GREEN INFRASTRUCTURE AND LOW-IMPACT DEVELOPMENT APPLICATION GUIDANCE FOR WASHINGTON COUNTY, UTAH

To be used in partial fulfillment of the requirements associated with
Small Municipal Separate Storm Sewer System (MS4)
General Permit

Updated:
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Dixie Storm Water Coalition

St. George, Washington, Ivins, Santa Clara

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Sponsoring Agency: Dixie Storm Water Coalition

Acknowledgments:

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Glossary of Acronyms

BMP(s)	Best Management Practices
CFR	Code of Federal Regulations
CGP	Construction General Permit
CWA	Clean Water Act
DMR	Discharge Monitoring Report
EPA	Environmental Protection Agency
GI	Green Infrastructure
GIS	Geographical Information System
IDDE	Illicit Discharge Detection and Elimination
LID	Low Impact Development
MCM	Minimum Control Measures
MEP	Maximum Extent Practicable
MS4	Municipal Separate Storm Sewer Systems
MSGP	Multi-Sector General Permit (non-mining)
NOI	Notice of Intent
NOT	Notice of Termination
NPDES	National Pollution Discharge Elimination System
O&M	Operations and Maintenance Plan
SWMP	Storm Water Management Program
SWPPP	Storm Water Pollution Prevention Plan
TMDL	Total Maximum Daily Load
UPDES	Utah Pollution Discharge Elimination System
WQRV	Water Quality Retention Volume

Glossary of Commonly Used Terms

Best Management Practices (BMPs): Methods, measures or practices to prevent or reduce storm water runoff and includes both structural and nonstructural controls and operation and maintenance procedures. These controls and procedures serve to project water resources, minimize fugitive dust, manage waste and mitigate erosion.

Detention: The process of temporarily collecting and storing surface water runoff such that the peak discharge is reduced below a specified threshold. Typically, a predevelopment value.

Disturbance: The result of altering soil from its native or stabilized condition thereby rendering it subject to movement or erosion by water to potentially become or becoming a pollutant in site storm water runoff; also means soil disturbance.

Erosion: The wearing away of land surface by water or wind, which occurs from weather or runoff, but is often intensified by human activity.

Evapotranspiration: The loss of water from the soil both by evaporation from the soil surface and be vegetative transpiration.

Facility: Any "point source" or any land, building, installation, structure, equipment, device, conveyance, area, source, activity or practice from which there is, or with reasonable probability may be, the introduction of storm water to the County MS4 or Storm Drainage Systems connected to the MS4 such that it is subject to regulation under the UPDES/NPDES program.

Green Infrastructure (GI): The range of measures that use plant or soil systems, permeable pavement or other permeable surface or substrates, storm water harvest or reuse, or landscaping to store, infiltrate, or evapotranspirate storm water and reduce flows to the sewer systems or to surface waters.

Low Impact Development (LID): Systems and practices that use or mimic natural processes that result in the infiltration, evapotranspiration or use of storm water in order to protect water quality and associated aquatic habitat.

Multi-Sector General Permit (MSGP): Permit that authorizes the discharge of storm water from facilities associated with any one of twenty-nine (29) industrial activities into a Municipal Separate Storm Sewer System that leads to a surface water or directly into a surface water.

Municipal Operations: Any facility that is owned, operated or maintained by the governing entity.

Municipal Separate Storm Sewer System (MS4s): a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels or storm drains) that are owned and operated by public entity, having jurisdiction to discharge into waters of the United States, and are designed or used for collecting or conveying storm water, but are not part of a combined sewer system and are not part of a publicly-owned treatment works (POTW).

Non-Storm Water Drainage: Any drainage that is not composed entirely of storm water.

Operator: A party or parties that either individually or taken together have operational control over the site specifications, including the ability to make modifications in specifications and they have day-to-day operational control of activities at the site necessary to ensure compliance with plan requirements and permit conditions.

Owner: The person, persons, or entity whose name appears on the title or deed to the subject property or properties.

Outfall: Any location within a project site where storm water runoff or a non-storm water discharge exits the site.

Operation and Maintenance Plan: A legally recorded document or section within a legally recorded document that specifies the processes, procedures and actions that will be implemented to ensure the long-term operation and maintenance of the post-construction storm water BMP's. The plan, which is to be reviewed and accepted by the permitting agency, will delegate to a party or entity that is tied to the property (e.g. Homeowner's Association, Neighborhood Association, Community Association, Property Managing Company or Condominium Association) the responsibilities of implementation of the plan in perpetuity with the understanding that failure to perform the duties specified in the plan can lead to fines and civil penalties to be assessed to the owners of the property.

Point Source: Any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collections system, vessel or other floating craft from which pollutants are or maybe discharged, excluding return flows from irrigated agriculture or agriculture storm water runoff.

Pollutant: Sediment, fluids, toxic waste, dredged spoil, solid waste, substances and chemicals, pesticides, herbicides, fertilizers, and other agricultural chemicals, incinerator residue, sewage, garbage, sewage sludge, munitions, petroleum products, equipment, rock, sand cellar dirt (e.g. overburden material) and mining, industrial, municipal and agricultural waste or any other liquid, solid, gaseous or hazardous substance which has the capacity to degrade water quality.

Retention: The process of collecting and indefinitely storing storm water runoff with the sole intent of infiltrating, evaporating, transpiring and/or reusing. For the purposes of this manual, retention systems should be expanded to include systems that temporarily detain storm water, filtering it through a soil medium and discharging through an underdrain and outfall at a rate and quality that does not adversely affect the downstream receiving waters.

Sediment: Small particles of loose, unconsolidated organic and inorganic material that is broken down by processes of decay, weathering or erosion and can be subsequently transported by wind or water.

Storm water: Any surface flow, runoff, and drainage consisting entirely of water from any form of natural precipitation and resulting from such precipitation.

Structural Best Management Practices: Any physical means of controlling, capturing, diverting or conveying runoff or a point source for the purpose of reducing, to the maximum extent practicable, pollutants from exiting a site.

Urbanized Area: A portion of the County that has a population density of at least one thousand (1,000) people per square mile and/or meets other criteria set by the U.S. Bureau of Census in the latest Decennial Census. Or a densely settled core of census tracts and/or census blocks that have population of at least 50,000, along with adjacent territory containing non-residential urban land uses as well as territory with low population density included to link outlying densely settled territory with the densely settled core. It is a calculation used by the Bureau of the Census to determine the geographic boundaries of the most heavily developed and dense urban areas.

Waters of the U.S.: As defined in 33 CFR 328.3(a) and 40 CFR 230.3(s).

Introduction and Background

In December 2018, the Utah Department of Environmental Quality Division of Water Quality (UT DWQ) prepared a manual intended to serve as a reference and guide for incorporating Low Impact Development (LID) approaches into new development and redevelopment projects in Utah. The manual was intended to provide guidance for planners and designers as well as small Municipal Separate Storm Sewer System (MS4) storm water managers in selecting appropriate practices for their communities.

To meet the requirements of the State Permit, MS4 municipalities require that LID practices be discussed and analyzed at the initial stages of development prior to the approval of the concept plans, development plans or preliminary plats.

UT DWQ guidance was provided to reduce to the maximum extent practicable pollutants transported in untreated storm water to the waters of the United States by using key Low Impact Development (LID) principles such as; mimicking natural processes, promoting infiltration/ evapotranspiration/ harvesting/ reuse, and managing storm water with distributed systems close to the source. Additional LID requirements are expected for permitted MS4's, to develop a LID approach for retention of storm water, from the 80th percentile storm event for all new development and redevelopment projects that are greater than 1 acre or equal to or part of a common plan of development. In so doing, the UT DWQ guidance is designed to increase the use of LID practices and specific applications.

While the UT DWQ manual provided a fairly comprehensive approach to LID applications to storm water management, concerns existed with the applicability, feasibility, and associated costs (long-term) of the LID practices presented within the manual as it related to the Dixie Metropolitan Area within Washington County, Utah.

- ## Code Requirements

  Starting with the enactment of the Federal Clean Water Act in the 1970s and subsequently the initiation of the National Pollution Discharge Elimination System (NPDES), there has been a concerted effort to protect the nations waterways from storm water borne contamination. As recent as the 2010's, it is understood that the EPA began developing new rules to encourage the use of LID practices. In this context, more of an emphasis was placed on low-tech retention-based strategies as a proxy for contaminant reduction. Accordingly, the Utah Department of Water Quality (UT DWQ) has established MS4 permit minimum performance measures and requirements within its permit that, as part of long-term storm water management for new development and re-development, requires the establishment of a retention-based criteria for new and redevelopment. An anticipated update to the permit requirement which became effective March 1, 2020 (based on the December 24, 2019 draft) is summarized below:

  1. New Development (> 1-acre disturbance): Retention of the 80th percentile rainfall event or to limit offsite discharges to a pre-developed hydrologic condition, whichever is less.

2. Redevelopment (> 1 acres): If the redevelopment increases the impervious surfaces by more than 10%, then the site design should prevent the discharge of (retain) the net increase in volume associated with all precipitation events up to the 80th percentile rainfall event.

The guidance further clarifies that these objectives must be accomplished by methods designed, constructed and maintained to infiltrate, evapotranspire and/or harvest and reuse the rainwater (UPDES, 2019). The permit also requires the evaluation of LID retention strategies to meet the storm water quality objectives to the maximum extent feasible. Feasibility or infeasibility as specified in the permit will require the developer to document and quantify how infiltration, evapotranspiration, and rainwater harvesting have been used to the maximum extent possible or provide documentation to explain why implementation of LID measures is not possible.

- ### Purpose

As part of the requirements associated with operating an MS4, Coalition Member Cities have prepared this Applicability Matrix in order to:

1. Provide regional context for application of LID based storm water management.
2. Provide minimum criteria for the regional use of UT DWQ LID practices.
3. Provide an understanding of relative costs associated with standard LID practice implementation.

This document addresses the initial screening of recommended practices and will aid as a decision-making-tool for planners, developers and engineers in the Dixie Metropolitan Area. It is not intended to replace or supersede any existing Local, Regional, State or Federal guidance nor is it intended to be used as a prescriptive tool. Each site should be evaluated independently to determine the best LID based storm water management practice.

- ### Urbanized Area - Geographical Limits

This manual is intended for regulated cities within Washington County, Utah, defined as the Dixie Metropolitan Area which includes the City of St. George, Washington City, Santa Clara City and Ivins City. This area is also referred to as the Dixie Storm Water Coalition Region. Guidance found in this manual could be applied to other arid regions. However, such use is beyond the intent of this document and is therefore cautioned.

- ### Receiving Waters

The receiving waters, often referred to as waters of the United States and/or navigable waters associated with Dixie Metropolitan Area of Washington County Utah are the Santa Clara River and the Virgin River.

Regional Constraints

Regional soils are known to be problematic for water retention or detention adjacent to infrastructure. While LID practices may have benefits, common concerns exist regarding the applicability of various LID practices with regard to the long-term maintenance and viability of these features in the Dixie Metropolitan Area. The following sections provide an overview of the geological and soil conditions that exist in the region. Maps that can be used to help determine applicability are provided at the end of this document.

- ## Soils & Geology

An understanding of the various geology and soils within the project area will aid in informing the user regarding the applicability of various Utah standard LID practices. As an overview, United States Department of Agriculture Natural Resources Conservation Service (NRCS) Soil Survey data was used to evaluate soil data within each of the metropolitan areas. Estimates are expressed as percentages of the total area in Table 1.

Table 1: Prevalence of Regional Soil Parameters

CITY	HYDROLOGIC SOIL GROUP (%)				Bedrock within 5 feet from surface (%)
	A+ B	C	D	Other	
Washington City	43.7	12	27.6	16.7	34.9
Saint George	44.5	20.7	6.8	28	18.9
Santa Clara	29.9	8.7	35.9	25.5	39.8
Ivins City	58.6	12.4	23	6	12.5

Regional data indicates a significant range of infiltration rates from about 0.16 to 4.0 inch/hour. Hydrologic Soil Group (HSG) ratings are somewhat indicative of the infiltration rates and can be useful for selecting LID BMPs. HSG A is characterized by a high infiltration capacity while HSG Type D soils typically shows very low infiltration capacity. Note that HSG type D soils cover approximately 23 percent of the Dixie Storm Water Coalition Region.

Regional data also suggests that near surface soils are predominantly of eolian or alluvial deposits. However, there are also residual soils derived from bedrock weathering/decomposition processes. The eolian deposits are characterized by relatively low plasticity, low density, and relatively high porosity. They exhibit collapse potential upon saturation, which may be as high as 10 percent. The alluvial deposits include a wide range of soils that are both plastic and non-plastic. They may exhibit expansion or collapse potential of slight to moderate magnitude. Properties of the residual soils derived from bedrock (sometimes referred to as “colluvium”) depend on the parent material type. Claystone derived soils, as well as weathered claystone, may exhibit expansion potential with sometimes high-expansive pressures. Additionally, gypsum and gyspsiferous soils are commonly found in the Dixie Storm Water Coalition Region. Hydration of these soils can dissolve the gypsum and cause severe complications for infrastructure. Special attention must be given when these conditions are concealed.

To aid in the planning stages of a proposed project and to inform the user regarding potential hazards that may affect their project several maps are provided. These maps **are not** a replacement for detailed geotechnical evaluation for a specific project but are provided as a guide for planning purposes only.

- ## Climatology

  Utah contains a wide range of climatological variability, Washington County alone contains three distinct climate regions; the Colorado Plateau Region (to the east and northeast), the Great Basin Region (to the northwest), and the Mojave Desert Region (which encompasses the Dixie Storm Water Coalition Region). Located in an arid desert region of southwest Utah, the Dixie Storm Water Coalition Region is characterized by hot summers (average high temperature in June, July and August is near or over 100 degrees Fahrenheit) and infrequent precipitation, generally less than an inch per month. With an annual precipitation of just over 8 inches and with some of the lowest elevations in Washington County there is little permanent vegetal ground cover and high sediment yields indicating an additional consideration for application of selected LID BMPs. Infrequent precipitation and climate variability should be considered in the selection of any LID BMP especially those that depend on the establishment of permanent vegetation. In accordance with UT DWQ gage analysis procedures the 80th percentile depth for the Dixie Storm Water Coalition Region is 0.44-inches.

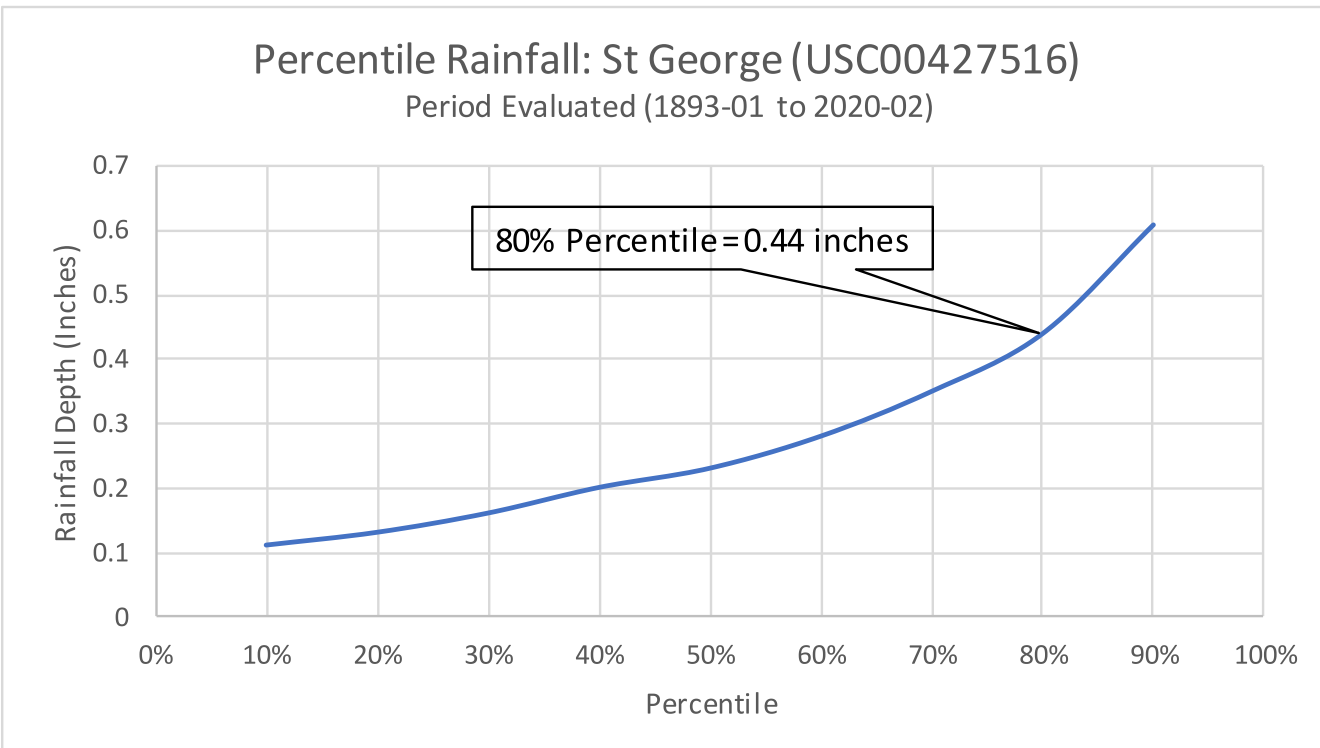


Figure 1 Percentile Rainfall Chart

Retention Volume

The Utah DWQ LID manual provides examples on how to calculate the Water Quality Retention Volume (WQRV) for compliance with the permit. In general, the form of the WQRV equation is as listed below:

$$WQRV = \frac{P_{80\%} * R_{new} * A}{12}, \qquad \text{EQ 1}$$

Where,

WQRV = Water Quality Retention Volume, in ac-ft,
$P_{80\%}$ = 80th percentile precipitation value (excluding snowfall, from gage analysis, in inches),
R_{new} = Storm Water Runoff Coefficient associated with the proposed new development, and
R_{new} = 1.14 (Imp) -0.371 when imp ≥ 55%
R_{new} = .225 (Imp) +-0.05 when imp ≤ 55%
A = Area, in Acres.
Imp = decimal percentage of impervious surface in the contributing watershed

For new development greater than 1-acre, and areas smaller than 1 acre but are part of a common plan of development, the permit specifies prevention of runoff from all events less than the 80th percentile rainfall or a predeveloped hydrologic condition, whichever is less.

For redevelopment greater than 1-acre, the current permit allows the retention from the increases only as shown in the Equation below:

$$WQRV = \frac{P_{80\%} * (R_{new} - R_{pre}) * A}{12}, \qquad \text{EQ 2}$$

Where,

WQRV = Water Quality Retention Volume required to maintain existing conditions, in ac-ft,
$P_{80\%}$ = 80th percentile precipitation value (excluding snowfall, from gage analysis, in inches),
R_{pre} = Storm Water Volumetric Runoff Coefficient for existing conditions
R_{new} = Storm Water Volumetric Runoff Coefficient for proposed conditions
$R_{pre/new}$ = Storm Water Volumetric Runoff Coefficient Equation (UDOT, 2018)
$R_{pre/new}$ = 1.14 (Imp) -0.371 when imp ≥ 55%
$R_{pre/new}$ = .225 (Imp) +-0.05 when imp ≤ 55%
A = Area, in Acres.
Imp = decimal percentage of impervious surface in the contributing watershed

Occasionally, it may be necessary to maintain consistency across differing hydrologic methods such as the SCS Method and the Rational Method. In general, the runoff coefficient is defined as the ratio of runoff to rainfall. Accordingly, Dr. Ron Rossmiller's Equation has historically been used for conversion of SCS Curve Number to a Runoff Coefficient (Rossmiller, 1980). However, special care must be used to understand the slight variance between a traditional Runoff Coefficient and the Utah Storm Water Volumetric Runoff Coefficient ($R_{pre/new}$). The Utah Storm Water Volumetric Runoff Coefficient is generally lower than the traditional runoff coefficient found in table (UDOT, 2018). Therefore, the Rossmiller Equation result should be considered an upper limit.

$$R_{pre/new} = 7.2 * (10)^{-7} * CN^3 * RI^3 * ((0.01 * CN)^{0.6})^{-S^{0.2}} * (0.01 * CN^{1.48})^{0.15-0.1(I)} * \left(\frac{(IMP+1)}{2}\right)^{0.7},$$

EQ 3

Where,

CN	=	SCS/NRCS Curve Number,
RI	=	Recurrence Interval (years),
IMP	=	Impervious coverage (decimal form, i.e. for a 30% impervious, IMP=0.3),
R_{pre}	=	Existing Condition Storm Water Runoff Coefficient
S	=	Average land slope (whole number percent, i.e. for a 4% slope S=4)
I	=	Rainfall Intensity calculated using methodologies consistent with local jurisdiction (inches/hour)

Importantly, the minimum requirement within the Dixie Storm Water Coalition Region is to disconnect impervious areas. The designer may use procedures as proposed by Bowen Collins & Associates (Bowen Collins & Associates, 2020) to establish a credit for disconnected impervious to be applied to the WQRV. Additionally, the Bowen Collins procedure can also be applied to LID BMPs such as Bio-swales (BR-3), Vegetative Strips (BR-4), or Pervious Surfaces (PS-1) where a clear volumetric quantity cannot be determined from BMP geometry. The Bowen Collins procedure is attached to this guidance document.

Due to the operation and maintenance efforts in addition to the need for irrigation water Green Roofs (BR-6) are not recommended within the Dixie Storm Water Coalition Region (arid or semi-arid settings). However, in the rare instance this LID BMP is selected. Green roof WQRV should be provided within the void space of the drainage layer and the growing media. Designer will need to provide evidence that this volume is sufficient to accept the additional runoff. Guidance for this application within the arid and semi-arid west is provided by the US EPA (Tolderlund, 2010).

Applicability

The Utah DWQ LID manual provides standard practices and applications intended for statewide use. As a part of its broad attempt to provide a comprehensive manual, UT DWQ provided three flow charts to be used in the selection of a LID BMPs from a list of twelve that were considered by UT DWQ to be most applicable for the State of Utah (Table 2).

For areas like the Dixie Storm Water Coalition Region, which contain the aforementioned regional constraints, additional criteria needed to be applied to the selection process, to ensure that a region-specific LID BMP can be implemented. The BMPs that the Dixie Storm Water Coalition considers region appropriate are highlighted in the table.

Table 2: Utah DWQ LID BMP

BR-1	Rain Garden
BR-2	Bioretention Cell
BR-3	Bioswale
BR-4	Vegetated Strip
BR-5	Tree Box Filter
BR-6	Green Roof
PS-1	Pervious Surfaces
ID-1	Infiltration Basin
ID-2	Infiltration Trench
ID-3	Dry Well
ID-4	Underground Infiltration Galleries
HR-1	Harvest and reuse

- ## BMP Selection Tools

  To aid the evaluation and selection process to following tools and guidance are provided:

  - ### Decision Making Flow Chart

    In similar fashion to the UTAH DWQ LID Manual, the decision-making process is summarized in a flow chart (Figure 2).

  - ### Region Applicability Matrix

    To further assist in the binary progression through the flowchart, a criteria matrix has been provided that summarizes how the uniqueness of the region effects the applicability of a given BMP (Table 3).

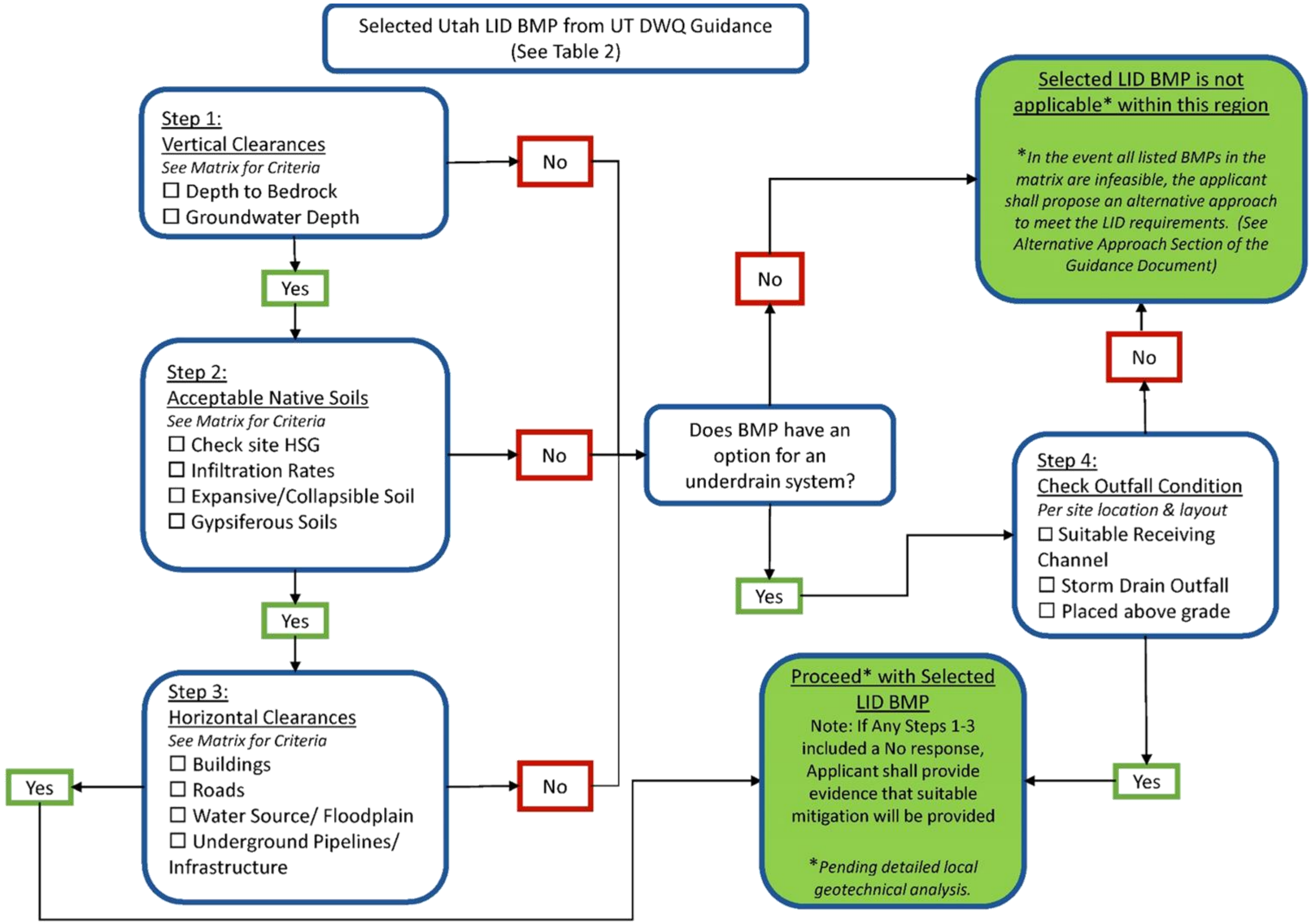


Figure 2 Applicability Matrix Flow Chart

Table 3: Region Applicability Matrix

UPDATED: 6/15/2020

Utah LID BMP		Step 1: Min. Acceptable Vertical Clearances		Step 2: Minimum Acceptable Native/ In-Situ Soil Parameters*					Step 3: Minimum Acceptable Horizontal Clearances***			
		Groundwater	Bedrock	HSG	Infiltration Rates**	Expansive/Collapse Risk	Gypsiferous Soils	Liquefaction Risk	Buildings (w/ basement)	Roads	Floodplains or Water Source	Underground Pipeline Infrastructure
BR-1	Rain Garden	> 10 ft	> 5 ft	A or B	0.5 in/hr.	Low to Moderate	< 3%	Low to Moderate	10 ft. (50 ft)	5 ft	Any	Any
BR-2	Bioretention Cell	Any	Any	Any	NA	Any	< 3%	Any	10 ft. (50 ft)	5 ft	Any	20 ft
BR-3	Bioswale	> 10 ft	> 5 ft	A or B	0.5 in/hr.	Low to Moderate	< 3%	Low to Moderate	10 ft. (50 ft)	5 ft	Any	Any
BR-4	Vegetated Strip	> 10 ft	> 5 ft	A or B	0.5 in/hr.	Low to Moderate	< 3%	Low to Moderate	10 ft. (50 ft)	Any	Any	Any
BR-5	Tree Box Filter	Any	Any	Any	NA	Any	< 3%	Any	Any	Any	Any	Any
BR-6	Green Roof	NA	NA	Any	NA	Any	NA	Any	Any	Any	NA	NA
PS-1	Pervious Surfaces	> 10 ft	> 5 ft	A or B	0.5 in/hr.	Low to Moderate	< 3%	Low to Moderate	10 ft. (50 ft)	Any	Any	20 ft
ID-1	Infiltration Basin	> 10 ft	> 10 ft	A or B	0.5 in/hr.	Low to Moderate	< 3%	Low to Moderate	10 ft. (50 ft)	5 ft	25 ft	20 ft
ID-2	Infiltration Trench	> 10 ft	> 5 ft	A or B	0.5 in/hr.	Low to Moderate	< 3%	Low to Moderate	10 ft. (50 ft)	5 ft	25 ft	20 ft
ID-3	Dry Well	> 10 ft	No Bedrock	A, B or C	NA	Low to Moderate	< 3%	Any	20 ft. (100 ft)	20 ft	100 ft	20 ft
ID-4	Underground Infiltration Galleries	> 10 ft	> 10 ft	A or B	0.5 in/hr.	Low to Moderate	< 3%	Low to Moderate	20 ft. (100 ft)	50 ft	50 ft	20 ft
HR-1	Harvest and reuse	NA	NA	Any	NA	Any	NA	Any	NA	NA	Any	NA

*Native soil values only. Per site specific geotechnical report. Engineered soil fills and liners may be required at additional costs if minimum recommended parameters are not met.
**Minimum State Requirement is 0.25 in/hr. This should be considered after aging.
***Geotechnical Analysis required to document safe horizontal setback per site conditions.
NOTE: This Matrix should be considered a living document. User's shall coordinate with local agency staff to verify most current version.

- ## Guidance

  Both tools along with the information presented below provides additional context for decision makers specific to the Dixie Storm Water Coalition Communities. Both the flowchart and applicability matrix, which has been provided within the appendix of this document, should be consulted during the planning stages of a future project to guide regional limitations and use of LID BMPs. In the event that a proposed retention-based LID Practice is not applicable to the site, the minimum requirement within the Dixie Storm Water Coalition Region is to disconnect impervious areas. If the WQRV is not met by disconnecting impervious areas, an alternative approach to LID that meets the water quality objectives shall be considered.

  - ### <u>Step 1:</u> Check Acceptable Minimum Vertical Clearances

    Minimum vertical clearances are important to the function of the selected LID BMPs in terms of ensuring proper installation and performance. The two most relevant categories for vertical clearances are related to the presence of groundwater and bedrock or impermeable lenses. Per the Matrix, each LID BMP is listed with the corresponding minimum acceptable vertical clearance. If the selected BMP does not meet the criteria, proceed to Step 4. If the selected LID BMP does meet the criteria for vertical clearances, the user shall proceed to Step 2.

  - ### <u>Step 2:</u> Check Acceptable Minimum Native/ In-Situ Soil Parameters

    Step 2 is intended to verify that the surrounding native soils have the capability and capacity to absorb additional storm water without negatively affecting surrounding infrastructure. This includes the Hydrologic Soil Group, Infiltration Rates, Expansive/Collapse Risk Potential, and Presence of Gysiferious Soils. For convenience, a collection of Maps (Figures 3-8) have been provided at the end of this document to aid in planning level efforts. Each of these categories/maps are intended to inform the user of the surrounding soil conditions and may require soil modification which may be cost prohibitive to mitigate. It should also be noted that the presence of a sloping impervious lens or obscured soils may further complicate the use of LID BMPs as it pertains to the risk to downstream properties. It is vital that a comprehensive site analysis be conducted so as to certify that proposed design features do not pose a negative risk to downstream owners.

    Using the Matrix, if the selected LID BMP does not meet the criteria for each of the native soil parameters, proceed to Step 4. If the selected LID BMP does meet the criteria for native soil parameters, the user shall proceed to Step 3.

- **<u>Step 3:</u> Check Acceptable Minimum Horizontal Clearances**

  Step 3 is to check is the horizontal distance or setback from relevant infrastructure such that water that has been infiltrated does not cause an adverse condition. While the guidance within the Matrix has been developed as a guide, the user is ultimately responsible for ensuring that adverse conditions are not created that impact existing adjacent infrastructure. Using the Matrix, the user must determine if adequate horizontal clearances exist. If the selected LID BMP does not meet the criteria, proceed to Step 4. If the selected LID BMP does meet the criteria for minimum horizontal clearances, the user also proceeds to Step 4 with selected LID BMP pending a detailed site-specific geotechnical analysis and cost-benefit analysis.

- **<u>Step 4:</u> Check for Logical Downstream Outfall Conditions**

  Some of the limitations for the use of LID BMPs in the Dixie Storm Water Coalition region can be mitigated with the use of impermeable liners in combination with a connection to an appropriate downstream storm water conveyance outfall system. Therefore, Step 4 in determining if a selected LID BMP or practice is applicable as shown on the matrix is whether the connection to a downstream outfall exists.

  Following the Matrix, if a suitable downstream condition exists, like a storm-drain or downstream channel, the use of a liner and underdrain system to contain, detain, treat and discharge to the acceptable downstream outfall is permissible. This may be used in conjunction with any detention or retention requirements for new or redeveloped parcels.

  If an acceptable downstream outfall does not exist and other limitations cannot be mitigated (pending detailed site-specific geotechnical analysis and design), or is cost infeasible, the selected BMP is not applicable for use within the Dixie Storm Water Coalition Region and an alternative approach may be requested.

- ### Alternative Approach

  If the user identifies that the available LID BMPs that meet the intent of the UT DWQ permit do not meet the criteria presented within the Matrix, a request for Alternative Approach shall be sought. In applying for an Alternative Approach, either for use of a non-regional approach LID BMP or an alternative approach, a site-specific engineering study that demonstrates the ability to meet the intent of the UPDES MS4 general permit will be required. The alternative will be submitted to the local jurisdiction for approval.

  In accordance with the UT DWQ permit, alternate approaches from the retention requirement will only be allowed with a site-specific engineering study that demonstrates infeasibility based on insurmountable constraints and may be permitted on a case-by-case basis. Any alternate approach will require that retention and LID BMPs are incorporated to the maximum extent feasible which includes disconnecting impervious areas, per the permit. This may include a reduction in the required retention volume permitted, as long as verifiable documentation can be provided to adequately show that the proposed plan will "protect water quality and reduce the discharge of pollutants to the MS4" (UT DWQ).

Costs

Costs have historically been a driving factor in the use or exclusion of LID practices from a proposed project. One key factor to consider when evaluating costs or cost-benefits of LID infrastructure is how to monetize social or environmental benefits, especially in arid regions. These social and environmental benefits are not discussed within this document but should be considered by the developer as part of any cost-benefit assessment.

- ### Implementation Cost

  Initial investments or capital costs are often the primary economic considerations for implementation of a specific BMP. Recently greater attention has been provided to understanding both life-cycle costs of specific BMP features as well as environmental or social benefits which can be difficult to monetize. While information in this area is growing, special consideration must be considered in arid regions. Specifically, when it comes to selection of vegetation and various BMP types. Relative initial and operation and maintenance costs for a respective BMP is presented in Table 4.

Table 4: Relative Costs of UT DWQ LID BMPs

Utah LID BMP		Costs[1, 2]	
		Initial	Operation & Maintenance
BR-1	Rain Garden	$	$
BR-2	Bioretention Cell	$$	$
BR-3	Bioswale	$	$
BR-4	Vegetated Strip	$	$
BR-5	Tree Box Filter	$$	$
BR-6	Green Roof	$$$	$$
PS-1	Pervious Surfaces	$$$	$$
ID-1	Infiltration Basin	$$$	$$
ID-2	Infiltration Trench	$$$	$
ID-3	Dry Well	$$	$$
ID-4	Underground Infiltration Galleries	$$$	$$
HR-1	Harvest and reuse	$	$$

[1] as adapted from Impact Infrastructure, LLC. & Stantec, 2014 for arid regions

[2] as adapted from Mateleska, K. 2016

- ### Inspections & Maintenance

  Long-term inspection and maintenance plans are key to ensuring successful implementation of LID Practices. Typical of any storm water management element, LID BMPs will require ongoing inspection and maintenance. As a part of the development approval, it is incumbent upon the developer/engineer to provide an operations and maintenance plan. The plan shall include responsibility for inspecting and maintaining, frequency of inspections and estimated upkeep or replacement costs. The plan should be submitted for approval to the local jurisdiction. If the operations and maintenance is to be provided by the local jurisdiction, a storm water fee may be assessed in accordance with local codes and ordinances.

Infeasibility

The U.S. Environmental Protection Agency (EPA) has documented that implementing well-chosen LID techniques designed to reduce runoff of water and pollutants into rivers and groundwater saves money while protecting and restoring water quality. There is much literature and documentation that is supportive that an overall LID Approach enhances property values by creating aesthetic amenities and improves the overall quality of life within a community.

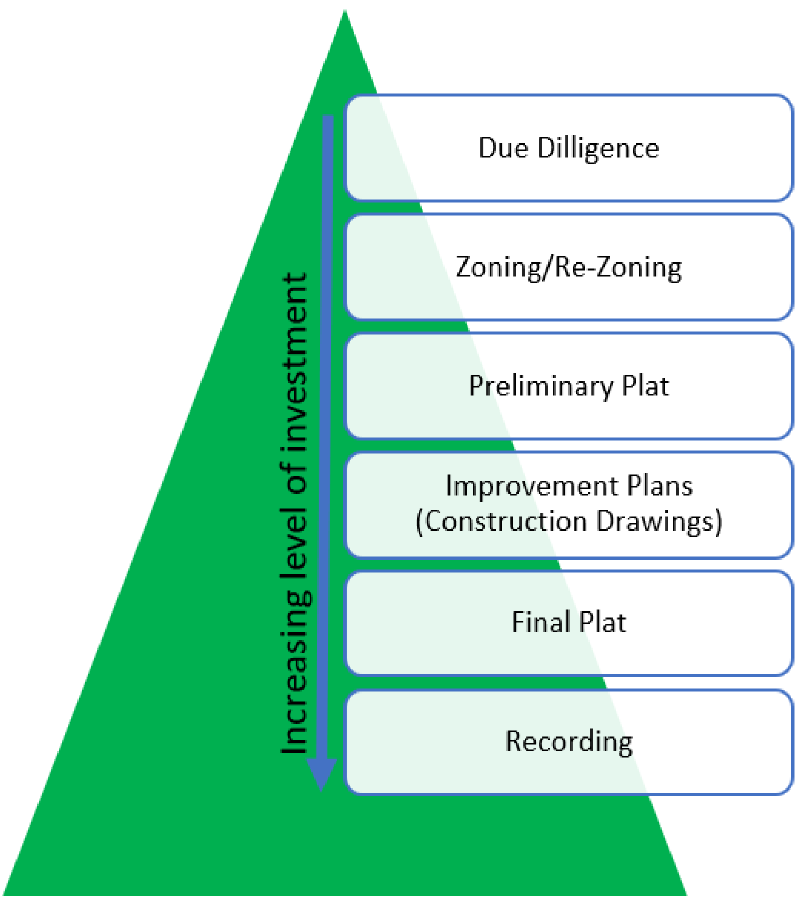
- **Technical Infeasibility**

This guidance document and matrix are intended to assist the user to work through feasibility of the UT DWQ LID BMPs for use within the Dixie Storm Water Coalition Region. According to the UPDES permit, infeasibility which would be considered technical are listed as:

- High groundwater,
- Drinking Water Source protection,
- Soil Conditions,
- Slopes, or
- Others.

- **Cost Infeasibility**

The Small MS4 General UPDES Permit describes "excessive cost" as a constraint contributing to infeasibility of the retention standards outlined in the General Permit for Discharges from Small Municipal Separate Storm Sewer Systems.



The following factors, not conclusive, would be considered by the entity when determining whether cost could be used as an infeasibility factor in meeting the retention requirement on-site. Other factors could be considered as appropriate:

- Cost infeasibility must be addressed early on in the approval process such as prior to preliminary plat, PD Zone Change, or the conceptual site plan phase of the approval process. Infeasibility due to cost would not be considered valid if only considered late in the approval process such as during final plan preparation.
- Consideration should be given to life-cycle vs initial installation cost.
- Where low maintenance non-structural BMP's incorporate existing landscape features (washes, rock outcrops, steep hillsides, open space, etc.) vs structural BMP's that require on-going long-term maintenance by the owner, HOA, or local agency.

• The cost of non-storm water required elements, such as drainage/flood control improvements, erosion protection, ground stabilization, detention requirements, that would be required regardless of the retention requirement, would generally not be included in the cost infeasibility analysis. However, these improvements may be considered in the overall LID Approach.

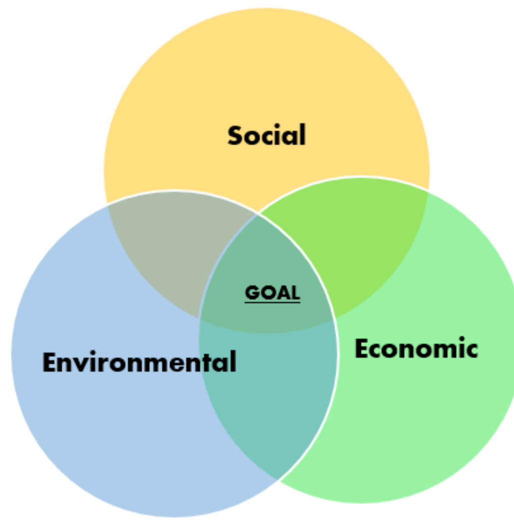
• Whether there is an impact and/or cost to downstream rivers and property due to releasing untreated runoff.

The above factors with accompanying documentation will be considered by the permitting agency on a case-by-case basis to determine if the retention requirement could be waived due to cost considerations.

All cost-based analyses, or cost-benefit scenarios are required to provide full considerations of the Social, Environmental, and Economic costs. The approach must provide an objective, defensible and repeatable approach to the cost-benefit of a particular LID BMP.

While there are several online tools to assist with this type of evaluation, it is essential that the selected tool includes cost tables associated with arid regions of the Southwestern United States. The following elements were identified within a recent study for the City of Phoenix and should be considered as a part of any TBL-CBA analysis (Autocase, Watershed Management Group, et. al., 2018).

1. Financial Costs and Benefits;
2. Carbon emissions and air pollution;
3. Heat island impacts;
4. Water quality improvement;
5. Flood risk reduction; and
6. Property value increases.



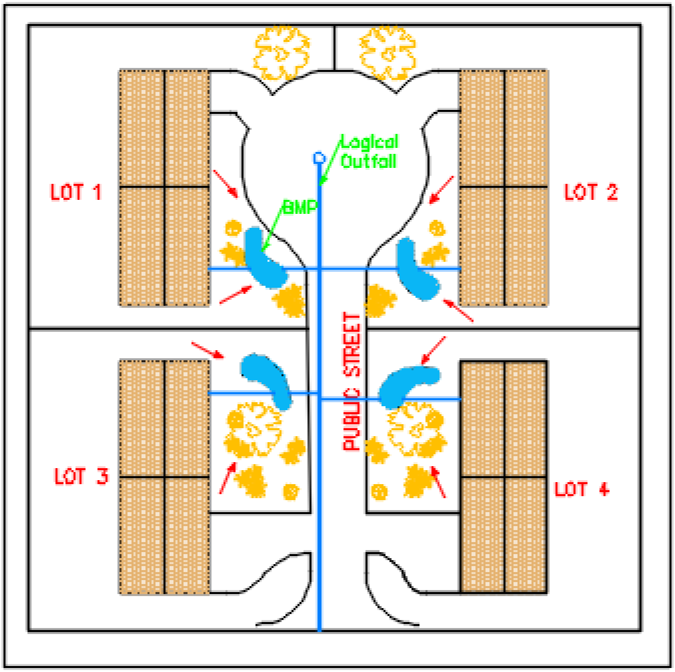
Example Application

Not every LID BMP is appropriate in every situation. The following worked example can serve as a guide for use of this Guidance Matrix and the Utah DWQ Guidance Manual. Note that the objective of this approach is the meet the requirements within the Utah DWQ Storm Water Permit. To the extent that meeting the conditions of that permit are not technically feasible, this manual can be used to support the case for a reduced (feasible) level of storm water retention based on satisfying the other constraints by walking through the Matrix.

Example – Subdivision Development

LID BMP Selection

An investor is considering a new 4-lot-per-acre single-family residential subdivision. During the due diligence phase concept planning efforts consider the potential for Lot Harvest & Reuse to meet the new state WQRV requirements.



Givens:

Logical downstream outfall condition exists.

Preliminary geotechnical engineering percolation test completed indicated infiltration rate of 0.51-inches.

No existing conditions to hinder percolation (P_{80} = 0.44-inches).

Estimate retention volume for each acre of development

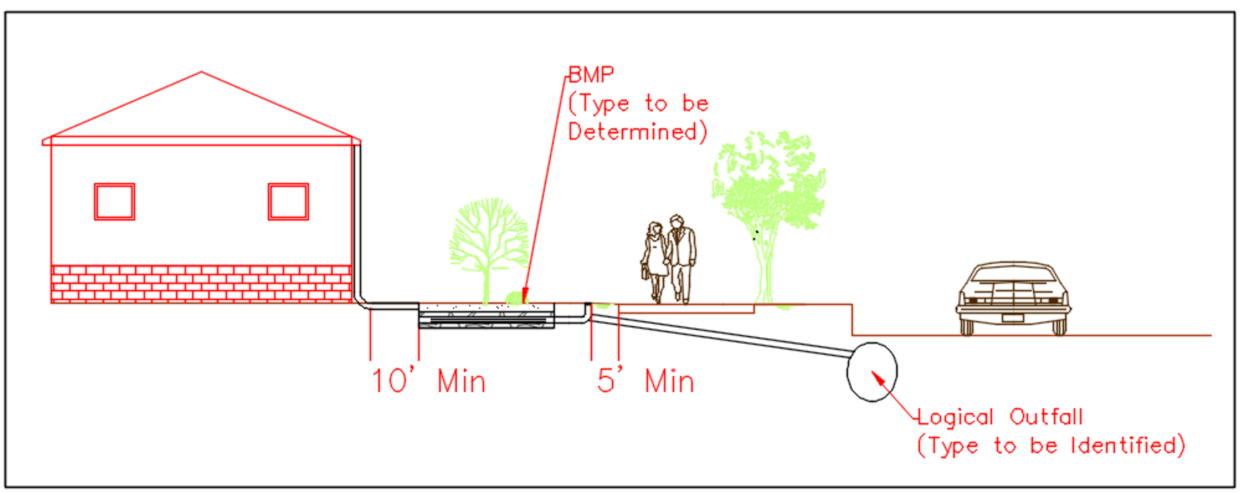
Area = 1 acre

Impervious cover = 35%

Storm Water Volume (Page 5):

R_{new} = 0.225 (Imp)+0.05
= 0.225*0.35+0.05
= 0.129

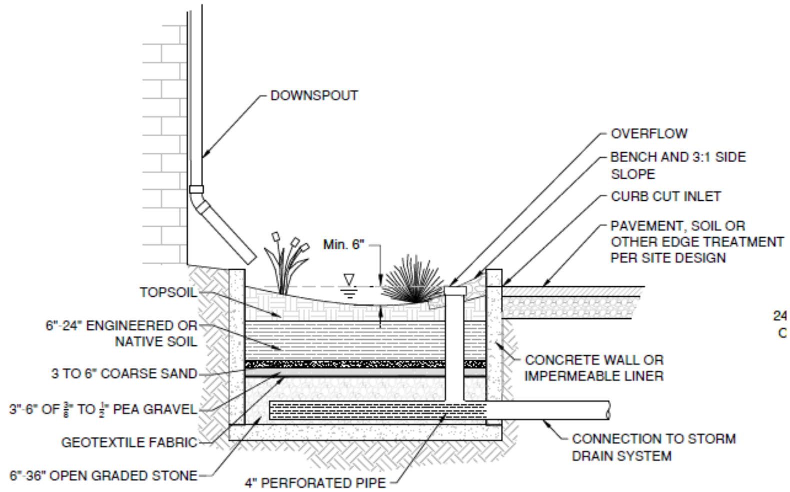
WQRV = (1)(0.129)(0.44)/(12)*43,560
= 206 cu-ft.



The 206 cu-ft is the amount of runoff that needs to be collected to meet the storm water quality requirements for each acre of development. On a per house basis this equates to 51.5 cu-ft. The total volume supplied by the selected BMPs must be equal to or greater than exceed that calculated or (Vbmp > WQRV).

Option 1 - Bio Retention Cell (BR-2)

$V_{br} = 1.2(V_{dep} + V_{ts} + V_{es} + V_{cs} + V_{pg} + V_{gl})$



Where,

V_{br} = Volume of Bio Retention Cell (cu-ft)
V_{dep} = Volume of Top Depression (cu-ft)
V_{cs} = Volume of Coarse Sand (cu-ft)
V_{ts} = Volume of Topsoil (cu-ft)
V_{pg} = Volume of pea gravel (cu-ft)
V_{es} = Volume of Engineered Soil (cu-ft)
V_{gl} = Volume of Gravel (cu-ft)

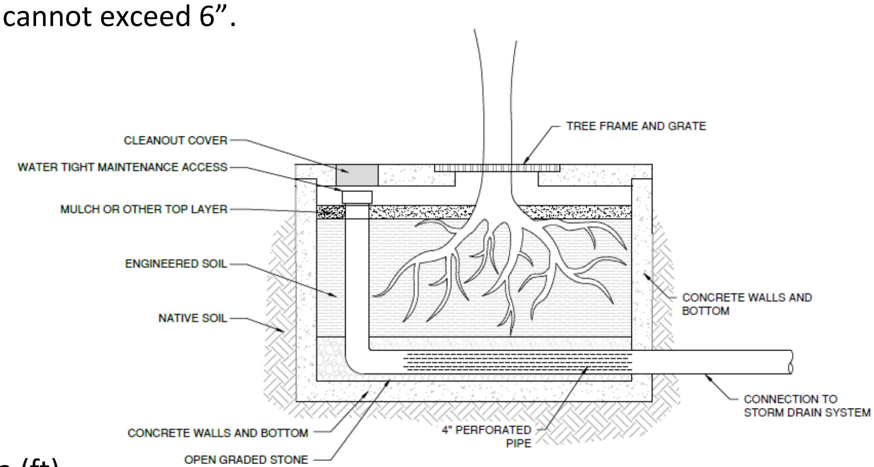
$V = A_{surface} \times T_{Layer} \times V_{Ratio}$.

$A_{surface}$ = Surface Area (ft)
T_{layer} = Thickness of Media (ft)
V_{ratio} = Void Ratio expressed as a decimal

The void ratio will be provided by a geotechnical engineer. No void ratio will be applied to the depression. The depression depth cannot exceed 6”.

Option 2 - Tree Box (BR-5)

$V_{tb} = 1.2(V_{gl})$



TREE BOX FILTERS
NTS

Where,

V_{tb} = Volume of Tree Box
V_{gl} = Volume of Gravel (cu-ft)

$V = A_{surface} \times T_{Layer} \times V_{Ratio}$.

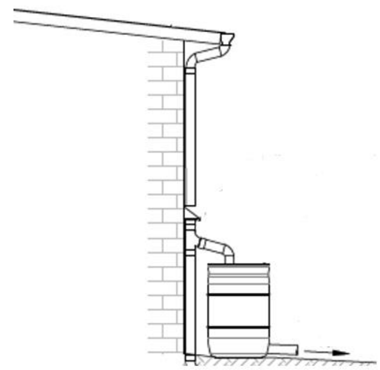
$A_{surface}$ = Surface Area (ft)
T_{layer} = Thickness of Media (ft)
V_{Ratio} = Void Ratio expressed as a decimal

The void ratio will be provided by a geotechnical engineer. No void ratio will be applied to the depression. The depression depth cannot exceed 6”.

Option 3 - Bio Swale[1] (BR-4)

$V_{bs} = 1.2(½(W_{top} + W_{Bottom})DL)$

Option 4 - Roof Cisterns (HR-1)



V_{cs} = will vary by manufacturer.

The size of the cistern cannot exceed the amount allowed be the State of Utah Code section 73-3-1.5. Should the volume of the cistern be less than WQRV then additional measures will be necessary to make up the deficiency.

Region Applicability Matrix

Step 1: Vertical Clearances

Applicability Matrix Step 1 Check:	
Step → / **Options**	**1 - Vertical Clearances**
1- Bio Retention Cell (BR-2)	Fully contained units have no vertical clearance limitations.
2- Tree Box (BR-5)	Fully contained units have no vertical clearance limitations.
3- Bio Swale (BR-4)	BR-4 requires more than 10-ft to groundwater and more than 5-ft to bedrock to be applicable
4- Roof Cisterns (HR-1)	Fully contained units have no vertical clearance limitations.

Step 2: Native/ In-Situ Soil Parameters

Applicability Matrix Step 2 Check:	
Step → / **Options**	**2 - *Native/ In-Situ Soil Parameters***
1- Bio Retention Cell (BR-2)	Fully contained units have engineered soil infill, no native soils.
2- Tree Box (BR-5)	Fully contained units have engineered soil infill, no native soils.
3- Bio Swale (BR-4)	Must have HSG Type A or B soils, infiltration rate of at least 0.5 in/hr., low to moderate risk of expansives/collapse and less than 3% gypsiferous soils.
4- Roof Cisterns (HR-1)	Generally comprised of above ground hollow cells, native materials must support bearing capacity only.

[1] Note: In-situ infiltration rate is equal to at least 0.5 in/hr.

Step 3: Horizontal Clearances

Applicability Matrix Step 3 Check:	
Step → / **Options**	**3 - *Horizontal Clearances***
1- Bio Retention Cell (BR-2)	Must be at least 10-ft from buildings (50-ft if basement), 5-ft from public road, and 20-ft from any pipeline infrastructure (gas, water, sewer, etc.)
2- Tree Box (BR-5)	Self-contained units can be placed without restriction
3- Bio Swale (BR-4)	Must be at least 10-ft from buildings (50-ft if basement), 5-ft from public roads.
4- Roof Cisterns (HR-1)	Self-contained units can be placed without restriction

Step 4: Downstream Outfall Conditions

Applicability Matrix Step 4 Check:	
Step → / **Options**	**4 - *Downstream Outfall Conditions***
1- Bio Retention Cell (BR-2)	Underground units require a downstream storm-drain or drywell (if applicable).
2- Tree Box (BR-5)	Underground Tree box filters require a downstream storm-drain or drywell (if applicable).
3- Bio Swale (BR-4)	Bio-swale can maintain a positive slope with positive outflow
4- Roof Cisterns (HR-1)	Above ground unit can overflow to yard as surface flow.

Summary of Region Applicability Matrix

Based on the example provided above, the table below provides a summary of the applicability of the selected options.

Applicability Matrix Check (Applicable - Y/N)				
Step → / **Options**	**1, Vertical Clearances**	**2, *Native/ In-Situ Soil Parameters***	**3, *Horizontal Clearances***	**4, *Downstream Outfall Conditions***
1- Bio Retention Cell (BR-2)	Y	Y	Y	Y
2- Tree Box (BR-5)	Y	Y	Y	Y
3- Bio Swale (BR-4)	Y	Y	Y	Y
4- Roof Cisterns (HR-1)	Y	Y	Y	Y

In addition to providing guidance on the selection of BMP and meeting the requirements set forth by UT DWQ, the Dixie Storm Water Coalition has provided a Storm Water Quality Report Template (Attachment 1). The Storm Water Quality Report Template shall be completed and submitted for review as part of the compliance process.

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Maps

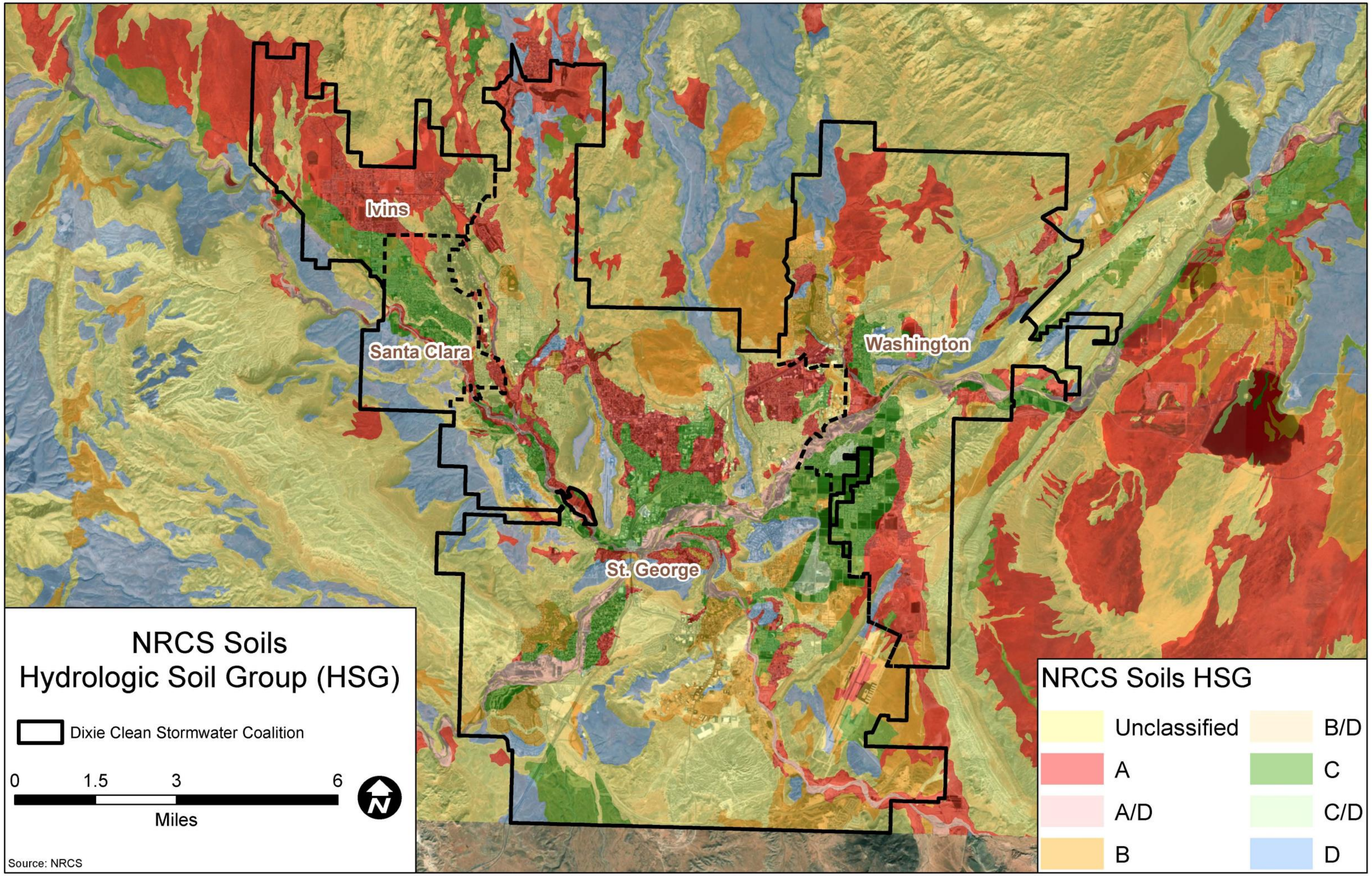


Figure 3 Hydrologic Soil Group Map

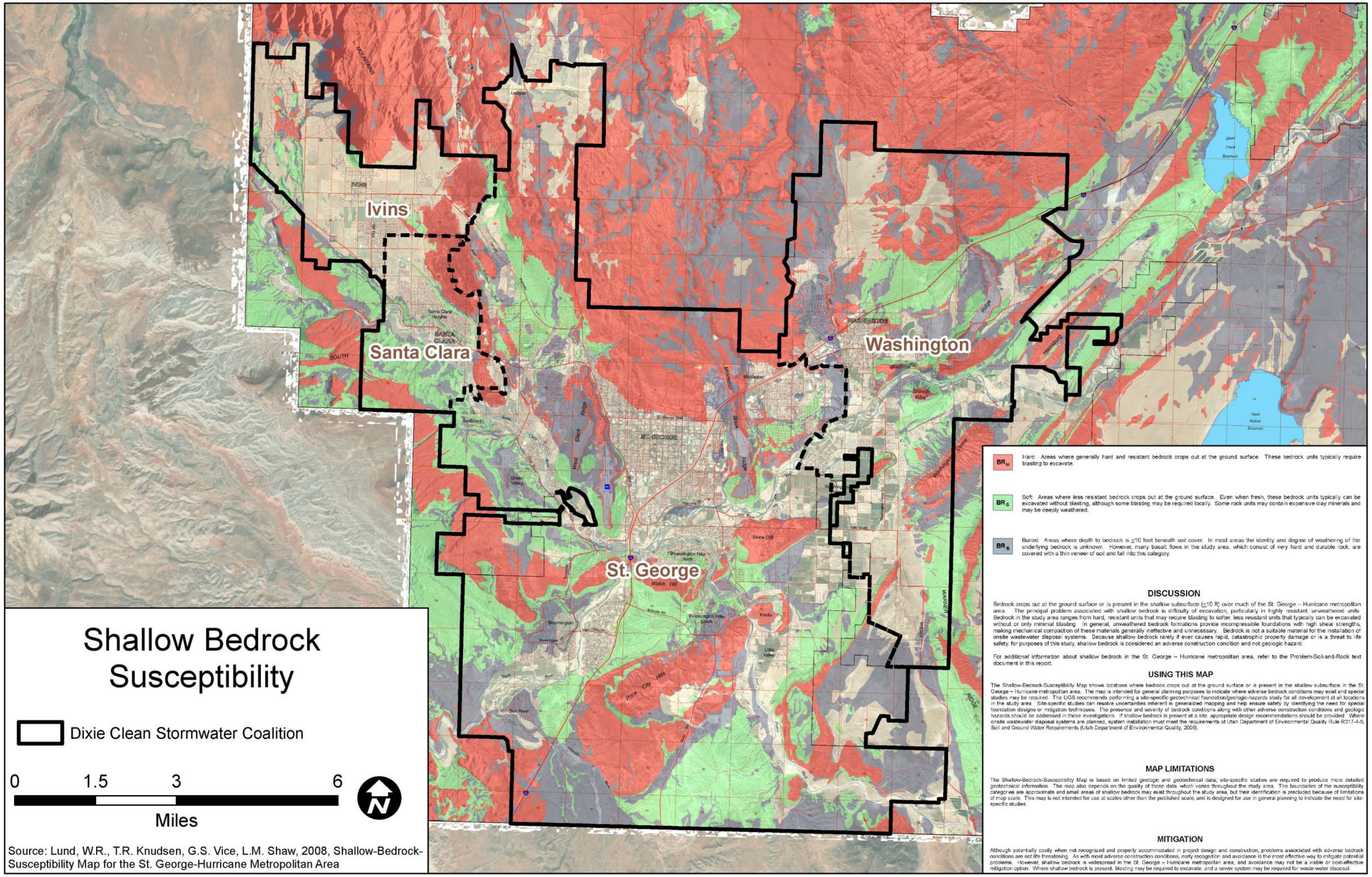


Figure 4 Shallow Bedrock Map

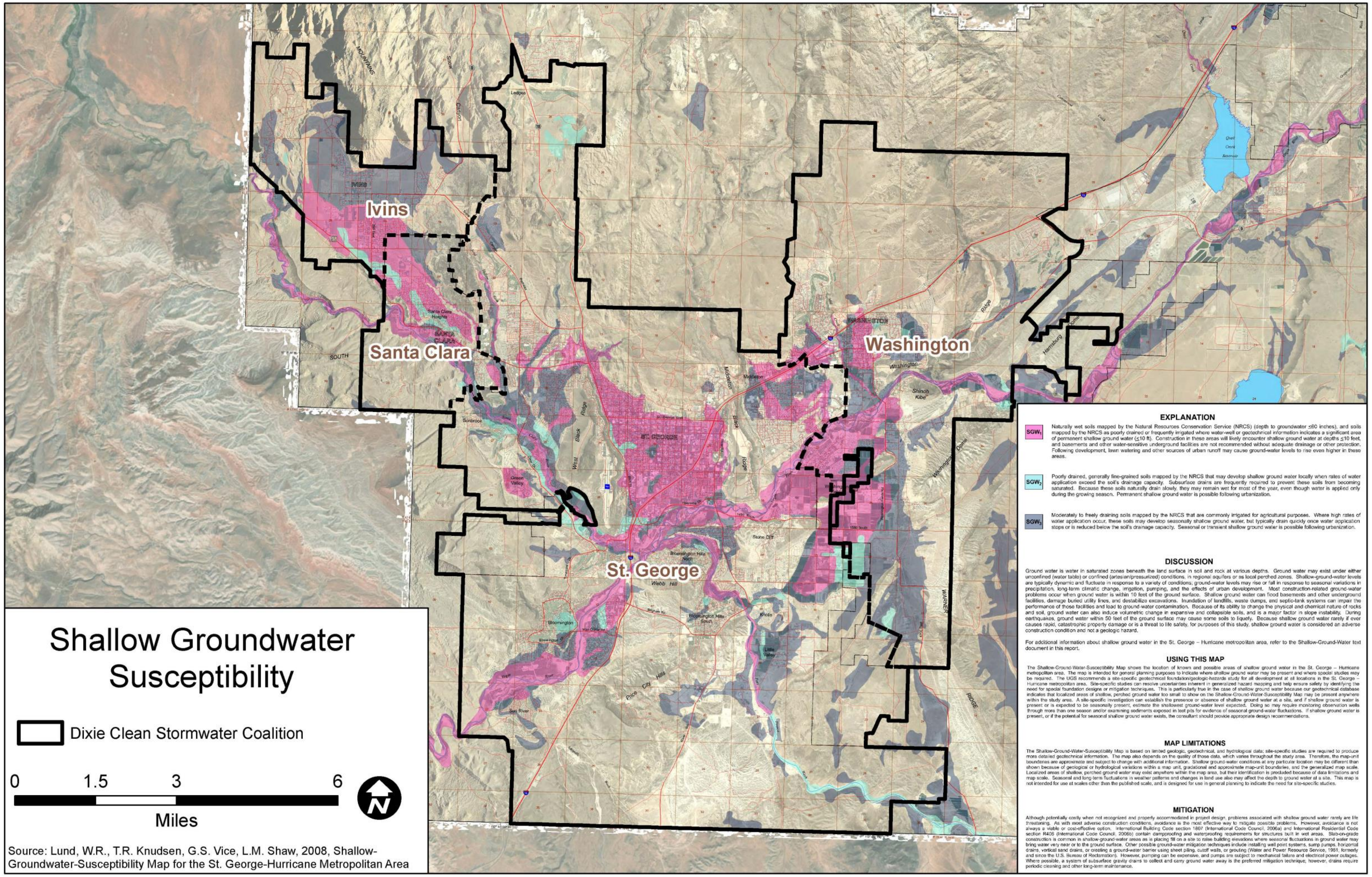


Figure 5 High/Shallow Groundwater Map

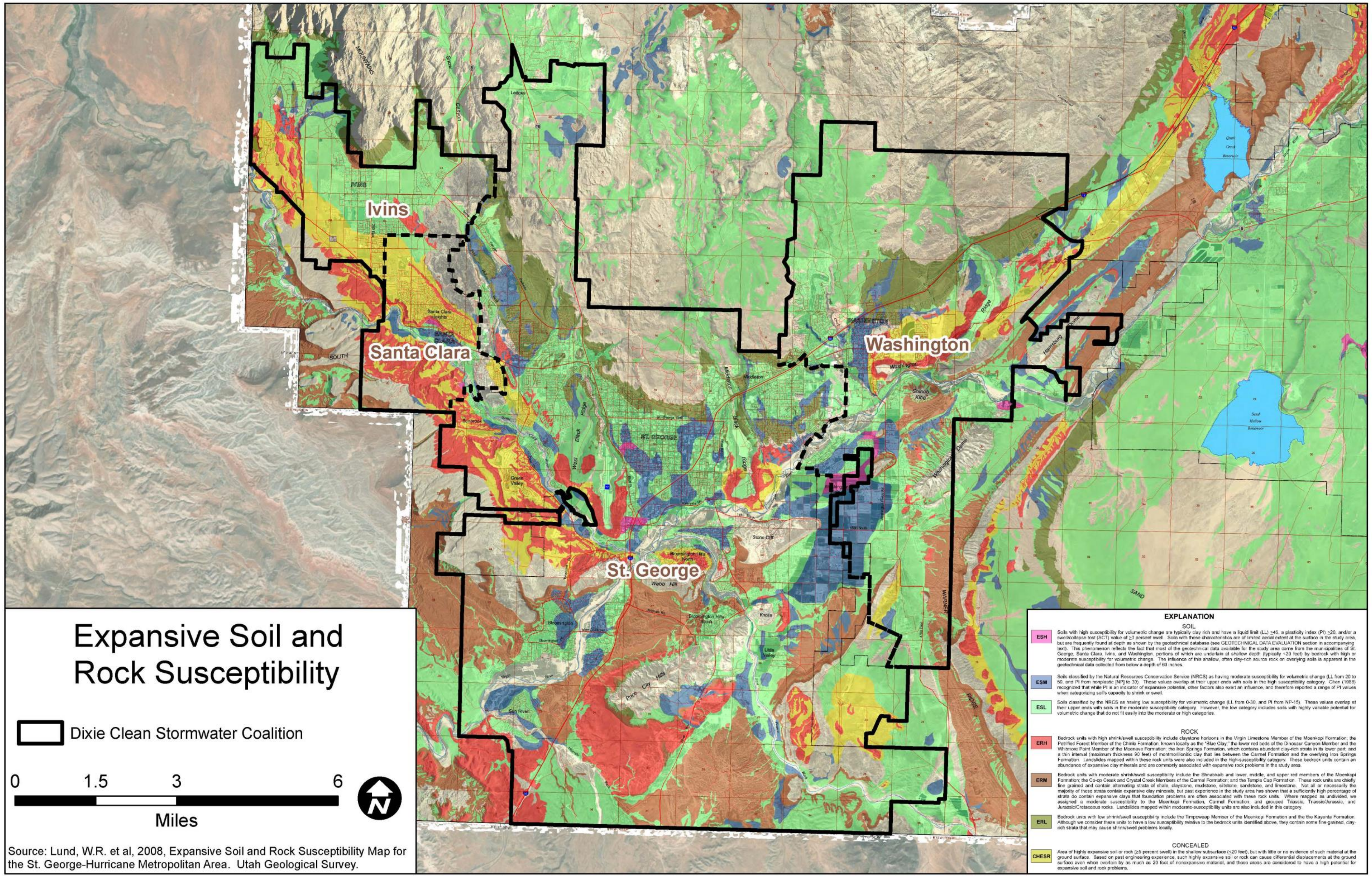


Figure 6 **Expansive Soil & Rock Map**

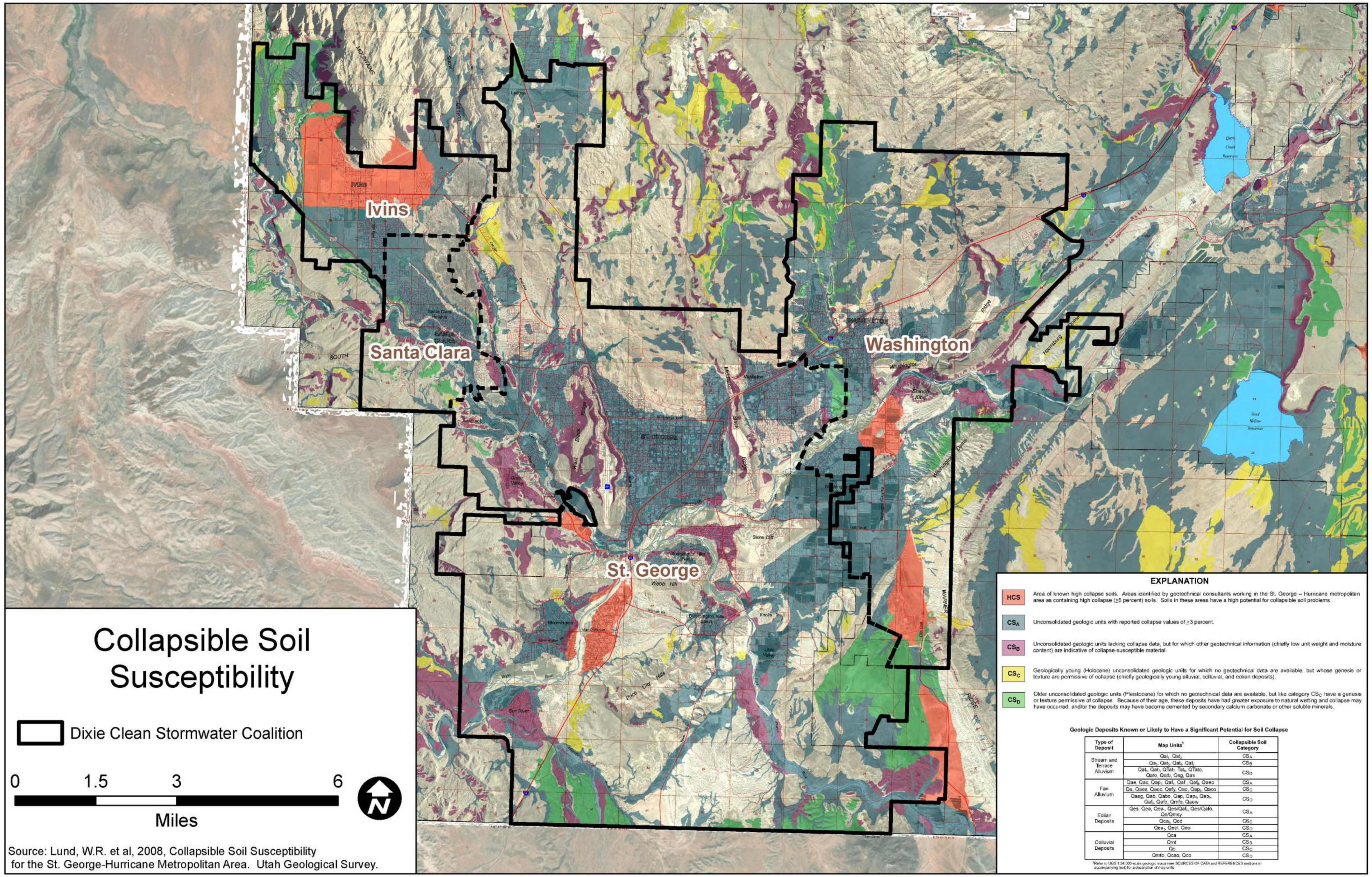


Figure 7 **Collapsible Soil Map**

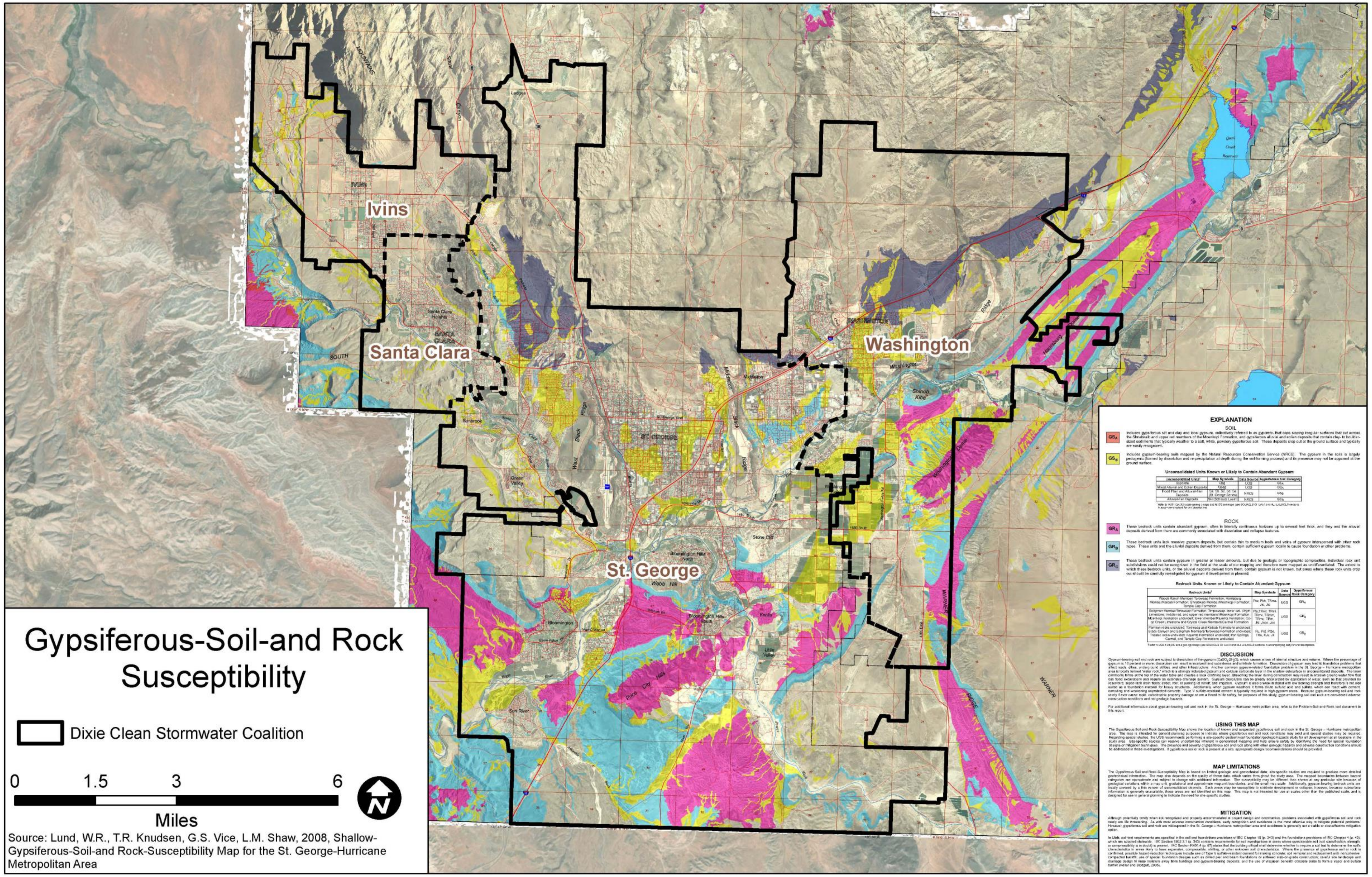


Figure 8 **Gypsiferous Soils Map**

Attachment 1 – Storm Water Quality Report - Template

Dixie Storm Water Coalition
St. George, Washington, Ivins, Santa Clara

Storm Water Quality Report – Template

Date: ________________________________

Project Name: _________________________

Project ID: ___________________________

Design Engineer: _______________________

Is the project within a watershed that is 303(d) listed? ______________

If yes:

Name of receiving water(s): ____

Listed Impairment(s): ____

Does the watershed have an approved TMDL? ______________

If yes:

Approved TMDL(s): ____

I have reviewed the storm water quality design and find this report to be complete, accurate, and current.

____

[name], Project Manager

____

[name], Designate Storm Water Coordinator

____

[name], Head of Maintenance

[stamp required at final design phase]

____

[name], Landscape Architect or Equivalent

Project Information

Type of Project (New Development, Redevelopment): ______________________

Area of Land Disturbance (ac): ________

Project Impervious Area (ac): _________

Project Imperviousness (%): __________

Project Volumetric Runoff Coefficient, R_V: ____________

80^{th} Storm Depth (in): ___________

Project 80^{th} Percentile Volume, V_{goal} (cf): _______

Subsurface Information

Groundwater

Depth to Groundwater (ft): _______

Historical High Depth to Groundwater if known (ft): _______

Source: ________________________________

Groundwater Contamination at Site: _______________

Soil Information

Infiltration Rate (in/hr): ____________

Hydrologic Soil Group: ________________

Source: ____________________________

Soil Contamination at Site: ____________

Drinking Water

Within Drinking Water Source Area Protection: __________

Additional Relevant Site Information

____

____

____

Dixie Storm Water Coalition
St. George, Washington, Ivins, Santa Clara

LID Drainage Areas

Add additional rows as needed.

Contributing Drainage Area	Area (ac)	Impervious Area (ac)	Imperviousness (%)	Volumetric Runoff Coefficient, R_V	Water Quality Volume, WQV (cf)
CDA 1					
CDA 2					
CDA 3					
CDA 4					
				Total WQV (cf)	

LID BMP Design

Add additional rows as needed.

Contributing Drainage Area	LID BMP Type	Water Quality Volume, WQV (cf)	Runoff Retained (cf)	Percent of Runoff Captured (%)
CDA1				
CDA 2				
CDA 3				
CDA 4				
		Total Volume Retained (cf)		

Percent of V_{goal} captured by LID BMPs: _____%

If 100% of V_{goal} is not captured, document and provide narrative of technical infeasibilities and/or alternate compliance measures below:

Describe additional storm water quality measures incorporated into the site:

Attachment 2 – Bowen Collins Procedure

BOWEN COLLINS & ASSOCIATES

TECHNICAL MEMORANDUM

TO:	Melinda Gibson Dixie Clean Storm Water Coalition Chair Ivins City Public Works 55 N Main Ivins, UT 84738
COPIES:	Lester Dalton – Washington City Public Works Todd Olsen – BC&A File
FROM:	Clinton Merrell, P.E., CFM 20 North Main, Suite No. 107 St. George, Utah 84770
DATE:	May 27, 2020
SUBJECT:	Disconnecting Impervious Areas to Increase On-site Infiltration and Reuse
JOB NO.:	446-20-01

BACKGROUND/PURPOSE

On February 26, 2020, the Utah Department of Environmental Quality (DEQ) General Permit for Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) was modified. This permit (Permit No. UTR090000) establishes the requirements most MS4s in the state of Utah must meet in order to discharge stormwater runoff to downstream surface waters under the Utah Pollutant Discharge Elimination System (UPDES). Section 4.2.5.1.2 of the permit states:

> *Retention Requirement. The Permittee must develop and define a specific hydrologic method or methods for calculating runoff volumes and flow rates to ensure consistent sizing of structural BMPs* [Best Management Practices] *in their jurisdiction and to facilitate plan review.*
>
> *By July 1, 2020, new development projects that disturb land greater than or equal to one acre, including projects that are part of a larger common plan of development or sale which collectively disturbs land greater than or equal to one acre must manage rainfall on-site, and prevent the off-site discharge of the precipitation from all rainfall events less than or equal to the 80th percentile rainfall event or a predevelopment hydrologic condition, whichever is less. This objective must be accomplished by the use of practices that are designed, constructed, and maintained to infiltrate, evapotranspire and/or harvest and reuse rainwater. The 80th percentile rainfall event is the event whose precipitation total is greater than or equal to 80 percent of all storm events over a given period of record.*

Washington City, a member of the Dixie Clean Storm Water coalition, asked Bowen Collins and Associates (BC&A) to determine how to quantify the increase in on-site infiltration and reuse of stormwater resulting from decreasing the amount of directly connected impervious area (DCIA) on a site. Specifically, BC&A evaluated the practice of disconnecting residential building rooftop drains (rain gutters) from downstream directly connected impervious areas (driveways, sidewalks, etc). This Technical Memorandum (TM) will provide background on the hydrologic analysis of both directly-connected and unconnected impervious areas, demonstrate how to apply these hydrologic methods to residential development in Washington County, and provide recommendations for implementing the practice of disconnecting directly connected impervious areas as a storm water Best Management Practice (BMP).

ESTIMATING RUNOFF FROM DIRECTLY CONNECTED IMPERVIOUS AREAS

Many different hydrologic methods exist for estimating the magnitude of runoff from any given site. The "SCS Curve Number" method described in the National Resource Conservation Service's (NRCS) National Engineering Handbook, Part 630 (NEH-630) and NRCS Technical Release 55, Urban Hydrology for Small Watersheds (TR-55) is a popular method due to its relative simplicity and ease of use. The method requires the user determine a "curve number," or CN, for the subject drainage area based on the combination of land cover and underlying soil type. This curve number is then used to determine the estimated volume of runoff that can be expected to result from a given volume of rainfall.

In addition to land use and soil type, the curve number for a given drainage area is dependent on the presence of impervious areas. The effects of impervious areas are more significant when the impervious areas are "directly connected." According to NEH-630.0901(c)(1):

> *"An impervious area is considered connected if runoff from it flows directly into the drainage system. It is also considered connected if runoff from it occurs as shallow concentrated flow that runs over a pervious area and then into a drainage system."*

TR-55 and NEH-630 provide several tables with typical CN values for various land cover and soil type combinations. Often engineers choose curve numbers directly from the TR-55 tables for their subject study areas. These table include descriptions for areas which include both pervious and impervious areas such as "Residential districts by average lot size." For these areas, the CN values listed include assumptions about the total percent impervious, directly connected impervious areas, and the hydrologic condition of pervious areas. If the subject area has different characteristics from those assumed to develop the CN values in the table, those values should not be applied to the subject area. Instead, NEH-630 provides additional equations and figures to determine the CN value representative of the subject area.

Another typically employed practice is to compute a composite CN value for a subject area based on an area weighted average of various land uses-soil type combinations present withing the subject area. While this approach is typically valid, special care should be taken in urban area hydrology where impervious areas are present in the drainage area. Per the limitations outlined in TR-55 page 1-4:

> *"The user should understand the assumption reflected in the initial abstraction term (Ia) and should ascertain that the assumption applies to the situation. Ia, which consists of interception, initial infiltration, surface depression storage, evapotranspiration, and other factors, was generalized as 0.2S based on data from agricultural watersheds (S is the potential maximum retention after runoff begins). This approximation can be especially important in an urban application because the combination of impervious areas with pervious areas can imply a significant initial loss that may not take place."*

Where directly connected impervious areas are present, the New Jersey Stormwater Best Management Practices Manual (NJ SWBMP 2004) recommends using a weighted average volume method instead of the traditional weighted average curve number technique. With the weighted average volume method, the runoff for pervious and impervious areas in a subject drainage area are calculated separately and added together. Example 5-2 of the NJ SWBMP manual illustrates the difference in runoff volume between the two approaches. In the example, 1.25 inches of rainfall on a 3-acre development site, with 1 acre of connected impervious area (CN 98) and 2 acres of lawn and woods (CN 65) results in the following runoff volumes:

Weighted Average Curve Number Method: **1089 cu. ft.**

Weighted Average Volume Method: 3775 cu. ft. (impervious area) + 36 cu. ft. (pervious area) for a total of **3811 cu. ft.**

In this example, the weighted average volume method predicts approximately 3.5 times more runoff than the weighted average curve number method. Please refer to the excerpts of chapter 5 of the NJ SWBMP manual in Attachment A for the complete example.

It should be noted that when the commonly used hydrologic modeling software HEC-HMS is used to compute runoff volumes for drainage areas with impervious areas, the software uses an approach like the weighted average volume method recommended by the NJ SWBMP manual. HEC-HMS computes runoff volumes for the impervious areas and pervious areas separately if a percent impervious value is supplied for a sub basin element; however, for the impervious area, instead of using a curve number value of 98, the software assumes there are no losses for the impervious areas (i.e. CN 100) and all rainfall on those areas becomes runoff. If HEC-HMS were used for the Example above, the estimated volume would be:

HEC-HMS with % impervious: 4537 cu. ft (impervious area) + 36 cu. ft. (pervious area) for a total of **4573 cu. ft.**

The HEC-HMS estimate is the most conservative, predicting approximately 4.2 times the total runoff volume of the weighted average curve number method.

Based on these examples, a review of relevant hydrologic texts and experience, BC&A recommends using either the weighted average volume method or HEC-HMS with percent impervious for estimating runoff volumes from drainage areas with directly connected impervious areas.

ESTIMATING RUNOFF FROM UNCONNECTED IMPERVIOUS AREAS

When impervious areas are not directly connected to the downstream storm drain system, the areas are considered "unconnected." According to NEH-630:

> *"If runoff from impervious areas occurs over a pervious area as sheet flow prior to entering the drainage system, the impervious area is unconnected."*

NEH-630 provides a separate figure (NEH-630 Figure 9-4) or an equation (NEH-630 Figure 9-4) to determine a composite curve number for drainage areas with unconnected impervious areas; however, according to NEH-630, when more than 30 percent of the total drainage area is impervious area the absorptive capacity of the remaining pervious areas will not significantly affect runoff, and the unconnected impervious areas should be treated as directly connected.

All sites considered in this study have total percent impervious values greater than 30%, therefore another method for determining the runoff volume from unconnected impervious areas was needed. The NJ SWBMP provides a two-step runoff estimation technique for drainage areas with unconnected impervious areas. When using this approach, runoff from the upstream unconnected impervious areas is computed, then added as an additional rainfall depth on the downstream pervious area it sheet flows onto. Example 5-3 of the NJ SWBMP manual demonstrates this method for a 1.25-inch storm on a 3-acre drainage area with 1 acre of unconnected impervious area (CN 98) and 2 acres of lawn and woods (CN 65). The results of this example are summarized below, additional details are provided in the excerpts of the NJ SWBMP provided in Attachment A.

Unconnected Impervious Area runoff volume: 3775 cu. ft.

Impervious area runoff spread over 2 acres of downstream pervious area:

(3775 cu. ft.) / (2 acres) x (43,560 sq. ft. per acre) = 0.52 inches

Total effective rainfall on downstream pervious areas: 1.25 + 0.52 = 1.77 inches

Total site runoff off (1.77 inches over 2-acre downstream pervious area: **581 cu. ft.**

The parameters of examples 5-2 and 5-3 (rainfall, total area, impervious area, etc.) are constant with the only difference being, the 1 acre of impervious area is directly connected in example 5-2 and unconnected in example 5-3. It is interesting to note the reduction in runoff volume between the two examples:

Example 5-2, one acre of directly connected impervious area: 3811 cu. ft.

Example 5-3, one acre of unconnected impervious area: 581 cu. ft.

Reduction from "disconnecting" one acre of impervious area: **3230 cu. ft.** (85% reduction)

APPLICATION TO RESIDENTIAL DEVELOPMENTS IN WASHINGTON COUNTY

A primary goal of this study was to determine how to quantify the increase in on-site infiltration and reuse of stormwater resulting from decreasing the amount of DCIA on a site. Specifically, BC&A evaluated the practice of disconnecting building rooftop drains (rain gutters) from downstream DCIAs. Thirteen sites were selected from recent development projects in Washington City. Nine sites from two developments in residential, ¼ acre zoning areas, three sites from a development in a residential 1/8-acre zoning area, and a single site of townhomes in a Planned Unit Development (PUD) were selected. Although these sites were all within Washington City, they were qualitatively compared to other recent developments throughout Washington County and are similar enough that results from the analysis of the selected sites can reasonably be applied to similar new developments throughout the county, based on sound engineering judgement.

For each site, the curve number method described previously was used to estimate runoff volume for several scenarios. The hydrologic parameters for each scenario were developed as described below.

Rainfall

The UPDES permit for MS4s as cited previously requires each permittee to "*prevent the off-site discharge of the precipitation from all rainfall events less than or equal to the 80th percentile rainfall event or a predevelopment hydrologic condition, whichever is less.*" The Utah DEQ Division of Water Quality (DWQ) published a guidance document titled "A Guide to Low Impact Development within Utah" (DWQ 2018) which includes guidance on how to determine the 90th percentile storm for a given location from historical daily rainfall data. Rainfall daily summaries were obtained from the National Oceanic and Atmospheric Administration (NOAA) website for St. George, Utah. Details regarding the weather station used can be downloaded from:

https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00427516/detail

Following the procedure in the DWQ document, the 80th percentile rainfall depth for St. George, Utah was determined to be **0.44 inches**. This rainfall depth was used for all runoff estimates performed for this study.

Land Cover

For each selected site, 3-inch resolution, 2018 aerial imagery provided by Washington County was used to create polygons representing each of the following land cover types: directly connected impervious areas (driveways and public sidewalks), unconnected impervious areas (detached sheds and private sidewalks/concrete pads), roofs and lawns. The remaining portion of each lot was typically artificial desert landscaping and rock mulch with pervious weed barrier. The extent of each selected site was determined based on existing perimeter walls and extended to the top back of curb at the public roadway. For the purposes of this study, it was assumed that retention of runoff from the public roadways would be accounted for and treated separately from each individual lot in a subdivision. Site number one is shown in Figure 1. Figures for each site are provided in the detailed calculations in Attachment B.

Figure 1. Land cover map for Study Site 1.

Soil Type

Because all four hydrologic soil types are found throughout Washington County, each site was analyzed four times, once for each soil type. This approach facilitates the application of the results to other similar sites throughout the county.

Curve Number Selection and Runoff Estimates

For each site, curve numbers were selected, and runoff volume estimates were created for the following scenarios:

1. Undeveloped – using TR-55 Table 2-2d CN value for desert in fair hydrologic condition (30-70% ground cover).
2. Developed (Composite Curve Number) – using the weighted average (composite) curve number method. Composite curve numbers for each site were computed using the typical

values from TR-55 shown in Table 1. This scenario was analyzed for comparison with the more conservative weighted average volume method.

Table 1
Curve Numbers Selected from TR-55

Land Cover Description	Curve Numbers for Soil Type			
	A	B	C	D
Undeveloped (Desert, Fair)	55	72	81	86
Natural Desert Landscaping	63	77	85	88
Lawn	39	61	74	80
Impervious Areas	98	98	98	98

3. Roof Connected (Weighted Average Volume) – This scenario is the same as the developed condition analysis, except the analysis was performed using the weighted average volume method described previously and in the NJ SWBMP manual. For this scenario, the roof of the main residence was assumed to be **directly connected** via rain gutters and yard drains to the downstream driveways, public sidewalks, and roadway storm drain system.
4. Roof Disconnected (Two-step Runoff Method) – This scenario is the same as the "Roof Connected" scenario, except that the roof of the main residence was assumed to be **disconnected** from the downstream driveways, public sidewalks, and roadway storm drain system. Specific guidelines for ensuring the rain gutters are adequately disconnected from downstream impervious areas will be provided later in this TM.

The difference between the volumes computed in the "Roof Connected" and "Roof Disconnected" scenarios is the reduction in runoff achieved by disconnecting a site's roof from the downstream impervious areas. A summary of the results of the runoff volume calculations for each studied site is included in Table 2 below. Detailed calculations for each site are provided in Attachment B. For specific details and step-by-step examples of the weighted average volume and two-step runoff methods, please refer to chapter 5 of the NJ SWMP manual.

Table 2
Summary of Runoff Volume Estimates

Site Parameters													
Site Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Zoning Type	Residential 1/4 Acre									Residential 1/8 Acre			Townhomes
Zoning Code	R-1-10									R-1-6			PUD
Total Area (acres)	0.23	0.24	0.19	0.19	0.19	0.29	0.23	0.21	0.26	0.12	0.14	0.12	12.77
Impervious Area (acres)	0.15	0.11	0.12	0.09	0.11	0.10	0.15	0.12	0.16	0.08	0.08	0.07	7.11
Total Percent Impervious	64%	49%	63%	46%	57%	34%	64%	57%	63%	64%	57%	57%	56%
Overall Average % Impervious	56%												
Runoff Volumes from the 80th Percentile Storm (0.46 in)													
Soil Type A													
Undeveloped (Desert, Fair) (Cu. Ft,)	0	0	0	0	0	0	0	0	0	0	0	0	0
Developed (Weighted Curve Number) (Cu. Ft,)	67	53	73	33	57	27	66	47	59	35	32	27	4756
Roofs Connected (Weighted Average Volume) (Cu. Ft,)	141	110	117	84	105	94	140	113	156	74	77	65	6813
Roofs Disconnected (Two-Step Runoff Method) (Cu. Ft,)	20	24	35	14	19	22	61	31	78	16	15	16	3538
Total Reduction in Runoff by Disconnecting Roofs (Cu. Ft,)	121	86	82	70	86	72	79	82	78	58	62	49	3275
Total Reduction in Runoff by Disconnecting Roofs (Gal.)	910	640	610	520	640	540	590	610	580	430	460	370	24500
Percent Reduction in Runoff by Disconnecting Roofs	86%	78%	70%	83%	82%	77%	56%	73%	50%	78%	81%	75%	52%
Average Reduction	74%												See Note 1
Soil Type B													
Undeveloped (Desert, Fair) (Cu. Ft,)	0	0	0	0	0	0	0	0	0	0	0	0	0
Developed (Weighted Curve Number) (Cu. Ft,)	67	53	73	33	57	27	66	47	59	35	32	27	4756
Roofs Connected (Weighted Average Volume) (Cu. Ft,)	141	110	117	84	105	94	140	113	156	74	77	65	6813
Roofs Disconnected (Two-Step Runoff Method) (Cu. Ft,)	20	24	36	14	19	22	61	31	78	16	15	16	3538
Total Reduction in Runoff by Disconnecting Roofs (Cu. Ft,)	121	86	81	70	86	72	79	82	78	58	62	49	3275
Total Reduction in Runoff by Disconnecting Roofs (Gal.)	910	640	610	520	640	540	590	610	580	430	460	370	24500
Percent Reduction in Runoff by Disconnecting Roofs	86%	78%	69%	83%	82%	77%	56%	73%	50%	78%	81%	75%	48%
Average Reduction	74%												See Note 1
Soil Type C													
Undeveloped (Desert, Fair) (Cu. Ft,)	0	0	0	0	0	0	0	0	0	0	0	0	0
Developed (Weighted Curve Number) (Cu. Ft,)	67	53	73	33	57	27	66	47	59	35	32	27	4756
Roofs Connected (Weighted Average Volume) (Cu. Ft,)	141	110	117	84	106	94	140	113	156	74	77	65	6850
Roofs Disconnected (Two-Step Runoff Method) (Cu. Ft,)	30	32	48	20	31	24	67	37	79	23	19	20	4002
Total Reduction in Runoff by Disconnecting Roofs (Cu. Ft,)	111	78	69	64	75	70	73	76	77	51	58	45	2848
Total Reduction in Runoff by Disconnecting Roofs (Gal.)	830	580	520	480	560	520	550	570	580	380	430	340	21300
Percent Reduction in Runoff by Disconnecting Roofs	79%	71%	59%	76%	71%	74%	52%	67%	49%	69%	75%	69%	42%
Average Reduction	68%												See Note 1
Soil Type D													
Undeveloped (Desert, Fair) (Cu. Ft,)	6	6	5	5	5	8	6	6	7	3	4	3	348
Developed (Weighted Curve Number) (Cu. Ft,)	67	53	73	33	57	27	66	47	59	35	32	27	4756
Roofs Connected (Weighted Average Volume) (Cu. Ft,)	141	113	120	87	109	97	141	114	156	75	78	66	7189
Roofs Disconnected (Two-Step Runoff Method) (Cu. Ft,)	43	47	63	32	47	35	79	49	88	31	29	27	4839
Total Reduction in Runoff by Disconnecting Roofs (Cu. Ft,)	98	66	57	55	62	62	62	65	68	44	49	39	2350
Total Reduction in Runoff by Disconnecting Roofs (Gal.)	730	490	430	410	460	460	460	490	510	330	370	290	17580
Percent Reduction in Runoff by Disconnecting Roofs	70%	58%	48%	63%	57%	64%	44%	57%	44%	59%	63%	59%	33%
Average Reduction	57%												See Note 1

Notes:

1. Site 13 was the only townhome site analyzed, therefore there is insufficient data to make solid recommendations for similar developments. Such developments should have a site-specific analysis performed to determine the estimated reduction runoff by disconnecting roofs.

Based on the results shown in Table 2 above, a number of observations can be made:

- The average total percent impervious across all sites is 56-percent, with values ranging from 34% to 64%. The typical residential development curve numbers in Table 2-2a of TR-55 assume a total percent impervious of 38% for 1/4-acre residential development and 65% for 1/8 acre or less residential developments. This reinforces the fact that engineers should exercise caution when using curve numbers for urban areas directly from Table 2-2a.
- For all soil types and all sites, there is a large difference in runoff volume predicted by the weighted average curve number and the weighted average volume methods. The weighted average volume method is about 200% of the weighted average curve number method for all sites except for the townhome subdivision, where the difference is about 150%.
- For all sites and soil types, there is a minimum 55% average reduction in estimated runoff when roofs are disconnected from downstream impervious areas.
- For soil types A and B at all sites (except site 13) when roofs are disconnected, the remaining downstream pervious area can absorb all the rainfall falling on the pervious area as well as all runoff from the rooftop. The only runoff from these sites is the runoff from rain fall on the remaining directly connected impervious areas (driveways and public sidewalks).

RECOMMENDATIONS

The DWQ low impact development (LID) guidance document (DWQ 2018) mentions the practice of disconnecting impervious areas as a recommended LID site design practice; however, no details are provided for quantifying the potential runoff reduction of the practice. The designer can use a site-specific analysis or approximate method as described in the following sections to refine post-development runoff volume estimates to account for disconnecting roofs from downstream impervious areas .

The reader should note that reducing runoff from a site by disconnecting rooftop drains as described in this TM will increase the amount of infiltration, retention, and evapotranspiration on a site. This TM provides guidelines and recommendations for determining the magnitude of this increase in infiltration. The potential geotechnical concerns which may arise from increasing retention and infiltration in the vicinity of structures is beyond the scope of this study. In evaluating the implementation of disconnected impervious areas as described herein, engineers, developers, and reviewers should exercise caution and consider all potential impacts of increased infiltration on a proposed site.

Site-Specific Analysis

A site-specific analysis can be conducted as follows:

1. Identify the 80th percentile rainfall depth
2. Determine the hydrologic soil type for the site – Sites with more than one soil type were not addressed in this TM but similar methods can be used to develop composite CN values for site pervious areas.
3. Determine undeveloped runoff volume – Calculate the estimated runoff for the site in the undeveloped condition using a weighted average for the undeveloped land cover. (Typically desert in Washington County)
4. Determine developed land cover areas –For the developed condition, delineate and measure the areas of land cover types present within a site, including but not limited to: directly connected impervious areas (driveways and public sidewalks), unconnected impervious

areas (detached sheds and private sidewalks/concrete pads), roofs and lawns, and other pervious areas (planters, gravel with pervious weed barrier).

5. Determine developed runoff volume with roofs connected – Use the weighted average volume method. Include the area of building rooftops in the value for DCIA. (See Example 5-2 of the NJ SWMP)
6. Determine developed runoff with roofs disconnected - Use the two-step runoff method (See NJ SWBMP Example 5-3)
    a. Calculate the runoff from building rooftops (using a CN of 98), then convert that volume to an equivalent rainfall depth over the area of the downstream unconnected pervious areas using the equations below:

$$P_{roofs} = \frac{V_{roofs}}{A_{per}} \, x \, 12$$

Where:
V_{roofs} = *Volume of runoff from roofs, cubic feet*
A_{per} = *Area of downstream, unconnected pervious areas where roof drains will discharge, square feet*
P_{roofs} = *Runoff from roofs as additional precipitation depth to be applied on downstream pervious areas, inches*

And:

$$P_{eqv} = P_{80} + P_{roofs}$$

Where:
P_{80} = *Precipitation depth of 80th percentile storm (0.44 inches in Washington County)*
P_{eqv} = *Total equivalent precipitation depth to be applied on downstream pervious areas, inches*

    b. Calculate the estimated runoff from the remaining pervious and connected impervious areas, using the weighted average volume method. For pervious areas, use the total equivalent precipitation depth (P_{eqv}) as calculated in 6a above. For remaining impervious areas, use the 80th percentile rainfall depth (P_{80}).
7. Determine volume reduction obtained by disconnecting roofs - Subtract the result of 6 from 5 above.
8. Compare undeveloped and developed runoff volumes – Subtract the result of 6 from 3 above. If the resulting difference in volume is greater than zero, additional BMPs can be implemented as feasible to further reduce post-development runoff volume to the maximum extent practical (MEP) as required by the general MS4 permit.

Approximate Method

Based on the results of the analysis conducted for sites 1 through 12, approximate reduction factors were selected to quickly approximate the runoff volume reduction achievable by disconnecting rooftops from downstream impervious areas. An approximate method analysis is conducted in the same manner as the site-specific analysis outlined above, however, the developed runoff volume with roofs disconnected (Step 6) can be approximated as follows:

6. Determine developed runoff volume with roofs disconnected – For a given site soil type, multiply the calculated volume by the appropriate factor from Table 3 below to obtain the runoff volume for the site when roofs are disconnected:

Table 3
Factors for Converting Runoff Volumes from Sites with Roofs Connected to Roofs Disconnected Condition

Soil Type	Reduction Factor[1]
A or B	0.35
C	0.45
D	0.55

Notes:
1. Reduction factor is the average ratio of disconnected to connected runoff with an additional factor for the uncertainty of site-specific conditions

This simplified method should be used only if the subject site meets the following conditions:

- The site is a single residential lot with land covers similar in type and proportion to the sites used in this study (see Attachment B for details).
- Total percent impervious is less than 65%.
- Pervious areas must include at least 20% lawn in good condition.

Additional Limitations

For any impervious area to be considered unconnected, the following conditions must be met:

1. All runoff from the unconnected impervious area must be sheet flow.
2. Upon entering the downstream pervious area, all runoff must remain as sheet flow.
3. Flow from the impervious surface must enter the downstream pervious area as sheet flow or, in the case of roofs, from downspouts equipped with splash pads, level spreaders, or dispersion trenches that reduce flow velocity and induce sheet flow in the downstream pervious area.
4. All discharges onto the downstream pervious surfaces must be stable and nonerosive.
5. The shape, slope, and vegetated cover in the downstream pervious area must be sufficient to maintain sheet flow throughout its length. Maximum slope of the downstream pervious area is 8 percent.
6. The maximum roof area that can be drained by a single downspout is 600 square feet.

In addition, downstream unconnected pervious areas must meet the following conditions:

1. The minimum sheet flow length across the downstream pervious area is 25 feet.
2. The maximum sheet flow length across the unconnected impervious area is 100 feet.
3. While the total flow length area may be greater, the maximum sheet flow length across the downstream pervious area that can be used to compute the total resultant runoff volume is 150 feet.

CONCLUSIONS

Based on the analysis of the residential sites selected for this study, the practice of disconnecting rooftops from downstream impervious areas can be used to reduce the runoff volume from the site by 55 to 74% on average, depending on the soil type. Using a combination of the weighted average volume and two-step runoff volume methods described in this TM, site designers and reviewers can quantify the estimated reduction in runoff volume achieved by disconnecting impervious areas for almost any site. When implementing this practice, designers and reviewers must ensure the proposed design meets the limitations for unconnected impervious and downstream unconnected pervious areas described in this TM.

REFERENCES

Natural Resources Conservation Service, National Engineering Handbook, Part 630, Hydrology.

New Jersey Department of Environmental Protection, April 2004, New Jersey Stormwater Best Management Practices Manual (https://www.njstormwater.org/bmp_manual2.htm).

U.S. Department of Agriculture, Soil Conservation Service, June 1986, Urban Hydrology for Small Watersheds, Technical Release 55.

Utah Department of Environmental Quality, Division of Water Quality, December 2018, A Guide to Low Impact Development within Utah.

Utah Department of Environmental Quality, Division of Water Quality, February 2020, General Permit for Discharges from Small Municipal Separate Storm Sewer Systems (MS4s), UPDES Permit Number UTR09000.

Attachment A – Excerpts from Chapter 5 of New Jersey Storm Water Best Management Practices Manual (2004)

Example 5-2: Site With Pervious and Directly Connected Impervious Cover
Runoff Volume Computation Using NRCS Methodology

Description: A 3-acre development site is comprised of 1 acre of impervious surface and 2 acres of lawn and woods with an NRCS Curve Number (CN) of 65. The entire impervious surface is directly connected to the site's drainage system. Compute the site's total runoff volume for the 1.25-inch stormwater quality design storm using the Weighted Average CN technique. Compare the results with the Weighted Average Volume technique.

Stormwater Quality Design Storm = P = 1.25 inches

Total drainage area = 3 acres

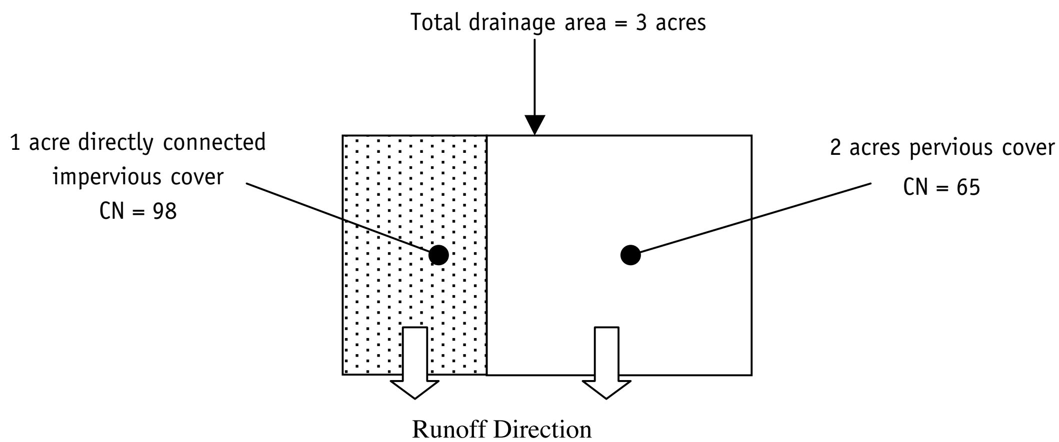
Impervious area = 1 acre (1/3 of total area)

Pervious area = 2 acres (2/3 of total area)

Pervious cover = mixture of lawn and woods   Pervious CN = 65

Impervious cover = asphalt   Impervious CN = 98

Note: All impervious cover is connected to the drainage system



1. Using Weighted Average Curve Number Technique

Weighted CN = (65)(2/3) + (98)(1/3) = 76

$$\text{Average } S = \frac{1000}{CN} - 10 = \frac{1000}{76} - 10 = 3.16 \text{ inches}$$

Average initial abstraction = Ia = 0.2S = (0.2)(3.16) = 0.63 inches

0.8S = (0.8)(3.16) = 2.53 inches

$$\text{Runoff volume} = Q = \frac{(P - 0.2\,S)^2}{P + 0.8\,S} = \frac{(1.25 - 0.63)^2}{1.25 + 2.53} = 0.10 \text{ inches}$$

Runoff volume = (0.10 inches/12 inches per foot)(3 acres)(43,560 sf per acre)

Total site runoff volume = 1089 cubic feet

2. Using Weighted Average Volume Technique

Impervious Area

$$\text{Impervious area } S = \frac{1000}{CN} - 10 = \frac{1000}{98} - 10 = 0.20 \text{ inches}$$

Impervious area initial abstraction = 0.2S = (0.2)(0.20) = 0.04 inches

0.8S = (0.8)(0.20) = 0.16 inches

$$\text{Impervious area runoff volume} = Q = \frac{(P - 0.2\,S)^2}{P + 0.8\,S} = \frac{(1.25 - 0.04)^2}{1.25 + 0.16} = 1.04 \text{ inches}$$

Runoff volume = (1.04 inches/12 inches per foot)(1 acre)(43,560 sf per acre)

Impervious area runoff volume = 3775 cubic feet

Pervious Area

$$\text{Pervious area } S = \frac{1000}{CN} - 10 = \frac{1000}{65} - 10 = 5.38 \text{ inches}$$

Pervious area initial abstraction = 0.2S = (0.2)(5.38) = 1.08 inches

0.8S = (0.8)(5.38) = 4.30 inches

$$\text{Pervious area runoff volume} = Q = \frac{(P - 0.2\,S)^2}{P + 0.8\,S} = \frac{(1.25 - 1.08)^2}{1.25 + 4.30} = 0.005 \text{ inches}$$

Runoff volume = (0.005 inches/12 inches per foot)(2 acres)(43,560 sf per acre)

Pervious area runoff volume = 36 cubic feet

Total site runoff volume = 3775 + 36 = 3811 cubic feet
(vs. 1089 cubic feet using weighted average CN)

As can be seen in Example 5-2 above, the weighted average CN technique produced an estimated stormwater quality design storm runoff volume that was less than 30 percent of the volume produced by the weighted average volume technique. Perhaps more significantly, the example also demonstrates how virtually the entire site runoff for the stormwater quality design storm comes from the impervious portion and that very little comes from the pervious portion (i.e., 3775 cubic feet vs. 36 cubic feet). The significant but erroneous initial loss that the NRCS cautions about in TR-55 can also be seen in the 0.63 inch initial abstraction for the entire site (including 1 acre of impervious surface) produced by the weighted average CN technique.

It is important to note that, in computing a weighted average runoff volume from the development site, Example 5-2 does not address the resultant peak discharge or hydrograph from the site. If both the pervious and directly connected impervious site areas will have the same time of concentration, the weighted runoff volume can then be used directly to compute the peak site discharge or hydrograph. However, if these areas will respond to rainfall with different times of concentration, separate hydrographs should be computed for each and then combined to produce the peak site discharge or hydrograph.

their own direct rainfall as well as the “rainfall” flowing from the upstream unconnected impervious areas. The resultant runoff from the downstream pervious areas in response to this combined rainfall can then be computed using the NRCS runoff equation again.

Example 5-3 illustrates this two-step runoff computation technique for unconnected impervious areas. In reviewing the example, it is important to note that the unconnected impervious area runoff depth must be converted to an equivalent uniform rainfall depth over the entire downstream pervious area based on the relative sizes of the unconnected impervious and downstream pervious areas.

Example 5-3: Site With Unconnected Impervious Cover
Runoff Volume Computation Using Two-Step Technique

Description: A 3-acre development site is comprised of 1 acre of impervious surface and 2 acres of lawn and woods with an NRCS Curve Number (CN) of 65. Runoff from the entire impervious surface sheet flows onto to the pervious portion of the site before entering the site's drainage system. Compute the total runoff volume for the 1.25-inch stormwater quality design storm using the NRCS methodology.

Stormwater Quality Design Storm = P = 1.25 inches

Total drainage area = 3 acres

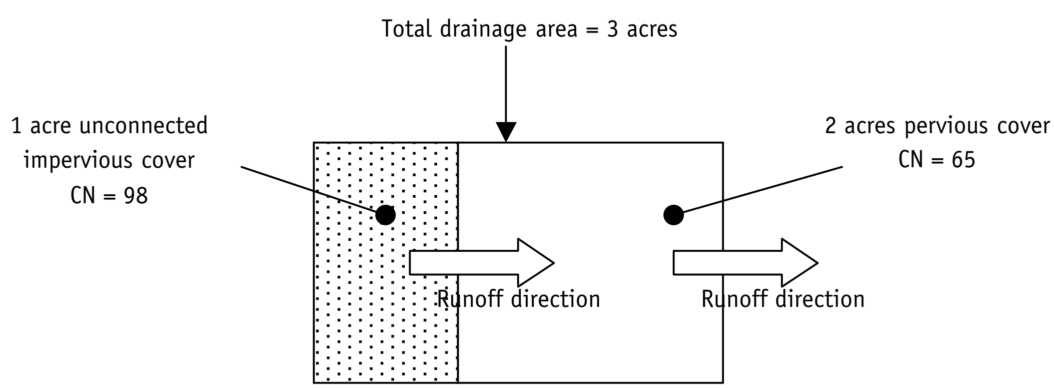
Impervious area = 1 acre (1/3 of total area)

Pervious area = 2 acres (2/3 of total area)

Pervious cover = mixture of lawn and woods pervious CN = 65

Impervious cover = asphalt impervious CN = 98

Note: All impervious area runoff sheet flows onto downstream pervious area



Impervious Area

$$\text{Impervious area } S = \frac{1000}{CN} - 10 = \frac{1000}{98} - 10 = 0.20 \text{ inches}$$

Impervious area initial abstraction = 0.2S = (0.2)(0.20) = 0.04 inches

0.8S = (0.8)(0.20) = 0.16 inches

$$\text{Impervious area runoff volume} = Q = \frac{(P - 0.2\,S)^2}{P + 0.8\,S} = \frac{(1.25 - 0.04)^2}{1.25 + 0.16} = 1.04 \text{ inches}$$

Runoff volume = (1.04 inches/12 inches per foot)(1 acre)(43,560 sf per acre)

Impervious area runoff volume = 3775 cubic feet

Equivalent rainfall depth on downstream pervious area =

(3775 cubic feet)/(2 acres)(43,560 sf per acre) = 0.043 feet = 0.52 inches

Pervious Area

Total effective rainfall = direct rainfall + unconnected impervious area runoff

= 1.25 inches + 0.52 inches = 1.77 inches total

$$\text{Pervious area } S = \frac{1000}{CN} - 10 = \frac{1000}{65} - 10 = 5.38 \text{ inches}$$

Pervious area initial abstraction = 0.2S = (0.2)(5.38) = 1.08 inches

0.8S = (0.8)(5.38) = 4.30 inches

$$\text{Pervious area runoff volume} = Q = \frac{(P - 0.2\,S)^2}{P + 0.8\,S} = \frac{(1.77 - 1.08)^2}{1.77 + 4.30} = 0.08 \text{ inches}$$

Runoff volume = (0.08 inches/12 inches per foot)(2 acres)(43,560 sf per acre)
= 581 cubic feet

Pervious area runoff volume = total runoff volume = 581 cubic feet

From the above example, it can be seen that a key parameter in the two-step runoff computation technique for unconnected impervious cover is the effective size of the downstream pervious area. The following three criteria, in conjunction with the seven requirements for all unconnected impervious areas shown above, should be used to determine the effective size of this downstream area:

1. The minimum sheet flow length across the downstream pervious area is 25 feet.
2. The maximum sheet flow length across the unconnected impervious area is 100 feet.
3. While the total flow length area may be greater, the maximum sheet flow length across the downstream pervious area that can be used to compute the total resultant runoff volume is 150 feet.

These criteria are illustrated below in Figures 5-5 and 5-6 for both on-grade and above-grade unconnected impervious areas, respectively. Additional criteria for determining the lower limits of the downstream pervious area are presented in Figure 5-7. When using Figure 5-6 with overlapping pervious areas downstream of roof downspouts, the overlapping areas should be counted only once in the computation of the total pervious area downstream of the roof.

Finally, when computing the peak runoff rate or hydrograph from an area with unconnected impervious cover, the time of concentration of the combined impervious and downstream pervious area should be based upon the Tc of the downstream pervious area only, with the Tc route beginning as sheet flow at the upper end of the pervious area.

Attachment B – Runoff Volume Calculations

Sample Site Data and Calculations are Provided FOR INFORMATION ONLY

Example Number	1
Zoning Type	Residential 1/4 Acre
Zoning ID	R-1-10

80th Percentile Storm Depth	**0.44**	in

Total Area	**0.229**	acres	9981	sq ft
Roof	0.119	acres	5187	sq ft
Driveway/sidewalk	0.021	acres	928	sq ft
Other Impervious	0.007	acres	288	sq ft
Lawn	0.046	acres	2021	sq ft
Other Pervious	0.036	acres	1556	sq ft

Impervious Areas				
Total Impervious Area	**0.147**	acres	6404	sq ft
	64%			
Directly Connected Impervious Areas				
w/ Roof connected	0.140	acres	6116	sq ft
w/ Roof disconnected	0.021	acres	928	sq ft
Unconnnected Impervious Areas				
w/ Roof connected	0.007	acres	288	sq ft
w/ Roof disconnected	0.126	acres	5476	sq ft

Curve numbers				
Soil Type	A	B	C	D
Undeveloped (Desert, Fair)	55	72	81	86
Natural Desert Landscaping	63	77	85	88
Lawn	39	61	74	80
Impervious Areas	98	98	98	98
Composite Pervious Numbers for this lot	**49**	**68**	**79**	**83**

Variable Abbreviations	
A_{imp}	Impervious Area, acres
A_{per}	Pervious Area, acres
P_{imp}	Percent Impervious, %
CN_p	Pervious Area Curve Number
CN_c	Composite Curve Number
S	Maxiumum Potential Retention, inches
Ia	Initial Abstraction, inches

Volume NEH 630/TR-55 Method

Scenario Description			A_{imp} (acres)	A_{per} (acres)	P_{imp} (%)	R (%)	CN_p -	CN_c -	S (in)	Ia (in)	Volume (in)	Volume (cu ft)	Volume (gal)	Comments
Soil Type A														
Undeveloped (Desert, Fair)					0	0	55	55	8.18	1.64	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.147	0.082	64		83	93	0.75	0.15	0.080	**67**	**500**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.082				49	10.41	2.08	0.000	0	0	
	Impervious Area		0.147					98	0.20	0.04	0.264	141	1055	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**141**	**1055**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.126					98	0.20	0.04	0.264	121	902	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.40												
	New Total Effective Rainfall Depth (in)	0.84												
	Downstream Pervious Area Runoff			0.082				49	10.41	2.08	0.000	0	0	
	Downstream Impervious Area Runoff		0.021					98	0.20	0.04	0.264	20	153	
	Weighted Volume Total											**20**	**153**	
Reduction in Runoff obtained by disconnecting Roof												**121**	**902**	
Soil Type B														
Undeveloped (Desert, Fair)					0	0	72	72	3.89	0.78	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.147	0.082	64		83	93	0.75	0.15	0.080	**67**	**500**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.082				68	4.71	0.94	0.000	0	0	
	Impervious Area		0.147					98	0.20	0.04	0.264	141	1055	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**141**	**1055**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.126					98	0.20	0.04	0.264	121	902	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.40												
	New Total Effective Rainfall Depth (in)	0.84												
	Downstream Pervious Area Runoff			0.082				68	4.71	0.94	0.000	0	0	
	Downstream Impervious Area Runoff		0.021					98	0.20	0.04	0.264	20	153	
	Weighted Volume Total											**20**	**153**	
Reduction in Runoff obtained by disconnecting Roof												**121**	**902**	
Soil Type C														
Undeveloped (Desert, Fair)					0	0	81	81	2.35	0.47	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.147	0.082	64		83	93	0.75	0.15	0.080	**67**	**500**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.082				79	2.66	0.53	0.000	0	0	
	Impervious Area		0.147					98	0.20	0.04	0.264	141	1055	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**141**	**1055**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.126					98	0.20	0.04	0.264	121	902	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.40												
	New Total Effective Rainfall Depth (in)	0.84												
	Downstream Pervious Area Runoff			0.082				79	2.66	0.53	0.032	10	71	
	Downstream Impervious Area Runoff		0.021					98	0.20	0.04	0.264	20	153	
	Weighted Volume Total											**30**	**224**	
Reduction in Runoff obtained by disconnecting Roof												**111**	**830**	
Soil Type D														
Undeveloped (Desert, Fair)					0	0	86	86	1.63	0.33	0.008	**6**	**47**	
Developed (Composite Curve Number Approach)			0.147	0.082	64		83	93	0.75	0.15	0.080	**67**	**500**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.082				83	2.05	0.41	0.000	0	1	
	Impervious Area		0.147					98	0.20	0.04	0.264	141	1055	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.265	**141**	**1056**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.126					98	0.20	0.04	0.264	121	902	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.40												
	New Total Effective Rainfall Depth (in)	0.84												
	Downstream Pervious Area Runoff			0.082				83	2.05	0.41	0.075	22	167	
	Downstream Impervious Area Runoff		0.021					98	0.20	0.04	0.264	20	153	
	Weighted Volume Total											**43**	**319**	
Reduction in Runoff obtained by disconnecting Roof												**98**	**736**	

Sample Site Data and Calculations are Provided FOR INFORMATION ONLY

Example Number	2	
Zoning Type	Residential 1/4 Acre	
Zoning ID	R-1-10	

80th Percentile Storm Depth	0.44	in

Total Area	0.235	acres	10255	sq ft
Roof	0.085	acres	3718	sq ft
Driveway/sidewalk	0.025	acres	1100	sq ft
Other Impervious	0.004	acres	170	sq ft
Lawn	0.030	acres	1289	sq ft
Other Pervious	0.091	acres	3978	sq ft

Impervious Areas				
Total Impervious Area	0.115	acres	4988	sq ft
	49%			
Directly Connected Impervious Areas				
w/ Roof connected	0.111	acres	4818	sq ft
w/ Roof disconnected	0.025	acres	1100	sq ft
Unconnnected Impervious Areas				
w/ Roof connected	0.004	acres	170	sq ft
w/ Roof disconnected	0.089	acres	3888	sq ft

Curve numbers				
Soil Type	A	B	C	D
Undeveloped (Desert, Fair)	55	72	81	86
Natural Desert Landscaping	63	77	85	88
Lawn	39	61	74	80
Impervious Areas	98	98	98	98
Composite Pervious Numbers for this lot	**57**	**73**	**82**	**86**

Variable Abbreviations	
A_{imp}	Impervious Area, acres
A_{per}	Pervious Area, acres
P_{imp}	Percent Impervious, %
CN_p	Pervious Area Curve Number
CN_c	Composite Curve Number
S	Maxiumum Potential Retention, inches
Ia	Initial Abstraction, inches

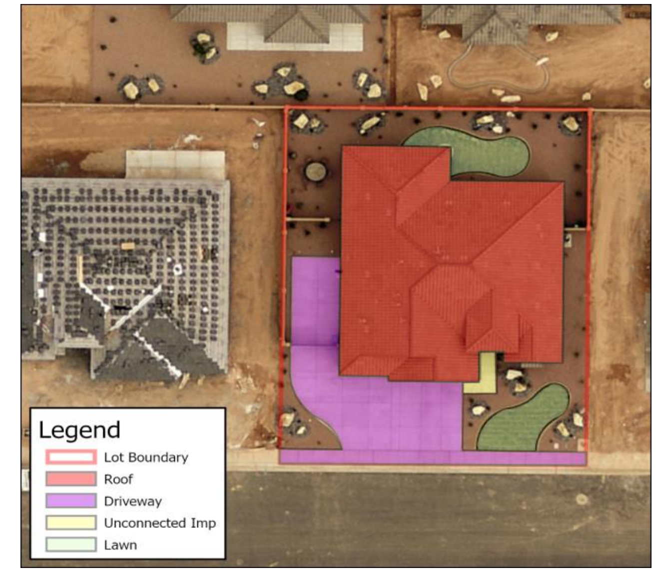
Volume NEH 630/TR-55 Method

Scenario Description			A_{imp} (acres)	A_{per} (acres)	P_{imp} (%)	R (%)	CN_p -	CN_c -	S (in)	Ia (in)	Volume (in)	Volume (cu ft)	Volume (gal)	Comments
Soil Type A														
Undeveloped (Desert, Fair)					0	0	55	55	8.18	1.64	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.115	0.121	49		86	92	0.87	0.17	0.062	**53**	**399**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.121				57	7.54	1.51	0.000	0	0	Calculates runoff from impervious area and pervious areas separately.
	Impervious Area		0.115					98	0.20	0.04	0.264	110	821	
	Weighted Volume Total										0.264	**110**	**821**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.089					98	0.20	0.04	0.264	86	640	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.20												
	New Total Effective Rainfall Depth (in)	0.64												
	Downstream Pervious Area Runoff			0.121				57	7.54	1.51	0.000	0	0	
	Downstream Impervious Area Runoff		0.025					98	0.20	0.04	0.264	24	181	
	Weighted Volume Total											**24**	**181**	
Reduction in Runoff obtained by disconnecting Roof												**86**	**640**	
Soil Type B														
Undeveloped (Desert, Fair)					0	0	72	72	3.89	0.78	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.115	0.121	49		86	92	0.87	0.17	0.062	**53**	**399**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.121				73	3.70	0.74	0.000	0	0	Calculates runoff from impervious area and pervious areas separately.
	Impervious Area		0.115					98	0.20	0.04	0.264	110	821	
	Weighted Volume Total										0.264	**110**	**821**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.089					98	0.20	0.04	0.264	86	640	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.20												
	New Total Effective Rainfall Depth (in)	0.64												
	Downstream Pervious Area Runoff			0.121				73	3.70	0.74	0.000	0	0	
	Downstream Impervious Area Runoff		0.025					98	0.20	0.04	0.264	24	181	
	Weighted Volume Total											**24**	**181**	
Reduction in Runoff obtained by disconnecting Roof												**86**	**640**	
Soil Type C														
Undeveloped (Desert, Fair)					0	0	81	81	2.35	0.47	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.115	0.121	49		86	92	0.87	0.17	0.062	**53**	**399**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.121				82	2.20	0.44	0.000	0	0	Calculates runoff from impervious area and pervious areas separately.
	Impervious Area		0.115					98	0.20	0.04	0.264	110	821	
	Weighted Volume Total										0.264	**110**	**821**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.089					98	0.20	0.04	0.264	86	640	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.20												
	New Total Effective Rainfall Depth (in)	0.64												
	Downstream Pervious Area Runoff			0.121				82	2.20	0.44	0.017	7	55	
	Downstream Impervious Area Runoff		0.025					98	0.20	0.04	0.264	24	181	
	Weighted Volume Total											**32**	**236**	
Reduction in Runoff obtained by disconnecting Roof												**78**	**585**	
Soil Type D														
Undeveloped (Desert, Fair)					0	0	86	86	1.63	0.33	0.008	**6**	**48**	
Developed (Composite Curve Number Approach)			0.115	0.121	49		86	92	0.87	0.17	0.062	**53**	**399**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.121				86	1.63	0.33	0.008	3	25	Calculates runoff from impervious area and pervious areas separately.
	Impervious Area		0.115					98	0.20	0.04	0.264	110	821	
	Weighted Volume Total										0.272	**113**	**846**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.089					98	0.20	0.04	0.264	86	640	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.20												
	New Total Effective Rainfall Depth (in)	0.64												
	Downstream Pervious Area Runoff			0.121				86	1.63	0.33	0.051	22	167	
	Downstream Impervious Area Runoff		0.025					98	0.20	0.04	0.264	24	181	
	Weighted Volume Total											**47**	**348**	
Reduction in Runoff obtained by disconnecting Roof												**67**	**498**	

Sample Site Data and Calculations are Provided FOR INFORMATION ONLY

Example Number	3
Zoning Type	Residential 1/4 Acre
Zoning ID	R-1-10

Variable Abbreviations	
A_{imp}	Impervious Area, acres
A_{per}	Pervious Area, acres
P_{imp}	Percent Impervious, %
CN_p	Pervious Area Curve Number
CN_c	Composite Curve Number
S	Maxiumum Potential Retention, inches
Ia	Initial Abstraction, inches



80th Percentile Storm Depth	0.44	in

Total Area	0.195	acres	8486	sq ft
Roof	0.083	acres	3624	sq ft
Driveway/sidewalk	0.037	acres	1613	sq ft
Other Impervious	0.002	acres	71	sq ft
Lawn	0.013	acres	563	sq ft
Other Pervious	0.060	acres	2615	sq ft

Impervious Areas				
Total Impervious Area	0.122	acres	5308	sq ft
	63%			
Directly Connected Impervious Areas				
w/ Roof connected	0.120	acres	5237	sq ft
w/ Roof disconnected	0.037	acres	1613	sq ft
Unconnnected Impervious Areas				
w/ Roof connected	0.002	acres	71	sq ft
w/ Roof disconnected	0.085	acres	3695	sq ft

Curve numbers				
Soil Type	A	B	C	D
Undeveloped (Desert, Fair)	55	72	81	86
Natural Desert Landscaping	63	77	85	88
Lawn	39	61	74	80
Impervious Areas	98	98	98	98
Composite Pervious Numbers for this lot	**59**	**74**	**83**	**87**

Volume NEH 630/TR-55 Method

Scenario Description			A_{imp} (acres)	A_{per} (acres)	P_{imp} (%)	R (%)	CN_p -	CN_c -	S (in)	Ia (in)	Volume (in)	Volume (cu ft)	Volume (gal)	Comments
Soil Type A														
Undeveloped (Desert, Fair)					0	0	55	55	8.18	1.64	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.122	0.073	63		87	94	0.64	0.13	0.103	**73**	**543**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.073				59	6.95	1.39	0.000	0	0	
	Impervious Area		0.122					98	0.20	0.04	0.264	117	874	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**117**	**874**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.085					98	0.20	0.04	0.264	81	609	
	Equiv. Rain on Downstream Pervious Area (in)	0.31												
	New Total Effective Rainfall Depth (in)	0.75												Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Pervious Area Runoff			0.073				59	6.95	1.39	0.000	0	0	
	Downstream Impervious Area Runoff		0.037					98	0.20	0.04	0.264	35	266	
	Weighted Volume Total											**35**	**266**	
Reduction in Runoff obtained by disconnecting Roof												**81**	**609**	
Soil Type B														
Undeveloped (Desert, Fair)					0	0	72	72	3.89	0.78	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.122	0.073	63		87	94	0.64	0.13	0.103	**73**	**543**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.073				74	3.51	0.70	0.000	0	0	
	Impervious Area		0.122					98	0.20	0.04	0.264	117	874	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**117**	**874**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.085					98	0.20	0.04	0.264	81	609	
	Equiv. Rain on Downstream Pervious Area (in)	0.31												
	New Total Effective Rainfall Depth (in)	0.75												Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Pervious Area Runoff			0.073				74	3.51	0.70	0.001	0	1	
	Downstream Impervious Area Runoff		0.037					98	0.20	0.04	0.264	35	266	
	Weighted Volume Total											**36**	**267**	
Reduction in Runoff obtained by disconnecting Roof												**81**	**607**	
Soil Type C														
Undeveloped (Desert, Fair)					0	0	81	81	2.35	0.47	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.122	0.073	63		87	94	0.64	0.13	0.103	**73**	**543**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.073				83	2.05	0.41	0.000	0	1	
	Impervious Area		0.122					98	0.20	0.04	0.264	117	874	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.265	**117**	**875**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.085					98	0.20	0.04	0.264	81	609	
	Equiv. Rain on Downstream Pervious Area (in)	0.31												
	New Total Effective Rainfall Depth (in)	0.75												Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Pervious Area Runoff			0.073				83	2.05	0.41	0.049	13	96	
	Downstream Impervious Area Runoff		0.037					98	0.20	0.04	0.264	35	266	
	Weighted Volume Total											**48**	**362**	
Reduction in Runoff obtained by disconnecting Roof												**69**	**513**	
Soil Type D														
Undeveloped (Desert, Fair)					0	0	86	86	1.63	0.33	0.008	**5**	**40**	
Developed (Composite Curve Number Approach)			0.122	0.073	63		87	94	0.64	0.13	0.103	**73**	**543**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.073				87	1.49	0.30	0.012	3	24	
	Impervious Area		0.122					98	0.20	0.04	0.264	117	874	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.276	**120**	**898**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.085					98	0.20	0.04	0.264	81	609	
	Equiv. Rain on Downstream Pervious Area (in)	0.31												
	New Total Effective Rainfall Depth (in)	0.75												Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Pervious Area Runoff			0.073				87	1.49	0.30	0.105	28	207	
	Downstream Impervious Area Runoff		0.037					98	0.20	0.04	0.264	35	266	
	Weighted Volume Total											**63**	**473**	
Reduction in Runoff obtained by disconnecting Roof												**57**	**425**	

Sample Site Data and Calculations are Provided FOR INFORMATION ONLY

Example Number	4		
Zoning Type	Residential 1/4 Acre		
Zoning ID	R-1-10		

80th Percentile Storm Depth	0.44	in

Total Area	0.193	acres	8394	sq ft
Roof	0.069	acres	3027	sq ft
Driveway/sidewalk	0.015	acres	638	sq ft
Other Impervious	0.004	acres	170	sq ft
Lawn	0.027	acres	1166	sq ft
Other Pervious	0.078	acres	3393	sq ft

Impervious Areas				
Total Impervious Area	0.088	acres	3834	sq ft
	46%			
Directly Connected Impervious Areas				
w/ Roof connected	0.084	acres	3664	sq ft
w/ Roof disconnected	0.015	acres	638	sq ft
Unconnnected Impervious Areas				
w/ Roof connected	0.004	acres	170	sq ft
w/ Roof disconnected	0.073	acres	3197	sq ft

Curve numbers				
Soil Type	A	B	C	D
Undeveloped (Desert, Fair)	55	72	81	86
Natural Desert Landscaping	63	77	85	88
Lawn	39	61	74	80
Impervious Areas	98	98	98	98
Composite Pervious Numbers for this lot	**57**	**73**	**82**	**86**

Variable Abbreviations	
A_{imp}	Impervious Area, acres
A_{per}	Pervious Area, acres
P_{imp}	Percent Impervious, %
CN_p	Pervious Area Curve Number
CN_c	Composite Curve Number
S	Maxiumum Potential Retention, inches
Ia	Initial Abstraction, inches

Volume NEH 630/TR-55 Method

Scenario Description			A_{imp}	A_{per}	P_{imp}	R	CN_p	CN_c	S	Ia	Volume			Comments
			(acres)	(acres)	(%)	(%)	-	-	(in)	(in)	(in)	(cu ft)	(gal)	
Soil Type A														
Undeveloped (Desert, Fair)					0	0	55	55	8.18	1.64	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.088	0.105	46		86	91	0.99	0.20	0.048	**33**	**249**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.105				57	7.54	1.51	0.000	0	0	Calculates runoff from impervious area and pervious areas separately.
	Impervious Area		0.088					98	0.20	0.04	0.264	84	631	
	Weighted Volume Total										0.264	**84**	**631**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.073					98	0.20	0.04	0.264	70	526	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.19												
	New Total Effective Rainfall Depth (in)	0.63												
	Downstream Pervious Area Runoff			0.105				57	7.54	1.51	0.000	0	0	
	Downstream Impervious Area Runoff		0.015					98	0.20	0.04	0.264	14	105	
	Weighted Volume Total											**14**	**105**	
Reduction in Runoff obtained by disconnecting Roof												**70**	**526**	
Soil Type B														
Undeveloped (Desert, Fair)					0	0	72	72	3.89	0.78	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.088	0.105	46		86	91	0.99	0.20	0.048	**33**	**249**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.105				73	3.70	0.74	0.000	0	0	Calculates runoff from impervious area and pervious areas separately.
	Impervious Area		0.088					98	0.20	0.04	0.264	84	631	
	Weighted Volume Total										0.264	**84**	**631**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.073					98	0.20	0.04	0.264	70	526	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.19												
	New Total Effective Rainfall Depth (in)	0.63												
	Downstream Pervious Area Runoff			0.105				73	3.70	0.74	0.000	0	0	
	Downstream Impervious Area Runoff		0.015					98	0.20	0.04	0.264	14	105	
	Weighted Volume Total											**14**	**105**	
Reduction in Runoff obtained by disconnecting Roof												**70**	**526**	
Soil Type C														
Undeveloped (Desert, Fair)					0	0	81	81	2.35	0.47	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.088	0.105	46		86	91	0.99	0.20	0.048	**33**	**249**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.105				82	2.20	0.44	0.000	0	0	Calculates runoff from impervious area and pervious areas separately.
	Impervious Area		0.088					98	0.20	0.04	0.264	84	631	
	Weighted Volume Total										0.264	**84**	**631**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.073					98	0.20	0.04	0.264	70	526	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.19												
	New Total Effective Rainfall Depth (in)	0.63												
	Downstream Pervious Area Runoff			0.105				82	2.20	0.44	0.015	6	43	
	Downstream Impervious Area Runoff		0.015					98	0.20	0.04	0.264	14	105	
	Weighted Volume Total											**20**	**148**	
Reduction in Runoff obtained by disconnecting Roof												**65**	**483**	
Soil Type D														
Undeveloped (Desert, Fair)					0	0	86	86	1.63	0.33	0.008	**5**	**39**	
Developed (Composite Curve Number Approach)			0.088	0.105	46		86	91	0.99	0.20	0.048	**33**	**249**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.105				86	1.63	0.33	0.008	3	21	Calculates runoff from impervious area and pervious areas separately.
	Impervious Area		0.088					98	0.20	0.04	0.264	84	631	
	Weighted Volume Total										0.272	**87**	**653**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.073					98	0.20	0.04	0.264	70	526	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.19												
	New Total Effective Rainfall Depth (in)	0.63												
	Downstream Pervious Area Runoff			0.105				86	1.63	0.33	0.048	18	136	
	Downstream Impervious Area Runoff		0.015					98	0.20	0.04	0.264	14	105	
	Weighted Volume Total											**32**	**241**	
Reduction in Runoff obtained by disconnecting Roof												**55**	**411**	

Sample Site Data and Calculations are Provided FOR INFORMATION ONLY

Example Number	5
Zoning Type	Residential 1/4 Acre
Zoning ID	R-1-10

Variable Abbreviations	
A_{imp}	Impervious Area, acres
A_{per}	Pervious Area, acres
P_{imp}	Percent Impervious, %
CN_p	Pervious Area Curve Number
CN_c	Composite Curve Number
S	Maxiumum Potential Retention, inches
Ia	Initial Abstraction, inches

80th Percentile Storm Depth	**0.44**	in

Total Area	**0.195**	acres	8474	sq ft
Roof	0.088	acres	3812	sq ft
Driveway/sidewalk	0.020	acres	855	sq ft
Other Impervious	0.003	acres	123	sq ft
Lawn	0.016	acres	684	sq ft
Other Pervious	0.069	acres	2999	sq ft

Impervious Areas				
Total Impervious Area	**0.110**	acres	4791	sq ft
	57%			
Directly Connected Impervious Areas				
w/ Roof connected	0.107	acres	4667	sq ft
w/ Roof disconnected	0.020	acres	855	sq ft
Unconnnected Impervious Areas				
w/ Roof connected	0.003	acres	123	sq ft
w/ Roof disconnected	0.090	acres	3935	sq ft

Curve numbers				
Soil Type	A	B	C	D
Undeveloped (Desert, Fair)	55	72	81	86
Natural Desert Landscaping	63	77	85	88
Lawn	39	61	74	80
Impervious Areas	98	98	98	98
Composite Pervious Numbers for this lot	**59**	**74**	**83**	**87**

Volume NEH 630/TR-55 Method

Scenario Description			A_{imp}	A_{per}	P_{imp}	R	CN_p	CN_c	S	Ia	Volume			Comments
			(acres)	(acres)	(%)	(%)	-	-	(in)	(in)	(in)	(cu ft)	(gal)	
Soil Type A														
Undeveloped (Desert, Fair)					0	0	55	55	8.18	1.64	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.110	0.085	57		87	93	0.75	0.15	0.080	**57**	**425**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.085				59	6.95	1.39	0.000	0	0	
	Impervious Area		0.110					98	0.20	0.04	0.264	105	789	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**105**	**789**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.090					98	0.20	0.04	0.264	87	648	
	Equiv. Rain on Downstream Pervious Area (in)	0.28												
	New Total Effective Rainfall Depth (in)	0.72												
	Downstream Pervious Area Runoff			0.085				59	6.95	1.39	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.020					98	0.20	0.04	0.264	19	141	
	Weighted Volume Total											**19**	**141**	
Reduction in Runoff obtained by disconnecting Roof												**87**	**648**	
Soil Type B														
Undeveloped (Desert, Fair)					0	0	72	72	3.89	0.78	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.110	0.085	57		87	93	0.75	0.15	0.080	**57**	**425**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.085				74	3.51	0.70	0.000	0	0	
	Impervious Area		0.110					98	0.20	0.04	0.264	105	789	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**105**	**789**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.090					98	0.20	0.04	0.264	87	648	
	Equiv. Rain on Downstream Pervious Area (in)	0.28												
	New Total Effective Rainfall Depth (in)	0.72												
	Downstream Pervious Area Runoff			0.085				74	3.51	0.70	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.020					98	0.20	0.04	0.264	19	141	
	Weighted Volume Total											**19**	**141**	
Reduction in Runoff obtained by disconnecting Roof												**87**	**648**	
Soil Type C														
Undeveloped (Desert, Fair)					0	0	81	81	2.35	0.47	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.110	0.085	57		87	93	0.75	0.15	0.080	**57**	**425**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.085				83	2.05	0.41	0.000	0	1	
	Impervious Area		0.110					98	0.20	0.04	0.264	105	789	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.265	**106**	**790**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.090					98	0.20	0.04	0.264	87	648	
	Equiv. Rain on Downstream Pervious Area (in)	0.28												
	New Total Effective Rainfall Depth (in)	0.72												
	Downstream Pervious Area Runoff			0.085				83	2.05	0.41	0.041	13	94	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.020					98	0.20	0.04	0.264	19	141	
	Weighted Volume Total											**31**	**235**	
Reduction in Runoff obtained by disconnecting Roof												**74**	**555**	
Soil Type D														
Undeveloped (Desert, Fair)					0	0	86	86	1.63	0.33	0.008	**5**	**40**	
Developed (Composite Curve Number Approach)			0.110	0.085	57		87	93	0.75	0.15	0.080	**57**	**425**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.085				87	1.49	0.30	0.012	4	28	
	Impervious Area		0.110					98	0.20	0.04	0.264	105	789	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.276	**109**	**817**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.090					98	0.20	0.04	0.264	87	648	
	Equiv. Rain on Downstream Pervious Area (in)	0.28												
	New Total Effective Rainfall Depth (in)	0.72												
	Downstream Pervious Area Runoff			0.085				87	1.49	0.30	0.093	28	213	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.020					98	0.20	0.04	0.264	19	141	
	Weighted Volume Total											**47**	**353**	
Reduction in Runoff obtained by disconnecting Roof												**62**	**463**	

Sample Site Data and Calculations are Provided FOR INFORMATION ONLY

Example Number	6
Zoning Type	Residential 1/4 Acre
Zoning ID	R-1-10

Variable Abbreviations	
A_{imp}	Impervious Area, acres
A_{per}	Pervious Area, acres
P_{imp}	Percent Impervious, %
CN_p	Pervious Area Curve Number
CN_c	Composite Curve Number
S	Maxiumum Potential Retention, inches
Ia	Initial Abstraction, inches

80th Percentile Storm Depth	0.44	in

Total Area	0.286	acres	12450	sq ft
Roof	0.062	acres	2696	sq ft
Driveway/sidewalk	0.023	acres	992	sq ft
Other Impervious	0.013	acres	580	sq ft
Lawn	0.063	acres	2744	sq ft
Other Pervious	0.125	acres	5438	sq ft

Impervious Areas				
Total Impervious Area	0.098	acres	4268	sq ft
	34%			
Directly Connected Impervious Areas				
w/ Roof connected	0.085	acres	3688	sq ft
w/ Roof disconnected	0.023	acres	992	sq ft
Unconnnected Impervious Areas				
w/ Roof connected	0.013	acres	580	sq ft
w/ Roof disconnected	0.075	acres	3276	sq ft

Curve numbers				
Soil Type	A	B	C	D
Undeveloped (Desert, Fair)	55	72	81	86
Natural Desert Landscaping	63	77	85	88
Lawn	39	61	74	80
Impervious Areas	98	98	98	98
Composite Pervious Numbers for this lot	**55**	**72**	**81**	**85**

Volume NEH 630/TR-55 Method

Scenario Description			A_{imp} (acres)	A_{per} (acres)	P_{imp} (%)	R (%)	CN_p -	CN_c -	S (in)	Ia (in)	Volume (in)	Volume (cu ft)	Volume (gal)	Comments
Soil Type A														
Undeveloped (Desert, Fair)					0	0	55	55	8.18	1.64	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.098	0.188	34		85	89	1.24	0.25	0.026	**27**	**202**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.188				55	8.18	1.64	0.000	0	0	
	Impervious Area		0.098					98	0.20	0.04	0.264	94	703	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**94**	**703**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.075					98	0.20	0.04	0.264	72	539	
	Equiv. Rain on Downstream Pervious Area (in)	0.11												
	New Total Effective Rainfall Depth (in)	0.55												
	Downstream Pervious Area Runoff			0.188				55	8.18	1.64	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.023					98	0.20	0.04	0.264	22	163	
	Weighted Volume Total											**22**	**163**	
Reduction in Runoff obtained by disconnecting Roof												**72**	**539**	
Soil Type B														
Undeveloped (Desert, Fair)					0	0	72	72	3.89	0.78	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.098	0.188	34		85	89	1.24	0.25	0.026	**27**	**202**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.188				72	3.89	0.78	0.000	0	0	
	Impervious Area		0.098					98	0.20	0.04	0.264	94	703	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**94**	**703**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.075					98	0.20	0.04	0.264	72	539	
	Equiv. Rain on Downstream Pervious Area (in)	0.11												
	New Total Effective Rainfall Depth (in)	0.55												
	Downstream Pervious Area Runoff			0.188				72	3.89	0.78	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.023					98	0.20	0.04	0.264	22	163	
	Weighted Volume Total											**22**	**163**	
Reduction in Runoff obtained by disconnecting Roof												**72**	**539**	
Soil Type C														
Undeveloped (Desert, Fair)					0	0	81	81	2.35	0.47	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.098	0.188	34		85	89	1.24	0.25	0.026	**27**	**202**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.188				81	2.35	0.47	0.000	0	0	
	Impervious Area		0.098					98	0.20	0.04	0.264	94	703	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**94**	**703**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.075					98	0.20	0.04	0.264	72	539	
	Equiv. Rain on Downstream Pervious Area (in)	0.11												
	New Total Effective Rainfall Depth (in)	0.55												
	Downstream Pervious Area Runoff			0.188				81	2.35	0.47	0.003	2	14	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.023					98	0.20	0.04	0.264	22	163	
	Weighted Volume Total											**24**	**177**	
Reduction in Runoff obtained by disconnecting Roof												**70**	**526**	
Soil Type D														
Undeveloped (Desert, Fair)					0	0	86	86	1.63	0.33	0.008	**8**	**58**	
Developed (Composite Curve Number Approach)			0.098	0.188	34		85	89	1.24	0.25	0.026	**27**	**202**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.188				85	1.76	0.35	0.004	3	21	
	Impervious Area		0.098					98	0.20	0.04	0.264	94	703	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.268	**97**	**724**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.075					98	0.20	0.04	0.264	72	539	
	Equiv. Rain on Downstream Pervious Area (in)	0.11												
	New Total Effective Rainfall Depth (in)	0.55												
	Downstream Pervious Area Runoff			0.188				85	1.76	0.35	0.020	13	101	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.023					98	0.20	0.04	0.264	22	163	
	Weighted Volume Total											**35**	**264**	
Reduction in Runoff obtained by disconnecting Roof												**61**	**459**	

Sample Site Data and Calculations are Provided FOR INFORMATION ONLY

Example Number	7
Zoning Type	Residential 1/4 Acre
Zoning ID	R-1-10

80th Percentile Storm Depth	0.44 in

Total Area	0.227	acres	9881	sq ft
Roof	0.077	acres	3345	sq ft
Driveway/sidewalk	0.063	acres	2764	sq ft
Other Impervious	0.006	acres	240	sq ft
Lawn	0.032	acres	1400	sq ft
Other Pervious	0.049	acres	2132	sq ft

Impervious Areas				
Total Impervious Area	0.146	acres	6349	sq ft
	64%			
Directly Connected Impervious Areas				
w/ Roof connected	0.140	acres	6109	sq ft
w/ Roof disconnected	0.063	acres	2764	sq ft
Unconnnected Impervious Areas				
w/ Roof connected	0.006	acres	240	sq ft
w/ Roof disconnected	0.082	acres	3585	sq ft

Curve numbers				
Soil Type	A	B	C	D
Undeveloped (Desert, Fair)	55	72	81	86
Natural Desert Landscaping	63	77	85	88
Lawn	39	61	74	80
Impervious Areas	98	98	98	98
Composite Pervious Numbers for this lot	**53**	**71**	**81**	**85**

Variable Abbreviations	
A_{imp}	Impervious Area, acres
A_{per}	Pervious Area, acres
P_{imp}	Percent Impervious, %
CN_p	Pervious Area Curve Number
CN_c	Composite Curve Number
S	Maxiumum Potential Retention, inches
Ia	Initial Abstraction, inches

Volume NEH 630/TR-55 Method

Scenario Description			A_{imp} (acres)	A_{per} (acres)	P_{imp} (%)	R (%)	CN_p -	CN_c -	S (in)	Ia (in)	Volume (in)	Volume (cu ft)	Volume (gal)	Comments
Soil Type A														
Undeveloped (Desert, Fair)					0	0	55	55	8.18	1.64	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.146	0.081	64		85	93	0.75	0.15	0.080	**66**	**495**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.081				53	8.87	1.77	0.000	0	0	
	Impervious Area		0.146					98	0.20	0.04	0.264	140	1045	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**140**	**1045**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.082					98	0.20	0.04	0.264	79	590	
	Equiv. Rain on Downstream Pervious Area (in)	0.27												
	New Total Effective Rainfall Depth (in)	0.71												
	Downstream Pervious Area Runoff			0.081				53	8.87	1.77	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.063					98	0.20	0.04	0.264	61	455	
	Weighted Volume Total											**61**	**455**	
Reduction in Runoff obtained by disconnecting Roof												**79**	**590**	
Soil Type B														
Undeveloped (Desert, Fair)					0	0	72	72	3.89	0.78	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.146	0.081	64		85	93	0.75	0.15	0.080	**66**	**495**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.081				71	4.08	0.82	0.000	0	0	
	Impervious Area		0.146					98	0.20	0.04	0.264	140	1045	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**140**	**1045**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.082					98	0.20	0.04	0.264	79	590	
	Equiv. Rain on Downstream Pervious Area (in)	0.27												
	New Total Effective Rainfall Depth (in)	0.71												
	Downstream Pervious Area Runoff			0.081				71	4.08	0.82	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.063					98	0.20	0.04	0.264	61	455	
	Weighted Volume Total											**61**	**455**	
Reduction in Runoff obtained by disconnecting Roof												**79**	**590**	
Soil Type C														
Undeveloped (Desert, Fair)					0	0	81	81	2.35	0.47	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.146	0.081	64		85	93	0.75	0.15	0.080	**66**	**495**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.081				81	2.35	0.47	0.000	0	0	
	Impervious Area		0.146					98	0.20	0.04	0.264	140	1045	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**140**	**1045**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.082					98	0.20	0.04	0.264	79	590	
	Equiv. Rain on Downstream Pervious Area (in)	0.27												
	New Total Effective Rainfall Depth (in)	0.71												
	Downstream Pervious Area Runoff			0.081				81	2.35	0.47	0.022	7	49	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.063					98	0.20	0.04	0.264	61	455	
	Weighted Volume Total											**67**	**504**	
Reduction in Runoff obtained by disconnecting Roof												**72**	**541**	
Soil Type D														
Undeveloped (Desert, Fair)					0	0	86	86	1.63	0.33	0.008	**6**	**46**	
Developed (Composite Curve Number Approach)			0.146	0.081	64		85	93	0.75	0.15	0.080	**66**	**495**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.081				85	1.76	0.35	0.004	1	9	
	Impervious Area		0.146					98	0.20	0.04	0.264	140	1045	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.268	**141**	**1055**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.082					98	0.20	0.04	0.264	79	590	
	Equiv. Rain on Downstream Pervious Area (in)	0.27												
	New Total Effective Rainfall Depth (in)	0.71												
	Downstream Pervious Area Runoff			0.081				85	1.76	0.35	0.060	18	132	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.063					98	0.20	0.04	0.264	61	455	
	Weighted Volume Total											**79**	**587**	
Reduction in Runoff obtained by disconnecting Roof												**62**	**467**	

Sample Site Data and Calculations are Provided FOR INFORMATION ONLY

Example Number	8
Zoning Type	Residential 1/4 Acre
Zoning ID	R-1-10

Variable Abbreviations	
A_{imp}	Impervious Area, acres
A_{per}	Pervious Area, acres
P_{imp}	Percent Impervious, %
CN_p	Pervious Area Curve Number
CN_c	Composite Curve Number
S	Maxiumum Potential Retention, inches
Ia	Initial Abstraction, inches

80th Percentile Storm Depth	**0.44**	in

Total Area	**0.206**	acres	8976	sq ft
Roof	0.075	acres	3255	sq ft
Driveway/sidewalk	0.033	acres	1417	sq ft
Other Impervious	0.010	acres	456	sq ft
Lawn	0.033	acres	1454	sq ft
Other Pervious	0.055	acres	2394	sq ft

Impervious Areas				
Total Impervious Area	**0.118**	acres	5128	sq ft
	57%			
Directly Connected Impervious Areas				
w/ Roof connected	0.107	acres	4672	sq ft
w/ Roof disconnected	0.033	acres	1417	sq ft
Unconnnected Impervious Areas				
w/ Roof connected	0.010	acres	456	sq ft
w/ Roof disconnected	0.085	acres	3711	sq ft

Curve numbers				
Soil Type	A	B	C	D
Undeveloped (Desert, Fair)	55	72	81	86
Natural Desert Landscaping	63	77	85	88
Lawn	39	61	74	80
Impervious Areas	98	98	98	98
Composite Pervious Numbers for this lot	**54**	**71**	**81**	**85**

Volume NEH 630/TR-55 Method

Scenario Description			A_{imp} (acres)	A_{per} (acres)	P_{imp} (%)	R (%)	CN_p -	CN_c -	S (in)	Ia (in)	Volume (in)	Volume (cu ft)	Volume (gal)	Comments
Soil Type A														
Undeveloped (Desert, Fair)					0	0	55	55	8.18	1.64	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.118	0.088	57		85	92	0.87	0.17	0.062	**47**	**349**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.088				54	8.52	1.70	0.000	0	0	
	Impervious Area		0.118					98	0.20	0.04	0.264	113	844	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**113**	**844**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.085					98	0.20	0.04	0.264	82	611	
	Equiv. Rain on Downstream Pervious Area (in)	0.25												
	New Total Effective Rainfall Depth (in)	0.69												
	Downstream Pervious Area Runoff			0.088				54	8.52	1.70	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.033					98	0.20	0.04	0.264	31	233	
	Weighted Volume Total											**31**	**233**	
Reduction in Runoff obtained by disconnecting Roof												**82**	**611**	
Soil Type B														
Undeveloped (Desert, Fair)					0	0	72	72	3.89	0.78	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.118	0.088	57		85	92	0.87	0.17	0.062	**47**	**349**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.088				71	4.08	0.82	0.000	0	0	
	Impervious Area		0.118					98	0.20	0.04	0.264	113	844	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**113**	**844**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.085					98	0.20	0.04	0.264	82	611	
	Equiv. Rain on Downstream Pervious Area (in)	0.25												
	New Total Effective Rainfall Depth (in)	0.69												
	Downstream Pervious Area Runoff			0.088				71	4.08	0.82	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.033					98	0.20	0.04	0.264	31	233	
	Weighted Volume Total											**31**	**233**	
Reduction in Runoff obtained by disconnecting Roof												**82**	**611**	
Soil Type C														
Undeveloped (Desert, Fair)					0	0	81	81	2.35	0.47	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.118	0.088	57		85	92	0.87	0.17	0.062	**47**	**349**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.088				81	2.35	0.47	0.000	0	0	
	Impervious Area		0.118					98	0.20	0.04	0.264	113	844	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**113**	**844**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.085					98	0.20	0.04	0.264	82	611	
	Equiv. Rain on Downstream Pervious Area (in)	0.25												
	New Total Effective Rainfall Depth (in)	0.69												
	Downstream Pervious Area Runoff			0.088				81	2.35	0.47	0.019	6	46	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.033					98	0.20	0.04	0.264	31	233	
	Weighted Volume Total											**37**	**279**	
Reduction in Runoff obtained by disconnecting Roof												**76**	**565**	
Soil Type D														
Undeveloped (Desert, Fair)					0	0	86	86	1.63	0.33	0.008	**6**	**42**	
Developed (Composite Curve Number Approach)			0.118	0.088	57		85	92	0.87	0.17	0.062	**47**	**349**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.088				85	1.76	0.35	0.004	1	10	
	Impervious Area		0.118					98	0.20	0.04	0.264	113	844	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.268	**114**	**854**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.085					98	0.20	0.04	0.264	82	611	
	Equiv. Rain on Downstream Pervious Area (in)	0.25												
	New Total Effective Rainfall Depth (in)	0.69												
	Downstream Pervious Area Runoff			0.088				85	1.76	0.35	0.054	17	130	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.033					98	0.20	0.04	0.264	31	233	
	Weighted Volume Total											**49**	**363**	
Reduction in Runoff obtained by disconnecting Roof												**66**	**491**	

Sample Site Data and Calculations are Provided FOR INFORMATION ONLY

Example Number	9
Zoning Type	Residential 1/4 Acre
Zoning ID	R-1-10

Variable Abbreviations	
A_{imp}	Impervious Area, acres
A_{per}	Pervious Area, acres
P_{imp}	Percent Impervious, %
CN_p	Pervious Area Curve Number
CN_c	Composite Curve Number
S	Maxiumum Potential Retention, inches
Ia	Initial Abstraction, inches

80th Percentile Storm Depth	0.44	in

Total Area	0.260	acres	11320	sq ft
Roof	0.072	acres	3147	sq ft
Driveway/sidewalk	0.081	acres	3548	sq ft
Other Impervious	0.009	acres	380	sq ft
Lawn	0.059	acres	2550	sq ft
Other Pervious	0.039	acres	1695	sq ft

Impervious Areas				
Total Impervious Area	0.162	acres	7075	sq ft
	63%			
Directly Connected Impervious Areas				
w/ Roof connected	0.154	acres	6695	sq ft
w/ Roof disconnected	0.081	acres	3548	sq ft
Unconnnected Impervious Areas				
w/ Roof connected	0.009	acres	380	sq ft
w/ Roof disconnected	0.081	acres	3527	sq ft

Curve numbers				
Soil Type	A	B	C	D
Undeveloped (Desert, Fair)	55	72	81	86
Natural Desert Landscaping	63	77	85	88
Lawn	39	61	74	80
Impervious Areas	98	98	98	98
Composite Pervious Numbers for this lot	**49**	**67**	**78**	**83**

Volume NEH 630/TR-55 Method

Scenario Description			A_{imp}	A_{per}	P_{imp}	R	CN_p	CN_c	S	Ia	Volume			Comments
			(acres)	(acres)	(%)	(%)	-	-	(in)	(in)	(in)	(cu ft)	(gal)	
Soil Type A														
Undeveloped (Desert, Fair)					0	0	55	55	8.18	1.64	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.162	0.097	63		83	92	0.87	0.17	0.062	**59**	**440**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.097				49	10.41	2.08	0.000	0	0	
	Impervious Area		0.162					98	0.20	0.04	0.264	156	1165	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**156**	**1165**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.081					98	0.20	0.04	0.264	78	581	
	Equiv. Rain on Downstream Pervious Area (in)	0.22												
	New Total Effective Rainfall Depth (in)	0.66												
	Downstream Pervious Area Runoff			0.097				49	10.41	2.08	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.081					98	0.20	0.04	0.264	78	584	
	Weighted Volume Total											**78**	**584**	
Reduction in Runoff obtained by disconnecting Roof												**78**	**581**	
Soil Type B														
Undeveloped (Desert, Fair)					0	0	72	72	3.89	0.78	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.162	0.097	63		83	92	0.87	0.17	0.062	**59**	**440**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.097				67	4.93	0.99	0.000	0	0	
	Impervious Area		0.162					98	0.20	0.04	0.264	156	1165	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**156**	**1165**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.081					98	0.20	0.04	0.264	78	581	
	Equiv. Rain on Downstream Pervious Area (in)	0.22												
	New Total Effective Rainfall Depth (in)	0.66												
	Downstream Pervious Area Runoff			0.097				67	4.93	0.99	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.081					98	0.20	0.04	0.264	78	584	
	Weighted Volume Total											**78**	**584**	
Reduction in Runoff obtained by disconnecting Roof												**78**	**581**	
Soil Type C														
Undeveloped (Desert, Fair)					0	0	81	81	2.35	0.47	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.162	0.097	63		83	92	0.87	0.17	0.062	**59**	**440**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.097				78	2.82	0.56	0.000	0	0	
	Impervious Area		0.162					98	0.20	0.04	0.264	156	1165	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**156**	**1165**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.081					98	0.20	0.04	0.264	78	581	
	Equiv. Rain on Downstream Pervious Area (in)	0.22												
	New Total Effective Rainfall Depth (in)	0.66												
	Downstream Pervious Area Runoff			0.097				78	2.82	0.56	0.003	1	8	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.081					98	0.20	0.04	0.264	78	584	
	Weighted Volume Total											**79**	**593**	
Reduction in Runoff obtained by disconnecting Roof												**77**	**572**	
Soil Type D														
Undeveloped (Desert, Fair)					0	0	86	86	1.63	0.33	0.008	**7**	**53**	
Developed (Composite Curve Number Approach)			0.162	0.097	63		83	92	0.87	0.17	0.062	**59**	**440**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.097				83	2.05	0.41	0.000	0	1	
	Impervious Area		0.162					98	0.20	0.04	0.264	156	1165	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.265	**156**	**1166**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.081					98	0.20	0.04	0.264	78	581	
	Equiv. Rain on Downstream Pervious Area (in)	0.22												
	New Total Effective Rainfall Depth (in)	0.66												
	Downstream Pervious Area Runoff			0.097				83	2.05	0.41	0.027	10	72	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.081					98	0.20	0.04	0.264	78	584	
	Weighted Volume Total											**88**	**656**	
Reduction in Runoff obtained by disconnecting Roof												**68**	**510**	

Sample Site Data and Calculations are Provided FOR INFORMATION ONLY

Example Number	10
Zoning Type	Residential 1/8 Acre
Zoning ID	R-1-6

Variable Abbreviations	
A_{imp}	Impervious Area, acres
A_{per}	Pervious Area, acres
P_{imp}	Percent Impervious, %
CN_p	Pervious Area Curve Number
CN_c	Composite Curve Number
S	Maxiumum Potential Retention, inches
Ia	Initial Abstraction, inches

80th Percentile Storm Depth	**0.44**	in

Total Area	**0.120**	acres	5225	sq ft
Roof	0.049	acres	2155	sq ft
Driveway/sidewalk	0.017	acres	722	sq ft
Other Impervious	0.011	acres	479	sq ft
Lawn	0.017	acres	762	sq ft
Other Pervious	0.025	acres	1107	sq ft

Impervious Areas				
Total Impervious Area	**0.077**	acres	3356	sq ft
	64%			
Directly Connected Impervious Areas				
w/ Roof connected	0.066	acres	2878	sq ft
w/ Roof disconnected	0.017	acres	722	sq ft
Unconnnected Impervious Areas				
w/ Roof connected	0.011	acres	479	sq ft
w/ Roof disconnected	0.060	acres	2634	sq ft

Curve numbers				
Soil Type	A	B	C	D
Undeveloped (Desert, Fair)	55	72	81	86
Natural Desert Landscaping	63	77	85	88
Lawn	39	61	74	80
Impervious Areas	98	98	98	98
Composite Pervious Numbers for this lot	**53**	**70**	**81**	**85**

Volume NEH 630/TR-55 Method

Scenario Description			A_{imp} (acres)	A_{per} (acres)	P_{imp} (%)	R (%)	CN_p -	CN_c -	S (in)	Ia (in)	Volume (in)	Volume (cu ft)	Volume (gal)	Comments
Soil Type A														
Undeveloped (Desert, Fair)					0	0	55	55	8.18	1.64	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.077	0.043	64		85	93	0.75	0.15	0.080	**35**	**262**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.043				53	8.87	1.77	0.000	0	0	
	Impervious Area		0.077					98	0.20	0.04	0.264	74	553	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**74**	**553**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.060					98	0.20	0.04	0.264	58	434	
	Equiv. Rain on Downstream Pervious Area (in)	0.37												
	New Total Effective Rainfall Depth (in)	0.81												
	Downstream Pervious Area Runoff			0.043				53	8.87	1.77	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.017					98	0.20	0.04	0.264	16	119	
	Weighted Volume Total											**16**	**119**	
Reduction in Runoff obtained by disconnecting Roof												**58**	**434**	
Soil Type B														
Undeveloped (Desert, Fair)					0	0	72	72	3.89	0.78	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.077	0.043	64		85	93	0.75	0.15	0.080	**35**	**262**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.043				70	4.29	0.86	0.000	0	0	
	Impervious Area		0.077					98	0.20	0.04	0.264	74	553	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**74**	**553**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.060					98	0.20	0.04	0.264	58	434	
	Equiv. Rain on Downstream Pervious Area (in)	0.37												
	New Total Effective Rainfall Depth (in)	0.81												
	Downstream Pervious Area Runoff			0.043				70	4.29	0.86	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.017					98	0.20	0.04	0.264	16	119	
	Weighted Volume Total											**16**	**119**	
Reduction in Runoff obtained by disconnecting Roof												**58**	**434**	
Soil Type C														
Undeveloped (Desert, Fair)					0	0	81	81	2.35	0.47	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.077	0.043	64		85	93	0.75	0.15	0.080	**35**	**262**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.043				81	2.35	0.47	0.000	0	0	
	Impervious Area		0.077					98	0.20	0.04	0.264	74	553	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**74**	**553**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.060					98	0.20	0.04	0.264	58	434	
	Equiv. Rain on Downstream Pervious Area (in)	0.37												
	New Total Effective Rainfall Depth (in)	0.81												
	Downstream Pervious Area Runoff			0.043				81	2.35	0.47	0.043	7	50	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.017					98	0.20	0.04	0.264	16	119	
	Weighted Volume Total											**23**	**169**	
Reduction in Runoff obtained by disconnecting Roof												**51**	**383**	
Soil Type D														
Undeveloped (Desert, Fair)					0	0	86	86	1.63	0.33	0.008	**3**	**24**	
Developed (Composite Curve Number Approach)			0.077	0.043	64		85	93	0.75	0.15	0.080	**35**	**262**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.043				85	1.76	0.35	0.004	1	5	
	Impervious Area		0.077					98	0.20	0.04	0.264	74	553	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.268	**75**	**557**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.060					98	0.20	0.04	0.264	58	434	
	Equiv. Rain on Downstream Pervious Area (in)	0.37												
	New Total Effective Rainfall Depth (in)	0.81												
	Downstream Pervious Area Runoff			0.043				85	1.76	0.35	0.094	15	110	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.017					98	0.20	0.04	0.264	16	119	
	Weighted Volume Total											**31**	**228**	
Reduction in Runoff obtained by disconnecting Roof												**44**	**329**	

Sample Site Data and Calculations are Provided FOR INFORMATION ONLY

Example Number	11
Zoning Type	Residential 1/8 Acre
Zoning ID	R-1-6

80th Percentile Storm Depth	**0.44**	in

Total Area	**0.142**	acres	6166	sq ft
Roof	0.054	acres	2333	sq ft
Driveway/sidewalk	0.016	acres	699	sq ft
Other Impervious	0.011	acres	475	sq ft
Lawn	0.025	acres	1093	sq ft
Other Pervious	0.036	acres	1566	sq ft

Impervious Areas				
Total Impervious Area	**0.081**	acres	3507	sq ft
	57%			
Directly Connected Impervious Areas				
w/ Roof connected	0.070	acres	3032	sq ft
w/ Roof disconnected	0.016	acres	699	sq ft
Unconnnected Impervious Areas				
w/ Roof connected	0.011	acres	475	sq ft
w/ Roof disconnected	0.064	acres	2808	sq ft

Curve numbers				
Soil Type	A	B	C	D
Undeveloped (Desert, Fair)	55	72	81	86
Natural Desert Landscaping	63	77	85	88
Lawn	39	61	74	80
Impervious Areas	98	98	98	98
Composite Pervious Numbers for this lot	**53**	**70**	**80**	**85**

Variable Abbreviations	
A_{imp}	Impervious Area, acres
A_{per}	Pervious Area, acres
P_{imp}	Percent Impervious, %
CN_p	Pervious Area Curve Number
CN_c	Composite Curve Number
S	Maxiumum Potential Retention, inches
Ia	Initial Abstraction, inches

Volume NEH 630/TR-55 Method

Scenario Description			A_{imp} (acres)	A_{per} (acres)	P_{imp} (%)	R (%)	CN_p -	CN_c -	S (in)	Ia (in)	Volume (in)	Volume (cu ft)	Volume (gal)	Comments
Soil Type A														
Undeveloped (Desert, Fair)					0	0	55	55	8.18	1.64	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.081	0.061	57		85	92	0.87	0.17	0.062	**32**	**240**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.061				53	8.87	1.77	0.000	0	0	
	Impervious Area		0.081					98	0.20	0.04	0.264	77	577	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**77**	**577**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.064					98	0.20	0.04	0.264	62	462	
	Equiv. Rain on Downstream Pervious Area (in)	0.28												
	New Total Effective Rainfall Depth (in)	0.72												
	Downstream Pervious Area Runoff			0.061				53	8.87	1.77	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.016					98	0.20	0.04	0.264	15	115	
	Weighted Volume Total											**15**	**115**	
Reduction in Runoff obtained by disconnecting Roof												**62**	**462**	
Soil Type B														
Undeveloped (Desert, Fair)					0	0	72	72	3.89	0.78	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.081	0.061	57		85	92	0.87	0.17	0.062	**32**	**240**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.061				70	4.29	0.86	0.000	0	0	
	Impervious Area		0.081					98	0.20	0.04	0.264	77	577	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**77**	**577**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.064					98	0.20	0.04	0.264	62	462	
	Equiv. Rain on Downstream Pervious Area (in)	0.28												
	New Total Effective Rainfall Depth (in)	0.72												
	Downstream Pervious Area Runoff			0.061				70	4.29	0.86	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.016					98	0.20	0.04	0.264	15	115	
	Weighted Volume Total											**15**	**115**	
Reduction in Runoff obtained by disconnecting Roof												**62**	**462**	
Soil Type C														
Undeveloped (Desert, Fair)					0	0	81	81	2.35	0.47	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.081	0.061	57		85	92	0.87	0.17	0.062	**32**	**240**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.061				80	2.50	0.50	0.000	0	0	
	Impervious Area		0.081					98	0.20	0.04	0.264	77	577	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**77**	**577**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.064					98	0.20	0.04	0.264	62	462	
	Equiv. Rain on Downstream Pervious Area (in)	0.28												
	New Total Effective Rainfall Depth (in)	0.72												
	Downstream Pervious Area Runoff			0.061				80	2.50	0.50	0.018	4	30	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.016					98	0.20	0.04	0.264	15	115	
	Weighted Volume Total											**19**	**145**	
Reduction in Runoff obtained by disconnecting Roof												**58**	**433**	
Soil Type D														
Undeveloped (Desert, Fair)					0	0	86	86	1.63	0.33	0.008	**4**	**29**	
Developed (Composite Curve Number Approach)			0.081	0.061	57		85	92	0.87	0.17	0.062	**32**	**240**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.061				85	1.76	0.35	0.004	1	7	
	Impervious Area		0.081					98	0.20	0.04	0.264	77	577	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.268	**78**	**584**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.064					98	0.20	0.04	0.264	62	462	
	Equiv. Rain on Downstream Pervious Area (in)	0.28												
	New Total Effective Rainfall Depth (in)	0.72												
	Downstream Pervious Area Runoff			0.061				85	1.76	0.35	0.063	14	105	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.016					98	0.20	0.04	0.264	15	115	
	Weighted Volume Total											**29**	**220**	
Reduction in Runoff obtained by disconnecting Roof												**49**	**364**	

Sample Site Data and Calculations are Provided FOR INFORMATION ONLY

Example Number	12
Zoning Type	Residential 1/8 Acre
Zoning ID	R-1-6

80th Percentile Storm Depth	**0.44**	in

Total Area	**0.120**	acres	5219	sq ft
Roof	0.048	acres	2097	sq ft
Driveway/sidewalk	0.017	acres	750	sq ft
Other Impervious	0.002	acres	104	sq ft
Lawn	0.019	acres	806	sq ft
Other Pervious	0.034	acres	1463	sq ft

Impervious Areas				
Total Impervious Area	**0.068**	acres	2951	sq ft
	57%			
Directly Connected Impervious Areas				
w/ Roof connected	0.065	acres	2847	sq ft
w/ Roof disconnected	0.017	acres	750	sq ft
Unconnnected Impervious Areas				
w/ Roof connected	0.002	acres	104	sq ft
w/ Roof disconnected	0.051	acres	2201	sq ft

Curve numbers				
Soil Type	A	B	C	D
Undeveloped (Desert, Fair)	55	72	81	86
Natural Desert Landscaping	63	77	85	88
Lawn	39	61	74	80
Impervious Areas	98	98	98	98
Composite Pervious Numbers for this lot	**54**	**71**	**81**	**85**

Variable Abbreviations	
A_{imp}	Impervious Area, acres
A_{per}	Pervious Area, acres
P_{imp}	Percent Impervious, %
CN_p	Pervious Area Curve Number
CN_c	Composite Curve Number
S	Maxiumum Potential Retention, inches
Ia	Initial Abstraction, inches

Volume NEH 630/TR-55 Method

Scenario Description			A_{imp} (acres)	A_{per} (acres)	P_{imp} (%)	R (%)	CN_p -	CN_c -	S (in)	Ia (in)	Volume (in)	Volume (cu ft)	Volume (gal)	Comments
Soil Type A														
Undeveloped (Desert, Fair)					0	0	55	55	8.18	1.64	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.068	0.052	57		85	92	0.87	0.17	0.062	**27**	**203**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.052				54	8.52	1.70	0.000	0	0	
	Impervious Area		0.068					98	0.20	0.04	0.264	65	486	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**65**	**486**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.051					98	0.20	0.04	0.264	48	362	
	Equiv. Rain on Downstream Pervious Area (in)	0.26												
	New Total Effective Rainfall Depth (in)	0.70												
	Downstream Pervious Area Runoff			0.052				54	8.52	1.70	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.017					98	0.20	0.04	0.264	16	123	
	Weighted Volume Total											**16**	**123**	
Reduction in Runoff obtained by disconnecting Roof												**48**	**362**	
Soil Type B														
Undeveloped (Desert, Fair)					0	0	72	72	3.89	0.78	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.068	0.052	57		85	92	0.87	0.17	0.062	**27**	**203**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.052				71	4.08	0.82	0.000	0	0	
	Impervious Area		0.068					98	0.20	0.04	0.264	65	486	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**65**	**486**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.051					98	0.20	0.04	0.264	48	362	
	Equiv. Rain on Downstream Pervious Area (in)	0.26												
	New Total Effective Rainfall Depth (in)	0.70												
	Downstream Pervious Area Runoff			0.052				71	4.08	0.82	0.000	0	0	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.017					98	0.20	0.04	0.264	16	123	
	Weighted Volume Total											**16**	**123**	
Reduction in Runoff obtained by disconnecting Roof												**48**	**362**	
Soil Type C														
Undeveloped (Desert, Fair)					0	0	81	81	2.35	0.47	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			0.068	0.052	57		85	92	0.87	0.17	0.062	**27**	**203**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.052				81	2.35	0.47	0.000	0	0	
	Impervious Area		0.068					98	0.20	0.04	0.264	65	486	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.264	**65**	**486**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.051					98	0.20	0.04	0.264	48	362	
	Equiv. Rain on Downstream Pervious Area (in)	0.26												
	New Total Effective Rainfall Depth (in)	0.70												
	Downstream Pervious Area Runoff			0.052				81	2.35	0.47	0.021	4	29	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.017					98	0.20	0.04	0.264	16	123	
	Weighted Volume Total											**20**	**153**	
Reduction in Runoff obtained by disconnecting Roof												**45**	**333**	
Soil Type D														
Undeveloped (Desert, Fair)					0	0	86	86	1.63	0.33	0.008	**3**	**24**	
Developed (Composite Curve Number Approach)			0.068	0.052	57		85	92	0.87	0.17	0.062	**27**	**203**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			0.052				85	1.76	0.35	0.004	1	6	
	Impervious Area		0.068					98	0.20	0.04	0.264	65	486	Calculates runoff from impervious area and pervious areas separately.
	Weighted Volume Total										0.268	**66**	**492**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		0.051					98	0.20	0.04	0.264	48	362	
	Equiv. Rain on Downstream Pervious Area (in)	0.26												
	New Total Effective Rainfall Depth (in)	0.70												
	Downstream Pervious Area Runoff			0.052				85	1.76	0.35	0.057	11	81	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Downstream Impervious Area Runoff		0.017					98	0.20	0.04	0.264	16	123	
	Weighted Volume Total											**27**	**204**	
Reduction in Runoff obtained by disconnecting Roof												**38**	**288**	

Sample Site Data and Calculations are Provided FOR INFORMATION ONLY

Example Number	13
Zoning Type	Townhomes
Zoning ID	PUD

Variable Abbreviations	
A_{imp}	Impervious Area, acres
A_{per}	Pervious Area, acres
P_{imp}	Percent Impervious, %
CN_p	Pervious Area Curve Number
CN_c	Composite Curve Number
S	Maxiumum Potential Retention, inches
Ia	Initial Abstraction, inches

80th Percentile Storm Depth	**0.44**	in

Total Area	**12.767**	acres	556120	sq ft
Roof	2.817	acres	122706	sq ft
Driveway/sidewalk	3.689	acres	160710	sq ft
Other Impervious	0.599	acres	26108	sq ft
Lawn	0.325	acres	14151	sq ft
Other Pervious	5.336	acres	232444	sq ft

Impervious Areas				
Total Impervious Area	**7.106**	acres	309525	sq ft
	56%			
Directly Connected Impervious Areas				
w/ Roof connected	6.506	acres	283416	sq ft
w/ Roof disconnected	3.689	acres	160710	sq ft
Unconnnected Impervious Areas				
w/ Roof connected	0.599	acres	26108	sq ft
w/ Roof disconnected	3.416	acres	148815	sq ft

Curve numbers				
Soil Type	A	B	C	D
Undeveloped (Desert, Fair)	55	72	81	86
Natural Desert Landscaping	63	77	85	88
Lawn	39	61	74	80
Impervious Areas	98	98	98	98
Composite Pervious Numbers for this lot	**62**	**76**	**84**	**88**

Volume NEH 630/TR-55 Method

Scenario Description			A_{imp} (acres)	A_{per} (acres)	P_{imp} (%)	R (%)	CN_p -	CN_c -	S (in)	Ia (in)	Volume (in)	Volume (cu ft)	Volume (gal)	Comments
Soil Type A														
Undeveloped (Desert, Fair)					0	0	55	55	8.18	1.64	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			7.106	5.661	56		88	94	0.64	0.13	0.103	**4756**	**35576**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			5.661				62	6.13	1.23	0.000	0	0	Calculates runoff from impervious area and pervious areas separately.
	Impervious Area		7.106					98	0.20	0.04	0.264	6813	50966	
	Weighted Volume Total										0.264	**6813**	**50966**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		3.416					98	0.20	0.04	0.264	3276	24504	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.16												
	New Total Effective Rainfall Depth (in)	0.60												
	Downstream Pervious Area Runoff			5.661				62	6.13	1.23	0.000	0	0	
	Downstream Impervious Area Runoff		3.689					98	0.20	0.04	0.264	3538	26463	
	Weighted Volume Total											**3538**	**26463**	
Reduction in Runoff obtained by disconnecting Roof												**3276**	**24504**	
Soil Type B														
Undeveloped (Desert, Fair)					0	0	72	72	3.89	0.78	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			7.106	5.661	56		88	94	0.64	0.13	0.103	**4756**	**35576**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			5.661				76	3.16	0.63	0.000	0	0	Calculates runoff from impervious area and pervious areas separately.
	Impervious Area		7.106					98	0.20	0.04	0.264	6813	50966	
	Weighted Volume Total										0.264	**6813**	**50966**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		3.416					98	0.20	0.04	0.264	3276	24504	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.16												
	New Total Effective Rainfall Depth (in)	0.60												
	Downstream Pervious Area Runoff			5.661				76	3.16	0.63	0.000	0	0	
	Downstream Impervious Area Runoff		3.689					98	0.20	0.04	0.264	3538	26463	
	Weighted Volume Total											**3538**	**26463**	
Reduction in Runoff obtained by disconnecting Roof												**3276**	**24504**	
Soil Type C														
Undeveloped (Desert, Fair)					0	0	81	81	2.35	0.47	0.000	**0**	**0**	
Developed (Composite Curve Number Approach)			7.106	5.661	56		88	94	0.64	0.13	0.103	**4756**	**35576**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			5.661				84	1.90	0.38	0.002	36	273	Calculates runoff from impervious area and pervious areas separately.
	Impervious Area		7.106					98	0.20	0.04	0.264	6813	50966	
	Weighted Volume Total										0.266	**6850**	**51239**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		3.416					98	0.20	0.04	0.264	3276	24504	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.16												
	New Total Effective Rainfall Depth (in)	0.60												
	Downstream Pervious Area Runoff			5.661				84	1.90	0.38	0.023	464	3473	
	Downstream Impervious Area Runoff		3.689					98	0.20	0.04	0.264	3538	26463	
	Weighted Volume Total											**4002**	**29935**	
Reduction in Runoff obtained by disconnecting Roof												**2848**	**21304**	
Soil Type D														
Undeveloped (Desert, Fair)					0	0	86	86	1.63	0.33	0.008	**348**	**2605**	
Developed (Composite Curve Number Approach)			7.106	5.661	56		88	94	0.64	0.13	0.103	**4756**	**35576**	Typical Method - Underestimates runoff for areas with directly connected impervious surfaces.
Roof Connected - Weighted Average Volume	Pervious Area			5.661				88	1.36	0.27	0.018	376	2810	Calculates runoff from impervious area and pervious areas separately.
	Impervious Area		7.106					98	0.20	0.04	0.264	6813	50966	
	Weighted Volume Total										0.282	**7189**	**53776**	
Roof Disconnected - Two-Step Runoff Method	Runoff from Disconnected Imp Area		3.416					98	0.20	0.04	0.264	3276	24504	Calculates runoff from roof, then applies that runoff as "rainfall" to the remaining downstream pervious areas.
	Equiv. Rain on Downstream Pervious Area (in)	0.16												
	New Total Effective Rainfall Depth (in)	0.60												
	Downstream Pervious Area Runoff			5.661				88	1.36	0.27	0.063	1302	9737	
	Downstream Impervious Area Runoff		3.689					98	0.20	0.04	0.264	3538	26463	
	Weighted Volume Total											**4839**	**36200**	
Reduction in Runoff obtained by disconnecting Roof												**2350**	**17576**	