UFC 3-210-10
15 NOVEMBER 2010

UNIFIED FACILITIES CRITERIA (UFC)

LOW IMPACT DEVELOPMENT

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U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**

This UFC supersedes UFC 3-210-10, dated 25 October 2004, UFC 3-210-10N (DRAFT) and ITG FY10-2, both dated 6 April 2010.

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD(AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the more stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Center for Engineering and the Environment (AFCEE) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request (CCR). The form is also accessible from the Internet sites listed below.

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- Whole Building Design Guide web site http://dod.wbdg.org/.

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: **UFC 3-210-10, Low Impact Development**

Superseding: **This UFC supersedes UFC 3-210-10, dated 25 October 2004, UFC 3-210-10N and ITG FY1-0-2, both dated 6 April 2010.**

Description of Changes: This update to UFC 3-210-10 presents criteria necessary to comply with new policy and legislation regarding implementation of Section 438 of the Energy Independence and Security Act 2007. These changes are required to handle stormwater runoff from development or redevelopment projects involving a Federal facility with a footprint that exceeds 5,000 square feet.

Reasons for Changes:

- In December 2007, Congress enacted the Energy Independence and Security Act (EISA). Section 438 of that legislation establishes stormwater runoff requirements for Federal development and redevelopment projects.

- A January 2010 Deputy Under Secretary of Defense, Installation and Environment (DUSD(IE)) memorandum directs DoD components to implement EISA Section 438 using LID techniques. The memorandum directs the policy be incorporated into applicable DoD Unified Facilities Criteria.

Impacts: Sites with available land and good vegetative cover and soil conditions may see a net reduction in site civil construction costs. Highly developed sites with fair to poor soils may see increased costs for LID implementation. However, the following benefits should be realized.

- Standardized criteria will provide a simple, uniform approach to assist the Services in complying with the Energy Independence and Security Act (EISA) Section 438 requirements.
- While care must be taken to ensure a shift in design paradigms, LID techniques can be used to manage site civil costs.
- Newer site design philosophies will provide additional treatment and control at a localized level. Low Impact Development techniques work alongside the current stormwater management approach to provide a micro-view of handling runoff at its source or point of origination, to mitigate adverse impacts from stormwater runoff and hold the net increase in stormwater runoff in the LID facilities provided on-site.
- Low Impact Development (LID) will help to protect natural resources from continuing degradation.

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CHAPTER 1- INTRODUCTION

1-1 PURPOSE AND SCOPE

This UFC provides technical criteria, technical requirements, and references for the planning and design of applicable projects to comply with stormwater requirements under Section 438 of the Energy Independence and Security Act (EISA) enacted in December 2007 (hereafter referred to as EISA Section 438).

1-2 DEFINITION OF LOW IMPACT DEVELOPMENT

Low Impact Development (LID) is a stormwater management strategy designed to maintain site hydrology and mitigate the adverse impacts of stormwater runoff and nonpoint source pollution.

LID actively manages stormwater runoff by mimicking a project site's pre-development hydrology using design techniques that infiltrate, store, and evaporate runoff close to its source of origin. LID strategies provide decentralized hydrologic source control for stormwater runoff. In short, LID seeks to manage the rain, beginning at the point where it falls. This is done through a series of techniques that are referred to as LID Integrated Management Practices (LID-IMPs). The LID-IMPs are distributed small scale controls that closely mimic hydrological behavior of the pre-project sites for a design storm event.

1-3 APPLICABILITY

The criteria and design standards in this UFC are required for all Department of Defense construction in the United States and United States Territories.

EISA Section 438 requirements apply to projects that construct facilities with a "footprint" greater than 5,000 gross square feet, or expand the footprint of existing facilities by more than 5,000 gross square feet. The project "footprint" consists of all horizontal hard surfaces and disturbed areas associated with the project development, including both building area and pavements (such as roads, parking, and sidewalks). These requirements do not apply to internal renovations, maintenance, or resurfacing of existing pavements.

Where EISA Section 438 is not applicable (e.g., projects under 5,000 square feet), LID techniques apply to the extent practical.

1-4 REFERENCES

Appendix A contains the list of references used in this document.

CHAPTER 2 - POLICY AND GENERAL REQUIREMENTS

2-1 STATUTORY REQUIREMENT

EISA Section 438 established into law new stormwater design requirements for Federal development and redevelopment projects. Under these requirements, Federal projects with a footprint over 5,000 square feet must "maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow".

2-2 DOD POLICY

The Deputy Under Secretary of Defense (Installations and Environment) memorandum of 19 January 2010 (Appendix C) directs DoD components to implement EISA Section 438 using LID techniques in accordance with the methodology illustrated in Figure 1 and further described below. In addition, this policy memo references U.S. Environmental Protection Agency (EPA) *Technical Guidance on Implementing the Stormwater Runoff requirements for Federal Projects under Section 438 of the Energy Independence and Security Act*. Individual Services may have more stringent implementation and applicability requirements relating to Low Impact Development.

2-2.1 Establishing Design Objective and Pre-Development Condition

The overall design objective for each applicable project is to maintain predevelopment hydrology and prevent any net increase in stormwater runoff. DoD defines "predevelopment hydrology" as the pre-project hydrologic conditions of temperature, rate, volume, and duration of stormwater flow from the project site. The analysis of the predevelopment hydrology must include site-specific factors (such as soil type, ground cover, and ground slope) and use modeling or other recognized tools to establish the design objective for the water volume to be managed from the project site.

The increase in runoff between pre- and post-development conditions is to be managed on the project site, to the maximum extent technically feasible, through interception, infiltration, storage, and/or evapotranspiration processes. Other design requirements may need to be considered.

2-2.2 Maximum Extent Technically Feasible

The designer shall evaluate project site options to achieve the design objective to the maximum extent technically feasible. The "maximum extent technically feasible" criterion requires full employment of accepted and reasonable stormwater retention and reuse technologies (further described in Chapter 3) subject to site and applicable regulatory constraints (e.g., site size, soil types, vegetation, demand for recycled water, existing structural limitations, state or local prohibitions on water collection). All site-specific technical constraints that limit the full attainment of the design objective shall be documented. If the design objective cannot be met within the project footprint, LID measures may be applied at nearby locations on DoD property (e.g., downstream from the project) within available resources. Examples of technical constraints are as follows:

- Retaining stormwater on-site would adversely impact receiving water flows
- Site has shallow bedrock, contaminated soils, high groundwater table, underground

facilities or utilities
- Soil infiltration capacity is limited
- Site is too small to infiltrate significant volume
- Non-potable water demand (irrigation, toilets, wash-water, etc.) is too small to warrant water harvesting and reuse system
- Structural, plumbing, and other modifications to existing building to manage stormwater are infeasible
- State or local regulations restrict water harvesting
- State or local regulations restrict use of green infrastructure/LID.

2-2.3 Restoration of Natural Hydrological Conditions

The designer shall consult with the government representative to determine whether natural hydrological conditions of the property can be restored, to the extent practical.

2-2.4 Documentation of Project Costs

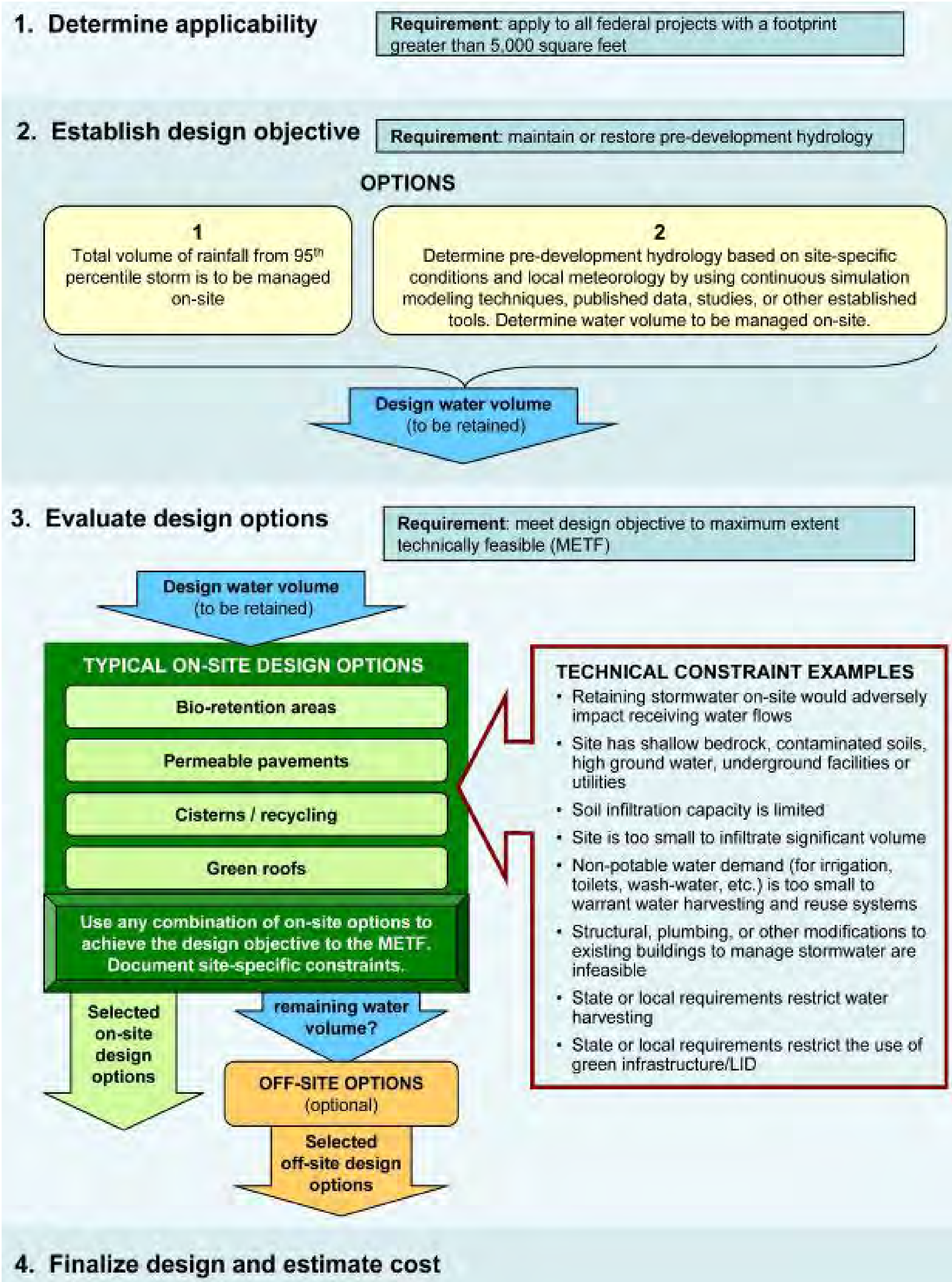
Estimated design and construction costs for implementing EISA Section 438 shall be documented in the project cost estimate as a separate line item. Final implementation costs will be documented as part of the project historical file.

Post-construction analysis shall also be conducted to validate the effectiveness of as-built stormwater features. For compliance the Designer of Record (DOR) shall provide documentation to validate the as-built LID-integrated management practices (IMP) meet the design requirements and analyses.

2-3 GENERAL BUILDING REQUIREMENTS

UFC 1-200-01, General Building Requirements, provides applicability of model building codes and government-unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, sustainability, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

FIGURE 1: IMPLEMENTATION OF EISA SECTION 438



CHAPTER 3 – PLANNING AND DESIGN

3-1 HYDROLOGIC ANALYSIS & RECOMMENDED TR-55 METHODOLOGY

DoD policy specifies that the designer is to determine pre-development hydrology based on site-specific conditions and local meteorology by using continuous simulation modeling techniques, published data, studies, or other established tools. The designer would then identify the pre-development condition of the site and quantify the post-development runoff volume and peak flow discharges that are equivalent to pre-development conditions. The post-construction rate, volume, duration and temperature of runoff should not exceed the pre-development rates and the redevelopment hydrology should be replicated through site design and other appropriate practices to the maximum extent technically feasible. These goals should be accomplished through the use of infiltration, evapotranspiration, rainwater harvesting and/or other proven LID techniques. Defensible and consistent hydrological assessment tools should be used and documented.

Service components may use a methodology or standard practice for estimating surface hydrology. These methods include, but or not limited to, Soil Conservation Service (SCS) weighted flow, the rational formula, or a dynamic rainfall-runoff simulation model like the EPA's Storm Water Management Model (SWMM). Models developed for watershed nonpoint source analysis like EPA's Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) should not be used for this type of hydrologic analysis.

To control the stormwater volume in accordance with DoD policy, the use of methodology from TR-55 Curve Number Methodology (SCS 1986), Chapter 2: "Estimating Runoff" is recommended. Calculate the runoff depth for both the pre- and post-development conditions, and the difference will be the depth from which the volume to be retained on-site can be determined (see equation 2 below).

This methodology is likely the most efficient and practical for designers to comply with EISA Section 438 requirements. Therefore, details of this methodology have been summarized in the following paragraphs.

During a storm event a portion of the precipitation is caught in the form of interception, depression storage, evaporation, transpiration, and infiltration. These losses are collectively referred to as *abstractions*. Only that part of the rainfall in excess of abstractions is defined as stormwater runoff.

The Soil Conservation Service (SCS 1986), now the Natural Resources Conservation Service (NRCS), presented an empirical method of determining initial abstraction based on the runoff curve number (CN) of the site and is given by:

EQUATION 1: Initial abstraction (inches), $I_a = 0.2*S$

Where S = potential maximum retention after <u>runoff</u> begins (inches) = $\frac{1000}{CN} - 10$

The initial abstraction defined in Eq. 1 also represents the rainfall at which the direct runoff begins. Any rainfall over and above the initial abstraction results in direct surface runoff.

EQUATION 2: Total depth of increase in runoff (inches), $D = \frac{(P - 0.2 * S')^2}{(P + 0.8 * S')} - \frac{(P - 0.2 * S)^2}{(P + 0.8 * S)}$

Where, P = design storm rainfall depth (inches)

S & S' = potential maximum retention after runoff begins (inches) during the pre- and post-development conditions, respectively

Note: Eq. 2 is valid if P > 0.2*S. Otherwise, the term calculating the runoff depth

$$\frac{(P - 0.2 * S)^2}{(P + 0.8 * S)} = 0$$

D= the depth of rainfall that becomes runoff

EQUATION 3: The design storage, $V_{LID} = D * A$

D = total depth of increase in stormwater runoff (inches)

A = drainage area or the area of the parcel being developed (square units)

The design storage of LID-IMP features, calculated using Equation 3, ensures no net increase in stormwater runoff volume for the design rainfall event replicating pre-development hydrology.

Additional details on hydrologic analysis are located in Appendix B – Low Impact Development Best Practices, Chapter 4.

3-2 DESIGN OPTIONS FOR LID INTEGRATED MANAGEMENT PRACTICES

The site designer shall give priority to those LID-IMPs that are proven in their regional area to have the greatest cost benefit ratio and lowest lifecycle costs. Highly developed sites, sites with a high ratio of impervious to pervious area, industrial sites, and airfield projects may require more costly, higher maintenance LID-IMPs in order to meet LID goals within the constraint of maximum extent technically feasible (see section 2-2.2).

The designer shall verify with the Installation the capability to maintain LID-IMPs prior to selecting for use on-site. LID-IMPs that cannot be maintained by the Installation with current capability and contract capacity shall require approval prior to construction.

LID-IMPs can be categorized in four main categories:

3-2.1 Bioretention

Natural type depression storage, infiltration, and evapotranspiration. This design option is typically the least costly and easiest to accomplish if site availability, soils, water table, etc. are conducive. Other site treatments such as swales, rain gardens, open space, etc. fall under this general category and are advisable due to lower initial costs.

3-2.2 Permeable Pavements

Provide infiltration and prevent concentrated flow. Permeable pavements (including pavers) are the next most cost effective method of meeting the design goals. Limitations on the use of these design options are wheel loading, traffic, ability to maintain, FOD danger, etc.

3-2.3 Cisterns/Recycling

Re-use systems that store and re-use stormwater. This design option is preferable if adequate demands for reuse water exist. Many facilities do not have the potential for reuse to make this option cost effective.

3-2.4 Green Roofs

Limit peak discharges and seasonal evapotranspiration. Green roofs are a design option where the site is constrained by space limitations and other design options do not meet the design goals. Green roofs should be assessed with consideration of other benefits such as lower energy costs.

3-3 TIME OF CONCENTRATION FOR PRE- AND POST-DEVELOPMENT CONDITIONS

In order to mimic pre-project hydrologic patterns the site designer needs to provide features that limit the rate at which runoff leaves the site. To the maximum extent technically feasible, the post-development time of concentration (T_c) must be equal to or greater than the pre-development T_c.

Maintaining T_c close to pre-development conditions is critical because the peak runoff rate, and thereby the volume of runoff from individual lots, is inversely proportional to the time of concentration. The T_c shall be maintained to the maximum extent technically feasible, by strategies such as reduction of impervious areas, maintaining natural vegetation, siting of impervious areas in poor draining soils, and disconnecting impervious areas.

3-3.1 Stormwater Flow Segments

The Soil Conservation Services TR-55 Curve Number Methodology (SCS, 1986) is well documented and is used widely in engineering practice and may be used to determine the T_c (other computerized methods based on site-specific conditions and acceptable to the local regulating authority may also be used). The method presumes that rainfall-runoff moves through a watershed as sheet flow, shallow concentrated flow, pipe/channel flow, or some combination of these. The time of concentration T_c is the sum of travel flow times calculated separately for the consecutive flow segments along the longest flow path. These three flow segments along with their implications on time of concentration are discussed separately. Typical site design shall use SCS TR-55 Manual: *Urban Hydrology for Small Watersheds* for calculating time of concentration. Other methods may be used for larger more complex sites.

3-4 DESIGN STORM EVENT

The design storm event shall be the 95th percentile rainfall depth or the required water quality depth as defined by State or local requirements, whichever is more stringent. Most Local and State stormwater regulations include a first-flush or water quality depth for 2-, 5-, 10-, 25-, 50-, or 100-year regulated storm events. The LID-IMPs shall be designed to control all regulated storm events, as stipulated by Local and State regulations, to handle the peak rate and/or volume of discharge for flood control purposes.

3-5 OFF-SITE OPTIONS

If the design goals objectives cannot be met within the project footprint, LID measures may be applied at nearby locations on DoD property (e.g.downstream from the project) to manage the remaining design water volume within available resources. Off-site options are generally less desirable than on-site options, as many of the benefits of managing the stormwater close to the source may be lost.

3-6 CLEAN WATER ACT PERMITS

Any applicable State and local requirement for stormwater management shall be met in addition to UFC requirements. State stormwater construction permits required under the Clean Water Act shall be obtained using their approved methodology. Coordination of the design is the responsibility of the site designer to insure that the criteria are met from both the regulatory and LID perspectives.

EISA Section 438 requirements are independent of stormwater requirements under the Clean Water Act. The DUSD (IE) EISA Section 438 policy directive (Appendix C) states, "EISA Section 438 requirements are independent of stormwater requirements under the Clean Water Act and should not be included in permits for stormwater unless a state (or EPA) has promulgated regulations for certain EISA Section 438 requirements (i.e., temperature/heat criteria) that are applicable to all regulated entities under its Clean Water Act authority."

3-7 OTHER DESIGN REQUIREMENTS

3-7.1 Regional Requirements

Regional regulatory requirements may affect the design of specific LID elements and practices as defined herein. LID implementation goals are achieved by selecting a set of LID-IMPs that can closely maintain or replicate hydrological behavior of the pre-project site for the design storm event. Most LID-IMPs are distributed small-scale controls that increase rainfall interception and slow the time of concentration. The design for LID-IMPs to be incorporated shall meet the stated goals (i.e. water volume design objectives) for compliance with EISA Section 438 per the DUSD(IE) memorandum in Appendix C.

For design of LID-IMPs to meet EISA 438 design objectives, the site designer shall refer to State and Local standards where available. In the absence of State and Local standards for design of LID-IMPs, refer to the LID National Manuals guidance prepared by the Prince George's County, Maryland, Department of Environmental Resources Programs and Planning Division (PGDER), and information provided by the US EPA.

3-7.2 Sustainable Design

Site design should incorporate sustainable development concepts to reduce energy consumption, O&M costs, reduce waste, and reduce pollution. Refer to UFC 4-030-01, *Sustainable Development* for specific design guidance.

3-7.3 Architectural Compatibility

LID-IMP facilities shall comply with DoD and Activity requirements and surrounding base architecture. Compliance with this UFC must be in accordance with other directives such as the new DoD Architectural Barriers Act (ABA) Accessibility Standard and Access for People with Disabilities Memorandum dated Oct. 31, 2008. In addition, LID design must follow applicable industry practice standards and locally restrictive building codes (e.g., earthquake zones).

3-7.4 Base Design and Development Documents

The intent of Installation Master Planning shall be incorporated into designs. The site designer shall follow published design guidelines that contain criteria relative to achieving, maintaining, and emphasizing a positive exterior visual environment applicable to military installations. The site designer shall consult the Project Manager for direction in case of conflicts. Direction to deviate from these documents should be given in writing.

3-7.5 Anti-Terrorism (AT)

The design of LID-IMP facilities shall comply with UFC 4-010-01, *DoD Minimum Antiterrorism Standards For Buildings* and UFC 4-010-02, *DoD Minimum Antiterrorism Standoff Distances For Buildings*. When conflicts arise between this document and UFC 4-010-01 or 4-010-02, UFCs 4-010-01 and 4-010-02 take precedence.

3-7.6 Airfield Criteria

The design of LID-IMP facilities shall comply with UFC 3-260-01, *Airfield and Heliport Planning and Design.* When conflicts arise between this document and UFC 3-260-01, UFC 3-260-01 takes precedence.

APPENDIX A – REFERENCES

1. U.S. EPA Technical Guidance on Implementing Section 438 of the Energy Independence and Security Act, December 2009.

2. Unified Facilities Criteria

UFC 3-200-10N	*Civil Engineering,* Final Draft
UFC 3-201-02	*Landscape Architecture*
UFC 4-010-01	*DoD Minimum Antiterrorism Standards For Buildings*
UFC 4-010-02	*DoD Minimum Antiterrorism Standoff Distances For Buildings*
UFC 4-030-01	*Sustainable Development*

3. Department of the Navy Low Impact Development (LID) Policy for Storm Water Management**,** *Assistant Secretary of the Navy (Installations and Environment) Memorandum,* November 2007

4. NAVFAC INSTRUCTIONS 9830.1: Sustainable Development Policy.

5. Low-Impact Development Design Strategies, An Integrated Design Approach, *Prince George's County, Maryland, Department of Environmental Resources, Programs and Planning Division*, June 1999.

6. Low-Impact Development Hydrologic Analysis, Prince George's County*, Maryland, Department of Environmental Resources, Programs and Planning Division*, July 1999.

7. Low Impact Development Manual for Michigan, *Southeast Michigan Council of Governments*, 2008.

8. Urban Hydrology for Small Watersheds, TR-55, *Natural Resources Conservation Services*, June 1986 (SCS 1986).

9. Sustainable Building Technical Manual: Green Building Design, Construction, and Operations, *Public Technology, Inc., and the U.S. Green Building Council, 1996.*

10. Urban Hydrology, Hydraulics, and Stormwater Quality, *A. Osman Akan and Robert J. Houghtalen*, 2003.

APPENDIX B – LOW IMPACT DEVELOPMENT BEST PRACTICES

This Best Practices appendix provides additional detail and analysis supporting the criteria and builds process action steps in the Planning, Design, and post-construction stages of project development. In addition, the appendix gives a basic level of understanding for the rationale behind the UFC criteria hydrology and methods of calculation.

The UFC criteria are predicated on standard practices in the field of stormwater management. The design storm event is typically defined by the 95th percentile storm (see also section 3-4 of this UFC). By averaging all storm events that occur within 24 hours for several years, the designer can statistically predict the intensity of a storm that is equal to or less than 95 percent of all storms. The method of calculation for this is taken to be the Natural Resource Conservation Service (NRCS), formerly the Soil Conservation Service (SCS) method TR-55. A site designer can easily hand calculate the necessary information for small sites using formulas given in the criteria. For larger sites, computer calculations and simulation modeling are encouraged.

By design, LID methods do not control runoff in excess of the pre-development condition, but are intended to bypass larger storm volumes to flood control measures as defined by the conventional stormwater management techniques. LID is in addition to the requirements of the stormwater permits required. There are other regulatory requirements that also affect the design of stormwater management, quality, and control that are specific to local regions and areas not covered in this document.

ACRONYMS AND ABBREVIATIONS

Item	Definition
ARC	Antecedent Runoff Condition
Bio	Biological
BMP	Best Management Practice
CN	Curve Number
CWA	Clean Water Act
DoD	Department of Defense
e.g.	for example
EISA	Energy Independence and Security Act
EPA	United States Environmental Protection Agency
Eq.	Equation
FEC	Facilities Engineering Command
hr	hour
HSG	Hydrologic Soil Group
I&E	Installations and Environment
I&F	Installations and Facilities
i.e.	as such
I_a	Initial Abstraction
IMP	Integrated Management Practice
in/hr	inches per hour
LEED	Leadership in Energy and Environmental Design
LID	Low Impact Development
DoD	Department of Defense
MWR	Morale, Welfare, and Recreation
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
O&M	Operations and Maintenance
OMSI	Operation and Maintenance Support Information
PGDER	Prince George's County Department of Environmental Resources
pH	Measure of the acidity of a solution
PWD	Public Works Department
SCS	USDA Soil Conservation Service
sec/hr	seconds per hour
sq ft	square feet
SWM	Stormwater Management
Tc	Time of Concentration
TR-55	NRCS Technical Release 55 (formerly SCS)
UFC	Unified Facilities Criteria
USDA	United States Department of Agriculture

APPENDEX B: CHAPTER 1 - BACKGROUND

Since 2004, LID techniques for controlling stormwater runoff have been considered for many projects based on-site requirements and constraints. LID strategies provide a decentralized hydrologic source control for stormwater. LID implementation is based on selecting LID-IMPs that are distributed small-scale controls that can closely maintain or replicate hydrological behavior of the pre-project site for a defined design storm event. The use of LID was pioneered in the 1990s by Prince George’s County, Maryland Department of Environmental Resources (PGDER) under a grant from the Environmental Protection Agency (EPA).

LID differs from conventional SWM principles in that it does not store and release stormwater. LID uses infiltration, evaporation, plant transpiration, and reuse of rainwater to keep the additional stormwater generated due to the developed condition contained on-site.

The application of LID to infrastructure development program is practical and achievable, but it will require a change of thinking on the part of the site designer. The LID-IMPs fall into five categories, as follows:

1) Site Utilization: Begin the site process by reducing the impervious footprint if possible. Narrower streets, vertical construction, parking structures, and the removal of curb, gutter, and paved swales are a few of the ways to reduce impervious surfaces. It is crucial to mimic the pre-development hydrologic conditions in order for LID to be effective. Choose rougher surfaces, disconnect impervious areas, and increase the time of concentration (Tc). Retain as much of the natural tree cover as practical, and place the impervious structures in areas of the poorest soil types where possible.
2) Filtration: Include filtration practices in the site design. Vegetative buffers, filter strips, vegetative swales, check dams, sediment traps, and overland flow will provide natural water quality treatment and increase the time of concentration (Tc).
3) Interception/Infiltration: The infiltration techniques of LID are the backbone of the runoff volume reduction. Depression storage, bio-infiltration, pervious pavements, open pavers, rain gardens, infiltration trenches, and tree boxes are gaining wide acceptance as tools in the SWM toolbox. Interception can also play a major role in reducing runoff volumes. Interception techniques include deep mulch beds, tree cover, and soil amendments.
4) Retention of Stormwater Volumes: Retention can play an important part in successful LID implementation. Retention seeks to hold runoff from localized impervious surfaces for subsequent treatment after the rainfall event. Rain barrels, storage and release cisterns, and parking lot storage that slowly drain to infiltration zones are examples of retention techniques. DoD discourages the construction of detention ponds
5) Structural Solutions: Structural solutions represent the last line of defense in the LID-IMPs. Structural solutions will increase the facility construction cost and must be balanced with mission requirements. In urban and industrial areas, sensitive environments, or known contaminated sites, structural solutions are often the only solution. These techniques are engineered solutions for the particular facility and can include green roofs, rainwater reuse systems, parking structures, and irrigation storage systems.

The site designer is encouraged to contact the Project Manager, Environmental Technical point of contact, State and local regulatory officials to verify the requirements of applicable stormwater programs. Table 1 has a link to NPDES specific State program statuses as granted by EPA. Table 1 also has additional useful links on LID topics by EPA.

A list of LID design reference material is included at the end of Chapter 4. Additional information may be found on the following link to the WBDG LID Resource Page: http://www.wbdg.org/resources/lidtech.php

Table 1: U.S. EPA Websites related to LID

U.S. Environmental Protection Agency

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. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treats stormwater as a resource rather than a waste product. Many practices have been used to adhere to these principles such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements. By implementing LID principles and practices, water can be managed in a way that reduces the impact of built areas and promotes the natural movement of water within an ecosystem or watershed. Applied on a broad scale, LID can maintain or restore a watershed's hydrologic and ecological functions. LID has been characterized as a sustainable stormwater practice by the Water Environment Research Foundation and others.

Low Impact Development (LID)
http://www.epa.gov/nps/lid/

Stormwater Program
http://cfpub.epa.gov/npdes/home.cfm?program_id=6

Authorization Status for EPA's Stormwater Construction and Industrial Programs
http://cfpub.epa.gov/npdes/stormwater/authorizationstatus.cfm

State Program Status
http://cfpub.epa.gov/npdes/statestats.cfm?view=specific

Managing Wet Weather with Green Infrastructure
http://cfpub.epa.gov/npdes/home.cfm?program_id=298

APPENDIX B: CHAPTER 2 - PLANNING

2-1 THE PLANNING COMPONENT

Successful implementation of LID begins during the planning process, which is one of the first steps. During the planning phase, the exact configuration of LID-IMPs and the ways in which LID will shape the site design is not expected to be determined. This section will provides the organizational tools and steps to build upon in considering LID in the final project.

Each step progresses further into the details of the planning process. For example, budget planning at an early stage may only develop Step 1, then move on to Cost Analysis. Master Planning would necessarily move through Step 4, and preliminary design through Step 6.

2-1.1 ORGANIZING THE PLANNING PROCESS AND TIMELINE

Step 1: *Define project objectives and goals at a macro-level*

1) Identify the LID objectives and legal requirements for the project (e.g., stormwater permits, state erosion control and flood requirements, EISA Section 438). Estimate runoff volume, peak runoff rate, duration, frequency, and water quality.
2) Make assumptions on existing stormwater infrastructure in terms of how well it functions with respect to each of these aspects.
3) Evaluate the goals and feasibility for control of runoff volume, duration, and water quality, as well as on-site use of stormwater (e.g. irrigation, flushing toilets).
4) Prioritize and rank basic objectives.
5) Identify applicable local regulations or codes.
6) Determine Typical LID-IMPs required to meet objectives as best as possible (i.e. infiltration, filtration, discharge frequency, volume of discharges, and groundwater recharge) taking into consideration available space, underground utilities, soil infiltration characteristics, slope, drainage patterns, water table protected areas, setbacks, easements, topographic features, and other site features that should be protected such as floodplains, steep slopes, and wetlands.

   Consider non-structural site planning techniques:
   - Minimize total site impervious area.
   - Use alternative roadway layouts that minimize imperviousness.
   - Reduce road widths and drive aisles where safety considerations allow.
   - Limit sidewalks to one side of roads.
   - Reduce on-street parking
   - Use permeable paving materials where it does not reduce the functionality and is permitted.
   - Minimize directly connected impervious areas.
   - Disconnect roof drains and direct drainage to vegetated areas.
   - Site layout to direct flows from paved areas to stabilized vegetated areas.
   - Site layout to break up flow directions from large paved surfaces.

> **LID Planning Steps:**
> Define Project Goals
> Evaluate Site
> Develop LID Strategies
> Assume LID Concept Design
> Target O&M Strategy

- Site development to encourage sheet flow through vegetated areas.
- Locate impervious areas so that they drain to permeable areas.
- Maximize overland sheet flow.
- Maximize use of open swale systems.
- Increase (or augment) the amount of vegetation on the site.
- Use site fingerprinting. Restrict ground disturbance to the smallest possible area
- Reduce construction on highly permeable soils.
- Locate impervious areas to avoid removal of existing trees.
- Maintain existing topography and associated drainage divides to encourage dispersed flow paths.
- Locate new buildings, parking, and ponds in areas that have lower hydrologic function, such as clayey or disturbed soils.

2-2 COST ANALYSIS

One of the most difficult challenges is to properly allocate resources for projects so that they are successful and fulfill the mission as programmed. LID requirements can add a new level of complexity to the project that must be addressed during planning. While it may be too early in the process to determine the exact final design configuration of the LID-IMPs, the information to determine a level of effort required to implement LID can be used. (LID-IMP design is discussed in Appendix B, Chapter 4).

The three resources that must be addressed for LID are:
1) Implementation cost (may be less than traditional)
2) Operation & Maintenance costs (lifecycle)
3) Time impacts to design and permitting process

Information on the project mission must be gathered including; geographical location, site requirements, available sites, programmed space requirements related to increased impervious area, and the ability of the installation to maintain the LID-IMP. These set points will also help to determine the proper resource allocations to apply for the implementation of the LID site. LID is a method of SWM that focuses on the macro vision for site development. LID is implemented on every square foot of the site at the point of rainfall onward. LID-IMPs used in conjunction with conventional SWM will create a treatment train to hold, infiltrate, and filter the stormwater runoff. The LID site will contain less channelization of stormwater, less impervious pavement, more trees, more open ditches (less curb and gutter), and more planting buffers (rainwater filters). Many parameters must be weighted in the design of a LID site. Design must match the particular regional conditions.

Many of these site conditions affect the design of LID. Regional differences in weather patterns, soil types, groundwater conditions, existing development status, and current stormwater patterns will greatly influence the actual design and layout of the LID site and the choice of the LID-IMPs. However, <u>one of the most important parameters will be the ratio of increased impervious surface area to the available land area or change in land cover</u>.

Optimal LID implementation on a suitable site may result is a reduction in project cost. Classic LID design should reduce the amount of disturbed land, reduce impervious surface area, eliminate curb and gutter, reduce the size of pipes and holding ponds, increase the area planted in low maintenance tree cover, and reduce high maintenance structural planting beds and grass. Building a large facility on a small site will cost more to implement LID than building a small building on a large site. The small site will require the selection of IMPs that are structural in nature and are more expensive to build and maintain, while the small building on the large site can use the more organic LID-IMPs that are less costly and more easily maintained.

2-3 EPA LID GUIDANCE

The following EPA manuals are referenced as sources: “Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices” and “Low Impact Development (LID) A Literature Review”. These manuals were based on the PDGR document “Low-Impact Development Design Strategies; An Integrated Design Approach”, and is geared toward general site development. Sites on military bases may have additional constraints that will influence which LID-IMPs may be used.

Other Federal Directives and Executive Orders that affect LID planning and design must be identified and considered.

APPENDIX B: CHAPTER 3 - STORMWATER MANAGEMENT

Human development increases impervious surfaces. Buildings, roads, sidewalks, and parking lots quickly shed rainwater and increase the percentage of rainfall that ends up as runoff. The resulting increase in runoff volume and the peak flows create negative consequences such as stream degradation and flooding risk. The principal objective of LID is to retain this increase in runoff on-site. LID techniques allow the developed site to mimic the pre-development hydrologic conditions.

LID builds on the conventional SWM philosophies and carries them a step further. LID processes begin at the point where the rain falls. Considering incorporating LID concepts, tools, and approaches requires assessment of the following at a minimum:

- Will the concept closely mimic the hydrology of pre-development condition thereby meeting certain regulatory requirement and/or resource protection goals?
- Will the concept mitigate adverse effects from increased stormwater runoff from the project?
- Can the drainage conveyance structures be optimized and reduce the overall cost of the project?
- What might be the hurdles for public acceptance? If required for the project to move forward, can these be reasonably achieved?

Implementing LID alone on the project may not suffice in meeting all regulatory requirements. LID must be used in combination with applicable BMPs in order to continue to produce effective SWM benefits.

3-1 HYDROLOGIC CYCLE

Dr. David Maidment in his *Handbook of Hydrology* states:

> "The hydrologic cycle is the most fundamental principle of hydrology. Water evaporates from the oceans and the land surface, is carried over earth in atmospheric circulation as water vapor, precipitates again as rain or snow, is intercepted by trees and vegetation, provides runoff on the land surface, infiltrates into soils, recharges groundwater, discharges into streams, and ultimately, flows out into the oceans from which it will eventually evaporate once again. This immense water engine, fueled by solar energy, driven by gravity, proceeds endlessly in the presence or absence of human activity."

Of the total precipitation that occurs, a portion of it is lost through the following:
(i) interception due to land cover
(ii) evapotranspiration
(iii) surface depression storage
(iv) infiltration

Only the excess precipitation results in runoff that reaches receiving water bodies, such as streams and lakes. The process of infiltration is responsible for the largest portion of rainfall losses in pervious areas. LID techniques seek to mimic pre-development hydrologic condition in the post-development phase.
An understanding of the dynamics and inter-relationships in the hydrologic cycle is essential in preserving the pre-development hydrology. A comparison of pre-development and post-

development hydrologic conditions is evaluated for four basic measures – runoff volume, peak rate of runoff, flow frequency/duration, and water quality. These four evaluation measures are discussed below:

Runoff Volume: LID techniques, if implemented properly into site design, will result in 'no net increase' in runoff for a specified design storm event.

Peak Rate of Runoff: LID is designed to maintain pre-development hydrologic conditions for all storms smaller than the design storm event. If additional controls are required, either to meet the state or local regulations and/or flooding issues for unusual storm events, conventional SWM facilities may be designed and implemented.

Flow Frequency/Duration: LID techniques mimic pre-development hydrologic conditions if implemented properly. The flow frequency/duration should be almost the same.

Water Quality: Because of the very nature of decentralized hydrologic source control, the nonpoint source pollution is greatly reduced, thereby, increasing the water quality of the receiving water bodies.

Table 2 compares and summarizes concepts of stormwater management and LID techniques. For designs with LID-IMPs, it is appropriate to analyze the site as discrete units and rationalize on a case-by-case basis. When calculating the runoff potential from LID sites one should consider land cover, impervious areas, its connection with centralized collection system, soil type and texture, and antecedent moisture condition. These should all be considered on a site-specific basis.

3-2 STORMWATER DISPOSAL VS. STORMWATER MANAGEMENT

The main principle of incorporating LID elements into site planning design is to ensure that there is no net increase in runoff volume for the design storm. As detailed in Chapter 2 of this manual, there are a number of techniques that can be employed in eliminating the increase.

The main processes or practices that affect elimination of an increase in runoff volume for the design storm include infiltration at decentralized locations, increasing the length and time of flow over pervious areas, and disconnecting impervious areas that drain to stormwater collection systems. These help to retain the increase in runoff from new development on-site.

Conventional SWM facilities are primarily designed to divert unusual storm event runoff volumes and to control flooding and downstream impacts due to this increased runoff, but also provide water quality benefits.

Table 2: Summary of Concepts of SWM and LID Techniques.

Concepts of SWM	Concepts of LID Techniques
End-of-pipe stormwater treatment.	Stormwater is treated at or very close to the source/origination of runoff.
Centralized collection system	Decentralized system
Reroute stormwater away from the site quickly and efficiently	Mimics the pre-development hydrologic condition. The goal of LID is to retain the same amount of rainfall within the development site as that was retained on the site prior to the project
Many of the stormwater management facilities are designed to control or attenuate peak runoff	LID techniques reduce the size of stormwater management facilities.
SWM facilities are designed to treat first-flush i.e. first ½ inch of runoff from impervious areas of development.	LID techniques may suffice to treat the first-flush on-site without a need for separate treatment options.

Table 2 above contrasts conventional SWM methods that use “end-of-pipe” treatment and LID techniques that may reduce land requirements associated with conventional treatment and may make the overall design more aesthetically pleasing if incorporated early on during the planning and design phase. LID may reduce the overall costs of a project and reap benefits in protecting the environment and natural habitats.

Table 3 summarizes how conventional SWM and LID technology alter the hydrologic regime for on-site and off-site conditions.

Table 3: Comparison of Conventional SWM and LID Technologies

Hydrologic Parameter	Conventional SWM	LID
	On-Site	
Impervious Cover	Encouraged to achieve effective drainage	Minimized to reduce impacts
Vegetation/Natural Cover	Reduced to improve efficient site drainage	Maximized to maintain pre-development hydrology
Time of concentration (Tc)	Shortened, reduced as a by-product of drainage efficiency	Maximized and increased to approximate pre-development conditions
Runoff Volume	Large increases in runoff volume not controlled	Controlled to pre-development conditions
Peak Discharge	Controlled to pre-development design storm (2 year & 10 year)	Controlled to pre-development conditions for all storms
Runoff Frequency	Greatly increased, especially for small, frequent storms	Controlled to pre-development conditions for all storms
Runoff Duration	Increased for all storms, because volume is not controlled	Controlled to pre-development conditions
Rainfall Abstractions (interception, infiltration, depression storage)	Large reduction in all elements	Maintained to pre-development conditions
Groundwater Recharge	Reduction in recharge	Maintained to pre-development conditions
	Off-Site	
Water Quality	Reduction in pollutant loadings but limited control for storm events that are less than design discharges	Improved pollutant loading reductions, full control for storm events that are less than design discharges
Receiving Streams	Severe impacts documented – channel erosion and degradation, sediment deposition, reduced base flow, and habitat suitability decreased, or eliminated	Stream ecology maintained to pre-development
Downstream Flooding	Peak discharge control reduces flooding immediately below control structure, but can increase flooding downstream through cumulative impacts & superpositioning of hydrographs	Controlled to pre-development conditions

Source: Low-Impact Development Design Strategies, prepared by Prince George's County, Maryland.

3-3 WATER QUALITY AND POLLUTION PREVENTION

LID or decentralized hydrologic source control, use LID-IMPs that are distributed small-scale controls, closely maintaining or replicating the hydrology of pre-development site conditions. LID-IMPs address additional regulatory requirements or other resource protection goals. Similarly, in meeting the regulatory requirements, BMPs can be designed to act as effective, practicable means of minimizing the impacts of development associated with water quality and quantity control.

Because of the very nature of decentralized hydrologic source control, the nonpoint source pollution is greatly reduced, thereby, increasing the water quality of the receiving water bodies.

3-4 DESIGN INPUTS

If possible, design inputs for successful implementation of LID techniques into a site development project obtain the following:

a. Detailed land cover and land-use information
b. Topographic contours, preferably at an interval that allows the flowpaths to be distinguished (Generally 1' interval contours minimum supplemented by spot elevations).
c. Soil borings, minimum of three borings, 15-foot deep. These borings should reveal nature and condition of the shallow subsurface soils at this location, as well as defining the groundwater table, usability of on-site material for select fill, and through compositional analysis should determine both vertical and horizontal hydraulic conductivities.
d. Existing site drainage outfall conditions and characteristics including water level elevation and water quality
e. Watershed reports and master plans
f. Flooding issues, past or present
g. Installation Appearance Guide

3-5 PRECIPITATION DATA

The intensity-duration-frequency (IDF) curves for the United States were recently revised and published by the National Oceanic and Atmospheric Administration (NOAA), and are called Atlas-14 curves. These curves should be used when determining the precipitation depth/intensity for required duration and/or frequency. Other sources such as State drainage manuals have IDF curve data as well.

Long-term rainfall records for regional weather stations can be obtained from many sources, including the NOAA data center, at http://www.nesdis.noaa.gov. Table 8 provides a summary of rainfall analysis for selected locations.

3-6 LOW-IMPACT DESIGN ELEMENTS FOR STORMWATER MANAGEMENT

The LID concept encourages innovation and creativity in management of site planning impacts. As mentioned earlier, the implementation of LID techniques must be carefully evaluated for opportunities and constraints on a case-by-case basis. Many of the techniques are site-specific. Table 4 summarizes the specific use of LID techniques, requirement, and applicability. Table 5 summarizes hydrologic functions of LID practices.

Table 4: Summary of LID Techniques, Constraints, Requirements and Applicability

	Space required	Soils	Slopes	Water Table/Bedrock	Proximity to building foundations	Max. depth	Maintenance
Bioretention	Minimum surface area range: 50 to 200 ft². Minimum width 5 to 10 ft. Minimum Length 10 to 20 ft. Minimum depth 2 to 4 ft.	Permeable soils with infiltration rates > 0.27 inches/hr are recommended. Soil limitations can be overcome with use of underdrains.	Usually not a limitation, but a design consideration.	2- to 4-ft clearance above water table/bedrock recommended	Minimum distance of 10 ft down gradient from buildings and foundations recommended	2- to 4-ft depth depending on soil type	Low requirement, property owner can include in normal site landscape maintenance
Dry Well	Minimum surface area range: 8 to 20 ft². Minimum width 2 to 4 ft. Minimum Length 4 to 8 ft. Minimum depth 4 to 8 ft.	Permeable soils with infiltration rates > 0.27 inches/hr are recommended.	Usually not a limitation, but a design consideration. Must locate down gradient of building foundations.	2- to 4-ft clearance above water table/bedrock recommended	Minimum distance of 10 ft down gradient from buildings and foundations recommended	6- to 10-ft depth depending on soil type	Low requirement
Filter/Buffer Strip	Minimum length of 15 to 20 ft.	Permeable soils perform better, but soil not a limitation.	Usually not a limitation, but a design consideration.	Generally not a constraint.	Minimum distance of 10 ft down gradient from buildings and foundations recommended	Not applicable	Low requirement, routine landscape maintenance
Swales: Grass, Infiltration, Wet	Bottom width: 2 ft minimum, 6 ft maximum	Permeable soils provide better hydrologic performance, but soils not a limitation. Selection of type of swale, grassed, infiltration or wet is influenced by soils.	Swale side slopes: 3:1 or flatter. Longitudinal slope: 1.0% minimum; maximum based on permissible velocities.	Generally not a constraint.	Minimum distance of 10 ft down gradient from buildings and foundations recommended	Not applicable	Low requirement, routine landscape maintenance
Rain Barrels	Not a factor	Not a factor	Usually not a limitation, but a design consideration.	Generally not a constraint.	Not a factor	Not applicable	Low requirement
Cistern	Not a factor	Not a factor	Not a factor				
Infiltration Trench	Minimum surface area range: 8 to 20 ft². Minimum width 2 to 4 ft. Minimum Length 4 to 8 ft.	Permeable soils with infiltration rates > 0.52 inches/hr are recommended.	Usually not a limitation, but a design consideration. Must locate down gradient of building foundations.	2- to 4-ft clearance required	Minimum distance of 10 ft down gradient from buildings and foundations recommended	6- to 10-ft depth depending on soil type	Moderate to high

Source: Low-Impact Development Design Strategies, prepared by Prince George's County, Maryland

Table 5: Summary of Hydrologic Functions of LID Practices

Hydrologic Functions	Bioretention	Dry Well	Filter/Buffer Strip	Swales: Grass, Infiltration, Wet Wells	Rain Barrels	Cistern	Infiltration Trench
Interception	High	None	High	Moderate	None	None	None
Depression Storage	High	None	High	High	None	None	Moderate
Infiltration	High	High	Moderate	Moderate	None	None	High
Ground Water Recharge	High	High	Moderate	Moderate	None	None	High
Runoff Volume	High	High	Moderate	Moderate	Low	Moderate	High
Peak Discharge	Moderate	Low	Low	Moderate	Moderate	Moderate	Moderate
Runoff Frequency	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Water Quality	High	High	High	High	Low	Low	High
Base Flow	Moderate	High	High	Moderate	Moderate	None	Low
Stream Quality	High	High	High	Moderate	None	Low	High
Source: Low-Impact Development Design Strategies, prepared by Prince George's County, Maryland.							

APPENDIX B: CHAPTER 4 - LID DESIGN

4-1 INTRODUCTION

LID strategies provide decentralized hydrologic source control for stormwater. LID implementation centers around selecting IMPs which are distributed small-scale controls that can closely maintain or replicate hydrological behavior of the natural system for a design storm event.

The principal goal of designing LID-IMPs is to maintain existing pre-development hydrology resulting in no net increase in stormwater runoff from major renovation and construction projects for the design storm under consideration. The designer will be required to design SWM BMPs as mandated by the State regulators, and LID-IMPs to control all regulated storm events. This section of the criteria guidance manual defines a design storm to provide consistent application of the LID criteria. Further, the guidance manual provides a few of the design considerations in designing LID-IMP features that are not discussed elsewhere in this document. LID-IMPs will control runoff volume and time of concentration (Tc) in order to mimic the pre-development hydrologic conditions, while standard BMPs will be used in conjunction with LID-IMPs depending on site conditions to handle the peak rate of discharge for flood control.

The site designer shall follow published design guidelines that contain criteria relative to achieving, maintaining, and emphasizing a positive exterior visual environment applicable to military installations.

HYDROLOGIC ANALYSIS

During a storm event, a portion of the precipitation is lost in the form of interception, depression storage, evaporation, transpiration, and infiltration. These losses are collectively referred to as *abstractions*. Only that part of the rainfall in excess of abstractions is realized as stormwater runoff. [1]

The Soil Conservation Service (SCS 1986) presented an empirical method of determining initial abstraction based on the runoff curve number (CN)[2] of the site and is given by:

EQUATION 1: Initial abstraction (inches), $I_a = 0.2*S$

Where S = potential maximum retention after <u>runoff</u> begins (inches) = $\frac{1000}{CN} - 10$

[1] Holding excess rainwater on-site that would ordinarily end up as runoff can be detrimental in some cases. Rainfall that is retained in excess of the initial abstraction can destabilize certain soils on slopes, impact sensitive coastal tidal zones, increase the need for mosquito control, and in certain riparian or usufructuary rights create an infringement. In many areas where shallow groundwater aquifers are used for supply or irrigation, excess infiltration the designer must consider contamination issues.

[2] The runoff CN method accounts for all types of losses. The value of the curve number depends on the hydrologic soil group, soil cover type, hydrologic condition, the percentage of impervious areas in the watershed, and the antecedent moisture condition of the soil.

The initial abstraction defined in Eq. 1 also represents the rainfall at which the direct runoff begins. Any rainfall over and above the initial abstraction results in direct surface runoff whether it is a virgin forest or a developed piece of land. Table 6 gives representative runoff curve numbers and the calculated initial abstractions for selected soil types. The runoff generated from a project site and the initial abstraction of the site does not have a linear relationship. For this reason, required design storage of LID-IMPs is calculated using Eq. 2 and Eq. 3 discussed later in this document in Section 4-1.4, Design Storage of LID-IMP Features.

Runoff curve numbers are determined by land cover type, hydrologic condition, antecedent runoff condition (ARD), and hydrologic soil group (HSG). Curve numbers for various land covers based on an average ARC for annual floods and Eq. 1 can be found in Urban Hydrology for Small Watersheds (Soil Conservation Service, 1986).

Table 6: Initial Abstraction for Indicated Soil Types

Existing Site Conditions	Curve Number (CN)	Initial Abstraction (inches)
Woods - good condition, HSG B	55	1.64
Woods - poor condition, HSG D	83	0.41
Pasture, grasslands - good condition, HSG B	61	1.28
Pasture, grasslands - fair condition, HSG C	79	0.53
Open space - lawns, park in fair condition, HSG B	69	0.90
Residential districts - 1/3 acre, 30% impervious, HSG B	72	0.78
Residential districts - 1/3 acre, 30% impervious, HSG C	81	0.47
Industrial area - 72% impervious, HSG B	88	0.27

4-1.1 Mimic Existing (Pre-Development) Hydrologic Conditions

From the preceding table, it can be seen that the hydrology of a naturally wooded environment in good condition provides a maximum retention that in turn increases the water quality treatment of stormwater runoff. For redevelopment the site is not set at maximum retention, but to maintain pre-development levels. However, the typical site development project results in the following adverse environmental impacts:

- Changes to existing land-use and land cover
- Changes to natural drainage patterns
- Clear cutting of the native vegetation
- Soil compaction due to the use of heavy construction vehicles on-site
- Increase in impervious area
- Drainage systems that quickly move the water downstream.

As a result, the post-development hydrologic conditions are worsened, and in many cases, the damage becomes irreversible. For this reason, it is important to consider LID and mimic pre-development hydrologic conditions. The 'pre-development' condition shall be taken to mean a typical condition of the project site just prior to project. The site designer should provide a site condition narrative to document the analysis of the pre-development condition. Apart from the potential increase in impervious area, the primary impacts due to human development are soil compaction, and increased efficiency of drainage patterns. The two land development conditions of concern are:

- Pre-Development Condition
- Post-Development Condition

In the development of the site narrative the site designer shall document the existing soil conditions, groundwater table of the project site, description of typical surrounding natural lands, and a brief history of existing development; including impervious area, lawns/meadows, forested area, wetlands, and water bodies, that comprises the existing development condition. It is recognized that there are very many different existing development conditions (including everything from leveling and fill, to existing conditions that bear no resemblance to what came before). The goal, however, is to document a return to a realistic natural pre-development condition for the particular locale and setting.

LID techniques mimic the natural systems by capturing at the minimum, all of the initial abstraction through bio-infiltration practices (such as shown by photo1 below) and/or structural solutions of reuse or footprint reduction for a design storm event.

Photo 1: Typical Bio-infiltration 'Rain Garden'.

Note curb cut inlet. Design should be based on regional plants and growing conditions.

4-1.2 Time of Concentration (Tc) For Pre- and Post-Development Conditions

In order to mimic natural hydrologic patterns the site designer needs to provide features that limit the rate at which runoff leaves the site. The post-development time of concentration (Tc) must be equal to or greater than the pre-development Tc. Maintaining Tc close to pre-development conditions is critical because the peak runoff rate and thereby the volume of runoff from individual lots, is inversely proportional to the time of concentration. The Tc shall be maintained by strategies such as reduction of impervious areas, maintaining natural vegetation, siting of impervious areas in poor draining soils, and disconnecting impervious areas.

Using traditional site planning techniques the post-development time of concentration (Tc) is invariably reduced. This is due to the curbs, channels, and pipes causing quicker drainage, resulting in higher peak flow rates. In order to mimic the natural hydrologic pattern the site designer needs to provide features that slow down the runoff from the site. To maintain the Tc use the following site planning techniques:

- Maintaining or increasing pre-development sheet flow length
- Preserving natural vegetation
- Increasing surface roughness
- Detaining flows
- Disconnecting impervious areas
- Reducing longitudinal slopes of swales and ditches.

Achieving a Tc close to pre-development conditions is often an iterative process and requires analyzing different combinations of the appropriate techniques.

4-1.3 Design Storm Event for LID Design and Implementation

Storm events are a complex natural phenomenon, and methods to predict and control their impacts rely upon empirical and mathematical modeling of the event. It is important to provide criteria to be used by the site designer that is easily understood and is based on recognized industry standards. Three principal approaches in determining the design storm event were analyzed, as follows:

Prince George's County Methodology (Soil Conservation Service, TR-55 Method):
As previously mentioned any rainfall over and above the initial abstraction will result in direct surface runoff. It is prudent to design and implement IMPs for that rainfall event that exceeds initial abstraction (Eq. 1) in the pre-development conditions. The design methodology would apply a modifying factor of 1.5 times the initial abstraction (as suggested in the Prince George's County LID manual) to serve as a practical approach to design LID-IMP features.

EPA Methodology:
See Technical Guidance on Implementing Section 438 of the Energy Independence and Security Act, *Guidance prepared by EPA*, December 2009 for Option 1 methodology.

First-Flush Water Quality Volume:
Many States and localities have adopted the conventional approach of collecting and treating the *first-flush* or *water-quality* depth of rainfall. These terms are defined by the local regulatory agency. In certain areas, this first flush depth is generally taken to be the first one inch of rainfall. In other localities with sensitive coastal or reservoir watersheds, the first-flush depth is

taken to be the first 1.5 inches of rainfall. The water quality volume is equated to the volume of stormwater runoff generated by the first-flush rainfall depth. Therefore, it would be practical to design LID-IMP features to handle the first-flush rainfall depth. The stormwater runoff quality is further improved by the design of conventional SWM practices required to meet the state regulations.

Most Local and State stormwater regulations include a first-flush or water quality depth for 2-, 5-, 10-, 25-, 50-, or 100-year regulated storm events. State and Local requirements for stormwater management shall be met before the LID requirements are satisfied. The SWM BMPs shall be designed to control all regulated storm events, as stipulated by Local and State regulations to handle the peak rate and/or volume of discharge for flood control purposes.

DOD Accepted Methodology:
DoD has chosen to use the 95th percentile design storm event in UFC 3-210-10 criteria for determining the LID design volume. When in conflict with other State or Local requirements the most stringent apply.

To control the stormwater volume in accordance with LID policy, use the methodology from TR-55, Chapter 2: “Estimating Runoff”. Calculate the runoff depth for both the pre- and post-development conditions, and the difference will be the depth from which the volume to be retained on-site can be determined.

4-1.4 Design Storage of LID-IMP Features

For the selected design storm event, the LID volume is equal to or greater than the total net increase in runoff from the pre- to post-development states. Physically, the total volume of stormwater runoff generated during the post-development conditions exceeds the total volume of stormwater runoff generated from the site during the pre-development conditions. The design storage of LID-IMP features would be the difference in total volume of stormwater runoff generated between pre- and post-development conditions. The required design storage is calculated using the SCS methodology for compliance with EISA Section 438. Other methods may be specifically required by State SWM guidance to comply with State SWM program requirements. The designer is to balance the various requirements to determine the LID-SWM design that meets all policies and programs.

EQUATION 2: Total depth of increase in runoff (inches), $D = \frac{(P - 0.2 * S')^2}{(P + 0.8 * S')} - \frac{(P - 0.2 * S)^2}{(P + 0.8 * S)}$

Where, P = design storm rainfall depth (inches)

S & S’ = potential maximum retention after runoff begins (inches) during the pre- and post-development conditions, respectively

Note: Eq. 2 is valid if P > 0.2*S. Otherwise, the term calculating the runoff depth

$$\frac{(P - 0.2 * S)^2}{(P + 0.8 * S)} = 0$$

EQUATION 3: The design storage, $V_{LID} = D * A$

D = total depth of increase in stormwater runoff (inches),

A = drainage area or the area of the parcel being developed (square units).

The design storage of LID-IMP features, calculated using Eq. 3, is compliant with DoD policy for stormwater runoff volume for the design rainfall event by maintaining pre-development hydrology.

Table 7 illustrates the total depth of increase in stormwater runoff for a hypothetical representative site. The depth of increase in stormwater runoff calculated will be used in designing the LID-IMP features to handle all of the net increases in stormwater runoff generated from a parcel being developed (using Eq. 3).

4-2 PREDEVELOPMENT HYDROLOGY AND NO NET INCREASE

The principal goal of designing LID-IMPs is to achieve no net increase in stormwater runoff volume and sediment or nutrient loading from major renovation and construction projects for the design storm under consideration. The design storage volume of LID-IMP features, as calculated using Eq. 3, is a minimum requirement and must be followed to ensure no net increase in stormwater runoff volume for the design storm depth. This will assure the most practical solution and provide the maximum value for achieving an improved water quality discharge downstream. In certain geographical areas on optimal sites, the site designer will be able to improve the efficiency of the LID features to handle a portion of the flood control element of stormwater. For other rainfall events, which exceed normal intensities, the runoff will be collected and conveyed to the conventional SWM facilities. The conventional SWM facilities should be designed to discharge/outfall over a 24-hour period to reduce the peak flow rate below the pre-development outflow rate. Further, outfall water quality is improved through an additional treatment from conventional SWM facilities. To design the LID-IMP features for gross increases in stormwater runoff over a range of storm events, for less frequent or high return period storm events, would be impractical. Depending on site conditions, the use of conventional SWM facilities in conjunction with LID-IMPs may be required to handle unprecedented rainfall events and to avoid any downstream flooding of facilities and roadways that might become a life safety concern.

4-3 DESIGN CONSIDERATIONS

A few of the most relevant design considerations are listed below. For a more detailed list, the reader is referred to published literature given in the References.

Develop LID control strategies:
Use hydrology as a design element. In order to minimize the runoff potential of the development, the hydrologic evaluation should be an ongoing part of the design process. An understanding of site drainage can suggest locations for both green areas and potential building sites. An open drainage system can help integrate the site with its natural features, creating a more aesthetically pleasing landscape.

a) Determine the State regulatory design storms. Regulatory requirements for design storms may also be stipulated in local ordinances, and these may limit or constrain the use of LID techniques or necessitate that structural controls be employed in conjunction with LID techniques.

b) Determine LID volumes using 95th percentile design storm and NRCS TR-55 Curve Number methodologies.
c) Evaluate current conditions. Analyze site with traditional hand methods or computer simulations. Use the results of modeling to estimate baseline values for the four evaluation measures: runoff volume, peak runoff rate, flow frequency and duration, and water quality.
d) Evaluate site planning benefits and compare with baseline values. The modeling analysis is used to evaluate the cumulative hydrologic benefit of the site planning process in terms of the four evaluation measures.
e) Evaluate the need for IMPs. If site planning is not sufficient to meet the site's LID objectives, additional hydrologic control needs may be addressed through the use of LID-IMPs. After LID-IMPs are selected for the site, a second-level hydrologic evaluation can be conducted that combines the IMPs with the controls provided by the planning techniques. Results of this hydrologic evaluation are compared with the baseline conditions to verify that the site LID objectives have been achieved. If not, additional LID-IMPs are located on the site to achieve the optimal condition.
f) Evaluate supplemental needs. If supplemental control for either volume or peak flow is still needed after the use of IMPs, selection and listing of additional management techniques should be considered. For example, where flood control or flooding problems are key design objectives, or where site conditions, such as poor soils or a high water table, limit the use of LID-IMPs, additional conventional end-of-pipe methods, such as large detention ponds or constructed wetlands, should be considered. In some cases their capacity can be reduced significantly by the use of LID upstream. It may be helpful to evaluate several combinations of LID features and conventional stormwater facilities to determine which combination best meets the stated objectives. Use of hydrologic evaluations can assist in identifying the alternative solutions prior to detailed design and construction costs.
g) For residential areas, Prince George's County, Maryland, has developed a detailed illustration of an approach for conducting a hydrologic evaluation based on the NRCS TR-55 method. Where NRCS methods (TR-20, TR-55) are accepted for hydrologic evaluation, the effect of LID features should be reflected in the curve numbers and times of concentration selected for the analysis. A full description of this process is available from Prince George's County (*Low-Impact Development Hydrologic Analysis*, Reference 2.)

LID Concept Design or Master Plan:

1) Maximize the efficiency of the existing site. Place impervious areas in poorer soils and retain existing trees where practical.
2) Sketch a design concept that distributes the LID practices appropriately around the project site. Keep in mind the multifunctional capability of LID technologies (i.e., parking lot with detention facility underground).
3) Develop a master plan that identifies all key control issues (water quality, water quantity, water conservation) and implementation areas. Specify specific LID technologies and any connections they have to stormwater overflow units and sub-surface detention facilities.

Develop landscaping plans to maximize the efficiency of the LID-IMPs and reduce maintenance:

Use hardy, native plantings.

1) In areas where soils have low infiltration rates, as determined by percolation tests, average depth of bio-infiltration practices is determined such that the volume held would infiltrate within stated limits. For example, if the State criteria indicates 72 hours and in soils with a low permeability rate (hydrologic soil group's C and D) of 0.05 inches/hour, the depth of infiltration basin = 72 hrs x 0.05 in/hr = 3.6 inches. Conservatively, the designer may opt to

restrict this depth to 3.0 inches and provide a larger area to satisfy the LID volume requirement or may want to incorporate other LID practices, such as footprint reduction of impervious surfaces, permeable pavers, etc., in conjunction with sizing of bio-infiltration facilities. (Verify all actual design parameters with State BMP manual.)

2) Flood control is based on protecting life and property. Flood control criteria are ultimately determined locally based on drainage needs and flood risk of any particular area and may go beyond LID design criteria to achieve the necessary level of flood protection.
3) If project site has limited land area for bio-infiltration practices, in order to satisfy the LID volume criteria, a combination of structural practices such as rain barrels and cisterns may be employed in addition to bio-infiltration practices. At any time the outflow from the structural practices must be controlled to the sum total of assimilating capacity of bio-infiltration practices provided downstream. For example, if a downstream bio-retention facility is of size 600 sq.ft, in soil type C with an infiltration rate of 0.15 in/hr, then the cisterns or rain barrels provided on site will discharge into bio-retention facility at a rate = 0.15 in/hr * 600 sq.ft /(12 in/ft * 3600 sec/hr) = 0.0021 cfs.
4) LID-IMP features are to be incorporated into the site plan at locations as close as possible to the origin of surface runoff from impervious areas. For example, runoff from roof drains is to be collected around the building (depending on ATFP requirements, a minimum of 10-ft offset from the face of the building is required, refer to bio-retention design manuals for more details on specifications), and runoff from parking lots will be held in traffic islands and all along the perimeter. The central idea is to mimic pre-development hydrology.
5) Prefer planting of bio-retention facilities with native vegetation; refer to local plant specialists and horticulturists.
6) Design positive overflow system to capture excess rainfall-runoff.

Develop Operation and Maintenance Procedures:
Development of Operation and Maintenance Support Information documentation (OMSI) is critical to ensure LID-IMPs are properly maintained in order to function properly. LID-IMPs should be viewed as environmental systems that have specific maintenance requirements. O&M procedures for each of the LID practices implemented in the site plan should be developed as part of the OMSI documents. Different types of LID-IMPs will have different maintenance requirements, but some general principles will apply:

1) Keep LID-IMPs and flow paths clear of debris.
2) Regular trash pickup will be required.
3) Use native, drought-tolerant plantings that can tolerate periods of saturation. If required, water vegetation regularly during dry periods. Use special care in selecting plants in areas of tidal influence.
4) Consider impact on plants by road salts.
5) Grassed areas should be mowed regularly using a longer length cut.
6) Plantings should be pruned as needed.
7) Deep raking and tilling of depression storage should be done on a yearly basis or as indicated.

4-4 GAINING ACCEPTANCE OF LID OPTIONS

Low Impact Development projects will require a higher level of communication to keep stakeholders informed during the planning and design phase. From building tenant commands to O&M personnel, communicating intent and purpose is the key to successful LID implementation. In addition, for some period, feedback on implementation and program success will be required for all new facilities through the local Environmental Office.

4-5 CONSTRUCTION PERMIT PROCESS

Conventional SWM is a patterned response to maximize the efficiency of site landscaping and site design to achieve a reduction in the volume, duration, and pollutant loading of rainfall that ends up as runoff due to human development. The EPA's CWA defined an appropriate level of SWM to help to keep our rivers, lakes, and shorelines clean. The CWA established the base guidelines for SWM, but for the most part turned the execution of those guidelines over to the local, state, and/or municipal regulatory agencies. The States then promulgated additional or clarifying requirements to a minimum level as the EPA requirements to meet the needs of the local geographic conditions. For example, SWM techniques suitable for Florida are not necessarily appropriate to the arid Southwest. Almost all projects will require Local or State construction permit in order to begin work. As such, the LID requirements must be complementary, and will overlay the State and Local requirements for SWM. Without the regulatory acceptance and approval of the SWM plan, a project cannot be constructed. However, with the continuing development and destruction of natural settings, most of these regulatory bodies have recognized that additional measures must be taken. For the State environmental regulators to improve stormwater discharge quality they must adopt alternative management methods or build treatment systems at the outfalls to treat the water. In order to avoid those large, expensive end-of-pipe treatment systems, an example was taken from nature to begin a process of retention, detention, infiltration, and treatment at the point of intersection (the point where a raindrop hits the earth). LID has gained widespread acceptance in the commercial and municipal arenas and is beginning to show up in most of the Local and State regulations as an appropriate response to assist with traditional SWM. As the States adopt and change their requirements, DoD's LID policies will increasingly align with the State's SWM requirements.

4-6 CONCLUSIONS

The methods for calculating, modeling, and sizing stormwater runoff are based on the *design storm*. The design storm is a designation that defines a unit depth of rainfall in order to quantify the volume of rainfall generated for a given site. This data is needed in order to calculate the impact of development on a particular piece of land.

The site designer shall use higher of either the 95th percentile rainfall depth, or the required water quality depth (as locally legislated) as the design storm event when calculating the LID volumes. This will result in a practical and reasonable approach (as being suggested by the EPA in their preliminary findings) in determining LID volumes. The design storm event is based on the regional 95th percentile, annual 24-hour rainfall depth averaged over several years (a minimum of 10-year daily, 24-hour precipitation events would be used). The 'design storm' will be used to calculate pre- and post-development LID volumes in order to determine the amount of excess runoff that must be controlled on-site so that the site contributes no net increase downstream. LID integrated management techniques will be encouraged throughout the site design to ensure control and water quality objectives.

Three practical design methodologies were evaluated in this guidance manual to compare and contrast the methodologies. The first two that were evaluated used accepted practices within the engineering community and demonstrated acceptable results. The third methodology examined was based on regulatory guidance regarding water quality volumes.

DoD has chosen to adopt the EPA's 95th percentile methodology to determine the design storm. Choosing the 95th percentile storm event as the LID design storm would result in a conservative design of LID-IMP features. Table 7 compares the three analysis methods for a few sample locations, by soil and type. Table 8 provides a summary of rainfall analysis for selected locations. Additional references for sources of rainfall data include NRCS TR20 manual rainfall maps and Air Force 14th Weather Squadron rainfall data for installations.

DoD criteria also recommend the use of industry standard methodologies for determining the LID volumes, such as TR-55 (Soil Conservation Services, 1986) or other recognized modeling software.

Table 7: Analysis Method Comparison

Existing Site Conditions	Existing Site Composite CN	Method 1.	Method 2.	Method 3.	Selected Design Storm Rainfall Depth (inches)	Developed Conditions[2] Composite CN	Depth of increase in Stormwater Runoff (inches)
Woods - good condition, HSG B	55	2.45	1.63[a]	1.00	1.63	76.5	0.25
Woods - poor condition, HSG D	83	0.61	1.45[b]	1.00	1.45	90.5	0.32
Pasture, grasslands - good condition, HSG B	61	1.92	1.63[a]	1.00	1.63	79.5	0.32
Pasture, grasslands - fair condition, HSG C	79	0.80	1.45[b]	1.00	1.45	88.5	0.33
Open space - lawns, park in fair condition, HSG B	69	1.35	1.63[a]	1.00	1.63	83.5	0.37
Residential districts - 1/3 acre, 30% impervious, HSG B	72	1.17	1.63[a]	1.00	1.63	85.0	0.38
Residential districts - 1/3 acre, 30% impervious, HSG C	81	0.70	1.45[b]	1.00	1.45	89.5	0.33
Industrial area - 72% impervious, HSG B	88	0.41	1.63[a]	1.00	1.63	93.0	0.30

Method 1: Design Rainfall Depth Based on Initial Abstraction (inches)

Method 2: Region1 - 95 Percentile Rainfall Depth (inches);

Method 3: First-Flush Rainfall Depth (inches)

1. In this example, regional refers to: a - Norfolk region; b- Cincinnati Region.

2. The developed conditions composite curve number is calculated as equal to existing composite CN plus a 50% of maximum full development potential of the parcel. A full development potential is where the entire parcel is developed with impervious surface resulting in a composite curve number of 98. Here, it is assumed 50% of maximum full development and calculated as = existing CN+0.5*(98-existing CN).

Table 8: Summary of Rainfall Analysis (1978-1997)

Description	State	Weather Station ID	Applicable Unit Identification Code						Annual Rainfall Depth (in)	99th Percentile	98th Percentile	95th Percentile	90th Percentile	75th Percentile	Rainy Days (>0.1")	Years of Available Record (1978-1997)
YUMA WSO AP	Arizona	029660	62974 (1 mi.)						3.38	2.20	1.46	0.98	0.73	0.43	8	17
BOULDER CREEK LOCAT RANCH	California	041005	44269 (mi.)						51.36	5.14	4.64	3.70	2.50	1.50	44	20
EL CENTRO 2 SSW	California	042713	45211 (1 mi.)						2.83	2.30	1.91	1.30	1.00	0.58	5	20
FAIRFIELD 3 NNE	California	042935	45653 (1 mi.)						21.55	3.26	2.48	1.80	1.30	0.90	31	20
FRESNO AIR TERMINAL	California	043257	44259 (27 mi.)						11.80	1.51	1.31	0.99	0.80	0.51	28	20
HETCH HETCHY	California	043939	64495 (36 mi.)						31.42	3.27	2.73	1.96	1.59	0.90	42	20
LOS ANGELES WSO ARPT	California	045114	44267 (17 mi.)	67399 (80 mi.)					13.95	2.56	2.30	1.64	1.23	0.77	23	20
MONTEREY NWSFO	California	045802	45210 (5 mi.)						20.10	1.70	1.47	1.37	1.14	0.85	31	2
SAN DIEGO WSO AIRPORT	California	047740	62473 (1 mi.)	00681 (30 mi)					11.69	1.74	1.58	1.28	1.01	0.60	23	20
VICTORVILLE PUMP PLANT	California	049325	3594A (60 mi.)	62204 (30 mi.)					6.47	1.73	1.60	1.12	0.90	0.60	12	19
COLORADO SPRINGS WSO AP	Colorado	051778	3455A (0 mi.)						17.06	2.11	1.59	1.12	0.85	0.48	37	20
JACKSONVILLE WSO AP	Florida	084358	57061 (18.75 mi.)	68931 (18 mi.)	68248 (25 mi.)	46134 (17.5 mi.)			52.35	3.46	2.86	2.12	1.59	0.87	74	20
KEY WEST WSO AIRPORT	Florida	084570	44222 (2 mi.)						39.68	3.76	2.95	1.92	1.41	0.76	59	20
MIAMI WSCMO AIRPORT	Florida	085663	30931 (2.5 mi.)						59.17	3.53	2.94	2.20	1.62	0.86	82	20
PANAMA CITY 5 NE	Florida	086842	44223 (9.5 mi.)	44224 (97 mi.)					56.51	4.24	3.30	2.40	1.80	1.10	63	20
TALLAHASSEE WSO AP	Florida	088758	67004 (83 mi.)						62.14	4.26	3.58	2.37	1.76	1.07	76	20
TAMPA WSO AIRPORT	Florida	088788	47030 (8 mi.)						46.24	3.22	2.70	1.92	1.48	0.88	66	20
SAVANNAH WSO AIRPORT	Georgia	097847	00263 (32 mi.)	44227 (35 mi.)					49.54	3.17	2.80	2.03	1.52	0.85	70	20
GUAM WSMO	Guam	914229	62395 (5 mi.)						95.12	4.24	3.27	2.20	1.45	0.70	143	14
HOKULOA 725.2	Hawaii	511540	44251 (mi.)						33.02	5.11	4.00	2.64	1.70	0.80	40	20
HONOLULU WSFO AP 703	Hawaii	511919	62742 (3 mi.)	47771 (9.5 mi.)					19.07	3.72	3.08	2.11	1.31	0.61	29	20
KEKAHA 944	Hawaii	514272	30614 (mi.)						20.08	4.83	3.86	2.80	1.91	0.90	24	20
CHICAGO OHARE WSO AP	Illinois	111549	65113 (23 mi.)						36.24	2.57	1.90	1.49	1.09	0.65	67	20
EVANSVILLE WSO AP	Indiana	122738	44204 (58 mi.)						43.72	2.78	2.16	1.74	1.25	0.78	71	20
NEW ORLEANS WSMO AIRPORT	Louisiana	166660	44218 (9 mi.)						65.10	4.38	3.33	2.48	1.81	1.06	77	20
SHREVEPORT AP	Louisiana	168440	45603 (11 mi.)						52.06	3.94	3.32	2.33	1.76	1.01	66	20
PORTLAND WSFO AP	Maine	176905	44214 (24 mi.)						42.49	2.88	2.23	1.55	1.17	0.71	71	20
BALTIMORE WSO ARPT	Maryland	180465	44201 (15.5 mi.)	0417A (14 mi.)					40.29	2.36	1.94	1.53	1.16	0.71	71	20
PATUXENT RIVER	Maryland	186915	00019 (0 mi.)	47370 (33 mi.)					24.97	2.90	2.58	1.80	1.30	0.80	36	20
BILOXI 9 WNW	Mississippi	220797	62604 (4 mi.)						60.53	5.64	4.04	2.74	2.07	1.20	59	9
TRENTON STATE COLLEGE	New Jersey	288880	3806A (30 mi.)						38.50	2.80	2.60	1.90	1.40	0.90	54	20
ALBUQUERQUE WSFO AIRPORT	New Mexico	290234	65460 (3 mi.)						9.74	1.15	1.06	0.88	0.65	0.39	25	20
MOREHEAD CITY	North Carolina	315830	00146 (16 mi.)	67001 (34 mi.)					38.57	4.10	3.30	2.40	1.70	1.00	46	20
HARRISBURG CAPITAL CITY	Pennsylvania	363699	68378 (6 mi.)						32.91	2.40	2.18	1.57	1.11	0.65	60	8
HARRISBURG WSO CITY OFFICE	Pennsylvania	363710	68378 (4.5 mi.)						30.58	2.05	1.84	1.32	1.08	0.70	56	8
MIDDLETOWN HARRISBURG INTL AP	Pennsylvania	365703	68378 (10 mi.)						34.91	2.46	2.25	1.39	1.10	0.69	62	7
PHILADELPHIA WSO AP	Pennsylvania	366889	45727 (2.5 mi.)						40.68	2.46	2.05	1.60	1.18	0.70	70	20
BLOCK ISLAND WSO AP	Rhode Island	370896	44210 (29 mi.)						33.37	2.54	2.08	1.52	1.23	0.74	56	16
NEWPORT ROSE	Rhode Island	375215	44211 (1.5 mi.)						32.86	2.80	2.30	1.79	1.30	0.80	46	20
CHARLESTON WSO AIRPORT	South Carolina	381544	69229 (4 mi.)						50.79	3.76	3.14	1.97	1.49	0.82	73	20
MEMPHIS WSFO	Tennessee	405954	44221 (18 mi.)						53.19	3.37	2.83	2.14	1.70	0.96	70	18
CORPUS CHRISTI WSO AP	Texas	412015	45974 (27 mi.)	68891 (11 mi.)	44215 (10 mi.)				32.44	4.40	3.42	2.50	1.73	0.91	42	20
NORFOLK WSO AIRPORT	Virginia	446139	62470 (5.7 mi.)						44.36	2.67	2.26	1.63	1.23	0.73	74	20
WASHINGTON NATL WSO AP	Virginia	448906	00025 (2.5 mi.)	00029 (1.5 mi.)	44252 (9.5 mi.)	44200 (22 mi.)	48429 (11 mi.)	45967 (25 mi.)	38.37	1.94	1.76	1.37	1.12	0.69	70	20
WILLIAMSBURG 2 N	Virginia	449151	44247 (11 mi.)						34.17	2.50	2.20	1.61	1.30	0.80	50	20
SEATTLE TACOMA AP WBAS	Washington	457473	44255 (17 mi.)						37.11	1.76	1.40	1.03	0.79	0.50	87	20
SEATTLE EMSU WSO	Washington	457458	44219 (mi.)						36.04	1.82	1.44	1.00	0.78	0.47	84	20
FRANKLIN 2 N	West Virginia	463215	31188 (5 mi.)						24.08	1.80	1.70	1.30	1.00	0.70	41	17

4-7 RESOURCE INDEX

1. *BMP Modeling Concepts and Simulation* (USEPA, 2006): www.epa.gov/nrmrl/pubs/600r06033/epa600r-06033toc.pdf
2. *Low-Impact Development Hydrologic Analysis* (Prince George's County, MD, Dept. of Environmental Resources, 1999): www.epa.gov/nps/lid_hydr.pdf
3. A Design Guide for Implementers and Reviewers Low Impact Development Manual for Michigan (Southeast Michigan Council of Governments, SEMCOG 2008): www.semcog.org
4. Urban Hydrology for Small Watersheds, TR-55 (Soil Conservation Services, 1986)
5. Technical Guidance on Implementing Section 438 of the Energy Independence and Security Act (February 2009)

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Under contract to the National Institute of Building Sciences (NIBS).

APPENDIX C – DUSD (IE) Policy Memo 19 JAN 2010

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

ACQUISITION, TECHNOLOGY AND LOGISTICS

JAN 19 2010

MEMORANDUM FOR ACTING ASSISTANT SECRETARY OF THE ARMY (INSTALLATIONS AND ENVIRONMENT)
ACTING ASSISTANT SECRETARY OF THE NAVY (INSTALLATIONS AND ENVIRONMENT)
ACTING ASSISTANT SECRETARY OF THE AIR FORCE (INSTALLATIONS, LOGISTICS, AND ENVIRONMENT)

SUBJECT: DoD Implementation of Storm Water Requirements under Section 438 of the Energy Independence and Security Act (EISA)

Reducing the impacts of storm water runoff associated with new construction helps to sustain our water resources. In October 2004, DoD issued Unified Facilities Criteria on Low Impact Development (LID) (UFC 3-210-10), a storm water management strategy designed to maintain the hydrologic functions of a site and mitigate the adverse impacts of storm water runoff from DoD construction projects. Using LID techniques on DoD facility projects can also assist in fulfilling environmental regulatory requirements under the Clean Water Act. Since 2004, DoD has implemented LID techniques for controlling storm water runoff on a number of projects.

EISA Section 438 (Title 42, US Code, Section 17094) establishes into law new storm water design requirements for Federal development and redevelopment projects. Under these requirements, Federal facility projects over 5,000 square feet must "maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow." Executive Order 13514, *Federal Leadership in Environmental, Energy, and Economic Performance* (October 5, 2009), directed the U.S. Environmental Protection Agency (EPA) to issue EISA Section 438 guidance. DoD shall implement EISA Section 438 and the EPA *Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act*, using LID techniques in accordance with the policy outlined in the attachment.

EISA Section 438 requirements are independent of storm water requirements under the Clean Water Act and should not be included in permits for storm water unless a State (or EPA) has promulgated regulations for certain EISA Section 438 requirements (i.e., temperature/heat criteria) that are applicable to all regulated entities under its Clean Water Act authority.

The attached policy will be incorporated into applicable DoD Unified Facilities Criteria within six months. My points of contact are Thadd Buzan at (703) 571-9079 and Ed Miller at (703) 604-1765.

Dorothy Robyn
Deputy Under Secretary of Defense
(Installations and Environment)

Attachment:
As stated

DoD Policy on Implementing Section 438 of the Energy Independence and Security Act (EISA)

1. EISA Section 438 requirements apply to projects that construct facilities with a footprint greater than 5,000 gross square feet, or expand the footprint of existing facilities by more than 5,000 gross square feet. The project footprint consists of all horizontal hard surfaces and disturbed areas associated with the project development, including both building area and pavements (such as roads, parking, and sidewalks). These requirements do not apply to internal renovations, maintenance, or resurfacing of existing pavements.

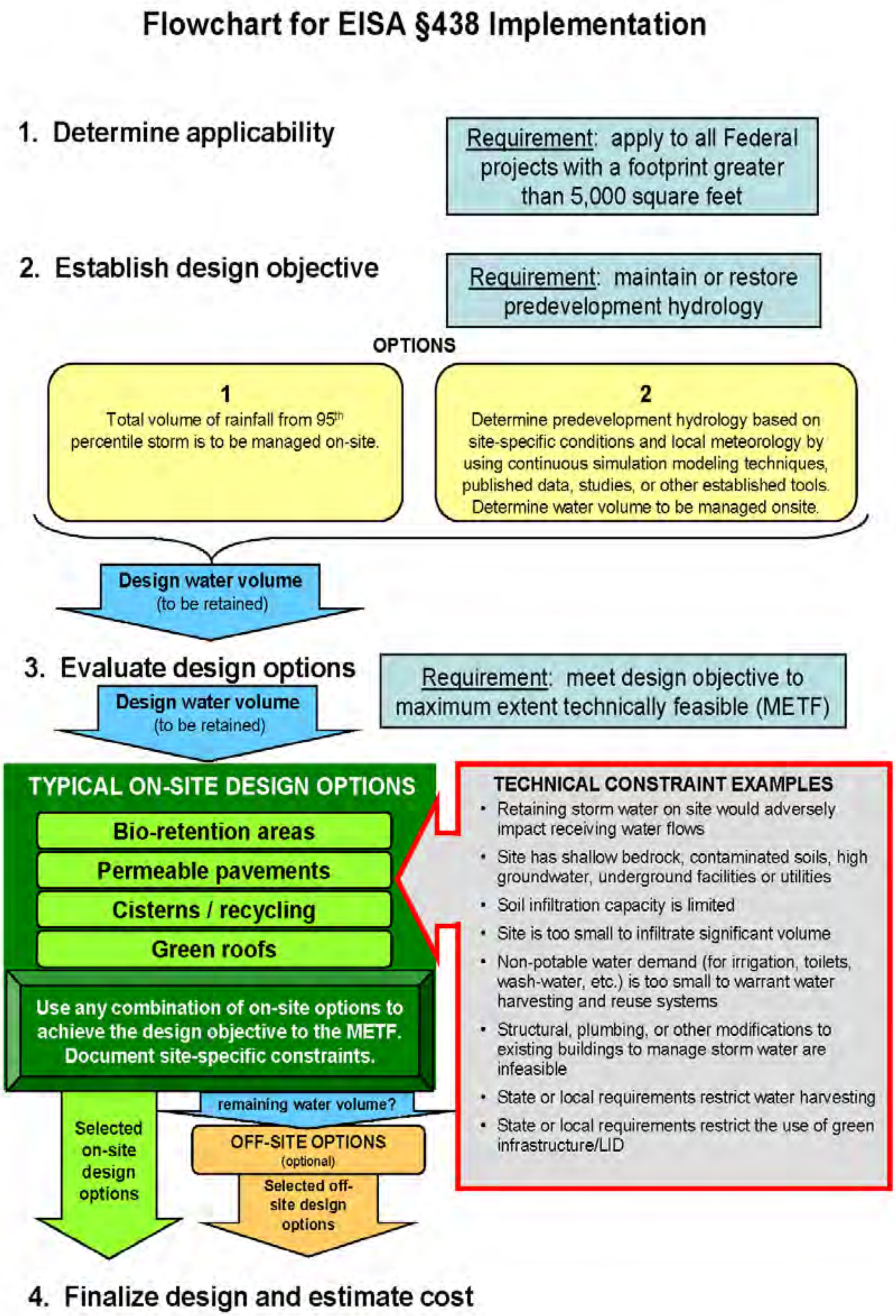
2. The overall design objective for each project is to maintain predevelopment hydrology and prevent any net increase in storm water runoff. DoD defines "predevelopment hydrology" as the pre-project hydrologic conditions of temperature, rate, volume, and duration of storm water flow from the project site. The analysis of the predevelopment hydrology must include site-specific factors (such as soil type, ground cover, and ground slope) and use modeling or other recognized tools to establish the design objective for the water volume to be managed from the project site.

3. Project site design options shall be evaluated to achieve the design objective to the maximum extent technically feasible. The "maximum extent technically feasible" criterion requires full employment of accepted and reasonable storm water retention and reuse technologies (e.g., bio-retention areas, permeable pavements, cisterns/recycling, and green roofs), subject to site and applicable regulatory constraints (e.g., site size, soil types, vegetation, demand for recycled water, existing structural limitations, state or local prohibitions on water collection). All site-specific technical constraints that limit the full attainment of the design objective shall be documented. If the design objective cannot be met within the project footprint, LID measures may be applied at nearby locations on DoD property (e.g., downstream from the project) within available resources.

4. Prior to finalizing the design for a redevelopment project, DoD Components shall also consider whether natural hydrological conditions of the property can be restored, to the extent practical.

5. Estimated design and construction costs for implementing EISA Section 438 shall be documented in the project cost estimate as a separate line item. Final implementation costs will be documented as part of the project historical file. Post-construction analysis shall also be conducted to validate the effectiveness of as-built storm water features.

The following flowchart illustrates the DoD implementation process for EISA Section 438, consistent with the U.S. Environmental Protection Agency's *Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act* (December 2009) (http://www.epa.gov/owow/nps/lid/section438/.


Flowchart for EISA §438 Implementation
1. Determine applicability
Requirement: apply to all Federal projects with a footprint greater than 5,000 square feet
2. Establish design objective
Requirement: maintain or restore predevelopment hydrology
OPTIONS
1
Total volume of rainfall from 95th percentile storm is to be managed on-site.
2
Determine predevelopment hydrology based on site-specific conditions and local meteorology by using continuous simulation modeling techniques, published data, studies, or other established tools. Determine water volume to be managed onsite.
Design water volume (to be retained)
3. Evaluate design options
Requirement: meet design objective to maximum extent technically feasible (METF)
Design water volume (to be retained)
TYPICAL ON-SITE DESIGN OPTIONS
Bio-retention areas
Permeable pavements
Cisterns / recycling
Green roofs
Use any combination of on-site options to achieve the design objective to the METF. Document site-specific constraints.
TECHNICAL CONSTRAINT EXAMPLES
• Retaining storm water on site would adversely impact receiving water flows
• Site has shallow bedrock, contaminated soils, high groundwater, underground facilities or utilities
• Soil infiltration capacity is limited
• Site is too small to infiltrate significant volume
• Non-potable water demand (for irrigation, toilets, wash-water, etc.) is too small to warrant water harvesting and reuse systems
• Structural, plumbing, or other modifications to existing buildings to manage storm water are infeasible
• State or local requirements restrict water harvesting
• State or local requirements restrict the use of green infrastructure/LID
remaining water volume?
Selected on-site design options
OFF-SITE OPTIONS (optional)
Selected off-site design options
4. Finalize design and estimate cost