UFC 3-210-10
28 August 2023

UNIFIED FACILITIES CRITERIA (UFC)

LOW IMPACT DEVELOPMENT

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UNIFIED FACILITIES CRITERIA (UFC)

LOW IMPACT DEVELOPMENT

Indicate the preparing activity beside the Service responsible for preparing the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

Change No.	Date	Location

This UFC supersedes UFC 3-210-10, dated June 2015.

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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 its territories, and possessions 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 most 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 Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide website https://www.wbdg.org/ffc/dod.

Refer to UFC 1-200-01, *DoD Building Code*, for implementation of new issuances on projects.

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TABLE OF CONTENTS

FIGURES

TABLES

CHAPTER 1 INTRODUCTION

1-1 REISSUES AND CANCELS.

This UFC reissues and cancels UFC 3-210-10 Low Impact Development, with Change 3, 1 March 2020.

1-2 PURPOSE AND SCOPE.

This UFC provides technical criteria, technical requirements, and references for the planning and design of applicable Department of Defense (DoD) 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) and the Deputy Under Secretary of Defense DoD policy on the implementation of stormwater requirements under EISA Section 438.

1-3 APPLICABILITY.

This UFC applies to all service elements and contractors involved in the planning, design, and construction of all permanent DoD projects in the United States, United States Territories and Possessions of the United States that meet both of the following conditions:

- The project includes construction or expansion of one or more buildings as part of its primary scope. For example, primary facilities vice supporting facilities.
- The “footprint” is greater than 5,000 gross square feet (464.5 square meters). “Footprint” consists of all new impervious surfaces associated with the building(s), including both building area and pavement area of associated supporting facilities (such as parking and sidewalks). “Footprint” does <u>not</u> include existing building area to be renovated, existing pavement area to be resurfaced, or new pavement area other than supporting facilities associated with the building(s).

For projects in the United States, United States Territories, and Possessions of the United States that do not meet the applicability requirements above, Low Impact Development (LID) techniques apply to the extent practicable.

1-3.1 Overseas Locations.

All design and construction outside of the United States and United States territories is governed by international agreements, such as the Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA), and country-specific Final Environmental Governing Standards or DoDI 4715.05. DoDI 4715.05 is commonly referred to as the Overseas Environmental Baseline Guidance Document (OEBGD). The OEBGD applies when there are no international agreements in place. Therefore, in foreign countries this UFC will be used for DoD projects to the extent that it is allowed by and does not conflict with the applicable international agreements. For projects where the OEBGD is applicable, consider and apply LID techniques to the extent practicable.

1-4 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *DoD Building Code*. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-5 CYBERSECURITY.

All facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy.

1-6 GLOSSARY.

APPENDIX B contains acronyms, abbreviations, and terms.

1-7 REFERENCES.

APPENDIX C contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

CHAPTER 2 TECHNICAL REQUIREMENTS

2-1 DESIGN OBJECTIVE.

2-1.1 Establishing Pre-Development Condition.

The overall design objective for each applicable project is to maintain pre-development hydrology and prevent any net increase in stormwater runoff. DoD defines "pre-development hydrology" as the pre-project hydrologic conditions of temperature, rate, volume, and duration of stormwater flow from the project site. The analysis of the pre-development 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 Designer of Record (hereafter referred to as the designer) must document the existing features that comprise the existing development condition.

Manage the increase in runoff between pre- and post-development conditions on the project site, to the maximum extent technically feasible, through interception, infiltration, storage, or evapotranspiration processes. Other design requirements may need to be considered. Calculations must be performed by the designer indicating the difference between the post-development hydrology and pre-development hydrology for the design storm event. Calculations must demonstrate "No net increase" in stormwater runoff where technically feasible.

2-1.2 Design Storm Event.

The design storm is the 95th percentile rainfall event. It is based on daily measured precipitation depths accumulated over a 24-hour period. The design storm event is derived from rainfall data collected for a minimum of 10 years, but ideally should be based on 30 years of data, where 30 or more years of rainfall records are available. Tables A-8 and A-9 in APPENDIX A contain rainfall analyses for selected locations. Use the values in APPENDIX A or calculate the 95th percentile rainfall depth based on rainfall records. Rainfall records can be obtained from National Oceanic and Atmospheric Administration (NOAA) at https://www.ncdc.noaa.gov/cdo-web/. A general procedure for selecting rainfall stations and downloading historical rainfall records is outlined in APPENDIX A, Section A-4.7.

2-1.3 Maximum Extent Technically Feasible (METF).

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 subject to in-situ site conditions and applicable regulatory constraints (for example, site size, soil types, vegetation, demand for recycled water, existing structural limitations and state or local prohibitions on water collection).

2-1.4 Technical Infeasibility.

Cost alone should not be used as a constraint to justify technical infeasibility. Document all applicable technical constraints if the design objective is infeasible due to technical constraints. In most cases, the designer should be able to document more than one technical constraint to demonstrate technical infeasibility. If the project meets the design objective, technical constraints do not need to be documented. 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, including irrigation, toilets, and wash-water, is too small to warrant water harvesting and reuse systems
- 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 or LID.

2-2 DOCUMENTATION.

Provide the following documentation at the pre-final design stage:

- Pre-development conditions, such as 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 areas, wetlands, and water bodies.
- Calculations for pre-development and post-development runoff volumes and rates using the 95th percentile rainfall event to identify the volume of stormwater requiring management and the extent to which the design objective was met.
- Technical constraints, if applicable.
- Stormwater management practices used to meet the design objective and whether they were located on-site, off-site or both.
- LID cost estimate from DD Form 1391.

Update pre-final data at the final design stage, as applicable, and perform post-construction analysis at the end of construction. Maintain this documentation as part of the project historical file.

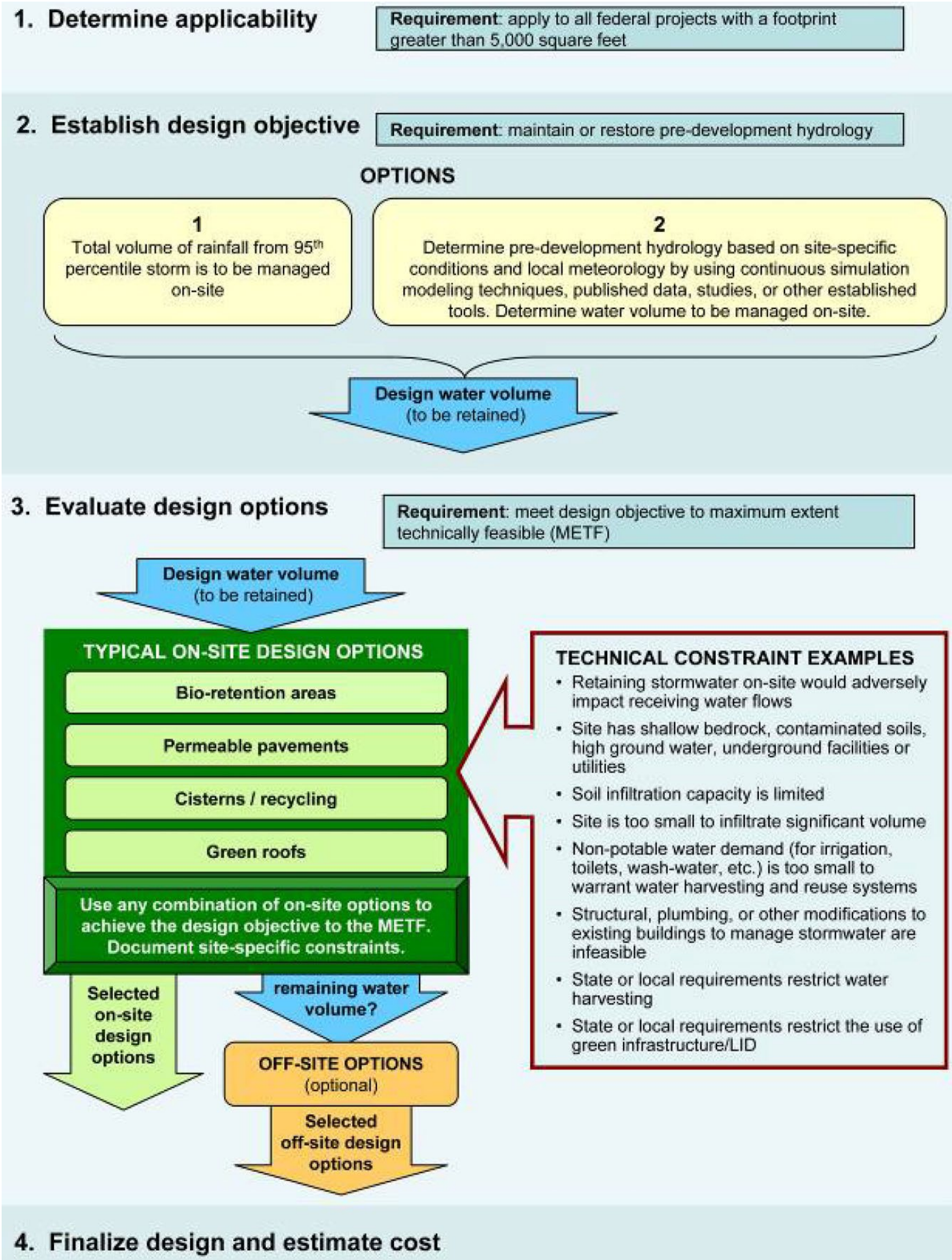
2-3 POST-CONSTRUCTION ANALYSIS.

The designer is required to validate LID features have been constructed according to plans and specifications. Validation may be accomplished by conducting a post-construction site visit to assess the as-built LID features or by having the construction contractor complete a post construction analysis report. If LID features were not constructed according to plans and specifications indicate the technical constraints that precluded meeting the design objective.

2-3.1 Documentation.

- Post-construction validation indicating that the LID features have been constructed according to plans and specifications.

Figure 2-1 Implementation of EISA Section 438



CHAPTER 3 PLANNING AND DESIGN

3-1 HYDROLOGIC ANALYSIS.

Determine pre-development hydrology based on site-specific conditions and local meteorology by using the 95th percentile storm. The designer must 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.

When performing hydrologic analysis, the designer is required to understand the hydrologic methodology, the limitations of the methodology, and the site-specific hydrologic conditions. The results of the hydrologic analysis are only as good as the assumptions and site-specific data used by the designer. Inappropriate assumptions or site data can affect the reliability of the results. The designer must be able to validate the design assumptions, site data and results to demonstrate that the design objective has been met.

3-1.1 Approved Methodologies.

To control the stormwater volume in accordance with DoD policy, the use of TR-55, Chapter 2: “Estimating Runoff”, Curve Number Methodology is approved and recommended. Continuous simulation modeling may be used to complete the hydrologic analysis. Other approved methodologies are WinTR-20 and the Storm Water Management Model (SWMM) computer program developed by the Environmental Protection Agency (EPA). Computer programs that use the approved methodology are also approved.

3-1.2 Other Methodologies.

If other hydrologic methodologies are used, they must be documented and submitted to the Government Civil Engineer for approval. 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.

3-2 TR-55 METHODOLOGY.

TR-55 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.

3-2.1 Storm Event.

During a storm event a portion of the precipitation is caught in the form of interception, depression storage, evaporation, transpiration, and infiltration. The process of infiltration is responsible for the largest portion of rainfall losses in pervious areas. These losses are collectively referred to as *abstractions*. Only that part of the rainfall in excess of abstractions is defined as stormwater runoff and reaches receiving water bodies, such as streams and lakes.

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 3-1. Initial Abstraction (inches)

$$I_a = 0.2 * S$$

Where:
I_a = Initial abstraction (inches)
S = potential maximum retention after runoff begins (inches)

$$S = \frac{1000}{CN} - 10$$

The initial abstraction defined in Equation 3-1 also represents the rainfall at which the direct runoff begins. Any rainfall over and above the initial abstraction results in direct surface runoff.

3-2.2 Runoff Depth for Calculating LID Volume.

Calculate the difference between pre- and post-development runoff depths, from which the volume to be retained on-site can be determined (for TR-55 methodology see Equation 3-2 below).

Equation 3-2. 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:
D = runoff depth for calculating LID volume (inches)
P = design storm rainfall depth (inches)
S = potential maximum retention after runoff begins (inches) during the pre - development conditions
S' = potential maximum retention after runoff begins (inches) during the post-development conditions

Note: Equation. 3-2 is valid if P > 0.2*S. Otherwise, the term calculating the runoff depth is:

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

When calculating pre- and post-development runoff volumes, consider water features present within the project footprint to be impervious.

3-2.3 LID Storage Volume.

Equation 3-3. LID Storage Volume

$$V_{LID} = D * A$$

Where:
V_{LID} = LID Storage Volume (cubic units)
D = total depth of increase in stormwater runoff (inches)
A = drainage area or the area of the parcel being developed (square units)

The minimum required LID Storage Volume is calculated using Equation 3-3 to comply with the design objective, and must be followed for the design storm depth (using Equation 3-2).

Additional details on hydrologic analysis are located in APPENDIX A, Section A-5, LID Design.

3-2.4 Time of Concentration for Pre- and Post-Development Conditions.

To mimic pre-project hydrologic patterns, the site designer needs to provide features that limit the rate at which runoff leaves the site. See A-5.2.2 for guidance on T_c. The post-development T_c should be as close as is technically feasible to the pre-development T_c.

3-3 LID IMPLEMENTATION.

LID implementation is achieved by selecting a set of LID features that can closely maintain or replicate hydrological behavior of the pre-project site for the design storm event. Most LID features are distributed small-scale controls that increase rainfall interception and lengthen the time of concentration (T_c). Some LID features provide greater benefits (that is, groundwater recharge and increased T_c) than others. Give priority to those LID features that are proven in their regional area, provide the most benefits in relation to replicating pre-project hydrology and have the lowest lifecycle costs. LID features typically include natural features with low maintenance costs. Selecting appropriate LID features with the lowest long-term maintenance cost will extend the useful life of the LID features. Highly developed sites, sites with a high ratio of impervious to pervious area (that is, industrial sites) may require more costly, higher maintenance LID features in order to meet the design objective within the constraint of maximum extent technically feasible (see Section 2-1.3). Provide a minimum 10 ft (3.05

m) offset from the LID feature to the face of the nearest building. Comply with the offset and clear zone requirements in UFC 4-010-01 *DoD Minimum Antiterrorism Standards for Buildings* when placing LID features near buildings.

Verify with the Installation the capability to maintain LID features prior to selecting for use on-site. LID features that cannot be maintained by the Installation with current capability and contract capacity may not be used.

3-3.1 LID Features.

Implementing LID features help replicate the pre-development hydrology and can generally be grouped into two categories.

3-3.1.1 Engineered Natural Treatments.

Engineered natural treatments provide depression storage, infiltration, and evapotranspiration. These design options are typically the least costly and easiest to accomplish if site availability, soils and groundwater table are conducive. Site features such as bioretention, vegetated swales, rain gardens, vegetated filter strips, downspout disconnection, reduced impervious area, tree preservation or re-vegetation using native plants, soil amendments, and open space fall under this general category and are advisable due to lower lifecycle costs.

3-3.1.2 Engineered Subsurface Treatments.

Engineered subsurface treatment provides infiltration and prevents concentrated flow. Site features may include permeable pavements and infiltration trenches. Engineered subsurface treatment may be the next most lifecycle cost effective method, as compared to engineered natural treatment, in meeting the design objective. These design options may be limited by wheel loading, traffic, ability to provide maintenance and foreign object debris danger. Avoid locating infiltration trenches and similar features under pavements wherever possible. Refer to UFC 3-201-01 for additional criteria on permeable pavement.

3-3.2 Non-Potable Rainwater Harvesting.

Rainwater harvesting systems store stormwater for non-potable uses, such as irrigation or toilet flushing. Site features may include LID features like cisterns and rain barrels. This design option may be used if adequate demands for reuse water exist. The reuse of harvested water (through rain barrels and cisterns, also called alternative sources of water) for purposes other than irrigation must comply with UFC 3-420-01 *Plumbing Systems*. Certain types of facilities, such as a warehouse, may not have adequate water demand to make reuse lifecycle cost effective. Consider freeze protection for winter months.

3-3.3 Green (Vegetative) Roofs.

Vegetative roofs increase both the T_c and seasonal evapotranspiration while reducing building energy usage and noise levels. They do not assist in infiltrating water into the ground at the source and have high initial and annual maintenance costs. Vegetative roofs are a design option where other LID features do not meet the design objective. Vegetative roofs should be assessed with consideration of other benefits such as lower energy costs and noise reduction.

3-4 OFF-SITE OPTIONS.

If the design objectives cannot be met within the project footprint, off-site options within the same watershed may be used. 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. The designer must confirm site approval for off-site options with the Government Project Manager.

3-5 CLEAN WATER ACT PERMITS.

Comply with applicable state and local requirements for stormwater management in addition to UFC requirements. Obtain state stormwater construction permits required under the Clean Water Act using the state's approved methodology. Coordination of the design is the responsibility of the designer to ensure that the criteria are met from both the regulatory and LID perspectives. Design the stormwater management (SWM) features to control all regulated storm events, as stipulated by state and local regulations to handle the peak rate and volume of discharge for flood control purposes.

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 (that is, temperature or heat criteria) that are applicable to all regulated entities under its Clean Water Act authority. Compliance with applicable regulatory stormwater management requirements may satisfy all or part of the EISA Section 438 requirement for the project.

3-6 OTHER DESIGN REQUIREMENTS.

Where state and local standards for design of LID features to satisfy EISA Section 438 requirements do not exist, refer to *Low-Impact Development Design Strategies, An Integrated Design Approach* and *Low-Impact Development Hydrologic Analysis* prepared by Prince George's County, Maryland, Department of Environmental Resources, Programs and Planning Division (PGDER). Follow applicable industry practice standards and local building codes (for example, earthquake zones).

3-6.1 Sustainable Design.

Incorporate sustainable development concepts to reduce energy consumption, O&M costs, reduce waste, and reduce pollution. Refer to UFC 1-200-02, for additional criteria.

3-6.2 Architectural Compatibility.

Comply with DoD, and Activity requirements and provide LID features compatible with surrounding base architecture.

3-6.3 Base Design and Development Documents.

Incorporate the intent of Installation Master Planning into designs. Follow published design guidelines that contain criteria relative to achieving, maintaining, and emphasizing a positive exterior visual environment applicable to military installations. Consult with the Government Project Manager for direction in case of conflicts. Direction to deviate from these documents should be given in writing.

3-6.4 Antiterrorism.

Comply with UFC 4-010-01 when designing LID features.

3-6.5 Airfield Criteria.

Where the criteria provided in this UFC conflicts with UFC 3-260-01, UFC 3-260-01 criteria governs.

APPENDIX A 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 defined by the 95th percentile storm. By using all storm events that occur within 24 hours for several years, the designer can statistically estimate the rainfall depth that is less than or equal to 95 percent of all storms, see Section 2-1.2.

By design, LID methods do not control runoff in excess of the runoff generated from the 95th percentile storm. Excess runoff from larger storm events, such as the 2-, or 10-year storm, is intended to bypass into conventional stormwater management facilities. LID practices help meet regulatory runoff requirements by reducing the volume of water leaving the site. The runoff calculation method is adopted from the NRCS, formerly the Soil Conservation Service (SCS) TR-55 method. 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.

A-1 BACKGROUND.

In December 2007, Congress enacted EISA which established into law new stormwater design requirements for federal agencies to develop and redevelop applicable facilities in a manner that maintains or restores stormwater runoff to the METF with regard to the temperature, rate, volume, and duration of flow. In December of 2009, EPA issued EPA 841-B-09-001. EPA 841-B-09-001 provides technical guidance to assist federal agencies in implementing EISA Section 438 and was intended solely as guidance.

Deputy Under Secretary of Defense (Installations and Environment) memorandum of 19 January 2010 directs DoD components to implement EISA Section 438 using LID techniques in accordance with the methodology illustrated in Figure 2-1 and further described below. This policy directs DoD to implement EISA Section 438 EPA technical guidance in accordance with DoD Policy on Implementing EISA Section 438. Where DoD policy or the criteria provided in this UFC conflicts with EPA Technical Guidance, the DoD policy and UFC govern. Individual Services may have more stringent implementation and applicability requirements relating to LID.

A-1.1 What is LID?

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 EPA. 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 features 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. These small-scale practices are sometimes referred to as integrated management practices (IMPs).

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. Increased impervious area changes the natural flow of water and decreases the quantity of water that infiltrates into the ground. Increased runoff increases sediment transport and decreases water quality. LID seeks to restore pre-development infiltration rates at the project site through one or more LID IMPs.

A-1.2 Types of LID Features.

The application of LID to an infrastructure development program is practical and achievable, but it will require a change of thinking on the part of the site designer. The engineered natural and subsurface LID treatments described in Section 3-3.1 fall into five types 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. Choose rougher surfaces, disconnect impervious areas, and increase the time of concentration (T_c). 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 T_c. By providing and maintaining natural buffers adjacent to water bodies, and directing stormwater to vegetated areas, stormwater infiltration is maximized thereby reducing pollutant discharges.
3. Interception and 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, cisterns, and parking lot storage that slowly infiltrates into the ground are examples of retention techniques.
5. Structural Solutions: Structural solutions represent the last line of defense in LID features. 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 feasible solution. These techniques are specific solutions engineered for the particular facility and can include green roofs, rainwater reuse systems, parking structures, and irrigation storage systems.

A-2 CONSTRUCTION PERMIT PROCESS.

Conventional SWM is a patterned response to maximize the efficiency of site landscaping and site design to achieve a reduction in 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, 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 to state and local requirements for SWM. Without the regulatory acceptance and approval of the SWM plan, a project cannot be constructed.

The site designer is encouraged to contact the Government Civil Engineer, as well as state and local regulatory officials to coordinate LID requirements with applicable stormwater programs. Table A-1 has useful links on stormwater topics which includes a link to NPDES state program statuses as granted by EPA. Additional information may be found on the following link to the WBDG LID Resource Page:
https://www.wbdg.org/resources/low-impact-development-technologies

Table A-1 U.S. EPA Websites Related to Stormwater

U.S. Environmental Protection Agency
LID Information
Urban Runoff: Low Impact Development (LID) https://www.epa.gov/nps/urban-runoff-low-impact-development
Managing Wet Weather with Green Infrastructure https://www.epa.gov/green-infrastructure
Regulatory Information
NPDES Stormwater Program https://www.epa.gov/npdes/npdes-stormwater-program
Authorization Status for EPA's Stormwater Construction and Industrial Programs https://www.epa.gov/npdes/authorization-status-epas-construction-and-industrial-stormwater-programs
State Program Status https://www.epa.gov/npdes/npdes-state-program-authority

A-3 INITIAL LID PLANNING COMPONENTS.

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

The initial planning phase begins with identifying possible LID features for a given project. Potential features to meet the project requirements will depend on considerations such as the required storage volume, existing infrastructure, and feasibility based on site conditions. Non-structural techniques should also be considered during the initial planning phase. Steps 1 through 6 below will help identify LID features which may satisfy the design requirements for a given project. In the preliminary planning phase, several alternatives may be identified which can then be narrowed down through cost analyses, or additional planning stages involving more detailed information about the site conditions, existing infrastructure, and project requirements.

A-3.1 Organizing the Planning Process and Timeline.

Step 1. Identify the LID objectives and legal requirements for the project (for example, stormwater permits, state erosion control and flood requirements, EISA

Section 438). Estimate runoff volume, peak runoff rate, duration, frequency, and water quality.

Step 2. Make assumptions on existing stormwater infrastructure in terms of how well it functions with respect to each of these aspects.

Step 3. Evaluate the goals and feasibility for control of runoff volume, duration, and water quality, as well as on-site use of stormwater (for example, irrigation, flushing toilets).

Step 4. Prioritize and rank basic objectives.

Step 5. Identify applicable local regulations or codes.

Step 6. Determine typical LID features required to meet objectives as best as possible (that is, infiltration, filtration, discharge frequency, volume of discharges, and groundwater recharge) taking into consideration available space, underground utilities, soil infiltration characteristics, slope, drainage patterns, groundwater table protected areas, setbacks, easements, topographic features, and other site features that should be protected such as floodplains, steep slopes, and wetlands.

Non-structural site planning techniques that may be considered:

- Minimizing total site impervious area.
- Reducing on-street parking.
- Using permeable pavement (pavers, concrete, or asphalt).
- Directing flows from paved areas to stabilized vegetated areas.
- Increasing overland sheet flow.
- Using open swale systems.
- Minimizing ground disturbance.
- Maintaining existing topography, where feasible.
- Locating new impervious areas where soils have lower hydrologic functions, such as clayey or disturbed soils.

For a more comprehensive list of non-structural site planning techniques refer to *Low-Impact Development Design Strategies, An Integrated Design Approach* from PGDER.

A-3.2 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 configuration of LID features, a preliminary analysis is needed to determine the level of effort required to implement LID. (LID Design is discussed in APPENDIX A, Section A-5).

The three items that should 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 should 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 feature. These set points will also help to determine the proper resource allocations to apply for the implementation of the LID site. LID features may be 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. Many parameters must be weighed during the LID design process. Design must match the particular regional conditions.

A-3.2.1 Cost Considerations.

Many of the following site conditions affect the design of LID features. 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 features. However, 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.

Optimal LID implementation on a suitable site may result in 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 and increase the area planted in low maintenance tree cover. Building a large facility on a small site will increase the cost of implementing LID because the small site may require the selection of LID features that are structural in nature and are more expensive to build and maintain. On the other hand, a small building on the large site may use more natural LID features that are less costly and more easily maintained.

A-3.3 EPA LID Guidance.

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

A-4 STORMWATER MANAGEMENT.

Man-made land 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 builds on the conventional SWM philosophies and carries them a step further. LID processes begin at the point where the rain falls. Consideration for 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?
- 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?

A-4.1 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."

A-4.2 Conventional Stormwater Management vs LID.

Conventional SWM facilities are primarily designed to temporarily store runoff, control flooding and downstream impacts due to increased runoff. These SWM facilities also provide water quality benefits. Whereas decentralized LID features include infiltration, increasing the length and time of flow over pervious areas, and disconnecting impervious areas that drain to stormwater collection systems. This helps to retain the increase in runoff from new development on-site.

Table A-2 contrasts conventional SWM methods that use "end-of-pipe" treatment and LID techniques that may reduce land requirements associated with conventional treatment. LID may reduce the overall costs of a project and reap benefits in protecting the environment and natural habitats.

Table A-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.
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 detain the first-flush (the first ½ inch (13 mm) of runoff) from impervious areas of development.	LID techniques infiltrate stormwater on-site.

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

Table A-3 Comparison of Conventional SWM and LID Technologies

Hydrologic Parameter	Conventional SWM	LID
	On-Site	
Impervious Cover	Encouraged to achieve effective drainage	Minimized to increase infiltration
Vegetation or Natural Cover	Reduced to provide or improve centralized drainage system	Maximized to maintain pre-development hydrology
Time of concentration (T_c)	Shortened, reduced as a by-product of drainage efficiency	Maintained or maximized 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 conditions for the design storm event (i.e., the 2-year, 10-year, or 25-year storms)	Controlled to pre-development conditions for the 95th percentile storm event
Runoff Frequency	Greatly increased, especially for small, frequent storms	Reduced or minimized
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 of stormwater volume leaving site	Improved pollutant loading reductions, full volume control for the 95th percentile storm event
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 conditions for the 95th percentile storm event
Downstream Flooding	Peak discharge control reduces flooding immediately below control structure, but can increase flooding downstream through cumulative impacts and super positioning of hydrographs	Controlled to pre-development conditions for the 95th percentile storm event
Source: Low-Impact Development Design Strategies, prepared by Prince George's County, Maryland.		

A-4.3 Low Impact Design Elements for Stormwater Management.

The LID concept encourages innovation and creativity in management of site planning impacts. As mentioned in Section 3-3, 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 A-4 summarizes the specific use of LID techniques, requirement, and applicability. Table A-5 summarizes hydrologic functions of LID practices.

Table A-4 Summary of LID Techniques, Constraints, Requirements and Applicability

Maintenance	Max. Depth	Proximity to Building Foundations	Water Table or Bedrock	Slopes	Soils	Space Required	
Low requirement, property owner can include in normal site landscape maintenance	2- to 4-ft (600 to 1200 mm) depth depending on soil type	Minimum distance of 10 ft (3 m) down gradient from buildings and foundations recommended	2- to 4-ft (600 to 1200 mm) clearance above water table or bedrock recommended	Usually not a limitation, but a design consideration.	Permeable soils with infiltration rates > 0.27 inches/hr (7 mm/hr) are recommended. Soil limitations can be overcome with use of underdrains.	Minimum surface area range: 50 to 200 ft^2 (4.6 to 18.6 m^2). Minimum length to width ratio 2:1	**Bioretention**
Low requirement	6- to 10-ft (1.8 to 3 m) depth depending on soil type	Minimum distance of 10 ft down gradient from buildings and foundations recommended	2- to 4-ft (600 to 1200 mm) clearance above water table or bedrock recommended	Usually not a limitation, but a design consideration. Must locate down gradient of building foundations.	Permeable soils with infiltration rates > 0.27 inches/hr (7 mm/hr) are recommended.	Minimum surface area range: 8 to 20 ft^2 (0.7 to 1.9 m^2). Minimum length to width ratio 2:1	**Dry Well**
Low requirement, routine landscape maintenance	Not applicable	Minimum distance of 10 ft down gradient from buildings and foundations recommended	Generally, not a constraint.	Usually not a limitation, but a design consideration.	Permeable soils perform better, but soil not a limitation.	Minimum length of 15 to 20 ft (4.6 to 6.1 m^2)	**Filter Buffer Strip**
Low requirement, routine landscape maintenance	Not applicable	Minimum distance of 10 ft down gradient from buildings and foundations recommended	Generally, not a constraint.	Swale side slopes: 3:1 or flatter. Longitudinal slope: 1.0% minimum; maximum based on permissible velocities.	Permeable soils provide better hydrologic performance, but soils not a limitation. Selection of type of swale, grassed, infiltration or wet is influenced by soils.	Bottom width: minimum 2 ft (600 mm), maximum 6 ft (1800 mm)	**Swales: Grass, Infiltration, Wet**
Low requirement	Not applicable	Not a factor	Generally, not a constraint.	Usually not a limitation, but a design consideration.	Not a factor	Not a factor	**Rain Barrels**
				Not a factor	Not a factor	Not a factor	**Cistern**
Moderate to high	6- to 10-ft (1.8 to 3 m) depth depending on soil type	Minimum distance of 10 ft down gradient from buildings and foundations recommended	2- to 4-ft (600 to 1200 mm) clearance required	Usually not a limitation, but a design consideration. Must locate down gradient of building foundations.	Permeable soils with infiltration rates > 0.52 inches/hr (13 mm/hr) are recommended.	Minimum surface area range: 8 to 20 ft^2 (0.7 to 1.9 m^2). Minimum length to width ratio 2:1	**Infiltration Trench**

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

Table A-5 Summary of Hydrologic Functions of LID Practices

Hydrologic Functions	Bioretention	Dry Well	Filter or 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.							

A-4.4 Water Quality and Pollution Prevention.

LID features may 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.

A-4.5 Design Inputs.

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

a. Detailed land cover and land-use information
b. Topographic contours, preferably at an interval that allows the flow paths to be distinguished (Generally 1 ft (.25 m) interval contours minimum, supplemented by spot elevations).
c. Soil borings; minimum of three borings, 15 ft (4.6 m) deep. These borings should reveal the 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

A-4.6 Precipitation Data.

The intensity-duration-frequency curves for the United States were recently revised and published by the NOAA and are called Atlas -14 curves. These curves are found on NOAA's Atlas 14 Precipitation Frequency Data Server at https://toolkit.climate.gov/dashboard-noaa-atlas-14-precipitation-frequency-data-server. These curves should be used when determining the precipitation depth and intensity for required duration and frequency.

Long-term rainfall records for regional weather stations can be obtained from many sources, including the NOAA's Climate Data Online webpage, at https://www.ncdc.noaa.gov/cdo-web/. Historical rainfall data are routinely published by many other agencies including the National Water and Climate Center, the United States Geological Survey, the Agriculture Research Service, etc., (NRCS NEH-4, 2019). Tables A-8 and A-9 provide a summary of rainfall analyses for 50 selected rainfall stations located in the continental United States, and 12 stations located overseas, respectively. Precipitation stations listed in Table A-8 and Table A-9 were selected based on proximity to those DoD installations anticipating major construction activity. The stations listed in Table A-8 and Table A-9 are from two types of station datasets found on the Climate Data Online webpage.

A-4.7 Types of Rainfall Datasets.

The first dataset type is daily summary data from the Global Historical Climate Network (GHCN). GHCN stations have an 11-character alpha-numeric station identification number. The GHCN observation data on NOAA's website incorporates measurement data from approximately 30 data sources from over 90,000 land-based stations worldwide including observation data from the World Meteorological Organization (WMO). Uploaded GHCN data undergoes a series of quality assurance checks.

The second dataset type is Global Surface Summary of the Day (GSOD) which is derived from the Integrated Surface Hourly (ISH) dataset. The ISH dataset includes data from the United States Air Force (USAF) Climatology Center. Data from approximately 9,000 stations are available online. GSOD stations are identified in Table A-8 and Table A-9 by an eleven-digit number.

More information about the GHCN and GSOD datasets can be found on NOAA's website at https://www.ncdc.noaa.gov/cdo-web/datasets.

A-4.7.1 GHCN Station Download Procedures.

The GHCN Station data download procedures involve several steps and depends on individual's knowledge of station and location. For clarity, these steps are listed below under separate headings.

A-4.7.1.1 GHCN Station Search.

When searching for GHCN stations near a specific Installation and the GHCN station name or ID number is not known, the user should navigate to NOAA's Daily Observational Data map page at https://www.ncei.noaa.gov/maps/daily/. By default, the GHCN Daily layer is checked in the upper left. The GHCN Daily layer displays weather station locations for the contiguous United States as well as Alaska and Hawaii as shown in Figure A-1. For GHCN observation data outside of the United States, selecting the WMO layer on the map page as shown in Figure A-2 displays GHCN station locations across the globe. The user may elect to show all GHCN stations including historical stations, or just the active stations using the settings icon beside the layer name for both the GHCN Daily and the WMO layers. The station selection and precipitation data download procedures described below are applicable to both GHCN Daily and WMO layers.

Figure A-1 NOAA's Daily Observational Map Page – GHCN Daily Layer

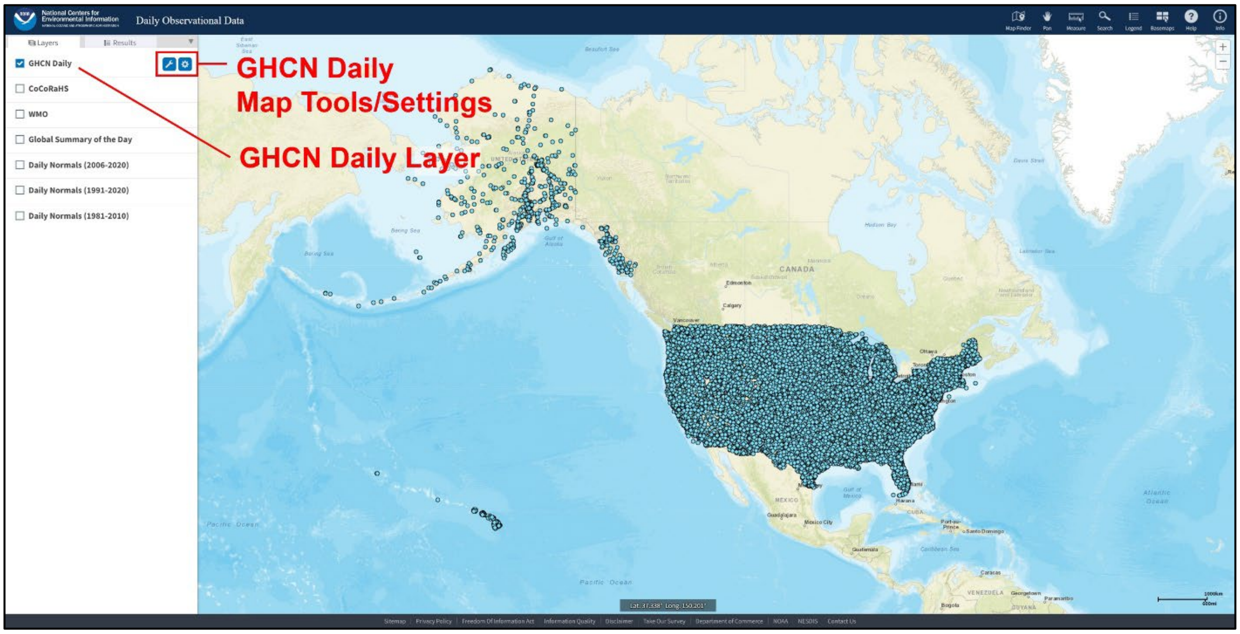
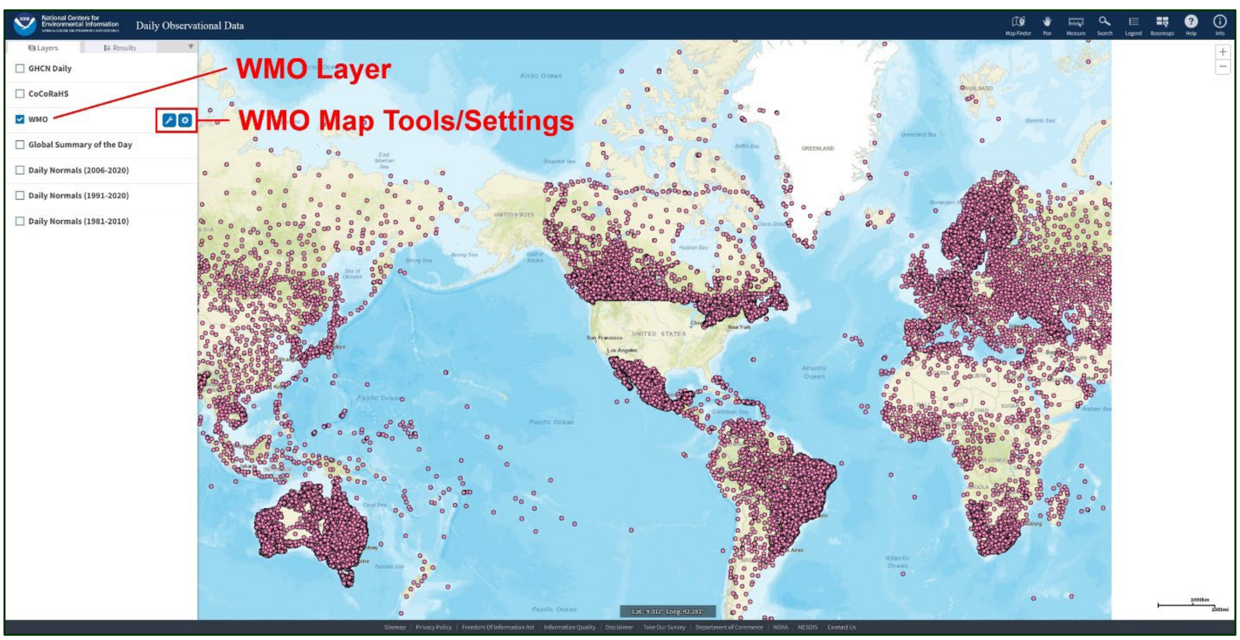


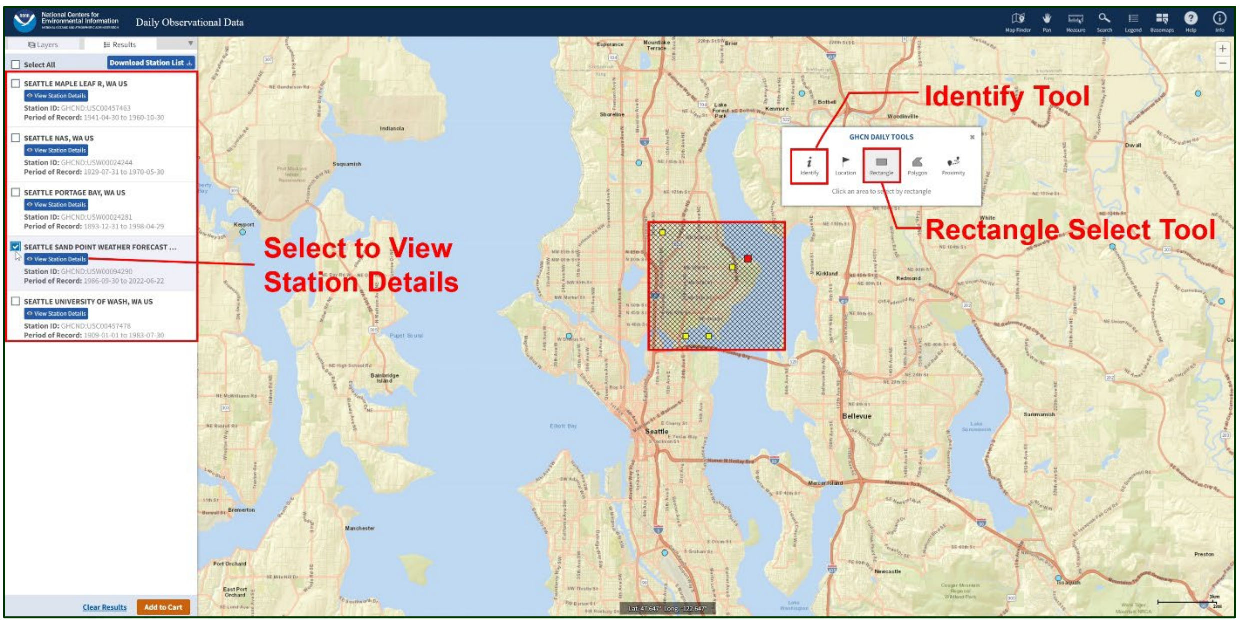
Figure A-2 NOAA's Daily Observational Map Page – WMO Layer



A-4.7.1.2 GHCN Specific Station Search.

From the Daily Observational Data map pages, users may zoom in and pan to a specific location, or search for a location or facility using the tools in the upper right of the page. Clicking on the Map Tools icon beside the layer name in the upper left allows the user to select an individual station using the identify tool, or multiple stations using the rectangle select tool to draw a box around multiple stations as shown in Figure A-3. Station information for the selected station(s) will appear in the results tab to the left and includes the station name, station ID, and period of record.

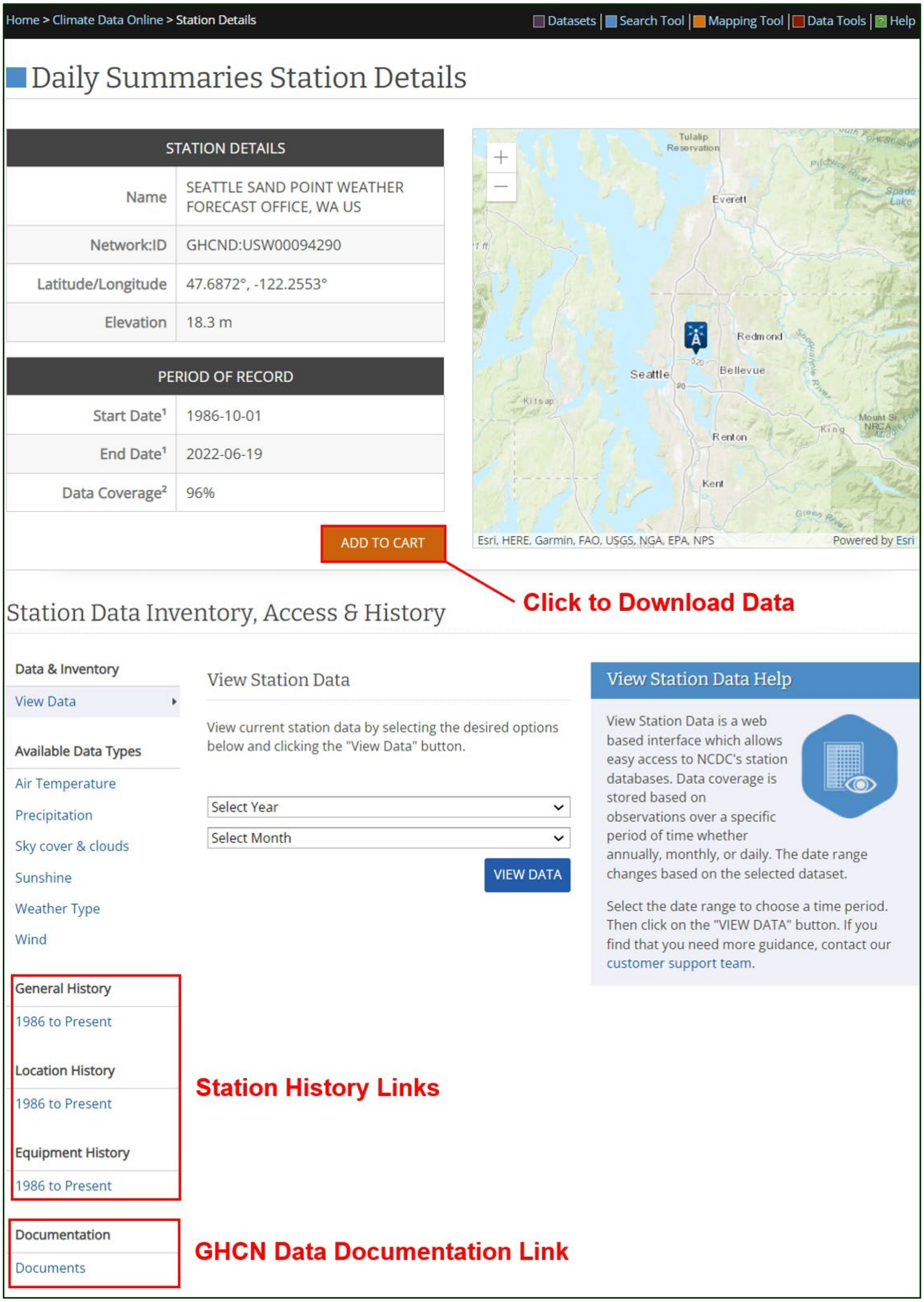
Figure A-3 GHCN Station Selection



A-4.7.1.3 Viewing GHCN Station Details.

Clicking on “View Station Details” below the station name will show additional information about the station as shown in Figure A-4. This includes Latitude/Longitude coordinates, station elevation, and the data coverage for the period of record as a percentage. Users should note that the data coverage percentage is for the most complete set of measurements at the station and may or may not reflect the precipitation data, but instead may refer to other observational data such as temperature or barometric pressure instead. The Station Details page will also have links to the station’s history if available and a link to GHCN Daily summary documentation detailing data formats, observation values, and a list of measurement, quality, and source flags for GHCN data.

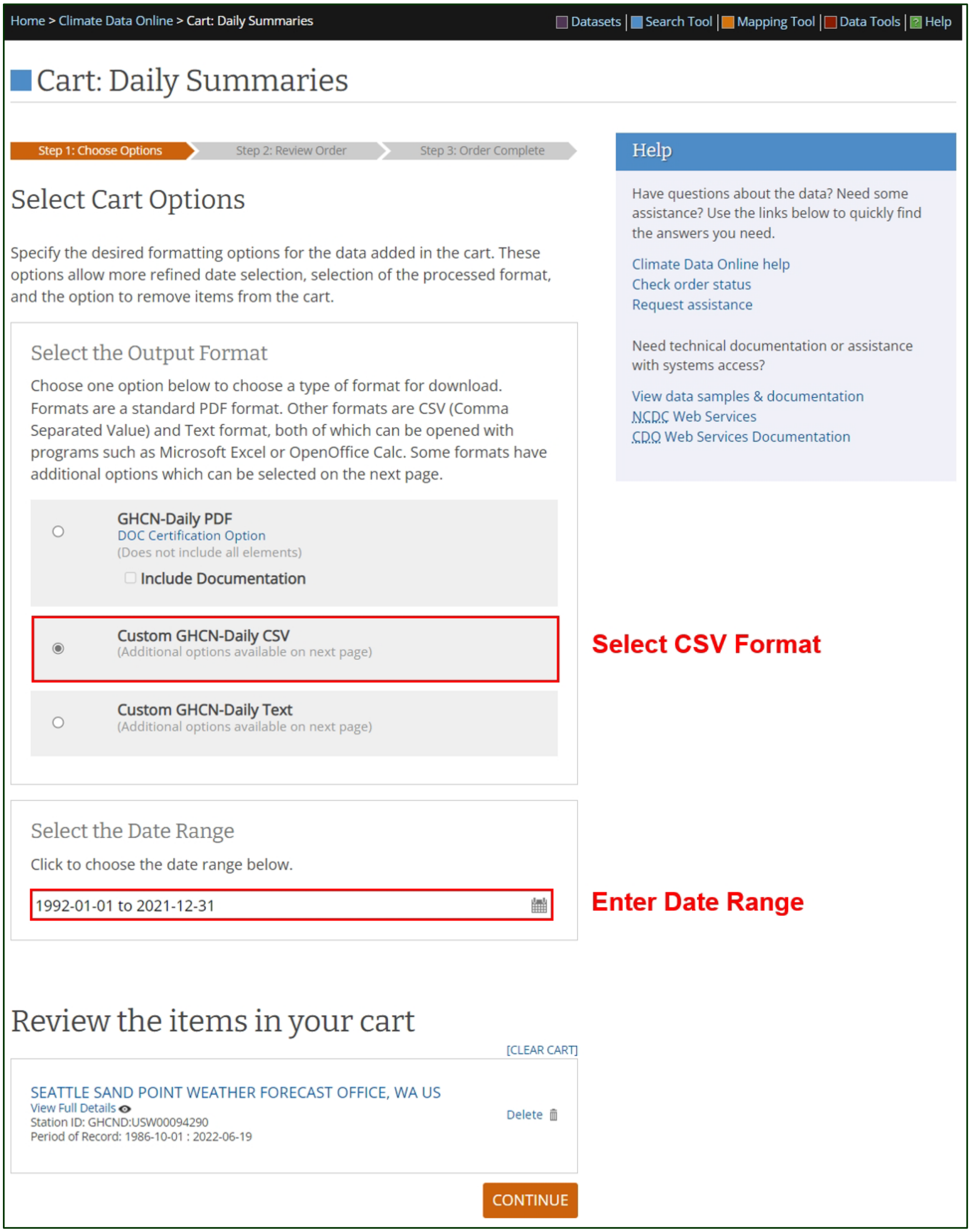
Figure A-4 Station Details



A-4.7.1.4 Adding GHCN Data to Cart.

To download the precipitation data for a selected station, click the “Add to Cart” button found on the Station Details page, or at the bottom of the Daily Observational Data map page. The station will then be added to the user’s cart. After clicking on the cart button at the top right of the page, users must then select the format and the date range of the data to be downloaded from the cart page as shown in Figure A-5. The preferred output format for the precipitation analysis is “Custom GHCN-Daily CSV”.

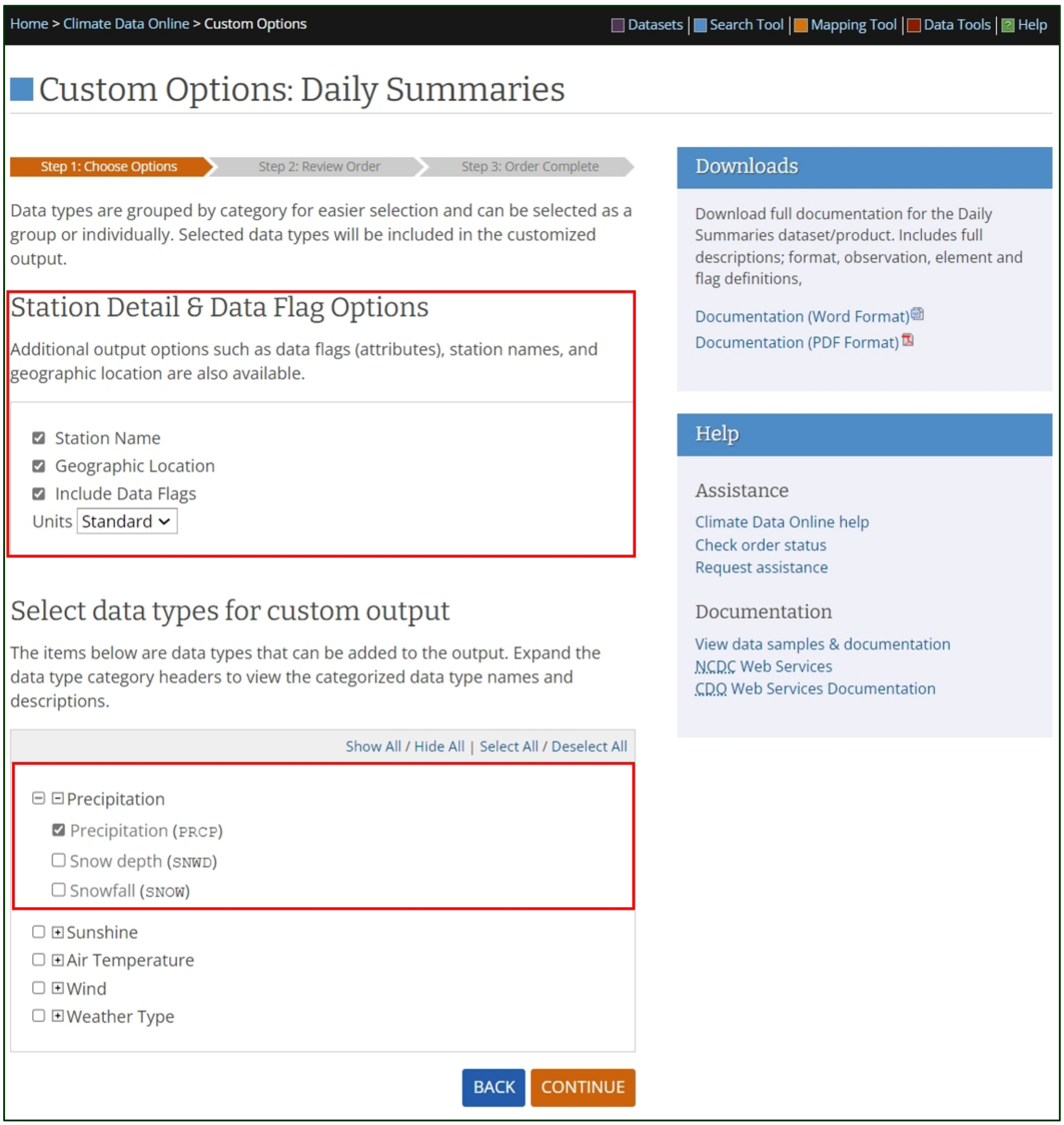
Figure A-5 Cart Options



A-4.7.1.5 GHCN Data Cart Options.

After selecting the format and date range, users should select "Continue" at the bottom of the page to select data options as well as station details to be included with the data. Figure A-6 shows the additional station details that may be included with the data download. If selected, the station name, geographic location and data flags will be included with the precipitation data. Geographic location is the station's latitude and longitude in decimal degrees. Information about the types of data flags can be found through the documentation link under "Downloads" beside the station detail and flag options.

Figure A-6 Data Download Options



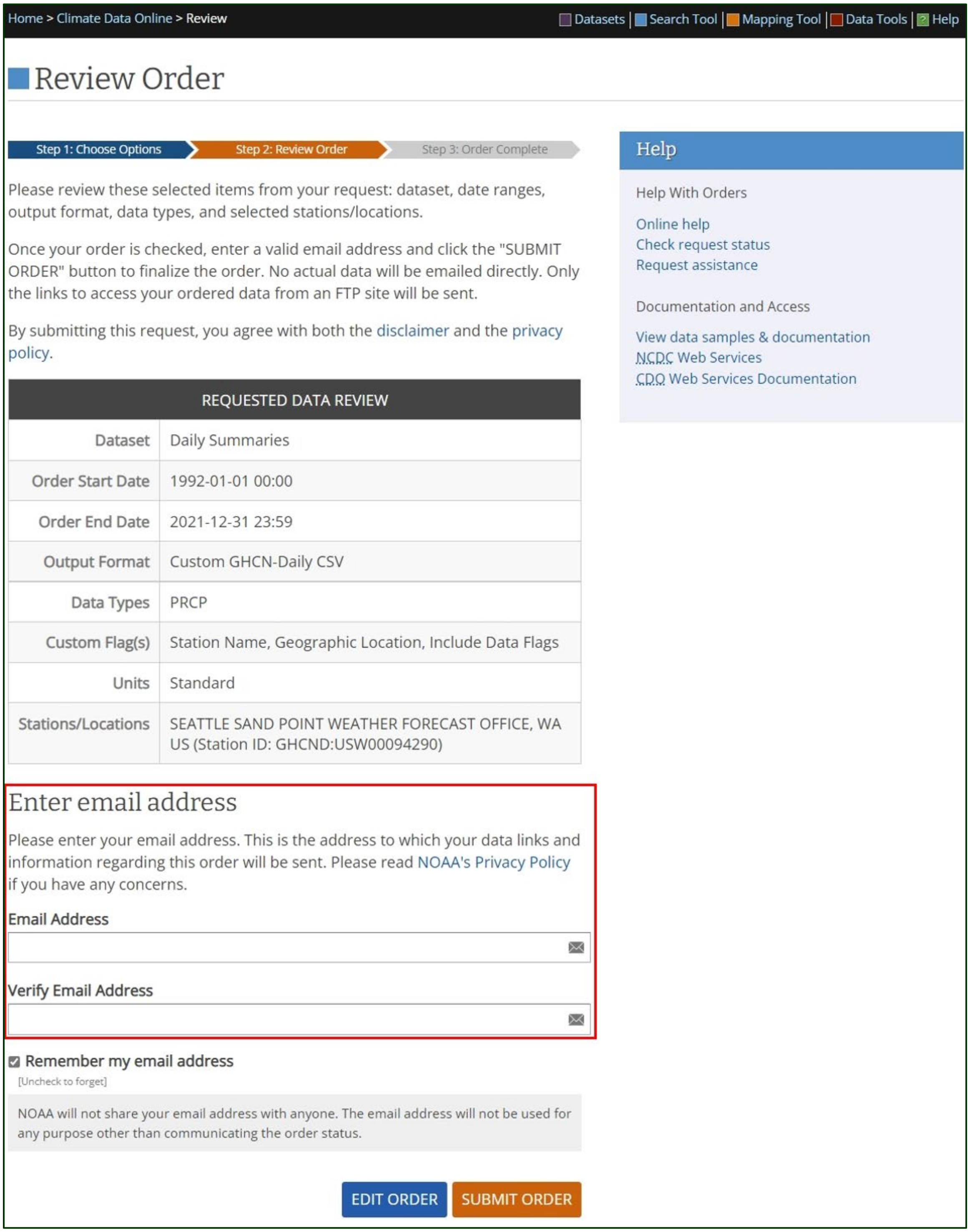
A-4.7.1.6 GHCN Data Units of Measure.

The default units of measure are “Standard” but may be changed to metric units under the Station Detail and Data Flag Options. The standard unit for precipitation data is inches measured to the hundredths of an inch. Users should note that the units of measure are not listed or shown with the downloaded precipitation data. Snow depth and snowfall measurements are not required. Precipitation measurements are for total precipitation during the recording period and include any snowfall during that period.

A-4.7.1.7 Review of GHCN Data and Submit Order.

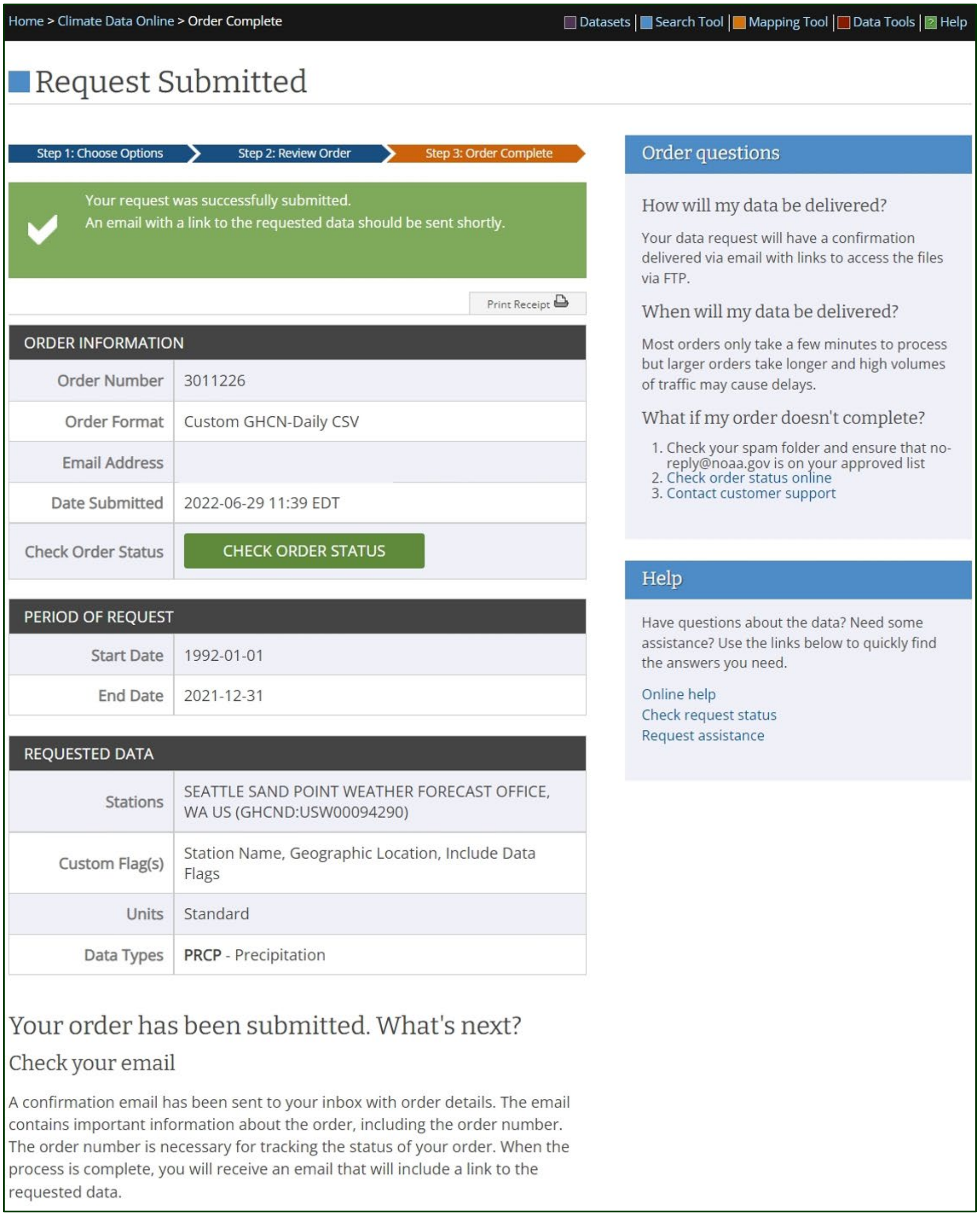
Once the station detail and data options have been set, clicking “continue” at the bottom of the page will take the user to the last page, shown in Figure A-7, before placing the order. Here the user can review the data request. The user must then enter and confirm their email address. The last step is to click “Submit Order.”

Figure A-7 Review of Order



Once the order has been submitted the user will see the order confirmation page, shown in Figure A-8, summarizing the data request. The user will receive an email from the National Centers for Environmental Information (NCEI) at noreply@noaa.gov confirming the data request, followed by an email with a download link for the data. The time between placing an order and receiving the data download link will vary but should not take more than a few minutes.

Figure A-8 Order Confirmation



A-4.7.2 GSOD Station Download Procedures.

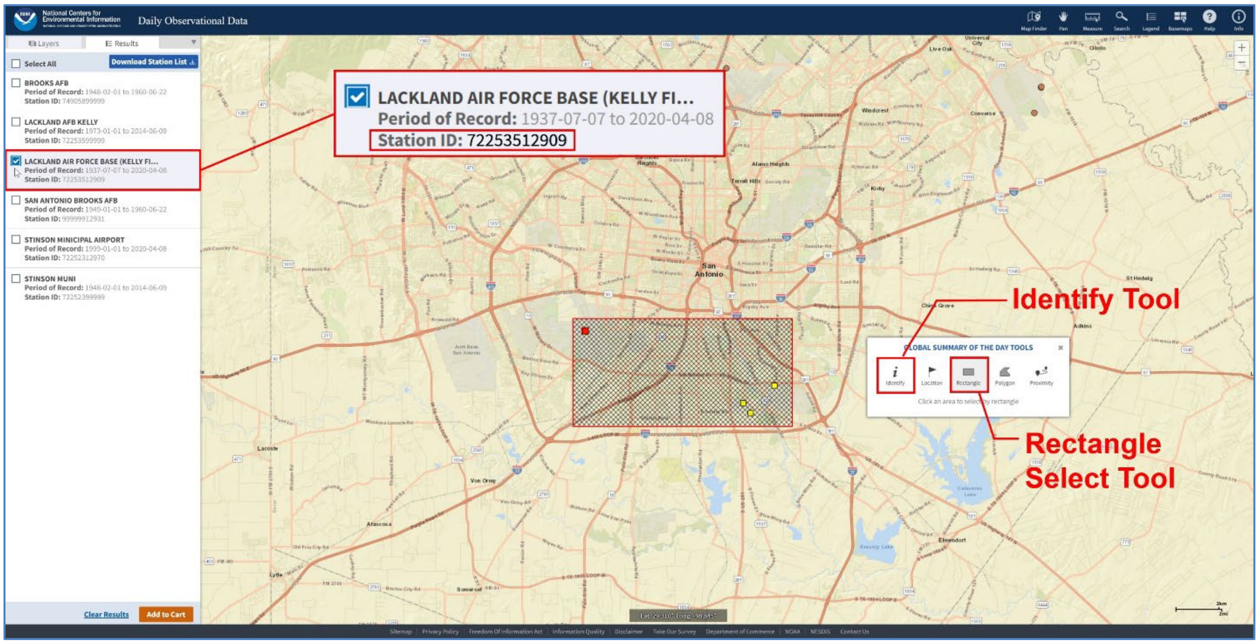
To download GSOD station data go to NOAA's Daily Observational Data map page at https://www.ncei.noaa.gov/maps/daily/ and select the Global Summary of the Day layer as shown in Figure A-9 to display GSOD station locations across the globe. The user may elect to show all GSOD stations including historical stations, or just the active stations using the settings icon beside the layer name.

Figure A-9 NOAA's Daily Observational Map Page – GSOD Layer

A-4.7.2.1 GSOD Specific Station Search.

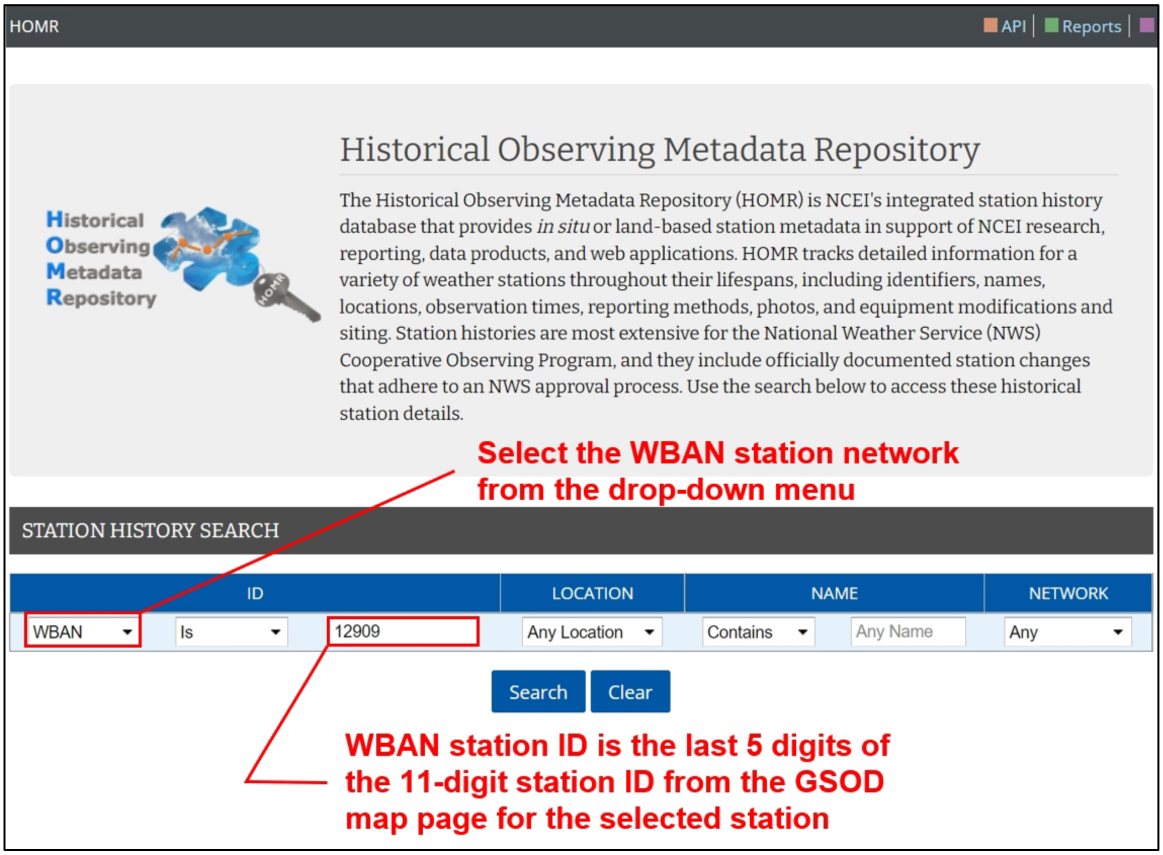
From the Daily Observational Data map page, users may zoom in and pan to a specific location, or search for a location or facility using the tools in the upper right of the page. Clicking on the Map Tools icon beside the layer name in the upper left allows the user to select an individual station using the identify tool, or multiple stations using the rectangle tool to draw a box around multiple stations as shown in Figure A-10. Station information for the selected station(s) will appear in the results tab to the left and includes the station name, station ID, and period of record.

Figure A-10 NOAA's Daily Observational Map Page



Unlike GHCN and WMO stations described in Section A-4.7.1.3, individual station details as shown in Figure A-4 are not linked to selected stations on the GSOD map page. Users must download and examine the data from a selected station to determine its completeness for a given period of record. Station history, if available, can be found on the NOAA website. The most efficient way to search for a GSOD station's history is from the Historic Observing Metadata Repository (HOMR) webpage at: https://www.ncei.noaa.gov/access/homr/;jsessionid=6C5634D8611E5A0E4F7FD2152BC1CE75. From the HOMR webpage, select WBAN from the drop-down menu for the network type as shown in Figure A-11. The WBAN station ID is the last five digits of the 11-digit station ID shown for a selected station on the GSOD map page.

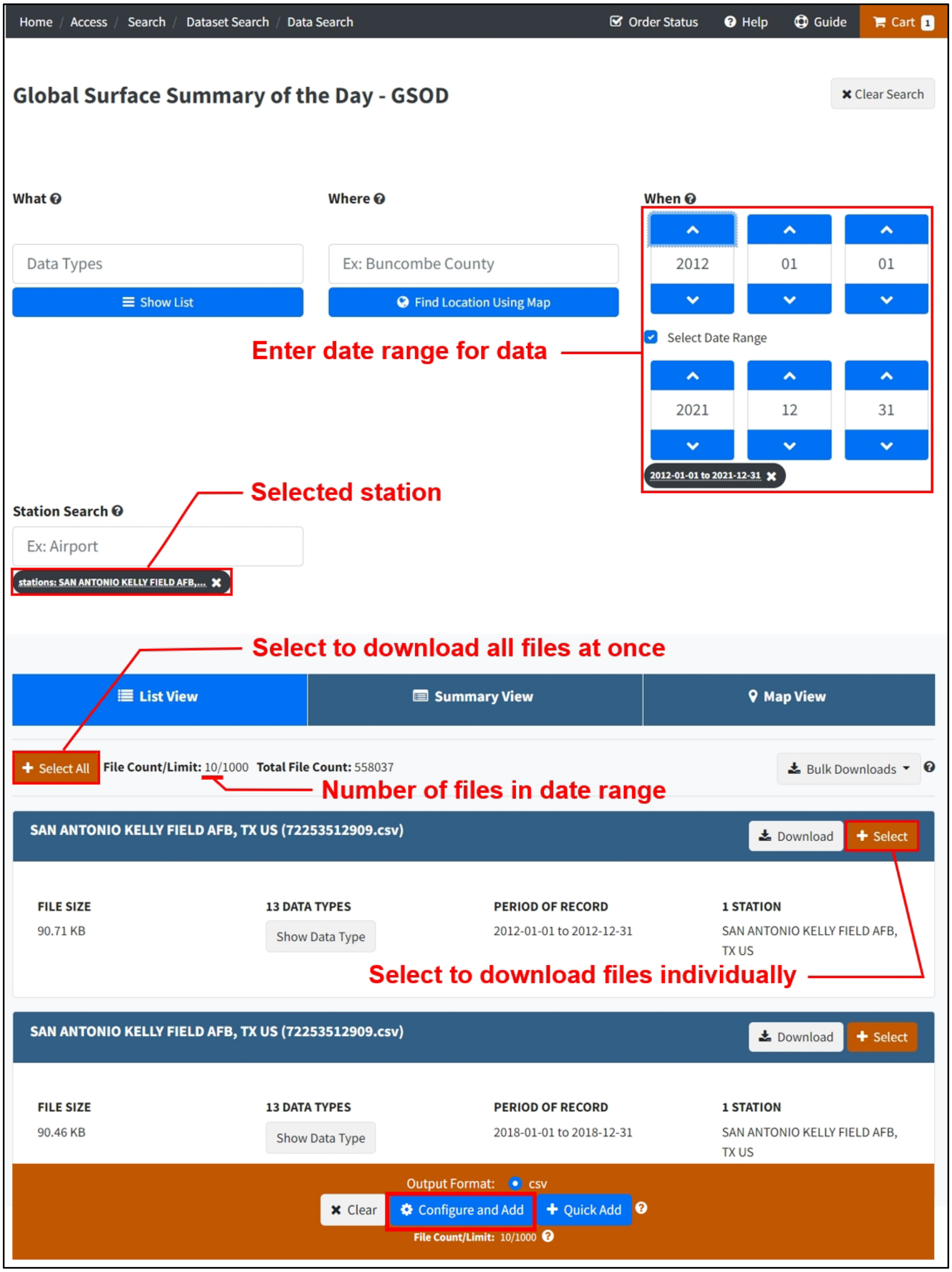
Figure A-11 GSOD Station History Search



A-4.7.2.2 Adding GSOD Data to Cart.

To download GSOD data after identifying a suitable station for analysis, select the station on the GSOD map page as shown in Figure A-10 and click “Add to Cart”. This will open a new webpage for the selected station as shown in Figure A-12 below. The selected station will be shown on the left side of the page below the station search bar.

Figure A-12 GSOD Data Selection



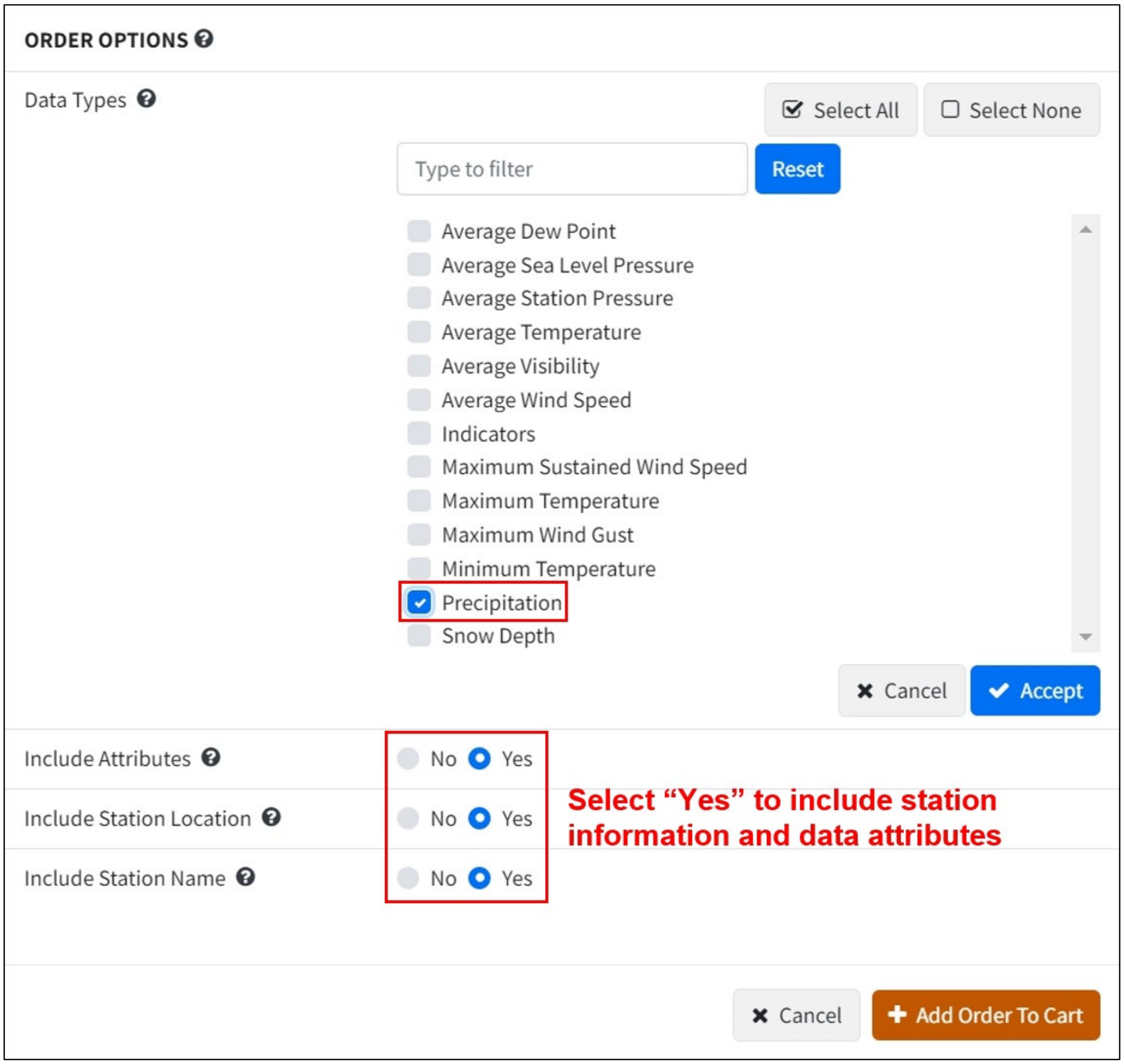
Below the station name, the number of files for the station will be displayed, with each file containing data for one calendar year. The default output file format for GSOD data is a comma separated values (.CSV) file. Before the user specifies a date range, the number of files for the station's entire period of record will be shown. Once a date range has been entered by the user, the number of files in the specified date range will be shown. The number of files should equal the number of years specified in the date range. When the number of files is fewer than years in the date range it indicates that data is missing for one or more years. The individual files for each year in the selected date range will be displayed at the bottom of the page and may continue on other pages depending on the length of the selected date range. Users can scroll down and look at the individual files to see which years are missing.

A-4.7.2.3 Options When Selecting GSOD Data.

Users may select and download the files individually, however the most efficient way to download the data is to click the “Select All” button on the left side of the page below the station name. This will select all the files for the specified date range and combine it into a single file for downloading. After the “Select All” button has been clicked, the user will see three options at the bottom of the page. The “Clear” button will unselect the files chosen for downloading but it does not clear the date range in the upper right of the page specified by the user. The “Quick Add” button automatically selects all data types collected by the station to include in the data download for each year in the date range and sends the request to the user's cart. However, this will include unneeded data such as wind speed, barometric pressure, etc. and will not include station information or data indicators with the data download.

Instead, users should select the “Configure and Add” button which lets them select or unselect the data types to be downloaded. More importantly, the station name and location, as well as data attributes, are not included with the data unless those items are selected. Figure A-13 below shows the order options for the GSOD data. Precipitation data attributes are listed in the GSOD data documentation and can be found at the following link https://www.ncei.noaa.gov/data/global-summary-of-the-day/doc/readme.txt. GSOD precipitation data is measured in inches to the nearest hundredth of an inch as stated in the GSOD data documentation linked above. Users should note that the units are not mentioned or shown on the download pages and are not listed with the downloaded data.

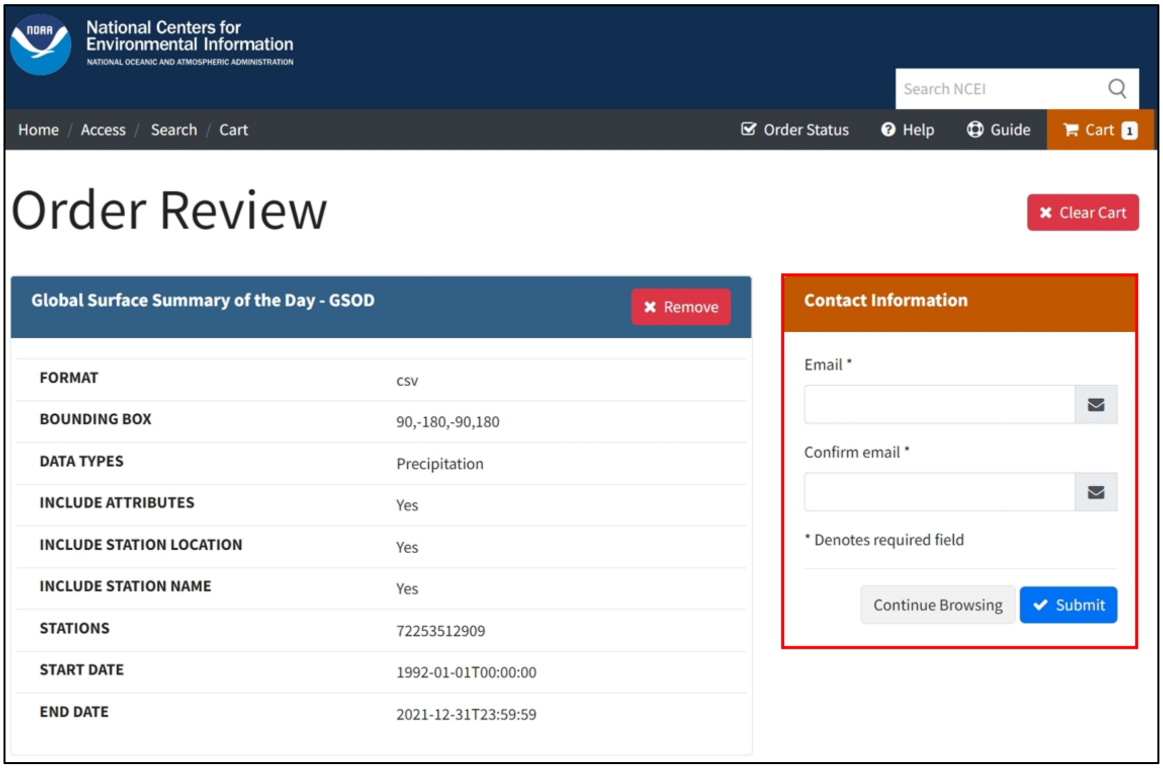
Figure A-13 GSOD Data – Order Options



A-4.7.2.4 Review of GSOD Data and Submit Order.

Once the data options have been selected, select "Add Order to Cart". This will take the user to the order review page shown in Figure A-14. After reviewing the order, the user must input and confirm their password before hitting the submit button to complete the data request.

Figure A-14 Order Review



After submitting the data request the user will receive an email from the NCEI at noreply@noaa.gov confirming the data request, followed by an email with a download link for the data. The time between placing an order and receiving the data link will vary but should not take more than a few minutes.

A-4.8 Procedure to Compute 95th Percentile Rainfall Event.

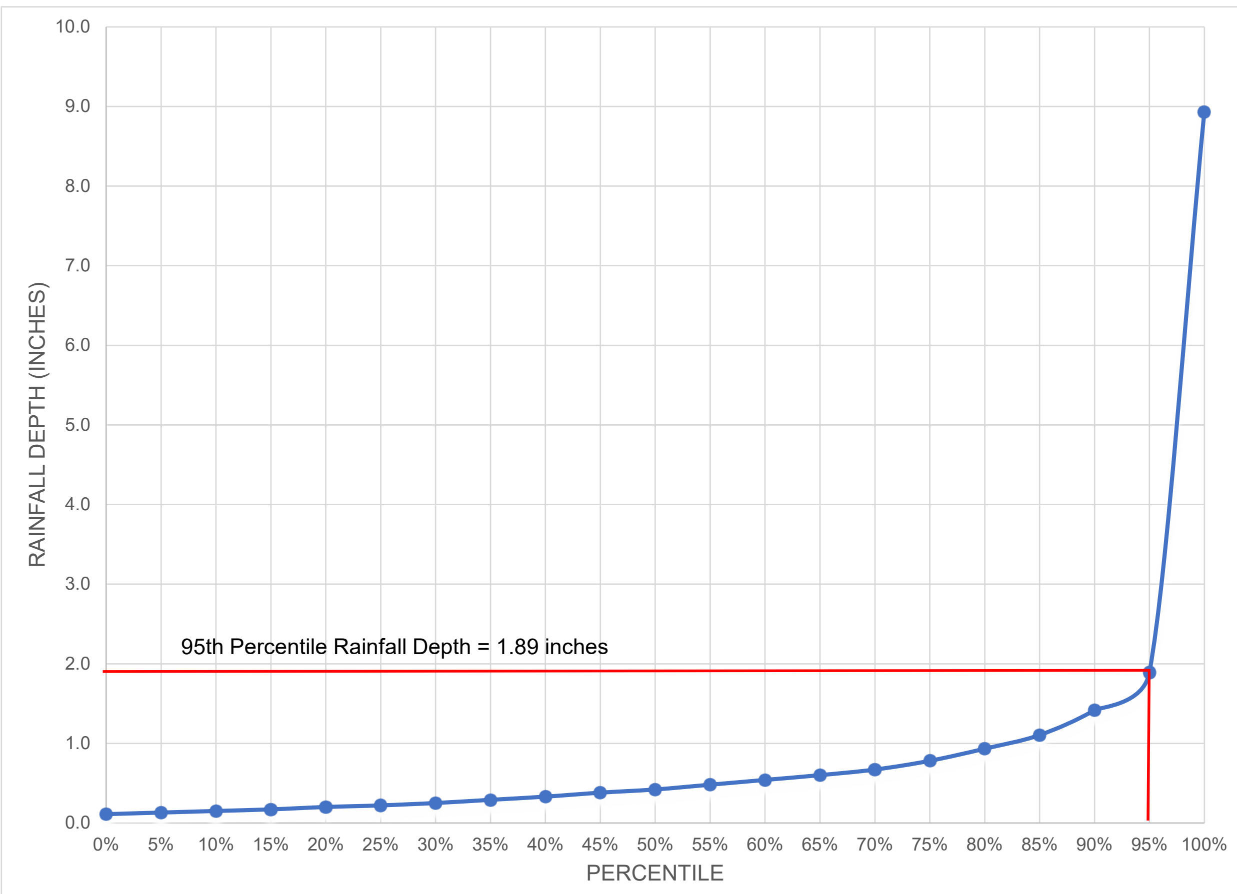
The design storm is the 95th percentile rainfall, described in Section 2-1.2. The step-by-step procedure for calculating the 95th percentile rainfall depth, using a spreadsheet, is summarized below:

1. Obtain a long-term rainfall record, in comma separated value or ".CSV" format, as detailed in Sections A-4.7.1 and A-4.7.2. These are daily or 24-hour rainfall records over the period.
2. Import the data into a spreadsheet. The daily precipitation data downloaded is typically arranged in a single column. If the original data set has multiple columns of daily precipitation data, then the user must rearrange the data into a single column.
3. Review the data for any anomalies or erroneous data points, measurement error flags (indicated in the precipitation data attributes) and remove this data from the list.
4. Remove data for small rainfall events that are 0.1 inch or less (≤ 0.1 inch) from the data set. These rainfall events (≤ 0.1 inch) are to be deleted since

they do not typically cause runoff and can potentially cause calculation of 95th percentile of runoff-causing rainfall event to be inaccurate.

5. It is preferable to sort the rainfall data (> 0.1 inch) from smallest value to highest value. The 95th percentile rainfall depth is calculated using the spreadsheet function PERCENTILE and specifying the range and percentile value (in this case it is 95th percentile and the value to be used in the spreadsheet function is 0.95). If MS Excel is used, the function attributes are [=PERCENTILE (precipitation data range, 0.95)]. Alternatively, the user can apply available statistical packages to determine the same.
6. A typical plot of rainfall depth versus percentile is shown in Figure A-15.

Figure A-15 Plot of Typical Rainfall Depth vs Percentile



A-5 LID DESIGN.

A-5.1 Introduction.

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

Standard BMPs may be used in conjunction with LID features, depending on site conditions, to handle the peak rate of discharge for flood control. Follow published design criteria relative to achieving, maintaining, and emphasizing a positive exterior visual environment applicable to military installations.

A-5.2 Hydrologic Analysis.

Table A-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, the required design storage of LID features is calculated using Equation 3-2 and Equation 3-3 discussed in Chapter 3.

Runoff curve numbers are determined by land cover type, hydrologic condition, antecedent runoff condition (ARC), and hydrologic soil group (HSG). Curve numbers for various land covers based on an average ARC can be found in the TR-55 manual.

Table A-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

A-5.2.1 Mimic Existing (Pre-Development) Hydrologic Conditions.

The preceding table shows 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.

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). As a result, the post-development hydrologic conditions are worsened, and in many cases, the damage becomes irreversible. 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 runoff in bio-infiltration practices (such as shown by Figure A-16 below), structural solutions, reuse, or footprint reduction for a design storm event. The pre-development condition is the typical condition of the project site just prior to the project. Apart from the potential increase in impervious area, the primary impacts due to man-made development are soil compaction, and increased efficiency of drainage patterns. The two land development conditions of concern are:

- Pre-Development Condition
- Post-Development Condition

Figure A-16 Typical Bio-infiltration 'Rain Garden'

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

A-5.2.2 Time of Concentration for Pre- and Post-Development Conditions.

In order to mimic natural hydrologic patterns, the site designer should provide features that limit the rate at which runoff leaves the site. 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 T_c. Manage T_c by utilizing 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 T_c 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 T_c, 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 T_c close to pre-development conditions is often an iterative process and requires analyzing different combinations of the appropriate techniques.

A-5.2.3 Stormwater Flow Segments.

TR-55 Curve Number Methodology is well documented and is used widely in engineering practice to determine the T_c. The method presumes that runoff from rainfall moves through a watershed as sheet flow, shallow concentrated flow, pipe flow, channel flow, or some combination of these. 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 T_c are detailed in the TR-55 manual. The use of TR-55 is recommended for calculating T_c. Other methodologies in accordance with applicable state or local stormwater regulations and based on site specific conditions may also be used.

A-5.2.4 LID Design Storm Event.

Storm events are a complex natural phenomenon, and methods to predict and control their impacts rely upon empirical and mathematical modeling of the event. In previous versions of this document, three principal approaches were analyzed in selecting the 95th percentile design storm event – (a) Prince George's County Methodology; (b) EPA Methodology; and (c) First-Flush Water Quality Volume. Over the years, the EPA Methodology of using the 95th percentile rainfall depth as the design storm event for design of LID features has been widely accepted and is adopted herein. For details pertaining to this refer to Section A-4.8 or EPA 841-B-09-001 for the EPA Methodology for calculating the 95th percentile rainfall event.

A-5.2.4.1 Design Storage of LID Features.

For the 95th percentile 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. Typically, 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 volume of LID features would be the difference in total volume of stormwater runoff generated between pre- and post-development conditions.

Table A-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 features to handle all of the net increases in stormwater runoff generated from a parcel being developed (using Equation 3-3).

A-5.3 Design Objective and Pre-Development Hydrology.

The LID Storage Volume assures the most practical solution and provides 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 or 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 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. Conventional SWM facilities may be needed in addition to LID features to meet with state/local stormwater requirements.

A-5.4 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.

It is important to note that 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 water supply or irrigation, the designer must consider contamination issues.

A-5.4.1 Develop LID Control Strategies.

Use hydrology as a design element. 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 those structural controls be employed in conjunction with LID techniques.

b. Determine LID volumes using 95th percentile design storm and 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 LID IMPs. If site planning is not sufficient to meet the site's LID objectives, additional hydrologic control needs may be addressed using LID features. After LID features are selected for the site, a second-level hydrologic evaluation can be conducted that combines the LID 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 features 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 LID IMPs, selection 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 groundwater table limit the use of LID features, 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 using LID features 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 TR-55 method. 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*)

A-5.4.2 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 (that is, 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 subsurface detention facilities.

A-5.4.3 Develop Landscaping Plans to Maximize Efficiency of LID Features and Reduce Maintenance.

1. Hardy, native plantings should be used.
2. 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 in soils with a low

permeability rate (hydrologic soil groups C and D) of 0.05 inches/hour (1.3 mm/hr), the depth of infiltration basin = 72 hrs x 0.05 in/hr (1.3 mm/hr) = 3.6 inches (93.6 mm). Conservatively, the designer may opt to restrict this depth to 3.0 inches (75 mm) and provide a larger area to satisfy the LID volume requirement. The designer may also want to incorporate other LID practices, such as footprint reduction of impervious surfaces and permeable pavers, in conjunction with sizing of bio-infiltration facilities. (Verify all actual design parameters with state BMP manual.)

3. 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.
4. 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 should be controlled to the sum total of assimilating capacity of bio-infiltration practices provided downstream. For example, if a downstream bioretention facility is of size 600 sq.ft, in soil type C with an infiltration rate of 0.15 in/hr (3.8 mm/hr), then the cisterns or rain barrels provided on site will discharge into bioretention facility at a rate = 0.15 in/hr * 600 sq.ft /(12 in/ft * 3600 sec/hr) = 0.0021 cfs.
5. LID features should 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 (minimum building offsets should comply with UFC 4-010-01), and runoff from parking lots will be held in traffic islands and along the perimeter.
6. Plant bioretention facilities with native vegetation; refer to Landscape Architect, local plant specialists, or horticulturists.
7. Design positive overflow system to capture excess rainfall-runoff.

A-5.4.4 Operation and Maintenance Procedures.

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

- Keep LID features and flow paths clear of debris and trash.
- Use native, drought-tolerant plantings that can tolerate periods of saturation. Vegetation should be watered regularly during dry periods. Use special care in selecting plants in areas of tidal influence.

- Consider impact on plants by road salts.
- Grassed areas should be mowed regularly using a longer length cut.
- Plantings should be pruned as needed.
- Deep raking and tilling of depression storage should be done on a yearly basis or as indicated.

A-5.5 Gaining Acceptance of LID Options.

A higher level of communication on LID projects should be maintained 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 of all new facilities may be required by the local Environmental Office.

Table A-7 Example Evaluations of Increased Post-Development Runoff Depth

Existing Site Conditions	Existing Site Composite CN	Design Storm Event 95th Percentile Rainfall EPA Methodology (inches)	Developed Conditions[2] Composite CN	Depth of Increase in Stormwater Runoff (inches)
Woods - good condition, HSG B	55	1.89[a]	76.5	0.37
Woods - poor condition, HSG D	83	1.38[b]	90.58	0.31
Pasture, grasslands - good condition, HSG B	61	1.89[a]	79.5	0.42
Pasture, grasslands - fair condition, HSG C	79	1.38[b]	88.5	0.31
Open space - lawns, park in fair condition, HSG B	69	1.89[a]	83.5	0.46
Residential districts - 1/3 acre, 30% impervious, HSG B	72	1.89[a]	85	0.47
Residential districts - 1/3 acre, 30% impervious, HSG C	81	1.38[b]	89.5	0.31
Industrial area - 72% impervious, HSG B	88	1.89[a]	93	0.34
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 A-8 Summary of Rainfall Analysis (1992 - 2021) – US Installations

	Rainfall Station Name	State	Station ID: GHCND (or GSOD)	Applicable DoDAAC[1] Numbers												Annual Rainfall Depth[2] (inches)	95th Percentile[3] (inches)	Rainy Days[4] (>0.1")	Years of Available Record (1992-2021)
				DoDAAC	(mi)	DoDAAC	(mi)	DoDAAC	(mi)	DoDAAC	(mi)	DoDAAC	(mi)	DoDAAC	(mi)				
1	YUMA WSO AP	Arizona	USW00003145	M62974	1											3.27	1.32	8	27
2	EL CENTRO 2 SSW	California	USC00042713	N60042	6											2.50	0.91	6	25
3	HETCH HETCHY	California	USC00043939	M64495	36											37.81	1.98	53	25
4	LEEMORE REEVES NAS	California	USW00023110	N44259	27											7.07	0.80	19	27
5	LOS ANGELES WSO AIRPORT	California	USW00023174	N61065	27	N69232	52	N67399	80							12.26	1.56	20	30
6	MONTEREY NWSFO	California	USC00045802	N61014	5											16.90	1.20	35	22
7	SAN DIEGO WSO AIRPORT	California	USW00023188	N62473	1	N00246	3	N63406	5	N00245	6	M00681	30			9.59	1.31	19	30
8	TRAVIS FIELD AFB	California	USW00023202	FA4427	1	FA4686	88									21.43	1.44	38	30
9	TWENTY NINE PALMS	California	69015093121	N67399	14	N68936	126	FA9300	102							2.81	1.16	6	23
10	VICTORVILLE PUMP PLANT	California	USC00049325	N3594A	60	M62204	30	FA9300	49	N68936	80					5.32	1.17	12	26
11	COLORADO SPRINGS WSO AP	Colorado	USW00093037	FA2550	0	FA2509	1									15.78	1.14	34	30
12	GROTON NEW LONDON AIRPORT	Connecticut	USW00014707	N44210	29											37.64	1.61	62	22
13	JACKSONVILLE WSO AP	Florida	USW00013889	N57061	19	N68931	18	N68248	25							52.64	2.03	74	30
14	KEY WEST WSO AIRPORT	Florida	USW00012836	N44222	2											39.76	1.95	59	30
15	MIAMI WSCMO AIRPORT	Florida	USW00012839	N30931	2.5	FA6648	23									67.04	2.33	87	30
16	PANAMA CITY 5 NE	Florida	USC00086842	N44223	9.5	FA4819	18	FA8651	65	N00204	97					60.65	2.30	73	26
17	TAMPA WSO AIRPORT	Florida	USW00012842	FA4814	8											49.65	2.18	67	30
18	ALBANY SW GEORGIA REGIONAL AP	Georgia	72216013869	M67004	9	FA4830	85									47.49	1.97	67	25
19	SAVANNAH WSO AIRPORT	Georgia	USW00003822	M00263	32	N44227	35									47.44	1.95	68	30
20	HONOLULU WSFO AP 703	Hawaii	USW00022521	N62813	1	N62742	3	N00318	10							16.37	2.11	25	30
21	LIHUE AIRPORT	Hawaii	USW00022536	N61064	1											36.03	1.90	61	30
22	BELLEVILLE SCOTT AFB	Illinois	72433813802	FA4407	1											43.19	1.65	70	30
23	CHICAGO OHARE WSO AP	Illinois	USW00094846	N65113	23											37.69	1.46	69	30
24	EVANSVILLE WSO AP	Indiana	USW00093817	N61018	85											48.27	1.81	74	30
25	MANHATTAN REGIONAL AIRPORT	Kansas	72455503936	SZ3586	10											33.26	1.79	53	15
26	FORT CAMPBELL AIRFIELD	Kentucky	74671013806	W34GL1	10											46.56	1.76	77	29
27	NEW ORLEANS WSMO AIRPORT	Louisiana	USW00012916	N44218	9											62.75	2.54	75	30
28	SHREVEPORT AP	Louisiana	USW00013957	FA4608	16											50.20	2.25	64	30

Table A-8 Summary of Rainfall Analysis (1992 - 2021) – US Installations (Cont'd.)

	Rainfall Station Name	State	Station ID: GHCND (or GSOD)	Applicable DoDAAC[1] Numbers												Annual Rainfall Depth[2] (inches)	95th Percentile[3] (inches)	Rainy Days[4] (>0.1")	Years of Available Record (1992-2021)
				DoDAAC	(mi)	DoDAAC	(mi)	DoDAAC	(mi)	DoDAAC	(mi)	DoDAAC	(mi)	DoDAAC	(mi)				
29	PORTLAND WSFO AP	Maine	USW00014764	N44214	24											47.68	1.65	78	30
30	BALTIMORE WSO ARPT	Maryland	USW00093721	N44201	15	N0417A	14									45.33	1.73	73	30
31	PATUXENT RIVER NAS	Maryland	USW00013721	N00019	0	N47370	33									45.47	1.74	70	27
32	GULFPORT BILOXI AIRPORT	Mississippi	USW00093874	N62604	4	FA3010	11									61.88	2.65	73	23
33	ALBUQUERQUE WSFO AIRPORT	New Mexico	USW00023050	FA7046	10											8.64	0.80	23	30
34	NIAGARA AIR RESERVE STATION	New York	USW00014733	FA6670	1											40.64	1.14	89	30
35	MOREHEAD CITY	North Carolina	USC00315830	M00146	16	M67001	34									60.52	2.32	78	29
36	WRIGHT PATTERSON AFB	Ohio	74570013840	FA8003	1											42.46	1.38	81	30
37	HARRISBURG CAPITAL CITY	Pennsylvania	USW00014751	N32414	9											41.16	1.47	73	21
38	PHILADELPHIA WSO AP	Pennsylvania	USW00013739	N00140	3											44.34	1.68	71	30
39	NEWPORT STATE AIRPORT	Rhode Island	USW00014787	N44211	2	N32411	2									42.04	1.60	70	23
40	CHARLESTON WSO AIRPORT	South Carolina	USW00013880	FA4418	1											52.78	2.08	72	30
41	ELLSWORTH AFB	South Dakota	72662524006	SZ3108	1											17.54	1.18	39	21
42	MEMPHIS WSFO	Tennessee	USW00013893	N44221	18											54.73	2.06	73	30
43	CORPUS CHRISTI WSO AP	Texas	USW00012924	N45974	27	N44215	10	N00216	17							31.69	2.52	39	30
44	LACKLAND AFB	Texas	72253512909	FA7037	1	FA8900	10	FA3002	24							28.91	2.13	41	24
45	NORFOLK WSO AIRPORT	Virginia	USW00013737	N62470	6	FA4521	20									48.99	1.89	72	30
46	WASHINGTON NATL WSO AP	Virginia	USW00013743	N00025	3	N61142	2	N33355	10	N44200	22	N48429	11	MMQQ50	25	42.27	1.61	71	30
47	WILLIAMSBURG 2 N	Virginia	USC00449151	N69212	10											51.50	1.77	79	30
48	SEATTLE TACOMA AP WBAS	Washington	USW00024233	N44255	17											39.55	1.08	90	30
49	SEATTLE SAND POINT	Washington	USW00094290	N68436	29	N68967	31									36.87	0.95	90	26
50	SPARTA	Wisconsin	USC00477997	W911SA	14											34.75	1.47	63	30

Note: [1] See Table A-10 for DoDAAC installation address

[2] Average Annual Rainfall Depth (inches) is averaged over number of years rainfall data is available from 1992 - 2021. In computing the Annual Rainfall Depth, all daily rainfall events (> 0.0 in) are included.

[3] 95th Percentile Rainfall Depth is computed for the most recent 30-year period (from 1992-2021), where available. The calculating 95th percentile rainfall depth daily rainfall depths greater than 0.1" (> 0.1 in) are used. Small rainfall events (≤ 0.1 inch) are lost due to abstractions and typically do not result in runoff.

[4] Average Annual Rainfall Days (> 0.1 inch) is averaged over number of years rainfall data is available from 1992 - 2021.

Table A-9 Summary of Rainfall Analysis (1992 - 2021) – Overseas Locations

	Rainfall Station Name	State	Station ID: GHCND (or GSOD)	Applicable DoDAAC[1] Numbers												Annual Rainfall Depth[2] (inches)	95th Percentile[3] (inches)	Rainy Days[4] (>0.1")	Years of Available Record (1992-2021)
				DoDAAC	(mi)	DoDAAC	(mi)	DoDAAC	(mi)	DoDAAC	(mi)	DoDAAC	(mi)	DoDAAC	(mi)				
51	BAHRAIN INT. AIRPORT, BA	Bahrain[5]	BA000041150	N63005	6											3.10	3.96	4	26
52	CAMP LEMONNIER	DjIbouti[6]	69675499999	N3379A	7											4.92	4.26	4	12
53	SOUDA AIRPORT	Greece	GR000167460	N66691	8											22.14	2.09	35	30
54	GUAM INTERNATIONAL AIRPORT, US	Guam	GQW00041415	N61755	12	N62395	11									99.75	2.06	152	30
55	GRAZZANISE, IT	Italy	ITM00016253	N62588	1											29.56	1.56	54	19
56	ISTRANA, IT	Italy	ITM00016098	FA5682	3											29.10	1.57	49	30
57	SIGONELLA, IT	Italy	ITW00033126	N62995	2											18.16	1.48	34	28
58	HACHINOHE, JA	Japan	JA000047581	N61060	10											38.03	1.85	61	28
59	YOKOHAMA, JA	Japan	JA000047670	N61054	11											61.87	2.67	73	28
60	BUSAN, KS	South Korea	KSM00047159	N32778	9											61.89	3.72	58	30
61	MORON DE LA FRONTERA, SP	Spain	SPE00120503	FA5575	5											20.04	1.42	39	30
62	ROTA, SP	Spain	SPE00119954	N62863	4											20.85	1.44	38	30

Note: [1] See Table A-10 for DoDAAC installation address

[2] Average Annual Rainfall Depth (inches) is averaged over number of years rainfall data is available from 1992 - 2021. In computing the Annual Rainfall Depth, all daily rainfall events (> 0.0 in) are included.

[3]95th Percentile Rainfall Depth is computed for the most recent 30-year period (from 1992-2021), where available. The calculating 95th percentile rainfall depth daily rainfall depths greater than 0.1" (> 0.1 in) are used. Small rainfall events (≤ 0.1 inch) are lost due to abstractions and typically do not result in runoff.

[4] Average Annual Rainfall Days (> 0.1 inch) is averaged over number of years rainfall data is available from 1992 - 2021.

[5] Bahrain average annual rainfall days (> 0.1 inch) = 4 days. For this reason, the 95th percentile rainfall depth computed is very high due to torrential storms that occur once or twice a year.

[6] Djibouti average annual rainfall days (> 0.1 inch) = 4 days. For this reason, the 95th percentile rainfall depth computed is very high due to torrential storms that occur once or twice a year.

Table A-10 DoDAAC Installation Address

DoDAAC Number	Installation Name	Address
FA2509	Peterson AFB	667 W Ent Ave, Colorado Springs, CO 80914
FA2550	Schriever AFB	210 Falcon Pkwy Ste 2116, Schriever AFB CO 80912-2116
FA3002	Randolph AFB	407 C St W, Randolph Air Force Base, TX 78150
FA3010	Keesler AFB	301 Fisher St, Biloxi MS 39534
FA4407	Us Air Force Scott AFB	201 E Winters St, Scott AFB IL 62225-5015
FA4418	Joint Base Charleston	101 E Hill Blvd, Charleston SC 29404-5021
FA4427	Travis Air Force Base	FA4427 60 CONS LGC, 350 Hangar Ave, Travis AFB CA 94535-2632
FA4521	Langley AFB	11 Nealy Avenue, Hampton VA 23665
FA4608	Barksdale AFB	801 Kenney Ave Bldg. 4400, Barksdale AFB LA 71110-2438
FA4686	Beale AFB	17855 Warren Shingle Rd, Beale Air Force Base, CA 95903
FA4814	MacDill AFB, FL	2610 Pink Flamingo Ave, Tampa FL 33621-5119
FA4819	Tyndall AFB	2580 Hwy 98, Panama City, FL 32403
FA4830	Moody AFB	4210 Bradley Cir, Moody AFB, GA 31699
FA6648	Homestead ARB	29050 Coral Sea Blvd, Homestead, FL 33039
FA6670	Niagara Air Reserve Station, Buffalo	800 Kirkbridge Dr, Niagara Falls NY 14304-5000
FA7037	US Air Force (USAF), San Antonio	102 Hall Blvd Bldg. 2000 Ste 258, San Antonio TX 78243-7091
FA7046	Kirtland AFB	1251 Wyoming Blvd Se, Kirtland AFB NM 87117-0001
FA8003	Wright Patterson AFB	1940 Allbrook Dr Bldg. 1, Wright Patterson AFB OH 45433-5344
FA8651	Eglin AFB	Eglin Pkwy, Eglin AFB, FL 32542
FA8900	Brooks AFB	3201 Sidney Brooks St, San Antonio TX 78235
FA9300	Edwards AFB	305 E Popson Ave, Edwards AFB, CA 93524
M00146	Marine Corps Air Station, Cherry Point	Cherry Point, NC 28533-0018
M00263	MX Marine Corps Regional	Contracting Office PO Box 5069, Marine Corps Recruit Depot/ERR, Parris Island, SC 29905-5069
M00681	NG Marine Corps Regional	Contracting Office PO Box 1609, Oceanside CA 92054-1609
M62204	Marine Corps Logistics Base, Barstow	PO Box 110340, Barstow CA 92311-5039
M62974	Marine Corps Air Station, Yuma	PO Box 99133, Station S-4/3KG, Yuma AZ 85369-9133
M64495	Marine Corps Mountain Warfare Training Center	Box 5009, Bridgeport CA 93517-5009
M67001	NB Marine Corps Regional Contracting Office	PSC Box 20004, Marine Corps Base, Camp Lejeune NC 28542-0004
M67004	Marine Corps Logistics Base (Code 89)	PO Drawer 43019, Albany GA 31704-3019
MMQQ50	Marine Corps Base Quantico	Marine Corps Base G4, 3250 Catlin Ave, Quantico VA 22134-5001
N00019	Naval Air Systems Command, Pax River	47123 Buse Road, Unit IPT, Patuxent River MD 20670-1547
N00025	NAVFAC Washington Navy Yard	1322 Patterson Avenue, Suite 1000, Washington DC 20374-5362

Table A-10 DoDAAC Installation Address (Cont'd.)

DoDAAC Number	Installation Name	Address
N00140	NAVSUP FLT LOG CTR Philadelphia	Naval Support Activity Philadelphia, 700 Robbins Ave, Philadelphia PA 19111-5083
N00204	Naval Air Station Pensacola	150 Hase Rd Suite A, Pensacola FL 32508-1051
N00216	NAS Corpus Christi	9604 Ocean Dr, Corpus Christi, TX 78418
N00245	NAVBASE San Diego	3455 Senn Rd, San Diego CA 92136
N00246	NAVBASE Coronado	4th St, Chula Vista CA 92118
N00318	Marine Corps Air Station Kaneohe Bay	MCBH Kaneohe Bay, HI 96863-5001
N0417A	Naval Support Facility Thurmont	PO Box 1000, Thurmont MD 21788-5001
N30614	Naval Outlying Landing Field	NOLF San Nicolas Island, NAWS Point Mugu CA 93042-5000
N30931	HQ USSOUTHCOM	3511 NW 91St Ave, Miami FL 33172-5000
N32411	NAVSTA Newport	8 Constitution Ave, Middletown, RI 02842
N32414	Naval Support Activity Mechanicsburg	5450 Carlisle Pike, Box 2020, Mechanicsburg PA 17055-0788
N33355	Naval Support Activity Bethesda	4655 Taylor Road, Bldg. 27, Room 308, Bethesda MD 20889
N3594A	Center For Seabees And Facilities	Engineering Bldg. 1444, 3502 Goodspeed Road Suite 1, Port Hueneme CA 93043-4336
N44200	NAVFAC Washington PWD South Potomac	Indian Head FEAD, 4474 McMahon Road Suite 3, Indian Head MD 20640-5035
N44201	NAVFAC Washington PWD, Annapolis FEAD	181 Wainwright Road, Annapolis MD 21402
N44210	NAVFAC Mid Atl PWD New London FEAD	135 Shark Blvd Bldg. 135 Box 26, Naval Submarine Base New London, Groton CT 06349-5026
N44211	NAVFAC Mid Atl PWD Newport FEAD	1 Simonpietri Drive, Newport RI 02841-1712
N44214	NAVFAC Mid Atlantic PWD Maine	FEAD ROICC, 437 Huey Drive Bldg. 53, Brunswick ME 04011
N44215	NAVFAC Southeast PWD Corpus Christi	8851 Ocean Dr Bldg. 19, Corpus Christi TX 78419-5525
N44218	NAVFAC Southeast PWD New Orleans	PW Dept Bldg. 552, New Orleans LA 70143-5000
N44219	NAVFAC Southeast PWD Meridian	229 Allen Rd, Bldg. 427 NAS Meridian, Meridian MS 39309-5427
N44221	PWD Mid-South	5722 Integrity Dr Bldg. 455, Millington TN 38054-5028
N44222	NAVFAC Southeast PWD Key West	PO Box 9018 Bldg. A 629, Key West FL 33040-9018
N44223	NAVFAC Southeast PWD Panama City	101 Vernon Ave, Bldg. 126, Panama City Beach FL 32407-7018
N44227	NAVFAC Southeast PWD Beaufort	PO Box 9310, Moore St Bldg. 658, Beaufort SC 29904-9310
N44251	NAVFAC Contracts (Guantanamo)	NAVFAC Southeast, PWD Guantanamo Bay Cuba, PSC 1005, Box 37, FPO AE 09593
N44255	Engineering Field Activity, Northwest	19917 7th Avenue NE, Poulsbo WA 98370-7570

Table A-10 DoDAAC Installation Address (Cont'd.)

DoDAAC Number	Installation Name	Address
N44259	NAVFAC Southwest PWD Lemoore	750 Enterprise Ave, NAS Lemoore CA 93246-6303
N45974	NAVFAC Southeast PWD Kingsville	201 Nimitz Ave Bldg. 4711, Kingsville TX 78363-5103
N47370	NAVFAC Washington PWD South Potomac	18329 Thomas Road, Dahlgren VA 22448-5000
N68248	Naval Submarine Base	Building 101, 1342 USS Simon Bolivar Road, Kings Bay, Ga 31547-2613
N48429	PWD South Potomac Site Andrews AFB	R53 Bainbridge St, Camp Springs MD 20762
N57061	US Naval Forces Southern Command	PO Box 280003, Mayport FL 32228-0003
N60042	Naval Air Facility El Centro	1605 3Rd Street Bldg. 214, El Centro CA 92243-5001
N61014	NSA Monterey	271 Stone Rd, Monterey CA 93943
N61018	NSA Crane	300 Hwy 361, Bldg. 3219, Crane IN 47522-5001
N61064	Pacific Missile Range Facility	Kekaha, HI 96752
N61065	Naval Weapons Station Seal Beach	Naval Weapons Station, 800 Seal Beach Boulevard, Seal Beach CA 90740-5000
N61142	Joint Base Anacostia Bolling	20 MacDill Blvd, Washington DC 20032-7711
N62470	NAVFAC - Atlantic Division	1510 Gilbert Street, Norfolk VA 23511-2699
N62473	NAVFAC Southwest	1220 Pacific Highway, San Diego CA 92132-5000
N62604	Naval Construction Battalion Center	5200 CBC 2nd Street, Gulfport MS 39501-5001
N62742	NAVFAC - Pacific Division	Building 258, Makalapa Drive, Pearl Harbor HI 96860-7300
N63406	NAVBASE Point Loma	140 Sylvester Rd, San Diego CA 92106
N65113	Navy Public Works Center	210 Decatur Avenue, Building 1A, Great Lakes IL 60088-5600
N67399	Twentynine Palms MCAGCC	Marine Corps Air-Ground Combat Ctr (MCAGCC), I And L, Box 788108, Twentynine Palms CA 92278-8108
N68248	Naval Submarine Base	Building 101, 1342 USS Simon Bolivar Road, Kings Bay GA 31547-2613
N68436	Naval Base Kitsap	120 South Dewey St, Bremerton WA 98314
N68931	FEC Southeast WCF	Det Box 30, Jacksonville FL 32212-0030
N68936	Naval Air Warfare Center	Weapons CT 25400E D, 429 E Bowen Rd Stop 4015, China Lake CA 93555-6018
N68967	NAVSTA Everett	2000 W Marine View Dr, Everett WA 98207
N69212	Naval Weapons Station	WPNSTA 160 Main Rd, Yorktown VA 23691-5111
N69232	NAVBASE Ventura County Pt Mugu	311 Main Rd Ste 1, Point Mugu NAWC, CA 93042
SZ3108	Ellsworth AFB	630 Twining St, Ellsworth AFB SD 57706-4920
SZ3586	DLA Disposition Services Riley	Camp Funston Bldg. 1950, Fort Riley KS 66442-2490
W34GL1	Fort Campbell, KY	CRP Bldg. 5207, 8th and Desert Storm, Fort Campbell KY 42223
W911SA	Us Army, Fort McCoy	Bldg. 1108 South R Street, Fort McCoy WI 54656-5142

Table A-10 DoDAAC Installation Address (Cont'd.)

DoDAAC Number	Installation Name	Address
OVERSEAS LOCATIONS		
FA5575	US Air Force	Base Aérea, 41600 Arahal, Sevilla, Spain
FA5682	US Air Force	600 Via Pordenone 89/B Area E, 33081 Aviano IT
N32778	US Navy, Fleet Activities Chinhae	1 Hyeon-Dong, Bldg. 606, Chinhae-Gu, Changwon-Si, Gyeongsangnam-Do Korea, Republic Of KR 51698
N3379A	Camp Lemonier Djibouti	Horn Of Africa, Camp Lemonier DJ; City - Camp Lemonier
N61054	US Navy, Commander Fleet Act Yokosuka	1 Banchi Tomari Cho Us Naval Base, Yokosuka JP 238-0001
N61060	Naval Air Facility Misawa Japan	1 Chome Hirahata Misawa, Aomori JP 033-0012
N61755	Naval Base Guam	Building 3190, Sumay Drive, Santa Rita Guam GU 96915
N62395	JK Navy Public Works Center, (Mariana Islands, Guam)	PSC 455, Box 195, FPO AP, GU 96540-2937
N62588	Naval Support Activity Naples	PSC 817 Box 1, FPO AE 09622-0000; Di Capodichino Bldg. 415; 80144 Napoli Italy IT
N62863	US Naval Station Rota Spain	Bldg. 55 Naval Station Rota, 11520 Rota ES, Spain, Rota
N62995	US Sigonella Naval Air Station	PSC 812 Box 1000, FPO AE 09627-1000
N63005	Naval Support Activity, Bahrain	Al Hidd Bh 115, Bahrain; City - Al Hidd
N66691	Naval Support Activity Souda Bay	Supply Dept Bldg. 6, Mouzouras Road Comm 30 28210 21256, Chania Crete GR 73100

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APPENDIX B GLOSSARY

B-1 ACRONYMS AND ABBREVIATIONS.

ARC	Antecedent Runoff Condition
Bio	Biological
BMP	Best Management Practice
CN	Curve Number
CWA	Clean Water Act
DoD	Department of Defense
DoDAAC	Department of Defense Activity Address Code
EISA	Energy Independence and Security Act
EPA	United States Environmental Protection Agency
GHCN	Global Historical Climate Network
GSOD	Global Summary of the Day
HN	Host Nations
HSG	Hydrologic Soil Group
I_a	Initial Abstraction
IMP	Integrated Management Practice
LID	Low Impact Development
NCEI	National Centers for Environmental Information
NEH	National Engineering Handbook of Hydrology
NPDES	National Pollutant Discharge Elimination System
NOAA	National Oceanic and Atmospheric Administration
NRCS	USDA Natural Resources Conservation Service (formerly SCS)
O&M	Operations and Maintenance
OMSI	Operation and Maintenance Support Information
PGDER	Prince George's County Department of Environmental Resources

SCS	USDA Soil Conservation Service
SWM	Stormwater Management
T_c	Time of Concentration
TR-55	NRCS Technical Release 55
UFC	Unified Facilities Criteria
USDA	United States Department of Agriculture
WMO	World Meteorological Organization

B-2 DEFINITION OF TERMS.

95th Percentile Rainfall Event: The 95th percentile rainfall event represents a precipitation amount which 95 percent of all rainfall events for the period of record do not exceed. In more technical terms, the 95th percentile rainfall event is defined as the measured precipitation depth accumulated over a 24-hour period for the period of record that ranks as the 95th percentile rainfall depth based on the range of all daily event occurrences during this period.

The 24-hour period is typically defined as 12:00:00 am to 11:59:59 pm. In general, a 30-year period of rainfall data is recommended for such an analysis, with a required minimum period of 10 years. Small rainfall events that are 0.1 inch or less (that is, ≤ 0.1 inches) are excluded from the percentile analysis because this rainfall generally does not result in any measurable runoff due to absorption, interception, and evaporation by permeable, impermeable, and vegetated surfaces.

Building: DODI 4165.14, Enclosure 2, defines a building as: A roofed and floored facility enclosed by exterior walls and consisting of one or more levels that is suitable for single or multiple functions and that protects human beings and their properties from direct harsh effects of weather such as rain, wind, sun, etc.

Federal Facility: Section 401(8) of EISA states: The term “Federal facility” means any building that is constructed, renovated, leased, or purchased in part or in whole for use by the Federal Government.

Low Impact Development (LID): 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. The LID features are distributed small-scale controls that closely mimic the hydrological behavior of the pre-project sites for a design storm event.

Pre-Development: pre-project conditions that exist at the beginning of design. Where phased development occurs, the existing conditions at the time prior to the first phase being submitted will establish pre-development conditions.

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APPENDIX C REFERENCES

DEPARTMENT OF DEFENSE

DODI 4165.14 *Real Property Inventory and Forecasting*

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https://www.epa.gov/water-research/storm-water-management-model-swmm

Low-Impact Development Design Strategies, An Integrated Design Approach, Prince George's County, Maryland, Department of Environmental Resources, Programs and Planning Division, January 2000.
https://www.princegeorgescountymd.gov/DocumentCenter/View/86/Low-Impact-Development-Design-Strategies-PDF

Low-Impact Development Hydrologic Analysis, Prince George's County, Maryland, Department of Environmental Resources, Programs and Planning Division, July 1999.
https://www.princegeorgescountymd.gov/DocumentCenter/View/87/Low-Impact-Development-Hydrologic-Analysis-PDF

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TR-55, *Urban Hydrology for Small Watersheds* June 1986
https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=22162.wba

WinTR-20*, Watershed Hydrology*, March 2015

Part 630 Hydrology, National Engineering Handbook of Hydrology, Chapter 4 (NEH-4), 2019

UNIFIED FACILITIES CRITERIA

https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc

UFC 1-200-01, *DoD Building Code*

UFC 1-200-02, *High Performance and Sustainable Building Requirements*

UFC 3-201-01, *Civil Engineering*

UFC 3-260-01, *Airfield and Heliport Planning and Design*

UFC 3-420-01, *Plumbing Systems*

UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*

UFC 4-010-06, *DoD Cybersecurity Of Facility-Related Control Systems*