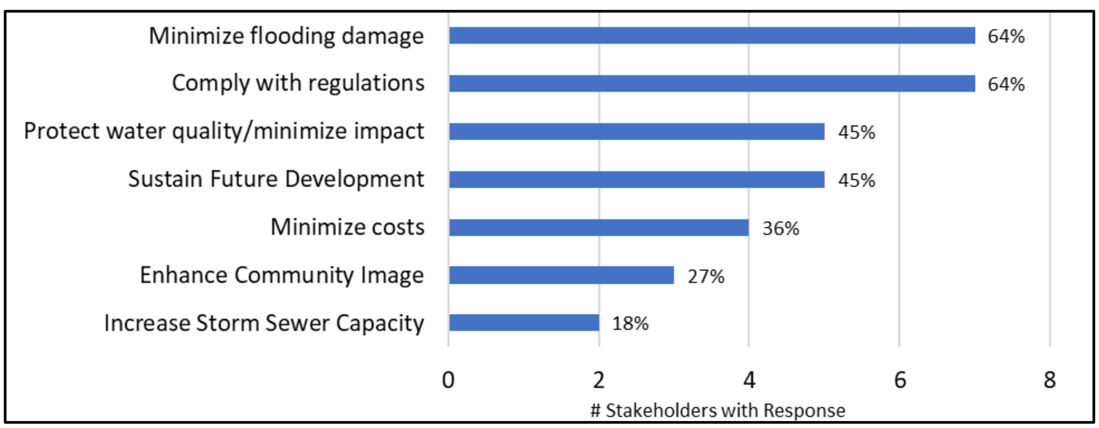


Figure 2.1- Benefits Sought from LID.

Figure 2.2 presents the most common barriers that stakeholders expressed would deter them from implementing LID. As expected, high costs were the most common barrier (82%). Based on this feedback, I frame the potential LID solutions in Chapter 4 according to their cost effectiveness. Another common theme among these barriers is a general distrust that LID would function well or gain public support. See section 4.1

for further discussion on how these responses guided the potential LID solutions. Full responses can be found in Appendix B.

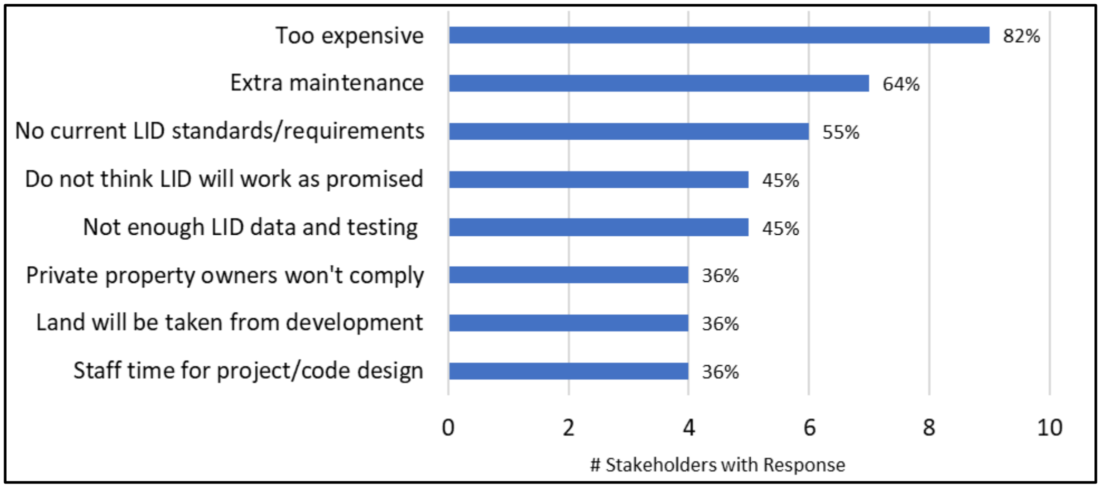


Figure 2.2- Barriers to LID Implementation.

Figure 2.3 presents the most common products or tasks that stakeholders expressed would be useful to them or that they wanted to see from me during this internship.
A common theme among these responses is the desire for more general knowledge regarding LID. I addressed these desires by creating a set of LID Implementation Tools in Chapter 5, including Future LID Project Idea Locations, Inventory of Current LID, and LID Resource Guide. See Chapter 5 for further discussion on how these responses guided the creation of the LID implementation tools. The desire for cost benefit research is addressed by preliminary research of solutions in Chapter 4. Full responses can be found in Appendix B.

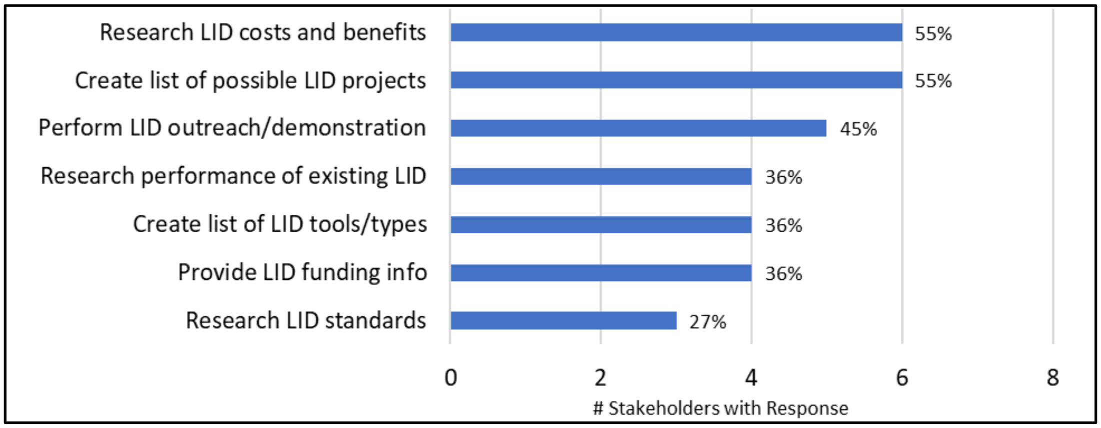


Figure 2.3- Desired Outcomes from Internship.

Table 2.4 lists the most LID implementation project types discussed during the interviews and whether or not the representatives were open to considering them. The ideas listed were all initially suggested by stakeholders. Once suggested by one stakeholder, I would bring the ideas up in later interviews when appropriate to see if more stakeholders support the idea. I explain in section 4.1 how I use this information to determine which solutions to explore in this project.

Table 2.4- Feasibility of LID Project Types.

	Indep.	Monm.	Dallas	Polk Co.	ACWCD
Incorporate LID into TMDL Fulfillment	Y			Y	
Develop LID Standards for New Development	Y	Y	Y	N	
Incentivize Voluntary LID Installation	Y	N	E		Y
Construct Stormwater Parks	Y	E	N		
Construct Large Detention Facilities		Y		N	Y
Plant Street Trees	E	E	E		
Revegetate Riparian Areas	E	E	Y		E
Construct Grassed Roadside Ditches		Y			
Perform Agricultural Controlled Flooding	Y				

Key: Y Open to project type N Not supportive of project type E Project type already exists

Note: Responses do not reflect any official statements or positions held by these organizations.

Note that these interviews are preliminary conversations only used for feasibility purposes; responses in Table 2.4 do not reflect any official positions or statements by these organizations. It is also important to note that time was limited in these preliminary conversations and did not allow for full discussion of all project types in each interview. Further, more guided discussions should take place to gain a clearer perspective of the degree of support for LID project types held by local organizations.

2.5: Chapter Summary

This chapter discusses the stakeholder interviews conducted with representatives from local organizations involved in stormwater in the Ash Creek watershed. These interviews were held as a fact-finding mission to learn more about the perspective of local stakeholders towards LID implementation, with the results used to guide the potential solutions and implementation tools in this project. A semi-structured interview guide approach was used, with the results generated from a mix of open and pre-set qualitative coding methods. Major findings establish the most common benefits sought from LID as minimizing flood damage and complying with regulations. The most common barrier to LID was high costs. Desired outcomes from this project and feasible LID project types are presented as well.

CHAPTER 3- PUBLIC FOCUS GROUP

This chapter discusses the public focus group that I moderated in September 2017, titled "Ash Creek Stormwater Solutions Forum" at the Monmouth Public Library with nine local residents. I explain my motivation behind the focus group, describe the methodology used, and present the results.

3.1: Focus Group Motivation

Similar to the stakeholder interviews, the focus group was held primarily to guide the rest of this project. The focus group was meant to gather information regarding the perspectives and interest levels of local residents towards LID. Additionally, the focus group itself was a form of outreach for the LWC, meant to build awareness of LID and inspiration for voluntary LID implementation.

3.2: Focus Group Methodology

A focus group can be defined as an informal group discussion engaging a small number of people to collect qualitative data on a particular topic (Wilkinson, 2004). Focus groups are useful because they allow for data collection from multiple individuals at once and are less threatening to participants than one-on-one interactions (Krueger & Casey, 2000). For these reasons, I chose to conduct a focus group rather than interviews with residents.

To recruit participants, the LWC posted flyers in downtown Independence and Monmouth storefronts and also ran printed advertisements in the local Polk County Itemizer-Observer newspaper and in the local utility bills. The focus group was advertised as the "Ash Creek Stormwater Solutions Forum", inviting participants to come to discuss concerns about Ash Creek, runoff, and stormwater and offered a free meal from a local bakery. The focus group was held in meeting room of the Monmouth Public Library. I chose not to directly invite attendees through the Friends of the LWC contact list to attempt to recruit a more neutral audience that may be unfamiliar with the LWC or critical of LID. Regardless, eight of the nine attendees consisted of individuals who have attended past LWC events. The participants were all homeowners from Monmouth and Independence with various backgrounds. Participants included riparian land owners, Ash Creek Water Control District board members, Luckiamute Watershed Council board members, and city council members. Most were generally familiar with stormwater issues, but were not professionals in the field. To maintain intimacy and the ability to cover the desired topics within the time allotted, I limited the registration to ten participants based on studies of focus group design (Onwuegbuzie et al., 2009). Nine of the ten registrants attended.

At the beginning of the focus group, I described to the participants that the purpose of the meeting was to learn more about the perspectives of local residents regarding stormwater management in Ash Creek and voluntary LID solutions. I asked for verbal consent from all participants for the LWC staff to record notes, explaining that a summary of results would be communicated to the cities and that no quotations that could be tied to their name would be used. I informed everyone that they may leave at any time, and may request I leave anything off the transcript. After distributing reference materials of a map and flyer of various backyard LID structures, we established some ground rules of conduct (speak one at a time, be respectful, etc.) together as a group.

As an icebreaker, I asked the audience to go one at a time in order and say briefly what motivated them to attend. The remainder of the focus group was mixed between discussing questions included in the guide (Appendix C) and questions brought up by participants. While not every question brought up by the participants was addressed during the focus group, I wrote all the questions as they came up on the whiteboard.

Following a note-based analysis process (Onwuegbuzie et al., 2009), I produced a summary of the focus group responses in Appendix D. Using the written notes of the dialogue taken by the LWC staff member, I categorized each idea recorded into one of the codes included in Appendix D. The codes correspond to the questions that I asked the participants. After the focus group, I distributed this summary, including answers to all the questions written down, to each participant.

3.3: Focus Group Results

The responses of each participant to the icebreaker question of "What is the main reason that motivated you to come to this forum?" are recorded below in Figure 3.1. One of the participants declined to answer, so there are only eight total responses. Unlike the interview results, flooding concerns were minor (13%) while water quality and ecological health concerns were most prevalent (50%). However, these responses should not be considered typical for residents in the watershed, as almost all the participants have been involved with LWC in the past and are generally passionate about environmental and watershed protection.

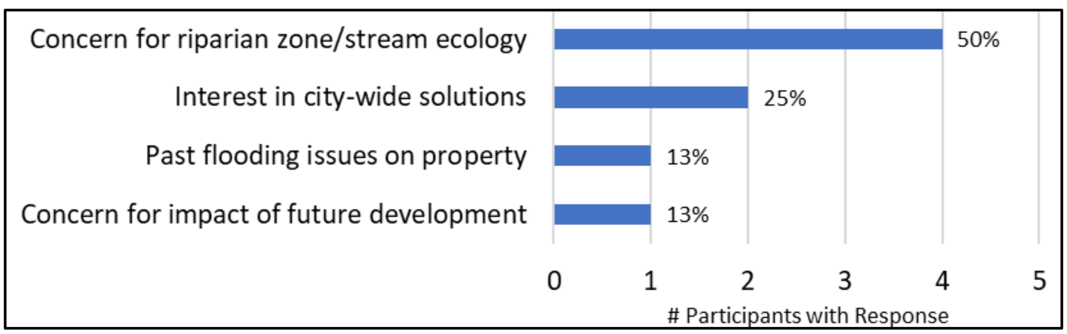


Figure 3.1- Reasons for Attending Public Focus Group.

During the focus group, I observed a philosophical conflict between watershed management methods. The prevailing philosophy (response 1 in Table 3.1) among the focus group participants advocates for a return to natural wooded habitat along the creek to slow down runoff and provide fish habitat. The other philosophy, held by a minority of participants, advocates for keeping Ash Creek clear of tree limbs and debris to keep water free-flowing (2). Multiple stakeholders mentioned in the interviews that this divide is prevalent throughout the stormwater field in general. While this conflict was not addressed in this project, tailored cost benefit research would help determine when and where each method would be appropriate for Ash Creek.

Table 3.1- Sample of Focus Group Responses. Full responses found in Appendix D.

Other Concerns for Ash Creek
1. Lack of riparian areas and floodplains are contributing to flooding
2. Polk County won't let homeowners clean out and remove tree limbs from Ash Creek
Desired Solutions
3. Stormwater solutions is too big a problem for the role of individual homeowners to help
4. Each citizen with roof should be encouraging infiltration on property to help this problem
Helpful Resources
5. Template that can be taken to a city council to convince them to adopt policy
6. Comprehensive guide for stormwater solution information

When bringing up solutions for Ash Creek, it was my intent to discuss voluntary homeowner LID implementation. I was surprised that six of the seven recorded responses instead revolved around calls for public city involvement (3) rather than homeowners taking action in their own backyards (4). While the participants were still interested in installing their own LID such as residential rain gardens or downspout disconnection, the overall consensus was that substantial benefits from LID will only come from a public policy level, rather than from individual homeowners. Based on this input, I focused more on developing public solutions rather than voluntary homeowner ones.

This theme of widespread public solutions also appeared when I asked participants about what resources could empower homeowners to help Ash Creek. Most of the responses involved documents that cities could use to adopt new public policy (5), which helped motivate the creation of section 5.6- LID Standards Creation Guide. Similar to the stakeholders, the participants also called for more general information on LID (6), which I addressed in section 5.7- LID Resource Guide.

3.4: Chapter Summary

This chapter discusses the public focus group conducted with local residents around Monmouth and Independence. This focus group was held both as a fact-finding mission to learn more about the perspective of local homeowners towards LID implementation, and as a form of outreach for the LWC. The participants primarily consisted of individuals who have participated in past LWC events. Summary notes were taken during the focus group and qualitative coding was applied to generate results. Major findings indicate an overall desire of participants for widespread, public LID solutions as opposed to voluntary, homeowner solutions for Ash Creek.

CHAPTER 4- POTENTIAL LID SOLUTIONS FOR ASH CREEK

This chaper incorporates the feedback from the stakeholder interviews and public focus group to introduce potential LID solutions to address the flood mitigation, regulatory compliance, and water quality impairment issues present in the Ash Creek watershed.

The potential solutions chosen to explore in greater detail are Incorporating LID into TMDL Requirements (section 4.2), Creating Regional LID Standards (4.3), Incentivizing Voluntary LID Installation (4.4), Building Stormwater Parks (4.5), and Building Constructed Wetlands (4.6). Other potential LID solutions that emerged during the interviews are briefly presented in section 4.7. I describe the methodology behind choosing these potential solutions and provide preliminary guidance towards the implementation of each. Note that these solutions have not been formally endorsed by any of the organizations represented in the interviews and that site design, regional management plans, and site-specific quantitative cost-benefits are all outside the scope of this preliminary project.

4.1: Methodology of Generating Potential Solutions

As stated in section 1.5, one of the goals of this project is to determine a set of potential LID solutions that adhere to the local suggestions and constraints from the stakeholder interviews and focus group. The potential solutions all come from ideas from stakeholders during the interviews. However, given that a large number of initial projects were suggested, I needed to narrow down which potential solutions to explore in greater detail. I chose to explore in greater detail only those solutions that were supported by multiple organizations, but have not been implemented yet on a widespread scale in the Ash Creek watershed. By doing so, I hope to provide the local organizations with information catered towards those solutions they are most interested in, but currently lack information about or preparation for. The project selection process is documented in Table 4.1. The chosen projects were able to address the desired solutions from the focus group as well. It is also important to note that time was limited in these preliminary conversations and did not allow for full discussion of all project types. Further, more guided discussions should take place to gain a clearer perspective of the degree of support for LID project types from these local organizations.

Table 4.1- Selecting Potential LID Solutions to Explore in Greater Detail. Only those solutions which are supported by representatives from multiple organizations but are not yet widely implemented are explored in greater detail in this section. Other solutions are presented briefly in section 4.7.

Solutions Explored in Greater Detail	Indep.	Monm.	Dallas	Polk Co.	ACWCD
Incorporate LID into TMDL Fulfillment	Y			Y	
Develop LID Standards for New Development	Y	Y	Y	N	
Incentivize Voluntary LID Installation	Y	N	E		Y
Construct Stormwater Parks	Y	E	N		
Construct Large Detention Facilities		Y		N	Y
Solutions Already Widely Implemented	Indep.	Monm.	Dallas	Polk Co.	ACWCD
Plant Street Trees	E	E	E		
Revegetate Riparian Areas	E	E	Y		E
Solutions Only Supported by 1 Organization	Indep.	Monm.	Dallas	Polk Co.	ACWCD
Construct Grassed Roadside Ditches		Y			
Perform Agricultural Controlled Flooding	Y				

Key: Y Open to project type N Not supportive of project type E Project type already exists

Note: Responses do not reflect any official statements or positions held by these organizations.

These chosen solutions in Table 4.1 are broad and it is outside the scope of this project to provide exhaustive information for each. So, I tailored my research based on the constraints poised by the interviews and focus group. Based on the overall local consensus, I framed my investigation to explore how these chosen LID solutions can benefit both TMDL permit compliance and flood mitigation in a cost-effective manner beyond the scale of individual homeowners. This interpretation is supported by the interview data. Minimizing flooding damage (64%) and complying with regulations (64%) were the most common benefits from LID and prohibitive costs (82%) were the most common barrier against LID implementation. This interpretation is also consistent with the focus group discussions, which called for implementing solutions on a city-wide rather than individual homeowner scale.

The interview and focus group feedback that is addressed by these solutions is shown in Table 4.2. The solutions are primarily meant to connect to the benefits sought from LID, barriers to LID implementation, and focus group desired solutions. Each response that is addressed by the solutions is highlighted in green in Table 4.2. The items that are not addressed are all related to lack of time and data and are more closely addressed by the LID implementation tools in Chapter 5.

Table 4.2- Connections between LID Solutions and Feedback from Interviews and Focus Group. Connections are shown between the five LID solutions discussed in this chapter and the responses from the interviews and focus group.

Benefits Sought from LID

Response Frequency	*Response Group*	*TMDL Permits*	*LID Standards*	*Voluntary Incentives*	*Stormwater Parks*	*Retention Facilities*
64%	Comply with Regulations	■	■	■	■	■
64%	Minimize Flooding damage	■	■	■	■	■
45%	Protect Water Quality/Minimize Impact	■	■	■	■	■
45%	Sustain Future Development		■		■	■
36%	Minimize Costs	■	■			
27%	Enhance Community Image	■		■	■	
18%	Increase Storm Sewer Capacity					

Barriers to LID Implementation

Response Frequency	*Response Group*	*TMDL Permits*	*LID Standards*	*Voluntary Incentives*	*Stormwater Parks*	*Retention Facilities*
82%	Too Expensive	■	■	■	■	■
64%	Extra Maintenance		■	■		
55%	No Current LID Standards/Requirements	■	■	■	■	■
45%	Do Not Think LID Will Work as Promised					
45%	Not Enough LID Data and Testing					
36%	Private Property Owners Won't Comply	■	■		■	■
36%	Land Will be Taken from Development			■	■	
36%	Staff Time for Project/Code Design					

Public Focus Group: Desired Solutions

Response Group	*TMDL Permits*	*LID Standards*	*Voluntary Incentives*	*Stormwater Parks*	*Retention Facilities*
Each homeowner should encourage infiltration on own property			■		
Encourage city to pass laws for new development		■			
Stormwater is too large a problem for individual homeowners	■	■	■	■	■
Require LID for future roads/sidewalks		■			
Find areas for large city projects				■	■
Convert public properties for stormwater function				■	
Convince cities that LID can save time and money in future					

4.2: Incorporating LID into Total Maximum Daily Load (TMDL) Requirements

Information in this section has been graciously provided by DEQ staff in Salem.

Representatives from Independence and Polk County were both open to using elements of LID to fulfill their TMDL requirements. Cities in Oregon with a population greater than 10,000 that are not covered under a Municipal Separate Storm Sewer System (MS4) permit must address each of the six Minimum Control Measures (Table 4.3) in their required TMDL Implementation Plan (DEQ, 2018).

Table 4.3- Minimum Control Measures (DEQ, 1999).

1.	***	Public Outreach & Education
2.	***	Public Participation & Involvement
3.		Illicit Discharge Detection & Elimination
4.		Construction Site Runoff Conrol
5.	***	Post-Construction Runoff Control
6.		Pollution Prevention & Good Housekeeping

*** Indicates that LID may be used to directly address this measure

The City of Dallas (2010 Census population 14,600) is already required to meet these Minimum Control Measures, while Monmouth (pop. 9,500) and Independence (pop. 8,600) (US Census, 2016) are on the cusp of having to meet them in the near future. As cities with a population less than 10,000 not covered under an MS4 permit, Monmouth and Independence must strongly consider addressing the Minimum Control Measures in their required TMDL Implementation Plan as a means to control stormwater and minimize soil erosion to reduce runoff of mercury and bacteria (DEQ, 2018).

These Minimum Control Measures for stormwater originate from the MS4 Phase II permit (DEQ, 2018). However, the current MS4 Phase II permit expired in 2012 and is currently under revision by DEQ. Any future changes to this permit may impact the requirements of these Measures. As of October 2017, DEQ Nonpoint Source Program staff and stakeholders are currently evaluating incorporating details on LID within the new MS4 Phase II permit. Specifically, the Post-Construction Runoff Control requirements (Measure #5) will be more clearly defined to include language regarding utilization of LID implementation as a component of post-construction in the forthcoming 2018 5th year review for TMDL Implementation Plans. Extent of city growth since 2008 is also a factor for determining post-construction requirements during the 5th year review. Dallas, Monmouth, and Independence will each be required to submit this 5th year review report in 2018 (DEQ, 2018).

The ability to use LID to comply with regulations was one of the top benefits sought by stakeholders. I recommend that Dallas, Monmouth, and Independence prepare for the possibility of LID implementation being included as a component of their upcoming TMDL permits. Doing so will enable the cities to allocate staff time, budget, and land to mobilize potential LID projects as needed in the future. Further guidance can be found in the EPA release, titled "Incorporating Green Infrastrcuture Concepts into TMDLs" (EPA, 2009a).

It is important to note that LID is a broad term and there are many different project types that all could be used to fulfill the TMDL Minimum Control Measures. Even if DEQ becomes explicit in a requirement for LID implementation in the future, cities will likely possess significant discretion in terms of the types and location of LID used. The other LID solutions presented in this chapter can all count towards TMDL fulfillment. Furthermore, even if cities are able to fulfill their TMDL permits with other types of projects, LID may still be the most cost efficient option because of its associated flood mitigation potential compared to projects focusing on water quality alone.

4.3: Creating Regional LID Standards

Representatives from Dallas, Monmouth, and Independence all appear open to creating LID standards. Given that multiple stakeholders desired for all three cities to follow the same standards, there is an opportunity to create regional LID Standards within the Ash

Creek watershed. LID standards represent a cost-efficent method to achieve water quality and quantity benefits from LID and help fulfill TMDL requirements.

4.3.1: Background on LID Standards

LID standards may consist of a variety of municipal code requirements for new or re-development projects with the end goal of managing stormwater on-site rather than allowing runoff to flow untreated into local waters. Common types of requirements relate to water quality treatment, infiltration, pervious surfaces or open space. Parcels built to LID standards often include clustered housing, infiltration facilities, open space, and less paving compared to conventional standards (see Figure 4.1).

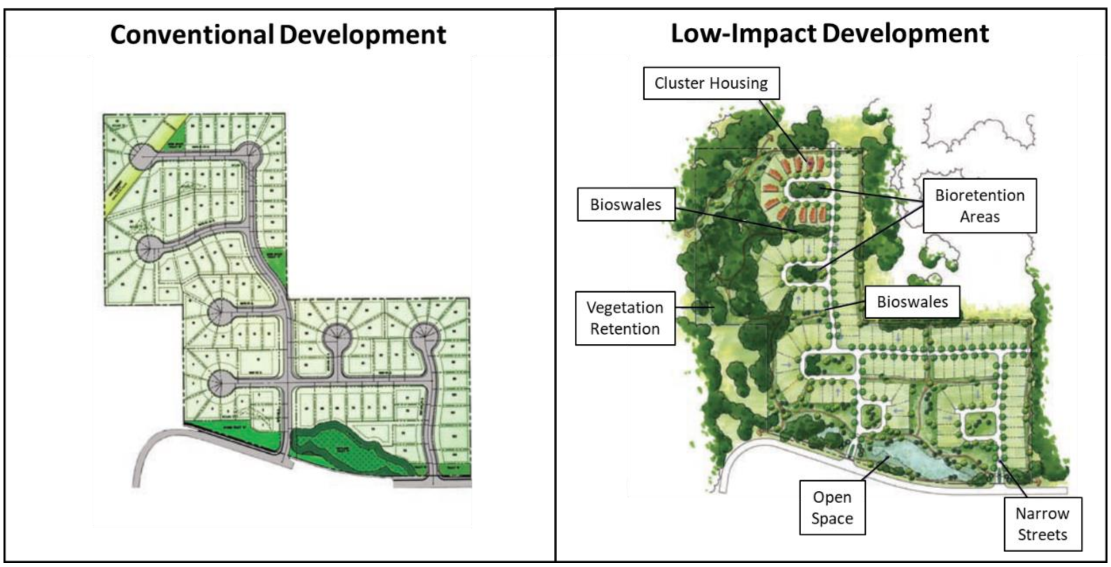


Figure 4.1- Example Illustration of Conventional Development versus LID (adapted from Carlson et al., 2012).

In Oregon, examples of cities with formal requirements for LID standards include Stayton, Florence, Gresham, Salem, Eugene, and Portland. Many of these standards share common requirements, summarized in Table 4.4, which may be adapted to create regional standards for Ash Creek. To overcome the barrier of excessive maintenance, the standards may call for the developers to perform BMP maintenance themselves, only requiring city staff to perform an annual inspection.

Table 4.4- Common LID Standards in Oregon. These standards reflect the LID requirements found in the stormwater code manuals for the cities of Eugene, Florence, Gresham, Portland, Salem, and Stayton.

Detention Requirements:	Post-developed must not exceed pre-developed flow from half of 2-year storm depth up to either 10 or 25-year storm
Counting LID towards Detention Requirements:	Common to allow reduced detention sizing requirements (perhaps by reducing site CN) with inclusion of certain BMP's
Water Quality Requirements for Volume-Based BMP's:	Must be capable of treating design storm (set at 80% of annual rainfall from 0.83-1.4 inch 24-hour storm)
Water Quality Requirements for Flow-Based BMP's:	On-line facilities (water must flow through): 0.2-0.22 in/hr Off-line facilities (water can bypass): 0.11-0.13 in/hr
If Infiltration is not Appropriate (< ~0.1 in/hr)	Common to allow soil amendments, use of filtration facilities (instead of infiltration), or use of off-site treatment

Conversations in October 2017 with staff from the small cities of Stayton (pop. 7,700) and Florence (pop. 8,500) reveal that these municipalities voluntarily adopted LID Standards with the primary goal to minimize flood problems with future development. Both cities adopted the requirements from the City of Portland Stormwater Management Manual, with minor changes to adjust for local conditions. Staff from the City of Stayton claim that their experience with their LID standards has been distinctly positive so far. Developers have been receptive, maintenance has not been overly burdensome, and runoff from new development appears to be contained.

4.3.2: Cost-Benefit Data on LID Standards

While preliminary cost-benefit information is included here as a reference, many studies warn against interpreting their results in other locations, as local differences in hydrology, site characteristics, construction labor costs, and existing infrastructure can significantly alter the cost-benefits (EPA, 2015b) (Atkins, 2015).

The most comprehensive publication directly comparing costs of LID to conventional development projects comes from the 2007 EPA study titled, "Reducing Stormwater

Costs through Low Impact Development (LID) Strategies and Practices" (EPA, 2007). This study found that 16 of 17 pilot LID project designs had lower costs compared to conventional designs for the same site, with a median cost savings of 31% (see Figure 4.2). The LID components varied in each project, but generally included land-use, landscaping, paving, and infiltration practices. Much of the savings resulted from reduced site paving and reduced site disturbance, with more forests and wetlands kept intact (EPA, 2007).

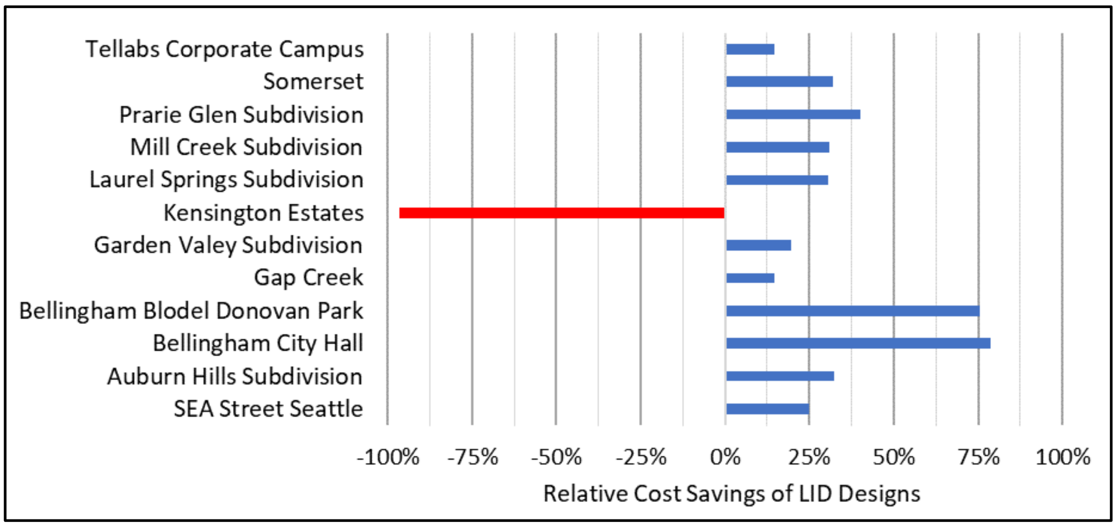


Figure 4.2- Design Cost Comparisons of Conventional Development versus LID (EPA, 2007).

The positive cost-benefits of LID Standards are supported by a 2013 study from the University of New Hampshire Stormwater Center, which directly compared the performance of conventional stormwater BMPs versus those encouraged by LID standards (Houle et al., 2013). The study found that LID BMPs generally offer more cost-effective pollution removal with a significantly smaller area footprint (Figures 4.3 and 4.4) than conventional stormwater ponds designed to treat identical flow volume (Houle et al., 2013). However, it is important to note that the rates of nitrogen, phosphorus, and total suspended solids (TSS) removal varied significantly in each BMP. Furthermore, the results may vary significantly according to local climate, construction labor costs, and BMP specifications. While these results support a likely overall cost and area efficiency for LID over conventional BMPs, they should not be used to estimate specific cost savings in the Ash Creek watershed.

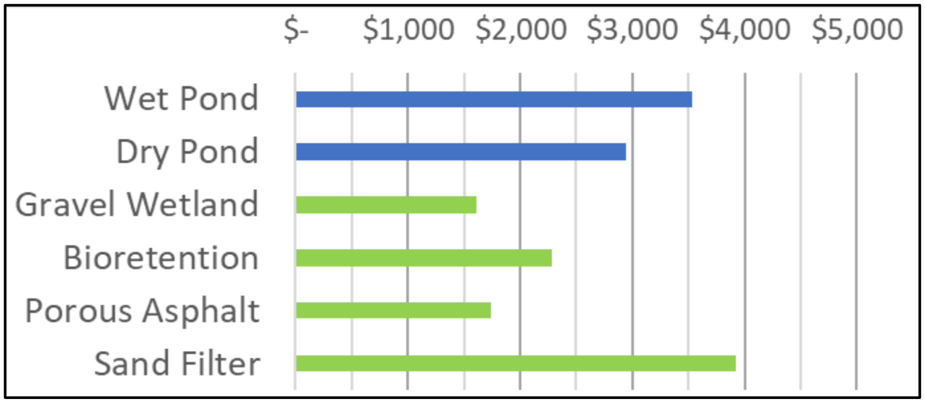


Figure 4.3- 10-Year BMP Construction and Maintenance Costs per Average Removal % of Nitrogen, Phosphorus, and TSS. Conventional BMPs are shown in blue while LID are shown in green (Houle et al., 2013).

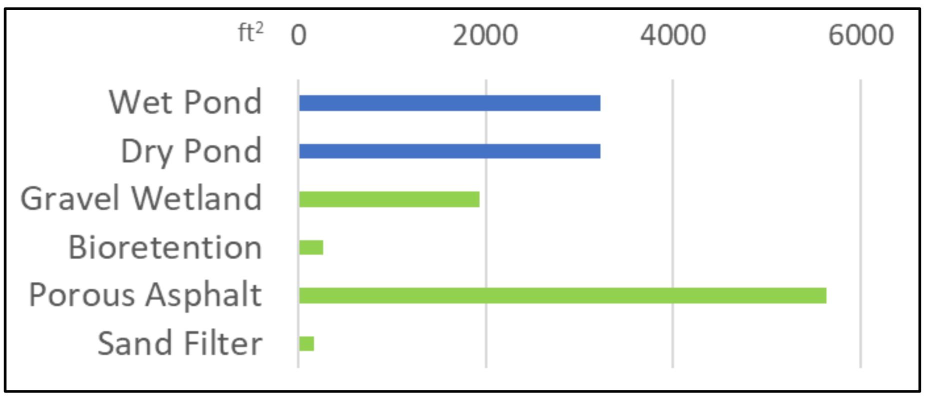


Figure 4.4- BMP Area Footprints. Conventional BMPs are shown in blue while LID are shown in green (Houle et al., 2013).

While the positive cost benefits of LID standards for overall site costs and pollution removal are supported by available data, it is less clear whether LID or conventional detention/retention offers more cost-effective flood mitigation at a watershed scale. Few studies on this topic exist and those that do warn against interpreting their local quantitative results for use in other locations (EPA, 2015b) (Atkins, 2015). However, multiple studies do support that more diverse mixes of unique drainage patterns in a watershed are able to mitigate floods more effectively (Qin et al., 2013) (Opperman, 2014). Therefore, any LID standards the cities adopt should offer methodology for many types of BMPs. Additionally, multiple studies support that vegetated land cover is often the most effective LID tool for flood mitigation (Loperfido et al, 2014) (Opperman, 2014) (Burns, 2012). Thus, any future LID standards should encourage developers to utilize forested open space, as opposed to structural BMPs only.

For more information on creating LID Standards, see Appendix E- Guide for Creating LID Standards. Appendix K- LID Resource Guide also contains external links for LID code examples, templates, calculators, and guides.

4.4: Incentivizing Voluntary LID Installation

Currently, only the City of Dallas has a voluntary LID installation program. Representatives from the City of Independence appear open to adopting a similar program. Incentivizing voluntary LID installation allows cities to promote LID implementation in previously developed areas of town or on private property without forcing any regulations. Similar to the LID standards, incentive programs may call for property owners to maintain the features themselves to overcome the barrier of excessive city maintenance. City staff may only be required to perform an annual inspection to confirm that the features are functioning properly. A few common types of incentive programs are shown in Table 4.5.

Table 4.5- Common Types of LID Incentives (EPA, 2009b).

Stormwater Fee Discount	Offer reduced stormwater fees if a property owner reduces or controls impervious surface. Discount often varies proportionately with % of imperviousness treated.
Development Incentives	Offer a developer benefits such as zoning upgrades, expedited permitting, increased desnity, etc. if LID conditions are met.
Grants	Directly fund property owners or homeowner associations to implement LID projects on their private property.
Rebates	Fund discounts on LID installation services or products (ie. rain barrel purchase or rain garden installation).

As of October 2017, the City of Dallas Low Impact Development Incentives program allows private property owners to earn credit towards up to 50% of their System Development Charges (SDC) for installing their own stormwater BMPs. The program also allows developers to build up to a 25% higher residential density based on design factors such as energy efficiency, open space, and runoff reduction. For examples of additional voluntary LID programs in the Pacific Northwest, see Appendix F.

Representatives from the City of Independence are highly interested in creating a similar incentive program. The representatives discussed creating a stormwater fee discount or rebate program, where residents or businesses can voluntarily install pervious areas or stormwater treatment devices on their property in exchange for System Development Charge (SDC) credits. Doing so would help Independence re-develop their older downtown areas.

Participants in the focus group provided the following suggestions in Table 4.6 for making a successful voluntary LID installation program in the Ash Creek watershed. In designing a voluntary program, it would be helpful to pursue further feedback from these participants and others active in LWC events, given they represent the motivated population in the community most likely to participate in such a program.

Table 4.6- Ideas from Focus Group Participants for a Potential Voluntary LID Installation Program in the Ash Creek Watershed.

1.	Reduction on stormwater bill (Independence has separate stormwater bill, Monmouth might be able to tie this in with water/sewer bill).
2.	Rebates to reduce the cost of purchasing rain barrels/LID items.
3.	City-provided resources with directions on what to do, who to talk to, how much it costs, permits, etc.
4.	Provide lenience in building permits if installing LID.
5.	City can fund and award grants to homeowner associations who want to do projects.

For more information on incentivizing voluntary LID installation, see Appendix F- Example Voluntary LID Programs. Appendix K- LID Resource Guide contains external links for example incentive programs, guides for creating programs, and materials for homeowner installation.

4.5: Building Stormwater Parks

During the interviews, Madrona Park in Monmouth, pictured in Figure 4.5, was presented as a prominent example of a local stormwater park. Representatives in Monmouth and Independence were open to additional similar projects in the future. A stormwater park may be defined as public park space utilized for both recreation and stormwater storage and/or treatment (EPA, 2015a).

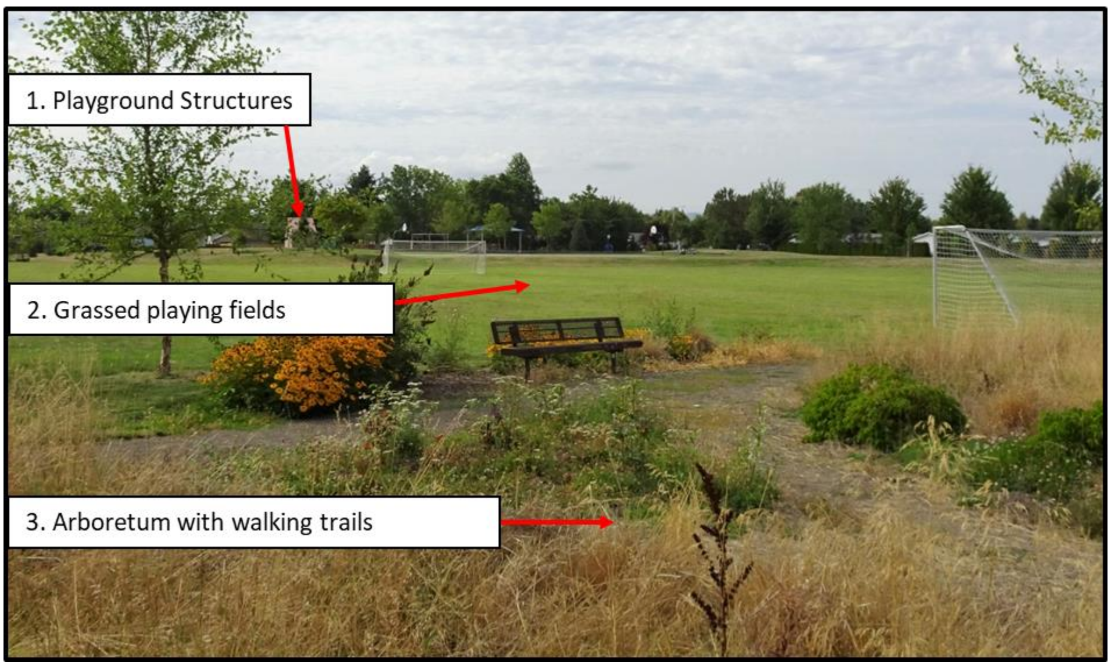


Figure 4.5- Madrona Park Photograph. Madrona Park, built in Monmouth in 2015, is an existing example of a local stormwater park.

City staff in Monmouth reported positive experiences with Madrona Park since its construction in 2015. The park features tiered use areas. Within the lowest elevation area is an arboretum with native plantings and walking trails. City staff report that this area holds standing water during certain wet winter periods, but is otherwise usable for walkers. Above the arboretum area are grassed playing fields, which can provide temporary runoff retention during large storms. City staff reported that the water storage has only reached the grassed fields a handful of times since opening in 2015, with the facility functioning properly each time. The playground structures are built above the grassed playing fields and generally remain dry outside of extreme events. The only negative experience reported so far is that residents have called in asking when the native arboretum plantings would be mowed. Educational interpretive signage may be able to prevent such issues in the future.

The success of Madrona Park supports the construction of more such stormwater parks as a potential LID solution. These parks can reduce flooding damage while fulfilling TMDL requirements, including Measure #5 (Post-Construction Runoff Control) and, if paired with interpretive displays of the stormwater features, Measure #1 (Public Outreach & Education. Combining park and stormwater projects together can also streamline costs and maintenance compared to separate projects. Additionally, since the entire space is usable for recreation, stormwater parks can also overcome the barrier of LID taking land away from other purposes. For a list of possible locations for future stormwater parks, see Appendix G. For external links about integrating LID into park spaces, see Appendix K- LID Resource Guide.

4.6: Building Constructed Wetlands

Representatives from the City of Monmouth and Ash Creek Water Control District initially expressed interest in creating a system of regional flood storage facilities along Ash Creek to prevent flooding damage during large storm events. Although these representatives initially envisioned detention/retention ponds, they supported my suggestion of constructed wetlands as an alternative stormwater management project with improved water quality treatment and wildlife habitat benefits.

Constructed wetlands are becoming a popular tool for managing stormwater, due to their tremendous flood mitigation and water quality benefits. Both conventional ponds and constructed wetlands reduce flood impacts by holding runoff for gradual release during large storm events. However, constructed wetlands also reduce the overall volume of runoff and recharge the underlying groundwater aquifer (OSU Extension, 2009) (Kim et al., 2010). Gravel constructed wetlands also have been found to handle identical flows to conventional ponds at only 60% of the area footprint and with only 50% of the 10-year costs per average removal of TSS, nitrogen, and phosphorus (Houle, et a., 2013). Though stakeholders were wary of attracting mosquitos, constructed wetlands are typically less attractive to mosquitos than treatment ponds are (OSU Extension, 2009), with design elements such as subsurface flow able to further address this issue (Akers, 2012). It may also be possible to take advantage of the US Department of Agriculture (USDA) Wetlands Reserve Program, which provides technical and financial support to landowners who voluntarily provide easements for wetlands on their property.

Similar to stormwater parks, constructed wetlands can reduce flooding damage while fulfilling TMDL requirements, including Measure #5 (Post-Construction Runoff Control). If desired, the project can use the wetland as a recreation area for walking and wildlife viewing, incorporating interpretive displays to address Measure #1 (Public Outreach & Education). Potential project sites for constructed wetlands in the Ash Creek watershed are shown in Appendix G.

4.7: Additional Potential LID Solutions

This section briefly introduces the additional potential LID solutions that were brought up by stakeholders during the interviews, but that did not meet the criteria I set to investigate in detail. Planting street trees and revegetating riparian areas are already being widely performed in the Ash Creek watershed. Constructing vegetated roadside ditches and performing controlled flooding of agricultural fields were only supported by a single represented organization. However, it is important to note that time was limited in these preliminary conversations and did not allow for full discussion of all project types in each interview. Further, more guided discussions should take place to gain a clearer perspective of the degree of support for LID project types from these local organizations.

4.7.1: Revegetating Riparian Areas

Revegetation of riparian areas along Ash Creek and its tributaries was suggested by representatives from the City of Dallas and the ACWCD. However, since the Luckiamute Watershed Council, partnering with the City of Independence, City of Monmouth, and ACWCD among others, has already been actively working to replant streamside areas since 2013 as part of the Ash Creek Restoration Project, I did not explore this topic further. As more of the accessible property becomes revegetataed, the LWC will need to shift its scope to pursue alternative projects. This LID study represents the start of this process.

4.7.2: Planting Street Trees

Street trees are a crucial component of encouraging infiltration in a watershed, capable of strong performance even in poor soils (Godwin, 2017). However, since Dallas, Monmouth and Independence each already have established street tree programs, I did not explore this further. However, it is important for Ash Creek that the cities continue these programs and that they consider counting them towards TMDL fulfillment.

4.7.3: Vegetated Roadside Ditches:

Representatives from the City of Monmouth are interested in resurging the past trend of smaller municipalities utilizing grassed roadside ditches as drainage features. While not offering the same benefits as a proper bioswale or rain garden structure, grass roadside can still infiltrate more runoff than can concrete. It may be possible to replace certain concrete roadside ditches with steeper slopes with vegetated roadside ditches.

4.7.4: Controlled Flooding

Representatives from the City of Independence introduced the idea to perform controlled flooding of agricultural fields. Controlled flooding can bring water to farmers who need it and has been performed in the past in western Oregon.

4.8: Chapter Summary

This chapter draws upon the results from the stakeholder interviews and public focus group to present five potential LID solutions for the Ash Creek watershed. These solutions include Incorporating LID into TMDL Requirements (section 4.2), Creating Regional LID Standards (4.3), Incentivizing Voluntary LID Installation (4.4), Building Stormwater Parks (4.5), and Building Constructed Wetlands (4.6). I chose to explore these solutions because they were supported by multiple organizations interviewed but have not been implemented yet on a widespread scale in the watershed. Based on the overall constraints encountered during the interviews and focus group, I framed the investigation to explore how these solutions can benefit how these solutions can benefit both TMDL permit compliance and flood mitigation in a cost-effective manner beyond the scale of individual homeowners.

CHAPTER 5- DESIGN OF LID IMPLEMENTATION TOOLS

This chapter presents the design of several LID implementation tools meant to help empower the stakeholders to institute any LID solutions for Ash Creek from Chapter 4 that they may choose.

The LID implementation tools presented in this chapter are the Green Infrastructure Implementation Forms (section 5.1), Potential LID Project Site Ideas (5.2), Preliminary Soils Data (5.3), Existing LID Inventory (5.4), Reported Flooding Locations (5.5), LID Standards Creation Guide (5.6), and LID Resource Guide (5.7).

These tools were chosen to address the feedback from the stakeholder interviews and public focus group as seen in Table 5.1. The idea for some of the tools came from the list of proposed deliverables in the internship proposal while others came about during the interview and focus group process based on the feedback given. The tools are meant to connect to the desired outcomes sought from the internship in the interviews and desired solutions from the focus group. Each response that is addressed by the tools is highlighted in green in Table 5.1.

Table 5.1- Connections between LID Implementation Tools and Feedback from Interviews and Focus Group**.**

Desired Outcomes from Internship

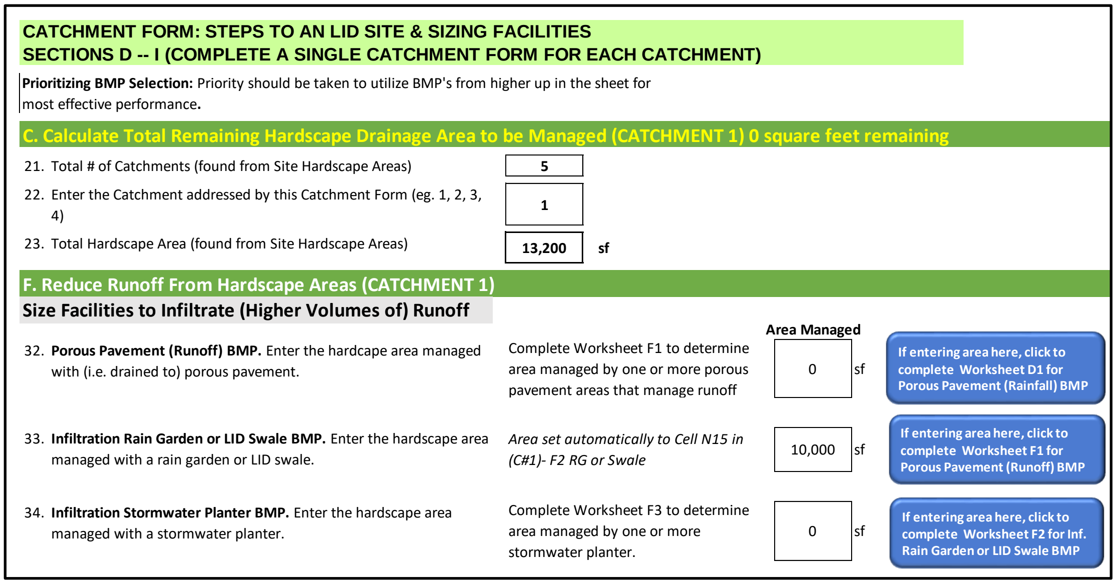
Response Frequency	*Response Group*	LID Implementation Forms	Future LID Project Idea Locations	Preliminary Soils Data	Inventory of Existing LID	Reported Flooding Locations	Guide for Creating LID Standards	LID Resource Guide
55%	Research LID Costs and Benefits							■
55%	Create List of Possible LID Projects		■			■		
45%	Perform LID Outreach/Demonstration							
36%	Research Performance of Existing LID				■			
36%	Create List of LID tools/Types	■		■	■			■
36%	Provide LID Funding Info							■
27%	Research LID Standards	■					■	
18%	Review Current City Codes						■	
18%	Voluntary Solutions							■
18%	Hyrologic Testing			■				
18%	Information on tools for Certain Soils	■		■				
9%	Complete Easy Projects		■					

Public Focus Group: Helpful Resources

Response Group	LID Implementation Forms	Future LID Project Idea Locations	Preliminary Soils Data	Inventory of Existing LID	Reported Flooding Locations	Guide for Creating LID Standards	LID Resource Guide
Volunteers to strip ivy from property							
Guidance on role of agencies in natural resources							
LID homeowner flyers with examples and costs							■
Comprehensive stormwater solution guide							■
Template for cities to adopt policies	■					■	
Comaparison of current city codes to LID codes						■	

5.1: Green Infrastructure Implementation Forms

Following the conclusion of my internship with the Luckiamute Watershed Council, I assisted the Oregon State University Extension Service (OSU Extension) and Green Girl LLC in creating the Green Infrastructure Implementation Forms. These forms consist of a series of Excel worksheets (Figure 5.1) and associated guidance for sizing LID structural and vegetated BMPs (rain gardens, pervious pavement, tree plantings, etc.) and for determining site compliance. The forms are hosted on the OSU Extension Stormwater Solutions website: (http://extension.oregonstate.edu/stormwater/).



CATCHMENT FORM: STEPS TO AN LID SITE & SIZING FACILITIES
SECTIONS D -- I (COMPLETE A SINGLE CATCHMENT FORM FOR EACH CATCHMENT)

Prioritizing BMP Selection: Priority should be taken to utilize BMP's from higher up in the sheet for most effective performance.

C. Calculate Total Remaining Hardscape Drainage Area to be Managed (CATCHMENT 1) 0 square feet remaining

21. Total # of Catchments (found from Site Hardscape Areas)	5	
22. Enter the Catchment addressed by this Catchment Form (eg. 1, 2, 3, 4)	1	
23. Total Hardscape Area (found from Site Hardscape Areas)	13,200	sf

F. Reduce Runoff From Hardscape Areas (CATCHMENT 1)

Size Facilities to Infiltrate (Higher Volumes of) Runoff

		Area Managed		
32. **Porous Pavement (Runoff) BMP.** Enter the hardcape area managed with (i.e. drained to) porous pavement.	Complete Worksheet F1 to determine area managed by one or more porous pavement areas that manage runoff	0	sf	If entering area here, click to complete Worksheet D1 for Porous Pavement (Rainfall) BMP
33. **Infiltration Rain Garden or LID Swale BMP.** Enter the hardscape area managed with a rain garden or LID swale.	*Area set automatically to Cell N15 in (C#1)- F2 RG or Swale*	10,000	sf	If entering area here, click to complete Worksheet F1 for Porous Pavement (Runoff) BMP
34. **Infiltration Stormwater Planter BMP.** Enter the hardscape area managed with a stormwater planter.	Complete Worksheet F3 to determine area managed by one or more stormwater planter.	0	sf	If entering area here, click to complete Worksheet F2 for Inf. Rain Garden or LID Swale BMP

Figure 5.1- Green Infrastructure Implementation Forms Excel Screenshot.

The Forms calculate the total required area to be treated, based on the site landscape and hardscape areas. To then perform this treatment, the Forms guide users through the selection of more than 30 BMPs, which are listed in order of cost-efficiency according to the Stormwater Management Hierarchy (Figure 5.2). The Stormwater Management Hierarchy encourages users to select the most cost-efficient BMPs available based on the local infiltration rate and site conditions established in the BMP Suitability Matrix (Cahill, 2017). The Forms then size the chosen BMP, using calculators based on the Santa Barbara Urban Hydrograph (SBUH) and Rational Methods.

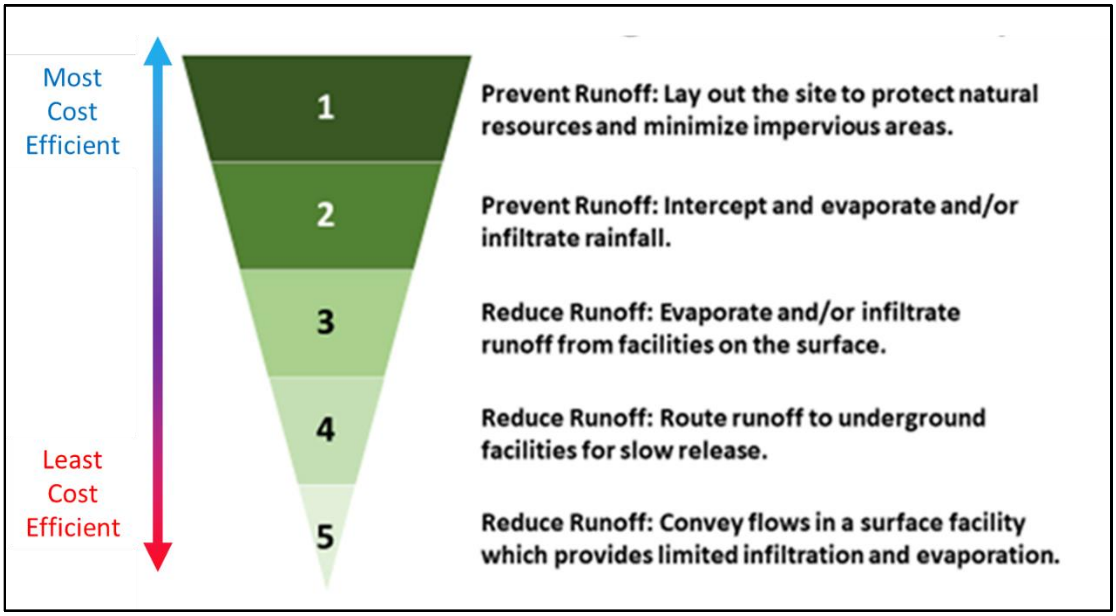


Figure 5.2- Stormwater Management Hierarchy. Based on this Hierarchy, the BMPs included in the Green Infrastructure Implementation Forms are listed in order from most to least cost-efficient (adapted from OSU Extension, 2017).

The Forms address current barriers in both Ash Creek and across Oregon, of smaller municipalities lacking time, money, and expertise to update their own stormwater codes. The cities of Dallas, Monmouth, and Independence can use the Green Infrastructure Implementation Forms to create their own regional LID Standard, as discussed in section 4.3. To adapt the calculations on the Forms for their own standard, a city simply needs to specify their local NRCS Storm Type (I, IA, or II) and design storm rainfall depth (guidance provided in Appendix E). Then, based on the local standards chosen, the city can modify the pre-established set of BMP specifications that correspond with the Forms. Furthermore, a city can easily check any plans submitted using the Forms, given the streamlined calculation formatting.

Previous user-friendly stormwater sizing forms in Oregon include FORM SIM developed by DEQ, and the Simplified Approach Form and Presumptive Approach Calculator, both developed by the City of Portland. However, the Green Infrastructure Implementation Forms are the first method in Oregon to be simplified for nonprofessionals, robust enough for sophisticated project submission, and easily adaptable across multiple locations all in one.

My personal contributions to the Green Infrastructure Implementation Forms include modifications to the calculations, user-interface upgrades, and creation of a user tutorial. The initial BMP worksheets and calculators were completed by Green Girl LLC. I assisted this effort by adjusting the hardscape area reduction procedure and performing calculation checks throughout the formatting process. To make the Forms more user-friendly, I programmed a macro user-interface into Excel to generate new sheets only when needed. This cut down the number of sheets initially visible from sixteen to three, preventing the user from becoming overwhelmed. To further enhance the usability of the forms, I also added a tutorial accompaniment, hosted on the Stormwater Solutions website at: (http://extension.oregonstate.edu/stormwater/). This tutorial visually guides the user through the worksheets using images such as Figure 5.3 alongside written commentary. The tutorials include a mock new development housing project in western Oregon sketched in AutoCAD and a mock re-development project of an office building in Wallowa County. Together, these examples showcase the wide range of projects that the Forms can be used for.

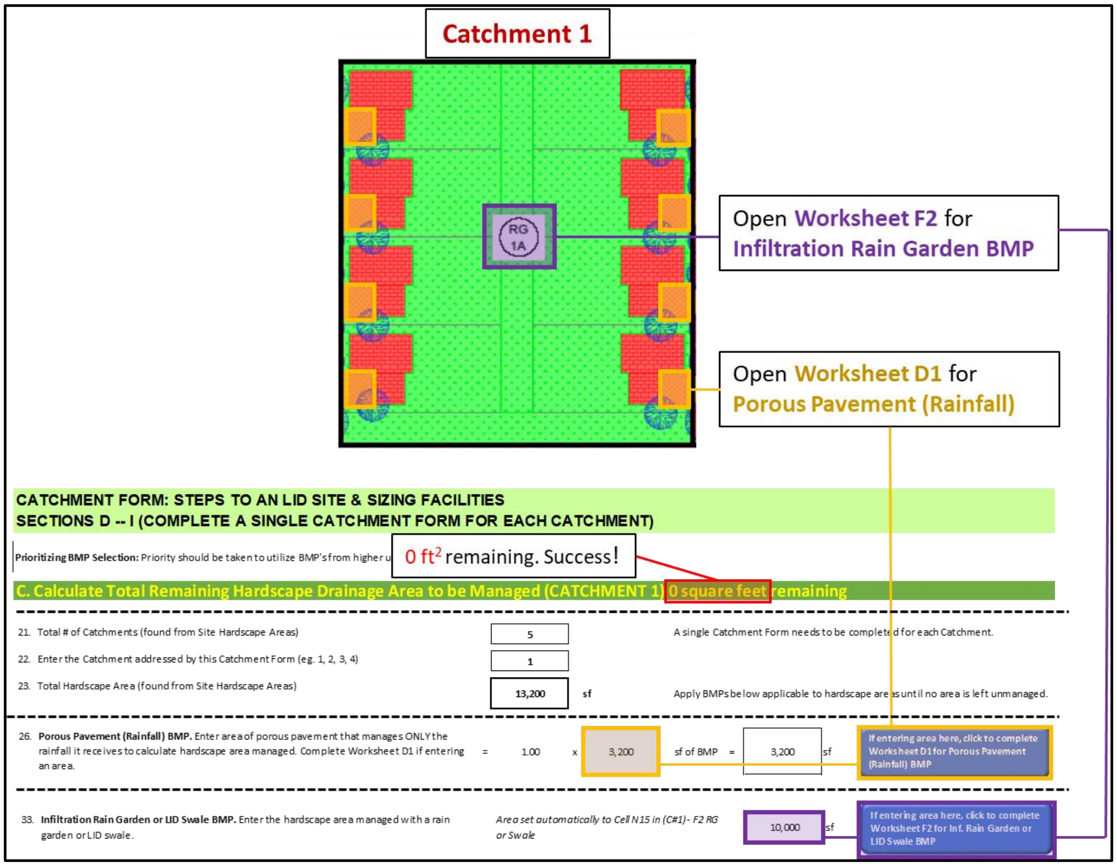


Figure 5.3- Green Infrastructure Implementation Forms Tutorial Example Image.

5.2: Potential LID Project Site Ideas

One of the questions in the interview guide asks stakeholders about locations or types of LID projects they would or would not like to see, believe are likely in the future, or that have had past interest. The responses yielded nineteen potential project locations, which I compiled together with background information, soil maps, and commentary in Appendix G. The project ideas discussed in Appendix G are categorized into Public Land Project Ideas (Figure 5.4), Opportunities to Work with Future Developers (Figure 5.5). and Possible Locations for Voluntary Projects on Private Land (Figure 5.6).

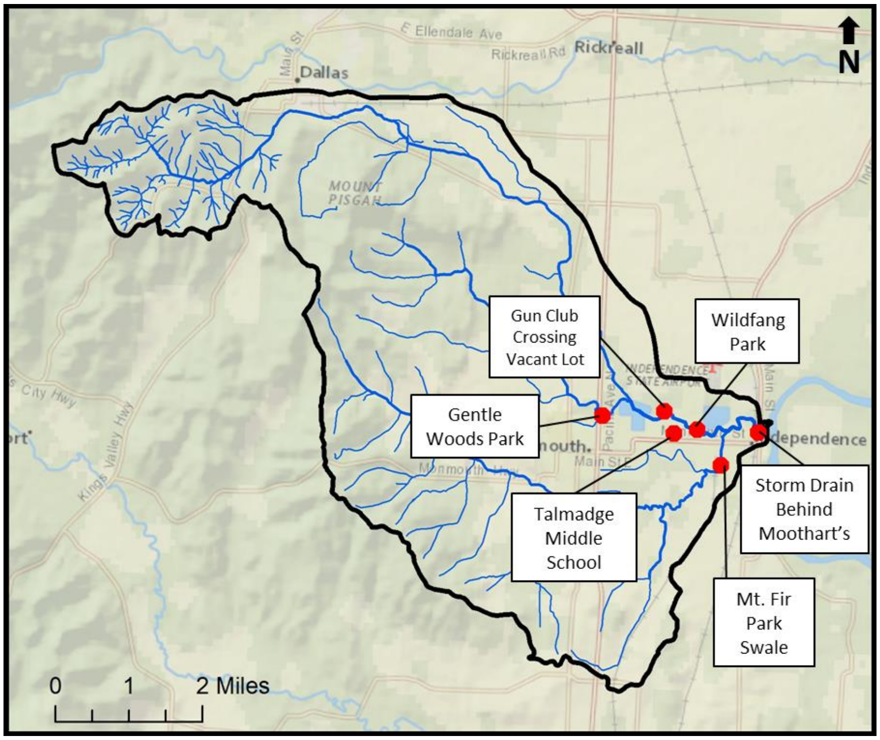


Figure 5.4- Public Land Project Ideas.

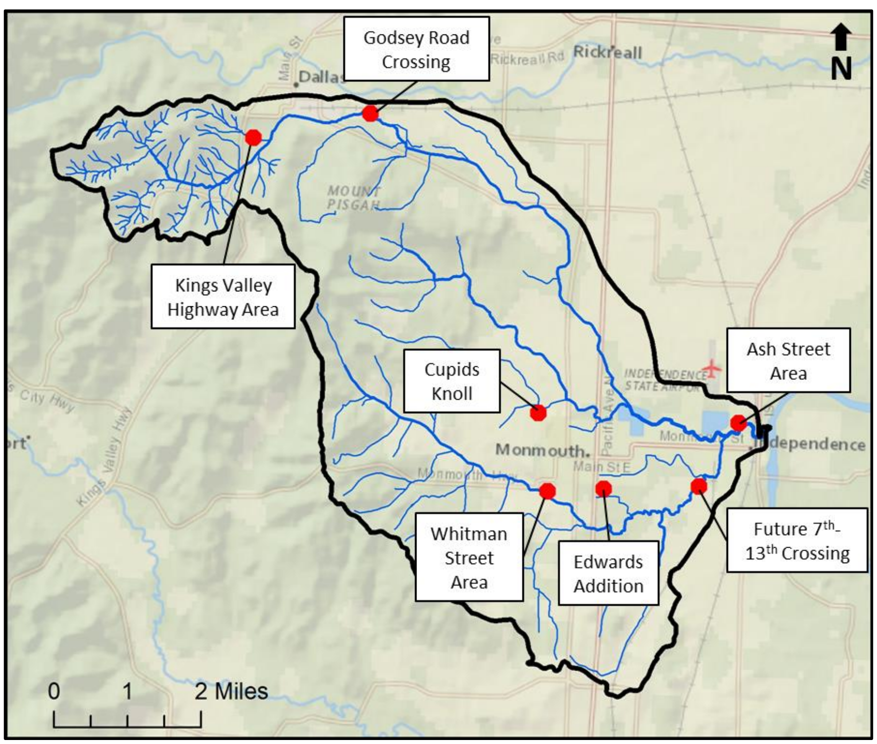


Figure 5.5- Opportunities to Work with Future Developers.

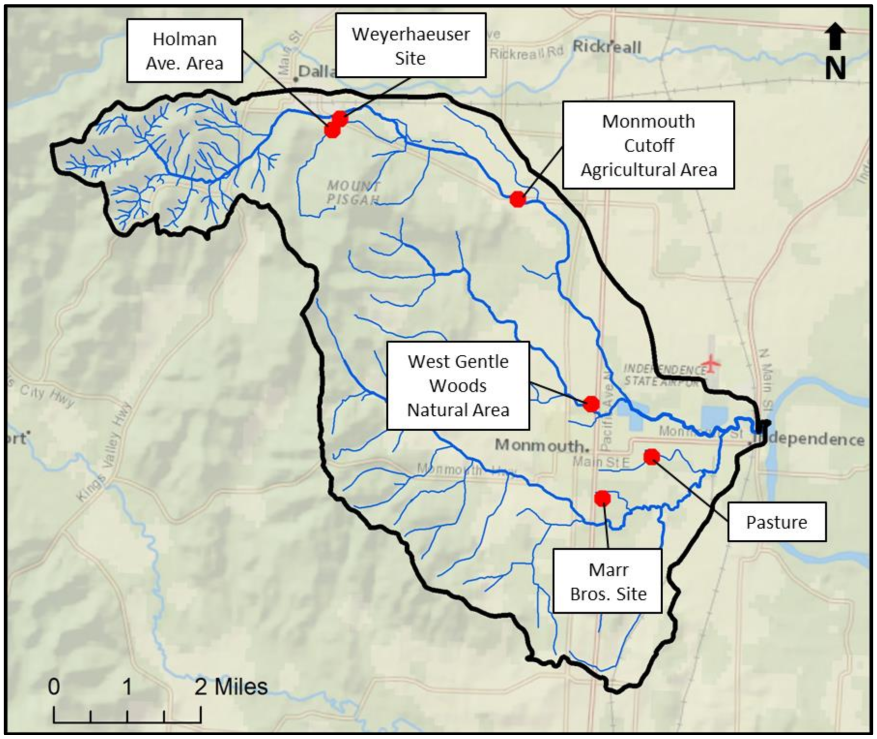


Figure 5.6- Possible Locations for Voluntary Projects on Private Land.
Disclaimer: Interest of landowners is unknown and inclusion in this report does not indicate that a project is planned or expected for this site.

These sites provide ideas for local entites is looking for flood mitigation or water quality project options. However, these locations are only meant to be used a brainstorming tool and the ideas should not be pursued without consulting a professional. More detailed site designs and infiltration tests for these projects is encouraged as a future step, but is outside the scope of this project. Note that the mention of private lands do not imply that any plans currently exist for implementation of these ideas and that the intent of the landowners is unknown.

These project ideas address one of the top desires of the stakeholders to create a list of possible LID projects. The locations mentioned may also be potential sites to implement the LID solutions discussed in Chapter 4. The public land ideas contain possible locations for constructing stormwater parks and constructed wetlands as discussed in sections 4.5 and 4.6. Although the intent of the landowners is unknown, the voluntary project ideas contain possible private properties that may participate in a voluntary LID incentive program discussed in section 4.4. The future development sites provide opportunities for pilot demonstration of any potential regional LID standards as discussed in section 4.3. Any of these project types mentioned can further assist the cities in fulfilling their TMDL permits.

5.3: Preliminary Soils Data

Local soil conditions play a critical role in determining the cost-effectiveness of LID projects. This chapter discusses the importance of site testing of infiltration rate to BMP design. The data and discussion contained here are meant to be used as a reference to accompany the project site ideas in section 5.2.

Soil properties are important for LID implementation, as the local infiltration rate and groundwater table depth determines the BMP types available and sizes required for a given site. The slower the soils drain, the larger and more expensive the BMP designs become. Additionally, the groundwater table must be sufficiently low to allow BMPs to perform infiltration properly. In conditions with infiltration rates below 0.1 inches/hour or groundwater table depths below 3 feet, BMPs may require soil amendments or routing to surface or underground facilities, generally at much higher costs (DEQ, 2016) (Godwin et al., 2011). Stakeholders discussed the clayey soils, which comprise 50% of the Ash Creek watershed (NRCS, 2018), as one of their concerns regarding LID implementation.

Testing in this project emphasizes that publicly available online Natural Resources Conservation Service (NRCS) Web Soil Survey data does not accurately describe the soil properties at a site-scale. Although NRCS Web Soil Survey data is provided in Appendix H as a reference for generalized watershed scale soil conditions, it is important to emphasize that the use of this data to guide LID design should be limited. Local infiltration tests of each BMP location are generally required for public submittals. Even test sites less than 100 feet apart possess different properties.

To illustrate the importance of infiltration tests, I performed my own test at the Gun Club Road Crossing Vacant Lot site in Independence. Using the Reduction Factor Method published by OSU Extension (Cahill et al., 2011), I performed infiltration tests for two boreholes in October 2017 (supporting calculations found in Appendix H). As seen in Table 5.2, the tested infiltration rates vary drastically from the estimates based on Web Soil Survey data. Furthermore, the tested infiltration rates from the two boreholes varied by 25% despite being less than 100 feet apart.

Table 5.2- Estimated Infiltration Rates at Gun Club Road Crossing Vacant Lot (NRCS, 2018) (NRCS, 1988) (Barr, 2010). USDA Web Soil Survey data is not able to accurately predict infiltration rates at a site scale. It is important to perform soils infiltration tests at the planning, rather than construction phase of BMP design.

Estimate Source	Estimated Infiltration Rate (inches/hour)
Local HSG	0.3
Local Soil Type	0.05 - 0.15
Site Infiltration Test	1.99 - 2.58

The results in Table 5.2 exemplify the importance of performing infiltration tests during the planning, rather than construction phase of BMP design. Performing multiple infiltration tests at a site enables the designer to select locations with higher infiltration rates and deeper groundwater tables, later reducing the sizes and costs of the BMPs needed. Additional soils testing at possible project sites would be a useful product to help local organizations around Ash Creek strategize LID implementation.

5.4: Existing LID Inventory

One of the interview guide questions asked about what existing LID stakeholders have seen around the watershed. The responses were used to generate an inventory of existing LID, pictured below in Figure 5.7. Appendix I contains the full version of the inventory, complete with photographs and background information from stakeholders on the performance of the facilities so far. While stakeholders were interested in learning more on performance data of LID BMPs, many were also skeptical that results from larger municipalities, such as Portland, with more maintenance resources would be applicable around Ash Creek. Stakeholders also wished to have a list containing different types of LID they may choose from. This inventory addresses these desires by allowing stakeholders to see examples of different types of LID in their own community and assess their performance by visiting in person or discussing with others.

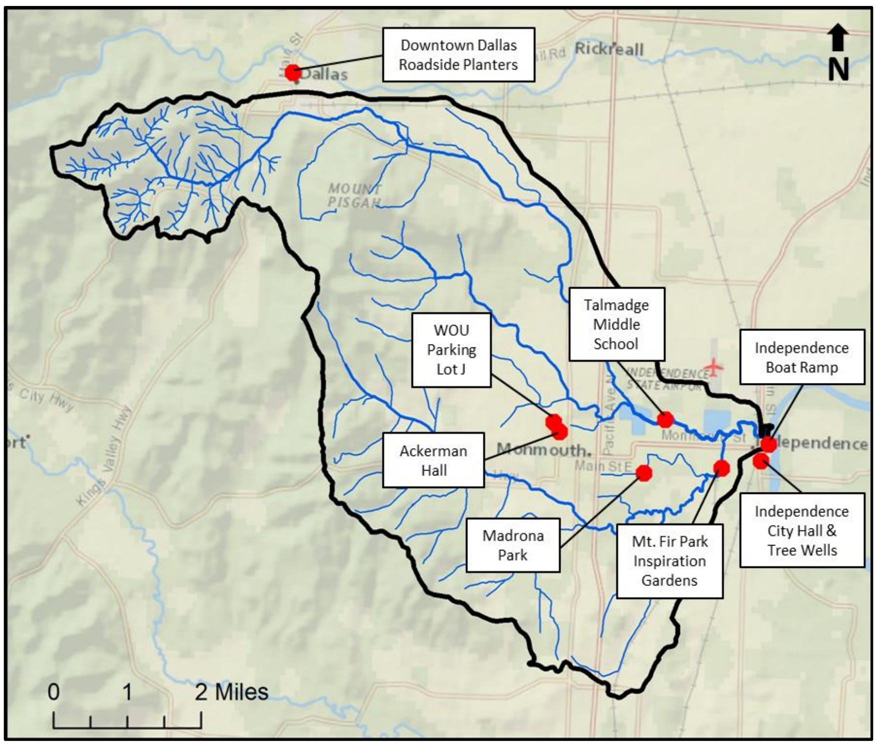


Figure 5.7- Existing LID in the Ash Creek Watershed.

5.5: Reported Flooding Locations

One of the questions in the interview guide asked stakeholders about stormwater problem areas or locations that have flooded in the past. The responses were used to populate an inventory of reported flooding locations, pictured below in Figure 5.8 (full version found in Appendix J). These flooding locations were used to generate the "#

Flooding Areas Downstream" parameter for the Site Ideas for Potential LID Projects in Appendix G. This parameter allows the reader to pinpoint project locations that can mitigate flooding at a maximum number of downstream problem areas. The map of these flooding locations may be particularly helpful for brainstorming sites for any future retention facility or constructed wetland.

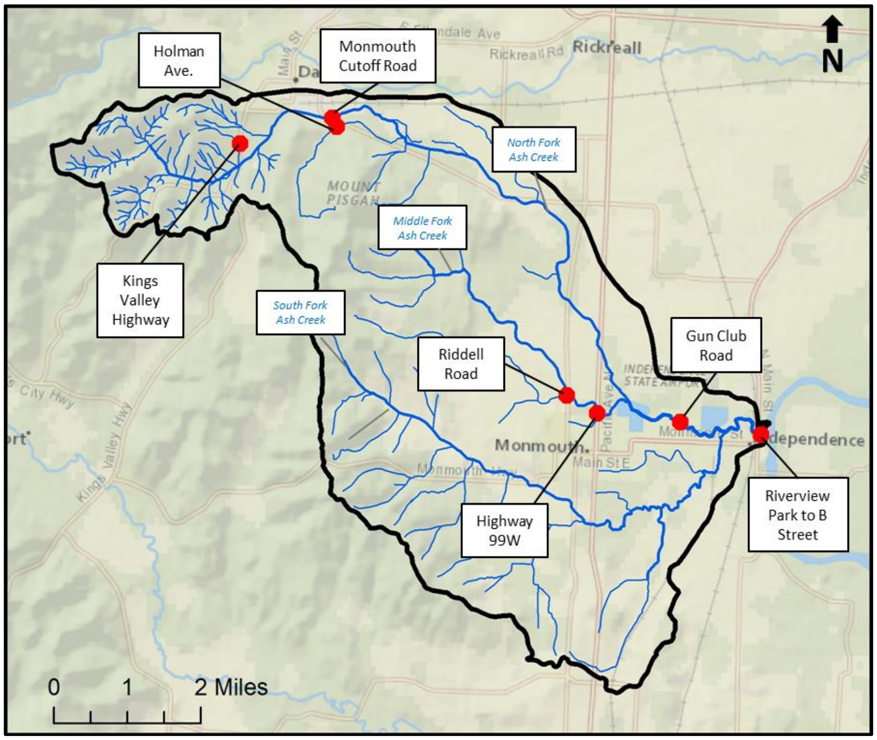


Figure 5.8- Reported Flooding Locations in the Ash Creek Watershed.

This map reveals no reported flooding locations for South Fork Ash Creek or any of the smaller tributaries in the watershed. Flooding locations are found only on the North and Middle Forks of Ash Creek. These reaches should be the focus of future flood mitigation projects to maximize benefits for the watershed. While the Riverview Park to B Street in Downtown Independence is included on this map, it is unlikely any that LID projects in the watershed will be able to help flooding there, which is caused by backup of the Willamette River instead of any effects from Ash Creek.

5.6: LID Standards Creation Guide

Since many stakeholders and focus group participants requested information on LID Standards, I developed a guide for creating LID standards in Appendix E. This guide is meant to help the cities develop the Regional LID Standards discussed in section 4.3. The information contained in the guide is based on the review of existing LID standards across Oregon and the current stormwater codes of Dallas, Monmouth, and Independence. The intended audiences are city staff members looking to create LID standards as part of their stormwater code. The information may be used to build upon the methods in the Green Infrastructure Implementation Forms from section 5.1, or to create a new standard altogether. The guide walks the reader through the following six questions:

(1): What are the goals of the standard?
(2): How would detention requirements be handled?
(3): What would be the water quality requirements?
(4): What BMP devices and standards will be accepted?
(5): How will BMP sizing calculations be performed?
(6): How will maintenance be handled?

5.7: LID Resource Guide

One of the most pervasive desires across the stakeholder interviews and public focus group was for more general information on LID. While most of the people I met with were at least familiar with LID, many admitted they were not well-informed on the topic. To address this desire, I developed an LID Resource Guide, contained in Appendix K. This guide provides residents and public officials with external links (current as of March 2018) to the most valuable and accessible information on LID that I encountered during my research on this project. Information is included on LID costs, funding, standard development, voluntary installation incentives, BMP performance, stormwater park construction. This guide draws from a variety of websites hosted by organizations including OSU-Extension, Green Girl LLC, City of Portland, Washington Department of Ecology, EPA, and more.

5.8: Chapter Summary

This chapter draws upon the results from the stakeholder interviews and public focus group to design seven LID implementation tools for the Ash Creek watershed. These tools include Green Infrastructure Implementation Forms (section 5.1), Potential LID Project Site Ideas (5.2), Preliminary Soils Data (5.3), Existing LID Inventory (5.4), Reported Flooding Locations (5.5), LID Standards Creation Guide (5.6), and LID Resource Guide (5.7). These tools were chosen based on the desired outcomes and helpful resources encountered during the interviews and focus group. The purpose of the tools is to help empower stakeholders to implement any of the potential solutions in Chapter 4 that they wish to pursue.

CHAPTER 6- CONCLUSION

This chapter synthesizes the overall information in this project to describe the opportunities available for organizations in the Ash Creek watershed to build off the efforts of this project. I also describe the limitations of this study and opportunities for future research opportunities.

6.1: Next Steps in the Ash Creek Watershed

The data and narratives in this study represent an initial baseline of information surrounding LID in the Ash Creek watershed. Although this study discusses many potential projects and policies, none are explored deeply enough to warrant implementation based on the information here alone. Detailed site design and policy research were outside the scope of this preliminary study. This study is instead meant to guide public officials to select which, if any, project types to fund a more formal investigation for. With this in mind, I have included several distinct steps for organizations in the Ash Creek Watershed to build off the efforts of this project.

<u>For Dallas, Monmouth, Independence, and Polk County:</u>

- Once the updated TMDL permits are released, speak with DEQ staff to see how LID project types, including stormwater parks or constructed wetlands, can fulfill permit requirements. Consider hiring a consultant to investigate the most cost-efficient combination of projects to fulfill TMDL requirements and achieve flood mitigation benefits. The information in section 4.2 may be used help this process.

- Consider launching a formal investigation of regional LID standards for new development to see what the technical requirements might look like, costs involved, economic impacts to development, etc. The information in section 4.3 and Appendix E, as well as the Green Infrastructure Implementation Forms may be used to help this process.

- Look at the list of project site ideas in Appendix G to find opportunities for stormwater parks or constructed wetlands as discussed in sections 4.5 and 4.6. The information in Appendix I and Appendix J may be used to help in this process as well.

- Consider creating incentives for voluntary LID installation. Such a program allows for LID implementation in previously developed areas of private property without forcing any mandatory regulations. Information in section 4.4 and Appendix F may be used to help this process.

For the ACWCD, LWC, and Western Oregon University:

- Brainstorm LID project ideas and apply for grants to fund them. Project ideas in Appendix G may be used to help this process.

- Initiate partnerships with the other organizations in Table 4.1 based on common project interests to collaborate resources together and complete these projects.

- Act as a source of local support, enthusiasm, and motivation for LID implementation in the watershed. Help spread this momentum to the municipalities and support new opportunities as they emerge.

For residents:

- Urge public officials to implement the type of LID you would like to see in your community, using the information in this study as evidence. Advocate for homeowner incentives for voluntarily implementing these practices.

- Consider installing BMPs on your own property, with the resources in Appendix K to help you.

I have previously shared these recommendations with local stakeholders in Ash Creek. In October 2017, I presented to the Ash Creek Water Control District and the Luckiamute Watershed Council my report on “Low Impact Development Findings &

Recommendations for the Ash Creek Watershed", which contains much of the same information as this thesis. I also distributed this report to all the organizations involved in the stakeholder interviews. Finally, I shared the focus group summary and provided resources for installing BMPs to all the participants.

6.2: Study Limitations

The primary limitations of this study are the scope of the stakeholder interviews and the lack of available data regarding LID.

Limitations of stakeholder interviews:

- I was not able to discuss all ideas with every stakeholder or discuss ideas brought up in later interviews with those I interviewed earlier on. Short follow-up interviews could have addressed these limitations.

- I only interviewed with stakeholders affiliated with public organizations involved with stormwater. Interviews with local business owners or developers would have further provided valuable local perspectives on LID.

Limitations of LID data:

- To accurately reflect regional climate factors and construction labor costs, LID cost-benefit data should come from local studies. However, there is a current lack of these studies in Oregon, with even official state DEQ resources relying on LID studies from the East Coast and elsewhere.

- Current LID data applicable to smaller municipalities is scarce. Most available case studies focus on large metropolitan cities that possess substantial capital and maintenance resources.

- There is limited available information that focuses on techniques to implement LID types that have minimal maintenance requirements.

- The relationship between LID and watershed-scale flood mitigation has not been widely studied. This topic is important to the stakeholders of Ash Creek, but is not well understood.

6.3: Future Research Opportunities

The Ash Creek watershed and Polk County contain research opportunities for future students interested in applied projects local to western Oregon. Ideas for student projects include:

- Assist the municipalities in any of the suggestions from section 6.1, including designing a new TMDL implementation plan, regional LID standard for development, LID voluntary incentive program, or a stormwater park or constructed wetland site BMP.

- Help inform the debate over management philosophies towards Ash Creek. Complete tailored cost benefit research to evaluate the water quality, aquatic habitat, and flood mitigation consequences of leaving woody debris in the streambed versus keeping debris clear.

- Perform local tests on soil infiltration and groundwater table depth. Contact the local organizations and ask which potential project sites listed in this report they would be most interested in. Perform the testing at these sites.

- Create a rainfall-runoff and/or groundwater model to gain a clearer idea of the influence that LID projects or future development may have on flooding and pollutant loading of Ash Creek. SWMM model or HEC-HMS would likely be appropriate models. The SWMM5 LID Control for Green Infrastructure Modeling tool may be useful here.

- Design a study to collect data on LID to address current limitations discussed in section 6.2. These limitations include data on local LID cost-benefits, LID implementation in small municipalities, LID implementation with minimal maintenance requirements, and measuring the relationship between LID and watershed-scale flood mitigation.

- Complete a formal literature review of available LID data. Data to consider may include information on cost-benefits of LID, flood mitigation benefits of LID, and experiences of different municipalities with implementing LID. A student could also identify which geographical areas lack available data.

- Build off past efforts to investigate the human and natural elements of groundwater flooding issues in Polk County. Past Oregon State University student, Joseph Kemper initially studied this issue in his thesis, “Groundwater Flooding and Guerrilla Trenches: a Participatory Approach for Flood Control” (Kemper, 2016).

6.4: Chapter Summary

This chapter discusses how this study can be used to guide stormwater management in the Ash Creek watershed and future academic studies of LID. This project is a preliminary study and the local stakeholders can build upon this effort by launching a more formal, targeted study of any LID solutions chosen, including TMDL permit compliance and regional LID standards. The local organizations can also use this study to guide collaboration with other organizations supportive of overlapping LID project types. This study is primarily limited by the lack of follow up interviews and availability of relevant data on LID. Future research opportunities exist in gathering more LID data and helping implement LID in the Ash Creek watershed.

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APPENDICES

APPENDIX A- STAKEHOLDER INTERVIEW GUIDE

The following document was used as the general template for the stakeholder interview guides. Individual guides with tailored details and names were produced for each interview, but these are withheld to protect the identity of the interviewees. All individual guides closely resembled this general template.

Intro Prompt

Hi, I'm Doug Chalmers. For this summer, I'm interning with the Luckiamute Watershed Council in Independence to investigate stormwater management along Ash Creek. We are performing a series of interviews with stormwater players around Polk County.

- May I use voice recorder?
    - Using summaries, some quotes. Nothing tied to name.
- Voluntary- Can stop interview, stop recording, leave off transcript
- What does LID mean to you?
    - (Show them picture of LID examples)

Interview Goals:

- *Determine LID status, objectives, barriers and opportunities in Ash Creek*
- *Collect data for problem areas to focus on*
- *Build partnerships between key organizations and start stormwater conversation*

1. What do you want from this internship? How can I **help**?
2. What **benefits** from LID would your organization be interested in?
    a. How can it help/hurt the goals of your organization?

3. What **barriers** would prevent your organization from pursuing LID?
    a. How can it help/hurt the goals of your organization?

4. Where are Ash Creek **flooding areas** or stormwater problems?
    a. Causes?
    b. Specific locations/map? (Frequent landowner calls, road issues, storm drain back-ups, etc.)

5. What **LID exists** already in the watershed?
    a. Why was it installed? Required/voluntary?
    b. How has its performance or maintenance been?

6. Where are some possible **pilot locations** for a LID project? What types of LID would work best?
    a. Any areas with land that can be accessed for this type of projects?
    b. What types of projects would you NOT want?

7. How do you envision a successful/unsuccessful LID program?

8. Are there any requirements related to LID in your current development **standards**?
    c. What about future development standards?

9. Where would you envision the **resources** coming from to implement LID?
    a. What other partnering organizations might want to help?

10. **Who else** should I to talk to?
    a. Homeowners/groups for focus group?
    b. Business owners/groups for focus group?

APPENDIX B- STAKEHOLDER INTERVIEW RESPONSES

Complete List of Barriers to LID Implementation:

# Stakeholders with Response	Response Group
9	Too expensive
7	Extra maintenance
6	No current LID standards/requirements
5	Do not think LID will work as promised
5	Not enough LID data and testing
4	Private property owners won't comply
4	Land will be taken from development
4	Staff time for project/code design
3	Aesthetic/environmental liability
3	Opposed to regulating
3	May not be applicable for current funding
2	Differing opinions on stormwater management
2	Too complicated
2	Lack of grants
2	Clayey/Impervious Soils
2	City area already highly developed
1	Cities are small overall portion of watershed
1	Conflicts with city codes
1	Do not need LID
1	Require herbicide use
1	Uninformed about LID

Complete List of Desired Outcomes from Internship:

# Stakeholders with Response	Response Group
6	Research LID costs and benefits
6	Create list of possible LID projects
5	Perform LID outreach/demonstration
4	Research performance of existing LID
4	Create list of LID tools/types
4	Provide LID funding info
3	Research LID standards
2	Review current city codes
2	Voluntary solutions
2	Hydrologic Testing
2	Information on tools for certain soils
1	Complete easy projects

APPENDIX C- PUBLIC FOCUS GROUP GUIDE

The following document was used as a guide for conducting the Ash Creek Stormwater Solutions Forum held on September 12, 2017 at the Monmouth Public Library.

1. Introduce Forum

- Hand outs
  - Handout map/flyer

- Forum:
  - **Room reservation until 7:30**. May leave anytime.
  - I will **ask questions**, LWC will take notes. **Consent?**
  - Voluntary- leave anytime, leave off transcript
  - Responses will be summarized, but **anonymous.**

- Purpose:
  - How **resident** perspectives and solutions can fit into overall stormwater management of Ash Creek

- My Background:
  - **Intern** with LWC You may ask me questions about these devices, but I am **not an expert** at all.
  - **Introduce LWC**. Local non-profit run by volunteer board with a service area of the Luckiamute and Ash Creek watershed focusing on voluntary restoration to improve the watershed.
  - It is more **my role to bring your perspective** to the ACWCD, LWC, and Independence and Monmouth
  -

2. Ground Rules

- Speak one at a time
- Be respectful
- Share the airtime. Limit time
- Cell phones
- Parking lot for questions
- Ask audience- what rules do you have?

3. Introduction

- **What motivated you** to come**?** In 1 or 2 sentences

4. Questions

- What **does stormwater mean** to you?

- There are many terms for the pictures that I have handed out. How familiar is everyone with the **terms stormwater solutions**, green infrastructure, or Low Impact development?

- What are your **concerns** for Ash Creek?

- What are the **solutions** you would like to see homeowners taking up?
  - In what ways would you be willing to **contribute**?

- What sorts of **resources** would you want to help reach these solutions?

- Some localities have cost-sharing or **rebate programs** to encourage homeowner stormwater solution installation. How could you imagine this happening here?

- Have you **seen any stormwater devices** around town or other areas? What are your **impressions**?

- What **questions** do you have **for me**?

APPENDIX D- PUBLIC FOCUS GROUP RESPONSES

These notes are a summary of the Ash Creek Stormwater Solutions Forum held on September 12, 2017 at the Monmouth Public Library. This forum was open to the public and nine local residents attended. These notes were sent to all the participants after the focus group.

Why did participants attend this forum?

- Concerned for riparian zone/helping stream ecology (x4)
- Interested in solutions beyond individual (x2)
- Past flooding issues on property
- Concerned of how future development will impact Ash Creek

What other concerns do participants have for Ash Creek?

- Polk County won't let homeowners clean out Ash Creek and remove tree limbs
- Lack of riparian areas and floodplains are contributing to flooding
- Concern that summer irrigation will cause water shortages with future population growth
- Bioswale plantings may add exotic, non-native plantings to the ecosystem

Desired solutions for Ash Creek:

- Each citizen with roof should be encouraging infiltration on property to help
- Encourage city to pass laws for new development
- Stormwater solutions is too big a problem for the role of individual homeowners to help
- Require low impact development for future sidewalks and roads
- Find areas for large city projects
- Convert public properties for stormwater function, such as Madrona Park
- Convince cities that LID can save time and money in the future

What resources would be helpful?

- Volunteers to come strip ivy from property
- Answers to questions about agencies involved with resources
- Flyers with examples and cost ranges for simple things that homeowners can do
- Comprehensive guide for stormwater solution information
- Template that can be taken to a city council to facilitate adoption of policies or ordinances
- Side-by-side review of what current city codes are and what they could be

Ideas for voluntary LID installation programs:

- Reduction on stormwater bill (Independence has separate SW bill). Monmouth might be able to tie this in with water/sewer bill
- Rebates to have cheaper rain barrels/LID items
- Resource with clear directions on what to do, who to talk to, how much it costs, any permits, etc.
- Provide lenience in building permits if installing LID
- City can find funds and award grants to homeowner associations who want to do projects

What are your impressions of any LID features you've seen?

- Permeable pavers in Monmouth, but seem to have bumps over the years.
- Rain gardens at WOU
- Whole parking lot in Dundee is permeable paved- beautiful

Questions from Participants

(Answers provided by Doug Chalmers) (*Answers provided by other participants*)

- **Can Polk County or Army Corps of Engineers send help to maintain a "free-flowing" Ash Creek?**

  I am not sure, unfortunately. This would be a question for public officials.

- **Is it a state or federal law to keep Ash Creek free-flowing?**

  While it is generally within US Common Law to maintain the "natural flow" of a river, I believe this applies to dams and diversions, not to natural blockages such as downed logs or vegetation. Not positive though!

- **Can you use Low Impact Development to mitigate flooding?**

  Yes! Low Impact Development increases infiltration, which decreases the amount of water rushing into the waterway during storm events. Whether or not Low Impact Development is the **best** way to mitigate flooding is unclear, but it certainly helps.

- **How can you pass county or city rules to require stormwater solutions with development?**

  Create LID Standards for development or a program for Voluntary LID Installation Incentives.

- **Are Hoffman and Riddel road going to be replaced in 2018?**

  ODOT said not doing work on Riddle Road.

- **How do the dynamics of the Ash Creek Basin impact its ability to move water through its system? What is the role of the floodplain?**

  This is a complex question that would require lengthy research to answer properly.

- **Who controls floodplain permits in Polk Co., Independence, and Monmouth?**

  Floodplain permitting is generally within the jurisdiction of the Army Corps of Engineers. However, I do not know the specifics!

- **Can Low Impact Development be used to alleviate water shortages in the summer?**

  Yes! Low Impact Development increases infiltration, which allows more water to soak into the ground instead of running off immediately into the storm sewer system. This means that there should be more moisture in the ground in the summer months and greater discharge of groundwater into local waterways. Unfortunately, I do not have any studies to quote on this and cannot say whether or not Low Impact Development is the **best way** to alleviate water shortages.

- **What role does the city planner have in implementing stormwater solutions?**

  I am not sure. This would be a question for the cities.

- **How to know if an individual homeowner site is a contributor to runoff?**

  Polk County Soil Water Conservation District and/or Luckiamute Watershed Council can likely help with this.

- **How to prevent standing water on property?**

  Polk County Soil Water Conservation District and/or Luckiamute Watershed Council can likely help with this.

- **Will the Luckiamute Watershed Council provide volunteers for ivy pulls and plantings?**

  LWC has limited capacity for organizing volunteer events outside of current projects. It may possible to put out a call for volunteers, but the LWC would not be able to cover cost of plants without initiating a project and seeking funding to support materials.

- **What are the downsides of rain barrels?**

  Because rain barrels involve standing water, they are legally unfit for potable use (humans and animals cannot drink it). If proper screening is not used, the barrel may attract mosquitos. Additionally, rain barrels are not able to collect rain when it is needed most for landscaping in the summer.

- **How much do homeowner LID features cost?**

  I was unable to find an easy answer to this. There are some homeowner brochures for LID features included in my report in Appendix K: LID Resource Guide -they may have more information.

- **How to avoid bumps in pervious pavers over time?**

  I was unable to find an answer for this. There are some materials on maintenance requirements for pervious pavers in my report in Appendix K- LID Resource Guide- they may have more information.

- **Do permeable pavers work in clay?**

  Generally, yes. Information from the BMP Suitability Matrix from OSU Extension: (http://extension.oregonstate.edu/stormwater/bmp-suitability-matrix-and-guidance) suggests that pervious pavers will work even in "slow infiltration soils" but will **not** work if the infiltration rate is < 0.1 inches per hour (this is **extremely** slow). Another way to think about it is that you are preventing runoff that would otherwise occur from asphalt. If you think it is hard for clays to absorb through pervious pavement, imagine how hard it would be for clays to absorb all the extra runoff coming off of asphalt!

APPENDIX E- GUIDE FOR CREATING LID STANDARDS

The following document was originally included within the "Low Impact Development Findings & Recommendations for the Ash Creek Watershed" report submitted to the Luckiamute Watershed Council and the Ash Creek Water Control District in October 2017. This document is included here to build off the information in section 5.6- Guide for Creating LID Standards to help enable municipalities to develop regional LID standards if they wish, as discussed in section 4.3.

LID Standard Creation Guide

Many local resources in Oregon are available to help minimize the staffing time required to design LID standards. The Green Infrastructure Implementation Forms by OSU Extension and the Template for LID Stormwater Manual for Western Oregon by Oregon DEQ were developed specifically for smaller municipalities to easily create their own standards.

Included below are a few of the questions that Polk County municipalities would need to answer to implement LID standards:

(1): What are the goals of the standard?

LID Standards can be used towards a number of different municipal goals.
Possible requirements include:

- *A given percent (%) of the site cover must be pervious*
- *Impervious areas must flow to a treatment BMP*
- *A design storm (often around 1-inch) must be managed on-site*
- *When feasible, infiltration must be used instead of detention to reduce peak flows*

(2): How would detention requirements be handled?

Given the local interest in flood mitigation, there is an important question of how to handle detention in the Ash Creek basin. There are a number of options, including:

1. *Keep current detention requirements, use LID standards only to address water quality*
2. *Eliminate detention requirements in certain downstream areas of Ash Creek*
3. *Require infiltration instead of detention whenever feasible*
4. *Allow LID BMPs to count towards detention requirements*

Possibility of Eliminating Detention Requirements Downstream

The City of Independence Stormwater Master Plan discusses the idea of eliminating detention requirements so that city runoff enters Ash Creek ahead of large surges from upstream. Eliminating detention in Independence and Monmouth may be a feasible way to reduce peak flows, although doing so in upstream areas around Dallas would likely not reduce peak flows to Ash Creek. Note that water quality would be adversely affected if this runoff is untreated.

Questions to ask include:

- *Would eliminating detention requirement in Monmouth and Independence be an effective approach to reduce peak flows in Ash Creek during large storms?*
- *How can development be kept on an even playing field if Monmouth and Independence eliminate detention requirements, but Dallas does not?*

Possibility of Using Infiltration-based Requirements

Given the uncertain flood mitigation effects of detention in downstream areas of the watershed, it may be possible to use an infiltration-based stormwater requirement (**i.e. require a certain inch/hour intensity of rainfall to be handled on-site**). Doing so would reduce the peak flows in Ash Creek by reducing the total volume of runoff from sites.

It may also be possible to integrate LID infiltration within current detention requirements. Many of the cities with existing LID standards included methods allowing the use of LID BMPs to reduce the required size of any detention facilities. These methods may include a reduction in Curve Number (CN), or a subtraction of the infiltrated depth from the total rainfall required to detain.

Questions to ask include:

- *Are infiltration-based standards appropriate for flood mitigation of large storm events?*
- *Are the poor soils common in the Ash Creek watershed too great a barrier to adopt infiltration standards?*
- *How can requirements be structured to encourage the use of LID towards flood mitigation?*

(3): What would be the water quality requirements?

Treatment Requirements

Common water quality requirements set treatment criteria for Volume-based BMPs (ponds, rain gardens, planters) and Flow-based BMPs (swales, filter strips, proprietary devices). The criteria are set to **treat 80% of annual rainfall**. The common standards encourage the use of infiltration-based BMPs, but allow for filtration-based BMPs instead in areas with poor soils (generally infiltration rate < 0.5 inches/hour).

Area Requirements

Area of the site required to be routed through a treatment device is another important consideration. DEQ recommends leaving no more than 500-1000 ft^2 of impervious area untreated, but many cities require 100% of impervious areas to be treated. Cities also set a minimum area for a development project needed to trigger the water quality requirements (often 500-1000 ft^2 of new or redeveloped impervious area).

Questions to ask include:

- *What would the 80% annual rainfall design storm be in the local area?*
- *How can the Standards encourage treatment without imposing overwhelming costs in areas of poor infiltration soils?*
- *How much impervious area should be required to be treated?*
- *What is the minimum project size needed to trigger water quality requirements?*

(4): What BMP devices and standards will be accepted?

Municipalities are able to select the types of BMPs and specify the standard detail designs that will be accepted for the LID standards. More options allow for more flexibility from the developer, but can require more training for Public Works staff to approve, inspect, and maintain all these different device types. See Appendix I- Inventory of Existing LID to see what types of devices are already being used in the watershed. Info on BMPs can be found in Appendix K- LID Resource Guide.

Common Types of BMPs:

- Rain garden
- Biofiltration
- Bioswale
- Stormwater planter
- Veg. filter strip
- Pervious pavement
- Tree credits
- Wet pond
- Dry pond
- Constructed wetland
- Sand filter
- Soakage trench
- Drywell
- Proprietary devices
- Green roof
- Curb extension
- Rainwater harvesting

BMP Standards Specifications

Standards, specifications, and details for the various BMPs can be found in the various stormwater manuals for Eugene, Florence, Gresham, Portland, and Salem as well as the Template for LID Stormwater Manual for Western Oregon. While it is common practice to adopt a set of existing specifications/details (Florence and Stayton use Portland's designs), special care must be taken to match them with the compliance goal and design storms used in the local standard. BMP Specifications can be found in Appendix K- LID Resource Guide.

Questions to ask include:

- *What types of BMPs will be accepted in which cities?*
- *How can the existing designs for these BMPs be used while staying compatible with local requirements?*

(5): How will BMP sizing calculations be performed?

To size water quality BMPs, the cities in Oregon use the following methods:

- Small residential and commercial projects use either:
    1. Green Infrastructure Implementation Forms *Newly developed (2018) by OSU Extension*
    2. FORM SIM: *Developed by DEQ, used by Eugene and Florence, Gresham*
    3. Simplified Approach Form: *Developed Portland, used by Portland, Stayton, Salem*

- Larger projects:
    1. Green Infrastructure Implementation Forms *Newly developed (2018) by OSU Extension*
    2. Presumptive Approach Calculator: *Developed by City of Portland*

Additional BMP sizing calculators can be found in Appendix K- LID Resource Guide.

(6): How will maintenance be handled?

The Operation & Maintenance tasks required for each BMP are generally specified within the stormwater code. The maintenance forms and requirements can be found within the stormwater manuals mentioned in this section.

Options for the developer to choose from for maintenance of LID BMP devices may include:

1. City Maintenance: *City performs maintenance with revenue from collected stormwater fees. Annual city inspection of device.*
2. Private Maintenance: *Developer performs maintenance themselves to earn stormwater fee rebate. City performs annual inspection and collects fines if BMP has not been properly maintained.*

APPENDIX F- EXAMPLES OF VOLUNTARY LID PROGRAMS

The following document was originally included within the "Low Impact Development Findings & Recommendations for the Ash Creek Watershed" report submitted to the Luckiamute Watershed Council and the Ash Creek Water Control District in October 2017. This document is included here to build off the information in section 4.4- Incentivizing Voluntary LID Installation as one of the tools developed to help implement LID in the Ash Creek Watershed.

Example Voluntary LID Programs in the Pacific Northwest:

Stormwater Fee Discounts:

City of Dallas Low Impact Development Incentives

- System Development Charges (SDC) Credits:
  - Credit for up to 50% of SDC charges may be earned for reducing stormwater runoff volume.

Sandy, OR Stormwater Management Incentive Program

- Stormwater Fee Discount:
  - Up to 33% discount awarded based on percent (%) of impervious surfaces treated by BMPs.
- Stormwater Fee Waiver:
  - Commercial properties may waive 100% of their stormwater fees if they completely avoid using impervious surfaces (i.e. only use pervious pavement or green roofs).

City of Eugene Stormwater Service Charge Reduction

- Stormwater Fee Discount for Containment:
  - Property owner may earn up to 100% fee discount based on percent (%) of impervious surfaces with 10-year storm runoff completely contained on-site.
- Stormwater Fee Discount for Water Quality Treatment:
  - Up to 10% discount awarded based on percent (%) of impervious surfaces treated by BMPs.

Portland Clean River Rewards

- Residential Stormwater Fee Discount:
  - Up to 35% discount awarded based on percent (%) of impervious surfaces treated by BMPs.
  - Up to 8% fee reduction may be earned based on number of trees on property.

- Commercial Stormwater Fee Discount:
  - Commercial areas eligible for larger discount, but subject to more rigorous requirements:

Marysville, Washington Rainwater Harvesting Reduction (14.19.080)

- Rainwater Harvesting Fee Discount:
  - A 10% stormwater fee discount is earned with installation of a roof rainwater harvesting system.

King County, WA Surface Management Fee Discounts and Cost-Sharing Program

- Stormwater Facility Discount:
  - Residential properties can earn up to 50% fee discount for installation of BMPs.
  - Non-residential properties can earn up to 90% fee discount for installation of BMPs.
- Discount for Forested Conditions:
  - Earn 50% annual fee break if property is 65% forested and has no more than 10% effective impervious area (calculated impervious area can be lowered by using BMPs).

Some additional options for Stormwater Fee Discounts are shown below:

Goal of Discount	**Mechanism for Fee Reduction**	**Process for Implementation**
Reduce Imperviousness	• Percent fee reduction • Per-square-foot credit	• Percent reduction in imperviousness • Square feet of pervious surfaces
On-site Management	• Percent fee reduction • Quantity/Quality credits (performance-based)	• List of practices with associated credits • Total area (square feet) managed
Volume Reduction	• Percent fee reduction • Performance-based quantity reduction	• Percent reduction in imperviousness • Performance-based • Total area (square feet) managed • Practices based on pre-assigned performance values
Use of Specific Practices	• Percent fee reduction • One time credit	List of practices with associated credits

Source: Green Infrastructure Incentive Mechanisms (EPA, 2009b)

Development Incentives:

City of Dallas Low Impact Development Incentives

- Residential Density Bonus:
    - Can increase development density by up to 25% based on measures of energy efficiency, open space, stormwater runoff reduction, and others.

Rebates:

Portland Clean River Rewards

- Downspout Disconnections:
    - Homeowner reimbursed $53 for installing downspout disconnections on property.
- Cost-Share and Credit Program:
    - Non-residential properties converting impervious areas to vegetated areas eligible to have 50% of the costs covered up to $20,000.

Seattle: RainWise Program

- Rain Garden Rebate
    - In certain priority areas of Seattle, homeowners can hire a RainWise contractor to install a rain garden or cistern (large rain barrel) on their property and will receive a rebate afterward.

APPENDIX G- IDEAS FOR POTENTIAL LID PROJECT SITES

DISCLAIMER:

Ideas are simply suggestions from stakeholder interviews, NOT formal plans:

The projects listed are simply a compilation of ideas suggested by stakeholders during the interviews. They are only meant to be used as a brainstorming tool. The mention of private lands do not imply that any plans currently exist for implementation of these ideas or that landowners have given consent for these activities.

Professionals should say what is possible:

These ideas should not be pursued without consulting a professional. Soil infiltration rate and groundwater table information needs to be tested on-site. The data provided here from USDA Web Soil Survey is not accurate to determine which types of projects are or are not possible without confirming with onsite testing. In many cases, special grading, liners, or soil amendments can be used to install different stormwater solutions even in sub-optimal conditions.

How to use this Guide:

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Wildfang Park	Med low	1	-	C to D	Some	Yes
Possibilites:	Native plantings, regional retention facility, LID infiltratiom					

Infiltration Potential:

- Data provided here are is not accurate at a site scale and infiltration rates should always be confirmed with onsite testing before determining what types of projects are possible.
- Note that soil amendments may always be used to increase infiltration
- A function of the **highest** hydrologic soil group (HSG) within the project area
  - HSG A = High infiltration potential (N/A in this basin)
  - HSB B = Medium infiltration potential (rare in this basin)
  - HSG C = Medium Low infiltration potential
  - HSG C/D or D = Low infiltration potential
  - HSG C/D or D with Shallow GW Table = Very Low infiltration potential

 # Flooding Areas Downstream:

- The number of the 7 listed Flooding Areas (see Appendix J- Reported Flooding Locations) that lie downstream of the project location.
- Theoretically, the more flooding areas lying downstream, the more benefit there is to the project.

Does it drain to a small tributary?

- Looks at whether or not the project site drains to a tributary of Ash Creek that is not a main branch of the North, Middle, or South Fork.
- The flood and erosion prevention benefits of these projects may be more pronounced at project sites along smaller streams.

Hydrologic Soil Group (HSG)

- The data from Web Soil Survey is not meant to apply to site-scale design. If interested in pursuing one of these projects, site-specific infiltration tests will provide more accurate data.
- Note that soil amendments may always be used to increase infiltration
- Data gathered from Web Soil Survey that is a measure of the runoff potential of the soil. HSG D is least suited for infiltration while HSG A is best suited for infiltration.

Shallow Groundwater Table? (< 2ft)

- Web Soil Survey data is not meant to apply to site-scale design. Field testing should be used to confirm this data.
- Data gathered from Web Soil Survey on the groundwater table depth at the site.
- Shallow groundwater table can make infiltration devices impractical. However, liners can sometimes overcome this issue.

Within 100-Year Floodplain

- Data from FEMA (National Flood Hazard Layer) on whether or not the site lies within the 100-year floodplain. Certain BMPs are not appropriate for floodplain areas.

Possibilities

- Loose ideas on what may be possible at site. In many cases, no more information was available than what was provided by interviews. These ideas are not exhaustive and should not be pursued without consulting a professional.

Background:

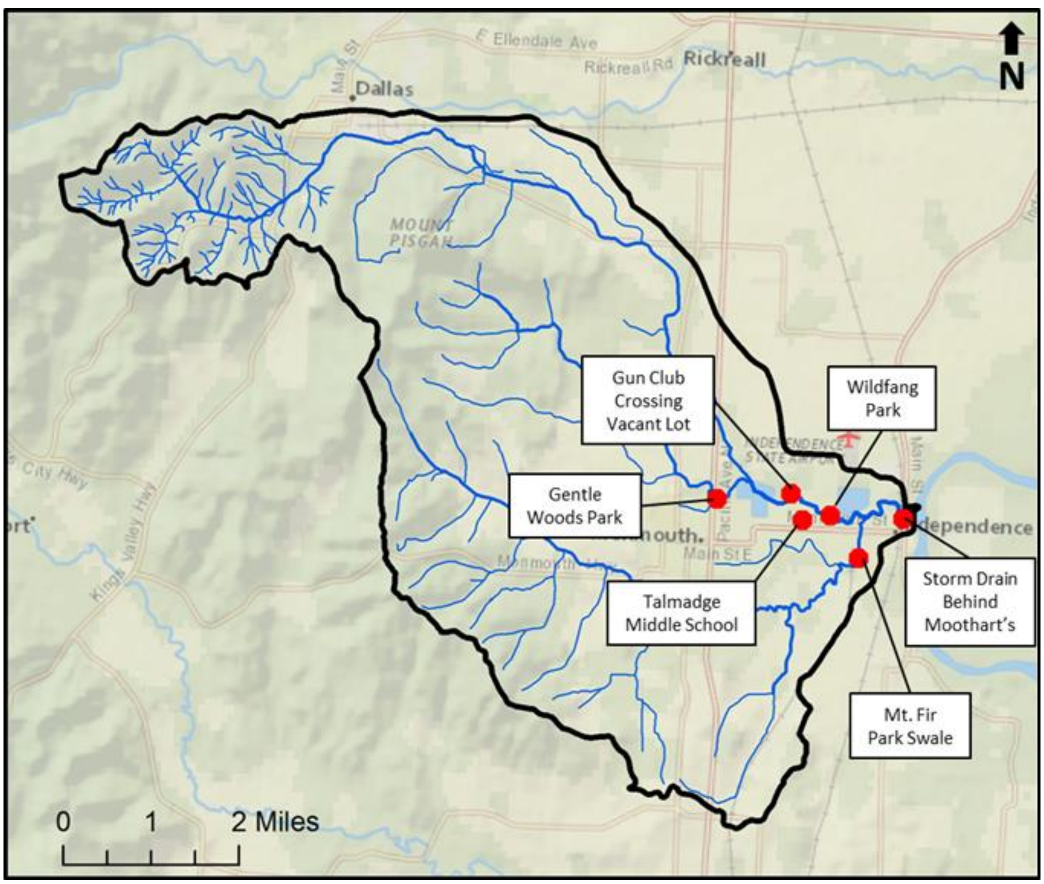
- Information provided from interviews (should be confirmed by field visits from professionals).

Possibilities:

- Brief commentary on what types of projects may be feasible on site. These ideas should not be pursued without consulting a professional.

Public Land Project Ideas:

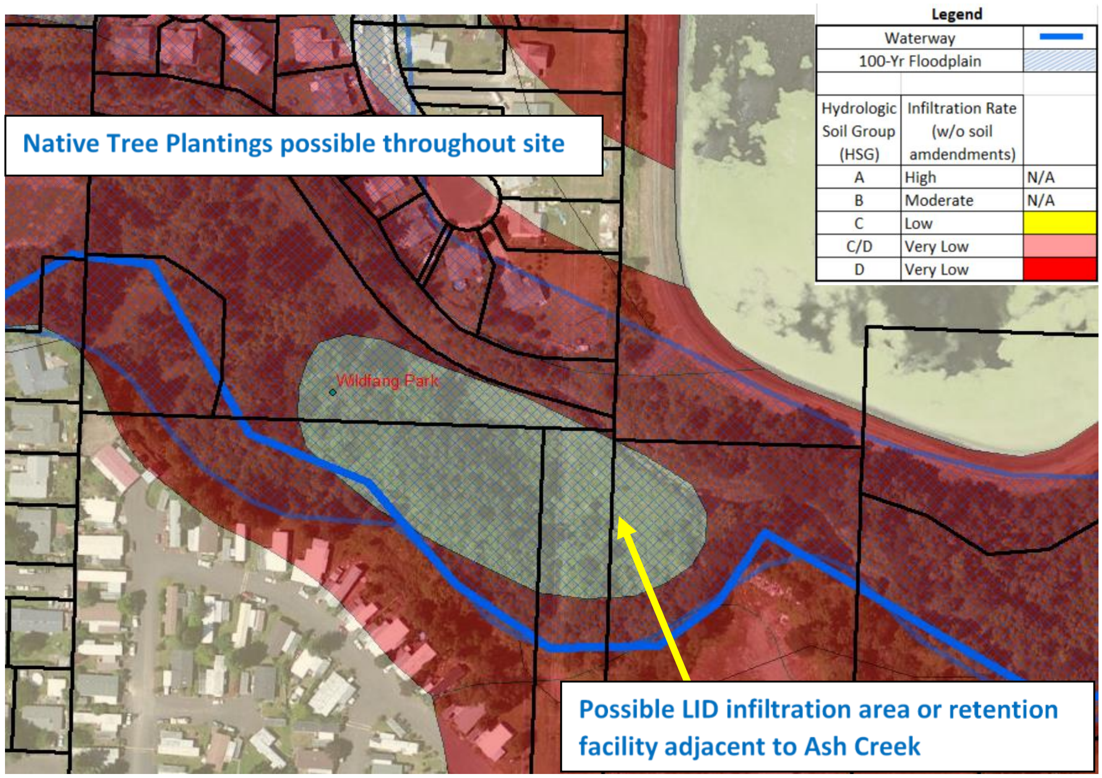
Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Wildfang Park	Med low	1	-	C to D	Some	Yes
Possibilites:	Native plantings, regional retention facility, LID infiltratiom					
Talmadge Middle School	Med low	2	-	C to C/D	Some	Some
Possibilites:	Stair-stepping device, LID infiltration					
Mt. Fir Park Swale	Low	1	-	C/D to D	-	Some
Possibilites:	LID infiltration					
Gun Club Road Crossing Lot	Very Low	2	-	D	Yes	Yes
Possibilites:	Regional retention facility					
Gentle Woods Park	Very Low	2	-	D	Yes	Yes
Possibilites:	Infiltration facility, regional retention facility native plantings					
Storm Drain behind Moothart's	Very Low	1	-	D	Yes	Yes
Possibilites:	Rip Rap, properietary BMP's					



Wildfang Park

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Wildfang Park	Med low	1	-	C to D	Some	Yes

Possibilities: Native plantings, regional retention facility, LID infiltration



Background:

Wildfang Park floods every year and is undevelopable. Native plantings may help to cut down on invasive grasses and spraying.

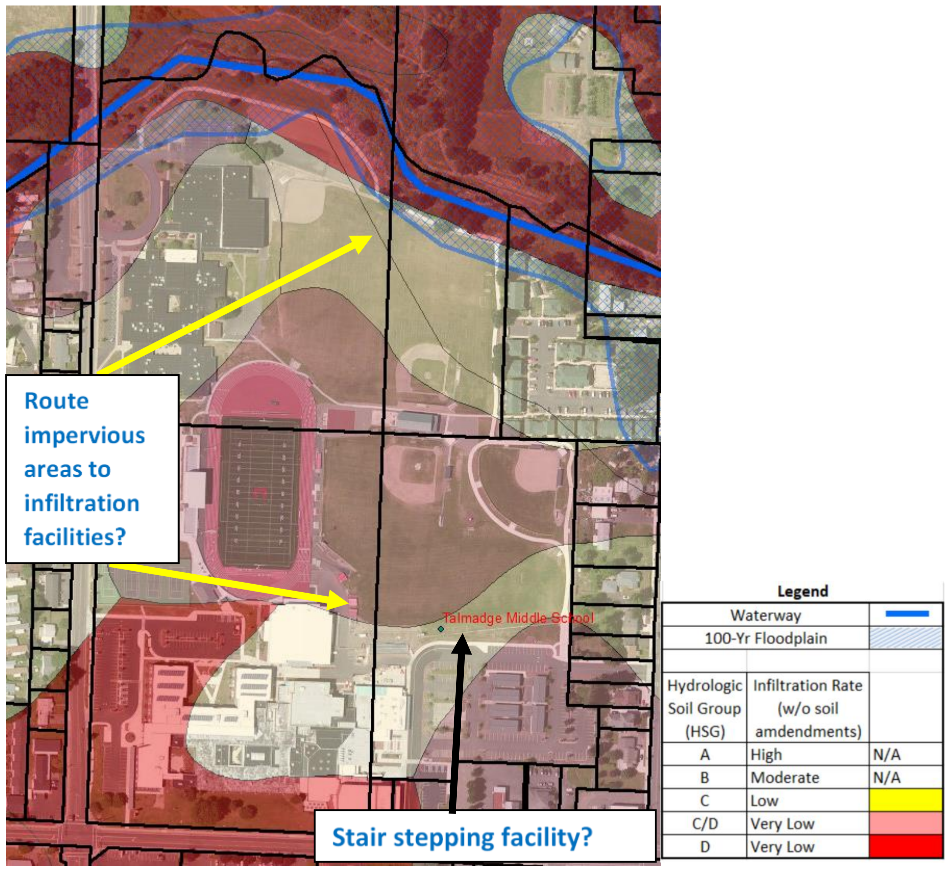
Possibilities:

Native plantings can help with infiltration even in poor soils. There is an area of open space with some natural infiltration (HSG C) where it may be possible to build a retention pond or rain garden/bioswale. However, if this area has a high groundwater table and is in the floodplain, extra measures such as liners or soil amendments may be necessary.

Talmadge Middle School and Central High School

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Talmadge Middle School	Med low	2	-	C to C/D	Some	Some

Possibilities: Stair-stepping device, LID infiltration



Background:

Previous projects were explored to add flood control and stair-stepping, but it was too expensive.

Possibilities:

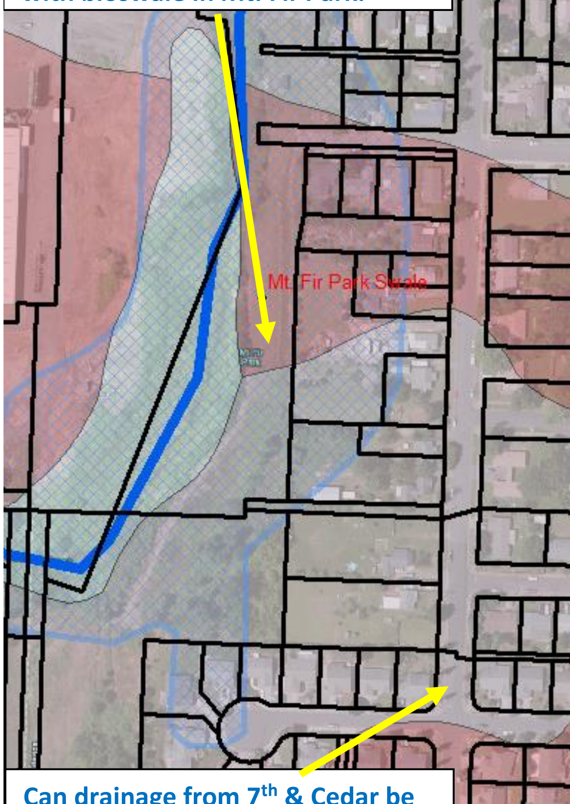
It may be possible to find another contractor and try to add stair-stepping again. There are many impervious areas here with the school buildings and parking lots, so it may be possible to route this areas to an LID infiltration rain garden/bioswale in the field areas similar to the existing one on the north side of the building.

Mt. Fir Park Area Swale

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Mt. Fir Park Area Swale	Low	1	-	C/D to D	-	Some

Possibilities: LID infiltration

It may be possible to connect pipe with bioswale in Mt. Fir Park.



Can drainage from 7th & Cedar be pre-treated in Mt. Fir Park?

Legend

Waterway		[blue line]
100-Yr Floodplain		[hatched]
Hydrologic Soil Group (HSG)	Infiltration Rate (w/o soil amdendments)	
A	High	N/A
B	Moderate	N/A
C	Low	
C/D	Very Low	
D	Very Low	

Background:

There is said to be a retention swale or drainage from 7th & Cedar Intersection leading to Mt. Fir Park. It appears as if this drainage is eventually piped to the creek. However, there is a small wetland of Oak Savannah and an existing bioswale on site that may be able to pre-treat this drainage.

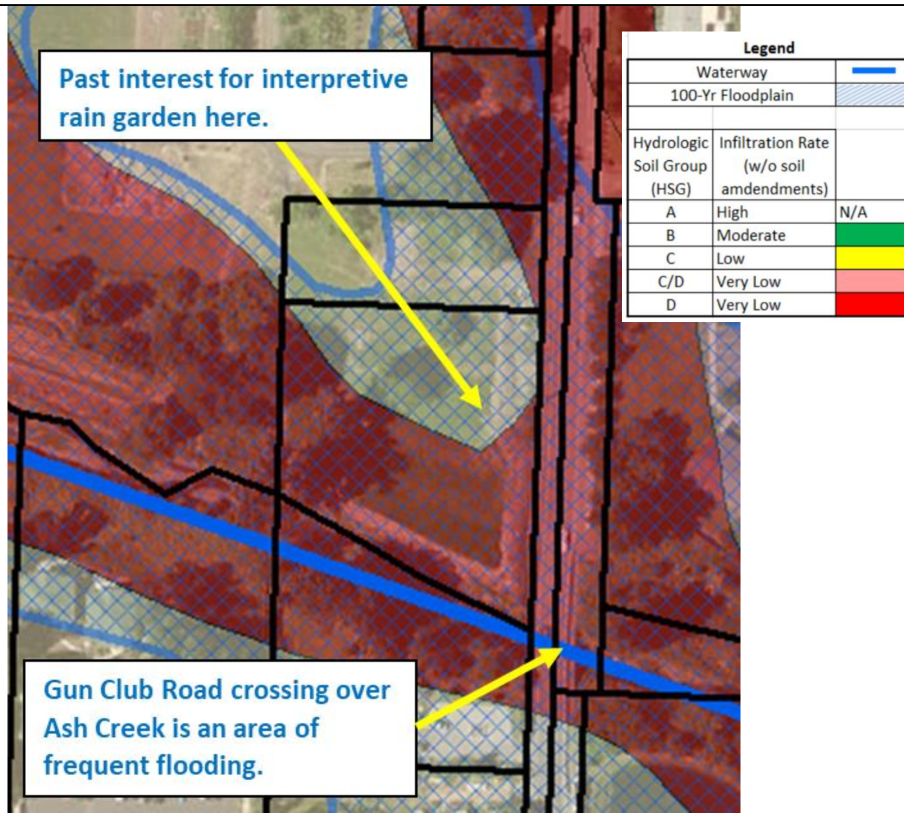
Possibilities:

Upon field visit, the nature of this drainage route is largely unclear. The desire of the Master Gardener's to use the bioswale in Mt. Fir Park for this purpose is unknown.

Gun Club Road Crossing Vacant Lot

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Gun Club Road Crossing Lot	Very Low	2	-	D	Yes	Yes

Possibilities: Native plantings, regional retention facility



Background:

The City of Independence has expressed past interest in taking the runoff from Gun Club and route it into a rain garden or retention facility. This property was initially purchased by the City of Independence in order to alleviate flooding damages.

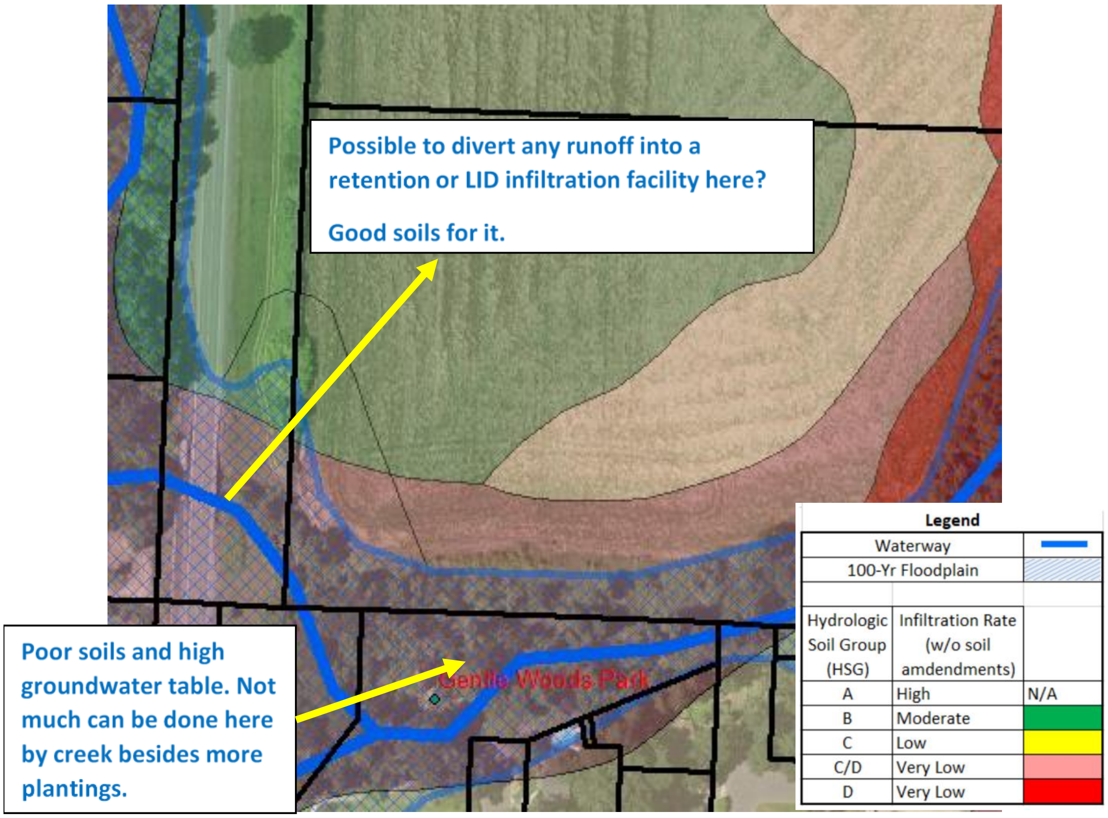
Possibilities:

Infiltration tests performed at this site (Appendix H) indicate that soils will likely support an infiltration facility.

Gentle Woods Park

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Gentle Woods Park	Very Low	2	-	D	Yes	Yes

Possibilities: LID infiltration, regional retention facility, native plantings



Background:

There was curiosity if something can be done in the low riparian area that would not take away from park space.

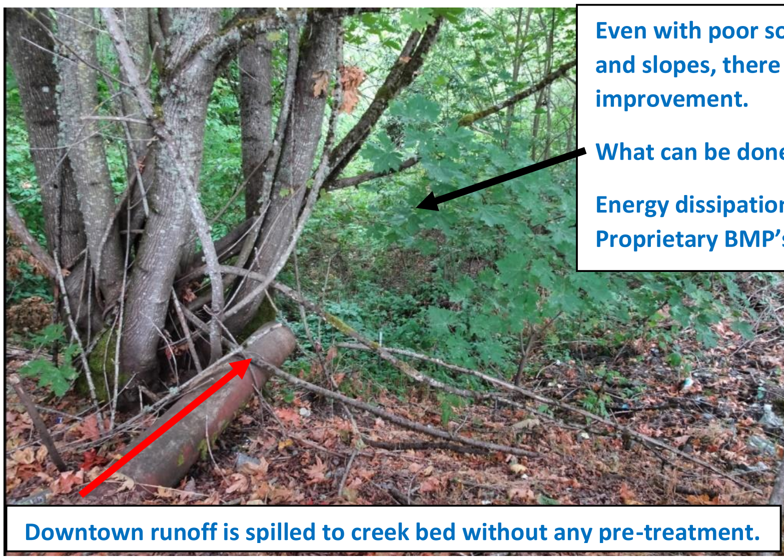
Possibilities:

Poor soils, likely high groundwater table, and lack of much open space means there is likely not much to be done in the riparian area besides continue native plantings.

Good soils exist to the north of Ash Creek by the site in an open area [private property- *Interest of landowner is unknown and inclusion in this report does not indicate that a project is planned or expected for this site*] if there is any way to route any runoff into a regional retention or LID infiltration facility there.

Storm Drain behind Moothart's Market

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Storm Drain behind Moothart's	Very Low	1	-	D	Yes	Yes
Possibilities: Rip rap, proprietary BMP's						



Background:

Interest in performing pre-treatment for this storm pipe. Storm pipe carries runoff from much of the downtown roads and currently straight pipes it into the creek.

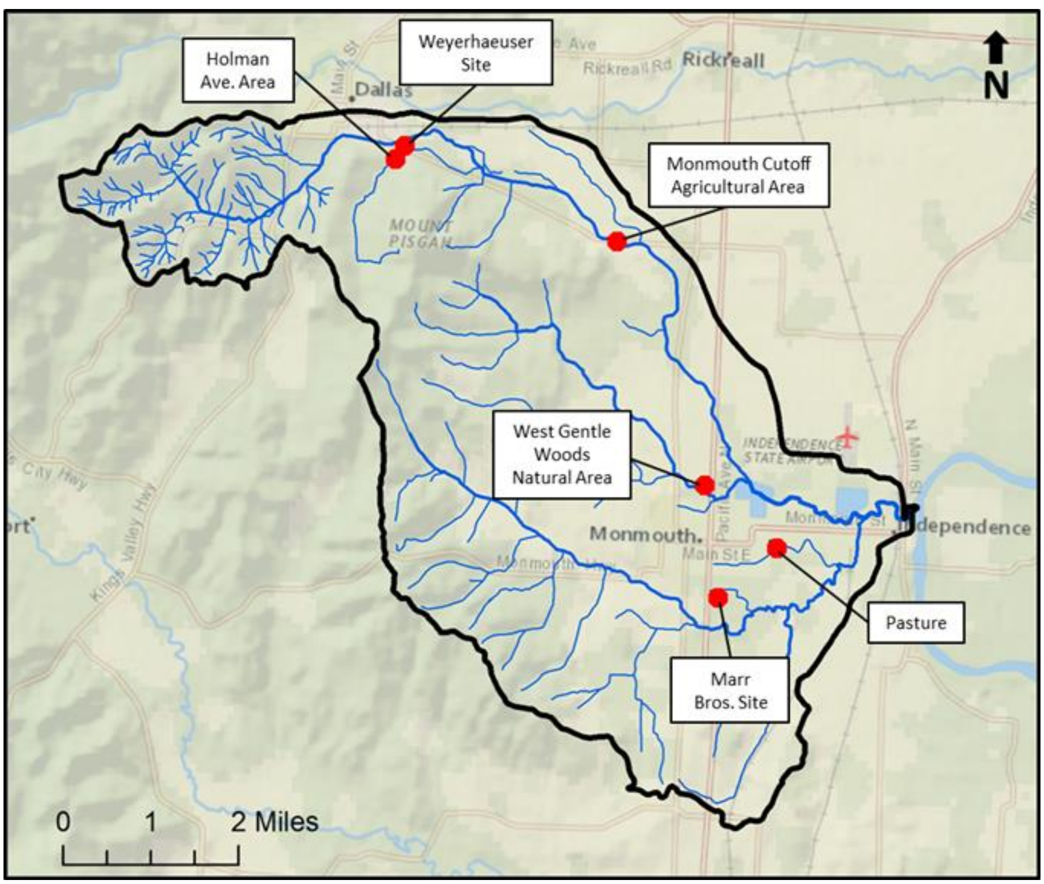
Possibilities:

Conditions are difficult in this area. Tight space, steep slopes, high groundwater table, poor soils. However, many options still likely can offer significant improvement over the current drainage. Rip rap/energy dissipation can prevent erosion, in turn helping water quality. Burying the pipe into a trench of drainage stone and amended soils may offer some pre-treatment. There are also likely proprietary BMPs (such as Contech) that can offer water quality and erosion benefits in this space.

Possible Locations for Voluntary Projects on Private Land:

Disclaimer: Interest of landowners are unknown and inclusion in this report does not indicate that a project is planned or expected for these sites.

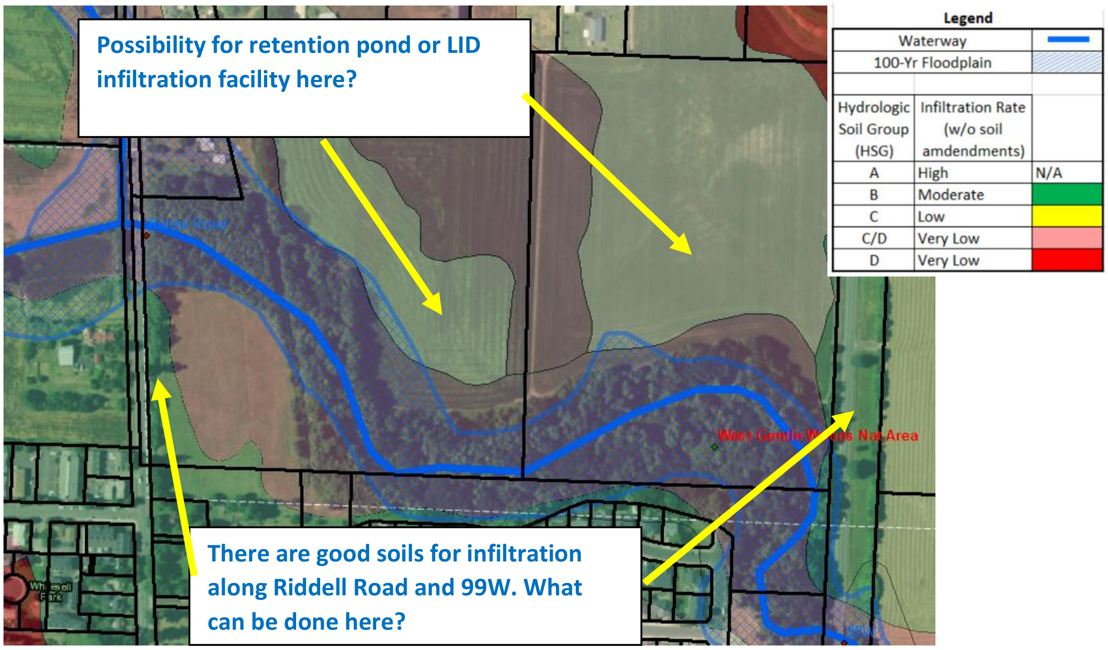
Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
West Gnt Wds Corridor Property	Medium	3	-	C/D	Yes	Yes
Possibilites:	Regional retention facility, LID infiltration, roadside BMP					
Pasture Site	Medium	1	Yes	B to D	-	-
Possibilites:	Regional retention facility, LID infiltration					
Holman Ave. Area	Med low	4	-	C	-	-
Possibilites:	Regional retention facility, LID infiltration, streambed restoration, incentives					
Monmouth Cutoff Agr. Area	Med low	2		C to D	Some	Yes
Possibilites:	Regional retention, USDA Wetlands Reserve, natve planting, contolled flooding					
Marr Bros. Site	Low	1	Yes	D	-	-
Possibilites:	Private incentives, LID infiltration facility					
Weyerhaeuser Site	Very Low	4	-	D	Yes	Yes
Possibilites:	Private incentives streambed restoration, native planting, retention facility					



West Gentle Woods Corridor Property

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
West Gnt Wds Corridor Property	Medium	3	-	C/D	Yes	Yes

Possibilities: Regional retention facility, LID infiltration, roadside BMP



Background:

This area (north of Burlwood Ave) is being privately maintained as a natural riparian corridor. There is some interest if anything more on the property can be done to mitigate flooding.

Possibilities

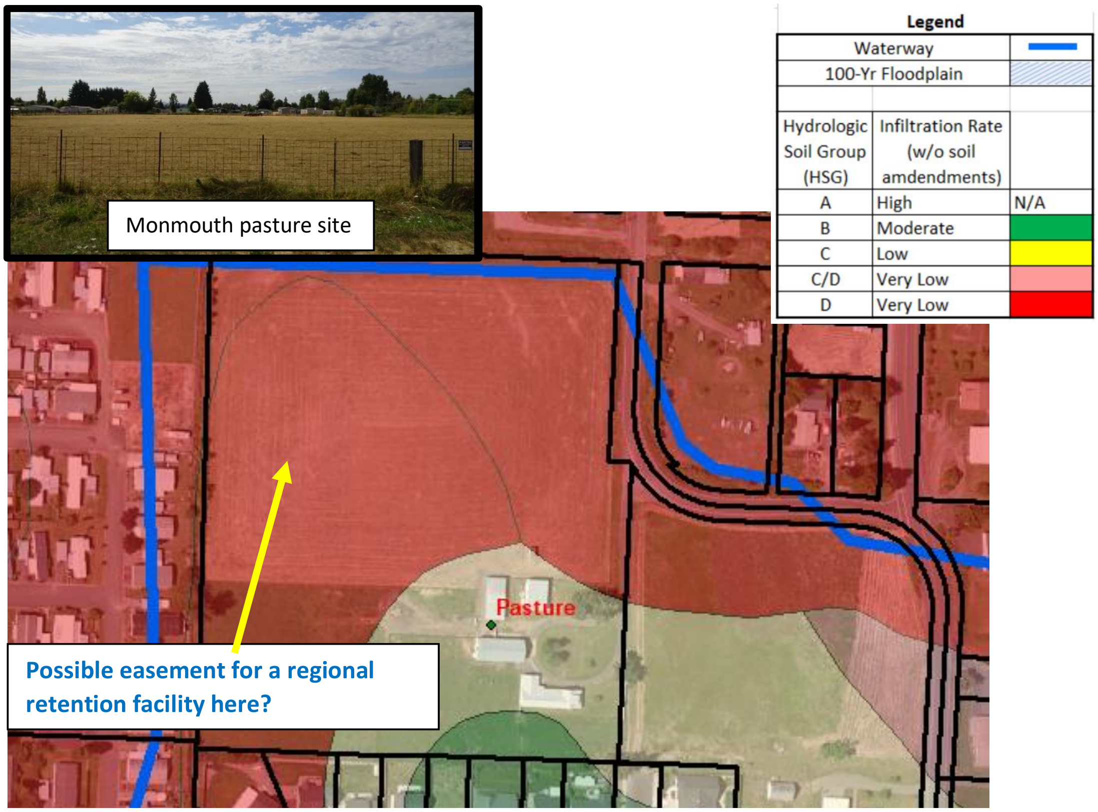
Although the soils immediately along the riparian area are very poor, there are good soils for infiltration along the edges of Riddell Road and 99W. A bioswale may be possible along these locations. There is enough space and good enough soils in the open fields to the north of the Creek. Would the owners be supportive of a retention or LID infiltration facility near here?

Disclaimer: Interest of landowner is unknown and inclusion in this report does not indicate that a project is planned or expected for this site.

Pasture Site

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Pasture Site	Medium	1	Yes	B to D	-	-

Possibilities: Regional retention facility, LID infiltration



Background:

This pasture site (north of Yosemite St. E) surrounded by residential areas in Monmouth has been identified as a possibility for a regional retention facility location based on the large amount of open space available.

Possibilities:

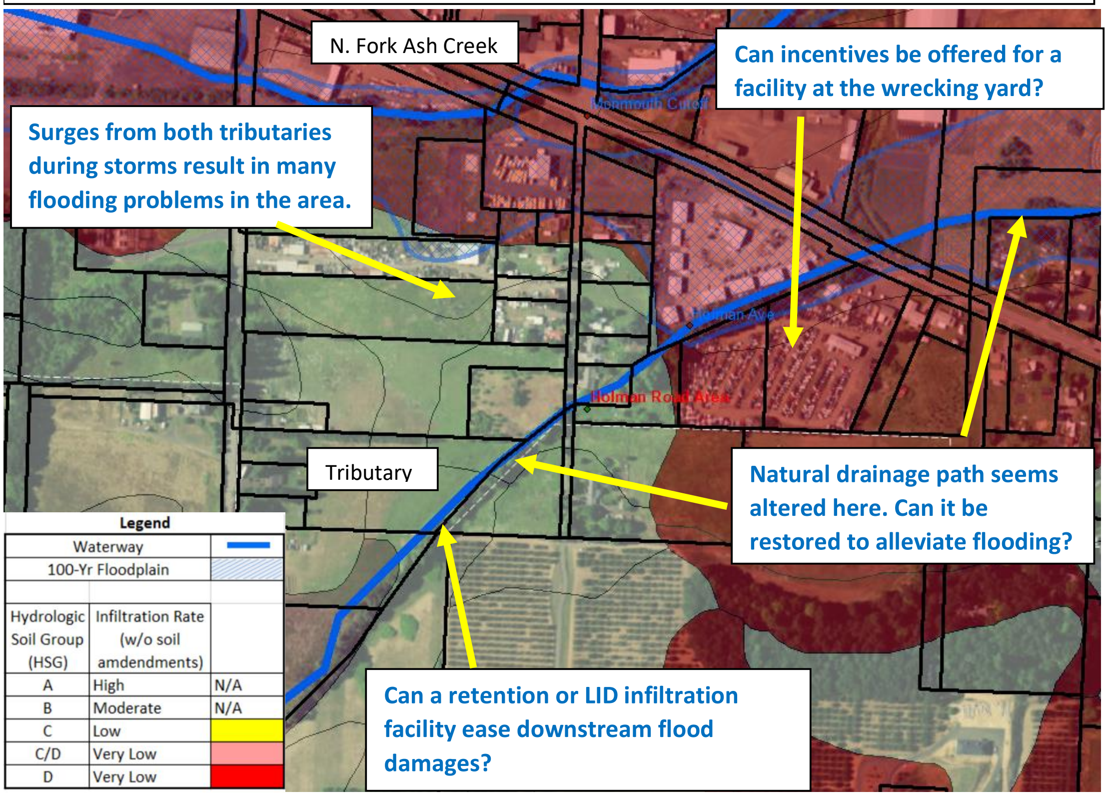
There is a creek running alongside the property and plenty of space for a retention facility. There are slow draining soils preventing much infiltration on most of the property. The southeast corner exhibits good soils for infiltration and an LID infiltration facility would be possible. The desires of the owner are unknown.

Disclaimer: Interest of landowner is unknown and inclusion in this report does not indicate that a project is planned or expected for this site.

Holman Ave. Area

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Holman Ave. Area	Med low	4	-	C	-	-

Possibilities: Regional retention facility, LID infiltration, streambed restoration, incentives



Background:

The pocket to the southeast of Holman Ave. and Monmouth Cutoff Road intersection experience surges from both North Fork Ash Creek and the tributary to the southeast. There are some older houses without foundations that experience significant flooding damage. The tributary has been rip rapped and culverted, so big surges often flood the areas in this pocket rather than following the creek. There has been past talk of performing a project in this area, perhaps near the wrecking yard site.

Possibilities:

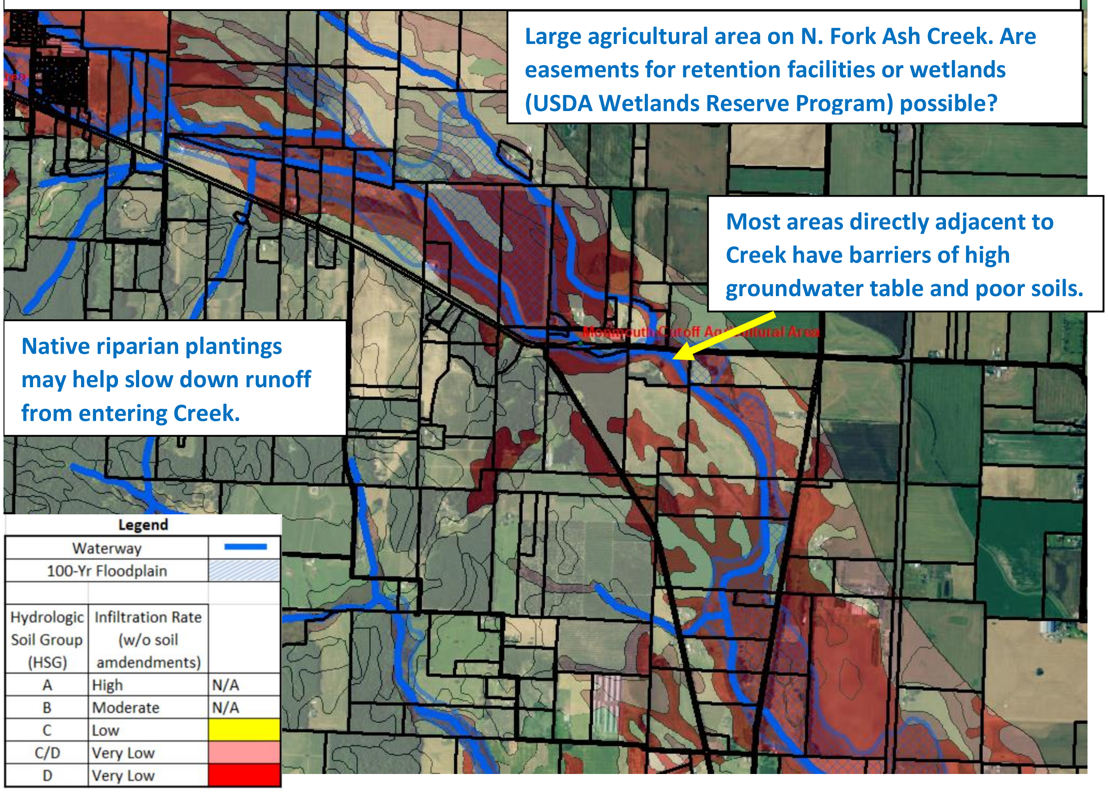
A retention or LID infiltration facility along the tributary could alleviate some of the large surges and prevent some flooding issues. It is possible that restoring some of the natural drainage paths and riparian vegetation could slow the tributary's surges down as well, benefiting all of those downstream.

Disclaimer: Interest of landowner is unknown and inclusion in this report does not indicate that a project is planned or expected for this site.

Monmouth Cutoff Agricultural Area

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Monmouth Cutoff Agr. Area	Med low	2		C to D	Some	Yes

Possibilities: Regional retention facility, USDA Wetlands Reserve, native plantings, controlled flooding



Background:

There was interest into using agricultural areas along the. N. Fork of Ash Creek to slow down surges, perhaps through retention basins. The possibility of controlled flooding was also discussed.

Possibilities:

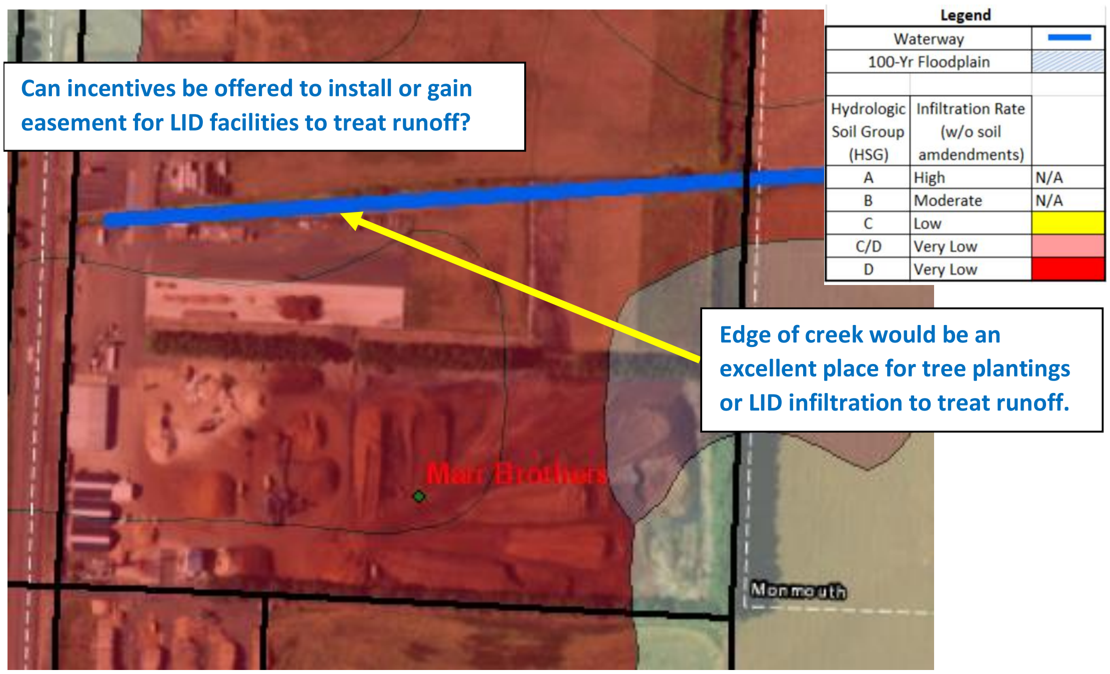
Immediately adjacent to the Creek, there are barriers towards retention basin or wetland construction such as high groundwater table and poorly draining soils. While not impossible, soil amendments and/or liners may be necessary. Further from the Creek, soils appear better. The USDA hosts the Wetlands Reserve Program which provides payment to farmers in exchange for an easement to construct wetlands on the property. Its applicability in this context is unknown.

Disclaimer: Interest of landowners is unknown and inclusion in this report does not indicate that a project is planned or expected for this site.

Marr Bros. Property

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Marr Bros.	Low	1	Yes	D	-	-

Possibilities: Private incentives, LID infiltration facility



Background:

The Marr Bros. Site was identified as a prime location to work with a private company to help implement LID runoff treatment measures.

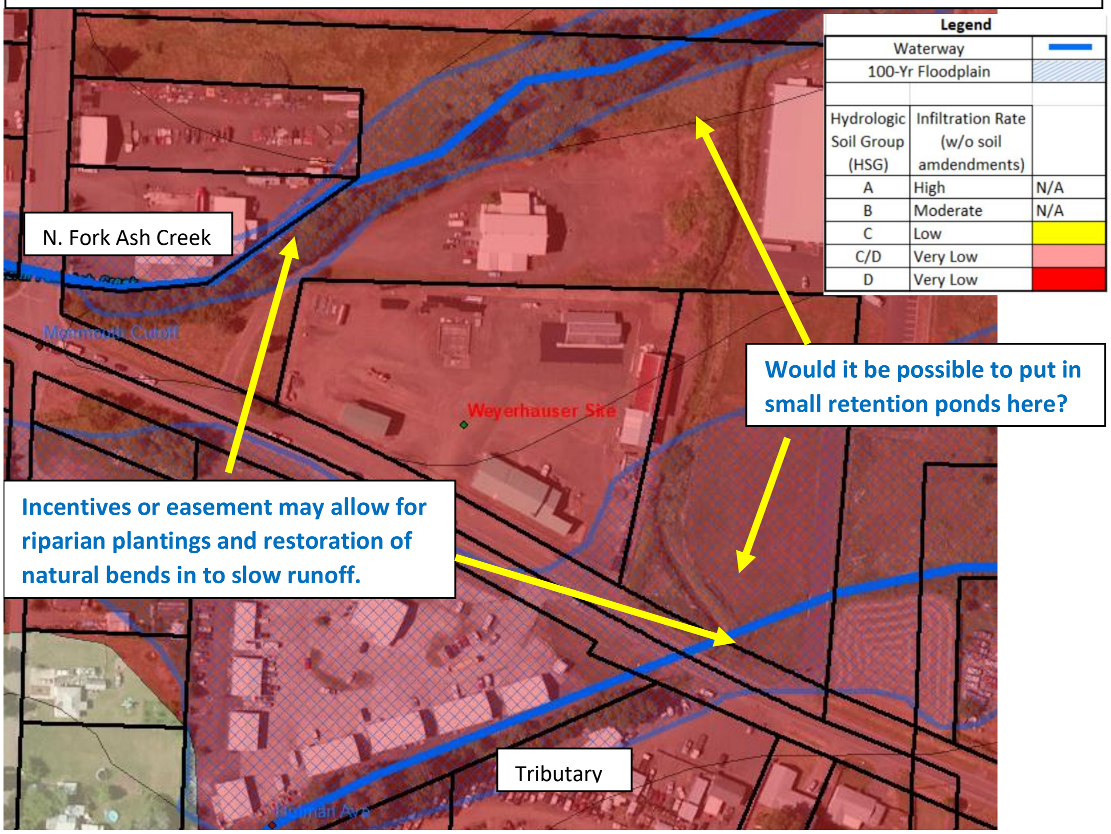
Possibilities:

The desire of Marr Bros. is unknown. Incentives may be a possibility to install or gain an easement for runoff control facilities along site. The soils are poor, but there are opportunities to treat the runoff on-site before it reaches the small tributary. Native plantings would work well even in poor soils and soil amendments may be used for a rain garden, bioretention, or other LID infiltration facility.

Disclaimer: Interest of landowner is unknown and inclusion in this report does not indicate that a project is planned or expected for this site.

Weyerhaeuser Site

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Weyerhaeuser Site	Very Low	4	-	D	Yes	Yes
Possibilities: Private incentives, streambed restoration, plantings, retention facility						



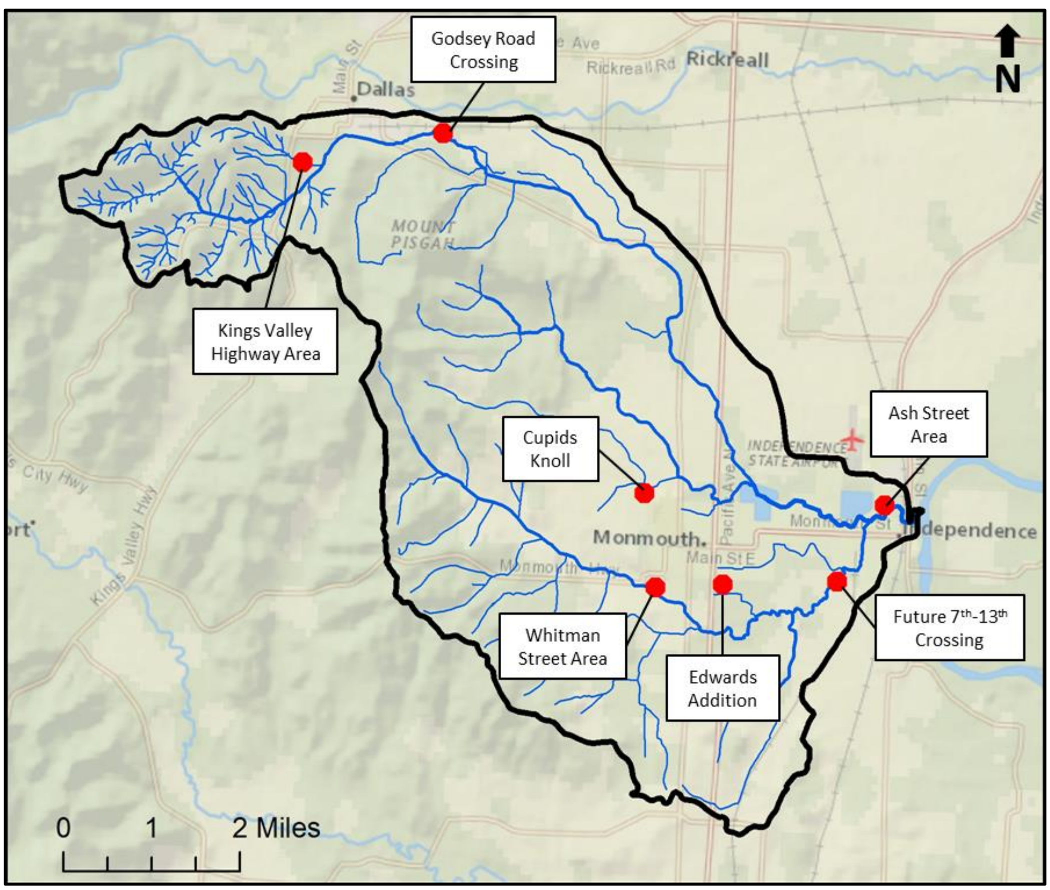
Background: During heavy rains, waters will jump across the Weyerhaeuser site and flood by Holman Road. Some portions of the Creeks near this site (unclear if N. Fork or tributary) have been paved over and culverted. There is interest in restoring the natural drainage and utilizing the area to mitigate flooding.

Possibilities: Weyerhaeuser has sold the site and the desire of the new owners is unknown. There is a possibility to offer incentives to restore or gain easements to restore bends in creek drainage. Field access to parts of the site were not possible, so the nature of the drainage paths could not be confirmed. Native plantings and restoration in riparian area could be beneficial. May be room for a small retention facility to the southeast and northeast of the site if the owners are willing. Note that the site likely features poor infiltration soils and high groundwater table.

Disclaimer: Interest of landowner is unknown and inclusion in this report does not indicate that a project is planned or expected for this site.

Opportunities to Work with Future Developers

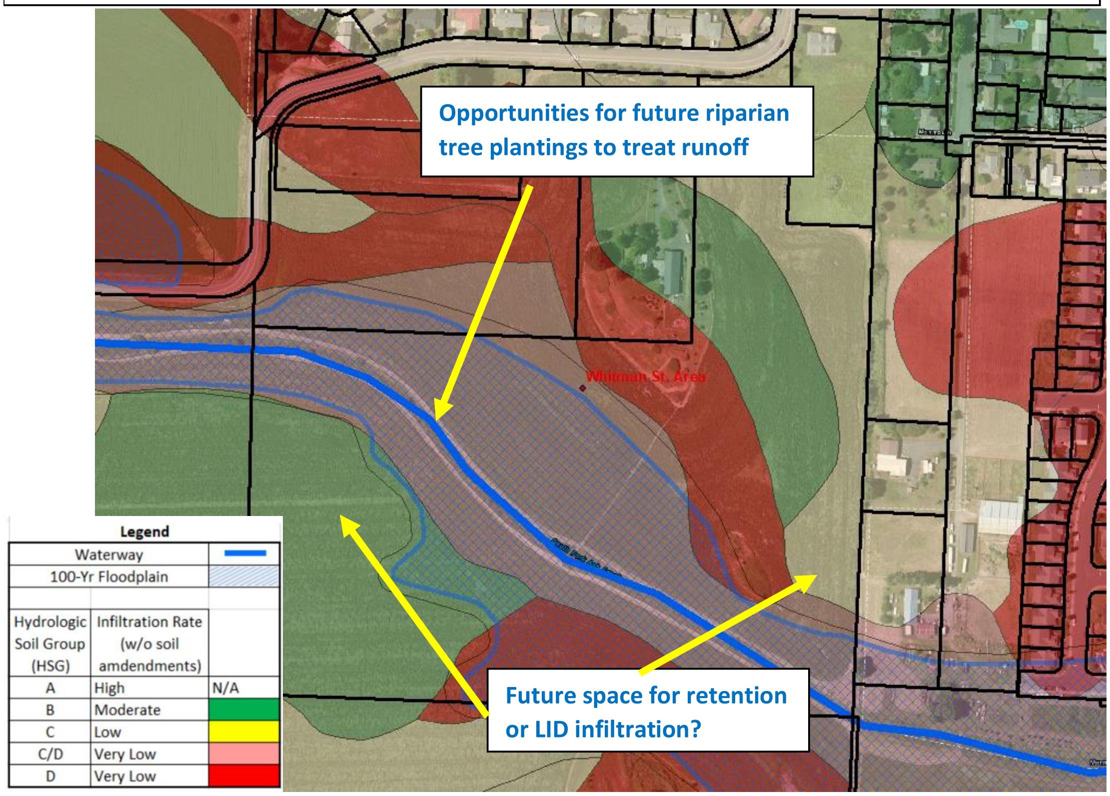
Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Whitman St. Area	Medium	1	-	B to D	Some	Some
Possibilites:	Native plantings, regional retention facility, LID infiltration					
Cupid's Knoll Area	Med low	4	Yes	C	-	Some
Possibilites:	Regional retention facility, developer incentives, native plantings					
Kings Valley Highway Area	Med low	4	Yes	C to D	Some	Some
Possibilites:	Regional retention facility, LID infiltration, native planting					
Future 7th-13th St. Crossing	Med low	1	-	C to C/D	-	Some
Possibilites:	Stormwater park, LID infiltration					
Ash Street Area	Med low	1	-	C to D	-	-
Possibilites:	Roadside BMP, voluntary solutions, LID infiltration					
Edwards Addition	Low	1	Yes	D	-	-
Possibilites:	Native plantings, developer incentives, LID infiltration					
Godsey Road Crossing	Very Low	2	-	D	Yes	Yes
Possibilites:	Roadside BMP, developer incentives					



Whitman Street Area

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Whitman St. Area	Medium	1	-	B to D	Some	Some

Possibilities: Native plantings, regional retention facility, LID infiltration



Background:

The Whitman Street Area (SW of S College Street and Gwinn St W intersection) was identified as an area of future development in Monmouth that may be able to incorporate projects benefiting flooding upon development.

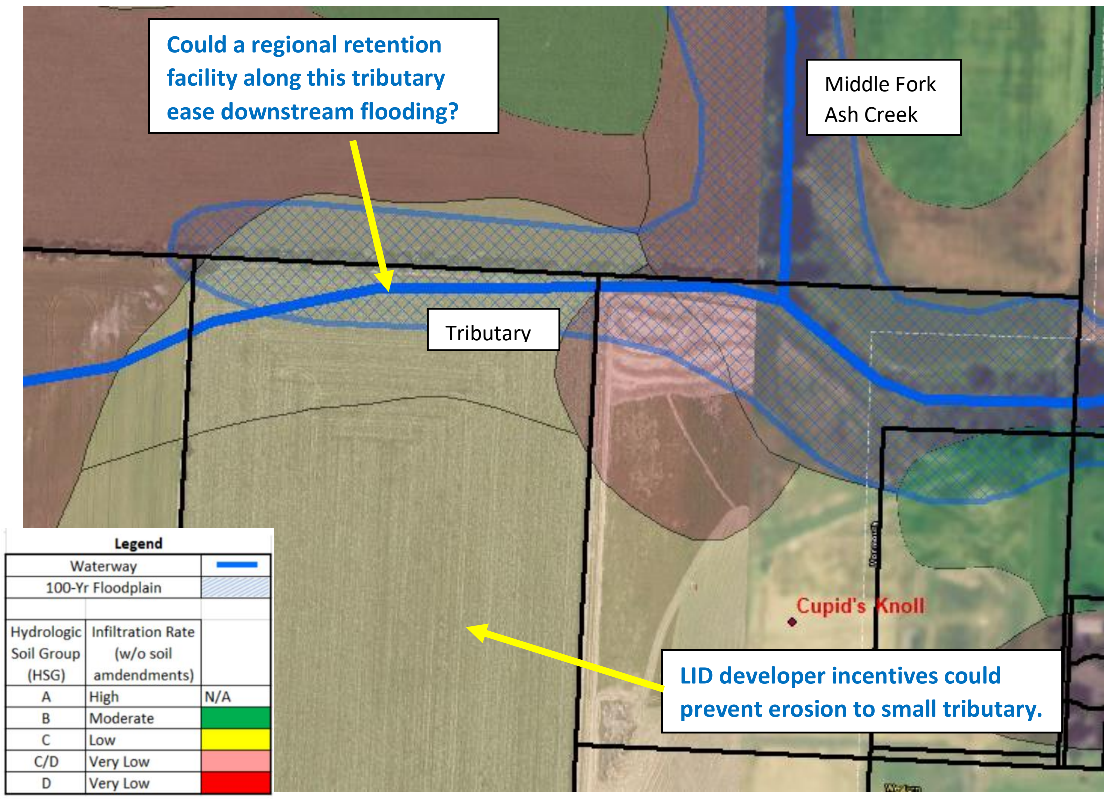
Possibilities:

The streambed appears bare from imagery. Native riparian plantings can help treat runoff in this area. There is an area of soils good for infiltration in the southwest just outside the floodplain. Once the land becomes developable, could a regional retention or LID infiltration facility go here?

Cupids Knoll Area

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Cupid's Knoll Area	Med low	4	Yes	C	-	Some

Possibilities: Regional retention facility, developer incentives, native plantings



Background:

Special interest was placed in Cupid's Knoll (west of Maria St.) as an area that may be utilized to alleviate flooding problems just downstream on Riddell Road. Cupid's Knoll will likely be developed for University housing in the near future. There may be city funding available for a public works project, which may be paired with possible funding from a University.

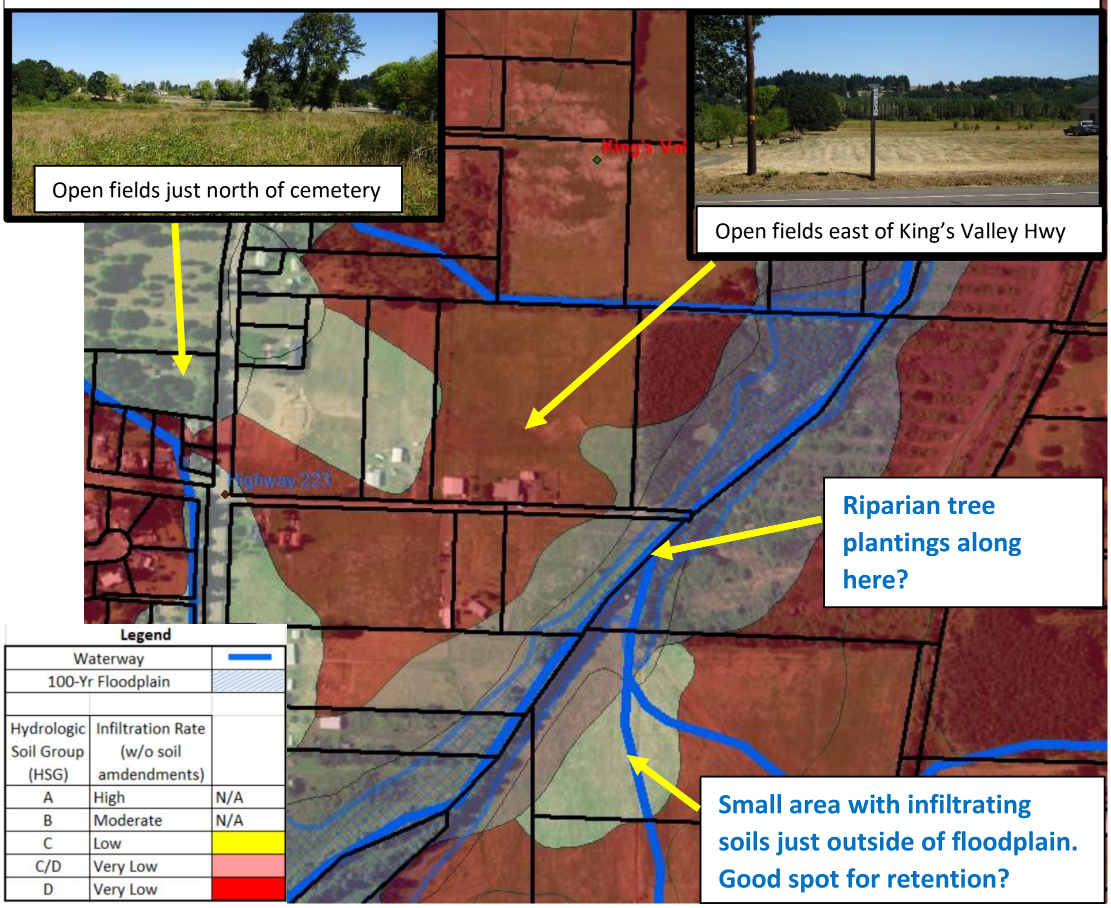
Possibilities:

There appear to be multiple possibilities for a regional retention facility. If placed along the small tributary, it could likely be sized to detain almost all the runoff from the small drainage area even during a large storm event. There also may be a possible to divert some runoff from the Middle Fork Ash Creek into a retention or LID infiltration facility. The small tributary is likely vulnerable to erosion from future development, so leveraging LID developer incentives (zoning/permitting upgrades) may be important.

Kings Valley Highway Area

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Kings Valley Highway Area	Med low	4	Yes	C to D	Some	Some

Possibilities: Regional retention facility, LID infiltration, native planting



Background:

Many large open areas in the region (between Kings Valley Highway and S Church St) are options for retention pond locations. Some flooding of Kings Valley Highway near Lauralwood Street. Dallas Stormwater Master Plan developed by CH2MHill lists a potential retention pond in this area. However, chances of future developer giving up land seems unlikely.

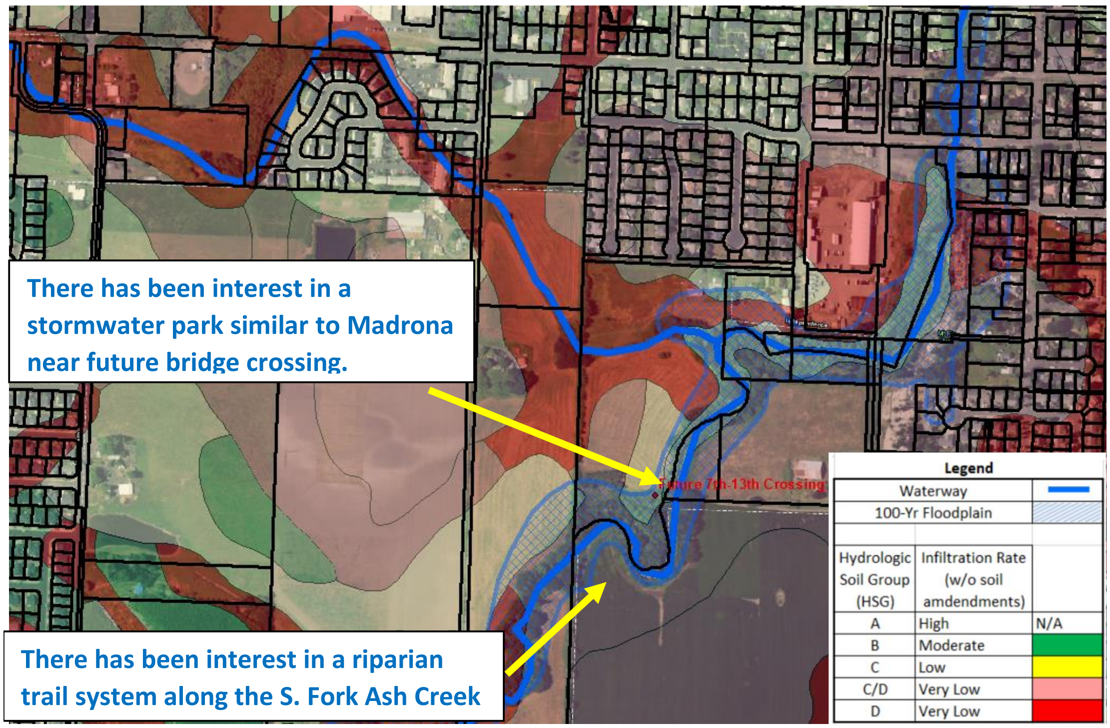
Possibilities:

There are many open spaces with infiltrating soils that would be good possibilities for a regional retention or LID infiltration facility. Land is upstream of many flooding areas in Dallas, so benefits may be felt by entire basin. Possibility of protecting riparian corridor with native plantings or stormwater park or trail running along the Creek.

Future 7th-13th St. Crossing

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Future 7th-13th St. Crossing	Med low	1	-	C to C/D	-	Some

Possibilities: Stormwater park, LID infiltration facilities



Background:

This area of future development has been targeted in the past for bioswales along the creek. While included in the development guidelines, there is no guarantee that they will be installed. There are plans to add a bridge over the S. Fork Ash Creek when the development goes in. There has been interest in creating a Madrona Park-style stormwater park with tiered wetland paths, playing fields, and playground equipment near this future bridge. There has also been interest in building a forested riparian trail park along the S. Fork Ash Creek in this area as well.

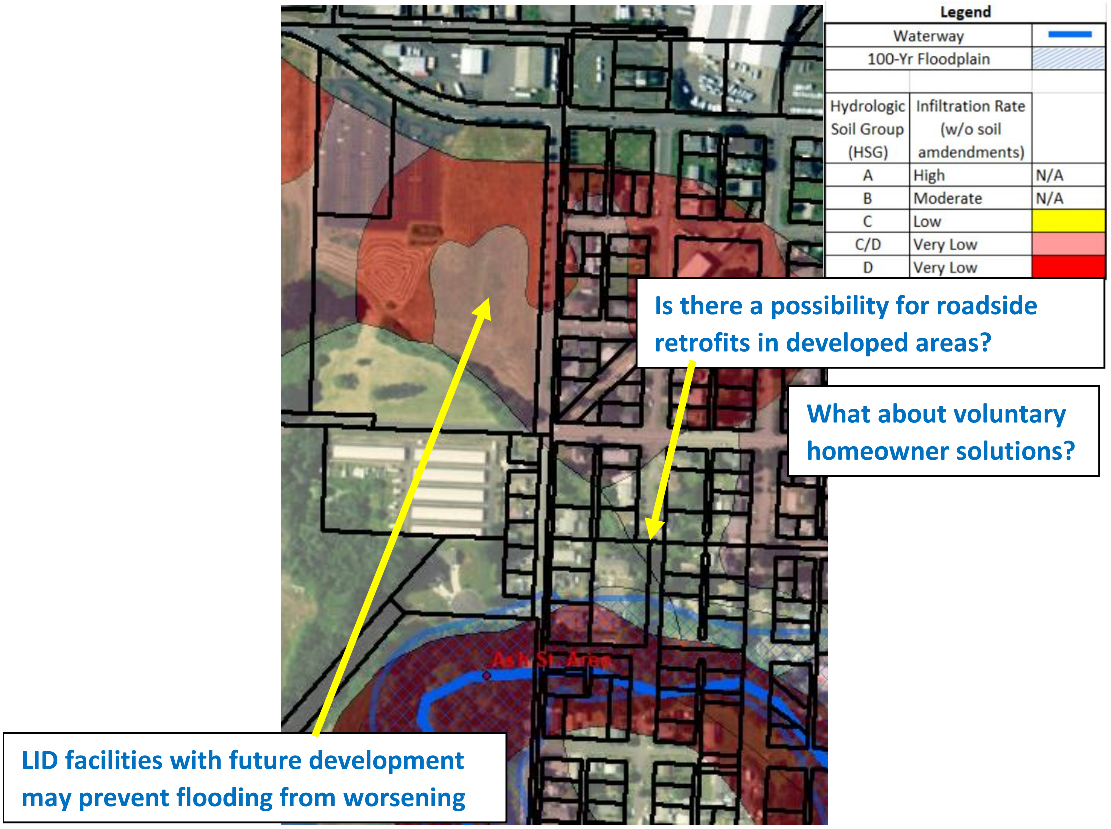
Possibilities:

Developing LID standards can help to ensure that the proposed bioswales do get installed along the creek. Since a regional park will likely be needed anyway, incorporating stormwater elements into it can be a cost-effective way of providing flood mitigation and water quality benefits. A riparian trail system with associated tree plantings can be a great way to protect the Creek from runoff.

Ash Street Area

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Ash Street Area	Med low	1	-	C to D	-	-

Possibilities: Roadside BMP, voluntary solutions, LID infiltration



Background:

This area was identified as vulnerable to additional flooding problems with new development. Flooding issues were noted along the main stem of Ash Creek running towards downtown Independence.

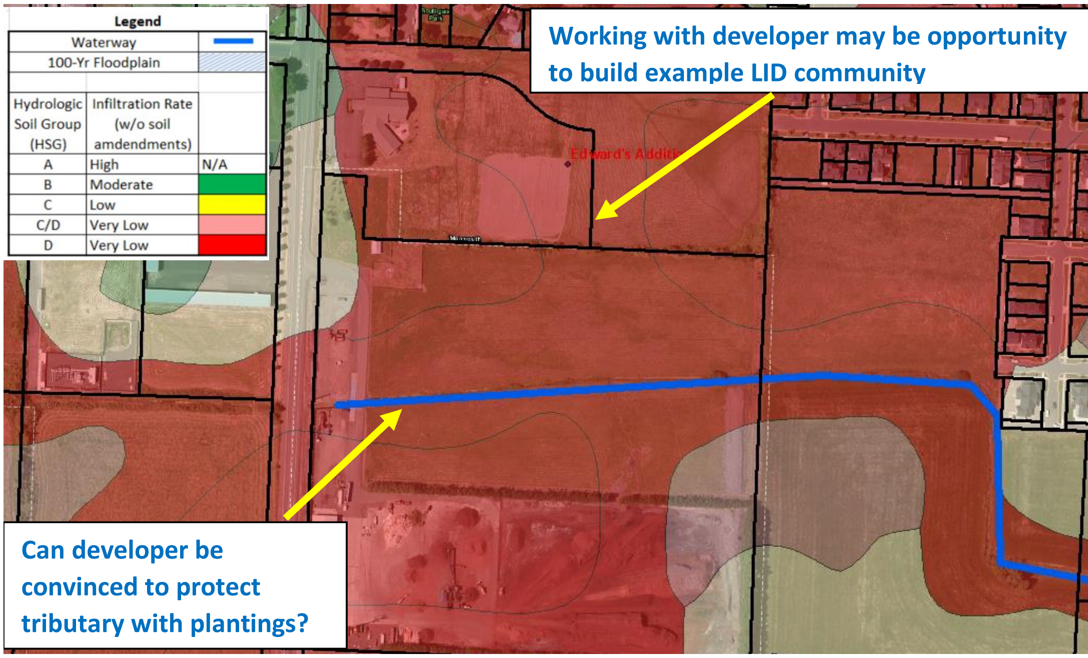
Possibilities:

LID standards can help prevent further flooding problems as future development occurs in this area. To help reduce runoff in this area, roadside retrofits such as a Filterra or bioswales may be possible. Targeting voluntary homeowner solutions such as downspout disconnects or rain gardens may be possible too.

Edwards Addition

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Edward's Addition	Low	1	Yes	D	-	-

Possibilities: Native plantings, developer incentives, LID infiltration



Background:

Edward's Addition was brought up as future development area headed by developers receptive to LID. There is interest in protecting the tributary to the south.

Possibilities:

It sounds possible to convince the developer to install LID without enforcing any standards. Perhaps offering incentives such as permitting, density, or zoning benefits may ensure that LID becomes installed here. Riparian tree plantings can protect the tributary from runoff.

Godsey Road Crossing

Project Site	Infiltration Potential (w/o soil amend.)	# Flooding Areas Downstream	Does it drain to a small tributary?	Hyd. Soil Group	Shallow GW Table (<2ft?)	Within 100-yr Floodplain?
Godsey Road Crossing	Very Low	2	-	D	Yes	Yes

Possibilities: Roadside BMP, developer incentives

.

Background:

Godsey Road bridge is scheduled to be replaced soon. Current development plans are to install sidewalk and curb across the whole road, which will increase runoff to the North Fork over present condition. The agricultural land to the east may also be turned into residential property in the future.

Possibilities:

This may be a good location to install roadside BMPs (tree wells, permeable pavement, stormwater planters, etc.) to prevent runoff from increasing here. Dallas currently does have incentives for LID development, so perhaps those can be leveraged if the land to the east is converted from agriculture to residential in the future.

APPENDIX H- INFILTRATION TEST RESULTS AND SOILS DATA

Testing was performed at a city-owned site in Independence just north of where Gun Club Road crosses Ash Creek. Location of infiltration testing boreholes shown below:

Infiltration Test Notes:	
Date:	10/26/2017
General Notes:	
Using Reduction Factor Method to test infiltration. Weather began cloudy and 55, became sunny and 70. Large rains over weekend, but has been dry for past 3-4 days.	

BH-1:

Notes:

6” Diameter, 10” deep. Soil all appeared homogenous throughout depth. Moist, medium dark brown/coffee color. Particles appear to all be fines and are not visible to eye. Soil does not clump or roll well and does not leave coating on fingers.

Began pre-soaking at 6" depth:	11:05 AM
Stopped adding water:	11:35 AM
Refilled hole and started testing:	12:05 PM

Testing Data:

	Time	Water Depth (in)	Water Drop (in)	Perc. Rate (in/hr)
Trial 1:	12:35 PM	2.25	3.75	7.5
Trial 2:	1:05 PM	2.50	3.50	7
Trial 3:	1:35 PM	2.75	3.25	6.5
Trial 4:	2:05 PM	3.00	3.00	6
Trial 5:	2:35 PM	3.00	3.00	6
Trial 6:	3:05 PM	3.00	3.00	6
Trial 7:	3:35 PM	3.25	2.75	5.5
Trial 8:	4:05 PM	2.75	3.25	6.5
Average		2.81	3.19	6.38

Infiltration Rate Calculations:

Reduction Factor Equation:

Rf = ((2d1-deltad)/DIA)+1

Rf =	2.47	Reduction Factor
d1 =	6	Initial Water Depth (in)
deltad =	3.19	Average water level drop (in)
DIA =	6	Diameter of Perc. Hole (in)

Design Infiltration Rate = Avg. Percolation Rate/Rf

Avg. Perc Rate =	6.38	(in/hr)
Rf =	2.47	
Design Inf. Rate =	**2.58**	**(in/hr)**

BH-2:

Notes:

6” Diameter, 10” deep. Soil all appeared homogenous throughout depth. Moist, medium dark brown/coffee color. Particles appear to all be fines and are not visible to eye. Soil does not clump or roll well and does not leave coating on fingers.

Began pre-soaking at 6" depth:	11:40 AM
Stopped adding water:	12:10 PM
Refilled and started testing:	12:40 PM

Testing Data:

	Time	Water Depth (in)	Water Drop (in)	Perc. Rate (in/hr)
Trial 1:	1:10 PM	4.25	1.75	3.5
Trial 2:	1:40 PM	1.75	4.25	8.5
Trial 3:	2:10 PM	3.75	2.25	4.5
Trial 4:	2:40 PM	1.75	4.25	8.5
Trial 5:	3:10 PM	3.25	2.75	5.5
Trial 6:	3:40 PM	4.50	1.50	3
Trial 7:	4:10 PM	4.50	1.50	3
Trial 8:	4:40 PM	3.75	2.25	4.5
Average		3.44	2.56	5.13

Infiltration Rate Calculations:

Reduction Factor Equation:
Rf = ((2d1-deltad)/(DIA))+1

Rf =	2.57	Reduction Factor
d1 =	6	Initial Water Depth (in)
deltad =	2.56	Average water level drop (in)
DIA =	6	Diameter of Perc. Hole (in)

Design Infiltration Rate = Avg. Percolation Rate/Rf

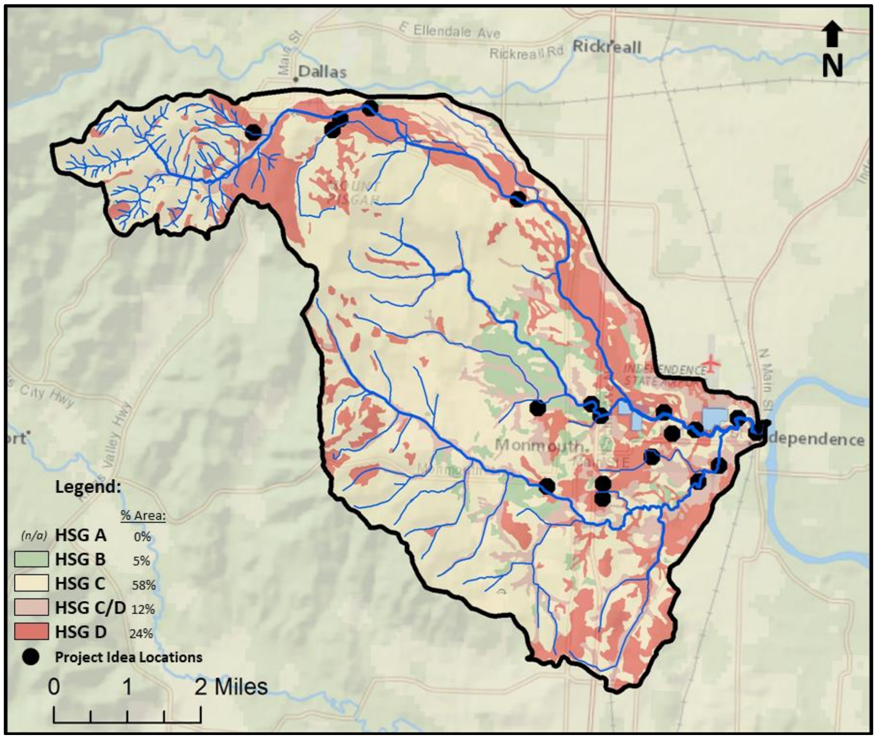
Avg. Perc Rate =		5.13	(in/hr)
Rf =		2.57	
Design Inf. Rate =		**1.99**	**(in/hr)**

Soil Types in the Ash Creek Watershed (NRCS, 2018) (Barr, 2010).

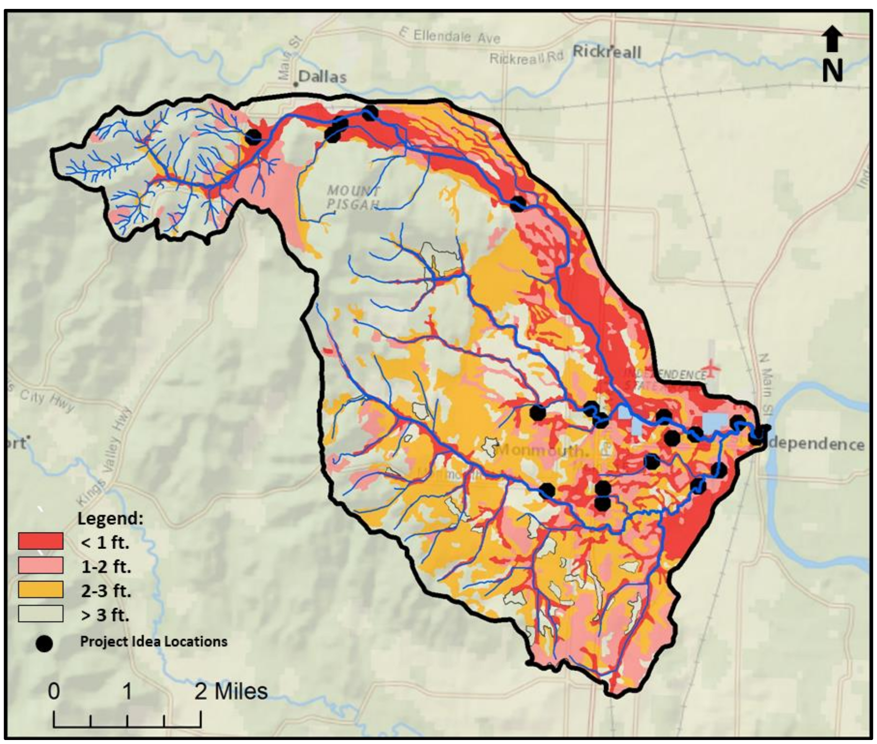
Soil Type	Total Area	Approximate Infiltration Rate Estimate (inches/hour)
Silt Loam	50.1%	0.17
Silty Clay Loam	49.2%	0.3

Hydrologic Soil Groups in the Ash Creek Watershed (NRCS, 2018) (NRCS, 1988).

Hydrologic Soil Group (HSG)	Total Area	Infiltration Rate Description	Minimum Infiltration Rate Estimate (inches/hour)
A	0.0%	High	0.3 - 0.45
B	5.1%	Moderate	0.15 - 0.30
C	58.2%	Slow	0.05 - 0.15
C/D	12.3%	Very Slow	0 - 0.05
D	24.4%	Very Slow	0 - 0.05



Hydrologic Soil Groups (HSGs) in the Ash Creek Watershed (NRCS, 2018).

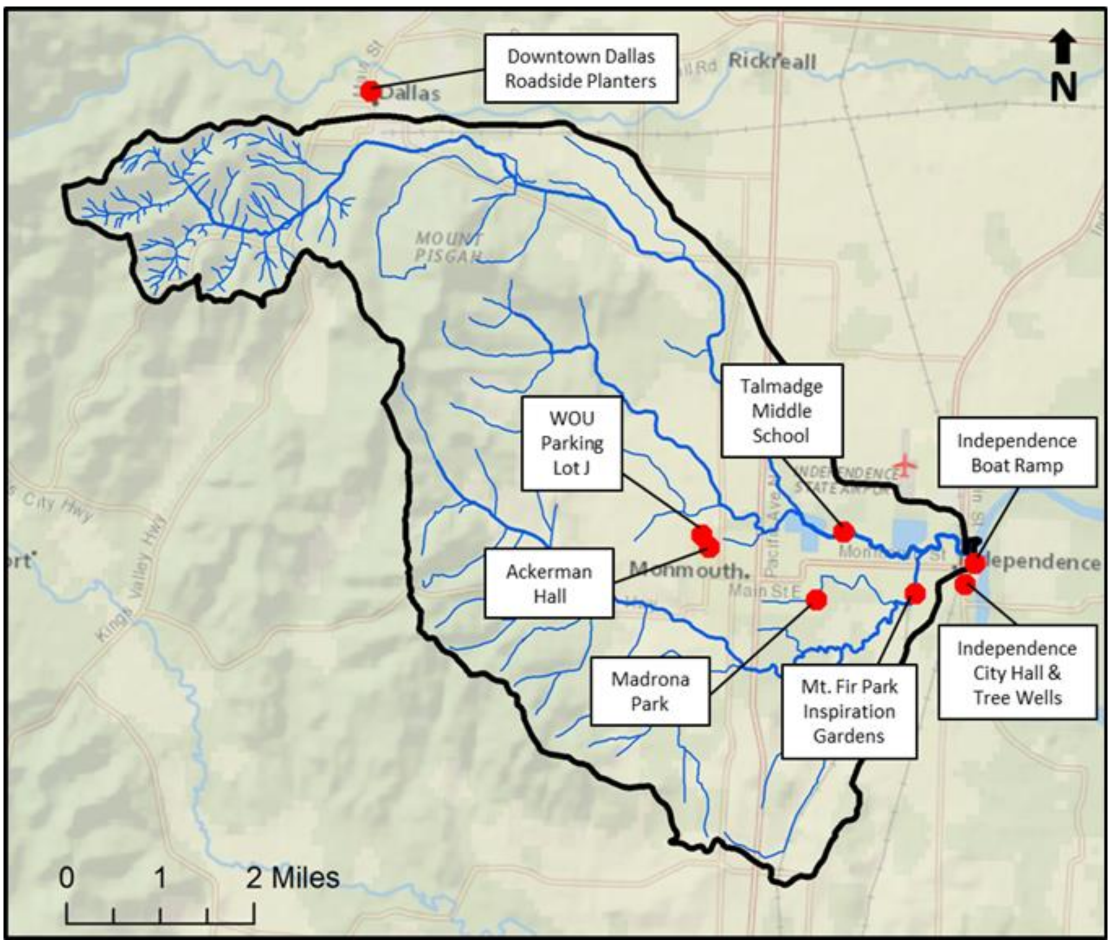


Groundwater Table Depths in the Ash Creek Watershed (NRCS, 2018).

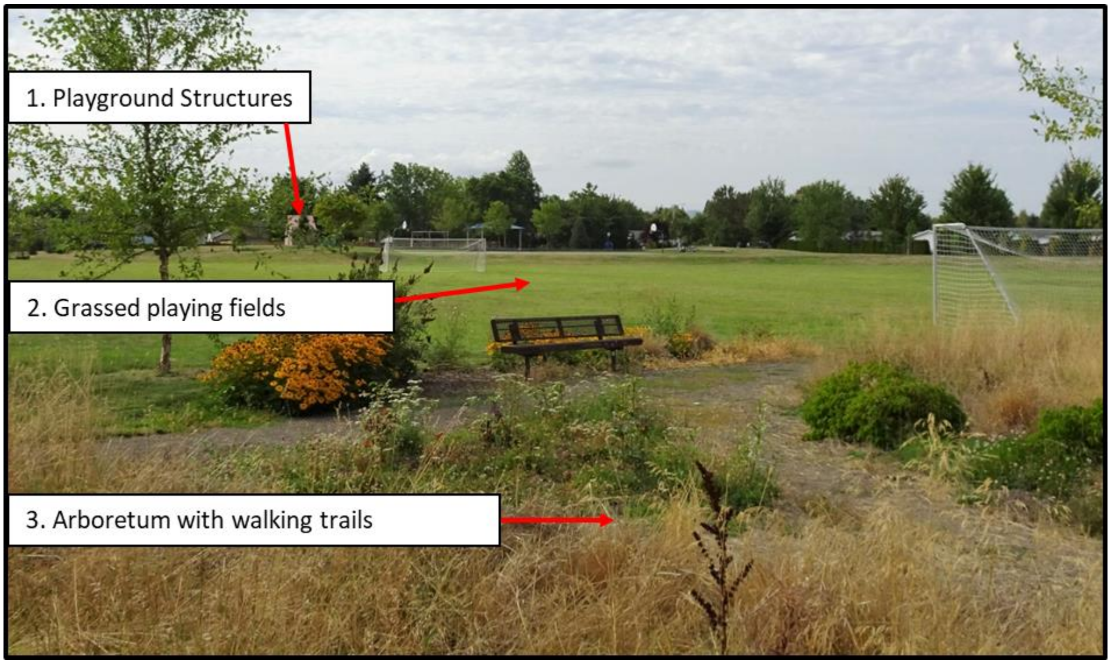
APPENDIX I- INVENTORY OF EXISTING LID

This inventory of existing LID in the Ash Creek Watershed is a compilation of input from interviews during this internship. This is NOT meant to be an exhaustive list of all LID in the watershed. Furthermore, the commentary included is based on feedback from the interviews. Current status and performance of the LID should be confirmed with field visits during the rainy season (photos were taken in August 2017).

Map of Existing LID



Madrona Park

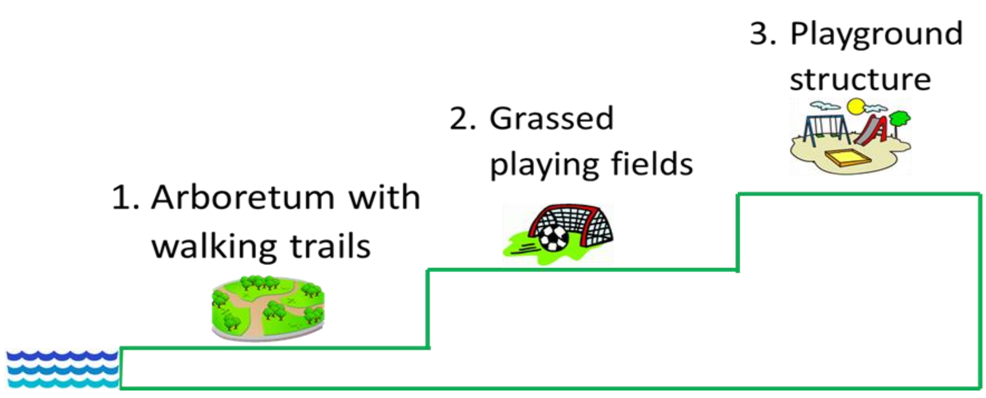


Built: 2015

Maintained by: City of Monmouth

Location: 1500 Block, Madrona Street, Monmouth, OR 97361

Description: Madrona Park is a 10-acre park in the City of Monmouth, recently transformed in 2015 with the addition of an arboretum with walking trails. The Park can be considered a "stormwater park with" features carefully tiered in elevation:



During large storms, the lower features fill up with water while the top ones remain dry. The City of Monmouth reports that drainage performance has worked according to plan so far. However, some people do wonder when the arboretum portion will be mowed.

Downtown Dallas Roadside Planters

Location: Courthouse area of downtown Dallas

Maintained by: City of Dallas

Description: The City of Dallas has reported that these planters perform well during storms and "swallow up water as fast as you can pump it." The only performance issues have come from some planters installed with poor quality concrete. Slow-growing plants chosen by a landscaper were used to minimize maintenance. Weed removal is reported to take a great deal of maintenance.

Independence City Hall Downspouts

Maintained by: City of Independence

Location: All along the outside of Independence City Hall

555 S Main Street, Independence, OR 97531

Downtown Independence Tree Wells

Location: Main Street, Independence

Maintained by: City of Independence

Description: The City of Independence has installed tree wells in its downtown area to capture and treat runoff from the streets. Pictured is the proprietary Filterra system by Contech Engineered Solutions, a device popular nationwide. Smaller storms are intercepted by soil in the tree well beneath the inlet and absorbed by the tree. Larger storms bypass the Filterra system and directly enter the storm sewer.

Independence Boat Ramp Bioswale

Built: Currently (Aug. 2017) under construction

Maintained by: Will be maintained by City of Independence

Location: SE corner of C St in Riverview Park. Independence Oregon.

Talmadge Middle School Bioswale

Maintained by: Central School District 13J

Location: Just north of Talmadge Middle School bus lanes. 51 S 16th St., Independence OR 9.

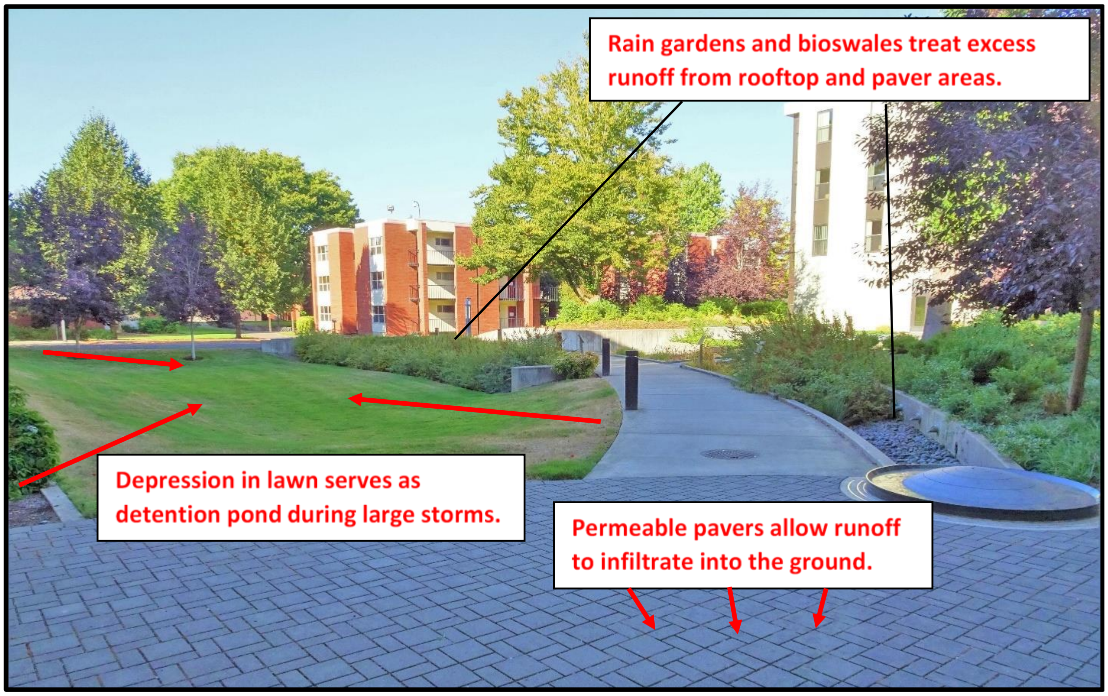
Description: The storm drains in the Talmadge Middle School bus lanes are piped underground into a bioswale, a relatively flat ditch with tall grasses growing out of it. In smaller storms, the runoff from the school parking lot is infiltrated and treated in this swale before reaching Ash Creek. In larger storms, the runoff will simply reach the elevation of the outfall pipe and drain into Ash Creek. The City of Monmouth has said that it appears to be working so far and captures some of the sediment from runoff like it is supposed to. The grasses are allowed to grow in the winter and then can be mowed the rest of the year.

Mt. Fir Park Inspiration Gardens

Location: Within the Inspiration Garden of Mt. Fir Park. 790 F Street, Independence

Maintained by: Polk County Master Gardeners

WOU Ackerman Hall



Built: 2010

Location: Outside of Ackerman Hall dormitory on Western Oregon University Campus

Church St. W, Monmouth, OR 97361

Maintained by: Western Oregon University

Description: Ackerman Hall was the first dormitory of its type in the country to receive LEED Platinum Certification. The walkways are covered with permeable paves, which allow rainfall to seep through small gaps into the ground. A rainwater harvesting tank captures water to use for flush toilets. A gently sloped depression in the lawn area outside allows for recreation, but can act as a temporary retention pond during large storm events.

WOU Parking Lot J Bioswale

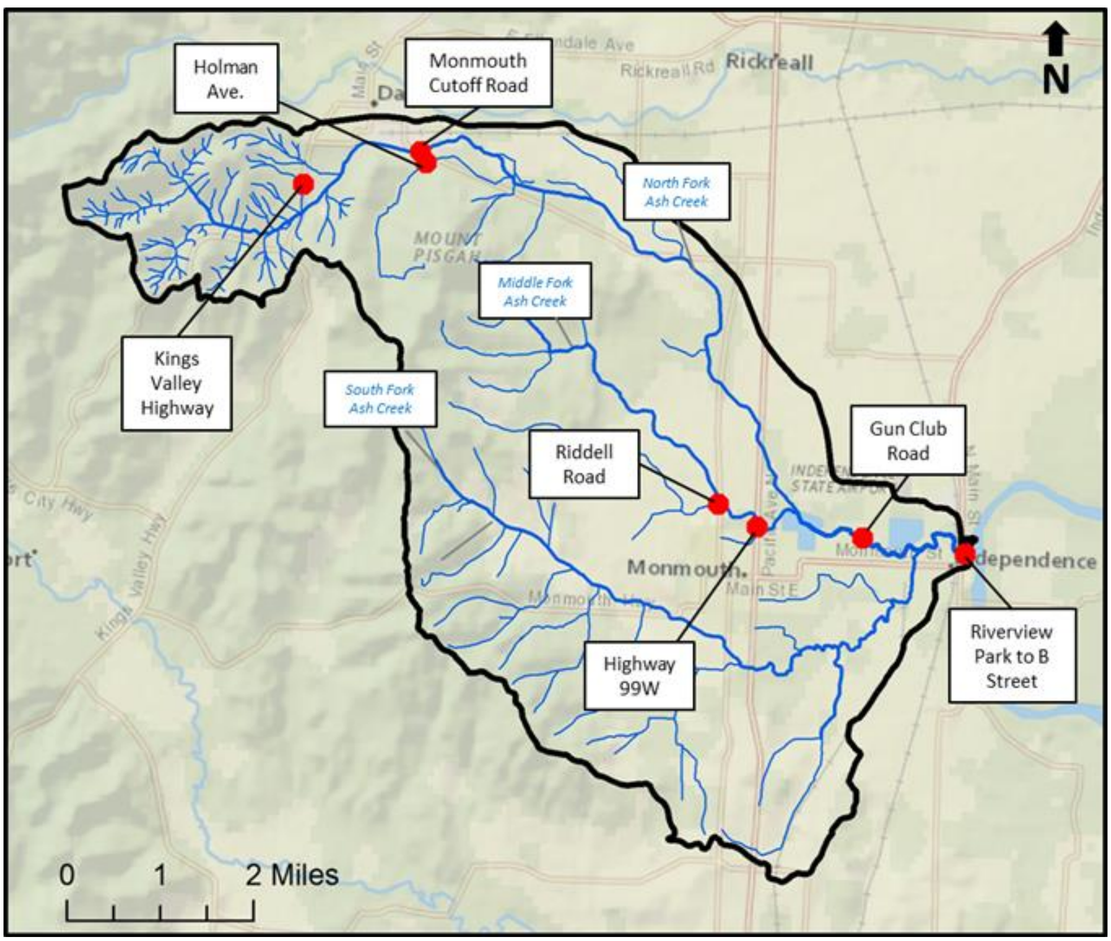
Location: Parking Lot J, Stadium Drive N, Monmouth, OR 97361

Maintained by: Western Oregon University

APPENDIX J- LOCATIONS OF REPORTED FLOODING

This inventory of flooding locations in the Ash Creek watershed is a compilation of input from interviews during this internship. It is being included as a reference, but is not meant to be an exhaustive list of all flooding locations in the watershed. This inventory was used to populate the "# Flooding Areas Downstream" parameter within Appendix G- Site Ideas for Potential LID Projects.

Map of Reported Flooding Locations in the Ash Creek Watershed:



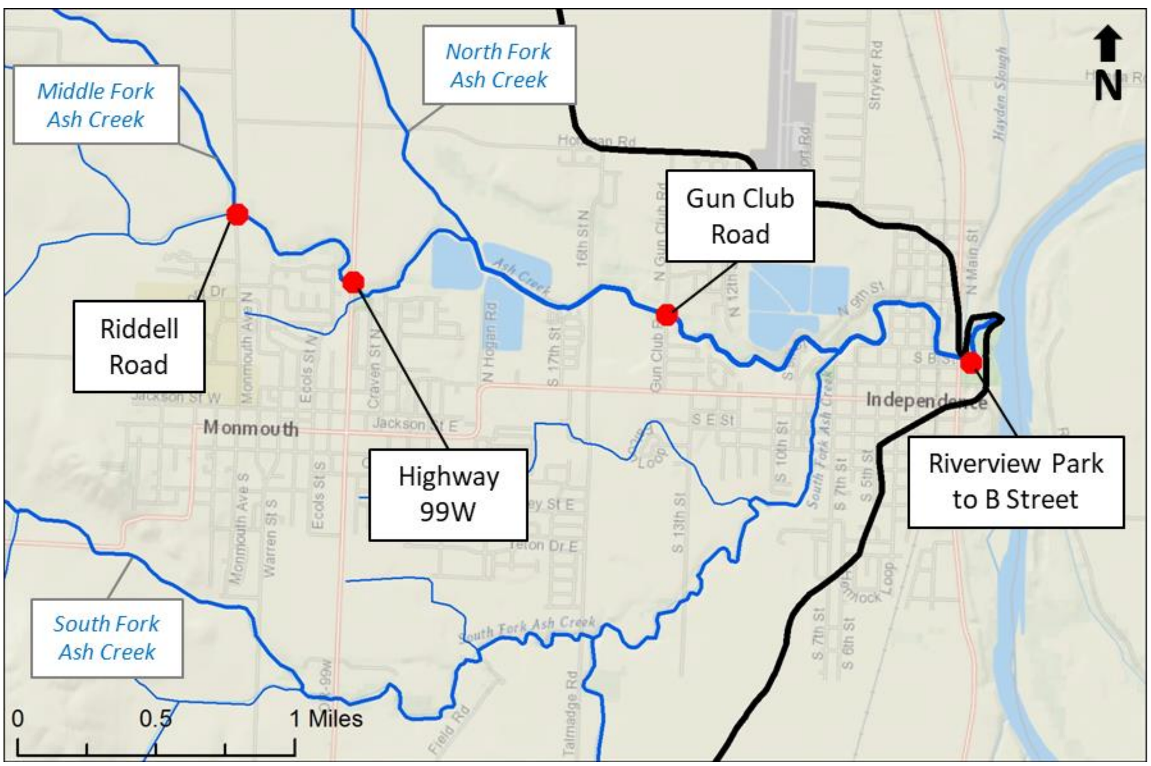
Flooding Locations in Ash Creek Watershed:

(ordered by distance from mouth, from furthest to closest)

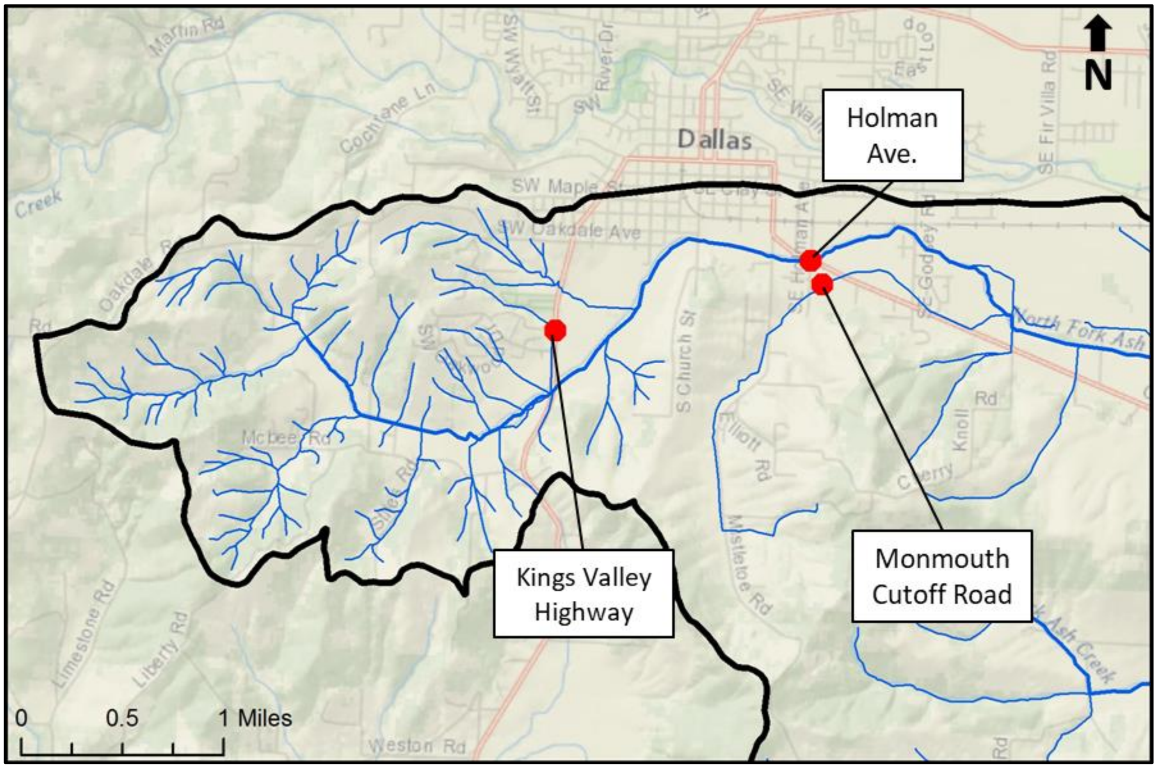
1. Kings Valley Highway 223 *(near SW Lauralwood St.)*
2. Monmouth Cutoff Road *(from Holman to Godsey)*
3. Holman Ave *(south of Monmouth Cutoff Road)*
4. Riddel Road *(from Hoffman to Whitesell)*
5. 99W Crossing
6. Gun Club Road bridge
7. Ash Creek from Riverview Park to B Street***

*** Note that flood events near the mouth of Ash Creek may be caused by backup of the Willamette River and not from any effect from the upstream of Ash Creek.

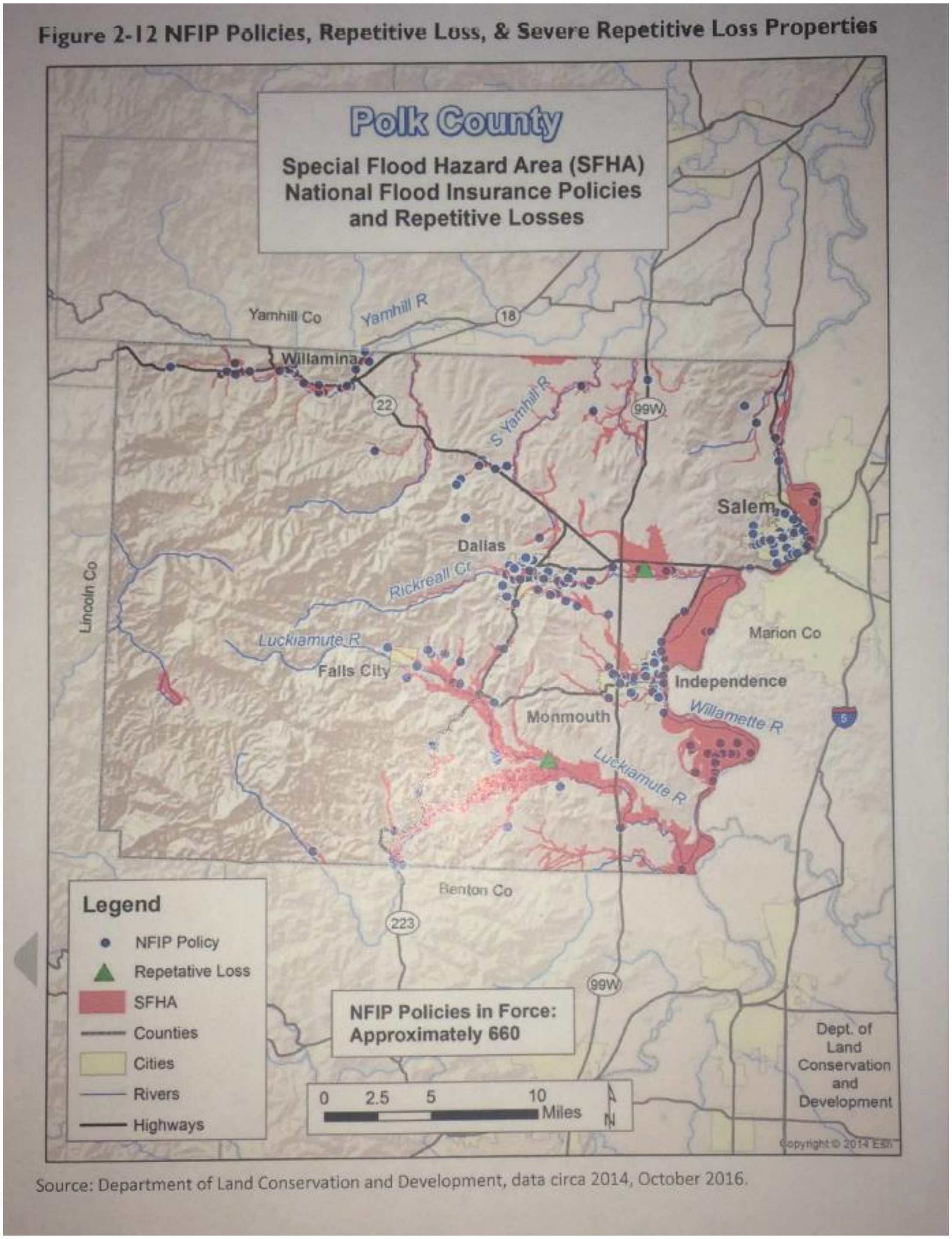
Map of Reported Flooding Locations in Monmouth/Independence



Map of Reported Flooding Locations in Dallas



This map was discovered during the interviews. While not used for analysis, it is included here as a reference. Provided by Polk County.



APPENDIX K- LID RESOURCE GUIDE

The following document was originally included within the "Low Impact Development Findings & Recommendations for the Ash Creek Watershed" report submitted to the Luckiamute Watershed Council and the Ash Creek Water Control District in October 2017. This This guide contains a list of the most helpful links (current as of January 2018) found during the course of research on LID. The most useful or introductory links generally appear at the top of each section, with the most recommended links highlighted.

Contents

LID Websites

The following sites contain websites devoted to LID with a broad array on information on multiple topics. Many of the resources within this document can be found within these databases.

OSU Extension: Stormwater Solutions [Website]
City of Portland: Green Infrastructure [Website]
Washington Stormwater Center: Low Impact Development Resources [Website]
EPA: Green Infrastructure [Website]
EPA: Urban Runoff Resources [Website]
Georgetown Law Center: Green Infrastructure Toolkit [Website]

Costs and Funding Information:

LID Cost Information:

EPA Green Infrastructure Cost-Benefit Resources [Website] (EPA, 2016)

- Lists case studies of LID costs and benefits across the country and tools to help reduce costs.

Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices
[Website with PDF- 37 pg] (EPA, 2007)

- Literature review compiling 17 case studies comparing costs of LID vs. conventional designs.

The Economics of Low Impact Development: A Literature Review
[PDF- 40 pg] (ECONorthwest, 2007)

- Literature review compiling case studies comparing costs of LID vs. conventional. Similar to EPA study.

Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional Stormwater Management [University of New Hampshire] (2013)

- Research article comparing lifecycle costs and performance of LID vs. conventional BMPs.

Available Grants/Funding:

OWEB Small Grant Program

- Funds of up to $15,000 for on-the-ground restoration projects.

OWEB Restoration, Stakeholder Engagement, Monitoring, and Technical Assistance Grants

- Restoration Grants have been used to fund LID projects.
- Technical Assistance Grants can help with planning and prioritizing.

DEQ Clean Water State Revolving Fund

- Provides low-cost loans for the planning, design, and construction of various water pollution control activities. Any public agency in Oregon is eligible.

DEQ Nonpoint Source Implementation 319 Grants

- Used for funding past LID projects. Funding has been declining recently and future availability is unknown.

National Fish and Wildlife Foundation

- Offers many grant programs, but they are national and highly competitive.

Green Infrastructure Funding Opportunities [Website] (EPA, 2017)

- Contains list of federal funding sources for LID

EPA Urban Waters Small Grants

- Grants up to $60,000 for projects to restore urban waters, improve water quality, and support community restoration. National and highly competitive.

EPA Five Star and Urban Waters Restoration Grant Program

- Supports projects addressing water quality and community stewardship. National and highly competitive.

Guidance for Developing LID Standards

Templates for LID Stormwater Codes:

Green Infrastructure Implementation Forms [Website] (OSU Extension, 2018)

- Adaptable set of calculations for Low Impact Development features.
- Contains associated BMP specifications to accompany calculations.

Template for LID Stormwater Manual for Western Oregon [Website] [ODEQ, 2017]

- Template created as an easy way for small jurisdictions in Western Oregon to easily integrate LID within stormwater manual.
- Commentary from Green Girl walks you through this template.

Stormwater Management Plan Template [Word.doc- 6 pg] (University of Oregon, 2012)

- Template intended for cities of 10,000-50,000 not covered by MS4 permit for Storm Water Phase II Regulations (applies to Dallas, may soon apply to Monmouth and Independence),

Water Quality Model Code & Guidebook
[Website] (OR Dep. Land Conservation & Development, 2015)

- Extended guide integrating LID language into stormwater codes for small cities in Oregon.
- Paired with Model Development Code for Small Cities [Website]

Example LID Standards:

Below are examples of stormwater code manuals in Oregon that incorporate LID. These manuals can be a resource for developing LID codes and also contain information on BMP designs, including maintenance forms, standards, and specifications.

City of Portland Stormwater Management Manual [PDF- 502 pg] (2016)
City of Eugene Stormwater Management Manual [PDF-252 pg] (2014)
City of Florence Stormwater Design Manual [PDF- 186 pg] (2011)
City of Gresham Water Quality Manual [PDF- 265 pg] (2010)
City of Salem Stormwater Design Handbook [PDF- 16 pg] (2014)

Calculators for LID Standards:

These calculators are used within the Example LID Standards.

Green Infrastructure Implementation Forms [Website with Excel sheet] (OSU Extension, 2018)

- Adaptable set of calculations for Low Impact Development features using Excel interface,
- Designed for ease of use and simplicity,

FORM SIM [Excel] (Oregon DEQ)

- Used for sizing treatment BMPs for small projects per LID Standards by Eugene, Florence, and Gresham,

Simplified Approach Form [PDF- 2 pg] (City of Portland)

- Used for sizing treatment BMPs for small projects per LID Standards by Portland, Stayton, and Salem,

Presumptive Approach Calculator [Website] (City of Portland)

- Used for sizing treatment BMPs for large projects per LID Standards across Oregon. Requires City of Portland login through this link. May be possible to find the calculator somewhere else.

Guides on Creating LID Stormwater Codes:

Post-Construction TMDL Implementation Guide [PDF- 22 pg] (DEQ)

- Provides guidance on how to expand TMDL's to include specific post-construction stormwater management strategies in Oregon.

Incorporating LID into TMDL's [Website with PDF- 11 pg] (EPA, 2008)

- Provides guidance on how to expand TMDL's to include LID. Includes case studies and resources.

MS4 Phase II Permit [Website] (ODEQ, 2017)

- Information on MS4 Phase II Permits and TMDL requirements for Oregon municipalities.

Integrating LID into Local Codes: A Guidebook for Local Governments [PDF- 152 pg] (Puget Sound Partnership, 2012)

- Includes detailed step-by-step process on how to edit existing codes, develop LID protocols in them, and successfully implement the measures.

Permitting Green Infrastructure [Website with PDF- 52 pg] (American Rivers, 2013)

- Guide on crafting municipal stormwater permits to incorporate LID.

Green Infrastructure Policy Guides [Website] (EPA, 2016)

- Contains links to various LID Policy Guides and Policy Tools.

LID Regulatory Tools [Website] (Georgetown Climate Center)

- Provides examples on regulatory tools from around the country.

Developing Voluntary LID Installation Incentives

Example Incentive Programs:

City of Dallas Low Impact Development Incentives [PDF- 126 pg]

- Low Impact Development Incentives found on page 26 and include opportunities property owners to earn Stormwater Fee Discount and for developers to earn Residential Density Bonuses.

City of Eugene Stormwater Service Charge Reduction [PDF- 2 pg]

- Stormwater Fee Discounts may be earned for water quality treatment or on-site containment of runoff from large storm events.

Sandy, OR Stormwater Management Incentive Program [Website]

- Stormwater Fee Discounts may be earned for treating impervious surfaces with BMPs.

Portland Clean River Rewards [Website]

- Stormwater Fee Discounts may be earned for treating impervious surfaces with BMPs.
- Rebates for homeowners purchasing downspout disconnections.
- Cost-share and Credit program for non-residential properties converting impervious areas to vegetated.

King County, WA Surface Management Fee Discounts and Cost-Sharing Program [Website]

- Stormwater Fee Discounts for installing BMPs or maintaining forest areas on property.

Marysville, Washington Rainwater Harvesting Reduction [Website]

- Stormwater Fee Discount earned with installation of roof rainwater harvesting system.
- Found in 14.19.080(d).

Seattle: Rainwise Program [Website]

- Rebates given for hiring program contractors to install rain garden or cistern (large rain barrel) on property.

Guides on Building LID Incentive Programs:

Green Infrastructure Municipal Handbook [Website] (EPA 2017)

- Includes guides on Incentive Mechanisms, Retrofit Policies, and Funding Options for LID.

Community Solutions for Stormwater Management: A Guide for Voluntary Long-Term Planning
[Website with PDF- 16 pages] (EPA, 2016)

- Simplified step-by-step guide for state and local governments on including voluntary community solutions in stormwater plans.

LID Incentive-Based Tools [Website] (Georgetown Climate Center)

- Provides examples on incentive programs around the country.

Materials for Homeowners:

Stormwater Solutions [Website] (City of Portland, 2017)

- Resources meant for helping private property owners install voluntary stormwater solutions.
- [PDF's]: Easy guides for homeowners to install Rain Gardens, Rain Barrels, Pervious Pavers, Downspout Disconnectors, French Drains/Soakage Trenches and Maintaining Facilities
- Guide for Stormwater Operation and Maintenance for Private Property Owners [PDF- 22 pg]

700 Million Gallons Program [Website] (City of Seattle, 2017)

- Contains extensive list of resources for homeowners to install and maintain stormwater devices.
- [PDF's] for designing Rain Gardens, Permeable Paving, Downspout Disconnections, Soakage Trenches.
- [PDF's] on Rain Garden Maintenance and Plant Selection

Homeowners Permeable Pavement Toolkit *[PDF- 2 pg] (Village of Elmsford, NY, 2012)*

- Homeowner guide on DIY installation of pervious pavement.

Information on BMPs

BMP Specifications:

Note: Many BMP Specifications can be found within the Example LID Standards (Eugene, Florence, Gresham, Portland, Salem)

Standard Details for Structural BMPs [Website] (OSU Extension, 2018)

- Contains illustrated details for various structural BMPs developed specifically for Oregon.

Green Infrastructure Fact Sheets [Website] (OSU Extension, 2018)

- Provides fact sheets for various BMPs on design, maintenance, and cost developed specifically for Oregon.
- Includes Rain Gardens, Porous Pavement, Green Roofs, Stormwater Planters, Swales, Soakage Trenches, Dry Wells, Vegetated Filter Strips.

Green Stormwater Operations and Maintenance Manual
[Website with PDF- 25 pg] (City of Seattle, 2009)

- Contains illustrations on how to achieve various performance levels with LID.

Green Infrastructure Design and Implementation [Website] (EPA, 2016)

- Contains lists of design manuals established by state and local jurisdictions.

BMP Calculators:

BMP Suitability Matrix [Website with PDF- 1 pg.] (Green Girl LLC, 2017)

- Simplified matrix to determine which BMPs are most appropriate for given site conditions and goals.

Green Infrastructure Implementation Forms [Website with Excel sheet] (OSU Extension, 2018)

- Contains calculators for pervious pavement, rain gardens, LID swales, and more.
- Determines if BMP type is suitable for local conditions and calculates size needed.

Green Infrastructure Modeling Tools [Website] (EPA, 2017)

- Lists a variety of outside calculator tools and desktop applications for LID design.

National Green Values Calculator [Website] (Center for Neighborhood Technology, 2009)

- Calculates cost of traditional vs. LID stormwater management based on site information.

BMP Performance:

International Stormwater BMP Database (BMPDatabase.org, 2016)

- BMP Performance Summary [PDF- 52 pg]: Statistics on BMP water quality treatment.
- BMP Database Map [Website]: Map with links to performance of local BMPs.
- BMP Statistics [Website]: Online calculator to find performance statistics based on BMP type, location, and water quality parameter.

BMP Suitability Matrix [Website with PDF- 1 pg.] (Green Girl)

- Simplified matrix to determine which BMPs are most appropriate for given site conditions and goals.

BMP Table [PDF- 8 pg.] (Oregon DEQ, 2016)

- Provides simplified matrix of which types of BMPs are effective for which goals.

Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional Stormwater Management [University of New Hampshire] (2013)

- Research article comparing lifecycle costs and performance of LID vs. conventional BMPs.

Rain Garden Information:

Choose the right Rain Garden [Website] (OSU Extension, 2018)
- Flow chart to help select the best rain garden configuration for your site.

Rain Garden Fact Sheet [Website with PDF- 12 pg] (OSU Extension, 2018)
- Brief overview of how to design rain garden with helpful diagrams.

Standard Details for Rain Garden [Website] (OSU Extension, 2018)
- Illustrated specification detail for rain gardens developed specifically for Oregon.

Building a Rain Garden [PDF- 2 pg] (City of Seattle, 2015)
- Homeowner guide on installing rain gardens.

How to Build a Rain Garden [PDF- 7 pg] (City of Portland, 2009)
- Homeowner guide on installing rain gardens

Oregon Rain Garden Guide [PDF- 44pg] (Oregon Sea Grant, 2010)
- Detailed step-by-step guide on rain garden design specific to Oregon.

Rain Garden Handbook for Western Washington [PDF-96 pg] (WA Dept. of Ecology, 2013)
- Extensive, but easy-to-understand guide for designing, installing, and maintaining rain gardens.

Pervious Pavement Information:

Homeowners Permeable Pavement Toolkit [PDF- 2 pg] (Village of Elmsford, NY, 2012)
- Homeowner guide on DIY installation of pervious pavement.

Pervious Pavement Fact Sheet [Website with PDF- 12 pg] (OSU Extension, 2018)
- Brief overview of how to design pervious pavement with helpful diagrams.

Standard Details for Pervious Pavement [Website] (OSU Extension, 2018)
- Illustrated specification detail for pervious pavement developed specifically for Oregon.

Reducing Pavement & Permeable Paving Options[PDF- 2 pg] (City of Seattle, 2009)
- Brief factsheet on pervious paving aimed at homeowners in the City of Seattle.

Pervious Pavers [PDF- 2 pg] (City of Portland, 2006)
- Brief factsheet on pervious paving aimed at homeowners in the City of Portland.

Parking Forest [Website] (Green Girl, 2014)
- Information on pervious pavement case study projects in Portland, OR area. Includes design criteria, specifications, and cost considerations.

General Reports and Guides

LID Overview Factsheet [PDF- 8 pg] (Oregon Environmental Council, 2009)

- Serves as a basic introduction to LID for those unfamiliar.

Stormwater Solutions Report: Turning Oregon's Rain Back into a Resource [PDF- 68 pg] (Oregon Environmental Council, 2007)

- Discusses regulatory context, barriers, recommendations, and Oregon LID funding sources.

Low Impact Development Approaches Handbook [PDF- 111 pg] (Clean Water Services, 2009)

- Handbook for public agencies in the Tualatin Basin, OR that can be used as a reference for LID-related planning.

Tools, Strategies, and Lessons Learned from EPA Green Infrastructure Technical Assistance Projects [PDF- 20pg] (EPA, 2015)

- Simple guide with great pictures of LID types, opportunities for LID, and list of case studies.

Green Infrastructure Municipal Handbook [Website] (EPA, 2015)

- [PDF's] Retrofit Policies, , Incentive Mechanisms, Green Streets, Funding, Rainwater Harvesting Policies

Green Infrastructure Toolkit [Website] (Georgetown Climate Center)

- Contains wealth of information on selecting pilot projects, implementing LID in existing processes, funding, and communication strategies.

The Value of Green Infrastructure [PDF- 80 pg] (Center for Neighborhood Technology, 2010)

- Discusses benefits of various LID types and how to quantify benefits.

Integrating LID into Park Spaces and Public Facilities

Green Infrastructure in Parks: A Guide to Collaboration, Funding, and Community Engagement
[Website with PDF- 28 pg] (EPA, 2017)

- Provides information on bringing together multiple partners, finding funding, designing, and maintaining LID in public parks.

City parks, clean water: Making great places using green infrastructure
[Website with PDF, 52 pg] (Trust for Public Land)

- Provides information on bringing together multiple partners, finding funding, designing, and maintaining LID in public parks.

Green Infrastructure Opportunities that Arise During Municipal Operations [PDF- 36 pg] (EPA)

- Guide discussing opportunities to incorporate LID within public parks, facilities, or transportation projects.

Municipal Handbook: Green Streets [PDF- 19 pg] (EPA, 2008)

- Green streets information on design, costs, and examples.