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Chapter 1: Low Impact Development

1.1 What is Low Impact Development?
In its broadest sense, Low Impact Development (LID) is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. The chief quality of this approach is that it is decentralized, integrated into the site, and implemented near the source of the flows.

The Washington State Department of Ecology (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 overall it promotes the movement of water within an ecosystem allowing for natural hydrologic, hydraulic and ecological functions. LID practices encourage the management of stormwater runoff at or as close to the source as possible, restoring natural processes and can reduce demand for stormwater detention and treatment.

1.2 LID in Eastern Washington
The Eastern Washington Low Impact Development Guidance Manual (Guidance Manual) is a practical tool for those who make or influence development design decisions. The content provides guidance for LID based development projects and retrofits. This Guidance Manual promotes and encourages the use of LID throughout Eastern Washington.

The varying climate, soils and geology east of the Cascade Mountains compliment the ability of LID solutions to be site specific. Each projects specialized characteristics are taken into account when planning, designing and constructing LID solutions and maintenance plans. Information and options are provided to allow for educated LID solution selection and design innovation.

This 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. Several of the Eastern Washington Phase II Municipal Stormwater Permittees (Phase II Permit) provided oversight during the development of this Guidance Manual through the Low Impact Development – Stakeholder Advisory Group (LID-SAG), consisting of the jurisdictions listed in the “Acknowledgements” section. See Map 1 for all Phase II Permit jurisdictions within Eastern Washington (see Map 1). The LID-SAG received professional technical assistance from the Low Impact Development – Technical Review Committee (LID-TRC), consisting of a group of volunteer technical specialists listed in the “Acknowledgements” section.
1.3 How to Use this Manual and Implement LID

State and regional stormwater manuals detail the legal guiding stormwater management standards. This Guidance Manual works in cooperation with State and regional stormwater Manuals. The focus of this manual is to describe LID planning principles and flow control techniques that can assist in meeting stormwater management standards. The use of LID techniques does not eliminate the requirement to meet Core Elements 5 and 6 in the SWMMEW, or local equivalent.

This Guidance Manual details the steps necessary to implement LID. Chapter 2 - Planning for Low Impact Development describes the LID planning principles, site analysis, site inspection, and composite map. Chapter 3 - LID Design Process describes the LID flow control fact sheets and selecting LID solutions to match site conditions. The “Fact Sheets” provide a description, applications and limitations, design factors, maintenance, additional resources and references for the flow control techniques. Chapter 4 - LID Site Plan Design describes LID design basis, design steps, and design process.

Within the various chapters is guidance on LID planning, design, construction and maintenance. The information educates planners, engineers, architects, landscape designers, and contractors about LID practices appropriate in Eastern Washington.

LID is encouraged everywhere, but certain techniques may not be allowed by local jurisdiction due to technical feasibility constraints or other reasons. The fact sheets contained in Chapter 4 identify potential feasibility constraints for each of the flow control techniques to aid designers in selecting the most appropriate technique(s). Ultimately, local permitting authorities will determine what LID techniques will be allowed for a given project.

1.4 LID Innovation

LID technologies and practices 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.
Figure 1: Eastern Washington and NPDES Municipal Stormwater General Permit Areas
<<INSERT A PAGE OF EASTERN WASHINGTON AND/OR SEMI-ARID CLIMATE LID PHOTOS HERE –

Exact Locations will be determined at 90% Draft>>
Chapter 2: Planning for Low Impact Development

2.1 Introduction

Planning is the process of thinking about and organizing the activities required to achieve a desired goal. The desired goal in an LID planning context involves organizing the site plan layout in way that utilizes natural features to manage stormwater via natural hydrologic processes. Those processes include 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.

The process of planning for LID includes an in-depth analysis of the natural conditions of the site (e.g., native vegetation, hydrology, ground water, soils, topography), as well as the built and regulatory elements (e.g., zoning, access, utilities, easements) that will influence development and the use of LID practices.

Below are guidelines on how to analyze a site 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 LID Planning Principles

LID planning principles strive to reduce environmental impacts of land development. Implementing LID planning principles at the beginning of a project allows the development to benefit from LID opportunities naturally afforded the property. LID planning principles promote compliance with water quality regulations and stormwater management goals.

Some of the LID planning principles are describe in detail in the following section and include: conserving existing resources and natural drainage facilities; minimize disturbance of existing topography, soils, and vegetation; minimize soil compaction; minimize new imperviousness and remove/reduce existing imperviousness; direct runoff from impervious areas onto pervious areas; sustain, enhance, and optimize infiltration; and protect, restore and enhance groundwater resources and surface water base flows.

2.2.a Conserve Existing Resources and Natural Drainage Facilities

The first and most important step in LID site planning is to preserve and help protect existing water resources, soils that infiltrate well and vegetated areas. Permanent protection and/or infiltration restrictions within wellhead protection areas and aquifer sensitive 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, enhances infiltration, restores groundwater, and reduces runoff volume.
and velocity which helps protect and enhance downstream water quality. Preservation of trees and vegetation may also reduce a site’s ultimate impervious area and the size of required water quality or storage facilities.

2.2.b Minimize Disturbance of Topography, Soils and Vegetation
Minimizing the disturbance of existing topography, soils and vegetation will assist in maintaining the natural hydrologic patterns. An LID based project should strive to work cooperatively with the natural features and existing character of the property. 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.

To minimize disturbances, identify protection areas 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. Plan for construction access routes and staging areas to avoid compacting soils in LID areas. These are a typical requirements of a Stormwater Pollution Prevention Plan (SWPPP) for a construction project requiring an NPDES Permit from the Department of Ecology (see Ecology’s webpage at: http://www.ecy.wa.gov/programs/wq/stormwater/construction/).

2.2.c 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.

Construction activities that compact native soils significantly reduce infiltration capacity and increase runoff volume. Clearing, grading and compaction by construction traffic reduces the natural absorption and infiltration capacities of the native 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.

2.2.d Minimize New Imperviousness and Remove/Reduce Existing Imperviousness
Site design should strive to manage the area of impervious surfaces to reduce and slow runoff from the built environment. Various LID practices (e.g. permeable pavement, vegetated roofs, minimal
excavation foundations) act to reduce the total impervious area on the site and may reduce the volume of stormwater to be treated.

If there are existing impervious areas on the property then those areas should be identified. If the imperviousness is the result of manmade causes such as compaction, then restoration of the areas to restore the permeability of the property may be possible through techniques such as tilling or aeration. Restoring permeability of those portions of the property may assist in LID design’s ability control stormwater flows on the property.

2.2.e Direct Runoff from Impervious Areas onto Pervious Areas
This is an important component in the line of defense against downstream stormwater related 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).

2.2.f Sustain, Enhance, and Optimize Infiltration
LID BMPs, when implemented with site improvements, can serve to optimize the infiltration capacity of a site. Indeed, a basic premise of LID is to promote and enhance the optimization of infiltration over conventional catchment, pipe and pond storm drainage systems. Infiltration optimization can be achieved by the distribution of smaller scale LID technologies across a site; preserving existing vegetation; and preserving and enhancing existing soils through appropriate soil amendments.

2.2.g Protect, Restore and Enhance Groundwater Resources and Surface Water Base Flows
A basic objective for the application of LID technologies is to contribute to maintaining surface base flows and protecting ground water resources. The application of LID technology, distributed across a site, designers can effectively manage storm drainage to per development base flows. In some instances, storm drainage management systems will require a combination of conventional and LID technologies. Nevertheless, LID technologies can contribute significantly to the maintenance site of base flows, and in some instances, result in significant construction and maintenance cost savings.

2.3 Site Analysis
The first step in implementing LID Planning Principles is to conduct a site analysis. The purpose of the site analysis is to understand the areas natural drainage functions and features as well as the locations on the property most and least suitable for development. The site analysis will determine where on the property the opportunities exist to implement LID planning principles. Site analysis is an inventory completed as a preparatory step to site plan design involving research, analysis, and synthesis.
Research and analysis of the property will involve analyzing land use/zoning/shoreline master program, topography, hydrology, vegetation and habitat, soils, access, and utility availability/conflicts. The research and analysis results will be synthesized and a composite map developed showing the overall results.

The site analysis process is depicted in Figure 2. This represents a general outline of the process and 32 the values listed are examples of site elements typically evaluated. It is important to realize the level 33 of analysis is detailed and must include a complete characterization of the specific element. For 34 example, a soils analysis would also include a geotechnical report include an array of test locations 35 to completely evaluate soils conditions and infiltration capacity.

2.3.a Land Use/Zoning/Shoreline Master Program
It is important to consult the local jurisdiction’s planning department and review land use regulations in order to determine the allowable land uses and development standards. Review of the local development standards will reveal if there are limitations on impervious surface coverage (lot coverage), minimum landscaping requirements, minimum lot area, setback requirements, parking requirements, and site design standards that may require building placement on areas of the site in order to facilitate a particular urban character.

2.3.b Hydrology
Contact the local permitting authority (e.g. Planning and/or Building Department) for the availability of information (e.g. maps, GIS data, documents) that depict the approximate location of on- and off-site water resources seeps and springs, and other areas where drainage hazards have been located. The FEMA website includes adopted floodplain and floodway mapping See FEMA Flood Insurance Rate Maps at:
https://msc.fema.gov/webapp/wcs/stores/servlet/CategoryDisplay?catalogId=10001&storeId=10001&categoryId=12001&langId=-1&userType=G&type=1&dfirmCatId=12009&future=false

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. Mitigation measures may be required 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.

Low impact development facilities that utilize Infiltration should have a minimum separation between seasonal high ground water, as required by the SWMMEW or local equivalent. A geotechnical
engineering report and/or well monitoring data can discover the depth seasonal depth to ground water. Consideration should also be given to season high ground water from irrigation.

2.3.c Topography
The steeper the slope, the more likely soil erosion or slides could occur. Also, infiltration restrictions may be applicable for sloped areas and within setbacks upslope of the slope areas. Generally, slopes greater than 15% may require engineering analysis prior to land disturbance and slopes 25% or greater should be avoided for clearing, grading, and building. Steep slopes and slide prone areas are not advisable for infiltration-based LID practices.

2.3.d Vegetation & Habitat
Native trees and vegetation should be protected, where possible. Vegetative root systems act to stabilize soil systems. Root systems also aid in the development of soil structure that promotes water infiltration and nutrient transport and uptake by plants. Plants assist in regulating soil moisture, reduce erosion, prevent concentrated flows and reduce flooding potential.

2.3.e Soils
The Natural Resources Conservation Service (NRCS) maintains soil data for areas covered by a published soil survey [web link: http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm]. Local soil information and soil maps may be acquired from the NRCS as part of the site analysis. Sizing for LID facilities 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 facilities are proposed.

Local jurisdictions are encouraged to provide prescriptive assumed infiltration rates for sizing of LID facilities on sites too small to justify the expense of a detailed geotechnical investigation.

2.3.f Access
What are the options for auto, bike and pedestrian access, circulation and parking?
Vehicular and pedestrian access, circulation, and parking can often represent a driving factor 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 of 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.

2.3.g Utility Availability and Conflicts
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 potentially extend to) and the impact that easements and restrictions may have on the site design.

2.4 Site Inspection

Prior to finalizing the Composite Map, the designer should evaluate the results of the seven (7) site analysis components and conduct a thorough site inspection. The site inspection often reveals unknown factors that can directly impact project development and flow control technique layout and design.

2.5 Composite Map

The designer should take the items identified under items above and compile them into a Composite Site Analysis Map (Composite Map). The composite map will identify the area’s most suitable for lots, buildings, access, parking, and stormwater management analysis of the Composite Map will reveal the LID opportunities available on the property, directing the design and layout of the site plan.

The composite map should also include a summary for each topic that includes any conclusions, recommendations and key findings.
Figure 2: Site Analysis Process
Figure 3: Parking Lot Applications
Figure 4: Streetscape Applications

- LID swales, flow-through planters or infiltration planters
- Pedestrian crossing over swale
- Flow-through or infiltration planters at corners
- Catch basin receives overflows
- Porous pavement in parking lanes
- Street trees for shading and stormwater inception
Figure 5: Building Applications
Figure 6: Site Planning Applications
Chapter 3: Low Impact Development Flow Control

3.1 Introduction
LID flow control techniques reduce and mitigate environmental impacts of land development or redevelopment by controlling stormwater flows and mimicking natural hydrology. LID offers more options to comply with stormwater management requirements and manage stormwater runoff reducing the environmental impacts associated with developing property.

3.2 LID Flow Control Fact Sheets
Various low impact development flow control techniques are applicable depending on the circumstances. LID flow control techniques include; bioretention, infiltration planter/rain garden, flow-through planter, permeable pavements, vegetated roofs, minimal excavation foundations, dispersion, amending on-site soils, rainwater harvesting, and conveyance and stormwater art (see Table 2. LID Fact Sheet Table). The LID Flow Control Fact Sheets provide a description, applications and limitations, design factors, maintenance, references and additional resources for LID flow control techniques.
3.2.a Bioretention Areas/Infiltration Planter

The term bioretention was created to describe an integrated stormwater management practices that use the chemical, biological, and physical properties of plants, soil microbes, and the mineral aggregate and organic matter in soils to transform, remove, or retain pollutants from stormwater runoff. Numerous designs have evolved from the original application; however, there are fundamental design characteristics that define bioretention across various settings.

Bioretention facilities are:

- Shallow landscaped depressions with a designed soil mix and plants adapted to the local climate and soil moisture conditions that receive stormwater from a small contributing area.
- Designed to more closely mimic natural forested conditions, where healthy soil structure and vegetation promote the infiltration, storage, filtration, and slow release of stormwater flows.
- Small-scale, dispersed, and integrated into the site as a landscape amenity.
- A BMP designed as part of a larger LID approach. For example, bioretention can be used as a stand-alone practice on an individual lot; however, best performance is often achieved when integrated with other LID practices.

Definition from Low Impact Development Guidance Manual for Puget Sound.

Bioretention comes in several forms including:

- Bioretention Cell
- Infiltration Planters
- Flow Through Planter
- Rain Garden

Stormwater runoff can be conveyed into the bioretention area by an inflow pipe or surface flow. Bioretention areas may incorporate drywells or infiltration trenches to infiltrate stormwater where soils have high infiltration rates. Under-drains may be incorporated where subgrade soils do not have sufficient capacity for infiltration. Under-drains and overflows from large events may overflow to an approved discharge point.

Application & Limitations:

Bioretention areas may help fulfill a site’s landscaping area requirement. Bioretention is appropriate for all types of impervious surfaces, including private property and the public right-of-way, rooftops, parking lots, and streets.

A bio-retention area can be designed for a dual benefit by combining flow control with treatment. Refer to BMP T5.30 Bio-Infiltration Swale in the Stormwater Management Manual for Eastern Washington for additional guidance.
**Design Factors:**

**Sizing**

Sizing of the bioretention area is determined by the local design regulations. The bioretention area shall be designed to completely store and discharge the design storm. Runoff can be discharged through infiltration through the pond bottom, injection into the subsurface, or conveyed to a storm sewer or other approved locations. Additional design guidance can be found in BMP F6.10 Detention Ponds and BMP T5.30 Bio-Infiltration Swale of the *Stormwater Management Manual for Eastern Washington* and IN.01 in the WSDOT *Highway Runoff Manual.* An emergency overflow path shall be evaluated to direct excess runoff from large events to streets or other path that will minimize potential for damage to structures and landscaping.

**Geometry/Slopes**

Maintenance should be considered in design of a bioretention area. Access and adequate minimum width of the bottom of the facility should take into account the means of maintenance. The maximum side slopes of the basin treatment area are 3H: 1V (33.33%); however flatter slopes may be desirable if mowing is anticipated.

Outlets should be placed as far as possible from incoming flows to maximize the potential infiltration through the pond bottom. Riprap should also be considered where significant or sustained flow is anticipated. Guidance for the design of the riprap can be found in HEC-11, "Design of Riprap Revetment," and HEC-14, "Hydraulic Design of Energy Dissipaters for Culverts and Channels."

**Pre-Treatment**

Stormwater runoff containing high levels of hydrocarbons, metals, phosphorus, sediment or other pollutants can be pretreated using a water quality manhole, oil water separator, filter strip, or methods approved by the regulatory agency. An approved outlet structure is provided for all flows. Refer to the *Stormwater Management Manual for Eastern Washington* for additional information on pre-treatment requirements.

**Setbacks**

Guidelines for setbacks, slopes, and embankments are included in section 5.3.3 of the *Stormwater Management Manual for Eastern Washington* (SWMMEW). Check with the local building department to confirm site-specific requirements.

Before site work begins, clearly mark infiltration planter areas to avoid soil disturbance during construction. No vehicular traffic should be allowed within 10 feet of infiltration planter areas, except as necessary to construct the facility. Consider construction of infiltration planter areas before construction of other impervious surfaces to avoid unnecessary traffic loads.

**Soil Amendment/Mulch**

Soil requirements will vary depending on the selected plants and site conditions; however they shall be sufficient to maintain vegetated cover. Research has indicated soil amendments can increase the
performance of the bioretention area and may be considered. The local jurisdiction will determine if any reduction in sizing is appropriate based upon soil amendments. Refer to section 4.5 for additional information on amending on-site soils.

Vegetation
The entire facility area (side slopes and treatment areas) is planted with vegetation appropriate for the varying planting conditions within the bioretention area. Planting conditions vary from saturated soil to relatively dry, and several planting zones should be considered. The flat bottom of the extended dry basin to the top of the outflow structure can be subject to inundation several times a year. The saturated zone should be planted with grasses, sedges, and other species (oxygenators) that are well-suited to water-saturated, oxygen-deprived (anaerobic) planting conditions.

The side slopes above the outflow depth will vary from occasionally wet at the bottom to relatively dry near the top where inundation rarely occurs. This moisture gradient will vary depending upon the designed maximum water depth and side slope steepness. This transition zone should be planted with sedges, perennials, grasses and shrubs that can tolerate occasional standing water and wet-to-moist planting conditions. The areas above the designed high water line and immediately adjacent to the extended dry basin will not be regularly inundated. The dry zone should be planted with drought tolerant, low maintenance grasses, perennials, and shrubs suitable for the site and micro-climate.

Trees are allowed in bio-retention areas and should be selected by their adaptability to wet-to-moist conditions and full size at maturity. An area twice the width of tree rootball and the depth of the rootball plus 12" (or total depth of 30"), whichever is greater) should be backfilled with amended soil for optimal growth, with no sub-surface rock layer. Trees in bio-retention areas with side slopes should be placed along the side slopes of the facility rather than at the bottom.

The use of native plants is encouraged, but appropriate, adapted non-invasive ornamentals are acceptable for added aesthetic and functional value. All vegetation should be densely and evenly planted to ensure proper hydrological function of the bioretention area.

Appendix B of the Yakima Regional Low Impact Development Stormwater Design Manual contains example plant lists.

Maintenance:
• For plant establishment water efficient irrigation should be applied for at least the first two years and preferable for three years. Occasional irrigation may be required after construction of the facility, particularly during the dry summer months. Irrigation after establishment will depend upon plant health.
• Look for and repair clogging, rapid release, subsidence, erosion, cracking, unwanted plant growth, and accumulation of sediment near inlets and outlets. Based on the inspections, determine an appropriate maintenance and repair schedule.
• Water should infiltrate within 24 hours after a major storm event.
• Remove nuisance or invasive plants such as weeds or blackberry and ivy when discovered.
• Remove and replace damaged or dead plants.
• Avoid the use of pesticides, herbicides and fertilizers.
• Remove all trash, debris and sediment regularly to keep outlet structures and trash racks operable during storm events. Proper maintenance also eliminates mosquito breeding habitats. Comply with debris and trash disposal regulations.
• Maintain adequate groundcover and shrubs in the basin, but not overgrown to the extent that storage capacity is inhibited.
• See Appendix A for a detailed maintenance checklist.

References:
Figure 7: Bioretention without Underdrain

Figure 8: Bioretention with Underdrain
Figure 9: Infiltration Planter
3.2.b Flow-Through Planter

Flow-through planters are structural landscaped reservoirs that collect stormwater and treat it through the vegetation, growing media, and gravel. Flow-through planters are appropriate where soils have poor infiltrative factors or contamination is known to exist. A liner may be required when located adjacent to buildings, over contaminated soils, and on unstable slopes. Underdrains, constructed with perforated pipe are used to collect stormwater after treatment and discharge it to an approved system.

Tree box filters are flow-through planters with a concrete “box” that contains filtering growing media and a tree or large shrub. Tree box filters are used singly or in multiples, often adjacent to streets where runoff is directed to them to treat stormwater runoff before it enters a public stormwater system.

Application & Limitations:

Flow-through planters may help fulfill a project’s landscaping area or street tree requirements and can be used to manage stormwater runoff from all types of impervious. Flow-through planters are also widely used for retrofit projects within public rights-of-way. Check with the local jurisdiction if proposing to use a flow-through planter in the public right-of-way. Flow-through planters can be placed next to buildings and can be designed to complement a variety of architectural themes. Design variations of shape, wall treatment, and planting scheme will fit the character of any site.

Design Factors:

Sizing

Sizing of the flow-through planter is determined by the local design regulations. The system shall be designed to accommodate the applicable design storm.

Tree box filters are generally propriety systems are certified under the Washington State Department of Ecology TAPE program. The certification contains design guidance for each technology as well as considerations and restrictions. Technologies are being reviewed and approved on a continual basis. Refer to the Evaluation of Emerging Stormwater Treatment Technologies website for current information.

Additional design guidance can be found in BMP F6.22 Infiltration Trenches of the Stormwater Management Manual for Eastern Washington.

An emergency overflow path shall be evaluated to direct excess runoff from large events to streets or other path that will minimize potential for damage to structures and landscaping.

Piping for Flow Through Planters

Follow local standards for connecting stormwater conveyance pipe to flow-through planters. Stormwater may flow directly from the public street right-of-way or adjacent parking lot areas via curb
openings. The overflow drain allows not more than 6 inches of water to pond in the planter prior to overflow. A perforated pipe system under the planter drains water that has filtered through the topsoil to prevent long-term ponding. On private property, the overflow drain and discharge must meet local requirements and direct treated stormwater to an approved disposal point.

**Setbacks**
Check with the local building department to confirm site-specific requirements. In some instances, an above ground flow-through planter may meet the definition of a structure under local zoning requirements. Where prescriptive standards do not exist, consider the following:

- For planters without an impermeable liner, set the flow-through planter back 10 feet from building structures.
- Typically, no building setback is necessary for planters lined with waterproofed concrete or 60 mil. PVC liner to prevent infiltration.

**Soil Amendment/Mulch**
Amended soils with appropriate compost serve numerous benefits: infiltration; detention; retention; better plant establishment and growth; reduced summer irrigation needs; reduced fertilizer need; increased physical/ chemical/microbial pollution reduction; and reduced erosion potential. Primary treatment will occur in the top 18 inches of the infiltration planter. Amended soil in the treatment area is composed of imported soil, mix of one part organic compost, one part gravelly sand, and one part top soil. Compost is weed-free, decomposed, non-woody plant material; animal waste is not allowed.

To avoid erosion, use approved erosion control BMPs for non-structural infiltration planters.

**Vegetation**
Planted vegetation helps to attenuate stormwater flows and break down pollutants through interactions with bacteria, fungi, and other organisms in the soil. Vegetation also traps sediments, reduces erosion, and limits the spread of weeds. Appropriate and carefully considered plantings enhance the aesthetic and habitat value of a flow-through planter.

Because the entire facility may be inundated periodically, plant the water quality treatment area with herbaceous species such as sedges, perennials, grasses and shrubs appropriate for wet-to-moist soil conditions. Most moisture-tolerant plants can withstand seasonal droughts during the dry summer months and do not need irrigation after they become established.

Native plants are encouraged, but non-invasive ornamentals that add aesthetic and functional values are acceptable. Vegetation should be planted densely and evenly for proper hydrological function of the flow-through planter and to prevent erosion.

**Maintenance:**
• Water efficient irrigation should be applied the first two years after construction of the facility, particularly during dry summer months, while plantings become established.
• If public, the permittee is responsible for the maintenance of the flow-through planter for a minimum of two years following construction and acceptance of the facility.
• All publicly maintained facilities, not in the public right-of-way must have a public easement. If private, the property owner will be responsible for ongoing maintenance per a recorded maintenance agreement (see Appendix D for example maintenance agreement).
• Water should drain through the planter within 24 hours after a major storm event.
• All planter components should be inspected for proper operation during major storm events.
• Remove nuisance or invasive plants when discovered.
• Remove and replace damaged or dead plants.
• Provide insect and rodent control as necessary.
• See Appendix for detailed maintenance checklist.

References:
Figure 10: Flow-Through Planter
3.2.c Dispersion

Dispersion utilizes existing soils, vegetation and topography to provide flow control. Dispersion attenuates runoff flows by discharging runoff from adjacent impervious areas across gently sloped vegetated areas. The dispersion area is vegetated with grasses and groundcovers that filter and reduce the velocity of stormwater. Peak stormwater flows are attenuated as stormwater travels across the filter strip and infiltrates or is stored temporarily in the soils below.

Dispersion can be either natural dispersion or engineering dispersion. They function similarly however natural dispersion requires little to no construction as stormwater runoff is directed to existing vegetated areas. Engineered dispersion is designed and constructed to mimic natural dispersion. This may involve directing stormwater to an area where it did not naturally flow.

Application & Limitations:
Dispersion areas are integrated into the overall site design and may help fulfill a site’s landscaping area requirement. Dispersion can be used to manage stormwater runoff from a variety of impervious surfaces such as walkways, driveways, and roofs within either private property or the public right-of-way.

Design Factors:
Sizing


Water quality treatment must be provided for any stormwater requiring treatment per local regulations. This can be provided by a separate facility before discharging to the dispersion area or by combining dispersion and vegetated filter strips. Refer to the Stormwater Management Manual for Eastern Washington for vegetated filter strips design criteria.

Geometry/Slopes
The key to effective dispersion is flows entering the dispersion area as sheet flow. This can be accomplished either by draining impervious areas directly to the dispersion area before concentrating the flow or by using a level spreader. Examples of level spreaders include grade board and sand/gravel trench which disperse runoff evenly across the filter strip. The top must be horizontal and at an appropriate height to direct sheet flow to the soil without scour. Grade boards
may be any material that withstands weather and solar degradation but should not be old railroad ties, used utility poles, or other pollutant source.

**Setbacks**

BMP F.640 Concentrated Flow Dispersion, BMP F6.41 Sheet Flow Dispersion, and BMP F6.42 Full Dispersion contain additional information for siting dispersion facilities. Check with local building department to confirm site-specific requirements.

**Soil Amendment/Mulch**

Dispersion areas can either contain natural soils or amended soils as necessary. Amended soils with appropriate compost serve numerous benefits: infiltration; detention; retention; better plant establishment and growth; reduced summer irrigation needs; reduced fertilizer need; increased physical/chemical/microbial pollution reduction; and reduced erosion potential. Amended soil in the dispersion area is composed of equal parts of organic compost, gravely sand and topsoil. Compost is weed-free, decomposed, non-woody plant material; animal waste is not allowed. Soil requirements will vary depending on the selected plants and site conditions; however they shall be sufficient to maintain vegetated cover. Refer to section 4.5 Amending On-Site soils for additional information.

Appendix B of the *Yakima Regional Low Impact Development Stormwater Design Manual* contains example plant lists.

**Vegetation**

The dispersion area is planted or seeded with a mix of grasses, wildflowers, and groundcovers well-suited to moist to semi-arid soil conditions. Plant selection should focus on species that require little maintenance after establishment. Native plants are encouraged but adapted, non-invasive ornamentals are acceptable for added aesthetic and functional value.

Trees are not required for dispersion areas, but are encouraged where applicable. Tree species should be selected by their adaptability to moist to semi-arid conditions and full size at maturity. The dispersion area conveys evenly-distributed sheet flows of water through vegetation for infiltration. Because unplanted areas may decrease infiltration and promote erosion, the entire filter strip must have 100% vegetation coverage to ensure proper hydrologic function.

If check dams are required, plants suited to wet-to-moist planting conditions may be supplemented on the upslope side of the check dam where occasional inundation and pooling of water may occur.

**Maintenance:**

- For plant establishment water efficient irrigation should be applied for at least the first two years and preferable for three years. Occasional irrigation may be required after construction of the facility, particularly during the dry summer months. Irrigation after establishment will depend upon plant health.
• The facility should be inspected monthly.
• Evaluate landscaping and replant as necessary to ensure 100% facility coverage. Remove non-native, invasive plant species when found in the facility.
• Remove garbage, landscaping debris and other material that may impede uniform sheet water flow.
• See Appendix A for a detailed maintenance checklist.

References:
Figure 11: Dispersion

- Adjacent impermeable surface
- Gravel trench & level set grade board (optional)
- Evenly distributed sheet flow of stormwater through vegetation
- Jute matting
- Check dam or berm every 10' for slopes greater than 20H:1V

18" Growing Medium (optional) or Native Soil
Existing subgrade
Slope (0.5 - 6%)
3.2.d Rain Garden

Rain gardens are a form of bioretention. They are landscaped reservoirs that collect, filter, and infiltrate stormwater runoff, allowing pollutants to settle and filter out as the water percolates through planter soil and infiltrates into the ground. A rain garden will typically not have gravel galleries, under drains, or outflow structures.

From the 2012 Low Impact Development Technical Guidance Manual for Puget Sound a rain garden is defined as “A non-engineered, shallow landscape depression with native soil or a soil mix and plants that is designed to capture stormwater from small, adjacent contributing areas.

Application & Limitations:
The benefits of managing stormwater runoff can be realized by all sites, however not all sites require an Engineer to design the stormwater management system. In these situations a rain garden can be used to provide a level of stormwater runoff management to the benefit of the property owner and public. Several rain gardens can be located throughout a project to manage stormwater runoff from several small drainage basins.

Rain gardens are typically small residential applications of bio-retention. Rain gardens should be integrated into the overall site design and may help fulfill the landscaping area requirement. They can be used to manage stormwater flowing from all types of impervious surfaces. A rain garden can be proposed for a project or location that does not meet the threshold for flow control or runoff treatment as defined in Stormwater Management Manual for Eastern Washington or other local regulatory requirements. If these thresholds are met refer to 4.1 Bioretention Areas for design guidance.

A geotechnical engineer should be consulted before installation of a rain garden on or near slopes of 15% or greater.

Design Factors:
Sizing
Sizing of the rain garden will be based upon the infiltration capability of the soil, the amount of area draining to the rain garden, and the depth of the rain garden. Procedures for estimating soil infiltration rate are described in Rain Garden Handbook for Western Washington Homeowners. Determine the impervious area draining to the rain garden. Impervious surfaces are concrete, roofs, asphalt, and gravel that do not permit significant infiltration.

<<<<<<<<<Rain Garden Sizing table to be inserted with 90% document>>>>>>>>

Rain gardens should be sized for a 4 to 12 inch ponding depth.
It is critical that overflows from a rain garden are directed to a location where the potential for damage to structures is minimized. Typically a street or other stormwater facility is the preferred
destination. Installation of 6” or smaller rock, also known as rip rap, is recommended along the overflow path to reduce erosion.

Geometry/Slopes
The shape may be circular, square, rectangular, etc. to suit the site design requirements. Rain gardens may have vertical walls or sloped sides no steeper than 3 feet horizontal to 1 foot vertical. In a relatively flat landscaped open area slope should not exceed more than 0.5% in any direction.

Setbacks
Check with the local building department to confirm site-specific requirements.

• Generally, a minimum setback of 10 feet from building foundations is recommended.
• Rain gardens should not be located immediately upslope of building structures.

Before site work begins, clearly mark rain garden areas to avoid soil disturbance during construction. No vehicular traffic should be allowed within 10 feet of, except as necessary to construct the facility.

Soil Amendment/Mulch
Soil requirements will vary depending on the selected plants and site conditions; however they shall be sufficient to maintain vegetated cover. Six to 24 inches of native or amended treatment soils are recommended. Research has indicated soil amendments can increase the performance of bioretention areas and may be considered. Refer to Fact Sheet 4.5 Amending on-site soils for additional information.

Vegetation
The entire facility area (side slopes and treatment areas) is planted with vegetation appropriate for the varying planting conditions within the bioretention area. Planting conditions vary from saturated soil to relatively dry, and several planting zones should be considered. The flat bottom of the extended dry basin to the top of the outflow structure can be subject to inundation several times a year. The saturated zone should be planted with grasses, sedges, and other species (oxygenators) that are well-suited to water-saturated, oxygen-deprived (anaerobic) planting conditions.

The side slopes above the outflow depth will vary from occasionally wet at the bottom to relatively dry near the top where inundation rarely occurs. This moisture gradient will vary depending upon the designed maximum water depth and side slope steepness. This transition zone should be planted with sedges, grasses, perennials, and shrubs that can tolerate occasional standing water and wet-to-moist planting conditions. The areas above the designed high water line and immediately adjacent to the extended dry basin will not be regularly inundated. The dry zone should be planted with drought tolerant, low maintenance grasses, perennials, and shrubs suitable for the site and microclimate.
Trees are allowed in rain gardens and should be selected by their adaptability to wet-to-moist conditions and full size at maturity. An area twice the width of tree rootball and the depth of the rootball plus 12" (or total depth of 30"), whichever is greater) should be backfilled with amended soil for optimal growth, with no sub-surface rock layer. Trees in rain gardens with side slopes should be placed along the side slopes of the facility rather than at the bottom.

The use of native plants is encouraged, but appropriate, adapted non-invasive ornamentals are acceptable for added aesthetic and functional value. All vegetation should be densely and evenly planted to ensure proper hydrological function of the rain garden.

Appendix B of the Yakima Regional Low Impact Development Stormwater Design Manual contains example plant lists.

Maintenance:
- For plant establishment water efficient irrigation should be applied for at least the first two years and preferable for three years. Occasional irrigation may be required after construction of the facility, particularly during the dry summer months. Irrigation after establishment will depend upon plant health.
- Look for and repair clogging, rapid release, subsidence, erosion, cracking, unwanted plant growth, and accumulation of sediment near inlets and outlets. Based on the inspections, determine an appropriate maintenance and repair schedule.
- Water should infiltrate within 24 hours after a major storm event.
- Remove nuisance or invasive plants such as weeds or blackberry and ivy when discovered.
- Remove and replace damaged or dead plants.
- Avoid the use of pesticides, herbicides and fertilizers.
- Remove all trash, debris and sediment regularly to keep outlet structures and trash racks operable during storm events. Proper maintenance also eliminates mosquito breeding habitats. Comply with debris and trash disposal regulations.
- Maintain adequate groundcover and shrubs in the basin, but not overgrown to the extent that storage capacity is inhibited.
- See Appendix A for detailed maintenance checklist.

References:
Figure 12: Rain Garden
3.2.e Amending On-Site Soils

Native soils, coupled with native vegetation are nature’s tools for managing storm drainage both in terms of quantity and quality. Native soil complex’s also serve to store rainfall and facilitate the slow release of storm flows. Native soils are highly complex systems providing essential bio-filtration of pollutants and nutrients for healthy plant growth. The ability of soils to effectively manage storm flows, is dependent on a variety of characteristics, including structure, texture, depth and biological character. Plant roots and micro-organisms together, work the soil by penetrating, excavating and chemically enhancing structure and porosity. Improved structure improves water holding capacity, infiltration, oxygen content and the phytoremediation characteristics of soils.

Organic matter (OM) is a critical component of a healthy functioning soil complex. Organic matter mixed into soil absorbs water, improves structure, and can reduce the potential for erosion. In Eastern Washington soil organic matter content varies, however levels between 4 and 6 percent are not uncommon. The organic content of substratum is significantly lower typically less than one percent.

Construction activity often removes the organic rich upper soil layers and compacts the substrata. Site construction typically alters a sites hydrologic character by disrupting infiltration and subsurface flows and converting storm flows primarily to the surface. Typically, landscape practices are often inadequate to properly prepare soils for planting. Top soil layers are often too thin, not appropriately amended with organic material, and inadequately tilled to appropriate depths.

Applications and Limitations:

The hydrological condition of disturbed site soils can be restored or enhanced by the addition of organic matter. A low impact approach to site landscape improvements includes proper preparation of disturbed site soils as an integral component of the storm drainage management system. Proper preparation of all planting areas reduces erosion potential, enhances storm water storage and attenuates storm flows. Additional benefits include creating a medium for healthy plant growth, reduced need for fertilizers and pesticides, and reduced irrigation requirements.

Soil amendment approaches and application rates will vary with site conditions, the specific site use, and the plants selected for the micro-climate of the site. Every effort should be employed in site clearing to protect and if possible, stockpile existing soils. The specifications for soil amendments should be based on the types of plants and planting areas being used. For example, specific soil amendments will be different for turf lawn areas verses shrub and groundcover planting beds.

Design Factors:

Protecting and enhancing site soils requires planning and sequencing of construction activities to reduce impacts. This should be accomplished with a Soil Management Plan (SMP). Special attention should be given to site areas intended for preservation, access, material storage, and special soil enhancement. These areas should be clearly delineated on site layout and grading plans.
and reviewed with contractors during a pre-construction review process. The SMP should also include the project soil, compost and mulch specification and work sheets including:

- All site areas to be protected.
- Soil areas to be disturbed and restored.
- Any soil areas previously disturbed and intended for restoration.
- Proposed site access and construction circulation route areas.
- Site areas intended for staging and material storage (to be restored post construction).
- Measures proposed to minimize compaction and restore compacted areas post construction.
- Specific soil amendment details for all areas to be landscaped listed by type and use.

To determine the amendment requirements for disturbed soils the following steps should be followed:

- Review site grading and landscape areas.
- Visit site and schedule soil sampling.
- Select amendments options based on soils analysis.
- Specify topsoil, mulch and compost.
- Calculate quantities.

Special attention should be given to areas intended for storm drainage facilities, particularly those intended for infiltration. The SMP should be coordinated with the project TESC/Stormwater Pollution Prevention Plan. Pre-approved application rates have been calculated and can be accessed using the resources identified at the end of the fact sheet. To enhance the hydrologic characteristics of disturbed site soils the following soil amendment characteristics are provided as a guideline:

- A target organic matter content of 6 to 8 percent by dry weight for all non-turf planting areas.
- A target organic matter content of 5 percent for turf areas.
- pH between 6.0 and 8.0 or as specified for particular plant choices.
- A minimum amendment depth of 8 inches.
- Subgrades should be tilled to a minimum depth of 6 inches and include topsoil to reduce soil stratification.
- All planting beds should include organic mulch with a minimum depth of 3 inches.

In many instances the organic matter content of existing site soils may be relatively good and not require as much amendment. In some instances calculating a site specific amendment rate may result in significant cost savings. This may be particularly true for large sites. Calculating a custom rate requires soil samples from the areas requiring amendment. Generally soils should be tested for bulk density, percent organic matter and moisture. Often suppliers will be able to supply the required contents of soils to be supplied.
Compost material should be mature and derived from organic waste materials including plant debris, manures, bio-solids, or wood wastes that meet the intent of the organic soil amendment specification.

Resources:

- Building Soil: Guidelines and Resources for Implementing Soil Depth and Quality BMP T5.13
- TMECC 05.07A “Loss-On-Ignition Organic Matter Method”
### 3.2.f Permeable Pavement

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

Permeable pavements can be sub-divided into main categories.

1. **Pervious concrete and porous 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.
2. **Permeable interlocking pavers** – solid, discrete units typically made of pre-cast concrete, brick, stone, or cobbles and set to allow water to flow between them.
3. **Cellular confinement paving systems** – open-celled plastic or concrete matrix containing vegetation or gravel infill.
4. **Permeable pavers** – an emerging technology similar to permeable interlocking pavers however the entire paver itself is permeable.

<<INSERT PERVIOUS PAVEMENT CROSS-SECTION DIAGRAM HERE>>

### 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 pavement for driveways, parking lots, and roadways per their standards.

Permeable surfaces may be considered Pollutant Generating Impervious Surfaces (PGIS) depending upon their use. Permeable pavement is not considered a water quality facility therefore treatment may be provided by a treatment layer (sand filter) under the permeable pavement, collection of runoff and treatment with a downstream facility or through existing site soils if they meet Site Suitability Criteria (SSC) described in section 5.4.3 of the Stormwater Management Manual for Eastern Washington (SWMMEW).

Permeable pavement should not be located over cisterns, utility vaults, underground parking or other impervious surfaces. Permeable pavement infiltrating stormwater shall meet the Site Suitability Criteria in SWMMEW 5.4.3. If installed to provide detention only the site suitability criteria do not apply, however stormwater treatment shall still be provided, if required.

Permeable pavement should not be applied in locations where there is a high risk of chemical spillage.
The additional considerations and restrictions under the infeasibility criteria in BMP T5.15
Permeable surfaces in the Stormwater Management Manual for Western Washington (SWMMWW)
shall be considered.

<<INSERT PHOTOGRAPHS OF PERVIOUS PAVEMENT AND POROUS PAVERS HERE>>

**Design Factors:**

*Flow Control Sizing*

Stormwater from the permeable pavement infiltrates directly into a crushed rock storage layer. Permeable pavements can be designed for flow control by storing stormwater in the aggregate section until infiltrated into the underlying subgrade or by a controlled release into another stormwater management facility.

If approved by the local jurisdiction, detention storage may be constructed beneath the permeable pavement and sized by approved calculation. On a sloped facility the available ponding depth may be less than the total aggregate depth. Average depth should be used, as determined by subsurface berms.

*Stormwater Management Credits*

Depending on local regulations, credits (reductions) for sizing of downstream stormwater management facilities may be available based upon the composition of the permeable pavement. These credits could be either flow control or runoff treatment credits. Typically if there isn’t runoff flowing onto permeable pavements the aggregate depth required for structural stability is sufficient for flow control. Poor infiltrating soils may require additional aggregate.

Credits for treatment could be applied by modeling the permeable pavement 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 pavement is reduced on steep slopes. Surface design shall consider the effects of slope on surface performance. Section 6.3.1 of the *Low Impact Development Technical Guidance Manual for Puget Sound* has recommendations for maximum slopes of permeable pavements. In eastern Washington additional consideration should be given for ice and snow conditions.

*Piping*

Subsurface piping is generally not required. Subsurface infiltration rates less than 0.5” per hour generally will not meet requirements for treatment and perforated piping may be used to convey stormwater runoff from the permeable pavement aggregate to a downstream facility.
A raised perforated pipe installed in the aggregate to collect runoff exceeding the design depth can provide a safeguard against freeze/thaw damage in the wearing course.

**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.

The additional considerations and restrictions regarding slopes under the infeasibility criteria in BMP T5.15 Permeable surfaces in the SWMMWW shall be considered.

**Pavement Section**

Permeable pavement design shall be based upon the desired surface infiltration rate. Permeable pavement clogging over time is to be anticipated and planned for in the design. Research by Curtis Hinman at WSU has suggested a conservative estimate of 3 inches per hour. Project mix design may need to be approved by the local jurisdiction. Permeable pavements generally consist of the following layers:

- Wearing Course
- Bedding Course
- Aggregate Base
- Subgrade

The following references for mix design should be used:

- Pervious asphalt and concrete:
  - Client Assistance Memo 2215, Seattle Department of Transportation
  - 2012 SWMMWW Volume V, BMP T5.15
  - 2005 SWMMWW Volume III, Appendix III-C
  - National Asphalt Pavement Association Information Series 131
  - Guide for Construction of Portland Cement Concrete Pervious Pavement, King County Department of Transportation

- Pavers:
  - Interlocking Concrete Pavement Institute specifications
  - 2012 SWMMWW Volume V, BMP T5.15

**Subgrade Preparation**

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. The surface should be lightly scarified or raked to provide infiltration values consistent with the design.
For traffic areas provide the minimum compaction necessary to ensure structural stability and minimize rutting the subgrade soil for public roadways, private streets, parking lots, and fire lanes. 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. Avoid compaction of impervious areas adjacent to the permeable pavement. It is imperative to protect the permeable pavement subgrade from over-compaction.

Construction

Installation of permeable pavements is crucial to success. Installation should be completed by a qualified and experienced contractor. Certification programs are available. An experienced representative of the agency or owner should also be on-site during installation.

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 pavement 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.

Construction activities, construction traffic, and stockpiling of landscape material should not be allowed on permeable pavements. If necessary to protect the permeable pavement areas can be covered with plastic.

Maintenance:

- Check with the local jurisdiction about use of permeable pavement 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 pavement on private roads must be in a separate tract. Refer to Appendix D for an example maintenance agreement.
- Permeable pavement 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. Porous asphalt must not be sealed or it will lose its pervious function. Care should be taken not to seal porous asphalt. If permeable pavement becomes sealed, additional stormwater treatment may be required.
- Application of sanding and deicer can reduce the long term effectiveness of permeable pavements. Care should be taken in site selection and application.
References:

- King County Department of Transportation. Guide for Construction of Portland Cement Concrete Pervious Pavement.
- Seattle Department of Transportation. Client Assistance Memo 2215.
- Yakima Regional Low Impact Development Stormwater Design Manual; Yakima County, 2011.
Figure 13: Permeable Asphalt
Figure 14: Permeable Pavers
3.2.g 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.

<<INSERT PHOTOGRAPHS OF VEGETATED ROOFS HERE>>

Applications:
Vegetated roofs can be an appropriate LID BMP in Eastern Washington. 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 benefits 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 if 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 Factors:
Many varieties of vegetated roofs may be appropriate, subject to the context of the project. The threshold requirements of a vegetated roof include:

- Structural stability of the building considering saturated soils
- Waterproof the roof
- Protect the roof surface from root penetration and damage
- Drain water off the roof
- Support the growth of vegetation
- Cold and drought conditions

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

- 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.
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?

**LID 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. The potential availability of stormwater credits will be dependent upon Washington State Department of Ecology and local approval. This credit could be applied by modeling the vegetated roof as partially to completely pervious. Refer to Stormwater Management Manual for Eastern Washington (SWMMEW) Chapter 4 for modeling guidance. 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. Working closely with a structural engineer throughout the design of the vegetated roof is essential. Consider the weight of saturated soils, weight of snow in the winter, as well as a maintenance regime to mechanically remove snow buildup to prevent roof damage and collapse.

<<INSERT PHOTOGRAPHS OF VEGETATED ROOFS HERE>>

**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 2 in 12 (horizontal to vertical). With stabilization, pitches of up to 7 in 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 3 in 12 degrees tend to provide the same level of retention as flat roofs (Dunnett and Kingsbury, 2008).

**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.

Irrigation
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. Rain water harvesting can be considered to supply irrigation. Refer to section 4.9 for additional information. 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 rain garden and one on a vegetated 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

Appendix B of the Yakima Regional Low Impact Development Stormwater Design Manual contains example plant lists.

Native Plants
Eastern Washington has many good native and highly-adapted plant choices that are appropriate to vegetated 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.

<<INSERT PHOTOGRAPHS OF VEGETATED ROOFS HERE>>

### 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. The following practices should be performed:

- For plant establishment water efficient irrigation should be applied for at least the first two years and preferable for three years. Occasional irrigation may be required after construction of the facility, particularly during the dry summer months. Irrigation after establishment will depend upon plant health.
- Avoid the use of pesticides, herbicides and fertilizers.
- 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% 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.
- See Appendix A for detailed maintenance checklist.

### References:
3.2.h Minimal Excavation Foundations

Grading and excavation during construction can degrade the infiltration and storage capacity of native soils. Minimal excavation foundations are a BMP that minimizes mass grading and site disturbance by distributing a building’s structural load onto piles or limited excavation perimeter walls.

As noted in the Low Impact Development Technical Guidance Manual for Puget Sound, “[m]inimal excavation foundation systems take many forms, but in essence are a combination of driven piles and a connecting component at, or above, grade. The piles allow the foundation system to reach or engage deeper load-bearing soils without having to dig out and disrupt upper soil layers, which convey, infiltrate, store, and filter stormwater flows.”

Piles are a less disruptive approach to site development. The piles may be vertical, screw-augured, or angled pairs that can be made of corrosion protected steel, wood, or concrete. The connection component handles the transfer of loads from the above structure to the piles and is most often made of concrete. Cement connection components may be pre-cast or poured on site in continuous perimeter wall or isolated pier configurations.

Applications & Limitations:
Minimal excavation foundations in both pier and perimeter wall configurations are suitable for residential or commercial structures up to three stories high. Secondary structures such as decks, porches, and walkways can also be supported, and the technology is particularly useful for elevated paths and foot-bridges in open spaces and other environmentally sensitive areas. Wall configurations are typically used on flat to sloping sites up to 10 percent, and pier configurations flat to 30 percent.

The minimal excavation foundation approach can be installed on A/B and C/D soils (USDA Soil Classification), provided the material is penetrable and will support the intended type of piles. Soils typically considered problematic due to high organic content (top soils or peats) or overall bearing characteristics may often remain in place provided their depth is limited and the pins have adequate penetration into suitable underlying soils.

These systems may be used on fill soils if the depth of the fill does not exceed the reaction range of the intended piles. Fill compaction requirements for support of such foundations may be below those of conventional development practice in some applications. In all cases, for both custom and pre-engineered systems, a qualified engineer should determine the appropriate pile and connection components and define criteria for specific soil conditions and construction requirements.
**Design Factors:**

Based on the type of structure to be supported and the specific site or lot topography, a pier type foundation or perimeter wall type foundation must first be selected. Soil conditions are determined by a limited geotechnical analysis identifying soil type, water content at saturation, strength and density characteristics, and in-place weight. However, depending on the pile system type, the size or scale of the supported structure, and the nature of the site and soils, a more complete soils report including slope stability and liquefaction analysis may be required.

**Pier Applications**

Piers using pin piles can be used for various structure types, including residential and light commercial buildings. When designing with piers, the engineer or vendor supplies the structural requirements (pile length and diameter and pier size) for the pier system. The structural engineer then determines the number and location of piers given the structure size, loads, and load bearing location.

**Grading for piers**

Pier applications require grubbing, and in some cases, blading to prepare the site. The permeability of some soil types can be significantly reduced even with minimal equipment activity; accordingly, the lightest possible tracked equipment should be used for preparing or grading the site. Consult a licensed engineer with soils experience for specific recommendations.

On relatively flat sites, blading should be limited to shaping the site for the best possible drainage and infiltration. Removing the organic topsoil layer is not typically necessary. On sloped sites, the soils may be bladed smooth at their existing grade to receive pier systems, again with the goal of achieving the best possible drainage and infiltration. This will result in the least disturbance to the upper permeable soil layers on sloped sites.

**Wall applications**

Piling combined with pre-cast walls with sloped bases, or slope cut forms for pouring continuous walls, may be used on sites with only minimal topography changes similar to the pier applications. Rectilinear wall systems (flat bottom sections), combined with piles, may also be used, but require more site preparation and soil disturbance.

**Grading for flat-bottomed walls**

While creating more soil disturbance, sloped sites should be terraced to receive conventional flat-bottomed forms or pre-cast walls. The height difference between terraces will be a result of the slope percentage and the width of the terrace itself. The least impacts to soil will be achieved by limiting the width of each terrace to the width of the equipment blade and cutting as many terraces as possible. Some footprint designs will be more conducive to limiting these cuts and should be considered by the designer.
The terracing technique removes more of the upper permeable soil layer and this loss should be figured into any analysis of storm flows through the site. As with the pier systems, consult a licensed engineer with soils experience for specific recommendations.

With wall systems a free draining, compressible buffer material (pea gravel, corrugated vinyl or foam product) should be placed on surface soils to prepare the site for placement of wall components. This buffer material separates the base of the grade beam from surface of the soil to prevent impacts from expansion or frost heave, and in some cases is employed to allow movement of saturated flows under the wall.

Additional soil may remain from foundation construction depending on grading strategy and site conditions. The material may be used to backfill the perimeter of the structure if the impacts of the additional material and equipment used to place the backfill are considered when evaluating runoff conditions.

*Disclaimer*

**Dispersing roof stormwater with minimal excavation foundations**

Roof runoff and surrounding storm flows may be allowed to infiltrate without using constructed conveyance when selection of the foundation type and grading strategy results in the top layers of soil being retained and without significant loss to soil permeability and storage characteristics.

Where possible, roof runoff should be infiltrated uphill of the structure and across the broadest possible area. Infiltrating upslope more closely mimics natural (preconstruction) conditions by directing subsurface flows through minimally impacted soils surrounding, and in some cases, under the structure. This provides infiltration and subsurface storage area that would otherwise be lost in the construction and placement of a conventional “dug-in” foundation system. Passive gravity systems for dispersing roof runoff are preferred; however, active systems can be used if back-up power sources are incorporated and a consistent and manageable maintenance program is ensured.

Garage slabs, monolithic poured patios, or driveways can block dispersed flows from the minimal excavation foundation perimeter and dispersing roof runoff uphill of these areas is not recommended (or must be handled with other stormwater management practices). Some soils and site conditions may not warrant intentionally directing subsurface flows directly beneath the structure, and in these cases, only the preserved soils surrounding the structure and across the site may be relied on to mimic natural flow pathways.

**Construction**

Minimal excavation systems may be installed “pile first” or “post pile.” The pile first approach involves driving or installing all required piles in specified locations to support the structure, and then installing a connecting component (such as a formed and poured concrete grade beam) to engage the piles. Post pile methods require the setting of pre-cast or site poured components first, through which the piles are then driven. Pile first methods are typically used for deep or problematic soils where final pile depth and embedded obstructions are unpredictable. Post pile methods are typically
shallower—using shorter, smaller diameter piles—and used where the soils and bearing capacities are well-defined. In either case, the piles are placed at specified intervals correlated with their capacity in the soil, the size and location of the loads to be supported, and the carrying capacity of the connection component.

The piles are driven with a machine mounted, frame mounted, or hand-held automatic hammer. The choice of driving equipment should be considered based on the size of pile and intended driving depth, the potential for equipment site impacts, and the limits of movement around the structure.

**Maintenance:**
Corrosion rates for buried galvanized or coated steel piling, or degradation rates for buried concrete piling, are typically very low to non-existent, and piling for these types of foundations are usually considered to last the life of the structure. Special conditions such as exposure to salt air or highly caustic soils in unique built environments, such as industrial zones, should be considered. Wood piling typically has a more limited lifetime. Some foundation systems also allow for the removal and replacement of pilings, which can extend the life of the support indefinitely.

**References:**
3.2.i Rain Water Harvesting
Rain water harvesting has traditionally been used in environments where rainfall or other conditions limit water supply. Many areas of Eastern Washington are situated in climatic zones where rain water collection systems, in the form of cisterns, may provide beneficial use.

Several of the well-documented benefits of rain water harvesting include:
- Reducing domestic water demand
- CSO reduction strategy
- Emergency water for fire suppression
- Sustainable source for irrigation and non-potable uses
- Reduces peak runoff and allows sediment to settle

Most cisterns are constructed of plastic, steel, or concrete. Plastic is commonly used where cisterns are placed underground. Plastic cisterns are lightweight, non-corrosive, and relatively inexpensive. Concrete or steel cisterns are sometimes used for aesthetic values and are often custom-designed to complement the scale and character of the structure. In other instances, a simple plastic or steel cistern may be clad with another material for greater aesthetic appeal. Japanese, Mediterranean and American southwest architecture offer examples of attractive cisterns.

Applications & Limitations:
Rain water harvest systems are often used in arid climates where water is rare or in highly urban areas where the supply has been depleted. Rain water harvest systems have been used with most types of land uses. Increasingly, cisterns are being used with residential and commercial uses with high irrigation and/or non-potable water demands.

Rain water harvest systems tend to be more expensive than other stormwater storage and treatment BMPs. However, in highly urbanized areas where land rents are high, these systems may allow scarce land resources to be placed into economically productive uses.

Urban areas with combined sewer overflow (CSO) problems have used rain water harvest systems to capture, store, and reuse stormwater thereby minimizing the flow of stormwater into combined sewer systems.

Design Factors:
- Rain water harvesting systems should be sized according to rainfall data and proposed indoor and outdoor water needs. The sizing of the collection system should only include non-pollution generating surfaces. Therefore, rain water harvesting systems are not appropriate for the collection of water collected from pedestrian or vehicular areas.
- Cisterns must be covered to prevent mosquitoes from breeding. The cover will protect the water from sunlight and minimize algae growth.
• Screen on the gutter and intake of the outlet pipe should be included to minimize clogging by leaves and other debris.
• Below grade cisterns shall have tie downs per manufacturer’s specifications to avoid the floating of the cistern resulting from elevated groundwater levels.
• Controls, overflows, and cleanouts should be readily accessible and alerts for system problems should be easily visible and audible.

Maintenance:
Rain water harvesting systems require regular monitoring and cleaning. The maintenance includes examining the cistern, filters, pumps, and valves as well as conveyance structures such as gutters that may feed the system. The following maintenance practices should be performed:

• Debris should be removed from the roof and gutters routinely cleaned. Cleaning should occur at least twice yearly.
• Screens and pre-filters should be regularly inspected and cleaned.
• Filters should be changed every six months or as a drop in pressure is noticed.
• UV units should be cleaned every six months and the bulb should be replaced every 12 months (or according to manufacturer’s recommendation).
• Storage tanks should be cleaned with a chlorine mix.
• Storage tanks should be inspected and sediment accumulating at the bottom be removed periodically as needed.

References:
3.2.j Conveyance and Stormwater Art

Stormwater conveyance is the flow, movement or transfer of stormwater from one location to another. Stormwater conveyance techniques are used to transport water from where it falls to where it will be treated and/or stored. The management and treatment of stormwater in these facilities improves water quality and attenuates peak stormwater flows.

While design standards for the sizing of various LID practices, aesthetic values do not need to be compromised when designing conveyance and treatment facilities. This fact sheet illustrates creative ways that designers have integrated stormwater management in innovative and artistic ways.

Applications & Limitations:
There are two general methods of stormwater conveyance, underground and above ground.

1. Underground conveyance typically directs stormwater through pipe into large detention/retention systems for disposal after treatment.

2. Above ground conveyance moves stormwater on the surface of the ground. In applicable locations, such as LID facilities, the benefits of above ground conveyance may include:
   - Lower construction costs due to less excavation and underground piping
   - Less site disturbance
   - Improved oxygenation and cleansing of water
   - More opportunities for artistic and creative design
   - Enhanced public awareness of urban stormwater

Design Factors:
Artistic conveyance and treatment facilities would be designed to the same engineering standards as other standard urban stormwater management practices.

Maintenance:
To maintain stormwater storage and treatment functions, artistic conveyance and treatment facilities do not necessarily require a greater degree of maintenance than other standard urban stormwater management practices. As the focal point of a site, however, artistic conveyance and treatment facilities may require a higher level of care to maintain the aesthetic values.

References:
Yakima, WA. A chain is used to disconnect roof downspouts and disperse stormwater into adjacent landscaped areas.

Seattle, WA. Stormwater storage designed with artistic edge for outdoor gathering.
3.3 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 stormwater runoff, and increase infiltration from a drainage area, or constructed in a series of multiple facilities.

It is important to consider maintenance when selecting LID practices. All LID facilities require some degree of maintenance to continue performing at peak efficiency over time. The method and frequency of maintenance activities varies by the type of facility. Specific maintenance requirements are included within each BMP Fact Sheet found in Chapter 4 and within Appendix A.

<<DISCUSS INSERTION OF FACT SHEET TABLE AT 90% DRAFT>>
Chapter 4: Low Impact Development Site Plan Design

4.1 LID Design Basis

Careful evaluation of the Site Analysis (composite map and topic summaries) provides an understanding of LID site design opportunities available to the site. Each project is unique and successful LID site plan design demands that the distinct features be recognized during the design phase.

LID based designs incorporate both LID principles (Section 2.2) and flow control techniques (Section 3.2). An initial meeting with the local government staff is necessary 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 preliminary LID design concepts with local regulations.

4.2 Design Steps

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 – Determine impervious area requiring treatment

- Refer to the Eastern Washington Stormwater Management Manual (or local equivalent) for instructions to calculate the impervious area requiring water quality treatment for new or redevelopment.

Step 2 – Deduct LID impervious area

- Deduct the areas designed with a non-pollution generating surface
- Check with the local jurisdiction about any deductions resulting from other LID techniques (e.g. rainwater harvesting)

Step 3 – Size LID facilities for remaining impervious area

- Determine the size of the LID facilities required to treat stormwater runoff from the remaining impervious area.
- Sizing factors for infiltration based on LID assume an existing site soil infiltration rate of less than 2 inches per hour. Fact sheets for these facilities (Chapter 3) provide information about soil infiltration testing that can be performed if the designer believes site soils have greater infiltration capacity and wants to produce information to support a smaller sizing factor.
- If more than one LID facility is used on the project site, each facility must be sized for the amount of impervious area draining to it.
• Step 4 – If needed, design water quality facilities for large impervious areas or remaining untreated impervious area
• The sizing factors noted in this Guidebook shall not be used for LID facilities treating runoff from more than 15,000 square feet of impervious area.
• For large project sites and impervious areas, a large water quality facility (e.g. vegetated swale) or other facility may be appropriate.

4.3 Design Process
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.

1. – Determine local regulations for stormwater runoff treatment and flow control
   • 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?

2. – Evaluate Chapter 2 Findings
   • Review LID Planning Principles
   • Review Site Analysis – Composite Map and Topic Summaries
   • Conduct an on-site inspection

3. – Select LID Solutions
   • Select the LID Principles that are applicable on the project
   • Select the LID flow control techniques that are applicable on the project
   • How will the LID practices support the aesthetic character of the proposed development?

4. – Meet with local jurisdiction to evaluate LID opportunities and to determine suitability
   • Review selected LID principles and control techniques
   • Identify and confirm site, local and regional surface water management, and water quality related issues, opportunities and constraints
   • What is the process required to approve the proposed LID components?

5. – Site and Size LID BMPs
   • Ensure stormwater runoff is managed as close to the source as possible.
   • Conduct hydrologic calculations to confirm that regulations for stormwater runoff treatment and flow control are met.

6. – Review implementation and calculations 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.
Appendices

Appendix A: Maintenance Checklist
Currently Under Development

Appendix B: Detail Drawings
Currently Under Development
Appendix C: Glossary

The vocabulary of low impact development (LID) is evolving, and many terms are used interchangeably to describe the same or similar things. This glossary is a compilation of commonly used terms and their sources. Several definitions for some terms are listed here to demonstrate various usages and sources, as there is no absolute authoritative definition for many of them. Please see the Additional Resources and Informational Web Sites pages for more definitions.

General Terms

Low Impact development is 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. (Eastern Washington Municipal Stormwater Permit Issued August 1, 2012)

Planning for Low Impact Development includes an in-depth analysis of the natural conditions of the site (e.g., native vegetation, hydrology, ground water, soils, topography, hydrology, etc.), as well as the built and regulatory elements (e.g., zoning, access, utilities, easements, zoning, etc.) that will influence development and the use of LID practices.

Low Impact Development Planning Principles strive to reduce environmental impacts of land development. Implementing LID planning principles at the beginning of a project allows the development to benefit from LID opportunities naturally afforded the property. LID planning principles promote compliance with water quality regulations and stormwater management goals.

Low Impact Development Flow Control techniques reduce and mitigate environmental impacts of land development or redevelopment by controlling stormwater flows and mimicking natural hydrology. These techniques offer more options to comply with stormwater management requirements and manage stormwater runoff reducing the environmental impacts associated with developing property.

Low Impact Development Designs incorporate both LID principles and flow control techniques. Evaluation of the Site Analysis provides an understanding of LID site design opportunities available to the site. Each project is unique and successful LID site plan design demands that the distinct features be recognized during the design phase.

Specific Terms

Bioretention cells: Shallow depressions accepting stormwater from small contributing areas with plants and soil media designed to provide a specific saturated hydraulic conductivity and pollutant removal characteristics and support healthy plants. A variety of plants are used in bioretention areas, including trees, shrubs, grasses, and/or other herbaceous plants. Bioretention cells man or
may not have an under-drain and are not designed as a conveyance system. (Low Impact Development Technical Guidance Manual for Puget Sound)

Bioretention swales: Incorporate the same design features as bioretention cells; however, bioretention swales are designed as part of a conveyance system and have relatively gentle side slopes and flow depths that are generally less than 12 inches. (Low Impact Development Technical Guidance Manual for Puget Sound)

Stormwater Dispersion: Release of surface stormwater runoff from a drainage facility system such that the flow spreads over a wide area, located so as not to allow flow to concentrate anywhere upstream of a drainage channel with erodible underlying granular soils. (Spokane Regional Stormwater Manual)

Natural Dispersion: Natural dispersion attempts to minimize hydrologic changes created by new impervious surfaces by restoring the natural drainage patterns of sheet flow and infiltration. There are three types of natural dispersion; concentrated flow dispersion, sheet flow dispersion, and full dispersion. (Stormwater Management Manual for Eastern Washington)

Ditch: A long narrow excavation dug in the earth for drainage with a top width of less than 10 feet at design flow. (Spokane Regional Stormwater Manual)

Drywell: A well installed above the water table so that its bottom and side are typically dry except when receiving fluids. Drywells are designed to disperse water below the land surface. (Spokane Regional Stormwater Manual)

Grassed swales: Water moving through these systems is slowed, filtered, and percolated into the ground. These systems can act as low-cost alternatives to curbs, gutters, and pipes. (HAHB Research Center Toolbase Services)


Hydrology: The science that encompasses the occurrence, distribution, movement and properties of the waters of the earth and their relationship with the environment within each phase of the hydrologic cycle. (USGS)

Hydrologic cycle: The continuous movement of water on, above and below the surface of the Earth. (USGS)

Infiltration (Hydrology): Infiltration is the process by which water on the ground surface enters the soil. Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or
irrigation. It is measured in inches per hour or millimeters per hour. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier. It is related to the saturated hydraulic conductivity of the near-surface soil. The rate of infiltration can be measured using an infiltrometer.

**Maintenance:** Activities conducted on structures, facilities, and equipment that involve no expansion or use beyond previously existing use, and result in no significant adverse hydrologic impact. (Spokane Regional Stormwater Manual)

**Permeable pavements:** Surfaces that allow water to pass through voids in the paving material and/or between paving units while providing a stable, load-bearing surface. An important component to permeable pavements is the reservoir base course, which provides stability for load-bearing surfaces and underground storage for runoff. (Seattle Green Parking)

**Permeable pavers:** Manufactured paving stones containing spaces where water can penetrate into the porous media placed underneath. (DOD Guidebook)

**Permeable soils:** Soil materials with a sufficiently rapid infiltration rate to greatly reduce or eliminate surface and stormwater runoff. These soils are generally classified as hydrologic soil types A and B. (Spokane Regional Stormwater Manual)

**Rain barrels and cisterns:** Containers of various sizes that store the runoff delivered through building downspouts. Rain barrels are generally smaller structures, located above ground. Cisterns are larger, are often buried underground, and may be connected to the building’s plumbing or irrigation system. (DOD Guidebook)

**Rain garden:** A non-engineered, shallow landscape depression with native soil or a soil mix and plants designed to capture stormwater from small, adjacent contributing areas. (Low Impact Development Technical Guidance Manual for Puget Sound)

**Runoff** is water that travels across the land surface, or laterally through the ground near the land surface, and discharges to water bodies either directly or through a collection and conveyance system. Runoff includes stormwater and water from other sources that travels across the land surface. See also “Stormwater.” (Eastern Washington Phase II Municipal Stormwater Permit, Effective August 1, 2014)

**Soil amendments:** Minerals and organic material added to soil to increase its capacity for absorbing moisture and sustaining vegetation. (DOD Guidebook)

**Stormwater** is runoff during and following precipitation and snowmelt events, including surface runoff, drainage and/or interflow.
Vegetated buffers: Natural or man-made vegetated areas adjacent to a water body, providing erosion control, filtering capability, and habitat. (DOD Guidebook)

Vegetated filter strips: Vegetated filters are gently sloping areas used to filter, slow, and provide pretreatment to stormwater flows.
Appendix D: Additional Resources/References
Currently Under Development