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Chapter 1: Low Impact Development

1.1 Introduction
The Eastern Washington Low Impact Development Guidance Manual (Guidance Manual) is designed to promote and encourage the use of Low Impact Development (LID). Implementing LID techniques and practices will reduce stormwater runoff and protect natural resources. LID stormwater management practices for new and redevelopment projects represent a nationally-recognized innovative land use and stormwater management approach.

The unique climate, soils and geology within the varying regions of Eastern Washington compliment the ability of LID solutions to be site specific. Each sites specialized characteristics can be taken into account when planning, designing and constructing an LID project. With the proper planning, design, construction and maintenance LID can accommodate varying climate, soils and geology throughout Eastern Washington.

The Eastern Washington Phase II Municipal Stormwater Permit (Permit) states that no later than December 31, 2017, each Phase II jurisdiction shall adopt an ordinance or other regulatory mechanism that includes requirements for project proponents and property owners to implement appropriate runoff treatment, flow control, and source control. This Guidance Manual provides guidance to planners and designers on LID planning tools (LID non-structural BMPs) and LID practices (LID structural BMPs) as options to meet Permit requirements.

The Guidance Manual is intended to be a practical tool for those who make or influence development design decisions including engineers, architects, planners and contractors. The content will provide baseline guidance for LID based development projects and retrofits. The Guidance Manual shall not define solutions that will achieve LID on every site, but shall provide information and options that allow for the educated selection and innovation in design when developing stormwater management plans. The LID strategies that are right for each site will likely be unique to that project.

The Guidance Manual is a collaborative product of Spokane County, the Washington State Department of Ecology (Ecology), the Washington Stormwater Center-Washington State University (WSC), and the Eastern Washington Phase II Municipal Stormwater Permittees. Funding for this project is provided by Ecology. There are twenty four (24) Eastern Washington Phase II Municipal Stormwater Permittees within Eastern Washington (see Map 1).
<<INSERT MAP 1 - EXACT SIZING AND LOCATION WILL BE DETERMINED AT 90 PERCENT DRAFT>>
1.2 Intent of LID Best Management Practices

LID Best Management Practices (BMPs) are intended to reduce and mitigate the environmental impacts of conventional development by mimicking natural hydrology. LID BMPs may meet water quality regulations and stormwater management goals by protecting vegetation and habitat. LID BMPs offer more options to comply with stormwater management requirements and manage stormwater runoff in ways that reduce the environmental impacts of developed areas. The five objectives of LID are to:

1. Conserve Existing Resources  
2. Minimize Disturbance  
3. Minimize Soil Compaction  
4. Minimize Imperviousness  
5. Direct Runoff from Impervious Areas onto Pervious Areas

1.3 Definition

In its broadest sense, LID is “an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible” (EPA, 2012). Ecology defines LID as a “stormwater and land use management strategy that strives to mimic pre-disturbance hydrologic processes of infiltration, filtration, storage, evaporation and transpiration by emphasizing conservation, use of on-site natural features, site planning, and distributed stormwater management practices that are integrated into a project design.”

LID can take a variety of forms, but an overall guiding principle is that high levels of impervious surface coverage interfere with the natural movement of water within an ecosystem, which can, in turn, impair hydrologic and ecological functions. Instead of conveying stormwater runoff to off-site detention or treatment facilities, LID practices allow for the management of stormwater runoff at its source, restoring natural processes and reducing demand for traditional stormwater detention and treatment.
<<INSERT A PAGE OF EASTERN WASHINGTON AND/OR SEMI-ARID CLIMATE LID PHOTOS HERE – EXACT LOCATIONS WILL BE DETERMINED AT 90 PERCENT DRAFT>>
1.4 Relationship to State and Regional Stormwater Manuals and UIC

The Guidance Manual is intended to provide guidance on planning, design, construction and maintenance. The information within this Guidance Manual is intended to inform and educate planners, engineers, architects, landscape designers, and contractors about LID practices. This document is not intended to replace or supersede the Stormwater Management Manual for Eastern Washington, or any local equivalent.

The Stormwater Management Manual for Eastern Washington and other locally-adopted equivalent manuals contain detailed standards for hydraulic analysis, runoff treatment facility design, flow control facility design, and construction stormwater pollution prevention. As a guidance document, this Guidance Manual does not contain specific design standards or regulations.

It is important to note that none of the LID BMPs discussed in this Guidance Manual employ Underground Injection Control (UIC) systems. The LID techniques discussed here rely on gravity for infiltration and drainage. Additional information on the use of UIC systems is available from the Department of Ecology.

LID is encouraged everywhere, but certain techniques may not be allowed by the local jurisdiction due to technical feasibility constraints or other issues. The BMP fact sheets contained in Chapter 4 of this Guidance Manual will identify potential feasibility constraints for each of the BMPs to aid property owners, developers, designers, and contractors in selecting the BMPs most appropriate for their site. Ultimately, local permitting authorities will determine what LID techniques will be allowed for a given project.

1.5 LID Innovation

As of this writing, LID is still a relatively new approach to stormwater management and technologies used to implement it are continuously evolving and maturing. The BMP recommendations featured in this Guidance Manual, particularly the fact sheets contained in Chapter 4, represent a snapshot of the current state of LID technology. It is anticipated that, over time, new technologies and refinements of current methods will provide even greater efficiency in meeting water quality standards and runoff reduction goals. Future users of this Guidance Manual are encouraged to utilize the best available solutions when constructing LID facilities, and local jurisdictions will have the ability to select specific LID practices that are appropriate in their region.
Chapter 2: Planning for Low Impact Development

2.1 Planning Principles
To properly implement LID at the site level, the designer must understand the physical and regulatory conditions on a given site. The process of planning for LID includes an in-depth analysis of the natural conditions of the site (e.g., soils, topography, hydrology, etc.), as well as the built and regulatory elements (e.g., access, utilities, easements, zoning, etc.) that will influence development and the use of LID practices.

Below are step-by-step instructions on how to analyze a site (or region) for its appropriate uses. Through this process the designer becomes very familiar with the area through analysis of soil, climate, vegetation, and hydrology, as well as the equally important built and regulatory elements. The following sections describe the site analysis, site planning, and BMP selection process in detail.

2.2 Site Analysis
In its broadest context, the purpose of the site analysis is to understand the areas of the site most and least suitable for development. Development refers not only to the proposed use of the site, but also ancillary features such as access, parking, and of course stormwater management features.

The first step in determining which LID practices are appropriate for a site is the preparation of a thorough site analysis. This allows the designer to learn how water moves through the site and how natural hydrologic functions could be preserved. An inventory of conditions on and adjacent to the site, including topography, soils, hydrology, and vegetation should be conducted. The site analysis should include site visits, topographical and vegetation/habitat surveys, review of maps and reports, and development of a site base map.

During the site analysis, the physical attributes of the development or redevelopment site should be reviewed prior to placing streets, parking lots, and buildings in order to optimize stormwater management and habitat protection. Existing features should be incorporated into the site design by working with, rather than against, site attributes and constraints.

Site analysis should follow the order depicted in Figure 1 and answer the questions below.
1. **Topography**  
*Is the site flat, steep, or moderately sloped?*  
The steeper the slope, the more likely soil erosion or slides could occur. Generally, slopes greater than 30 percent should be avoided for clearing, grading, and building. Steep slopes and slide prone areas are not advisable for infiltration-based LID practices. A geotechnical engineering analysis may be necessary to determine appropriate BMPs.

2. **Soils**  
*What is the site soil type, hydrologic group, infiltration capacity, and are groundwater tables high?*  
The Natural Resources Conservation Service (NRCS) maintains soil data for areas covered by a published soil survey. Local soil information and soil maps should be acquired from the NRCS as part of the site analysis. Sizing for some LID BMPs may be adjusted based on tested infiltration rates unless high groundwater levels are present. Ultimately, the final engineering design will likely require expertise of a geotechnical engineer to establish the infiltration rates in the areas where the LID BMPs are proposed.

3. **Hydrology**  
*What are the flow patterns into, on, and from the site? Where will runoff drain? Does the site have FEMA floodplains or floodways, drainage hazard areas, or Water Quality Sensitive Areas, seeps or springs?*  
The local permitting authority will likely maintain maps that depict the approximate location of on- and off-site water resources, seeps and springs, and other areas where drainage hazards have been documented. Many local governments also maintain geographic information systems (GIS) that contain topography at contour intervals as small as one or two feet. The FEMA website includes adopted floodplain and floodway mapping.

4. **Vegetation & Habitat**  
*Are there trees and vegetation, or native vegetation on the site?*  
Native trees and vegetation should be protected where possible.

5. **Water Quality Sensitive Areas**  
*Are there year-round or intermittent streams or channels or wetlands?*  
Streams and wetlands are water resources that are protected by a myriad of state and federal laws. Activities with the potential to affect these resources are regulated by the US Army Corps of Engineers, the Washington State Department of Ecology, and the Washington Department of Fish and Wildlife (WDFW). Development proposals that affect one of these water bodies may be subject to review by these agencies, as well as mitigation measures to ensure protection of ecological resources and habitat. Refer to National and Local Wetlands Inventory maps and consult with the local government staff to determine requirements for application review. The accuracy of these maps can vary greatly and it is common for applicants to need the expertise of a wetland or stream...
ecologist/biologist at the site analysis stage not only to identify the edge of the water resource, but also to categorize it so that the appropriate protective buffer can be applied.

6. Land Use/Zoning/Shoreline Master Program

What type and density of development is allowed/required? Are there special or protective overlay zones? Can development be clustered or lot sizes altered?

It is important to consult the local jurisdiction’s planning and development codes in order to understand the opportunities and constraints of the site. In addition to understanding allowable uses, the codes should be consulted so that the designer understands limitations on impervious surface coverage, minimum landscaping requirements, minimum lot area and setback requirements, and site design requirements that may require building placement on areas of the site in order to facilitate a particular urban character.

7. Access

What are the options for auto, bike and pedestrian access, circulation and parking?

Vehicular and pedestrian access, circulation, and parking can often represent guiding factors to the design of a development site. The designer should be prepared to consult both local government and state requirements for site access. These requirements will establish the number required access points, the width of the access, the spacing of access points between sites on the same or opposite side of the adjacent street right-of-way, and pedestrian circulation requirements along and through the site to the proposed use.

8. Utility Availability and Conflicts

What potential utility conflicts exist? Where are existing utility connections (water, sewer, storm drainage, electricity/phone/cable, etc.)? Where can new utilities be constructed with least impacts?

The location of wet (e.g., water, sewer, stormwater, etc.) and dry (power, phone, cable, etc.) utilities should be located and the adequacy or concurrency of these utilities should be ascertained. Where utilities already exist on the site, easements or other covenants that may stipulate on-site restrictions should be identified and mapped. The county auditor or recorder’s office or a title company is often a good source of finding restrictions and easements that may be recorded against the title of the property. Also consider directly contacting the utility purveyors for this information.

If new utilities need to be extended to the site, the designer will need to understand where the utility will come from and the impact that easements and restrictions may have on the site design.

9. Composite Map

The designer should take the items identified under items 1-8 above and compile them into a Composite Site Analysis Map (Map). The Map will depict those areas most and least suitable for development. The Map will identify those areas most suitable for stormwater management, access, parking, and building sites.
2.3 Site Planning

After completing the site analysis, prepare a site plan for permit submittal that addresses the five LID objectives listed below:

1. **Conserve Existing Resources**

   The first and most important step in LID site planning is to preserve and protect existing water resources and vegetated areas. Although permanent protection of sensitive water quality areas and vegetated corridors may be required by local planning and development codes, protection of other elements such as mature trees and vegetation provides habitat, prevents erosion, captures significant rainfall, provides summer shading, and reduces runoff volume and velocity which protects and enhances downstream water quality. Preservation of additional trees and vegetation may also reduce a site’s ultimate impervious area and the size of required water quality or storage facilities.

2. **Minimize Disturbance**

   Protecting existing vegetation provides more water quality benefits than replanting areas that have been cleared. Undisturbed areas provide more rainfall interception, evapo-transpiration and runoff rate attenuation than replanting, even with soil amendments. Construction activities that compact native soils significantly reduce infiltration capacity and increase runoff volume. To minimize disturbances, identify areas required to be protected and other areas that will not be cleared or impacted during construction. On plan submittal drawings, identify site work zones and no-disturbance areas. On the site, use orange construction fencing to mark work zones, access points, materials storage locations, and areas where no disturbance is allowed.

3. **Minimize Soil Compaction**

   Avoid activities that could cause soil compaction in areas designated for infiltration-based LID BMPs. Soil compaction should also be avoided or minimized in areas where other types of LID BMPs, water quality or detention facilities, or landscaping will be placed. Clearing, grading and compaction by construction traffic reduces the natural absorption and infiltration capacities of the native soils, and while subsequent tilling and/or addition of soil amendments can help, it will not restore the original infiltration capacity of the soils. To minimize compaction, soil amendments should be prepared off-site; if prepared on-site, soil amendment preparation should be conducted in a designated location using appropriate erosion prevention and sediment control methods.

4. **Minimize Impervious Surface Coverage**

   Site design should strive to reduce the actual footprint of buildings and hard surfaces to reduce and slow runoff from the built environment. Various LID practices (e.g. permeable surfaces, vegetated roofs, minimal excavation foundations) serve to reduce the total impervious area on the site and may reduce the volume of stormwater to be treated.

5. **Direct Runoff from Impervious Areas onto Pervious Areas**
This is the last line of defense against downstream impacts. While the first four objectives prevent runoff and pollution transport, this addresses pollutants in runoff from roofs, parking lots, streets, and other impervious surfaces. Many LID practices fulfill this objective (e.g. flow-through planters, swales, and landscaped areas designed to receive runoff from impervious areas).

2.4 Selecting LID Solutions to Match Site Conditions

LID solutions can be implemented on and/or adjacent to buildings, as well as integrated into site landscaping and hardscape such as parking lots and along streets. LID practices can be used individually to manage rainfall and runoff from a drainage area, or constructed in a series of multiple facilities. The site analysis process helps identify the types of LID practices best suited to the site. Owners and designers may use Table 1 below as a quick reference to match each LID practice with common stormwater management objectives and site constraints to select the most appropriate facilities.
### Table 1: LID Solution Selection for Site Conditions

<table>
<thead>
<tr>
<th>Site Condition</th>
<th>Bioretention Area</th>
<th>Infiltration Planter / Storm Garden</th>
<th>Flow-through Planter</th>
<th>Flow-through Planter</th>
<th>Permeable Surfaces</th>
<th>Vegetated Roofs</th>
<th>Minimal Excavation Foundations</th>
<th>Rainwater Harvesting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce Impervious Coverage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infiltrate</td>
<td>✓</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Detention/flow Control</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Provide Habitat</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
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<td></td>
<td>✓</td>
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<tr>
<td>Near Vegetated Corridor</td>
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<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Private Property</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Private Street</td>
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<tr>
<td>Public Street/ROW*</td>
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<td>✓</td>
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<tr>
<td>On or next to building</td>
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<td></td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Parking lot</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>✓</td>
</tr>
<tr>
<td>Landscaped area</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Steep Slope</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Soils with low infiltration rate</td>
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<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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</tr>
<tr>
<td>High groundwater table</td>
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<td></td>
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</tr>
<tr>
<td>Shallow depth to bedrock</td>
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</tr>
<tr>
<td>Contaminated Soils</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
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</tr>
</tbody>
</table>
In addition to the site conditions listed in Table 1, it is important for owners and designers to consider maintenance requirements when selecting LID practices. All LID facilities require some degree of maintenance to continue performing at peak efficiency over time, but the method and frequency of maintenance activities varies by the type of facility.

At the earliest stages of project conception, the designer should consider how the future users of the site will maintain the stormwater features and the types of controls (e.g., covenants, title notifications, financial sureties, etc.) that will be necessary to ensure that maintenance is performed. For example, the future owners of porous pavement areas should understand and be compelled to perform periodic cleaning to remove sediment buildup that can reduce the efficiency of stormwater infiltration. The ability to provide adequate, regular maintenance for installed LID facilities at a given site should be considered alongside other technical constraints when selecting stormwater solutions. Specific maintenance requirements are included within each BMP Fact Sheet found in Chapter
<<INSERT LID IN PARKING AREAS FIGURE HERE – EXACT LOCATION AND SIZING TO OPTIMIZE PAGE LAYOUT WILL OCCUR AT 90 PERCENT DRAFT >>
<<INSERT LID FOR STREETS HERE – EXACT LOCATION AND SIZING TO OPTIMIZE PAGE LAYOUT WILL OCCUR AT 90 PERCENT DRAFT >>
<<INSERT LID FOR BUILDINGS AND ADJACENT AREAS HERE – EXACT LOCATION AND SIZING TO OPTIMIZE PAGE LAYOUT WILL OCCUR AT 90 PERCENT DRAFT >>
Chapter 3: LID Design Process

3.1 Design Basis

Comprehensive site planning is integral with Low Impact Development (LID) storm drainage selection and design. The process involves collaboration with the project team, including the property owner and designers (e.g. civil engineer, landscape architect, architect, and planner). Successful LID design is dependent upon quality evaluation of the site analysis from the planning stage (Chapter 2) and integration with the project goals. Careful evaluation of specific site features will provide an understanding of LID site design opportunities available to the site. Each site is unique and successful LID demands that the distinct qualities be recognized during the design phase.

The primary goal of LID site design is to mimic natural site hydrology in the post-developed state. Generically, this is accomplished with small-scale components distributed through the site. These components manage stormwater runoff as close to where it falls as possible. Each component is selected as part of an overall stormwater management system. These components are typically a combination of structural and/or non-structural LID elements and often can be integrated with the landscaping requirements. The use of LID practices can reduce the amount of stormwater runoff by providing distributed stormwater management practices that are integrated into a project design.

Designs that incorporate LID may require close coordination between the regulatory agency and the project design team. An initial meeting with the local government staff is highly recommended to explore the suitability of specific LID practices for the project and clarify the design approval process. Prior to developing detailed LID designs solutions, the project team should inquire with local government staff on the feasibility and compatibility of the proposed LID design concepts with local objectives.

3.2 Design Steps for LID Facilities

A sample design process for a project that incorporates LID practices is outlined below. The exact process will vary based upon many factors including site constraints, local regulatory requirements, and the project proposal.

Step 1 – Evaluate Chapter 2 Findings
- Review Site Analysis
- Review Site Plan
- Review Selected LID Solutions

Step 2 – Determine local regulations for stormwater quantity and quality
- What are the appropriate design storms?
- What level of treatment for stormwater runoff is required?
• Does the stormwater runoff rate discharged off-site need to be controlled?
• Are there limits on the quantity of runoff discharged off-site?

Step 3 – Evaluate site suitability for potential LID practices
• Is the site’s soil suitable for infiltration-based LID practices?
• Do critical areas exist on the site?
• How will the LID practices support the aesthetic character of the proposed development?
• Are there any spatial constraints that should be understood and mapped?

Step 4 – Meet with local jurisdiction to evaluate LID opportunities and to determine suitability
• What is the process required to approve the proposed LID components?

Step 5 – Complete stormwater modeling on a per-component basis
• Ensure stormwater runoff is managed as close to the source as possible.
• Confirm that regulations for stormwater runoff quantity and quality are met

Step 6 – Review implementation and modeling with local jurisdiction
• Confirm and ensure that the design meets regulatory requirements.
• Prepare documents required to support the design as part of approval processes such as design deviations or administrative exceptions.

3.3 Modeling
Modeling of LID designs shall be done in accordance with the approved stormwater management manual of the local jurisdiction. This shall include any quantity and quality restrictions. An important component of LID is to manage runoff at the source. Therefore the modeling should be done at a relatively small scale, focusing on the network of LID facilities installed on the site. Modeling techniques found in the following resources should be consulted:

• Stormwater Management Manual for Eastern Washington (Washington State Department of Ecology) or locally adopted equivalent manual
• Highway Runoff Manual (Washington State Department of Transportation)
• Yakima Regional Low Impact Development Stormwater Design Manual
• Spokane Regional Stormwater Manual
• Yakima County Regional Stormwater Manual
Chapter 4: Fact Sheets

4.1 Low Impact Development Planning Tools (Non-structural BMPs)

Conserve Existing Resources

Minimize Disturbance

Minimize Soil Compaction

Minimize Imperviousness

Habitat Creation/Restoration/Planting Design
4.2 Low Impact Development Practices (Structural BMPs)

Bioretention Areas

Infiltration Planter/Storm Garden

Flow-Through Planter

Dispersion

Amending On-Site Soils

Permeable surfaces

Permeable surfaces are water permeable structural systems that infiltrate precipitation while attenuating stormwater runoff flows and volumes. Permeable surfaces provide a stable load-bearing surface without increasing a project’s total impervious area.

The two main categories of permeable surfaces are 1) pervious concrete and asphalt, and 2) permeable pavers. Pervious concrete and asphalt resemble their solid counterparts, except that the fines (sand and finer material) are reduced to create more void space for water to flow through. Permeable pavers are solid, discrete units typically made of pre-cast concrete, brick, stone, or cobbles and set to allow water to flow between them.

Application & Limitations:
Pervious asphalt, pervious concrete, and permeable pavers can be used in most pedestrian areas, sidewalks and other Non-Pollutant Generating Impervious Surfaces (NPGIS) as defined in the Stormwater Management Manual for Eastern Washington. Local jurisdictions may approve permeable surfaces for driveways, parking lots, and roadways on a case-by-case basis.

Permeable surfaces should not be located over cisterns, utility vaults, underground parking or other impervious surfaces and should be applied in accordance with the requirements for infiltration trenches in the Stormwater Management Manual for Eastern Washington or local requirements. The 2004 manual recommends a 5-foot separation between the facility’s bottom or drain rock and the
seasonal high water table or bedrock. Permeable surfaces should not be applied in locations where there is a high risk of chemical spillage.

Design Factors:

Sizing
Stormwater from the permeable surfaces infiltrates directly into a crushed rock storage layer. If approved by the local jurisdiction, detention storage may be constructed beneath the permeable surfaces and sized by approved calculation. Water quality treatment must be provided for any stormwater requiring treatment per local regulations.

Stormwater Management Credits
Depending on local regulations, credits for sizing of downstream stormwater management facilities may be available based upon the composition of the permeable surfaces. These credits could be applied by modeling the permeable surfaces as partially to completely pervious.

Aggregate bases designed to provide detention may receive flow control credit based upon the storage capacity of the system and are modeled as an infiltration basin.

Slopes
The effectiveness of permeable surfaces is reduced on steep slopes. Surface design shall consider the effects of slope on surface performance.

Piping
Where existing soils have an infiltration rate of 0.5” per hour or less, flat slopes, or a large amount of permeable surfacing is proposed an under-drain to an approved outlet structure should be provided.

Setbacks
Site-specific requirements for setbacks should be confirmed with the local building department. Impermeable liners are recommended between base rock and adjacent foundations and conventional Asphalt Cement Concrete (ACC) or Portland Cement Concrete (PCC) pavement.

Permeable Surfaces Design
Permeable surfaces design shall be based upon the desired surface infiltration rate. Various rates of clogging have been observed and should be anticipated and planned for in the design. Project mix design shall be approved by the local jurisdiction. The following references for mix design should be used:

- Pervious asphalt and concrete:
Bedding Course
The bedding course beneath pervious asphalt or concrete pavement consists of clean 1” or greater choker course meeting AASHTO No. 57.

Aggregate Base
The base course consists of washed, 3/4” to 2” uniformly graded aggregate. The depth of the aggregate base course will vary per design.

Geotextile Fabric
Non-woven geotextile fabric should be placed between the subgrade (native soil) and the aggregate base for proper separation.

Subgrade
Excavate to the bed bottom elevation. Care should be taken to avoid compaction of the subgrade surface and all construction equipment should be kept off the subgrade. If based on the soil type, the excavation of the surface has been sealed, the surface should be lightly scarified or raked to provide infiltration values consistent with the design.

For traffic areas, compact the subgrade soil for public roadways, private streets, parking lots, and fire lanes to ensure structural stability and minimize rutting. Compaction should be to sufficient to preserve structural integrity. Because compaction reduces soil permeability it should be done with caution and scarified prior to setting the aggregate base. Protect the subgrade from truck traffic. It is imperative to protect the permeable surfaces subgrade from over-compaction.

Construction
Erosion and the introduction of sediment from surrounding land uses should be strictly controlled during and after construction. Erosion and sediment controls should remain in place until the area is completely stabilized. Install permeable asphalt system toward the end of construction activities to minimize sediment inputs. The sub-grade can be excavated to within 12 inches of final grade and grading completed in later stages of the project.

Maintenance:
- Check with the local jurisdiction about use of permeable surfaces for public facilities.
• If approved for use in the public right-of-way, the permittee must comply with local jurisdiction requirements for a maintenance assurance period. If private, the property owner is responsible for ongoing maintenance per a recorded maintenance agreement. Permeable surfaces on private roads must be in a separate tract.

• Permeable surfaces requires regenerative air style vacuuming at least once a year, but twice a year is recommended to remove fine particulates from the infiltration spaces. Without this ongoing maintenance, the facility may become impervious. Over time, settling may occur and aggregate base, washed sand, and/or pavers may need to be replaced or repaired.

• Sealing is a common maintenance practice with conventional asphalt. Pervious asphalt must not be sealed or it will lose its pervious function. Owners should take extra care not to seal pervious asphalt pavement. If permeable surfaces are sealed, additional stormwater treatment may be required.

References:
• Clean Water Services Design and Construction Standards
• Stormwater Management Manual; City of Portland
• Yakima Regional Low Impact Development Stormwater Design Manual; Yakima County, 2011.
Vegetated Roofs

Roofs on buildings represent nearly half of all impermeable surfaces in urban areas. One way of managing the runoff generated by those surfaces is through the use of vegetated roofs. In the context of a building, the roof setting is the first opportunity to implement a low impact development (LID) BMP. For the purposes of this document, we use the term vegetated roofs, so as not to limit the description or application of the technology.

Applications:
Vegetated roofs can be an appropriate LID BMP in Eastern Washington if design and construction responds appropriately to the environmental conditions. Freezing temperatures, heavy snowfall, strong winds, and hot, arid summers all need to be considered when implementing vegetated roofs.

Vegetated roofs should be designed on a site-by-site, building-by-building basis, so all potentials and constraints are comprehensively evaluated and used to guide the roof design. There are many products and producers of vegetated roof technology. It is important to test these various products will work in various micro-climatic conditions. This section identifies the essential design considerations for all vegetated roofs and makes recommendations based upon climatic and environmental conditions.

Design:
Many varieties of vegetated roofs may be appropriate, subject to the context of the project. The threshold requirements of a vegetated roof include:

- Waterproof the roof;
- Protect the roof surface from root penetration and damage;
- Drain water off the roof; and
- Support the growth of vegetation.

In addition, every vegetated roof is composed of basic components, or layers, that support the aforementioned functions (from bottom to top, see Figure ______):

- Roof Structural Support (supports the roof deck);
- Roof Deck (the hard surface that supports everything on the roof);
- Protective Layer (composed of insulation, or a root protection barrier, and a waterproof membrane);
- Drainage Layer (a sub-layer through which water drains, capped by a filter mat);
• Substrate (the vegetative growing medium and irrigation system);
• Vegetation.

The arrangement of these layers may vary depending upon the type of green roof (Cold, Warm, or Inverted Warm). Design intent, structural considerations, maintenance, and the use of other LID BMPs will influence the selection of construction techniques and materials for these layers. The designer should consider:
• What is the appropriate type and design of vegetated roof based on its intended function?
• Is the load bearing capacity of the building able to support the intended vegetated roof? What is that capacity? Is the size of the roof sufficient?
• Can the vegetated roof be maintained easily and affordably?
• What stormwater benefits will accrue from the design?

Stormwater Management Credits
Depending on individual local regulations, stormwater credits for sizing of downstream stormwater management facilities may be a possibility based upon the composition and size of the vegetated roof. This credit could be applied by modeling the vegetated roof as partially to completely pervious. Appropriate modeling would include credits approved by the local jurisdiction. The design of each layer can have an impact upon the potential for stormwater runoff from the vegetated roof system and any associated comments. A discussion of the impacts is included below.

Roof Structural Support
It will be important to ensure that the additional weight of the vegetated roof is distributed evenly across the roof deck and support structure below. We suggest working closely with a structural engineer throughout the design of the vegetated roof. Also, consider the additional weight of snow in the winter, as well as a maintenance regime to mechanically remove snow buildup to prevent roof damage and collapse.

Roof Deck Slope
Vegetated roofs installed on sloping roofs are subject to greater moisture stress than on flat or gently sloping roofs. Without additional slope stabilization measures, vegetated roof slopes should be no steeper than 1:6. With stabilization, pitches of up to 7:12 can be achieved. Steeper pitched roofs require specialized media mixes and devices. In terms of the quantity of stormwater runoff, vegetated roof slopes of up to 15 degrees tend to provide the same level of retention as flat roofs.

<<INSERT PHOTOGRAPHS OF VEGETATED ROOFS HERE – EXACT LOCATION AND SIZING TO OPTIMIZE PAGE LAYOUT WILL OCCUR AT 90 PERCENT DRAFT >>
Fire Protection
Dry heat is a design factor in Eastern Washington, so the use of flammable materials in the construction of the vegetated roof should be avoided, and designers should maintain a clear stone or gravel border around parapet walls, roof top windows, chimneys, and other openings where fire may spread. Specifying fire-resistant vegetation can also minimize the total amount available fire fuel.

Protective Layer
Root penetration layer
Maintaining a continuous separation between the roof membrane and vegetative root zone will reduce the potential for root damage. The material should be raised above the substrate at the edges and around vertical projections, like vents.

Waterproof Layer
More organic construction materials, such as oil-based bitumen and asphalting felt and fabrics decompose and require more frequent maintenance, leaving roofs susceptible to leaks. They are also the most common form of roofing materials. Various mechanically-produced materials are available for waterproofing the roof, such as rolled sheets or inorganic single-ply membrane or fluid-applied membranes. Ensuring a complete seal on these membranes, especially at the joints, is critical.

Drainage Layer
Drainage layers store and channelize stormwater infiltrated through the substrate and offer additional space for plant roots. Materials used may be granular stone, porous mats, lightweight plastic or polystyrene drainage modules. Selection of materials will depend upon weight requirements as well as the objectives of stormwater system design.

Runoff
Vegetated roofs provide their greatest contribution to stormwater management for low-intensity to moderate storms. Heavy storms saturate the soil more quickly, thereby reducing retention potential on a shorter timeline, although generally speaking, a roof with vegetation and planting medium will retain the greatest possible amount of stormwater. The drainage layer, therefore should seek to balance the objectives of storage and conveyance.

Substrate
Vegetated roof soil, or substrate, varies in depth and composition for structural, planting, and stormwater management purposes. Depending on the soil composition and weight, additional roof support may be required. It is possible to vary the depth of substrate to “maximize ecological variety”. Weight, water retention, and nutrient holding capacity are the primary factors to be considered when selecting substrate and drainage material.

Water Retention and Quality
The substrates of vegetated roofs perform the majority of water retention. The amount of water retained is primarily a factor of substrate depth although studies suggest that substrates deeper than 6 inches do not necessarily provide more retention capability.

**Growing Medium**

Substrate depths of 2 to 3 inches support a wider range of succulent species, grasses, and herbaceous plants. Depths of 4-8 inches will enable a wide range of drought-tolerant perennials and grasses and some tough small shrubs. Substrate depths of 12-20 inches will enable many perennials and shrubs to be grown, whereas trees require 32-52 inches.

<<INSERT PHOTOGRAPHS OF VEGETATED ROOFS HERE – EXACT LOCATION AND SIZING TO OPTIMIZE PAGE LAYOUT WILL OCCUR AT 90 PERCENT DRAFT >>

**Irrigation**

As the main growing medium for roof plantings, irrigating the substrate is an important consideration. For areas with drier summers and cold winters irrigation is typically necessary for both plant establishment and watering during drought conditions. Appropriate irrigation will need to be selected based upon substrate and plant selection. Substrate drip and tube systems that are either pegged to the surface or buried in the substrate are preferred. Other options include porous capillary mat systems for substrate depths of less than 8 inches. It is critical to ensure that the irrigation system is properly winterized on an annual basis.

**Vegetation**

The main difference between a plant palette in a storm garden and one on a green roof is root depth. Vegetated roofs need shallow rooted species that are adapted to thin soil profiles in addition to high temperatures and periods of drought. Additionally, diverse palettes, as opposed to monocultures, tend to result in better overall plant survival. Select plants that:

- Cover and anchor the substrate surface relatively quickly;
- Form a self-repairing mat;
- Take up and transpire the available / retained water; and
- Survive the extreme climatic conditions (cold hardy, drought-tolerant, wind-tolerant).

**Planting Strategies**

There are many ways of establishing plants in a vegetated roof. Methods will vary but some of the most common include:

- Direct application of seed or cuttings
- Planting of pot-grown plants or plugs
- Laying of pre-grown vegetation mats or grids
- Spontaneous colonization

**Native Plants**
Eastern Washington has many good native and highly-adapted plant choices that are appropriate to green roof settings, primarily because of the extreme climatic conditions that exist and the adaptation of native species to those extremes. Consider embracing naturally-occurring, “weedier” plant species that survive with little to no input, especially in extensive applications. Meadow-like bunchgrass mixes and desert shrub-steppe plants are particularly appropriate.

Maintenance:
Vegetated roofs should be low maintenance but will require some scheduled maintenance to avoid or resolve problems. The level of maintenance will vary depending on soil depth, vegetation type, and location.

- During the fall and spring rainy seasons, check drains monthly and remove any accumulated debris.
- Remove dead plants and replant as needed in spring and fall to maintain substantial plant coverage. At least 90 percent coverage is recommended.
- During the first growing season remove weeds and undesirable plant growth monthly, and in late spring and early fall in subsequent years.

References:
- Clean Water Services Design and Construction Standards
- Stormwater Management Manual; City of Portland Bureau of Environmental Services, 2008
- Planting Green Roofs and Living Walls; Nigel Dunnett and Noël Kingsbury, 2008
Minimal Excavation Foundations

Rain Water Harvesting

Conveyance and Stormwater Art
Appendices

Appendix A: Maintenance

Appendix B: Detail Drawings

Appendix C: Glossary

Appendix D: Additional Resources/References
This Manual is intended for use by the 18 Eastern Washington cities and URBANIZED portions of the 6 counties described in the 2012 Eastern Washington Phase II Municipal Stormwater Permit.