Low Impact Development

Definition

Low Impact Development (LID) is a design strategy with the goal of maintaining or replicating the pre-development hydrologic regime through the use of design techniques to create a functionally equivalent hydrologic site design. Hydrologic functions of storage, infiltration and ground water recharge, as well as the volume and frequency of discharges are maintained through the use of integrated and distributed micro-scale stormwater retention and detention areas, reduction of impervious surfaces, and the lengthening of runoff flow paths and flow time. Other strategies include the preservation/protection of environmentally sensitive site features such as riparian buffers, wetlands, steep slopes, valuable (mature) trees, flood plains, woodlands, and highly permeable soils.

Purpose

LID design strategies, including ***structural**** and/or ***non-structural stormwater practices****, can be applied to land development projects, where practicable, to meet certain technical requirements of federal, state, and local government stormwater management (SWM) regulations, as well as natural resource protection and restoration goals.

The Federal Clean Water Act, the Virginia SWM Regulations, the Virginia Erosion and Sediment Control (ESC) Regulations, the Virginia Chesapeake Bay Preservation Area Designation and Management Regulations, and the Virginia Water Protection Permit Regulations establish criteria for protecting sensitive natural resources and adjacent properties and waterways from the impacts of land development. Maintaining or replicating the pre-development surface and sub-surface hydrologic regime on a development site is generally considered to meet some of those criteria. Therefore, the design techniques intended to create a functionally equivalent hydrologic landscape must be quantified or measured in order to document compliance with regulatory principles and technical requirements. The following provides a brief description of some of the current regulatory requirements that may be met in part or in full by LID practices.

* *Bold italics* indicate that a definition is provided in the glossary.

Stream Channel Erosion

SWM Regulations (4VAC3-20-81 et seq.)
ESC Regulations (4VAC50-30-40.19 et seq.)

LID structural and non-structural practices can be used to protect downstream natural channels and waterways by maintaining the pre-developed stormwater runoff volume, duration, frequency, peak rate of discharge, groundwater recharge, and surface and groundwater drainage patterns. LID may be used as a stand-alone design approach or in conjunction with other stormwater structural practices and/or channel improvements to meet channel protection requirements.

It should be noted that the ESC and SWM regulatory requirements for protecting stream channels are based on the capacity of the downstream natural and/or manmade channel or conveyance system. When a downstream channel or conveyance system is determined to be inadequate, the designer must either provide for downstream channel or system improvements, develop a site design that will not cause the pre-developed peak rate of runoff to increase, or provide a combination of channel improvements, stormwater detention, or other measures satisfactory to the plan approving authority to prevent downstream erosion[1].

The most common practice for protecting inadequate downstream channels has been to detain the runoff from the 2-year 24-hour design storm and release it at the pre-developed rate. An alternative criterion that has been accepted by the state and some local plan approving authorities is the extended detention of the runoff from the 1-year 24-hour design storm[2]. Currently available LID design guidance[3] includes simplified computational procedures for sizing LID ***Integrated Management Practices*** (IMP's) to maintain the pre-developed runoff volume and/or rate of discharge for a specified rainfall amount. In addition, other more rigorous analytical methods can be used to quantify the hydrologic response of LID strategies in order to calculate compliance with any regulatory criteria. However, the extent to which these methods can show LID practices to satisfy regulatory requirements for stream channel protection may be site-specific and require a detailed hydrologic analysis. In order to accommodate LID designs, localities may choose to simplify this process by developing their own regulatory criteria (consistent with the VA SWM Regulations) for applying LID design strategies and techniques based on local conditions and practices. (Refer to Computational Methods section of this Technical Bulletin for additional information on these methods.)

[1] Virginia Erosion and Sediment Control Regulations Minimum Standard 19 (4VAC50-30-40.19 et seq.)
[2] Department of Conservation and Recreation Technical Bulletin #1, Stream Channel Erosion Control.
[3] Low Impact Development Hydrologic Analysis, Prince George's County, Maryland; July 1999.

Stormwater Runoff Quality

SWM Regulations (4 VAC 3-20-71 et seq.)
Chesapeake Bay Preservation Area Designation and Management Regulations (9 VAC 10-20-10 et seq.)

LID structural and non-structural practices can protect downstream waterways by reducing the post-developed pollutant loading through stormwater runoff volume reduction and/or the filtering and settling of pollutants. Stormwater volume reduction and the corresponding reduction in the peak rate of discharge can also serve to reduce water quality impacts associated with channel erosion.

Permits and Certifications

Virginia Water Protection Permit Regulation (9 VAC 25-210 et seq.)
§401 and §404 Permits

LID structural and non-structural practices may reduce the direct impacts of development on wetlands and water bodies by reducing or eliminating the need for structural stormwater facilities that would otherwise be located in wetlands or other protected lands. (In some cases, however, LID practices may not provide adequate quantity control of large storms so as to eliminate the need of structural facilities designed for flood or large storm control.) LID structural and non-structural practices may also serve to reduce indirect impacts on these lands by satisfying the stream channel erosion and water quality requirements of the land development activity as described above.

Total Maximum Daily Load (TMDL) Requirements

To the extent that water quality impairments are a result of stormwater runoff inputs, LID structural and non-structural practices and strategies implemented on a development site can assist in reducing the pollutant loadings that contribute to the TMDL of the receiving water body.

Applicability

SWM must be considered early in the land development planning process in order to fully realize the benefit of the natural hydrologic features of the landscape. While the use of LID practices may be limited by the physical characteristics of a development site, those same characteristics help to identify and prioritize the best locations for utilizing IMP's, non-structural stormwater practices, or ***conventional*** or ***centralized Best Management Practices*** (BMP's). Introducing LID concepts during the preliminary planning and concept phase of site design will serve to maximize the extent and effectiveness of LID practices. In contrast, once the site and development infrastructure design has been established, the proposed site features, and not the existing natural physical characteristics, will dictate the location and extent of LID implementation.

The applicability and effectiveness of LID practices on development projects will be influenced by physical site characteristics such as:

- Soil suitability
- Depth to water table
- Tidal effects
- Topography
- Karst topography
- Drainage area size
- Maintenance Considerations
- Expansiveness of impervious cover
- Density of on-site structures
- Overall spatial constraints
- Downstream drainage and runoff conveyance infrastructure

Refer to Appendix A for additional information on design considerations.

It should also be noted that local land use ordinances might also influence the implementation of certain LID practices. These include:

- Zoning
- Local subdivision ordinances
- State and local building codes
- Open space requirements

In general, when introduced early in the development process, LID planning strategies and techniques, such as reducing impervious cover, conserving natural areas, and diffusing and disconnecting stormwater runoff, can conform to most local ordinances and still be both hydrologically and economically effective.

The applicability and effectiveness of LID site design strategies should be progressively evaluated at the zoning, preliminary planning, conceptual drainage and SWM design, and final site design phases of project development. At each successive step in the process, as more detailed site evaluations reveal more information regarding the site's physical characteristics, the designer can evaluate and continually modify the design to better mimic the pre-developed hydrology, meet stormwater regulatory requirements, and achieve aquatic resource protection goals.

When the use of LID practices on a particular site is limited by physical constraints or other factors, or the stormwater regulatory requirements cannot be satisfied solely with the use of LID design techniques, then a ***"hybrid" design*** may be employed. A hybrid design employs both LID and conventional BMP's or detention practices (e.g., ***centralized BMP's***) to meet stormwater requirements. Such a design might conserve specific natural features and provide open space to the greatest extent possible, while detention measures or centralized BMP's are also implemented to provide peak rate or quantity control beyond the site-specific capabilities of the LID strategy. Another example of a hybrid design is one that incorporates LID for both the attenuation and infiltration of small storm events, and centralized BMP's to provide storage for larger storm events. (Control of runoff from larger storm events may be necessary to protect downstream manmade or natural conveyance systems in accordance with MS-19, or other watershed specific criteria.)

Once LID site design strategies and practices have been evaluated and employed to the greatest extent practicable, and, where needed, additional SWM controls have been added, the designer must measure and document the target performance of the design in satisfying any regulatory requirements. While the calculation procedures for documenting compliance using traditional detention, extended detention, or other types of BMP's have been in use for many years (refer to the Virginia SWM Handbook), the use of LID type strategies for regulatory compliance is relatively new. (Some of the currently accepted computational methods for calculating regulatory compliance are provided in this Technical Bulletin.) In addition, there may be a desire to quantify the extent to which LID practices are implemented in order to establish that the development is indeed an "LID design". This can be accomplished by calculating the percentage of the total site area or total site impervious area being treated by appropriate LID strategies, or calculating the ratio of the estimated depth of rainfall or volume of runoff being treated by the LID strategy to the total depth or volume respectively. (At this time there is no established standard for a design to be qualified as an LID design.)

LID Design Components

The LID strategy of replicating the pre-development surface and sub-surface hydrologic regime is accomplished through the combination of design principles: *Conservation*, *Minimization of Impacts*, *Maintaining Site Runoff Rate and Patterns, the use of IMP's, and Pollution Prevention (P2).* These design principles incorporate structural and non-structural stormwater practices into a site design, and will each have either a ***direct*** or ***indirect effect*** on the measurable hydrologic characteristics of the site. Structural practices, when considered in the context of LID design strategies, imply small-scale stormwater BMP's distributed throughout a site or drainage area, and are often referred to as IMP's and can include, but are not limited to, engineered and natural temporary surface storage for runoff attenuation, and infiltration for groundwater recharge and runoff volume reduction.

Non-structural practices can include, but are not limited to, preservation of natural areas and functions such as permeable soils and existing flow paths, the disconnection of impervious surfaces, and P2 activities. (A list of accepted structural and non-structural practices will be provided by the Virginia Department of Conservation and Recreation or the local plan approving authority.)

The following provides a brief description of these design principles and how they may be incorporated into the site development design to replicate the pre-developed hydrology. Design principles 1 through 4 are listed in the order of expected consideration and evaluation during the development planning and design process in order to utilize the natural hydrologic processes in the final development stormwater design. Design principle 5, P2, should be an integral part of the site design process from beginning to end in order to facilitate the post-construction site function and management in addition to any construction related requirements of the ***Stormwater Pollution Prevention Plan*** (SWPPP).

1.) ***Conservation.*** Conservation of any natural lands within a development site may have the direct effect on the site hydrology of minimizing impervious cover that would otherwise generate higher rates and volume of runoff. Indirect benefits of conservation can be derived by locating and protecting certain hydrologic features such as drainage paths, permeable soils, steep slopes, etc.; and, in accordance with appropriate zoning and subdivision requirements, strategically locating setbacks, easements, woodland conservation zones, buffers, utility corridors, and other permanent site features to enhance the overall goals of maintaining the pre-developed hydrology.

   The Center for Watershed Protection offers 22 “Better Site Design”[4] principals aimed at reducing the impacts of development on sensitive lands and aquatic resources. Conserving specific sensitive lands on a site is a crucial first step. The implementation of a SWPPP and/or ***Erosion and Sediment Control Plan*** further minimizes the impact of construction and development activities on these sensitive lands.

2.) ***Minimization of Impacts.*** Minimization of impacts refers to reducing the extent of construction and development practices that adversely impact the hydrologic conditions of the site. This includes limiting the clearing and grading of land to the minimum needed to construct the development and associated infrastructure, as well as locating the land disturbances so as to avoid impacting hydrologically sensitive areas. The designer must conduct a thorough analysis of the existing topography and site geometry when locating fixed improvements such as roads, houses or buildings, sanitary and storm sewer utility corridors, etc., in order to minimize unnecessary grading and/or compaction of the natural soil horizon, clearing of trees, and creating of impervious surfaces.

   The minimization of impacts can have both direct and indirect beneficial effects on the hydrologic characteristics of the site. The extent of these benefits is dependent on the ability of the selected hydrologic analysis method to accurately depict impervious cover, land slope, soils, types of vegetation, and other factors that affect surface and subsurface hydrology.

3.) ***Preserve Pre-development Runoff Rate and Patterns.*** Preserving the site pre-developed runoff rate and patterns are two of the overall objectives in replicating the pre-developed hydrology (other objectives include maintaining the pre-developed volume, frequency, and duration of runoff). Effectively implementing

[4] Better Site Design – An Assessment of the Better Site Design Principles for Communities Implementing Virginia’s Chesapeake Bay Preservation Act; The Center for Watershed Protection. http://www.cwp.org/better_site_design.htm

conservation practices and minimizing impacts, as described above, represent the first steps in achieving these objectives. Further steps involve evaluating how certain design choices can influence the post-developed hydrologic processes to reduce the rate and volume of runoff. These design choices include disconnecting impervious cover in order to maintain sheet flow conditions, lengthening the developed condition time of concentration (Tc), etc. Ideally the post-development drainage divides should replicate those of the pre-developed condition

Stormwater detention practices can be effective in maintaining the pre-developed rate of runoff, however detention practices alone are not able to achieve the objectives of maintaining the pre-development volume, frequency, and duration of runoff. LID design strategies, on the other hand, focus on using site design techniques to influence the hydrology before (or instead of) conveyance of the runoff to a centralized detention practice.

4.) ***Integrated Management Practices*** **(IMP's)**. IMP's refer to decentralized small-scale (source control) stormwater retention and detention structural BMP's integrated uniformly throughout the site or drainage area. These practices can be integrated into the landscape, buildings, and overall development infrastructure to reduce the volume and rate of stormwater runoff. These systems are designed to emulate the natural processes of detention, retention, interception, evaporation, transpiration, and groundwater recharge, in order to replicate the pre-developed hydrology. Common examples of IMP's include: bioretention cells (or rain gardens), water quality swales, green roofs, and other small scale runoff attenuation practices.

5.) ***Pollution Prevention (P2).*** P2 is a non-structural practice aimed towards reducing pollutant loads at the source by eliminating the behavior or practices within the urban and suburban landscape that have been shown to generate a non-point source pollutant load. P2 is applicable both during the active construction phase of development and during the life of the facility. This includes the implementation of soil conservation and erosion control measures employed during construction, long-term management of post-construction BMP's, and proper onsite storage, use, and disposal of chemicals or potential pollutants.

Pollution prevention can also include community-wide education efforts and specific training and education programs directed toward the owners/operators of properties designed and constructed in accordance with these principles. Common examples of P2 techniques include storm drain stenciling, public outreach and education on the appropriate use of fertilizers and pesticides, street sweeping, etc.

Computational Methods

The level of effectiveness to which LID techniques and practices satisfy the technical regulatory requirements can be measured using conventional hydrologic parameters. These parameters or values are used in several different computational methods to calculate the pre- and post-developed hydrologic response of the land. These methods include relatively simple calculations using charts calibrated for the rainfall distributions of Virginia, as well as detailed routing of stormwater through individual IMP's and any other structural practices within a given subwatershed, or some combination of these methods.

Much of the basis for these computational methods have been developed and detailed in numerous references. The selection of a specific computational method will often be a function of the stormwater component being measured: stormwater quality, quantity, or both. LID practices applied to a development site with the goal of improving runoff quality may also achieve some level of quantity or peak rate control. Likewise, practices that are designed with the goal of rate or volume control may also derive a water quality benefit.

This section will provide an overview of some of the existing methods available with which to measure the effectiveness of an LID design strategy. The scope of this section will in no way serve as a design manual or otherwise replace the available documentation for each of the methods listed, nor are the available options limited to those presented here. The U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) National Engineering Handbook Section 4: Hydrology (NEH 4), and Section 5: Hydraulics (NEH 5), and the Virginia SWM Handbook (VSWMH) provide detailed information on the accepted analytical methods described in this Bulletin, as well as other methods that may be determined to be acceptable by the designer or plan approving authority.

This Technical Bulletin will not establish one acceptable method, rather it will give designers and plan reviewers the information needed to hopefully design and evaluate an LID strategy for a development project using the best suited method. However, the compatibility or translation of the chosen analytical techniques to NRCS methods may serve to facilitate the acceptance of the analysis in those jurisdictions where NRCS methods are utilized.

<u>Water Quality Control</u>

Compliance with the Virginia water quality criteria (4VAC3-20-71 et seq.) may be achieved by applying the *Performance-based* criteria or the *Technology-based* criteria to the site as outlined in the VSWMH.

The Performance-based criteria utilize the percent impervious cover of the site to calculate the post-developed pollutant load, and then apply the target pollutant removal efficiency of the stormwater BMP's to determine compliance. Each stormwater BMP, including accepted non-structural practices, must therefore have an assigned target pollutant removal efficiency associated with the accepted design standard.

The Technology-based criteria require that the runoff from the impervious cover of the site be captured by an appropriately designed BMP (considered to be the best available technology for the specific site characteristics).

Strategically locating IMP's through out the development site or as part of a hybrid design, can serve to meet either the Performance or Technology-based criteria. The VSWMH provides a list of currently accepted stormwater BMP's, including design criteria and corresponding target pollutant removal efficiencies. The Virginia SWM Regulations also allow for innovative or alternate BMP's not included in the VSWMH to be approved at the discretion of the plan approving authority. Additional design and performance guidance may be necessary to expand this list to include certain IMP's, site design techniques, and non-structural practices, in order to effectively document compliance with either criterion.

Water Quantity Control

Quantity (or rate) controls are implemented to reduce the peak rate of stormwater discharge from the developed site in order to prevent stream channel erosion and/or localized flooding. These controls are generally volume-based practices and utilize recognized hydrologic and hydraulic analytical methods in order to make comparisons between the pre- and post-developed conditions. The VSWMH specifically refers to NRCS TR-55 and the modified rational methodologies for such computations. These analytical methods vary in terms of flexibility and complexity. It is the responsibility of the designer to be familiar with these methods and determine the appropriate method, or combination of methods, that will demonstrate the effectiveness and verify compliance with applicable Federal, state, or local codes and ordinances.

This section provides four methods or categories of procedures that can be used to analyze and evaluate the effectiveness of LID designs. They are: Hydrologic and Hydraulic Models, Hydrograph Modification, LID Hydrologic Analysis (PGDER, 1999) and a Credit or Point System. The first three methods utilize recognized hydrologic and hydraulic analytical methods in order to make comparisons between the pre-and post-development conditions. A Credit or Point System can be developed and implemented by localities to place an emphasis on design and protection strategies that protect or enhance critical watershed natural resource areas.

1. Hydrologic and Hydraulic Models

   The following provides a general description of the procedures associated with accepted hydrologic and hydraulic models used to determine the effectiveness of an LID design.

   Hydrology – The first step in evaluating an LID design or any SWM strategy is to characterize the runoff from the site or drainage area. The methods for characterizing the hydrology or runoff range from the Rational Method to single event distribution methods, such as widely used NRCS models that develop a rainfall and runoff relationship with respect to time (i.e., a runoff hydrograph), to continuous simulation models that develop runoff hydrographs from multiple storm events.

The evaluation or measure of the performance of LID techniques must consider runoff volume, frequency, duration, and peak rate of discharge. Therefore, the method employed to calculate the site hydrology must be capable of generating a runoff hydrograph. The designer must establish the runoff characteristics with respect to time at each proposed IMP location or other critical locations throughout the drainage area as input parameters for the model. The model then must evaluate these characteristics for each area all on the same time scale and then sum the hydrographs at the selected study point. Critical locations include any areas where an engineered or natural control is proposed.

Hydraulics – Once the rainfall-runoff hydrographs are developed for specific locations, the engineer can apply standard hydraulic calculations to account for groundwater abstraction, storage attenuation, and surface runoff velocity at each location. The calculations should reflect the individual hydraulic characteristics of each IMP or critical area, and be physically based on the measurable unit processes being considered.

For simplicity, many SWM software packages generalize interactions with groundwater and other losses rather than perform a detailed routing. Most, however, allow the user to export the hydrograph in order for it to be modified to reflect specific infiltration rates, retention storage volume, or other losses as appropriate. The modified hydrograph can then be imported back into the model. (The designer must determine the analytical values for these losses through field investigations or acceptable documented sources and should coordinate those values with the plan approving authority.)

Detailed modeling of LID designs, therefore, can be accomplished in much the same manner as hydrologic and hydraulic analyses used for traditional SWM designs. The key differences are: (1) the designer must identify and model a potentially large number of structures or control points, and (2) a greater emphasis is placed on quantifying the volume reduction associated with infiltration, retention storage volume, ***evaporation***, ***transpiration***, rainwater harvesting, etc. at each control point. The benefit of detailed modeling is a more direct prediction of the decrease in the peak rate and volume of runoff attributed to the measurable LID design features in order to verify compliance with regulatory requirements. However, complex modeling may not necessarily result in greater accuracy in predicting the developed condition hydrology. The selection of the most appropriate analytical method will vary depending on the site conditions and design values.

2. Hydrograph Modification

Routing hydrographs through IMP's and other LID site features as discussed above may require a significant amount of time and effort to quantify all of the site characteristics in enough detail to meet the requirements of the various models. The following theoretical methods provide more simplistic approaches for modifying the runoff hydrograph in order to reflect the site conditions represented by a comprehensive LID design. Some of these methods have been accepted in other jurisdictions; however, further evaluation and modification may be required before they are accepted for use by the local plan approving authority.

- *Truncated Hydrograph Method,* (MDE, 1983). This approach analyzes distributed retention storage by assuming that the sum of the retention storage is available for filling at the beginning of the runoff event (like an empty pond), and that there is no resultant runoff until all available retention storage has been filled. This method does not take into account the spatial distribution of the retention storage (small pockets throughout the watershed) and the timing of outflows from these facilities. Additional work is needed to verify the accuracy of this method and/or calibrate the relationships between the distributed storage, drainage area size, and overall hydrologic benefits as reflected in the final hydrograph at the study point. However, the value of this method is its simplicity and may be effective in assessing the LID potential of a development site during the early stages of development.

- *Change in Curve Number Method,* (MDE, 1983). This method reduces the post-developed curve number to reflect the runoff volume stored by the IMP's. This assumes that all of the storage volume is infiltrated, evaporated, or otherwise available for the next storm event. As with any method that assumes infiltration, care must be taken in the proper location and design of the infiltration IMP's to ensure long-term function.

- *Scalar Multiplication,* (LID Center, 2004). This method estimates the effects of IMP storage by reducing the ordinates of the runoff hydrograph by the ratio of total retention storage to total runoff generated. This approach assumes that volume of retention storage provided will proportionally reduce the runoff volume and rate uniformly at all points along the runoff hydrograph.

- *Subtract Retention from Rainfall,* (LID Center, 2004). Subtraction of IMP storage volume from the <u>rainfall</u> depth by modifying the NRCS equation for the relationship between rainfall and runoff.

- *Subtract Retention from Runoff,* (LID Center, 2004). Subtraction of IMP storage volume from the <u>runoff</u> depth by modifying the NRCS equation for the relationship between rainfall and runoff.

- *Adjust CN for 24-hour Storm Depth,* (LID Center, 2004). Subtraction of the IMP storage volume from the runoff depth at the end of the storm event.

3. Low Impact Development Hydrologic Analysis, Prince George's County, Maryland.

This approach is described in detail in the "Low Impact Development Hydrologic Analysis" (PGDER 1999) and can be used to determine the storage volume required to maintain the frequency of pre-development runoff volume and/or peak runoff rate that is generated from the post-development condition for a range of 24-hour Type II storm events.

The method can be used to analyze a variety of storm frequencies or recurrence intervals, and is most useful for analyzing volume replication and peak attenuation goals for specified storm events. The design storm can be selected in accordance with local requirements, although the stated goal is to replicate the pre-developed hydrology. Therefore, the design storm is calculated as that which generates initial runoff from the pre-developed site condition (assumed to be woods in good hydrologic condition, and the actual hydrologic soil group classification of the site), or the 1-year event, whichever is greater. Using design charts aimed at simplifying the computational procedures, the designer determines the total storage volume required on the site. The designer must then determine if the resulting volume requirement meets the regulatory requirements for channel protection, flooding, or other criteria.

There is no standardized method within the manual to correlate the resulting distributed storage with the 1-year extended detention channel protection or larger storm requirements. However, the designer may use various acceptable hydrologic parameters to compare the LID design with the peak rate or extended detention requirements and make up any shortfall through a hybrid design. Any method chosen to document compliance may be subject to local review and approval.

This method is based on the NRCS computational procedures found in Urban Hydrology for Small Watersheds Technical Release 55 (TR-55), and therefore has similar limitations to TR-55 in that it cannot be used for complex storage routing or when a high degree of accuracy in the storage/discharge relationship of any BMP is required. Also, the design charts generally require that the pre- and post-development drainage areas are the same, and that the designer is able to maintain the pre-development Tc. Further, the method assumes that the volume of the required structural controls are decentralized or distributed evenly throughout the site. The reader is encouraged to review this methodology further in the referenced manual.

4. Credit or Point System Approach

A credit or point system can be developed by a locality in order to encourage the use of certain design strategies, protection methods, or IMP's to address local water quality goals, natural resource protection objectives, or regulatory requirements. Such a system may function as a stand-alone compliance assessment tool or may be used in conjunction with other analytical (hydrologic and hydraulic) methods. If stand-alone, the results are "presumptive," i.e., compliance is based on a project receiving a certain number of credits or points based on the proposed management practices that are presumed to meet the relevant requirements (e.g., biofilters or open space protection is presumed to meet certain water quality goals).

Alternately, a credit or point system can be used to enhance the use of other analytical methods to influence the design towards certain LID measures. For instance, hydrologic and hydraulic computations may be used to verify design criteria, and the credit/point system added to promote the protection of open space or critical areas, or other practices aimed at preserving the pre-developed hydrologic condition.

A stand-alone credit or point system may be appropriate for those developments where a highly analytical approach to ensure compliance for LID features may act as a disincentive for LID implementation. These developments may include relatively simple projects, redevelopment projects, or projects with relatively low impervious cover (such as a typical rural subdivision) or where downstream drainage and flooding are not a concern. In these cases, the program authority may elect to develop a simplified compliance system in order to encourage LID design strategies.

The premise of this approach is that LID practices are presumed to achieve certain water quantity and/or quality requirements if certain performance standards are met. Although such a methodology is not specified in the VSWMH, it can be viewed as an enhancement to the technology-based criteria for water quality compliance, where certain LID practices are included in the allowable technology list. A credit or point system can also be adapted into the performance-based criteria if LID practices can be assigned target pollutant removal credits or proportional pollutant removal efficiencies. In either case, guidance on specific design criteria and target pollutant removal efficiencies must be provided in order to ensure consistent application.

As stated above, a credit or point system can also be used in conjunction with other computational methods. The hydrologic and hydraulic model chosen can be used to verify partial compliance with water quality/quantity requirements, with the gap being filled by other LID measures (e.g., open space protection) that are not easily modeled, but should still receive points or credits towards the overall compliance objective.

Several examples of a credit or point system can be found throughout the Chesapeake Bay watershed. In one Virginia county, a BMP point system is used as a technology-based approach to ensure that development sites are adequately covered by preferred BMP's. The proportion of the site served by the BMP weights the pre-set points assigned to each BMP. In addition, points assigned to specific site development practices such as preservation or minimization of impacts are weighted by the value of the practice, e.g.: open space is positioned in a way that accepts and treats stormwater or is adjacent to a wetland, mature forest, or Resource Protection Area.

Another example includes a water quality credit system for non-structural measures such as adding additional stream buffer area to the minimum requirement, re-vegetating existing buffers, protecting buffers with permanent easements, and disconnecting impervious cover. While some of these practices provide both direct and indirect benefits to the site hydrology and can therefore be measured by accepted analytical tools, the credit system serves to create an incentive by simplifying the required design calculations and associated plan review requirements. Additional credits can be assigned to the modification or use of certain structural practices, such as using open space as stormwater treatment areas (if certain design parameters can be met) and using individual lot practices, such as rain gardens.

Specific design standards and performance criteria must be developed if a local program authority elects to use a credit or point system. Design standards can include relationships between the required water quality volume based on impervious cover and the individual BMP or cumulative distributed storage volume or surface area coverage associated with IMP's, as well as any variable design criteria that may allow for additional points or credits based on certain performance goals. At a minimum, design and performance standards should provide for the long-term maintenance and proper function of the BMP's, IMP's, and/or other LID site features, as well as be consistent with accepted statewide design standards.

The credit or point system is a very flexible concept; the program authority can adapt it to meet local needs and conditions or to promote particular practices. One main caution to using this approach is that it may require interpretation on the part of the reviewer and may be viewed as more of a negotiated approach to compliance than other, more quantitative methods. The positive side is that it can be simple for both plan preparers and reviewers and can lead to designs that more fully incorporate LID and encourage use of natural open space. The program authority should strive for review procedures that are equitable while allowing for a certain amount of case-by-case interpretation.

Construction and Maintenance

The first steps in ensuring the long-term effectiveness of any LID practice are the proper selection, location, and design of the practice. Equally important are the construction and long-term maintenance practices and techniques. Ideally, the designer will not only have all the site information necessary for the design related activities, but also an understanding of the construction requirements and the ultimate land use and management (or ownership with regard to maintenance). It should be noted that while these elements are critical to the effectiveness of any stormwater practice, the distributed and small-scale nature of LID practices and techniques make them especially vulnerable to impacts from mass grading and construction operations, as well as long-term neglect.

The location and design of LID practices must include a sequence of construction. The sequence of construction is important because some LID practices cannot be built until the contributing drainage area has been stabilized. Similarly, if certain areas of the site are to be preserved for post-construction LID practices, the site design must account for adequate access to the proposed construction areas without impacting those protected areas. Impacts to protected areas, even if only temporary, can cause compaction of the natural soil horizon or contamination with silt, thus reducing the effectiveness and long-term function of the practice. If impacting a select area is unavoidable, the plans should include provisions for restoration and preparation of the area for the post-construction use.

Therefore, the construction drawings must reflect areas to be preserved and include adequate ESC measures to protect those areas (especially since those areas may serve as natural drainage paths). The sequence of construction should be prominently displayed on the plans as a critical element to the site design, and reflect the multiple phases of the construction as related to the implementation of the designed LID practices within the overall construction activity. Local officials are encouraged to incorporate intermediate inspections to ensure proper soils, materials, and construction practices related to the stormwater features.

The design and construction of any structural LID practice (or stormwater BMP) should be in accordance with the accepted standards of the local jurisdiction or state regulations. The references provided at the end of this Technical Bulletin provide an array of guidance documents, including the VSWMH, as well as guidance documents from other states. Local plan approving authorities may adopt plan design and construction inspection criteria that exceed the current state minimum in order to ensure the long-term effectiveness of LID designs.

Post-construction inspections and maintenance of LID structural and non-structural practices are equally important to ensure effectiveness. Annual inspections are recommended at a minimum, with more frequent inspections during the first year or growing season for vegetated practices, or as required by any permit conditions. Some LID practices may require more frequent inspections, (e.g. after significant rain events, quarterly, during property transfers, etc.). Inspection and maintenance of structural LID practices such as cisterns, vegetated roofs, permeable pavements, infiltration structures, and manufactured proprietary devices should follow local heath department, state or local stormwater minimum standards, as well as manufacturer's recommendations for maintenance or repair. Any under-drains or outfall structures should be inspected on a regular basis and cleaned out or repaired as necessary.

The primary maintenance requirement for vegetative LID structural and non-structural practices is inspection and periodic repair or replacement of the treatment area's components. This often includes the upkeeping of the vegetative cover (pruning), replacing mulch, removing weeds, and possibly removing sediment to preserve the practice's hydraulic properties. For many LID practices, this generally involves little more than the routine periodic landscape type maintenance.

To ensure continued long term maintenance, all affected landowners should be made aware of their individual or collective maintenance responsibilities through legal instruments such as maintenance agreements and maintenance easements that convey with the property. Outreach materials, such as LID brochures or facts sheets that explain the function of practices and the anticipated maintenance responsibilities for homeowners, should be included in settlement or home owner association documents.

Glossary

Best Management Practices (BMP's) are activities, procedures, and structural and non-structural devices or features that are specifically identified or designed to prevent or reduce the impact of development on surface and groundwater systems.

Conventional (centralized) Best Management Practices (BMP's) are structural BMP's designed to capture and treat stormwater runoff from a large drainage area. SWM ponds and basins located at the bottom of a developed drainage area or watershed are generally considered to be conventional (centralized) BMP's.

Direct effects are those that are measured or quantified with analytical methods to identify the hydrologic or hydraulic response of the site to the post-development condition or the SWM strategy or technique. For example, the direct effect of providing on-site storage is that the rate of peak discharge.

Erosion and Sediment Control (ESC) Plan means a document that is prepared in accordance with good engineering practices and containing details and instructions for the conservation of soil and water resources of a unit or group of units of land during land disturbing activities.

Evaporation is the process of liquid water becoming water vapor, including vaporization from water surfaces, land surfaces.

"Hybrid" design means a design that employs both LID and conventional BMP's or detention practices to meet stormwater requirements. Such a design might include LID practices or strategies such as the conservation of specific natural features and open space to the greatest extent possible, while detention measures or centralized BMP's are also implemented to provide peak rate or quantity control beyond the site-specific capabilities of the LID strategy. Another example of a hybrid design is one that incorporates LID for both the attenuation and infiltration of small storm events, and centralized BMP's to provide storage for larger storm events.

Indirect effects are those where the hydrologic or hydraulic response may not be quantifiable by established analytical methods, yet they have inherent effects on the hydrologic and hydraulic response of the site to the post-development condition, including water quality. For example, the preservation and/or enhancement of the natural stream buffer, or the strategic location of utility corridors may preserve and protect certain hydrologic components of the pre-developed site, without the benefit of being quantified in the hydrologic analysis.

Integrated Management Practices (IMP's) are small-scale structural stormwater practices distributed through out a site or drainage area for the purpose of managing or influencing the site hydrology.

Non-structural practices are natural features or directed activities specifically utilized for the purpose of managing or influencing the site hydrology and/or improving water quality. Non-structural practices can include pollution prevention, preservation of open space and natural flow paths, street sweeping, etc.

Stormwater Pollution Prevention Plan (SWPPP) means a document that is prepared in accordance with good engineering practices and that identifies potential sources of Pollution that may reasonably be expected to affect the quality of stormwater discharges from a construction site or its associated land disturbing activities. In addition the document shall describe and ensure the implementation of best management practices, and shall include, but not be limited to the inclusion of, or the incorporation by reference of, an erosion and sediment control plan, a post construction stormwater management plan, a spill prevention control and countermeasure (SPCC) plan, and other practices which will be used to reduce pollutants in stormwater discharges from land disturbing activities.

Structural practices include any man made stormwater practice or feature that requires maintenance in order to function or provide the hydrologic benefit as designed. Structural practices include, but are not limited to, rain gardens, stormwater bioretention basins, stormwater infiltration facilities, stormwater retention and detention facilities, engineered vegetated filter strips, and any other features that are designed, constructed and maintained in order to managing or influencing the site hydrology and/or improve runoff water quality.

Transpiration is the process by which water that is absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface, such as leaf pores.

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Appendix A

Design Considerations

Soil Permeability
The soil permeability, or infiltration rate, is critical to the proper function of IMP's that incorporate infiltration as part of their control mechanism. The best location for these practices is in areas that have characteristics of Hydrologic Soils Groups A and B, which have high infiltration rates during saturated conditions. These are typically sandy soils. Hydrologic Soil Groups C and D have low to very low infiltration rates when thoroughly wetted. These are typically silts and clays or compacted soils. Due to these characteristics, soil groups C and D are not conducive to exfiltration and may impact the proper functioning of IMP's, such as grass swales, bioretention basins, and permeable pavements. Underdrains can be used in these facilities to control the rate of flow and to ensure that the facility will not become inundated with runoff over a long period of time.

High Water Table
A high water table may reduce the storage capacity of the below ground portion of the IMP and may also impede the ability of the media in the IMP to filter out pollutants before they enter the groundwater.

Topography (Steep Slopes)
A slope stability analysis should be conducted in areas with high potential for slope failure or fill slopes to ensure that any proposed infiltration IMP will not affect the stability of the area

Karst Topography
Infiltration IMP's placed in karst topography may cause subsurface collapse and sink hole formation. A subsurface analysis and the depth of the table should be determined at the beginning stages of design to determine the capacity of the soils for saturation when LID infiltration practices are considered.

Septic Systems
An adequate buffer between any infiltration practice and a septic system should be provided to ensure that the septic field will not be inundated, the infiltration rate of the field will not be affected, or any roots from the practices will enter the reserve area.

Water Supply Wells
Infiltration IMP's should be located in areas where there is the potential for contamination. Particular attention should be paid in areas where there are high pollutant loads (e.g. industrial areas) or shallow wells.

Structures and Foundations

A sufficient buffer should be provided between IMP's and basements building structural areas that must not become saturated. Impermeable liners and underdrains are appropriate for use in these areas.

Expansive Impervious Areas

The amount of drainage to each individual IMP in large impervious areas such as parking lots or compacted areas with high runoff potential should be minimized due to the high frequency and potentially large volumes of water that these areas will receive. Adequate underdrains and overflow paths, such as a secondary storm drain system, should be included for high flow events.

High Sediment Loads

Areas that drain to filtering or infiltration IMP's that are not adequately stabilized and have high erosive potential or soils with high "K" values will require additional control measures to filter the sediment or more frequent maintenance to reduce the potential for clogging of the facility.

Flood Control

Site constraints, such as limited downstream storm drain infrastructure, inadequate channel capacity, and flooding considerations, may necessitate additional volume storage by employing traditional end-of-pipe detention and retention basins in addition to LID practices at the discharge points.

Spatial Constraints

A high density of infrastructure or building areas on a site may limit the use of IMP's.

Appendix C

Example Checklists