
A guide for city planners, engineers, homeowners and green thinkers.

*Fall 2011*

Metropolitan Council

# Stormwater Reuse GUIDE

# Table of Contents

This guide contains seven sections: About this Guide, Reuse Fact Sheet, Project Planning, Case Studies, Toolbox, Glossary and Sources & Links. Each section can be used as a stand alone section, though all sections work together as one comprehensive guide to stormwater reuse.

# About this Guide

***A guide for city planners, engineers, home owners and green thinkers.***

## Goals of Stormwater Reuse

- *Reduce the demand on existing potable water treatment and distribution infrastructure, reducing future water supply capital costs.*
- *Manage future demands on groundwater to ensure adequate supply into the future.*
- *Reduce the volume and mass loading of pollutants to surface waters.*
- *Create a beneficial use for stormwater runoff, an underutilized resource.*

## Goals of the Guide

- *Introduce effective alternative techniques to reduce reliance on potable water supplies and reduce stormwater discharges to surface waters.*
- *Provide guidance to policy makers, planners, and designers who are considering a stormwater reuse project.*
- *Suggest references for additional research.*


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## Prepared by

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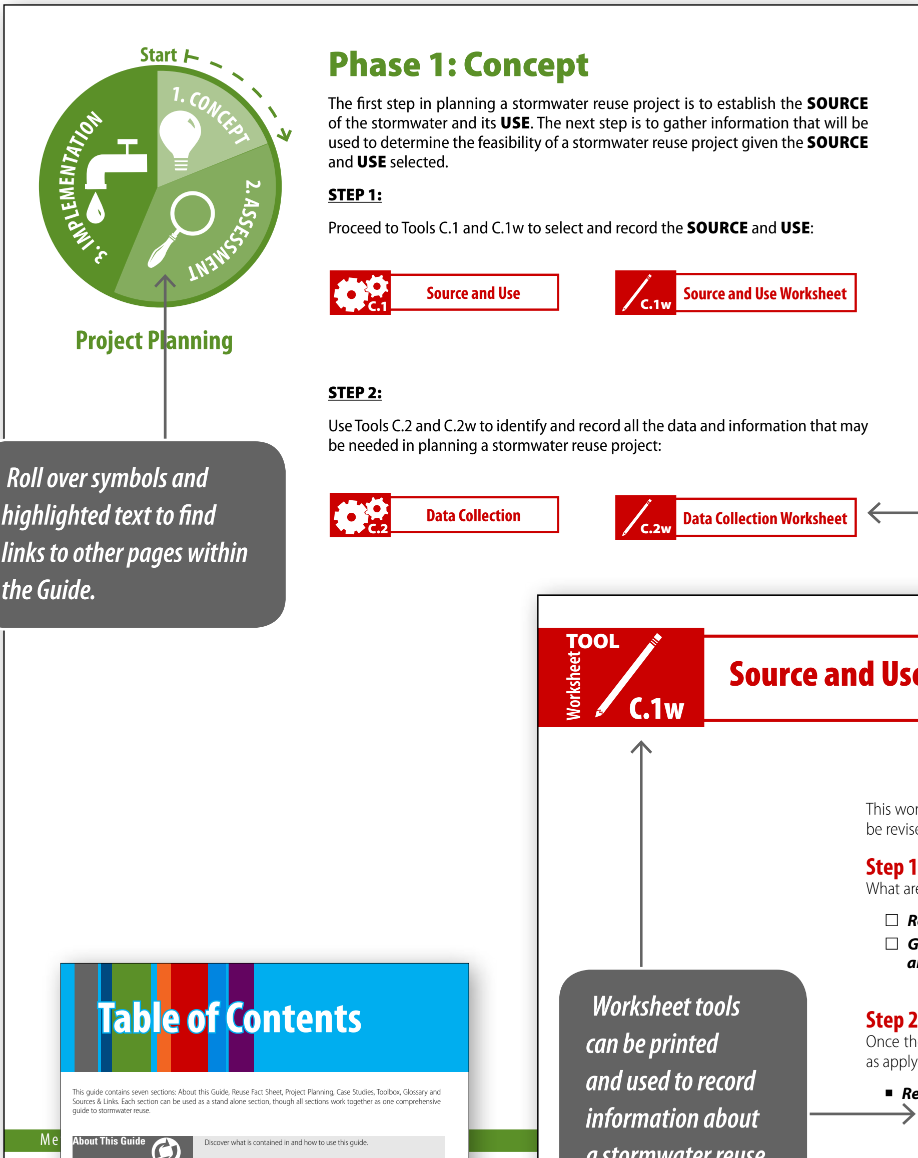
# How to use this Guide

*The Guide is made up of seven PDF documents that are meant to be viewed online.*

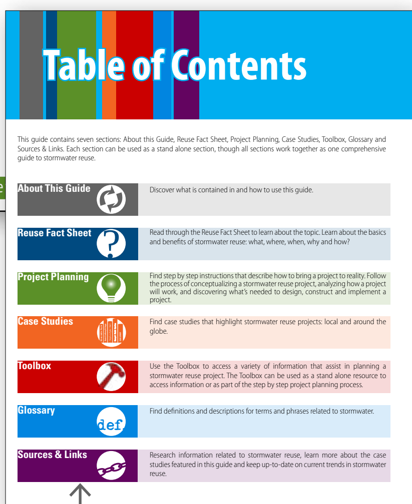
*Use the links in the documents to move within and between the various PDFs.*

*Print specific pages as needed for future reference or to record data.*

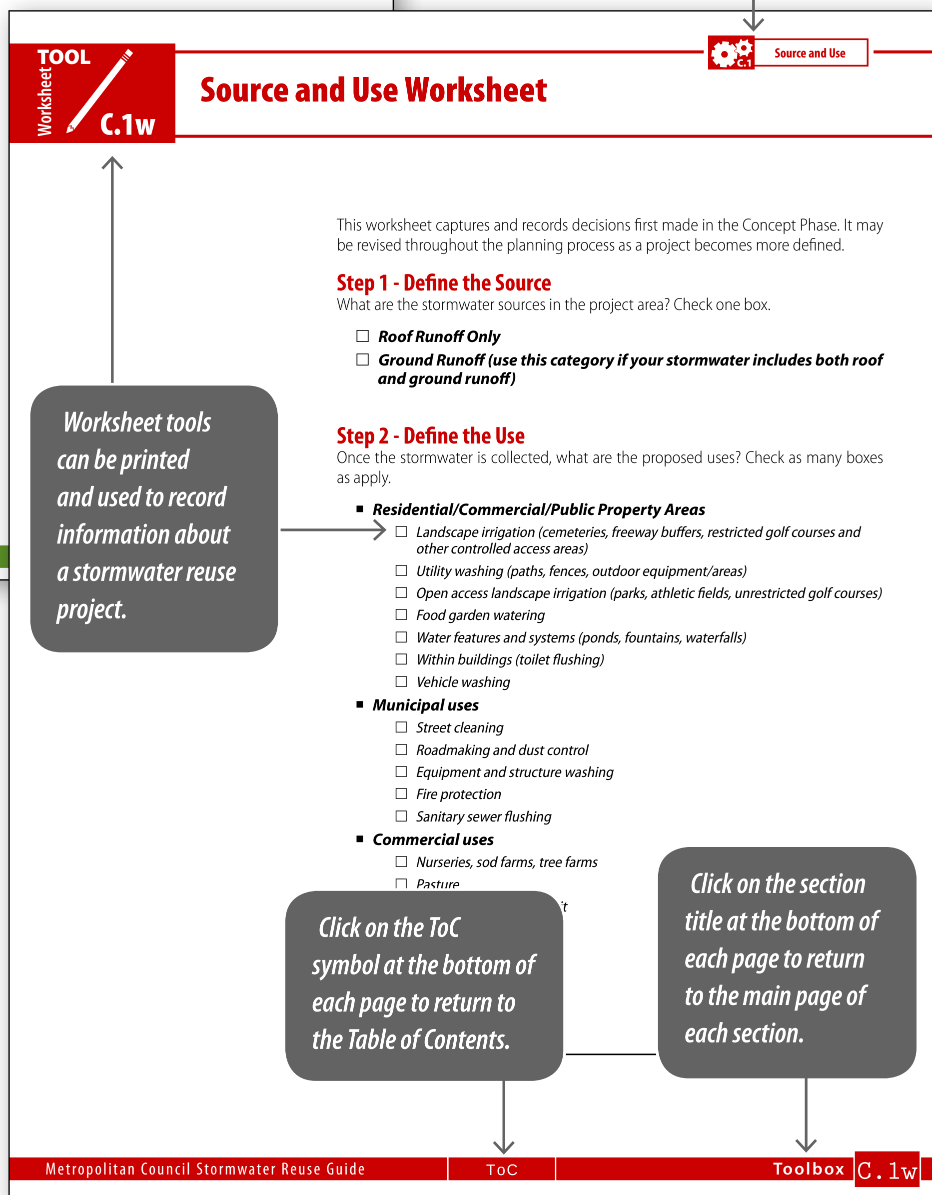



*Roll over symbols and highlighted text to find links to other pages within the Guide.*

*This symbol indicates a tool to be used - click on the symbol to open the tool.*




*On the Table of Contents page, click on each section bar to bring up the first page of that section.*

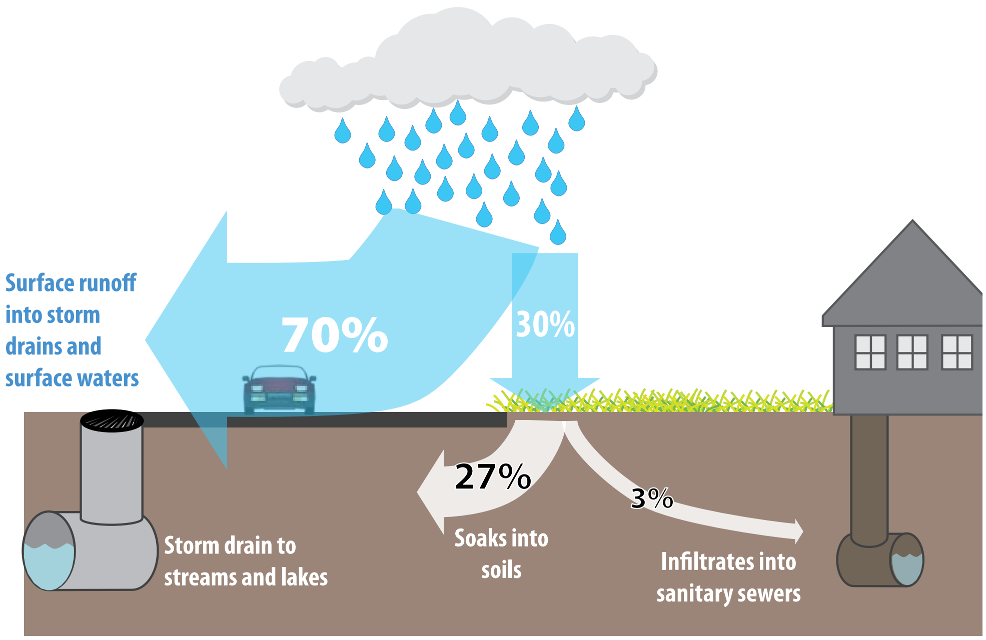



*Worksheet tools can be printed and used to record information about a stormwater reuse project.*

*Click on the ToC symbol at the bottom of each page to return to the Table of Contents.*

*Click on the section title at the bottom of each page to return to the main page of each section.*

# Reuse Fact Sheet




Source: CDM and HKGi

**Stormwater Reuse** is defined as:

*The collection and use of stormwater runoff that is reclaimed for specific, direct, and beneficial uses. The term is also used to describe water that is collected on-site and utilized in a new application. It is also called rainwater harvesting, rainwater recycling, or rainwater reclamation.*[2]

Two water problems are emerging in urban areas, including the Twin Cities: excessive stormwater runoff is degrading our surface waters, and water treatment plants are undergoing costly expansions. These may seem to be unrelated problems, yet there is a common solution.

In an average year, 29 inches of precipitation (including 56 inches of snow) will fall on the Twin Cities region of Minnesota.[1] Typically 70% of non-snow urban precipitation and 100% of the snowmelt becomes runoff; essentially all of the precipitation that falls on hard surfaces, such as rooftops, parking lots, sidewalks, and streets. This runoff is collected and allowed to drain to our lakes and streams through underground pipe networks, called storm sewers or storm drains.

The 30% of non-snow precipitation that falls onto our yards, gardens, parks and fields is not enough to maintain urban vegetation. During hot weather and extended periods of drought, Twin Cities property owners will use 45 to 120 gallons per person per day of treated drinking water for outdoor uses.[3]

[1] Minnesota Climatology Working Group, Normals, Means, and Extremes for Minneapolis/St. Paul (1971-2000)

[2] Adapted from Alliance for Water Efficiency, Glossary of Common Water Related Terms, Abbreviations, and Definitions.

[3] Metropolitan Council, Metropolitan Area Master Water Supply Plan, 2010.

Rain barrels are common ways for homeowners to collect and reuse stormwater on their properties.

Source: ***Wood Grain Rain Barrel – 50 Gallons.*** Photograph. http://www.composters.com/rain-barrels/wood-grain-rain-barrel---50-gal_161_10.php. GREENCulture, Inc., 2007. Web. 28 October 2011.

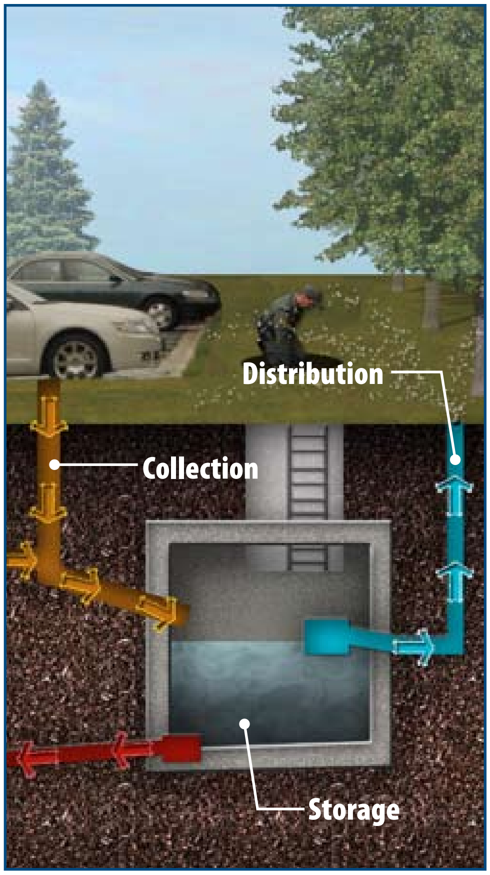
## Stormwater is an Underutilized Resource

Capturing this runoff for reuse is a growing movement, both internationally and locally. For example, two major Twin Cities projects constructed since 2007 have collected and stored runoff specifically to irrigate athletic fields: **St. Anthony Village Municipal Park**, and **Target Field**. On a smaller scale, the hundreds of homeowners that have installed rain barrels to collect rooftop runoff are collectively contributing to this stormwater reuse movement.

## Benefits of Stormwater Reuse

Collection and use of stormwater has regional and local benefits, including:

- *Conserve potable water supplies for essential uses.*
- *Reduce demand on existing potable water treatment and distribution systems; reserve current capacity for higher value potable use; and lengthen service life of existing infrastructure.*
- *Reduce peak demands on the potable water system that typically occurs during the summer irrigation and landscape watering season.*
- *Reduce the volume of stormwater and quantity of pollutants discharged to lakes and streams, ultimately improving the quality of these natural resources.*




Stormwater Reuse System Diagram

Source: HKGi

## Common Features of a Stormwater Reuse System

Each site is unique; therefore, the quantity and quality of the stormwater is also unique. Designers of stormwater reuse systems must consider the need for, and the sizing of, the following typical components:

- *Collection piping*
- *Storage unit(s)*
- *Treatment device(s)*
- *Distribution piping*

## Collect Stormwater

Stormwater can be collected from any surface in the urban landscape:

- *Rooftops, including green roofs*
- *Driveways, including pervious pavement surfaces*
- *Sidewalks/bicycle trails*
- *Parking lots*
- *Streets*

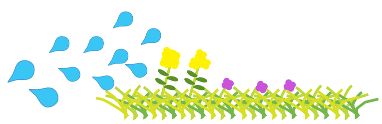
Stormwater can also be drawn from our existing stormwater collection systems:

- *Gutters*
- *Storm sewers*
- *Underground drains*
- *Stormwater ponds*
- *Raingardens or bioretention basins*

## Storage

## Treatment

## Reuse Stormwater



Numerous activities that utilize water from the potable drinking water system can, with appropriate treatment, use stormwater. Human contact requires the highest level of treatment.* The most common uses of treated stormwater include:

- *Irrigation: athletic fields, golf courses, parks, landscaping, community gardens, water features*
- *Municipal uses: utility washing, street cleaning, construction dust control, equipment washing, sanitary sewer flushing*
- *In-building: toilet flushing, cleaning*
- *Industrial: cooling water, process water, washdown water*

*Consumption of treated stormwater is not recommended. The Minnesota Plumbing Code prohibits a cross connection between potable water and stormwater piping unless backflow prevention is provided.

Summer residential irrigation and other outdoor uses account for up to 50% of potable water per person per day in the Twin Cities.

Source: ***Rotating Sprinklers.*** Photograph. http://www.toro.com/en-us/homeowner/do-it-yourself-irrigation/rotating-sprinklers/pages/default.aspx. The Toro Company, 2011. Web. 28 October 2011.

## Twin Cities Water Facts

- *Twin Cities municipal water supply = 30% from surface water; 70% from groundwater.*
- *Average of 120 billion gallons of water used in Twin Cities each year for residential, commercial and industrial uses (excluding power generation).*[3]
- *Twin Cities population is projected to reach 3,608,000 in 2030.*[4]
- *Water demand growth between 2004 and 2030 could increase by 29%, or approximately 112,000,000 gallons per day. It is possible to limit water growth to 16% with improved efficiency and reduction in uses.*[3]
- *Overall water supply is adequate to meet future water demands. However localized limitations exist, including hydrogeologic limitations to groundwater supply, competing demands, reduced groundwater recharge caused by increased runoff, surface water contamination, and aquifer contamination.*[3]
- *Outdoor residential water use averages 45 to 120 gallons per person per day in the Twin Cities, with peak usage at 200 gallons per person per day for large lots and new turf.*[3]
- *In the summer, as much as 50% of potable water supply is used for outdoor, nonpotable uses.*
- *Common household non-potable water use.*[5]
  - *Sprinkler =* $^1/_2$ *to 4 gallons per minute*
  - *Drip irrigation =* $^1/_2$ *to 2 gallons per minute*
  - $^1/_2$*" hose = 300 gallons per hour*
  - $^5/_8$*" hose = 500 gallons per hour*
  - $^3/_4$*" hose = 600 gallons per hour*
  - *Toilet = 1.1 to 3 gallons per flush*
- *On a national basis, use of reclaimed water (stormwater and wastewater) is growing at a pace of 15% per year.*[6]
- *During a typical year, 35 to 50 rain events occur in Minnesota. 90% of these rain events generate a rainfall depth of 1.05" or less.*[7]
- *1 acre parking lot = 27,000 gallons of runoff during a 1" rainfall*
- *1000 sf rooftop = 624 gallons during 1" rainfall*
- *Rain barrel volumes vary from 49 to 70 gallon (no standard exists)*

[3] Metropolitan Council, Metropolitan Area Master Water Supply Plan, 2010.

[4] Metropolitan Council, 2030 Regional Development Framework - Revised Forecasts as of December 31, 2010.

[5] Metropolitan Council, Water Conservation in the Twin Cities Metropolitan Area, June, 1991.

[6] USEPA, Guidelines for Water Reuse, 2004.

[7] Minnesota Pollution Control Agency, Minnesota Stormwater Manual, 2005.

# Project Planning


## Overview

The Project Planning section provides an overview and structure to the many tools available in this guide. The user can opt to either access the tools directly, or to use this Project Planning Section as a guide as a step-by-step process that moves stormwater reuse projects from concept through implementation.

### Phase 1: Concept

Pin down the basics of a stormwater reuse project.

- *Identify the **SOURCE** of stormwater runoff*
- *Determine the **USE** of the stormwater runoff*
- *Identify information that may need to be obtained to plan a stormwater reuse project.*

### Phase 2: Assessment

Research critical factors necessary to implement a stormwater reuse project.

- *Perform a series of assessments*
- *Record key findings that are used to establish the basis for Phase 3: Implementation*

### Phase 3: Implementation

Define specific stormwater reuse project features.

- *Determine project components:*
  - » *Collection*
  - » *Storage*
  - » *Treatment*
  - » *Distribution/Use*
- *Identify key considerations:*
  - » *Predesign*
  - » *Design*
  - » *Operation & Maintenance*
  - » *Costs*


Project Planning

# Phase 1: Concept

The first step in planning a stormwater reuse project is to establish the **SOURCE** of the stormwater and its **USE**. The next step is to gather information that will be used to determine the feasibility of a stormwater reuse project given the **SOURCE** and **USE** selected.

**STEP 1:**

Proceed to Tools C.1 and C.1w to select and record the **SOURCE** and **USE**:

C.1 Source and Use

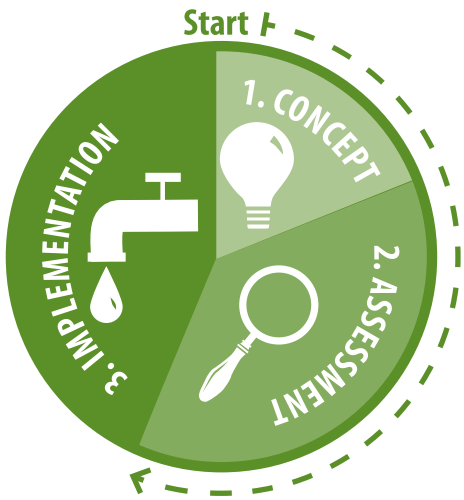
C.1w Source and Use Worksheet

**STEP 2:**

Use Tools C.2 and C.2w to identify and record all the data and information that may be needed in planning a stormwater reuse project:

C.2 Data Collection

C.2w Data Collection Worksheet




**Project Planning**

# Phase 2: Assessment

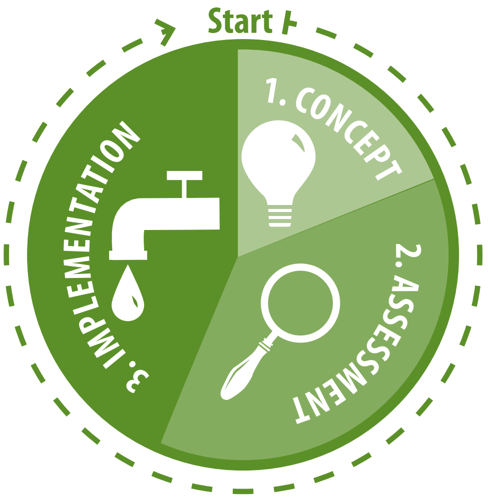
This phase researches critical factors necessary to implement a stormwater reuse project.

During this phase, users are presented with a series of assessment tools to investigate specific project features, such as stormwater quality, water quality required for specific uses, water quantity and storage considerations, the impacts of upstream and downstream uses, site suitability and permit requirements.

Apply **Tool A.0 Assessment Steps** to identify critical factors and key considerations for project implementation.

A.0 **Assessment Steps**

There are seven steps in the assessment process, each defined as a separate tool titled A.1 - A.7. There are worksheets to record the outcomes of each assessment step, titled A.1w - A.7w.




Project Planning

# Phase 3: Implementation

In this Guide, Implementation is used broadly to describe the design, construction, and operation phases of a stormwater reuse project. Each tool in this section is organized according to the typical components of a reuse system: collection, storage, treatment and distribution. It is assumed that the user has a basic knowledge of stormwater management, or has resources to assist or advise on stormwater issues. Planners, designers, owners and operators are supplied with supplemental information needed to create a successful stormwater reuse project in Minnesota. Since cold winters are the norm for Minnesota, cold climate design and operation tips are embedded into each tool. Additionally, designers are encouraged to include features that aid in the inspection and maintenance of a reuse system.

**Implementation Tools** contain schematics and tips for each of the four basic components of a stormwater reuse project:

I.1a Collection Systems

I.1b Ground Runoff Collection

▶ *Collection Systems (I.1a) and Ground Runoff Collection (I.1b) include features that are important to both roof and ground stormwater collection systems.*

I.2 Storage Systems

▶ *Storage Systems (I.2) describes features for both above ground and below ground storage.*

I.3 Treatment

▶ *Treatment (I.3) provides guidance on the common features of treatment systems, while pointing out that each manufactured system is unique and designed to treat specific stormwater constituents.*

I.4 Distribution

▶ *Distribution (I.4) includes information for distribution of reuse water for a land application system such as irrigation. Because each non-irrigation project is unique, such projects are not included in this guide.*

Take a look at the three Layout Tools for generic stormwater reuse project examples:

**R.6a - Stormwater Pond Retrofitted for Athletic Field Irrigation**

**R.6b - Rooftop Runoff Collected for Community Garden**

**R.6c - Stormwater Runoff Collected for Public Works Vehicle Washing**

# Case Studies

## Overview

This section highlights five stormwater reuse case studies from around the globe. These project examples are meant to be used to gain inspiration and learn lessons from projects already in the ground.

Source: ***Stephen Epler Hall.*** Photograph. http://www.pdx.edu/sites/www.pdx.edu.sustainability/files/sus_epler_case_study.pdf. Portland State University, 2011. Web. 28 October 2011.

## QUICK FACTS:

***Over 10,000 sq. ft. of rooftop rainwater collected and reused***

### Project Owner

- *Portland State University (PSU) and the Oregon University System (OUS)*

### Project Costs

- *Capital Cost: N/A*
- *O&M Cost: N/A*

### Water Fact

- *110,000 gallons of water savings per year*

# Stephen Epler Hall Rainwater Reclamation System

## Portland State University, Portland, Oregon

### Project Description

For Portland State University (PSU)'s mixed-use student housing facility (Stephen Epler Hall), a rainwater reclamation system was designed to collect rooftop rainwater that is treated and used for irrigation and toilet flushing.

### Project Objectives

- *Recycle rooftop rainwater for irrigation and for toilet and urinal flushing.*
- *Reduce municipal potable water consumption.*
- *Create educational opportunity for students and staff regarding the benefits of rainwater reuse.*

### Source Water

Rooftop rainwater from the 10,000 square ft roof and from a portion of the roof of the neighboring King Albert Hall

### Regulatory Requirements

- *Standard building permits, as required by the City of Portland*

### Public Involvement

The project was required to go through a design review process including a public presentation to the City and the neighborhood association.

## Project Components:

### Collection

- *The water flows from the roof area of two buildings to scuppers that direct the water to exposed downspouts. The water flows from the downspouts to an above-grade splash block (largely ornamental in nature). The water then flows from the splash block area via an above-grade runnel and below grade pipe to a planting bed where it is filtered downward. It then flows via pipe to an underground storage tank.*

### Storage

- *1,170 cubic ft below-grade storage tank*

### Treatment Process

- *The water is filtered through the planting bed and then piped to the storage tank. It is then pumped into the building where it passes through a UV purifier.*

### Distribution

- *After it passes through the UV purifier it is distributed either to the irrigation system or the toilets. If there is insufficient rainwater, the system automatically shifts to City provided potable water.*

## Operation and Maintenance

- *UV system monitoring to make sure that the bulb is operating properly.*
- *Pump operation and maintenance*

## Project Outcomes

- *Conserves approximately 110,000 gallons of potable water annually, providing a savings of $1,000 each year*
- *Reduces stormwater runoff*
- *PSU's first LEED project*

## Lessons Learned

- *A larger storage system is needed to accommodate the dry season water demand from late June through September.*
- *Correct equipment choice (pumps, etc.) is critical for a successful project.*
- *Need staff and resident buy-in to be successful.*

*Stormwater planters drain to rainwater storage tank below the plaza.*

Source: ***Water Savings.*** Photograph. http://www.pdx.edu/sustainability/stephen-epler-residence-hall. Portland State University, 2011. Web. 28 October 2011.

*Storage reservoir site at 25% constructed.*

Source: WSB & Associates

## QUICK FACTS:

***Over 15 acres of ground runoff from athletic fields and streets collected and reused***

**Project Owner**

- *City of Saint Anthony Village*

**Project Designer**

- *WSB & Associates, Inc.*

**Project Costs**

- *Capital Cost: $1.5 million*
- *O&M Cost: $3,000 per year (estimated)*

**Water Fact**

- *77.5% reduction in phosphorus discharges to nearby surface waters*

*The storage tank is below an aesthetically designed stormwater pond with fountains.*

Source: HKGi

# Saint Anthony Village Water Reuse Facility

## City of Saint Anthony Village, Minnesota

### Project Description

The Saint Anthony Village Water Reuse Facility collects stormwater runoff from 15.4 acres of land, including Silver Lake Road (Hennepin County Road 136), the City Hall, and local streets, plus filter backwash water from the City's water treatment plant. The collected runoff and filter backwash water is stored in a half million-gallon reservoir located underground and adjacent to Silver Lake Road. Water stored in the reservoir is recycled to irrigate a 20-acre site that includes a municipal park and St. Anthony's City Hall campus.

### Project Objectives

- *Capture and reuse filter backwash water to eliminate discharge to sanitary sewer.*
- *Capture and reuse stormwater runoff to reduce pollutant discharge to surface waters.*
- *Conserve groundwater by replacing potable water used for field irrigation with reuse water.*
- *Reduce irrigation costs for City and comply with stormwater management requirements for Hennepin County roadway improvements and for public school parking lot upgrades.*
- *Create educational opportunities for stormwater management professionals and the public to view and learn about water reuse in Minnesota.*

### Site Characteristics

- *Runoff from15.4 acres of surface area, including Silver Lake Road, 33rd Avenue NE, City Hall campus and the school parking lot*
- *0.5-million gallon storage reservoir located underground between tennis courts and Silver Lake Road right-of-way*

### Source Water

- *Stormwater runoff including snowmelt*
- *Filter backwash water from the City's water treatment plant*

### Regulatory Requirements

- *Water Treatment Facility General Permit (MPCA)*
- *NPDES/SDS Permit (MPCA) for water treatment plant discharge*
- *NPDES general stormwater permit for construction activity (MPCA) for site construction*
- *Sanitary Sewer Extension Permit (MPCA/Metropolitan Council) for discharge to sanitary sewer from storage reservoir*

## Project Components:

### Collection

- *Stormwater runoff and backwash water conveyed via gravity flow into the storage reservoir*

### Storage

- *0.5-million gallon underground storage reservoir*
- *Additional storage capacity provided by pumping water into a pond located above the storage reservoir*

### Treatment Process

- *Backwash water chlorinated prior to entering the storage reservoir*
- *Settling of suspended pollutants in the storage reservoir*
- *Filtration through a self-cleaning disc filter prior to reaching the irrigation distribution system*

### Distribution

- *Treated water pumped to two irrigation systems*
- *Potable water supply is directed to the reservoir and used for irrigation if reuse water is not available.*

- *Rice Creek Watershed District Permit for construction activity*
- *Rice Creek Watershed District Rules and the City's Ordinances*
- *Minnesota Department of Health (MDH) did not require a permit for the project.*

## Public Involvement

Several presentations and an educational sign on the site have helped to educate residents about stormwater management issues in the community.

Some concerns regarding water quality of reused water were initially raised by the public. These concerns diminished once the public was informed of the water quality of reused water.

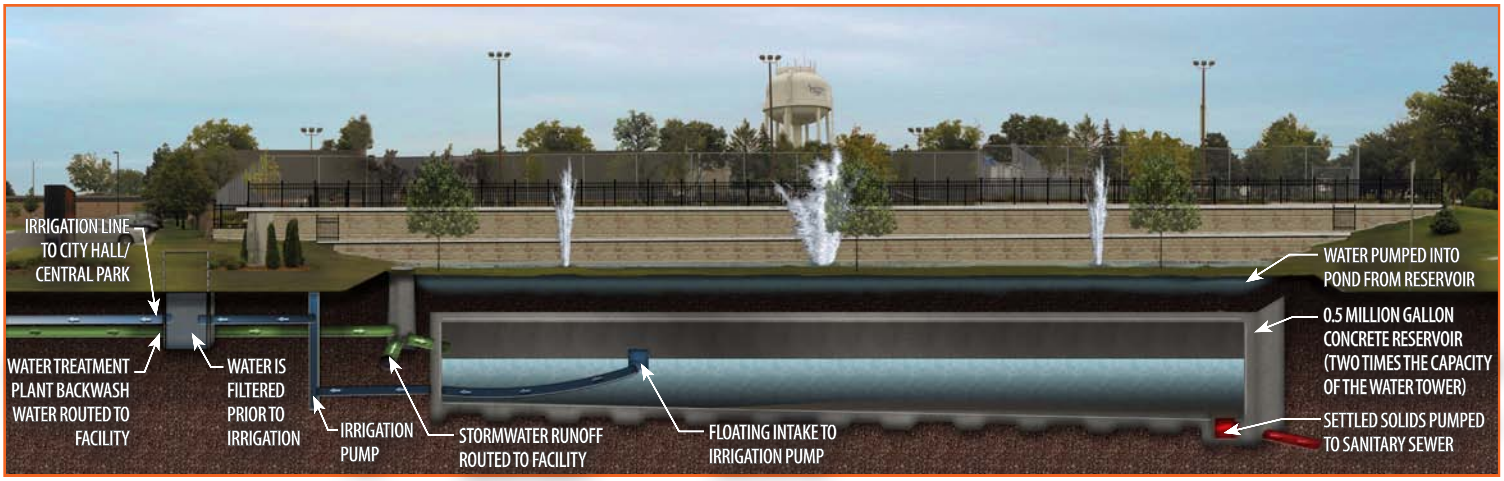
## Project Outcomes

- *Surface water discharge reduced by 4.6 MGY, from 8.3 MGY to 3.7 MGY (55% reduction)*
- *Potable water used for irrigation on the site reduced from 6.0 MGY to 1.4 MGY, saving $16,000/yr*
- *Estimated annual pollution loads to nearby surface waters reduced by 77.5% for phosphorus and 95% for total suspended solids (TSS)*

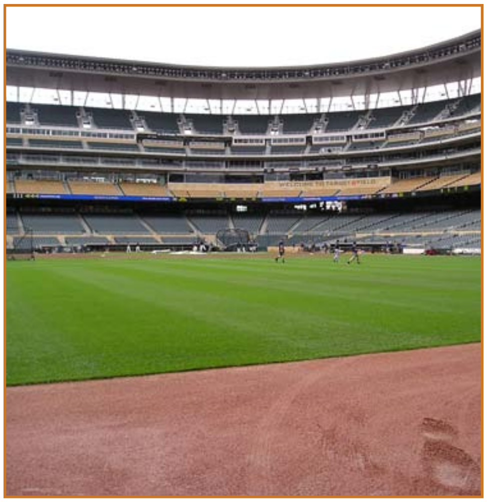
## Monitoring Results

Testing has been performed to detect chloride and fecal coliform present in the reservoir. Results indicate there are no public health concerns and that water is suitable for turf irrigation.

The volume of reused water has been monitored from 2009 through 2011. Results indicate more than 6.0 million gallons per year are being reused for irrigation. This monitored volume exceeds original expectations by 30%.




*Saint Anthony Village Water Reuse Facility*
Source: WSB & Associates



*Treated water is used to irrigate the ball field and to provide wash-down water for the lower deck of the stadium.*

Source: CDM

## QUICK FACTS:

***Over 7 acres of ground runoff from baseball field collected and reused***

### Project Owner and Partner

- *Owner: Minnesota Twins*
- *Partner: Pentair, Inc.*

### Project Costs

- *Capital Cost: $150,000 to $500,000*
- *O&M Cost: $50,000/ yr (estimated) including energy consumption, filters, winterization, etc.*

### Treatment

- *Energy consumption is the equivalent of one hundred 75W light bulbs*

# Target Field Rainwater Recycling System

## Target Field, Minneapolis, MN

### Project Description

A custom-designed rainwater recycling system (RWRS), developed, installed, and maintained by Pentair Inc., recycles rainwater and irrigation water to maintain turf and to provide wash-down water for the lower deck of the stadium.

### Project Objectives

- *Enable the Minnesota Twins to reduce their "water footprint."*
- *Reduce municipal water consumption.*
- *Reduce stormwater runoff volumes and pollutant loads discharged to the Mississippi River.*
- *Create awareness of water management by citizens, businesses and other organizations.*

### Site Characteristics

The project is located at Target Field – a 40,000 seat outdoor baseball stadium located in downtown Minneapolis. Within the stadium, the cistern (water storage tank) is located beneath the field under the "warning track." The filtration system is predominantly above ground (holding tank, main filtration systems, controls and majority of the pressure pumps) and located underneath the seating in left-center field.

### Source Water

- *Rainwater/stormwater from the ballpark (field and stadium seating)*
- *Recycled irrigation water on the ballpark field*
- *Catchment area: 7 acres*

### Quantity and Quality Requirements

- *Quantity requirements: treatment system must be able to deliver at a rate of 15,000 gallons of water per use. The system is designed at 250 gallons per minute for 6 usage zones at a maximum of 90 minutes per zone with 40 minutes recovery between each zone watering.*
- *Quality based on California EPA Title 22 Guidelines for Direct Contact Water*

### Regulatory Requirements

Standard electrical permits and standard construction (plumbing) permits

## Project Components:

### Collection

- *Rain water and irrigation water funneled into and captured in an underground cistern*

### Storage

- *200,000 gallon underground storage cistern*

### Treatment Process

- *Mixing and aeration in the cistern*
- *Initial filtration*
  - *Water from the cistern filtered to a minimum level of 200 microns with a back-washable filter*
  - *Filtrate further filtered through Pentair's proprietary AquaLine™ Filtration System to a level of approximately 5-10 microns*
- *Ultraviolet disinfection prior to ultrafiltration process*
- *Ultrafiltration process filters water to approximately 0.01 microns*
- *Chlorination following ultrafiltration*
- *Ultrafiltered and chlorinated water is placed in a 5,000 gallon holding tank which is continuously re-circulated through ultraviolet lights to provide a consistent, high-level of disinfection.*

### Distribution

- *Treated water pumped to irrigation system or wash-down system at a rate of up to 250 gallons per minute*
- *When irrigation and wash-down systems are off, there is no demand for water, and the treatment system runs in an idle (recirculation) mode at 125 gallons per minute. The treated water overflows from the 5,000 gallon holding tank back to the cistern.*

## Operation and Maintenance

- *Replacement of cartridge filters periodically*
- *Clean-In-Place (CIP) of the UF filters*
- *Annual or semi-annual removal of debris in the cistern*
- *Winterization and de-winterization of the system*
- *Periodic quality tests of the water in the system*

## Public Involvement

No issues were raised. The project has been positively received by the public.

## Project Outcomes

- *Municipal water consumption for the Twins and Target Field stormwater runoff reduced by approximately two million gallons per year*
- *Irrigation of the ballfield using treated stormwater*
- *Wash-down water for the lower grandstand using treated stormwater*
- *Public education regarding stormwater treatment and reuse*
- *Target Field attained LEED Silver Certification*


*Target Field Rainwater Recycling System*

Source: CDM

*Aerial view of Riverside Park*
Source: Bing Maps

# Riverside Park Stormwater Reuse Project

## Chipping Norton, Australia

### Project Description

A wetland system treats stormwater that is used to irrigate sporting fields in Chipping Norton, New South Wales, Australia.

### Project Objectives

- *Reduce potable water use at the Riverside Park sporting fields through the use of stormwater for irrigation.*
- *Utilize an existing constructed wetland system for treatment.*

### Site Characteristics

The catchment area is approximately 116 acres. Land use consists of primarily of industrial development (47%), residential uses (31%) and the Riverside Park itself (22%).

### Source Water

- *Stormwater runoff*

## QUICK FACTS:

***Over 100 acres of runoff from industrial and residential land collected and reused for irrigation***

### Project Owner

- *Liverpool City Council, New South Wales, Australia*

### Project Costs

- *Capital Cost: $68,200(AU)*
- *O&M Cost: $5,700(AU)/yr*

### Water Fact

- *3.2 million gallon annual reuse volume*

## Project Components

### Collection

- *Stormwater channel*

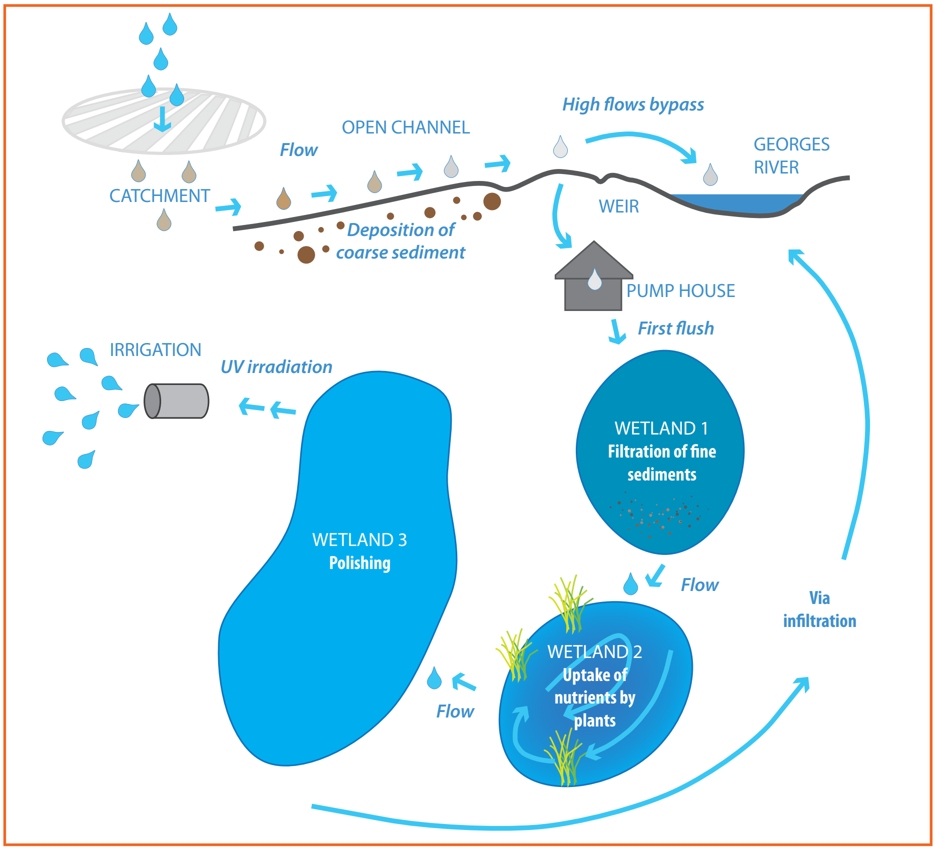
### Treatment Process

- *Three treatment wetlands*
- *The first two wetlands provide water treatment through sedimentation and biological processes.*
- *The third wetland serves as a polishing pond.*
- *UV disinfection prior to irrigation*

### Distribution

- *Treated water is pumped from the third wetland for distribution to an existing irrigation system to irrigate an area of 4.9 acres of athletic fields.*
- *Potable water provides a back-up supply for the irrigation system.*

## Process Diagram




Source: HKGi. Graphic adapted from Graphic adapted from New South Wales Department of Environment and Conservation, Managing Urban Stormwater, Harvesting and Reuse, April 2006.

## Operation and Maintenance

- *Minimal operation and maintenance requirements, including pump operation and maintenance, and UV system monitoring.*

## Project Outcomes

- *Estimated annual stormwater reuse volume of 3.2 million gallons, saving $17,760 (AUD).*
- *Estimated annual stormwater pollution loads reduced by 37,400 lb for suspended solids, 51 lb for total phosphorus and 81 lb for total nitrogen.*

## Monitoring Results

| Parameters | Effluent | |
|---|---|---|
| Fecal Coliform | cfu/100 mL | 150 |
| Total Suspended Solids | mg/L | 2.5 |
| Turbidity | NTU | <2 |
| Total Phosphorus | mg/L | 0.1 |
| Total Nitrogen | mg/L | 0.2 |
| Oil and Grease | mg/L | 80 |

*Dissolved air flotation system*
Source: Brewer, ***Figure 8-2: Dissolved Air Flotation Treatment at the SMURRF.*** Texas Water Development Board, Stormwater Guidance Document, March 2010.

**QUICK FACTS:**

***Located next to Santa Monica Pier to aid public education.***

### Project Owner and Designer

- *Owner: City of Santa Monica*
- *Designer: CH2M Hill*

### Project Costs

- *Capital Cost: $12 millon*
- *O&M Cost: approximately $401,850/yr*

## Monitoring Results

| Parameters | | Influent[1] | Effluent[1] |
|---|---|---|---|
| Oil and Grease | mg/L | 1.82 | 1.90 |
| pH | | 8.07 | 8.23 |
| Turbidity | NTU | 13.02 | 0.67 |
| Total Suspended Soilds (TSS) | mg/L | 29.5 | ND |
| Total Dissolved Solids | mg/L | 926 | 1,095 |
| Alkalinity | mg/L | 185 | 163 |
| Conductivity | umho/cm | 1,394 | 1,639 |
| Total Coliform | per 100 mL (MPN) | 211,079 | 2.9 |
| Fecal Coliform | per 100 mL (MPN) | 5,126 | 1.1 |

[1]Based on 2009/2010 monitoring data

# Santa Monica Urban Runoff Recycling Facility (SMURRF)

## Santa Monica, California

## Project Description

The Santa Monica Urban Runoff Recycling Facility (SMURRF) in Santa Monica, California, treats dry weather urban runoff[1] by conventional and advanced treatment systems to remove pollutants such as sediment, oil, grease, and pathogens. The treated urban runoff is reused for irrigation and indoor commercial building use.

## Project Objectives

- *Eliminate pollution of Santa Monica Bay caused by urban runoff during dry season (storm drain low flows).*
- *Produce high quality water for reuse.*
- *Raise public awareness of Santa Monica Bay pollution issues and create educational opportunities.*

## Site Characteristics

The project catchment area is approximately 5,100 acres, and is highly urbanized. The treatment facility is located next to the Santa Monica Pier on the northwest corner of Moss Avenue and Appian Way. The location was chosen for its high visibility and proximity to the pier, thus improving its educational utility for stormwater and urban runoff issues.

## Source Water

- *Urban stormwater runoff from the City of Santa Monica's two largest flows: the Pico-Kenter and Pier storm drains, which contribute about 90 percent of the City's total daily dry weather runoff.*
- *Dry weather runoff is created from excess irrigation, spills, construction sites, pool draining, car washing and washing down paved areas.*

## Quantity and Quality Requirements

- *Quantity requirements: 500,000 gallons of water per day*
- *Quality requirements: California EPA Title 22 Guidelines*

## Regulatory Requirements

- *Approval required from the California Coastal Commission*
- *Approval required through California Environmental Quality Act (CEQA)*
- *Building and Safety Permit required*
- *State of California Regional Water Quality Control Board required a monitoring plan in lieu of a NPDES permit because SMURRF was classified as a Best Management Practice.*

[1] Dry weather runoff – the term used for nuisance runoff, like irrigation flows, which can occur all year long, not including small storms. The term used for the dry time of the year is the "dry season," typically April 1 through October 1.

## Project Components

### Collection

- Storm drain

### Storage

- 265,000 gallon influent equalization basin
- 280,000 gallon effluent equalization basin

### Treatment Process

- Coarse screening: remove large floating debris and trash
- Fine screening (rotary drum screen): remove fine floating particles that are greater than 0.04 inches in size
- Grit and sand removal: remove inorganic settleable material
- Raw water storage
- Dissolved air floatation: remove oil and grease
- Microfiltration: filters water to approximately 5 microns
- Ultraviolet disinfection
- Clean water storage

### Distribution

- Distribution system for landscape irrigation and indoor commercial building use

*Santa Monica Urban Runoff Recycling Facility*

Source: ***SMURRF: Santa Monica Urban Runoff Recycling Facility.*** Photograph. http://www.smgov.net/Departments/PublicWorks/ContentCivEng.aspx?id=7796. City of Santa Monica, 2010. Web. 28 October 2011.

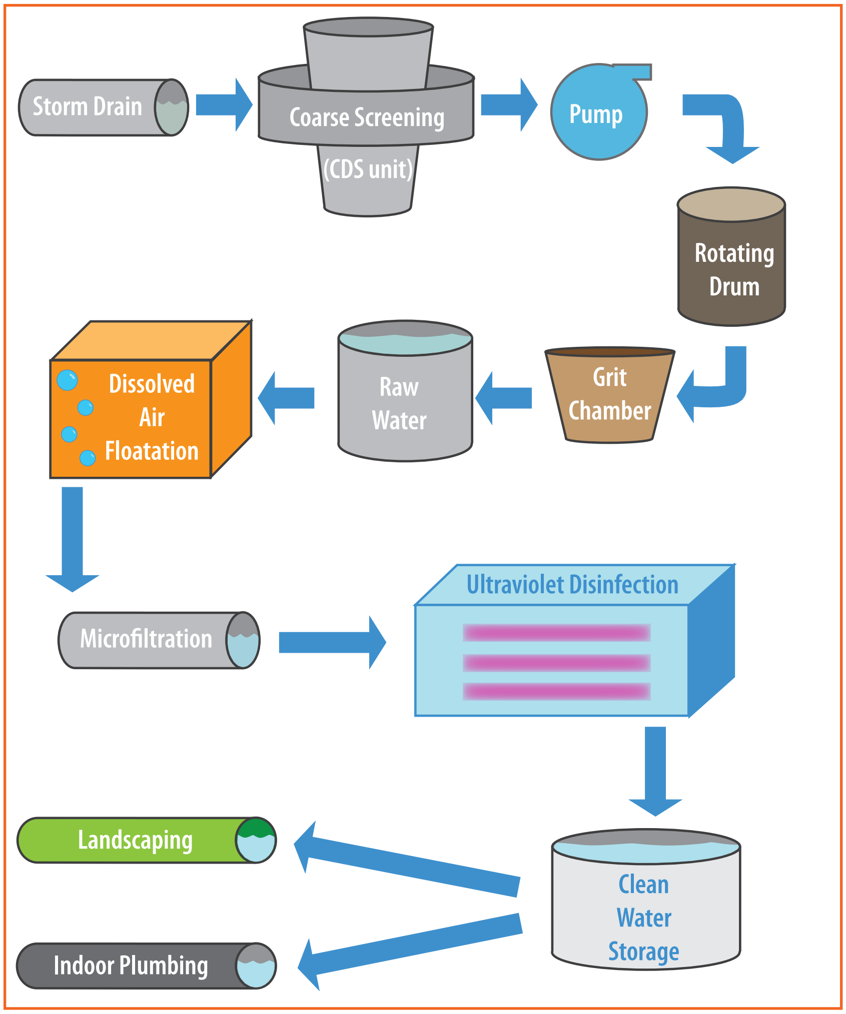
## Operation and Maintenance

- *The rotating drum screen, grit chamber, and UV disinfection system require regular monitoring and preventative maintenance for proper performance. The microfiltration membranes will require eventual replacement.*
- *There is no means for introduction of potable make-up water into the irrigation distribution system downstream of the SMURRF plant. The plant can not be taken out of service to allow routine maintenance of the recycled water distribution system downstream of SMURRF.*
- *Access to the influent and effluent equalizations basins for servicing maintenance is difficult due to the lack of access ladders and the basins cannot be taken off line.*

## Project Outcomes

- *Reduced stormwater pollution loads to Santa Monica Bay by 167,400 lb/yr for suspended solids.*
- *Estimated annual stormwater reuse volume of 182.5 million gallons.*

## Project Components




*SMURRF process flow diagram*

Source: ***How the SMURRF Works….*** Graphic. http://www.smgov.net/uploadedFiles/Departments/OSE/Categories/Urban_Runoff/UR_SMURRF_Info_Sheets.pdf. Web. City of Santa Monica, CH2MHill, 2010. Web. 28 October 2011.

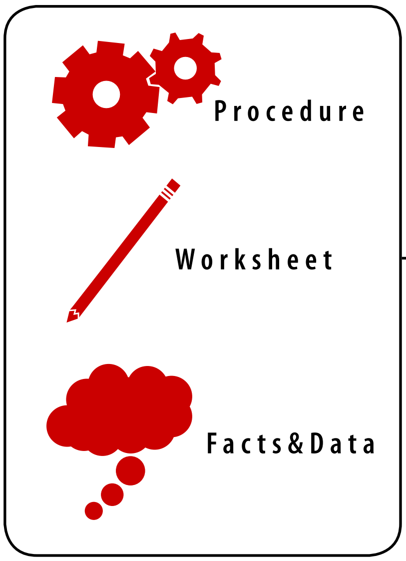
# Toolbox

## Overview

The toolbox contains a variety of information to assist in planning a stormwater reuse project. The information is grouped according to the three project planning phases and supporting resources.

- *Concept (C)*
- *Assessment (A)*
- *Implementation (I)*
- *Resources (R)*

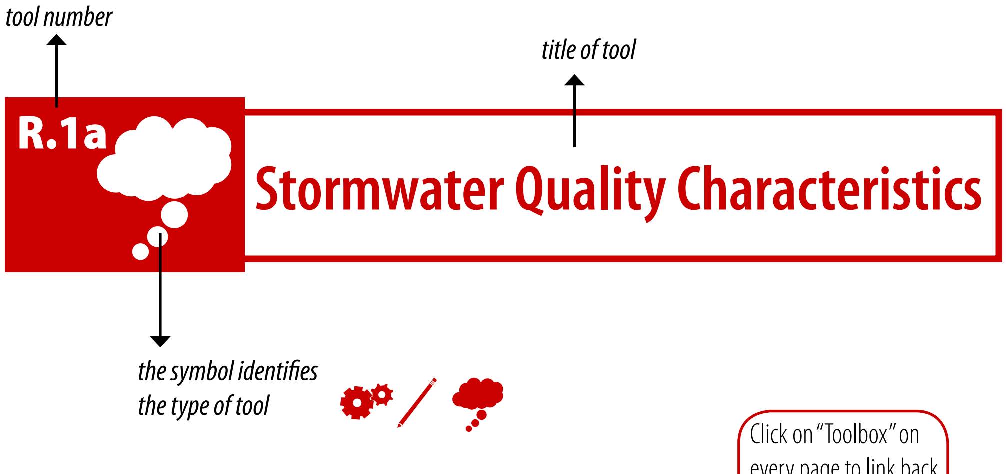

The tools can be used in sequence with the planning phases or as individual resources for specific project features of interest. Many tools reference other tools. It will be useful to reference the complete **list of tools** before proceeding and to revisit the list throughout the project planning process.




The list identifies the type of tool by how it is used:

- *Planning steps and procedures to analyze specific topics (Procedure)*
- *Worksheets to record key information (Worksheet)*
- *Supporting data and text (Facts & Data)*

## Tool Symbol




Click on "Toolbox" on every page to link back to the **list of tools**.

# What's in the Toolbox?

| Section | Number | Title | Procedure | Worksheet | Facts & Data |
|---|---|---|---|---|---|
| Concept Phase Tools | C.1 | Source and Use | x | | |
| | C.1w | Source and Use Worksheet | | x | |
| | C.2 | Data Collection | x | | |
| | C.2w | Data Collection Worksheet | | x | |
| Assessment Phase Tools | A.0 | Assessment Steps | x | x | |
| | A.1 | Source Water Quality | x | | |
| | A.2 | Quantity and Storage | x | | |
| | A.3 | Upstream Source | x | | |
| | A.4 | Downstream Use | x | | |
| | A.5 | Use Criteria | x | | |
| | A.6 | Site Suitability for Land Application | x | | |
| | A.7 | Permits | x | | |
| | A.1w | Source Water Quality Worksheet | | x | |
| | A.2w | Quantity and Storage Worksheet | | x | |
| | A.3w | Upstream Source Worksheet | | x | |
| | A.4w | Downstream Use Worksheet | | x | |
| | A.5w | Use Criteria Worksheet | | x | |
| | A.6w | Site Suitability for Land Application Worksheet | | x | |
| | A.7w | Permits Worksheet | | x | |
| Implementation Phase Tools | I.1a | Collection Systems | x | | |
| | I.1b | Ground Runoff Collection | x | | |
| | I.2 | Storage Systems | x | | |
| | I.3 | Treatment | x | | |
| | I.4 | Distribution | x | | |
| Resource Tools<br>*R.1 Stormwater Quality* | R.1a | Stormwater Quality Characteristics | | | x |
| | R.1b | Stormwater Quality Data Tables | | | x |
| | R.1c | Upstream Water Quality Considerations | x | | |
| *R.2 Water Quantity & Measurement* | R.2a | Water Balance | x | | x |
| | R.2b | Stormwater Monitoring (Flow & Quality) | x | | |
| *R.3 Use Water Quality* | R.3a | Use Water Quality Characteristics | | | x |
| | R.3b | Water Quality Criteria Tables | | | x |
| | R.3c | Use Criteria Matrix | | | x |
| | R.3d | Treatment Process Considerations | | | x |
| *R.4 Treatment* | R.4 | Treatment | | | x |
| *R.5 Cost* | R.5 | Construction Cost Development | | | x |
| *R.6 Concept Layouts* | R.6a | Stormwater Pond Retrofitted for Athletic Field Irrigation | | | x |
| | R.6b | Rooftop Runoff Collected for Community Garden | | | x |
| | R.6c | Stormwater Runoff Collected for Public Works Vehicle Washing | | | x |

# Source and Use

The primary drivers for stormwater reuse can be one or both of the following:

- *Reduce the use of potable water supplies*
- *Control stormwater flows and/or pollutant loadings*

If the main purpose for a stormwater reuse project is to replace nonpotable water demand, it makes sense to start by defining potential uses and then identify stormwater sources in proximity to those uses. If runoff management is the primary goal, the location to collect stormwater is typically identified first and then potential uses in the area are investigated. Regardless of the reason for considering stormwater reuse, key to establishing the system needs and feasibility of a specific project are identifying:

- *The SOURCE of the stormwater*
- *The USE(s) of the stormwater*

The SOURCE of the stormwater establishes the water quality and quantity characteristics of the supply that enters a stormwater reuse system. The USE(s) dictate the water quality and quantity that must exit a reuse system. If there is not a match in quality and quantity of the SOURCE and USE, then a reuse system must provide treatment and/or storage components to meet the requirements for the final intended use.

This tool is the first step in the first of the planning phases, the Concept Phase. For some users of this guide, it is likely that the exact SOURCE and USE(s) are not known at this initial inquiry. This tool suggests basic information that should be researched in order to move forward in the planning process and then be revised and updated as the project is developed.

STEP 1: Identify whether the SOURCE stormwater will be collected either:

- *Directly from a building rooftop (roof runoff)*
- *From overland stormwater (ground runoff), which can also contain roof runoff*

Record this on **Tool C.1w**.

STEP 2: Identify the planned USE(s) as listed on **Tool C.1w** (refer to the **Reuse Fact Sheet** and **Case Studies** for examples).

Record this on **Tool C.1w**.

# Source and Use Worksheet

This worksheet captures and records decisions first made in the Concept Phase. It may be revised throughout the planning process as a project becomes more defined.

## Step 1 - Define the Source

What are the stormwater sources in the project area? Check one box.

☐ ***Roof Runoff Only***

☐ ***Ground Runoff (use this category if your stormwater includes both roof and ground runoff)***

## Step 2 - Define the Use

Once the stormwater is collected, what are the proposed uses? Check as many boxes as apply.

- ***Residential/Commercial/Public Property Areas***
  - ☐ *Landscape irrigation (cemeteries, freeway buffers, restricted golf courses and other controlled access areas)*
  - ☐ *Utility washing (paths, fences, outdoor equipment/areas)*
  - ☐ *Open access landscape irrigation (parks, athletic fields, unrestricted golf courses)*
  - ☐ *Food garden watering*
  - ☐ *Water features and systems (ponds, fountains, waterfalls)*
  - ☐ *Within buildings (toilet flushing)*
  - ☐ *Vehicle washing*
- ***Municipal uses***
  - ☐ *Street cleaning*
  - ☐ *Roadmaking and dust control*
  - ☐ *Equipment and structure washing*
  - ☐ *Fire protection*
  - ☐ *Sanitary sewer flushing*
- ***Commercial uses***
  - ☐ *Nurseries, sod farms, tree farms*
  - ☐ *Pasture*
  - ☐ *Orchards, vegetables/fruit*
- ***Industrial Uses***
  - ☐ *Cooling water*
  - ☐ *Process water*
  - ☐ *Wash-down water*

☐ ***Other*** ____________________________________________

# Data Collection

The following data is required to select and design an effective stormwater reuse project. Data availability will vary from site to site, but the first stage of project planning should include a search for the following available information. A record of available information can be created using Worksheet C.2w.

**1. System maps and surveys**
- *GIS or other contour map with sufficient resolution to define catchment areas and drainage pathways*
- *Municipal storm sewer maps for systems collecting runoff and/or discharging excess runoff to the municipal system; also used to locate downstream stormwater BMPs*
- *USGS topographic map or other map to locate downstream surface water*
- *FEMA floodplain maps to determine if site is in floodplain*
- *County soils and karst maps for land application systems*
- *Municipal, County and/or MNDOT maps to locate major highways in catchment areas*
- *State and/or County maps to locate hazardous waste sites*

**2. Studies and reports**
- *Precipitation volume from rain gauges for each monitored event*
- *Runoff monitoring data and reports that define existing stormwater quality*
- *Hydraulic analyses that define existing rate and volume of runoff*
- *Stormwater design data for sites with pre-existing stormwater collection systems for use in laying out components of reuse system*
- *Pre-existing permits, including land use, zoning, building, plumbing, and stormwater discharge permits for use in determining any limitations that must be considered or mitigated*
- *Pre-existing site soil borings and other geotechnical analyses for land application systems to determine depth to bedrock, soil suitability, depth to groundwater and other considerations*

**3. Site specific data and surveys**
- *Site plan or other surveys to locate existing structures, roof areas, impervious surfaces, slopes, and drainage pathways*
- *Gopher State One-Call to locate above and below ground utilities, including electrical and potable water services*
- *Storm sewer survey noting collection points (grates and rooftop collections), pipe size, pipe material, pipe depth, pipe slope, manholes, pump stations, control structures, storage structures, and discharge locations*
- *Stormwater pond or other BMP dimensions, depth, structures and operating requirements if stormwater is being collected downstream of pond or other BMP*
- *Pre-existing storage tank properties, including dimensions, control valves, cover, fencing, elevations, access, inlets, outlets, and condition*
- *County Well Index (to check for proximity of land application systems to wells; also includes groundwater quality information)*
- *Building plans that show roof structures, materials, and drainage systems (particularly for larger building roof runoff collection systems)*
- *Precipitation data for local area (long-term historical record for regional area and site-specific information if available)*

**4. USE data**
- *Minimum rate and volume of USE*
- *Maximum rate and volume of USE*
- *For irrigation systems: additional soil borings to supplement information not collected in previous studies, including soil types, infiltration rates, slope, depth to water table, depth to bedrock, karst, and salinity*
- *Distance to public areas (for spray irrigation), sanitary sewers, structures, and wells*
- *For non-irrigation USE: textbooks, technical articles or other literature to research rate and volume of USE*

**5. Regulatory data**
- *Municipal Zone and Zoning Code to determine if restrictions exist or special features are required*
- *Municipal Permits including plumbing, storm sewer, and land use permitting requirements*
- *Minnesota Plumbing Code to determine if proposed system is subject to new plumbing requirements*
- *Watershed District or WMO permitting requirements*
- *County and State Health Department design and/or permitting requirements*

# Data Collection Worksheet

| Data Collected | Not Used | Completed | Outcomes / Comments |
|---|---|---|---|
| **1. SYSTEM MAPS AND SURVEYS** | | | |
| **GIS or other contour map** | | | Map name:<br>Web address: |
| **Municipal storm sewer maps** | | | Map name:<br>Web address:<br>Contact: |
| **USGS topographic map or other map** | | | USGS topographic map name:<br>Other map name:<br>Web address: |
| **FEMA floodplain maps** | | | FEMA Map ID:<br>Flood zone (if applicable):<br>Web address: |
| **County soils and karst maps** | | | Map name:<br>Web address: |
| **Municipal, County and/or MNDOT maps** | | | Map name:<br>Web address: |
| **Hazardous waste site maps** | | | Map name:<br>Web address: |
| **2. STUDIES AND REPORTS** | | | |
| **Runoff monitoring data and reports** | | | Runoff monitoring report title and date:<br>Author:<br>Web address: |
| **Hydraulic analyses** | | | Hydraulic report title and date:<br>Author:<br>Web address: |
| **Stormwater design data for sites with pre-existing stormwater collection systems** | | | Design report title and date:<br>Author:<br>Web address: |
| **Pre-existing permits, including land use, zoning, building, plumbing, and stormwater discharge permits** | | | Permit #1, name, and date issued:<br>Permit #2, name, and date issued:<br>Permit #3, name, and date issued:<br>Permit #4, name, and date issued:<br>Permit #5, name, and date issued: |
| **Pre-existing site soil borings and other geotechnical analyses** | | | Report title and date:<br>Author:<br>Web address: |
| **3. SITE SPECIFIC DATA AND SURVEYS** | | | |
| **Site plan or other survey** | | | Site plan or survey file location:<br>Owner:<br>Date: |

| | | | |
|---|---|---|---|
| **Gopher State One-Call** | | | Gopher State locate request date:<br>Survey data for marked utilities: |
| **Storm sewer survey** | | | Survey date and data: |
| **Stormwater pond or other BMP dimensions, depth, structures and operating requirements** | | | Survey date and data: |
| **Pre-existing storage tank properties** | | | Survey date and data: |
| **County Well Index** | | | Source:<br>Contact: |
| **Building Plan** | | | Source:<br>Contact: |
| **Precipitation data** | | | Source:<br>Contact/Website: |
| **4. USE DATA** | | | |
| **Minimum rate and volume of USE** | | | Minimum rate:<br>Minimum volume: |
| **Maximum rate and volume of USE** | | | Maximum rate:<br>Maximum volume: |
| **Annual dates to start up and shut down of system** | | | Start date:<br>Shut down date: |
| **For irrigation systems: additional soils borings** | | | Soil boring map:<br>Date of borings:<br>Soil analysis report title and date: |
| **For irrigation systems: distance** | | | *Distance to:*<br>Public areas:<br>Potable water source and/or wells:<br>Sanitary sewers:<br>Surface water: |
| **For non-irrigation USE: textbooks, technical articles or other literature** | | | Reference #1 title, date and author:<br>Web address:<br>Reference #2 title, date and author:<br>Web address:<br>Reference #3 title, date and author:<br>Web address:<br>Reference #4 title, date and author:<br>Web address: |
| **5. REGULATORY DATA** | | | |
| **Municipal Zone and Zoning Code** | | | Site Zone:<br>Special requirements?<br>Web address: |
| **Municipal Permits** | | | *Web address for:*<br>Plumbing permit application form:<br>Building permit application form:<br>Erosion and sediment control permit application form:<br>Site plan approval application form:<br>Storm/sanitary/water connections permit application form:<br>Other: |
| **Minnesota Plumbing Code** | | | Web address:<br>Special requirements: |
| **Watershed District or WMO** | | | Web address:<br>Permits required: |
| **County Health Department** | | | Web address:<br>Permits required or special treatment requirements: |

TOOL Procedure / Worksheet A.0

# Assessment Steps

Use this tool to assess the feasibility of a stormwater reuse project and key considerations for project implementation.

An assessment consists of a series of steps that lead to specific actions. The actions will result in various outcomes and information that will be recorded on worksheets (**Tools A.1w-A.7w – Assessment Worksheets**) for use in **Phase 3-Implementation**.

To help organize this effort, check off the assessment steps as they are completed in this worksheet.

| Assessment Step | | Procedure Tools | Worksheet Tools | Not Used | Complete |
|---|---|---|---|---|---|
| 1. Source Water Quality | Identify the pollutants that are present in the stormwater **SOURCE.** | A.1 Source Water Quality | A.1w Source Water Quality Worksheet | | |
| 2. Quantity and Storage | Identify water quantity requirements and on-site storage considerations. | A.2 Quantity and Storage | A.2w Quantity and Storage Worksheet | | |
| 3. Upstream Source | Determine if there are any upstream stormwater devices that will affect the quality or quantity of the **SOURCE.** | A.3 Upstream Source | A.3w Upstream Source Worksheet | | |
| 4. Downstream Use | Determine if there are any downstream stormwater practices that would be affected by the **USE** of stormwater being considered. | A.4 Downstream Use | A.4w Downstream Use Worksheet | | |
| 5. Use Criteria | Determine the **USE** quality required and treatment considerations. | A.5 Use Criteria | A.5w Use Criteria Worksheet | | |
| 6. Site Suitability for Land Application | Determine site suitability for irrigation and other land application practices. (Go to Step 7 if **USE** is not irrigation/land application) | A.6 Site Suitability for Land Application | A.6w Site Suitability for Land Application Worksheet | | |
| 7. Permits | Identify permits that may be required. | A.7 Permits | A.7w Permits Worksheet | | |

# Source Water Quality

## Purpose

Characterize the water quality of the Source stormwater and identify key parameters to consider in planning the project.

## Overview

It is critical to define the characteristics of the stormwater to provide a supply that is safe for the public and the environment in which it is used. Stormwater quality is highly variable and dependent on the drainage area and precipitation characteristics. Quality characteristics of concern are categorized as microbiological, physical/chemical indicators, nutrients, metals, and organics. In addition to the variability introduced with the characteristics of the drainage area, the intensity of the storm events provides significant differences in concentrations of constituents. In some cases, assumptions can be used to characterize water quality. In others, including the majority of larger applications, water quality monitoring is recommended.

| Assessment Step | Action | Reference Resources / TOOLS |
|---|---|---|
| **1. Identify the SOURCE drainage area tributary to the collection point.** | a. If the **SOURCE** is from rooftop(s) only, Go To Step 3. | |
| | b. Review maps and other references and perform a site visit. | Topographics maps and surveys<br>Site Plans<br>Public works records |
| **2. Within the SOURCE drainage area, identify features that are indicators of water quality constituents of concern.** | a. Determine if any of the following are in the drainage area:<br>▶ *Industries/businesses using petroleum hydrocarbons and metals in outdoor areas*<br>▶ *Large industrial/commercial buildings and complexes with metal roofs*<br>▶ *Major roads and freeways (high traffic corridors)*<br>▶ *Large parking lots*<br>▶ *Waterways with significant stream bank erosion*<br>▶ *Construction activity with high levels of erosion*<br>▶ *On-site sewage management systems (septic tanks)*<br>▶ *Storm sewers with connections to the sanitary sewers; or a sanitary sewer overflow/bypass location* | |
| | b. Record findings on **Tool A.1w**. | **Tool A.1w** |
| **3. Determine the water quality characteristics of the SOURCE.** | a. Learn about stormwater quality and important considerations for public health, environmental impacts, and implications for specific Uses in **Tool R.1a**. | **Tool R.1a** |
| | b. Review water quality values for different types of drainage areas in **Tool R.1b**. | **Tool R.1b** |
| | c. List water quality parameters and potential concentration ranges for your **SOURCE** on **Tool A.1w**. | **Tool A.1w** |
| **4. Determine if water quality monitoring needs to be conducted.** | a. Based on your findings from **Tool R.1a**, site inspection, and drainage area characteristics (Steps 2&3 above), determine if you need to perform monitoring. | **Tool R.1a** |
| | b. If required, conduct water quality monitoring. Go to **Tool R.2b** or return to **Tool A.0 Assessment Steps**. | **Tool R.2b**<br>**Tool A.0** |

Return to **Tool A.0 Assessment Steps**.

# Source Water Quality Worksheet

Use this tool to summarize the information obtained during this assessment phase.

| Assessment Task Performed | Not Used | Complete | Outcomes / Comments |
|---|---|---|---|
| **1. Topographic maps, surveys, site plans, other public records**<br>■ What information was reviewed?<br>■ Record the source reference.<br>■ What information is missing or needs additional research? | ☐ | ☐ | |
| **2. Drainage Area Characteristics**<br>■ List general drainage area characteristics<br>■ Are there any features listed in Step 2 of **Tool A.1**? | ☐ | ☐ | |
| **3.** R.1a Stormwater Quality Characteristics<br>■ Record potential water quality characteristics and concentration ranges of the **SOURCE** stormwater.<br>■ Identify specific parameters of concern. | ☐ | ☐ | CATEGORY / Specific Parameter / Concentration/ Range:<br>Microbiological<br>Physical/ Chemical<br>Nutrients<br>Metals<br>Organics |
| **4.** R.2b Stormwater Monitoring<br>■ Is additional monitoring required?<br>■ Record pertinent information from **Tool R.2b**. | ☐ | ☐ | |
| **5. Other** ________________ | ☐ | ☐ | |

Return to **Tool A.0 Assessment Steps**.

# Quantity and Storage

## Purpose

Use this tool to determine the volume and rate required for **USE**. Assess the features of a storage system.

## Overview

Most stormwater reuse systems will require storage of the collected stormwater runoff to provide sufficient volume of water for **USE** between rain events. Storage may be an independent structure, or it may be within a stormwater Best Management Practice, typically a stormwater pond. The design of the storage basins should consider such issues as public safety, animal control, mosquito breeding, algae, odor control, and oxygenation.

| Assessment Step | Action | Reference Resources / TOOLS |
|---|---|---|
| **1. Determine the rate and volume of stormwater runoff available from SOURCE.** | a. Determine impervious area of **SOURCE** drainage area | Field survey, GIS data, or record drawings |
| | b. For drainage areas without GIS data or too large to directly measure impervious surface, conduct hydraulic analysis to determine peak flow rates from storm sewers or other structure that will be used to collect the runoff. | Use computer software or consult with professional |
| | c. Record findings in **Tool A.2w**. | **Tool A.2w** |
| **2. Determine the rate and volume of stormwater runoff required for USE.** | a. Determine weekly irrigation water demand for land application **USE**s. | |
| | b. For existing non-irrigation **USE**s, monitor existing activity to develop weekly rate and volume demands. | |
| | c. For new non-irrigation **USE**s, review literature for expected rate and volume demands. | Wastewater Engineering: Treatment and Reuse. McGraw-Hill, 2003, Chapter 3, wastewater flowrates. |
| | d. Record findings in **Tool A.2w**. | **Tool A.2w** |
| **3. Compute available storage volume on sites with existing storage ponds/ tanks/cisterns.** | a. Review site plans for existing storage structures, if available. | |
| | b. Inspect site, confirm and/or measure storage dimensions, total volume and effective volume of structure or pond. | |
| | c. Inspect collection system for presence of flow control valves and/or bypass structures. | |
| | d. Record findings in **Tool A.2w**. | **Tool A.2w** |
| **4. Determine volume of storage required.** | a. Conduct water balance to determine total storage required for **USE**. | **Tool R.2a - Water Balance** |
| | b. Compute net storage by subtracting existing storage volume from total storage required. | |
| | c. Record findings in **Tool A.2w**. | **Tool A.2w** |
| **5. Assess design, construction, and operational features of storage pond.** | a. Conduct geotechnical investigation to determine if liner is required to prevent storage from infiltrating into the groundwater. | |
| | b. In karst regions, conduct geotechincal investigation to determine if karst features are present. | Consult with a professional |
| | c. Review adjacent site uses to determine if fencing is needed to protect safety. | |
| | d. Record findings in **Tool A.2w**. | **Tool A.2w** |
| **6. Assess design, construction, and operational features of an above-ground storage tank.** | a. Consider cover to control access for animals, mosquito breeding, and general safety. | **Tool I.2 Storage** |
| | b. Covered tanks will require oxygenation/aeration to prevent anaerobic conditions from developing. | |
| | c. Assess whether adequate space exists to access tanks for sediment removal and winterization. | |
| | d. Record findings in **Tool A.2w**. | **Tool A.2w** |
| **7. Assess design, construction, and operational features of below ground storage structure.** | a. Conduct geotechnical investigation to assess the soil stability and groundwater elevations. | **Tool I.2 - Storage Systems** |
| | b. Assess whether adequate space exists for proper access to the tank for sediment removal and winterization. | |
| | c. Buried tanks will require oxygenation/aeration to prevent anaerobic conditions from developing. | |
| | d. Record findings in **Tool A.2w**. | **Tool A.2w** |

Return to **Tool A.0 Assessment Steps**.

# Quantity and Storage Worksheet

Use this tool to summarize the information obtained during this assessment phase.

| Assessment Task Performed | Not Used | Complete | Outcomes / Comments |
|---|---|---|---|
| **1. Determine the rate and volume of stormwater runoff available from SOURCE.** | ☐ | ☐ | a. Impervious Area ______ Reference ______<br>b. Peak flow rate ______ Reference / Method ______ |
| **2. Determine the maximum and minimum rate and volume of stormwater runoff required for USE.** | ☐ | ☐ | a. Maximum weekly demand ______<br>b. Minimum weekly demand ______<br>c. Other **USE** demand ______ |
| **3. Compute available storage volume on sites with existing storage ponds/tanks/ cisterns.** | ☐ | ☐ | a. Existing storage volume, total and effective ______<br>b. Any control valves or bypass structures? ______ |
| **4. Determine volume of storage required.** | ☐ | ☐ | a. Total storage required ______<br>b. Net storage ______ |
| **5. Assess design, construction, and operational features of storage pond.** | ☐ | ☐ | a. Liner required ______<br>b. Karst features present ______<br>c. Fencing needed ______ |
| **6. Assess design, construction, and operational features of an above-ground storage tank.** | ☐ | ☐ | a. Cover required ______<br>b. Aeration method ______<br>c. Adequate space for maintenance access ______ |
| **7. Assess design, construction, and operational features of a below-ground storage structure.** | ☐ | ☐ | a. Soil stability and groundwater elevations ______<br>b. Adequate space for maintenance access ______<br>c. Aeration required ______ |

Return to **Tool A.0 Assessment Steps**.

# Upstream Source

## Purpose

Use this tool for collection of stormwater from larger municipal systems where the rate and volume could be influenced by upstream stormwater structures, infiltration, or other **USES**.

## Overview

The rate and volume of runoff available for **USE** could be influenced by an independent upstream **USE**. Typical devices that could affect the quantity would be a stormwater Best Management Practice such as a raingarden, stormwater infiltration system, stormwater reuse installation, or stormwater treatment pond.

| Assessment Step | Action | Reference Resources / TOOLS |
|---|---|---|
| **1. Identify the SOURCE drainage area tributary to the collection point.** | a. Review maps and other references to delineate area tributary to collection point. | Topographic maps, surveys, site plans, other public records (Refer to **Tool A.1w**) |
| **2. Determine if the tributary area includes any on-site or off-site structures that would control the rate, volume or quality of runoff.** | a. Schedule a site visit to investigate the presence of stormwater structures in the area tributary to the **SOURCE** collection point. | |
| | b. Record findings on **Tool A.3w**. | **Tool A.3w** |
| **3. Determine if pre-existing monitoring or design information is available.** | a. Research whether any monitoring has been conducted in the previous 5 years that reports the rate, volume, and/or quality of runoff discharged from upstream structure(s). | Property owner or manager, Public Works Department, Local Watershed District/ WMO, Soil and Water Conservation District |
| | b. Alternatively, consider design reports if structure has been in operation for 5 years or less. | Property owner or manager for privately owned structures, Public Works Department for publically owned stormwater structures. |
| | c. Record findings on **Tool A.3w**. | **Tool A.3w** |
| **4. Conduct additional monitoring to supplement information collected in Step 3.** | a. If research does not produce sufficient information, then monitor flow near collection point. | **Tool R.2b - Stormwater Monitoring** |
| | b. Record findings on **Tool A.3w**. | **Tool A.3w** |
| **5. Determine if rate and volume from SOURCE is sufficient for USE.** | a. Compare rate and volume available at collection point to the rate and volume computed in **Tool A.2 - Quantity and Storage**. | Refer to **Tool A.2w** |
| | b. Record findings on **Tool A.3w**. | **Tool A.3w** |

Return to **Tool A.0 Assessment Steps**.

# Upstream Source Worksheet

Use this tool to summarize the information obtained during this assessment phase.

| Assessment Task Performed | Not Used | Complete | Outcomes / Comments |
|---|---|---|---|
| **1. Identify Source drainage area**<br>■ List maps and other records reviewed<br>■ Identify missing information that requires field investigation | | | Maps reviewed:<br>1.<br>2.<br>3.<br>Missing information:<br>1.<br>2. |
| **2. Structures that affect rate or volume of runoff in Source**<br>■ Record results of site investigations<br>■ Identify owner of structure<br>■ Collect physical information for use in quantity analysis | | | Structures identified / owner / contact:<br>1.<br>2.<br>3. |
| **3. Pre-existing monitoring studies**<br>■ Owner and date of monitoring<br>■ Monitoring collection point(s)<br>■ Document information and results needed for analysis | | | Monitoring studies identified / owner / contact:<br>1.<br>2.<br>3. |
| **4. Tool R.2b - Stormwater Monitoring**<br>■ Is there additional monitoring required?<br>■ Record pertinent information from **Tool R.2b** | | | Additional monitoring required: |
| **5. Other** ______________________________ | | | Other information discovered:<br>1.<br>2. |

Return to **Tool A.0 Assessment Steps**.

# Downstream Use

## Purpose

Determine whether the **USE** of stormwater runoff will create downstream water deficiencies.

## Overview

The proposed **USE** could affect the availability of runoff for existing downstream **USES**. For example, an existing downstream regional pond could be the **SOURCE** of water for irrigation of an adjacent municipal golf course. If the proposed **USE** withholds a significant volume of the runoff contributed to this pond, then a deficiency may be created that will ultimately influence the golf course.

| Assessment Step | Action | Reference Resources / TOOLS |
|---|---|---|
| **1. Locate the existing receiving water or stormwater BMP that is downstream of planned stormwater reuse system collection point.** | a) Review municipal or other maps to determine the existing downstream stormwater discharge location. | Site visit, Municipal Street Use Maps, Municipal/County Public Works Department |
| | b. If discharge is to a groundwater infiltration area or to an existing stormwater reuse system, go to Step 2. | |
| | c. If discharge is to a wetland, go to Step 3. | |
| | d. For all other waterbodies, record findings in **Tool A.4w** and return to **Tool A.0**. | **Tool A.4w**<br>**Tool A.0** |
| **2. Investigate if withdrawal of stormwater will affect infiltration.** | a. Determine if the volume of stormwater to be used is less than 10% of the mean annual volume infiltrated. If yes, then record findings in **Tool A.4w**. | Review design reports, use computer software to conduct analysis, or consult with professional |
| | b. If volume of stormwater to be used is greater than 10% of the mean annual volume discharged to an infiltration basin or raingarden, then contact owner to determine the minimum volume is required to maintain vegetation. | **Tool A.2 - Quantity and Storage** |
| | c. If volume of stormwater to be used is greater than 10% of the mean annual volume discharged to a groundwater recharge area, then contact owner or Department of Natural Resources to determine the minimum rate or volume required to maintain groundwater recharge goals. | |
| | d. Recompute the rate and volume available for **USE**. | |
| | e. Record data in **Tool A.4w**. | **Tool A.4w** |
| **3. Investigate if withdrawal of stormwater will affect a hydrologically sensitive wetland or other receiving water.** | a. Determine if volume of stormwater to be used is less than 10% of the mean annual volume infiltrated. If planned stormwater reuse volume is less than 10%, then no additional rate or volume adjustments are necessary. | Review design reports, use computer software to conduct analysis, or consult with professional |
| | b. If volume of stormwater to be used is greater than 10% of the mean annual volume discharged to the hydrologically sensitive receiving water, then contact watershed district/WMO or Department of Natural Resources to determine the minimum rate or volume required to hydrologically sustain the sensitive receiving water. | |
| | c. Recompute the rate and volume available for **USE**. | |
| | d. Record data in **Tool A.4w**. | **Tool A.4w** |

Return to **Tool A.0 Assessment Steps**.

# Downstream Use Worksheet

Use this tool to summarize the information obtained during this assessment phase.

| Assessment Task Performed | Not Used | Complete | Outcomes / Comments |
|---|---|---|---|
| **1. Locate downstream receiving water**<br>■ List maps, records, and web addresses containing receiving water information<br>■ List existing infiltration areas<br>■ List sensitive wetlands and/or water bodies on MPCA impaired waters list | | | Receiving water:<br>Source or map name:<br>Location of infiltration areas:<br>1.<br>2.<br>Sensitive wetlands and water bodies:<br>1.<br>2. |
| **2. Determine % of runoff to existing downstream receiving water that will be collected for USE**<br>■ Document computations<br>■ Document records, reports and other information used as basis of computations<br>■ Record results | | | Annual volume runoff to receiving water:<br>Annual volume runoff redirected to reuse:<br>% of receiving water runoff redirected to reuse:<br>Source used for computations: |
| **3. Investigate**<br>■ Record results of negotiations and discussions | | | Restrictions imposed on reuse system related to downstream use: |

Return to **Tool A.0 Assessment Steps**.

# Use Criteria

## Purpose

Define the water quality characteristics required for the specific **USE**(s) of water and considerations for treatment.

## Overview

A stormwater reuse system must provide a supply that is safe for the public and the environment in which it is used. At the time of publication, there were no federal or state regulations[1] in Minnesota or city or metro-wide ordinances with requirements related to the quality of stormwater for reuse. There are regulations applied to the use of reclaimed wastewater in Minnesota and for stormwater in other states and cities. Treatment considerations based on the State of Minnesota criteria for wastewater reuse and assumed source water quality are reviewed to provide the basis for selection of system components in the Implementation Phase.

| Assessment Step | Action | Reference Resources / TOOLS |
|---|---|---|
| **1. Identify the health-based water quality criteria for the specific USE(S).** | a. Go to **Tool R.3a**, Part 1<br>i. Learn about health-based water quality criteria established for reclaimed wastewater for Minnesota and wastewater and stormwater outside of Minnesota.<br>ii. Research water quality limits and treatment technologies for specific **USE**s in **Tool R.3b - Tables R.3b.1, R.3b.2, and R.3b.3**. | **Tool R.3a - Use Water Quality Characteristics, Part 1**<br>**Tool R.3b - Water Quality Criteria Tables**<br>**Tool R.3c - Use Criteria Matrix** |
| | b. Go to **Tool R.3c** - select health criteria listed by the type of **USE**, as recorded on **Tool C.1w**. | Refer to **Tool C.1w - Source and Use Worksheet** records |
| | c. Record the health criteria level on **Tool A.5w - Use Criteria Worksheet**. | **Tool A.5w** |
| **2. Identify environmental and system equipment-based water quality criteria.** | a. Go to **Tool R.3a**, Part 2<br>i. Learn about water quality criteria associated with specific uses of water that are not health-based and are generally established to protect the environment or the equipment/facilities of the reuse system or water application.<br>ii. Research water quality limits and treatment technologies for specific **USE**s in **Tool R.3b - Tables R.3b.1-9** | **Tool R.3a - Use Water Quality Characteristics, Part 2**<br>**Tool R.3b - Water Quality Criteria Tables** |
| | b. Go to **Tool R.3c** - select the environmental/system criteria listed by the type of **USE** for the project, as recorded on **Tool C.1w**. | **Tool R.3c - Use Criteria Matrix**<br>Refer to **Tool C.1w - Source and Use Worksheet** records |
| | c. Record the environmental/system criteria level on **Tool A.5w - Use Criteria Worksheet**. | **Tool A.5w** |
| **3. Determine treatment processes for further consideration in the Implementation Phase.** | a. Compare the **SOURCE** water quality recorded on **Tool A.1w** and the water quality criteria recorded on **Tool A.5w - Use Criteria Worksheet**. | **Tool A.1w**<br>**Tool A.5w** |
| | b. Go to **Tool R.3d** and review treatment process considerations. | **Tool R.3d - Treatment Process Considerations** |
| | c. List potential treatment processes and the pros/cons of each on **Tool A.5w - Use Criteria Worksheet**. | **Tool A.5w** |

Return to **Tool A.0 Assessment Steps**.

[1] The national and state plumbing codes were being reviewed for revisions at the time this report was prepared (2011). Check with the most recent publications of the code and for specific references for systems using stormwater.

# Use Criteria Worksheet

Use this tool to summarize the information obtained during this assessment phase.

| Assessment Task Performed | Not Used | Complete | Outcomes / Comments |
|---|---|---|---|
| **1. Health-based criteria** | | | List health criteria recommended for **USE**: |
| **2. Environmental and/or equipment-based criteria** | | | List environmental criteria recommended for **USE**: |
| **3. Treatment considerations** | | | List treatment components recommended for **USE**: |

Return to **Tool A.0 Assessment Steps**.

# Site Suitability for Land Application

## Purpose

Use this tool to assess the suitability of the site for land application of stormwater runoff.

## Overview

Land application can be defined as a **USE** that is as large as irrigation of an athletic field, or as small as a commercial green space. There is a potential that site features, such as slope, or proximity to a building foundation, could limit the space available for land application.

| Assessment Step | Action | Reference Resources / TOOLS |
|---|---|---|
| **1. Assess the soil conditions that could limit the land application of stormwater runoff.** | a. Confirm that all of these conditions exist for suitable land application:<br>■ Depth to seasonal high groundwater or bedrock > 3 feet.<br>■ Soil permeability between 0.06 and 20.0 inches per hour.<br>■ Soil salinity (measured as Electrical Conductivity) < 4 mmhos/cm.<br>■ No surface rock outcrop that would conflict with planned irrigation equipment. | Geotechnical evaluation by professional |
| | b. Record findings in **Tool A.6w**. | **Tool A.6w** |
| **2. Assess the topographic features that could limit irrigation systems.** | a. Confirm these slopes exist for suitable irrigation:<br>■ Gravity irrigation < 1%<br>■ Trickle, drip or microspray irrication < 9%<br>■ Center pivot irrigation < 15% | Topographic survey, GIS topographic database |
| | b. Record findings in **Tool A.6w**. | **Tool A.6w** |
| **3. Assess that land application will not cause damage or degradation.** | a. Locate structures, underground utilities and surface waters in area of land application. | Topographic survey, Gopher State One-Call (http://www.gopherstateonecall.org/ ) |
| | b. Confirm a minimum separation of <u>10 feet</u> from the following:<br>■ Sanitary sewers (to prevent infiltration into the sewer)<br>■ Buildings (to protect integrity of foundation)<br>■ Streets (to protect integrity of base materials)<br>■ Gas/Communication/Power utilities (to protect integrity of utility) | |
| | c. Confirm a minimum separation of <u>35 feet</u> from the following:<br>■ On-site septic systems | |
| | d. Confirm a minimum separation of <u>50 feet</u> from the following:<br>■ Public or private water supply wells (to prevent cross contamination)<br>■ Surface waters | |
| | e) Record findings in **Tool A.6w**. | **Tool A.6w** |

Return to **Tool A.0 Assessment Steps**.

# Site Suitability for Land Application Worksheet

Use this tool to summarize the information obtained during this assessment phase.

| Assessment Task Performed | Not Used | Complete | Outcomes / Comments |
|---|---|---|---|
| **1. Document soil conditions** | | | a. Depth to seasonal high groundwater:<br>b. Depth to bedrock:<br>c. Soil permeability:<br>d. Soil salinity:<br>e. Presence of rock outcroppings:<br>f. Other: |
| **2. Environmental and/or equipment-based criteria** | | | a. Planned irrigation equipment:<br>b: Maximum slope of irrigation area:<br>c: Other: |
| **3. Treatment considerations** | | | a. Distance to wells:<br>b. Distance to sanitary sewers:<br>c. Distance to buildings and other permanent structures:<br>d. Distance to streets:<br>e. Distance to utilities:<br>▶ *Gas:*<br>▶ *Electric:*<br>▶ *Communication:*<br>f. Distance to on-site or adjacent surface waters:<br>g. Distance to athletic fields, school playgrounds, or other public area: |

Return to **Tool A.0 Assessment Steps**.

# Permits

## Purpose

Use this tool to determine the need for permits for the **SOURCE** or **USE**.

## Overview

Stormwater reuse is an evolving technology that has limited case studies to reference for permitting requirements. This tool compiles the most likely permits that a project could require and suggests information that may be important to the public agency granting the permit.

| Assessment Step | Permit/Permissions to Consider | Detail | Governing Statute or Rule |
|---|---|---|---|
| **1. Permissions/ permits required for SOURCE** | a) Research need for **SOURCE** related permits, including: | | |
| | ■ Municipal permits | ■ Zoning codes, construction permits | ■ Municipal zoning codes |
| | ■ Municipal storm drain connection permit | ■ If **SOURCE** is from public storm sewer | ■ Minnesota Plumbing Code and local building ordinances |
| | ■ Municipal, watershed organization, and MPCA Erosion Control permits | ■ For construction activities | ■ Clean Water Act |
| | ■ DNR Groundwater Appropriation Permit | ■ If supplemental **SOURCE** is needed. | ■ Minnesota Statutes, Chapter 103G |
| | b) Record results in **Tool A.7w**. | | **TOOL A.7w** |
| **2. Permissions/ permits required for USEs** | a) Research need for **USE** related permits/permissions, including: | | |
| | ■ MN Department of Health and/or County Health Department | ■ Determination that **USE** is not public health nuisance if potential for human exposure exists | ■ MN Statute 145A.02 - Public Health Nuisance<br>■ MN Statute 145A.04, Subd. 8 - Removal or abatement of Public Health Nuisance |
| | ■ Municipal plumbing permit | ■ Multiple requirements governed by MN Plumbing Code, including materials and professional standards for plumbers installing systems | ■ MN Rule Chapter 4715 |
| | ■ MCES Industrial Discharge Permit | ■ Required if **USE** is defined as Industrial, including vehicle maintenance activities | ■ Waste Discharge Rules for the Metropolitan Disposal System |
| | ■ MPCA and MCES Sanitary Sewer Extension Permit | ■ Required for new or modifications to existing public sanitary sewers | ■ MN Stat. 115.07, Subd. 3 |
| | b) Affirm **USE** is compatible with related permits, including: | | |
| | ■ MPCA Industrial Stormwater Permit | ■ Required for management of stormwater runoff from specific industrial activities | ■ Clean Water Act and Rules 40CFR 122, 123 and 124 |
| | ■ MPCA Construction Site Permit | ■ If **USE** is for construction activity, such as dust control, then activity must comply with management requirements contained in SWPPP (Storm Water Pollution Prevention Plan) | ■ Clean Water Act and Rules 40CFR 122, 123 and 125 |
| | ■ MN Department of Agriculture | ■ For commercial operations, including nurseries and fruit-vegetable-grain producers | ■ MN Statute Chapter 17 |
| | ■ Municipal permits | ■ Consult with local officials | |
| | c) Record results in **Tool A.7w**. | | **TOOL A.7w** |
| **3. Exemptions** | a) Affirm that exemptions apply to the **SOURCE** or **USE**, including: | | |
| | ■ Above ground storage tank exemption | | ■ MN Rule 7151.1200 |
| | ■ Below ground storage tank exemption | | ■ MN Rule 7150.0010 |
| | b) Record results in **Tool A.7w**. | | **TOOL A.7w** |

Return to **Tool A.0 Assessment Steps**.

# Permits Worksheet

Use this tool to summarize the information obtained during this assessment phase.

| Assessment Task Performed | Not Used | Complete | Outcomes / Comments |
|---|---|---|---|
| **1. Permits identified for collection of runoff from SOURCE**<br>■ For each permit list agency, contact, permit processing time frames, and application forms | | | Permit / agency / timeframe / location of application forms:<br>1.<br>2.<br>3.<br>4. |
| **2. Permits identified for USE**<br>■ For each permit list agency, contact, permit processing time frames, and application forms | | | Permit / agency / timeframe / location of application forms:<br>1.<br>2.<br>3.<br>4. |
| **3. Exemptions identified for USE and SOURCE**<br>■ Review permit requirements for any exemptions | | | Permit / agency / timeframe / location of application forms:<br>1.<br>2.<br>3.<br>4. |

Return to **Tool A.0 Assessment Steps**.

# Collection Systems

## Overview

Collections systems for reuse can be as simple as rainwater collection in a roof-top gutter or as complex as stormwater runoff collection in an underground network of catch basins and storm drains. Essentially rainwater and stormwater collection follows the same principles as traditional systems. Tool I.1a - Collection Systems focuses on those additional components or designs that are specifically important to reuse systems.

Rooftop collection owners and designers are encouraged to refer to the numerous rainwater harvesting manuals available on-line, many of which are listed in the **Sources and Links** section of this *Guide*. Keep in mind that some of these manuals are prepared for milder climates than Minnesota and may not include winterization features.

## Pre-Design

1. Determine SOURCE of stormwater runoff to be collected:
   - *Determine the SOURCEs of runoff that could be collected for USE. Determine if all the runoff should be collected from a roof/gutter system, ground drainage/swales/catch basins, or both. Refer to Tool C.1w*
   - *The table below shows system criteria that should be considered in selecting collection system components and which SOURCE typically provides the best value to meet those criteria.*

| Selection Criteria | SOURCE<br>Roof Runoff | <br>Ground Runoff |
|---|---|---|
| High Water Quality Requirements[1] | √ | |
| Large Volumes Required for USE | | √ |
| Lower Pumping Costs | √ | |
| Lower Treatment Costs[2] | √ | |
| Collection System Efficiency | | √ |

[1]Refer to Tools R.1a-Stormwater Quality and R.3a-Use Water Quality for additional information

[2]Refer to Tool I.3- Treatment for additional information

   - *Systems requiring flow augmentation by collecting from surface or ground water bodies will require an Appropriations Permit from Minnesota DNR. (http://www.dnr.state.mn.us/permits/water/index.html)*

2. The rate of runoff to be collected for reuse will be based on local requirements.

- *Refer to Refer to* ***Tool A.2w****. for data collected during the Assessment Phase on the rate of collection required by municipality and/or watershed district/management organization.*
- *Typical design standard is to convey the rate of runoff generated by a 1 % rain event, also called 100-year / 24-hour return period rain event. See:*
  - a. Rainfall frequency Atlas of the Midwest (http://www.isws.illinois.edu/pubdoc/B/ISWSB-71.pdf); or
  - b. TP-40 (http://www.nws.noaa.gov/oh/hdsc/PF_documents/TechnicalPaper_No40.pdf)
  - c. Refer to **Tool R.2-Water Quantity and Measurement**

3. Determine the need for first flush system

- *First flush systems divert the early stage of each rain event, typically the portion of runoff that has the highest concentration of contaminants.*
- *First flush devices should be considered for stormwater reuse systems that are sensitive to certain contaminants that are difficult to remove with treatment, such as vegetation that may be damaged from a high concentration of chlorides in spring runoff.*
- *The concentration of contaminants in the first flush will vary greatly based on the time period between rain events – a longer amount of time between rain events will allow additional debris and contaminants to be collected. Winter snowmelt will also have higher concentrations of pollutants. Additional information can be found in Chapter 9 (Cold Climate Impact on Runoff Management) of the Minnesota Stormwater Manual (http://www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/stormwater-management/minnesota-s-stormwater-manual.html)*
- *It is strongly encouraged that the first flush runoff be diverted to a stormwater treatment pond or other treatment device and not be allowed to flush directly to a surface water or public storm sewer system.*

4. Consider the following for retrofitting stormwater reuse systems onto existing sites:

- *Existing roof*
  - » ***Assess whether rooftop provides sufficient volume to meet the volume requirements of the USE using following quick calculation:***

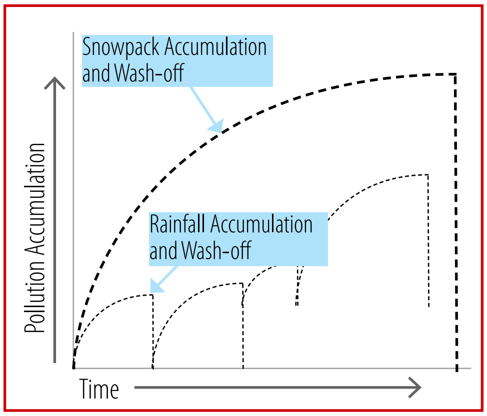
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Volume | = | Rainfall | x | roof area | x | 0.62 | x | 0.90 |
| (gallons) | | (inches) | | (square feet) | | (conversion) | | (efficiency) |

i. 1" rainfall = 0.62 gallons per square foot of roof area

ii. Average rainfall in Twin Cities = 0.5" per week (1980 through 2010)

iii. Rooftop efficiency accounts for the portion of rainfall that is trapped or evaporated from roof. Smooth rooftops such as metal have efficiencies higher than rough rooftops such as asphalt. 90% efficiency is a conservative value appropriate for preliminary calculations.

- » ***Assess whether gutters can be retrofitted to divert flow to reuse system.***
- » ***Assess the feasibility of replacing roof drainage structures with pre-treatment devices such as screens or filter if roof is to be renovated or replaced.***
- » ***Collect runoff from rooftops that do not have standing water, uncontrolled vegetation growth, animal habitat, excessive rusting, deterioration or other conditions that could contaminate the runoff and/or clog downstream***




Source: ***Snowpack Pollution Accumulation and Wash-off as Compared to Rainfall.*** EOR, CWP, Issue Paper G, Cold Climate Considerations for Stormwater Management, Minnesota, 2005.

*piping or filters.*

- *Existing stormwater collection system:*
  - » *Assess whether existing catch basins can be retrofitted to divert flow to reuse system.*
  - » *Assess the feasibility of replacing or retrofitting catch basins and storm sewers with devices that provide pre-treatment, such as settling or filtration if pavement is to be demolished or renovated.*
  - » *Assess whether existing topography promotes adequate drainage for stormwater reuse collection.*
  - » *Computer software programs or engineering professionals may be required to determine the capacity of the existing system and the proper way to retrofit for stormwater reuse.*

5.Considerations for compatibility with Storage (refer to **Tool I.2-Storage Systems**)

- *Design in parallel with the drainage system for highest efficiency.*
- *If storage system limits the amount of stormwater that can be collected, then include overflow structures and/or bypass valves that direct the excess rate and/ or volume of runoff to stormwater treatment device or to nearby stormwater conveyance systems.*
- *Assess the need for installing a pump if the site does not have sufficient change in elevation to accommodate a gravity system.*

## Design

### Roof / Gutter

1. Select roofing material that is compatible with reuse project:

| Material | Advantages | Disadvantages |
|---|---|---|
| **Metal** | ▶ *Rapid collection of rainwater*<br>▶ *Easy to clean*<br>▶ *Heat prevents growth of bacteria* | ▶ *Potential for metals to leach into runoff, especially when roof is newly installed* |
| **Slate** | ▶ *Rapid collection of rainwater*<br>▶ *Sealant not necessary*<br>▶ *Asbestos roofs constructed before 1970 often misidentified as slate roof* | ▶ *High cost* |
| **Clay / concrete** | ▶ *Sealers available that will prevent growth of bacteria* | ▶ *Porous material absorbs more water* |
| **Composites** | ▶ *Low cost* | ▶ *Textured materials slow rate of runoff collection and reduce capture efficiency by up to 10%*<br>▶ *Potential to leach toxins and release particulates into runoff as material ages and decays* |
| **Green rooftops** | ▶ *Provides filtration of runoff* | ▶ *Majority of water is retained in vegetation – typically 10% to 20% per storm event can be collected*<br>▶ *Typically may have brown discoloration* |

- *The National Sanitation Foundation (NSF) has created a certification program (NSF Protocol P151) that specifically tests roofing sealants for reuse systems (http://nsf.org/consumer/rainwater_collection/index.asp)*

2. Select gutter / downspout material
    - *PVC, vinyl, seamless aluminum, and galvanized steel are generally accepted materials used for gutters and downspouts*
    - *Seamless materials eliminates joints, which can contain bacteria and algae*
    - *PVC and vinyl will deteriorate due to sunlight exposure; apply a coating to increase their useful life*
    - *Solder used for gutter seams cannot be made of toxic materials, such as lead.*
3. Design gutter system for new and retrofit systems:

Use standard engineering practices to layout and design the gutters and scuppers for the rooftop collection system. The following additional considerations should be taken into account when collecting the runoff for stormwater reuse:

- *Size the gutters and scuppers to capture the maximum volume of runoff without overtopping. If the runoff from the roof exceeds the rate and volume required for USE, then consider capturing the runoff from a smaller portion of the roof.*
- *Provide access to gutters to for occasional inspection and clearing of debris.*
- *Provide bypass (by installing a valve on the existing downspout) to allow precipitation in winter months to bypass reuse system. Outlet bypass system to area that is not subject to flooding and/or erosion.*

***Green Roof***

Source: CDM

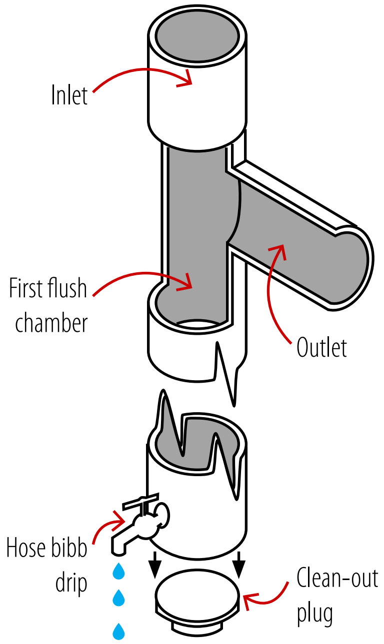
# Ground Runoff Collection

Use standard engineering practices, such as FHWA Urban Design Manual, HEC 22, (http://www.fhwa.dot.gov/engineering/hydraulics/pubs/10009/index.cfm) to size and layout the ground runoff collection system and select proper construction materials. The following additional considerations should be taken into account when collecting the runoff for stormwater reuse:

1. Catch basins
   - *Consider sumps or internal grates to prevent debris from reaching the storage system.*
   - *Consider oil/water separators for industrial sites, gas stations, or other sites that could have a higher concentration of oil or other petroleum products.*
   - *If site generates more volume than needed for USE, then consider collecting the runoff from a portion of the site.*

2. Storm sewer piping
   - *Set slope of piping to a minimum of 1% to completely drain all stormwater.*
     - ***Helps winterize the reuse system by not allowing leftover water to freeze, expand, and potentially crack pipes.***
     - ***Prevents algae / bacterial growth and mosquito breeding.***
   - *Locate overflow structures and bypass valves in accessible locations that will not create downstream erosion or flooding in the event of extreme storm conditions.*

3. Pumps (if required)
   - *Pump stations can be set up with baffles to trap floating materials.*
   - *Pump stations should be in accessible locations for ease of maintenance and cleaning.*

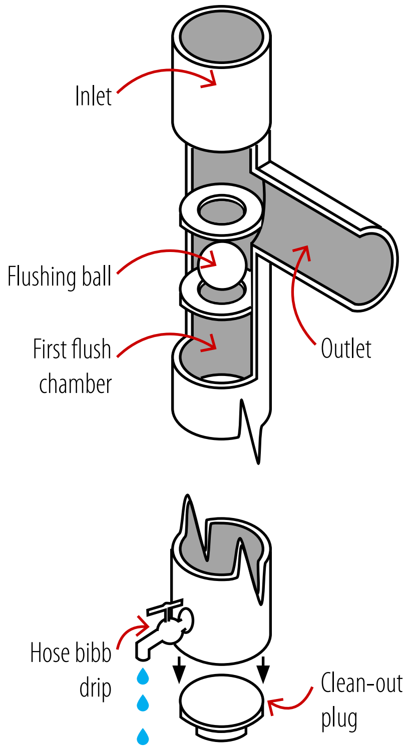



Source: HKGi. ***First Flush Diverter.*** Graphic adapted from Texas Development Board, Texas Manual on Rainwater Harvesting, 2005.

## First-Flush Diverter

The following considerations should be taken into account ***IF*** it is determined that a first-flush system is necessary for the integrity of the stormwater reuse system being designed.

1. Determine rate or volume of runoff to divert, considering the following variables:
   - *Steep sloped surfaces and smooth surfaces create rapid delivery of the first flush of runoff to the collection point.*
   - *The concentration of contaminants in the first flush will vary greatly based on the time period between rain events – a longer amount of time between rain events will allow additional debris and contaminants to be collected. Winter snowmelt will also have higher concentration of pollutants at the end of snowmelt.*
   - *Smaller particulates (e.g. dust, fine particles) will be collected in a short amount of time. Larger contaminants (e.g. fecal matter) are slower to be delivered to the point of collection.*
   - *There are no rules in Minnesota regarding diversion of first flush of runoff. Other states suggest diversion of 1-2 gallons for each 100 square feet of collection surface (Texas), or 0.02 to 0.06 inches of runoff (Virginia).*




The standpipe with ball valve is a variation of the standpipe filter. The cutaway drawing shows the ball valve. As the chamber fills, the ball floats up and seals on the seat, trapping first-flush water and routing the balance of the water to the tank.

Source: HKGi. ***Standpipe with Ball Valve.*** Graphic adapted from Texas Development Board, Texas Manual on Rainwater Harvesting, 2005.

2. Select type of first-flush diverter
   - *Stand-pipe*
   - *Ball valve*
   - *Other – the basic idea is to allow contaminated water to be collected by the collection system, but not enter the reuse system. For a surface collection system, this can be as simple as designing the invert of the collection pipe to be a set amount above the bottom of the catch basin.*

## Bypass / Overflow

1. Design safe path for first-flush and peak flow diversions, if required.
   - *Diversion to stormwater pond or other treatment device such as pervious surface, vegetated swale, or infiltration area is strongly recommended.*
   - *Diversion to an existing public storm drainage system is appropriate IF downstream stormwater treatment exists.*
   - *Direct diversion and bypasses to surfaces that will not erode.*
   - *Do not direct diversion to low areas that will create flooding or cause standing water; this situation may lead to nuisances such as mosquito breeding in the summer and freezing in the winter.*

2. Potential bypass designs include:
   - *Standpipe (also doubles as a first-flush diverter) for roof collection systems*
   - *Curb cuts to allow overflows in surface system to drain to pervious area*
   - *If retrofitting an existing catch basin, design so that the pipe leading to the reuse system is below the existing storm sewer. Once water reaches a certain level, it can then be directed to the storm sewer network*

## Collection System Filter

Locating a filter at the point of collection will prevent downstream stormwater reuse structures from clogging and will prevent anoxic conditions that could be created by the decomposition of organic debris in storage or other retention structures. Regular sweeping of surfaces can be considered to supplement debris removal and extend the life of the filters.

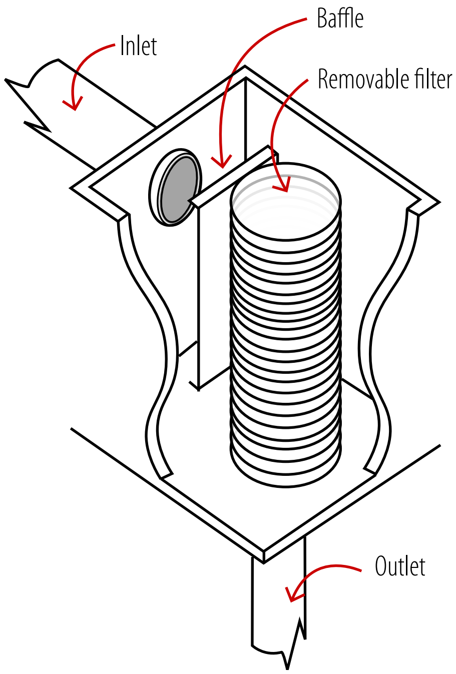
1. Considerations:
   - *Filters at points of collections should be sized to prevent clogging that would reduce hydraulic efficiency.*
   - *Filter material should be self-cleaning and self-drying between rain events to reduce algae and biofilm growth that can block filter pores.*
   - *Stainless steel is considered the best filter media as it is self-cleaning, self-drying, maintains its shape, and doesn't rust.*
   - *Filters at entry to storage tanks should use screens with a mesh spacing of less than 0.5 mm.*
   - *Consider using several parallel filters to maintain hydraulic capacity in the event that one filter becomes clogged.*
   - *Locate filters in areas that are accessible for maintenance.*

2. Typical filters used at points of collection include:
   - *Leaf guards at roof gutters.*
   - *Downspout filters in downspouts.*
   - *Sumps and screens in catch basins.*

- *Roof washers.*
- *Filter socks at catch basin inlets.*
- *Commercially available products, such as Vortex and Maxi-Clean filters. Fine filters are used just before entrance to storage tank.*

## Operations & Maintenance Plan

All stormwater reuse systems should have an O&M plan for operating personnel to follow. The following lists information related to collection system O&M that should be detailed in the Plan:




Source: HKGi. ***Box Roof Washer.*** Graphic adapted from Texas Development Board, Texas Manual on Rainwater Harvesting, 2005.

1. Inspection schedule with the following activities:
    - *Inspect entire collection system and clean winter debris accumulation at start of spring snowmelt.*
    - *Inspect entire collection system and clean accumulated debris in fall prior to winter operations or seasonal shut-down.*
    - *Conduct additional inspections and cleaning of filters as recommended by manufacturer.*
    - *Inspection of first-flush and high-flow diverters at least 3 times per year AND after each rain event that exceeds the design capacity of the collection system.*
2. Site plans showing:
    - *Location of access for all O&M activities for collection system.*
    - *Location and type of valves, and description of conditions that require valves to be open or shut.*
    - *Location and type of filters.*
    - *Location of debris collection sumps.*
3. Pump manufacture and maintenance information if pump system is installed.
4. Sweeping schedule. A minimum of monthly sweeping is recommended.

## Resources (Sources and Links)

- *FHWA, Urban Drainage Design Manual, HEC 22, 2001*
- *MPCA, Minnesota Stormwater Manual, 2005*
- *MNDOT, Drainage Manual, 2005*
- *Cabell Brand Center, Virginia Rainwater Harvesting Manual, 2007*
- *Council on the Environment for New York City, Rainwater Harvesting 101, 2008*
- *Texas Water Development Board, The Texas Manual on Rainwater Harvesting, 2005*
- *Texas Commission on Environmental Quality, Harvesting, Storing, and Treating Rainwater for Domestic Indoor Use, 2007*
- *Virginia Department of Conservation and Recreation, Stormwater Design Specification No. 6 – Rainwater Harvesting, 2011*

TOOL Procedure I.2

# Storage Systems

***Stormwater Pond***

Source: HKGi

## Overview

Storage systems are important for reuse systems in that they provide a constant supply for efficient treatment and for USE. Storage structures typically include tanks / cisterns, and ponds. Tool I.2 - Storage Systems, provides information that is common to all types of storage structures, while pointing out features that may be unique to a pond, an above ground cistern or a below ground tank.

This *Guide* provides for non-pressurized tanks that supply water for USE by either gravity or pumps. Owners in need of a pressurized storage system are encouraged to consult with a professional and/or manufacturer.

Small site owners and designers that are using only roof runoff are encouraged to refer to the numerous rainwater harvesting manuals available on-line, many of which are listed in the **Sources and Links** section of this *Guide*. Keep in mind that some of these manuals are prepared for milder climates than Minnesota and may not include winterization features.

## Pre-Design

1. Determine type of storage to be used in stormwater reuse system.

| Type | Advantages | Disadvantages |
|---|---|---|
| **Open / ponds** | • Low capital costs<br>• Low maintenance costs<br>• Ponds provide dual purpose (when stormwater treatment is required) | • Public safety concerns if unfenced<br>• Habitat for mosquito breeding<br>• Potential for storage losses due to evaporation<br>• Storage in ponds above the permanent pool (see image on page 4) level could limit flood protection capacity |
| **In-Ground** | • Concealed from view | • Greater capital costs<br>• Higher maintenance costs<br>• Stronger structure required if located in parking area with vehicle traffic |
| **Above Ground** | • Moderate capital costs<br>• Moderate maintenance costs | • Aesthetic issues |

2. Design in parallel with the collection system for highest efficiency (refer to Tool I.1, Collection Systems)

3. Site tank / pond according to the following:

- ▶ *Locate close to the collection and end-use areas in order to reduce pumping and distribution costs.*
- ▶ *Avoid direct sunlight to prevent algae growth.*
- ▶ *Locate so that it is accessible for operation and maintenance purposes as well as filling with a supplemental water supply, if determined to be required.*
- ▶ *Situate on higher ground than the end-use activity in order to reduce pumping costs.*

- *Situate so that the inlet is a couple of feet lower than the stormwater collection point to eliminate pumping requirement.*
- *Situate so that overflows do not drain to septic fields or to foundations.*
- *Situate close to electrical source if pumps are to be installed.*

4. Determine volume of stormwater required to be stored to ensure constant supply for USE (refer to **Tool A.2w-Quantity and Storage Worksheet** and **Tool R.2 - Water Quantity & Measurement**):
   - *Note: **Tool R.2a-Water Balance** computes the runoff only from the impervious surface areas of the site, based on the assumption that the contribution of runoff from grass or other pervious surfaces is minimal for a typical rain event in the Twin Cities. Runoff volumes from sites with a significant contribution of runoff from pervious areas should be computed using alternative stormwater hydrologic/ hydraulic models or other computational techniques.*
   - *Stormwater Reuse Systems designed to comply with (future) Minnesota Minimal Impact Design Standards (MIDS) should capture all the runoff resulting from a rain event of 1.1" or less. (http://www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/stormwater-minimal-impact-design-standards-mids.html)*

## Design

### Above Ground Storage Tank

1. Design Foundation
   - *Assess the need for a foundation based on the weight of the tank when full of water.*
   - *The Minnesota State Building Code (https://www.revisor.mn.gov/rules/?id=1303) requires foundations not designed by a structural engineer to have a minimum footing depth of 3 ½ feet in the Twin Cities.*
   - *Locate foundation away from natural drainage pathways.*
   - *Situate smaller tanks without concrete foundation on a compacted subgrade of granular material such as aggregate.*

***Above Ground Storage Tanks***

Source: CDM

**2. Select Tank Material**

| Material | Advantages | Disadvantages |
|---|---|---|
| **Fiberglass** | • Commercially available<br>• Alterable, moveable<br>• Little maintenance required<br>• Durable<br>• Corrosion-resistant | • Requires smooth, solid, level footing<br>• Expensive for tanks <1,000 gallons |
| **Polypropylene** | • Commercially available<br>• Alterable, moveable<br>• Inexpensive<br>• Little maintenance required<br>• Corrosion-resistant | • UV-degradable<br>• Do not retain paint well; must find opaque tanks<br>• Fittings subject to leaking |
| **Galvanized Steel** | • Commercially available<br>• Alterable, moveable<br>• Corrosion-resistant | • Typically only available up to 2,500 gallons |
| **Poured-In-Place Concrete** | • Durable<br>• Immoveable | • Prone to cracking, leaking<br>• Expensive<br>• Long term corrosion near salt deicing areas |
| **Concrete Block** | • Durable<br>• Immoveable | • Expensive<br>• Difficult to maintain |
| **Ferrocement** | • Inexpensive<br>• Durable<br>• Immoveable | • Prone to cracking, leaking |
| **Wood** | • Aesthetically pleasing<br>• Alterable, moveable<br>• Corrosion-resistant | • Expensive<br>• Requires skilled contractor to construct tank on-site |

Source: Reproduced from TX, VA Guides

3. Other considerations

- *Minnesota State Building Code requires storage covers be able to withstand a snow load of 50 lbs per square foot. (https://www.revisor.mn.gov/rules/?id=1303.1700)*
- *Create accessible locations for valves and other maintenance devices*

## In-Ground Storage Tank

1. Select tank material

   - *Polypropylene, fiberglass, and concrete are the materials commonly used for in-ground storage tanks*
   - *Concrete may need to be used if the tank has to be buried deeper or if the tank is to store a large volume*
   - *Refer to above table for additional information.*

Source: ***Fiberglass In-ground Storage Tank.*** CDM

2. Additional considerations

   - *The Minnesota State Building Code (https://www.revisor.mn.gov/rules/?id=1303) requires foundations not designed by a structural engineer to have a minimum footing depth of 3 ½ feet in the Twin Cities.*
   - *Tanks that will be operational throughout the winter should have insulation.*
   - *Do not bury the tank below the groundwater table.*
   - *Avoid underground storage in areas that have highly expansive types of clays due to the potential for damage caused by swelling of the clays. This is typically not a concern in the Twin Cities region.*
   - *Review utility plans to avoid conflicts and/or the need to relocate utilities.*
   - *Avoid locating the tank where traffic or other heavy loads can cross above the tank – this may require the load bearing capacity of the tank to be increased.*

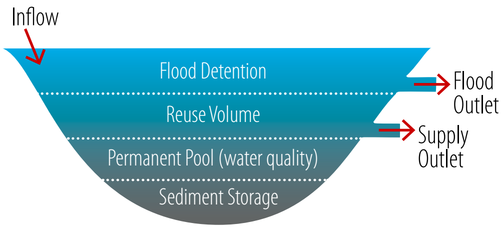
## Open Storage / Pond System

1. Stormwater ponds should be designed according to local requirements including municipalities, watershed district / management organizations, and the Minnesota Pollution Control Agency.

2. Detailed design procedures for Minnesota systems can be found in Chapter 12 of the Minnesota Stormwater Manual (http://www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/stormwater-management/minnesota-s-stormwater-manual.html).

3. Consider the following in addition to the volume required for USE when sizing an open storage system:

   - *Stormwater ponds may have a permanent pool of water that provides treatment. Storage volumes for reuse should be above the elevation of the permanent pool such that withdrawal does not interfere with treatment.*
   - *Ponds are often required to have sufficient capacity to store the volume of runoff generated from a 100-year storm event. Designers must consult with local authorities to determine if the reuse storage can be incorporated into or must be separate from the flood storage.*




Source: HKGi. ***Pond Storage.*** Graphic adapted from New South Wales Department of Environment and Conservation, Managing Urban Stormwater, Harvesting and Reuse, April 2006.

4. Ponds without permanent pools should include sufficient depth to accommodate sediment storage that does not reduce the volume available for reuse.

## Pumps

- *Refer to pump manufacturers for information on pump selection.*
- *For small site reuse storage, consider pre-assembled stormwater / rainwater collection storage systems that include pumps.*

## Detention Time

- *Detention times should not exceed the following limits in OPEN storage systems in order to prevent algae blooms:*

| Detention Time (days) | Average Daily Temperature (°F) |
|---|---|
| 50 | 59 |
| 30 | 68 |
| 20 | 77 |

Source: Adapted from New South Wales Department of Environment and Conservation, Managing Urban Stormwater, Harvesting and Reuse, April 2006.

- *Consider treatment requirements (refer to **Tool I.3-Treatment**). Storage system can be used as a sedimentation basin to reduce transport of solids to distribution and irrigation systems. Locate drawdown valve at least one foot above the floor of the storage for sediment collection. Provide secondary valve at floor of storage for cleaning.*
- *Provide accessibility for cleaning and debris removal.*

## Overflow / Spillway

- *Refer to overflow discussion in **Tool I.1.b** for locating overflow drainage pathways.*

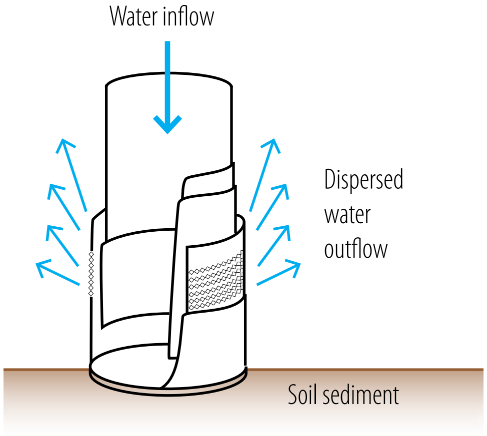
## Other Design Considerations

- *Provide insulation if above ground storage tank provides storage for winter USE.*
- *Seal unnecessary tank openings with a gasket and bolts.*
- *Protect the inlet of the tank from mosquitoes and other insects by using a mesh with spacing no more than 1/16" wide. (See diagram of a calming inlet on page 6.)*
- *Consider energy dissipation, such as internal baffles or calming inlet, to prevent sediment re-suspension.*
- *Provide oxygenation/aeration to the storage system to prevent anaerobic conditions.*
- *Design an overflow system for when the tank reaches capacity; the overflow pipe diameter should be the same as the inlet pipe diameter and should be directed away from the foundation and towards a surface that will not erode.*
- *Create operation and maintenance accessibility – including a manhole for larger tanks or access for a hose/siphoning equipment for smaller tanks.*
- *Provide back-flow prevention valves if system has cross-connection with potable water supply.*
- *Provide signage around open systems to reduce public safety issues.*
- *Consult with MN Plumbing Code for other requirements (https://www.revisor.mn.gov/rules/?id=4715&view=chapter).*
- *Submit plans to the Department of Labor and Industry, or designated municipality, for compliance with MN Plumbing Code.*

## Operations & Maintenance Plan

All stormwater reuse systems should have an O&M plan for operating personnel to follow. The following lists information related to storage system O&M that should be detailed in the Plan:

1. Inspection schedule with the following minimum activities:
   - *Inspection of valves and operational structures each Spring prior to annual start-up. Fill system with water and inspect for leaks. Repair, as necessary.*




Source: HKGi. ***Box Roof Washer.*** Graphic adapted from The Cabell Brand Center, Virginia Rainwater Harvesting Manual, 2007.

- *During first year, inspect and record sediment depth monthly to determine the rate of sediment accumulation. Decrease rate of future inspection cycle based on findings.*
- *Inspect vents monthly.*

2. Cleaning schedule
   - *Periodic removal of accumulated sediment based on inspection findings.*
   - *Fall cleaning of entire structure as part of winterization procedures.*
3. Winterization
   - *Establish schedule for winterization.*
   - *Empty water from entire system.*
   - *Clean inside and outside of tanks.*
   - *Valves should remain open during winter.*
4. Pump maintenance and winterization procedures, as recommended by manufacturer.
   - *Follow manufacturer's instructions for pump maintenance and winterization.*
5. Site plan showing:
   - *Location of all underground structures.*
   - *Location and types of valves, and description of conditions that require valves to be open or shut.*
   - *Location of drain plug / cleanout sump.*

## Resources (Sources and Links)

- *MN State Building Code*
- *MN State Plumbing Code*
- *MPCA Stormwater Manual*
- *Texas Water Development Board. The Texas Manual on Rainwater Harvesting, Third Edition.*
- *Texas Commission on Environmental Quality. Harvesting, Storing, and Treating Rainwater for Domestic Indoor Use.*
- *The Cabell Brand Center. Virginia Rainwater Harvesting Manual.*
- *Department of Environment and Conservation New South Wales, Australia. Managing Urban Stormwater: Harvesting and Reuse*
- *Council on the Environment of New York City, Rainwater Harvesting 101*

TOOL Procedure I.3

# Treatment

## Overview

As of the publication date of this Guide, there are no rules in Minnesota that determine the need for, or the level of treatment required for stormwater reuse.[1] As described in other sections of this Guide, the quality of the SOURCE of runoff is highly variable. And the level of treatment to protect the USE is also highly variable. This Tool assumes that the user has determined that treatment is necessary. Additional guidance in this Tool focuses on considerations that affect all types of treatment systems.

## Pre-Design

1. Refer to the following Tools in this guide to assist with selection of a stormwater reuse treatment system:
   - *Define the quality of the SOURCE water – Complete* ***Tool A.1-Source Water Quality*** *and review of related* ***Tool R.1a*** *&* ***Tool R.1b****.*
   - *Define quality required for the intended USE(s) – Complete* ***Tool A.5-Use Criteria*** *and review of related* ***Tools R.3a - c****.*
   - *Consider other factors as defined in* ***Tool R.3d–Treatment Considerations****.*
   - *Review the different types of treatment processes and site conditions and select alternative treatment process combinations. Refer to* ***Tool R.4-Treatment****.*
2. Perform a life cycle cost analysis to select the appropriate treatment process equipment and layout for the project.
3. Site the treatment system according to manufacturer recommendations.
4. Research whether a manufactured system has been certified by programs coordinated through the National Sanitation Foundation (NSF) (http://www.nsf.org) and the California Title 22 approved list of manufacturers (California State Department of Health Services, 2007) (http://www.cdph.ca.gov/certlic/drinkingwater/Documents/DWdocuments/treatmenttechnology.pdf)

## Design

General design considerations that apply to all water treatment systems include:

- *Adjust sizing of treatment components if filtration or sedimentation has been provided upstream of the treatment system.*
- *Determine if system should be located inside a structure to protect from winds, rain, snow, animals, etc.*
- *Locate near electrical source.*
- *Provide accessibility for maintenance.*
- *Color interior piping according to requirements in the Minnesota Plumbing Code – typically purple for reuse systems.*
- *Provide valves, including back-flow prevention valves, as required by the Minnesota Plumbing Code and as recommended by manufacturer.*

[1] The national and state plumbing codes were being reviewed for revisions at the time this report was prepared (2011). Check with the most recent publications of the code and for specific references for systems using stormwater.

## Operations & Maintenace Plans

All stormwater reuse systems should have an O&M plan for operating personnel to follow. The following lists information related to treatment system O&M that should be detailed in the Plan:

1. Inspection schedule for all treatment components, as recommended by manufacturer.

2. Schedules for cleaning of filters, replacement of chemicals, etc.

3. Winterization procedures.

## Resources (Sources and Links)

- *Minnesota Building Code*
- *Minnesota Plumbing Code*
- *NSF Certified Drinking Water System Components*
- *California State Department of Health Services, Treatment Technology Report for Recycled Water, 2007*
- *Metcalf & Eddy, Water Reuse, 2007*
- *Texas Water Development Board, The Texas Manual on Rainwater Harvesting, 2005*
- *National Sanitation Foundation, Rainwater Connection, Rainwater Collection & Harvesting systems – Design, Installation, Service, 2004*

# Distribution

## Overview

Distribution systems are unique to the planned USE. This Tool focuses on the distribution systems used for land application/irrigation types of USEs. Professionals should be consulted for recommendations on distribution for non-irrigation USEs.

## Pre-Design

1. Determine demand requirements for USE
   - *If irrigating, use historical or real-time evapotranspiration (ET) data as a guide to determine minimum and maximum plant watering requirements.*
     - *Refer to **Tool R.2a- Water Balance***
     - *Measure weekly water consumption or refer to http://climate.umn.edu/for historical data.*
     - *Consider irrigating to maximum rate tolerable by plant and soil conditions to maximize the stormwater reuse.*
   - *Refer to literature to determine the  demands for other non-irrigation USEs.*

2. Select distribution method
   - *Irrigation system*

| Distribution Method | Advantages | Disadvantages |
|---|---|---|
| **Hose** | • Inexpensive<br>• No infrastructure / design required | • Least water efficient<br>• Difficult to effectively meet plants' water demand<br>• Require higher operating pressures |
| **Spray Irrigation** | • Apply water quickly<br>• Proper design (including integration with soil moisture sensors) allow for plants' watering needs to be effectively met | • Water lost to evaporation and wind before reaching plant<br>• Higher level of design required to reduce overwatering, water inefficiency<br>• Require higher operating pressures<br>• Costs may be higher |
| **Drip Irrigation** | • Most water efficient<br>• Effectively meets plants' water demand<br>• Easily designed<br>• Inexpensive<br>• Works well with stormwater reuse as it lessens the chance of human exposure<br>• Require lower operating pressures<br>• Typically exempt from watering restrictions due to its efficiency | • Highly susceptible to clogging<br>• Subject to damage from other landscaping activities / rodents<br>• Surface systems have shorter life cycle due to increased exposure to sunlight |

   - *Non-irrigation*
     - *Identify potential distribution methods to supply the non-irrigation USE through market research. Assess advantages and disadvantages of each.*

3. Determine pressure requirements for USE

- *Irrigation system*
  - » *Typical municipal potable water system provides 40 psi of pressure.*
  - » *Spray irrigation pressure requirements are generally dependent on the type of sprinklers used and their location from each other.*
  - » *Drip irrigation systems are generally operated at a lower pressure than other irrigation methods.*

- *Non-irrigation*
  - » *Measure pressure at point of USE or refer to site historical data for retrofit projects.*

| Irrigation System | Potential Efficiency (Percent) |
|---|---|
| **Gravity (Surface)** | |
| Gravity | 75-85% |
| Furrow | 55-70% |
| Flood | 40-50% |
| **Sprinklers** | |
| Low energy | 80-90% |
| Center pivot | 70-85% |
| Sideroll | 60-80% |
| Solid set | 65-80% |
| Hand-move | 60-65% |
| Big gun | 60-65% |
| **Microirrigation** | |
| Drip | 80-95% |

Source: U.S. EPA, Guidelines for Water Reuse, 2004

4. Storage and Treatment Considerations

- *Areas with high potential for human contact should consider drip irrigation.*
- *Buffer zones between spray irrigation systems and public spaces and/or surface waters should be provided to minimize public exposure.*
- *Review treatment system to determine that suspended solids and other pollutants have been treated to tolerable concentrations such that distribution system will not clog or otherwise be damaged during operations (See* ***Tool I.3****).*

5. Water efficiency considerations (see table at left)

- *Automated irrigation systems can be designed to best mimic the water requirements of the specific plants / turf by using soil moisture sensors.*
- *Research current literature for water conservation tips.*
  - ***Metropolitan Council Water Conservation Toolbox***
  - ***Alliance for Water Efficiency***
  - ***U.S. EPA WaterSense***

## Design

1. Locate the distribution lines

- *Layout of spray irrigation system will be based on the distribution pattern of the spray nozzles.*
- *Layout of drip irrigation lines can be adapted for sites with irregular shapes. The piping may either be laid on the surface or buried at a depth that can reach the plant roots.*
- *Cross connections with potable water supply are prohibited by MN Plumbing Code unless approved backflow prevention is provided.*
- *If a potable supply is used to augment the stormwater supply, it should be added downstream of the treatment system; a backflow prevention device should be added to ensure that the stormwater does not infiltrate the potable water supply.*
- *Contact Gopher State One-Call to locate existing utilities to ensure that the design does not conflict with existing utilities.*
- *Below ground distribution lines for spray irrigation systems are typically buried 18" below grade and sloped such that lines can be fully drained prior to winter freezing.*

2. Select pipe material

- *Plastic pipe is less susceptible to corrosion. Refer to American National Standards Institute for additional information on plastic irrigation piping. http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2fASAE+S376.2+JAN1998+(R2010)*
- *Thin-wall copper pipe / tubing should be avoided due to its potential to develop pinhole leaks.*

- *Piping material should be certified by ANSI (American National Standards Institute), or other certified testing organization.*

3. Size the distribution system based on demands of the USE.

4. Design / select pump for distribution needs.
   - *Consider on-demand pumps; advantages include:*
     - *Commercially available.*
     - *The pump, motor, controller, check valve, and pressure tank are all combined into one unit.*
     - *Eliminates the need, cost, and space of a separate pressure tank.*
     - *Pumps available for specific use with stormwater.*

## Other Design Considerations

- *Must include backflow prevention devices (to ensure the stormwater does not infiltrate potable water supply)*
- *The potable water supply line should be separated vertically from the maximum water level in the tank by at least 1.5 times the diameter of the potable water supply line.*
- *Shut-off valves located in accessible areas for maintenance and winter shut-down.*
- *Drain plug or cleanout sump should be designed to allow the system to be completely emptied for winter or other situations. Direct the cleanout to a pervious area.*
- *If the stormwater reuse system will be operated during the winter, then all aboveground piping and/or piping that is shallower than the frost depth must be insulated or heat-wrapped.*
- *Submit plans to the Department of Labor and Industry, or designated municipality, for compliance with MN Plumbing Code (https://www.revisor.mn.gov/rules/?id=4715&view=chapter).*
  - *Pipes and spigots must be labeled as non-potable in accordance with the Minnesota Plumbing Code. The current code 4715.1910 requires non-potable piping be painted yellow and/or be tagged with metal tags (section 4715.1910). Other states, including California and Florida, require that reclaimed water piping be purple. This is not a requirement in Minnesota at this time.*
  - *Note: this manual considers stormwater being applied to outdoor uses. Additional considerations are required if distributing the stormwater indoors. Refer to the Minnesota Plumbing Code for additional details.*

## Operations & Maintenance Plans

All stormwater reuse systems should have an O&M plan for operating personnel to follow. The following lists information related to treatment system O&M that should be detailed in the Plan:

1. Inspection schedules with the following minimum activities:
   - *Inspection of valves and all operational structures each spring prior to annual start-up. Test system for leaks. Repair, as necessary.*
   - *Monthly inspection for accumulation of biofilm and for accumulation of sediment in filters.*
   - *Testing of control equipment on schedule recommended by manufacturer. At a minimum, all control equipment should be tested at spring start-up.*

2. Operation
   - *Nighttime hours of operation for irrigation are recommended for systems that must limit human exposure created by mist for untreated or minimally treated stormwater.*

3. Winterization
   - *Annual winterization schedule.*
   - *Procedures for draining distribution system and taking off-line.*

4. Pump manufacture and maintenance information (if pump system is installed).
   - *Follow manufacturer's instructions for pump maintenance and winterization.*

5. Site plan showing:
   - *Location of distribution system.*
   - *Location of potable connection (if augmenting stormwater supplies).*
   - *Location of backflow prevention devices.*
   - *Location and types of valves, and description of conditions that require valves to be open or shut.*
   - *Location of drain plug / cleanout sump.*

## Resources (Sources and Links)


- *Minnesota Plumbing Code*
- *Minnesota Building Code*
- *USEPA, Weather Based Landscape Irrigation Controllers, 2011*
- *North Dakota State University, Soil, Water and Plant Characteristics Important to Irrigation, EB-66, 1996*
- *Rainbird Sprinkler Manufacturing Corp., Landscape Irrigation Design Manual, 2000*
- *State of California Department of Natural Resources, Irrigation Scheduling, 2009*

TOOL Facts&Data R.1a

# Stormwater Quality Characteristics

In this document, the term **Stormwater Runoff** is used to describe the aggregate runoff that is collected at a single source. The terms **Roof Runoff** and **Ground Runoff** are used for those situations where the rooftop runoff is collected separately from the ground runoff.

## Water Quality Matters

A stormwater reuse system must provide a supply that is safe for the public and the environment in which it is used. In addition, the system must be reliable and meet operation and maintenance expectations. The water quality of the stormwater collected needs to be characterized to properly plan a stormwater reuse system. This tool is an overview of stormwater quality constituents to consider when planning a stormwater reuse system and focuses on the SOURCE stormwater. Information on the requirements for specific USES are provided in another tool - **Tool R.3a-Use Water Quality**.

Pollutants in the water supplied by a stormwater reuse system are a concern for three basic reasons:

- *the health risks associated with human contact (health)*
- *the impact on the environment given the various uses (environment)*
- *issues for the system equipment and operational impacts (equipment)*

### Health

Any water supply with a potential for human contact must be free of disease-causing organisms or have restricted access to the supply and controls on its use. While this guide is concerned only with nonpotable uses of water, there are uses that have a higher likelihood of a person ingesting the water. One possible route is through dispersion of water droplets in a mist with irrigated water. For systems in public areas with access to open storage vessels/ponds or pipe valves, the supply could be mistaken for a potable supply without signage or if the person does not understand the sign.

### Environment

The primary environmental concern is related to the potential toxicity to soils and plants that are irrigated with stormwater. If toxic constituents are suspected or have been identified through historic water quality monitoring in the drainage area, then a new monitoring program is recommended to fully evaluate whether treatment processes or limits on irrigation applications are needed as part of stormwater reuse system design.

### Equipment

Some stormwater quality constituents can affect the operation of the reuse system equipment and related structures, resulting in increased maintenance requirements and reduced life of the system.

## Water Quality Constituents of Concern

The water quality constituents of concern for stormwater reuse include:

- *Microbiological*
- *Physical/Chemical*
- *Nutrients*
- *Metals*
- *Organics*

## Table R.1a.1 Stormwater Constituents of Concern

| Constituent | Basis of Concern: Health | Basis of Concern: Environmental | Basis of Concern: Equipment |
|---|---|---|---|
| **Microbiological** | | | |
| E. Coli (#/100 mL) | x | | |
| Fecal Coliform (#/100 mL) | x | | |
| Total Coliform (#/100 mL) | x | | |
| **Physical/Chemical** | | | |
| Biochemical Oxygen Demand (mg/L) | x | x | |
| Chemical Oxygen Demand (mg/L) | x | x | |
| Total Organic Carbon (mg/L) | | x | |
| Total Suspended Solids (mg/L) | x | x | x |
| Volatile Suspended Solids (mg/L) | x | x | |
| Turbidity (NTU) | x | x | x |
| Total Dissolved Solids (mg/L) | | x | x |
| Chlorides (mg/L) | | x | x |
| Anions/Cations (mg/L) | | x | x |
| Total Hardness (mg/L) | | | x |
| Free Chlorine (mg/L) | x | | |
| pH | | x | |
| **Nutrients** | | | |
| Total Kjeldahl Nitrogen (mg/L) | x | x | |
| Ammonia - N (mg/L) | x | x | |
| Nitrate - N (mg/L) | x | x | |
| Total Phosphorus (mg/L) | x | x | |
| Total Dissolved Phosphorus (mg/L) | x | x | |
| Soluble Reactive Phosphorus (mg/L) | x | x | |

**Table R.1a.1** lists the water quality constituents that should be investigated and the primary basis of concern for each.

### What Levels of Pollutants Are a Concern?

The tremendous variability in the natural landscape, human and animal activity, weather, and other factors makes it difficult to generalize stormwater quality constituents. To provide some context for the concentration of constituents in stormwater, tables in **Tool R.1b** provide the potential range of concentrations and median values for a variety of constituents developed from different studies in the U.S. and Australia. **Table R.1b.1** presents water quality constituents for roof runoff and **Tables R.1b.2** and **R.1b.3** list ground runoff quality concentrations. **Table R.1b.4** characterizes several collection points for snowmelt. Concentration data presented in this tool refer to these tables and the cited references.

### Microbiological

Stormwater can contain disease- or illness-causing microorganisms, commonly called pathogens, which pose a health concern for water uses with the potential for human contact. Microscopic parasites, bacteria, and viruses are found in animal and bird feces in the catchment area from which stormwater is collected, including roofs. Pathogens can also be found in stormwater that has received sanitary sewage resulting from an overflow of the sanitary sewer or a cross-connection. While there are no known reports of disease associated with stormwater reuse[3], understanding the potential occurrence of pathogens in stormwater and the risk of exposure to humans, should be an integral part of planning and designing a reuse system.

There are a number of pathogens that have been identified in stormwater, as listed in Table R.1a.2. Given the different types of pathogens and costs to analyze water for pathogens, detection is typically accomplished by measuring an indicator organism. For treated wastewater, the constituent usually measured is fecal coliform or Escheria coli (E. coli). For drinking water and reclaimed water (termed wastewater reuse in Minnesota), total coliform is the standard constituent for regulatory reporting. These bacterial indicators are important in assessing the performance of disinfection processes. Drinking water standards require no presence of indicator organisms.

Bacterial indicator organisms commonly occur in both roof and ground runoff, yet are typically less in rooftop runoff. A comparable monitoring study of urban areas in Australia showed that the log-normal mean concentration of total coliform for roof runoff (1,875 No./100ml) was only 2% of the ground runoff concentration (97,665 No./100ml)[3]. Studies in the U.S. indicate that geometric mean and median total coliform concentrations range from 10,000 – 175,000 No./100ml in total stormwater runoff[3,4,5,6,7] and were less than 1,000 No./100ml in a Minneapolis roof runoff study[8] (refer to Tool R1B - Tables R1B.1-Table R1B.4).

### Physical/Chemical

There are a host of physical and chemical constituents that are indicative of health, and/or environmental concerns, or could be an issue for equipment performance in stormwater reuse systems. They can be grouped as solids, oxygen demanding substances, salts/inorganics and other constituents.

## Table R.1a.1 Stormwater Constituents of Concern (continued)

| Constituent | Basis of Concern: Health | Environmental | Equipment |
|---|---|---|---|
| **Metals** | | | |
| Aluminum | * | x | |
| Arsenic | * | x | |
| Beryllium | * | x | |
| Boron | * | x | |
| Cadmium | * | x | |
| Chromium | * | x | |
| Cobalt | * | x | |
| Copper | * | x | |
| Fluoride | * | x | |
| Iron | * | x | |
| Lead | * | x | |
| Lithium | * | x | |
| Manganese | * | x | |
| Mercury | * | x | |
| Molybdenum | * | x | |
| Nickel | * | x | |
| Selenium | * | x | |
| Strontium | * | x | |
| Tin, Tungsten, & Titanium | * | x | |
| Vanadium | * | x | |
| Zinc | * | x | |
| **Organics** | | | |
| Oils & Greases | x | x | x |
| Organics (e.g. hydrocarbons, pesticides) | x | x | |

* Health-based concern through uptake into crops irrigated with stormwater

## Table R.1a.2 Types and Sources of Pathogens in Stormwater

| Type of Pathogen | Organism | Source |
|---|---|---|
| Parasite | Giardia lamblia | cats and wild animals |
| | Cryptosporidium parvum | cats, birds, rodents, and reptiles |
| | Toxoplasma gondii | cats, birds, and rodents |
| Bacteria | Campylobacter spp. | birds and rats |
| | Salmonella spp. | cats, birds, rodents, and reptiles |
| | Leptospira spp. | mammals |
| | Escherichia coli | birds and mammals |
| Virus | Hantavirus spp. | rodents |

**Particulates** in stormwater are measured by various constituents including total suspended solids (TSS) and turbidity. Solids in the stormwater may not be a direct health threat, but can harbor pathogens. Particulates carried through a stormwater reuse system can cause problems with pumps, clogging of pipes and irrigation nozzles, and related issues. High concentrations of suspended solids commonly are found in areas with excessive soil erosion and occur during high intensity storm events when larger volumes of water at higher velocities are able to carry heavier solids loads. Mean and median TSS concentrations were found to range from 100-184 mg/L in stormwater[3,4,5,6,7] and from 10-12 mg/L in roof runoff.[3,8,9]

The **organic content** of water presents a food source for organisms in the water that exert a demand for oxygen, measured by biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total organic carbon (TOC). The higher the BOD, the more potential there is to deplete the water of oxygen or possibly result in removal of all oxygen (anaerobic conditions). For stormwater reuse, this becomes an issue in the storage of the stormwater supply, where anaerobic conditions lead to the release of hydrogen sulfide and other gases which produce odors and a corrosive environment. In addition, organic content in the water supports the growth of microorganisms and the potential for pathogens. The mean and median BOD concentrations in stormwater range from 10-55 mg/L and COD ranges from 60-170 mg/L.[3,4,5,6,7]

The **inorganic constituents** in stormwater have not been studied in much detail. Chlorides and other salts are being evaluated in stormwater and the receiving streams of Minnesota. Chlorides and the use of road salt for winter de-icing has commonly been known to destroy vegetation in the areas of application and runoff. Total dissolved solids, of which chloride is one component, is another measure of the salinity of the water. Many types of vegetation and specific turf grasses on golf courses are sensitive to high salt concentrations. Hardness is also a water quality characteristic important to consider with stormwater reuse. Hard water can lead to precipitates forming in pipes and clogging irrigation nozzles. It can also be a problem for non-irrigation uses such as for cooling water. Stormwater runoff for a variety of impervious surfaces was observed to have hardness range from 35-30 mg/L as $CaCO_3$.[9]

## Nutrients

Similar to BOD, phosphorus and nitrogen in stormwater provide an important source for the growth of aquatic life, specifically algae, and microorganisms. High nutrient waters can lead to anaerobic conditions, as well as algal blooms which can clog system equipment. In addition, nutrients support the growth of biofilms that can affect equipment performance and can also be pathogenic.

Nutrients at appropriate concentrations in irrigation water can displace the use of a portion or all of the fertilizer application. Specific monitoring will be required to characterize the runoff quality and compare this with the recommended nutrient applications for the irrigated property. For areas that collect and reuse water from the same property, buildup of nutrients and salts need to be considered in the design. Previous studies [3,4,5,6,7,8,9] indicate mean and median total phosphorus concentrations range from 0.3-0.6 mg/L and dissolved phosphorus from 0.05-0.20 mg/L in stormwater. The roof runoff concentrations were less, ranging from 0.1-0.25 mg/L total phosphorus and 0.08-0.11 dissolved phosphorus. The total nitrogen concentrations ranged from 1.5-3.1 mg/L in stormwater and 0.4-1.5 mg/L in roof runoff.

## Metals

Metals have demonstrated toxicity to humans, animals, and plants. Since we are considering only nonpotable uses of stormwater, the concerns associated with metals are primarily related to the effects on the plants and soils with irrigated water and on the system's operational performance. For roof runoff, it is important to know the construction materials of the roof. Metals have been observed in roof runoff and could be of concern for irrigation given the soil chemistry and stormwater application rates. However, most data collected to date shows average concentrations below plant toxicity thresholds. The use of proper materials and protective coatings on a roof can reduce the risk of having significant concentrations of metals in roof runoff. If roofs are old or materials are not known, it is recommended to monitor for cadmium, copper, iron, lead, and zinc.

Historic monitoring of stormwater, in studies such as the National Urban Discharge Program (NURP)[7], has included the metals on the priority pollutant monitoring list. Higher metal concentrations are more prevalent in areas with industrial processing and large commercial buildings with metal roofs. If there are known industrial sites in the catchment area, it is recommended to obtain monitoring reports or to conduct monitoring to characterize the metals concentrations in stormwater runoff. In addition to those listed for roof runoff, it is recommended to monitor for all the priority pollutant metals in preliminary monitoring and then refine future monitoring to specific metals of concern.

## Organics

The organics group, including oil & grease, hydrocarbons, and pesticides, has been less extensively studied in stormwater. The best indicator for identifying concerns with organics in the SOURCE water is to evaluate the area for current and past industrial and commercial businesses, or potential for runoff from roadways, where hydrocarbons from vehicles accumulate. Synthetic organic chemicals have been documented in stormwater and include petroleum hydrocarbons, pesticides, herbicides, and other man-made products. Volatile organic chemicals can be introduced when water comes into contact with materials containing refined organic products. The sources include plastics, glues, and solvents, as well as gasoline, greases, and oils. Volatile organic chemicals can also be introduced by the materials used to construct the reuse system (for example, tetrahydrofuran from PVC glue).

There is a vast array of chemicals that occur at very low levels (in the parts per trillion or ng/L) in stormwater and are known or suspected of toxicity. Of heightened interest, is the environmental impact of several emerging contaminants of concern, such as:

- *pharmaceutically active chemicals (PhACs)*
- *endocrine disrupting compounds (EDCs)*
- *disinfection by products (DBPs) such as N-nitrosodimethylamine (NDMA)*
- *groundwater contaminants such as 1,4-dioxane and methyl tertiary-butyl ether (MTBE)*
- *Polycyclic Aromatic Hydrocarbons (PAHs)*

These chemicals are being monitored in our drinking water supplies and in studies of wastewater treatment plants to learn more about their occurrence. Toxicity studies are underway to assess the health effects of these chemicals. For nonpotable uses of stormwater it is not anticipated that monitoring for these emerging contaminants is needed unless activities or other monitoring in the catchment area suggest these chemicals could be present.

### Relationship of Drainage Area Activities and Pollutants of Concern

Some land use types and specific activities in a drainage area have common pollutants of concern. **Table R.1a.3** summarizes activities with typical pollutants of concern for stormwater reuse systems.

## Table R.1a.3 Drainage Area Activity Pollutants of Concern

| Site Activity | Nutrients | Metals | Organics Oil / Hydrocarbons | Organics Toxics | Other |
|---|---|---|---|---|---|
| **Vehicle Repair** | Minor | Major | Major | Major | |
| **Vehicle Fueling** | Minor | Major | Major | Major | |
| **Vehicle Washing** | Major | Moderate | Moderate | Major | |
| **Vehicle Storage** | None | Moderate | Major | Minor | Trash |
| **Outdoor Loading** | Moderate | Moderate | Minor | Minor | Organic matter |
| **Outdoor Storage** | Moderate | Moderate | Moderate | Moderate | |
| **Dumpsters** | Moderate | Moderate | Moderate | Major | Trash |
| **Landscaping** | Major | None | None | Major | Pesticides |
| **Golf Courses** | Major | Minor | None | Major | Pesticides |
| **Hobby Farms / Race Tracks** | Moderate | None | None | None | Bacteria |
| **Construction** | Moderate | Minor | Minor | Moderate | Trash, sediment |
| **Marinas** | Moderate | Moderate | Moderate | Major | Bacteria |

Source: SEH, Inc. Adapted from Minnesota Pollution Control Agency, Minnesota Stormwater Manual, 2005.

## Source Control Measures

A comparison of roof runoff and ground runoff quality shows that most roof runoff systems have lower concentrations of contaminants and in most cases will require less treatment for use. However, the type of treatment required is most strongly influenced by how the water will be used. **Tool R.3a – Use Water Quality** provides a detailed account of the water quality characteristics required for specific USEs.

There are general source control measures that can be taken to minimize health, environmental, and equipment-based concerns associated with specific water quality characteristics.

### Roof Runoff Quality Protection

The type of materials and features on a roof will affect the quality of the water collected. The following features should be considered for roofs within a stormwater reuse system:

- *public access (except with maintenance access)*
- *structures on or above the roof that may rust or corrode or provide a nesting place for birds*
- *roof-mounted appliances, such as air conditioning units, hot water services and solar heaters with discharge, overflow or bleed-off pipes*
- *a chimney or flue from an industrial process within or adjacent to the building*
- *exposure to chemical sprays from processes within the building, such as spray painting, or nearby industrial sources with air pollutants that may be deposited on the roof*
- *vegetation growing on the roof (e.g. a 'green roof')*
- *high pressure cleaning practices*
- *lead-based painted surfaces (or repaint with non-lead based paints/sealant)*
- *asbestos roofing material that has deteriorated*
- *copper roofing material*
- *overhanging vegetation that may attract birds and drop debris onto the roof*
- *bitumen-based materials or lead-based paints*
- *exposure to preservative-treated wood*

These characteristics may result in higher pathogen levels or chemical concentrations, which may increase health and/or environmental risks. If a roof has these characteristics, water quality monitoring is recommended as defined in **Tool R.2b – Stormwater Monitoring**.

### Ground Runoff Quality Protection

The selection of the collection point of stormwater in the drainage basin should consider the range of water quality characteristics that could occur in the basin. While the quantity required and proximity to facilities to store and treat the water are likely more influential factors in selecting a point of collection in the watershed, it is important to determine the potential pollutants, as well as the potential for locating the collection point upstream of the sources of these pollutants. In addition, as reviewed through **Tool A.3 – Upstream Source** and **Tool R.1.c – Upstream Water Quality Considerations**, location of the collection point downstream of a stormwater treatment device such as a biofiltration device or stormwater pond, may be optimal for both water quality and distribution needs.

## Water Quality Effect on System Equipment and Performance

A stormwater reuse system must be reliable and have an annual operation and maintenance cost that is equitable when compared to a traditional water source. It is essential to have the water quality characterized in the planning process, so that the most optimum system components are selected. The stormwater quality constituents that could affect the operation of the reuse system equipment and structures include:

- *Debris and particulates associated with sediment and leaves could potentially block or clog pipes, irrigation nozzles or drip irrigation systems, or damage pumps.*
- *Organic matter (measured by BOD, COD, or TOC), for example from grass clippings, that causes reduced dissolved oxygen levels through decomposition could result in odors and release of pollutants from sediments.*
- *Nitrogen and phosphorus could support algal growth in open storage facilities, which can lead to higher turbidity and/or create algal blooms with biofilm characteristics that could clog irrigation equipment.*
- *Iron concentrations could clog irrigation systems and decrease the effectiveness of the disinfection system.*
- *Hardness could result in clogged irrigation systems.*
- *Anaerobic conditions or high salt concentrations could result in corrosion of system components.*

There are system design features and operation and maintenance procedures that can handle these issues and others related to typical stormwater quality characteristics. For example, screens or coarse filters can be used to remove larger debris and particulates. The **Implementation Phase** will explore the options to minimize issues related to specific water quality characteristics and maximize system performance.

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[3]Natural Resources Management Ministerial Council, etal., Australian Guidelines for Water Recycling: Managing Health and Environmental Risks, 2009

[4] Brezonik, Staldman, 2002

[5] Steuer etal, 1997

[6] Washbusch etal, 1999

[7] USEPA, 1983

[8] Minneapolis Department of Public Works, Minneapolis Rain Barrel Partnership, 2008

[9] Bannerman, et al, Sources of Pollutants in Wisconsin Stormwater, 1992

# Stormwater Quality Data Tables

## Table R.1b.1 Typical Roof Runoff Quality

| Constituent | Constituent Concentration | | |
|---|---|---|---|
| | Minneapolis [1] | Australia [2] | Wisconsin [3] |
| E-Coli (#/100 mL) | 764 | 671 | -- |
| Fecal Coliform (#/100 mL) | -- | 93 | -- |
| Total Coliform (#/100 mL) | -- | 1875 | -- |
| Biochemical Oxygen Demand (mg/L) | -- | -- | -- |
| Chemical Oxygen Demand (mg/L) | -- | -- | -- |
| Total Solids (mg/L) | -- | -- | 126 |
| Suspended Solids (mg/L) | 10 | 17.7 | 19 |
| Turbidity (NTU) | -- | 2.48 | -- |
| Total Hardness (mg/L) | -- | -- | 44 |
| pH | -- | 6.42 | -- |
| Total Nitrogen (mg/L) | 0.421 | 1.53 | -- |
| Ammonia - N (mg/L) | 0.268 | -- | -- |
| Nitrate - N (mg/L) | 0.586 | -- | -- |
| Total Phosphorus (mg/L) | 0.104 | 0.122 | 0.24 |
| Total Dissolved Phosphorus (mg/L) | 0.076 | -- | 0.11 |
| Soluble Reactive Phosphorus (mg/L) | 0.065 | -- | -- |
| Arsenic (mg/L) | -- | 0.005 | -- |
| Cadmium (mg/L) | -- | 0.0005 | 0.0004 |
| Chromium (mg/L) | -- | 0.012 | -- |
| Copper (mg/L) | 0.0075 | 0.185 | 0.01 |
| Iron (mg/L) | -- | 0.115 | -- |
| Lead (mg/L) | 0.0032 | 0.079 | 0.01 |
| Nickel (mg/L) | -- | 0.016 | -- |
| Strontium (mg/L) | -- | 0.017 | -- |
| Zinc (mg/L) | 0.101 | 2.45 | 0.363 |

[1] Arithmetic mean concentrations; Reference: Minneapolis Public Works, City of Minneapolis Neighborhood Rain Barrel Partnership Project, 2008

[2] Log-normal mean concentrations; Reference: Natural Resource Management Ministerial Council et al, Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2), 2009

[3] Highest geometric mean concentration reported; Reference: Roger T. Bannerman and Richard Dodds, Sources of Pollutants in Wisconsin Stormwater, 1992

## Table R.1b.2 Typical Urban Stormwater Quality Characteristcs

| Constituents | Twin Cities[2] | Marquette, MI[3] | Madison, WI[4] | U.S. Cities[5] | Australia[1] |
|---|---|---|---|---|---|
| Total Coliform (#/100 mL) | -- | 10,200 | 175,100 | 21,000 | 69,500[a] |
| Biochemical Oxygen Demand (mg/L) | -- | 15 | -- | 9 | 54 |
| Chemical Oxygen Demand (mg/L) | 169 | 66 | -- | 65 | 58 |
| Total Suspended Solids (mg/L) | 184 | 159 | 262 | 100 | 100 |
| Total Phosphorus (mg/L) | 0.58 | 0.29 | 0.66 | 0.33 | 0.48 |
| Dissolved Phosphorus (mg/L) | 0.20 | 0.04 | 0.27 | 0.12 | 0.67[b] |
| Total Kjeldahl Nitrogen (mg/L) | 2.62 | 1.50 | -- | 1.50 | 3.09 |
| Nitrate (mg/L) | 0.53 | 0.37 | -- | 0.68 | -- |
| Ammonia (mg/L) | -- | 0.2 | -- | -- | 1.14 |
| Lead (mg/L) | 0.060 | 0.049 | 0.032 | 0.144 | 0.073 |
| Zinc (mg/L) | -- | 0.111 | 0.203 | 0.160 | 0.293 |
| Copper (mg/L) | -- | 0.022 | 0.016 | 0.034 | 0.055 |
| Cadmium (mg/L) | -- | 0.0006 | 0.0004 | -- | 0.0198 |

**1** Log-normal mean concentrations; Reference: Natural Resource Management Ministerial Council et al, Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2), 2009

**2** Event mean concentrations; Reference: Brezonik and Staldman, 2002

**3** Geometric mean concentrations; Reference: Steuer et al., 1997

**4** Geometric mean concentrations; Reference: Waschbusch et al.. 1999

**5** Median concentrations; U.S EPA, 1983

**a** Fecal coliform, No./100 mL

**b** Soluble reactive phosphorus, mg/L

# Table R.1b.3 Urban Stormwater Quality Characteristcs for Diffferent Drainage Areas

| | Constituent Concentration | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Wisconsin Data [2] | | | | | | | | |
| Constituent | Australia[1] | Arterial Street | Feeder Street | Collector Street | Parking Lot | Residential Driveway | Residential Lawn | Outfall | Twin Cities Highways [3] | Nationwide Highways [3] |
| E-Coli (#/100 mL) | 59,339 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Fecal Coliform (#/100 mL) | 69,429 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total Coliform (#/100 mL) | 97,665 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Aluminum (mg/L) | 1.19 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arsenic (mg/L) | 0.009 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Barium (mg/L) | 0.028 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Cadmium (mg/L) | 0.0198 | 0.0028 | 0.0008 | 0.0017 | 0.0012 | 0.0005 | -- | 0.0006 | 0.0025 | 0.0063 |
| Chromium (mg/L) | 0.009 | 0.026 | 0.007 | 0.013 | 0.016 | 0.002 | -- | 0.005 | -- | -- |
| Copper (mg/L) | 0.055 | 0.085 | 0.025 | 0.061 | 0.047 | 0.02 | 0.013 | 0.02 | 0.023 | 0.0527 |
| Iron (mg/L) | 2.842 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Lead (mg/L) | 0.073 | 0.085 | 0.038 | 0.062 | 0.062 | 0.02 | -- | 0.04 | 0.242 | 0.254 |
| Manganese (mg/L) | 0.111 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Mercury (µg/L) | 0.218 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Nickel (mg/L) | 0.009 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Strontium (mg/L) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Zinc (mg/L) | 0.293 | 0.629 | 0.245 | 0.357 | 0.361 | 0.113 | 0.06 | 0.254 | 0.123 | 0.923 |
| Total Kjeldahl Nitrogen (mg/L) | 3.09 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Ammonia - Nitrogen (mg/L) | 1.135 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Nitrate - Nitrite (mg/L) | -- | -- | -- | -- | -- | -- | -- | -- | 0.77 | 0.79 |
| Total Phosphorus (mg/L) | 0.48 | 1.01 | 1.77 | 1.22 | 0.48 | 1.5 | 3.47 | 0.86 | 0.43 | 0.48 |
| Total Dissolved Phosphorus (mg/L) | -- | 0.62 | 0.55 | 0.36 | 0.07 | 0.87 | 2.4 | 0.34 | -- | -- |
| Soluble Reactive Phosphorus (mg/L) | 0.664 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Bicarbonate (as CaC03 mg/L) | 35.21 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Biological Oxygen Demand (mg/L) | 54.28 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Chemical Oxygen Demand (mg/L) | 57.67 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Chloride (mg/L)[4] | 11.4 | -- | -- | -- | -- | -- | -- | -- | 11.5 | 33 |
| Oil and Grease (mg/L) | 13.13 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| pH | 6.35 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Sodium (mg/L) | 10.63 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total Suspended Solids (mg/L) | -- | 993 | 1152 | 544 | 603 | 328 | 656 | 462 | -- | -- |
| Suspended Solids (mg/L) | 99.73 | 875 | 1085 | 386 | 474 | 193 | 457 | 374 | -- | -- |
| Total Dissolved Solids (mg/L) | 139.6 | -- | -- | -- | -- | -- | -- | -- | 116.3 | 157.3 |
| Total Organic Carbon (mg/L) | 16.9 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Turbidity (NTU) | 50.93 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Total Hardness (mg/L) | -- | 41 | 30 | 32 | 48 | 34 | 51 | 27 | -- | -- |

[1] Log-normal mean concentrations; Reference: Natural Resource Management Ministerial Council et al, Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2), 2009

[2] Arithmetic mean concentration; Reference: Roger T. Bannerman and Richard Dodds, Sources of Pollutants in Wisconsin Stormwater, 1992

[3] Reference: University of Minnesota Water Resources Center, Assessment of Stormwater Best Management Practices Manual, 2008.

[4] Data represents chloride concentrations during monitoring season, typically April through October. Chloride concentrations in winter snow melt grab samples have been found to be as great as 3600 mg/l.

## Table R.1b.4 Flow-Weighted Mean Snowmelt Concentrations in the St. Paul Area[1]

| Constituents | Storm Sewers | Open Channels | Creeks | NURP [2] |
|---|---|---|---|---|
| Total Suspended Solids (mg/L) | 148 | 88 | 64 | -- |
| Volatile Suspended Solids (mg/L) | 46 | 15 | -- | -- |
| Chemical Oxygen Demand (mg/L) | 169 | 82 | 84 | 91 |
| Total Phosphorous (mg/L) | 0.7 | 0.56 | 0.54 | 0.46 |
| Dissolved Phosphorous (mg/L) | 0.25 | 0.18 | -- | 0.16 |
| Total Kjeldahl Nitrogen (mg/L) | 3.52 | 2.36 | 3.99 | 2.35 |
| Nitrate (mg/L) | 1.04 | 0.89 | 0.65 | 0.96 |
| Chloride (mg/L) | 230 | 49 | 116 | -- |
| Lead (mg/L) | 0.16 | 0.2 | 0.08 | 0.18 |

[1] Reference: Water Environment Research Foundation, Urban and Highway Snowmelt: Minimizing the Impact of Receiving Water, 1999

[2] Median concentrations from more than 2,300 rainfall events monitored across the nation; EPA, 1983

# Upstream Water Quality Considerations

Use this tool to assess the impact of upstream stormwater management practices on the water quality of the SOURCE used for a project.

## Overview

Typical devices that could affect the SOURCE water quality are stormwater best management practices (BMPs) such as raingardens, stormwater infiltration systems, or stormwater treatment ponds. These stormwater system facilities are designed to reduce pollutant loadings downstream. The water quality criteria selected in designing a stormwater reuse system should include the implications these BMPs have on the pollutant load and concentrations of the SOURCE.

## Input Assumption:

A BMP device has been identified upstream of the SOURCE withdrawal location. Refer to **Tool A.3-Upstream Source**.

**Step 1.** Identify and contact the owner/designer of the BMP to determine the water quality and quantity design criteria.

**Step 2.** If design criteria are not available or the designer recommends water quality monitoring, perform monitoring. Refer to [1]University of Minnesota, 2010.

**Step 3.** Consult references to learn about water quality considerations.

## Outcomes:

Estimate of the pollutant concentrations and flows discharged from the upstream BMP.

Recognizing the implications of upstream BMPs on SOURCE water quality and accounting for this in system design.

[1] University of Minnesota College of Science and Engineering, Stormwater Assessment and Maintenance, 2010

# Water Balance

## Water Balance Considerations

This interactive spreadsheet has been prepared to assist in computation of the storage volume needed for a stormwater reuse project using precipitation records of the Twin Cities area of Minnesota and surrounding region. The user will input site impervious area, volume of existing storage, and season of USE. The spreadsheet computes the difference between weekly precipitation, storage evaporation, and withdrawal to develop the volume of storage required to ensure a constant supply.

The following general conditions apply to the water balance spreadsheets. If site conditions differ, then the user is encouraged to use hydrologic / hydraulic software to develop site specific computations.

- *All impervious areas are connected, and none of the runoff from impervious areas is directed across pervious surfaces before being collected for storage.*
- *Runoff from pervious surfaces is negligible.*
- *March snowmelt is included in the water balance, but it is assumed that mid-winter snowmelt that occurs earlier than March is not available for storage.*
- *Precipitation is based on weekly time steps instead of on a per-event or per-day basis. This provides the best fit with irrigation requirements, which are based on weekly water needed. It is assumed that other uses can be adjusted to a weekly rate for ease of computation.*
- *Irrigation rates of 1" per week is generally based on literature values. This rate can be changed to accommodate the specific need of the vegetation being irrigated. If excess runoff is available, then the user is encouraged to increase the rate of irrigation to the maximum that is tolerable by the vegetation and soil conditions.*
- *Cells can be left blank for parameters that are not required in a site-specific analysis.*
- *Maximum storage required is determined as the capacity needed to meet the demands of the reuse system. Flow may still need to be augmented during seasons in which precipitation values cannot fill the storage system to capacity.*
- *Weeks tank is empty represents the number of weeks over the 30-year period that the demand exceeded the supply. The user can use this information to judge whether supplemental supply is needed.*

## Water Balance Spreadsheets

The Matrix was developed using MS Excel 2007 and consists of a workbook with several tabs.

The individual tabs are described below:

| Worksheet Name | Worksheet Description |
|---|---|
| **Daily Data** | This tab uses the weekly precipitation and evapo-transpiration data from January 1, 1980 through December 31, 2010 to compute the amount of precipitation available for collection in reuse storage structures. Includes seasonal adjustments for snowmelt. |
| **Average Weekly Data** | This tab computes averages 31 years of weekly precipitation and evapo-transpiration data to determine which weeks, on average, ET exceeds precipitation. |
| **Irrigation Constant Demand** | This tab is an active tab (user input required) where the user inputs impervious area and irrigation rate. Spreadsheet computes the storage volume for sites that use a constant rate of irrigation per week. |
| **Irrigation Variable Demand** | This tab is an active tab (user input required) where the user inputs impervious area and irrigation rate. Spreadsheet computes the storage volume for sites that irrigate only when the precipitation is less than the irrigation rate. |
| **Non-Irrigation Constant Demand** | This tab is an active tab (user input required) where the user inputs impervious area and weekly rate of USE. Spreadsheet computes the storage volume assuming a constant rate of USE per week. |
| **Week Look-Up Table** | This tab is a look-up table for users that want to adjust the typical weeks of use within each of the "Demand" tabs. |

# Stormwater Monitoring

Use this tool to assess the volume , rate, and quality of water available from the SOURCE drainage area through the installation of flow meters and sampling equipment.

## Overview

Installation of flow monitoring and water sampling equipment and rainfall gauges near the point of collection of stormwater runoff will provide the most accurate measure of the quantity of stormwater that is available for USE.

## Input Assumption:

Stormwater runoff is from a fully developed area where the runoff is collected by an existing storm sewer network.

**Step 1.** Identify and contact the owner/designer of the storm sewer network to obtain maps noting the location, size and depth of the storm sewers and manholes.

**Step 2.** Select a manhole for installation of flow monitoring equipment that best represents the point where the stormwater runoff will be withdrawn for USE. Conduct a site visit to ensure the location is accessible and safe, and that the manhole is in good condition.

**Step 3.** Select flow monitoring and sampling equipment. Develop monitoring plan , including data collection protocols.

**Step 4.** Install flow meters and samplers. Monitor for a period that matches the period of USE water demand. Periodically download data and inspect equipment.

**Step 5.** Analyze flow data. Send samples to certified laboratory for additional analysis.

## Outcomes:

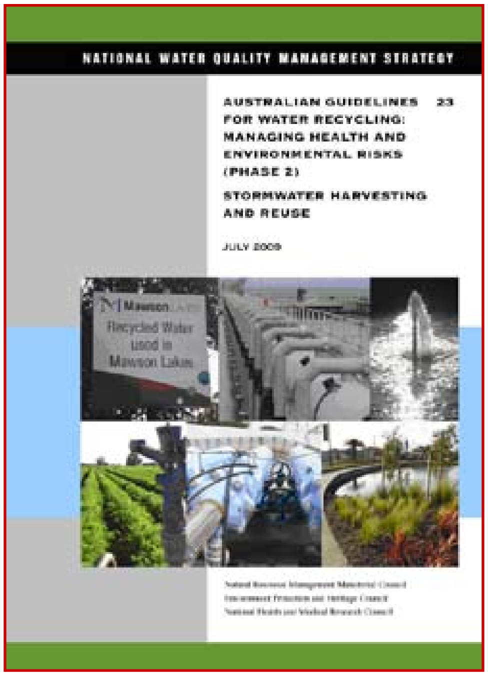
Compute the rate and volume of runoff for USE in the Water Balance (**Tool R.2a**).

Determine the water quality concentrations for parameters of concern, identified through assessment of the SOURCE water quality (**Tool A.1**) and USE criteria (**Tool A.5**).

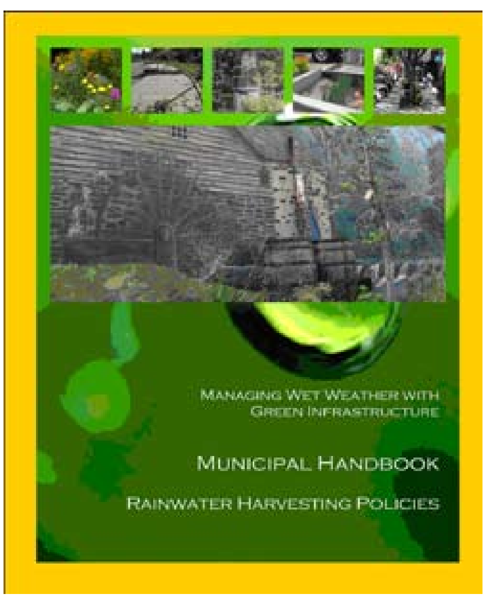
## References


- *Stormwater Treatment: Assessment and Maintenance Manual (Gulliver, J.S., A.J. Erickson, and P.T. Weiss (editors). 2010. University of Minnesota). http://stormwaterbook.safl.umn.edu/*
- *Guidance Manual: Stormwater Monitoring Protocols (Second Edition)(California Department of Transportation, July 2000). http://www.dot.ca.gov/hq/env/stormwater/special/guidance_manual/one_file/GUIDANCE_MANUAL.pdf*
- *MN Department of Health, Environmental Laboratory Search. https://apps.health.state.mn.us/eldo/public/accreditedlabs/labsearch.seam*

# Use Water Quality Characteristics




Australia's stormwater reuse guide approaches planning from a public health perspective.




The U.S. EPA's rainwater harvesting guide provides a general overview and examples of programs throughout the country.

## The Type of Water Use Matters

Fundamental to any water supply system is delivery of a supply that is safe for the public and the environment in which it is used. There are no current federal or state regulations in Minnesota or city or metro-wide ordinances with requirements related to the quality of reclaimed stormwater. There are regulations applied to the use of reclaimed wastewater in Minnesota and for reclaimed wastewater and stormwater in other states and cities. There are also plumbing code requirements that must be adhered to for any system supplying water in the state[1]. This tool provides an overview of regulations and criteria developed to provide a supply that protects public health (Part 1) and criteria and considerations to protect the environment and the water infrastructure systems associated with supply of reclaimed stormwater (Part 2).

Companion tools, **Tools R.3b-d**, are used in the assessment of water quality considerations for the use of the water:

- ***Tool R.3b*** *– Water Quality Criteria Tables provides lists of a variety of criteria used by other states, cities, and industries to serve as examples for water quality required for different uses.*
- ***Tool R.3c*** *– Use Criteria Matrix defines health criteria and environmental and equipment-based considerations for specific uses.*
- ***Tool R.3d*** *– Treatment Process Considerations presents treatment process goals and links to other tools related to stormwater reuse system treatment processes.*

## Water Quality Criteria

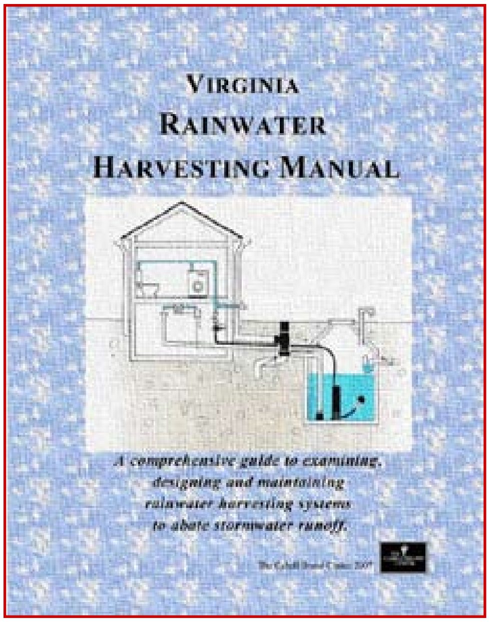
### Part 1 – Health-Based Criteria

#### *Non-Potable Water Supply Regulatory Background*

Water supplies for non-potable water uses are regulated on a state-basis in the United States. While there are national standards for our drinking water, there are currently no federal standards for water supplied for non-potable uses. Many states have developed programs and standards for the use of reclaimed wastewater, but comparable programs are lacking for the supply of reclaimed stormwater. The regulation of reclaimed wastewater in Minnesota has an established structure related to the regulation of wastewater treatment facility discharges. In the case of stormwater, the point discharge permitting structure is not in-place, unless it concerns a larger community with permitted stormwater discharges – and this is still an evolving permitting system that does not include established operating licensure for facilities as exist for our wastewater and drinking water treatment facilities.

The drive to conserve water and protect our water resources through a reduction in stormwater runoff has provided an opportunity to do both with stormwater reuse. Several communities, and some states, have developed specific ordinances and guidelines to assist residential, municipal, commercial, and industrial entities in the implementation of stormwater reuse systems. At the federal level, the U.S. EPA has prepared a municipal handbook for rainwater harvesting policies (U.S. EPA, 2008). Most of these are guidelines for smaller systems related specifically to roof runoff. Some

[1] The national and state plumbing codes were being reviewed for revisions at the time this report was prepared (2011). Check with the most recent publications of the code and for specific references for systems using stormwater.




Virginia is one of several states with rainwater harvesting guidance.

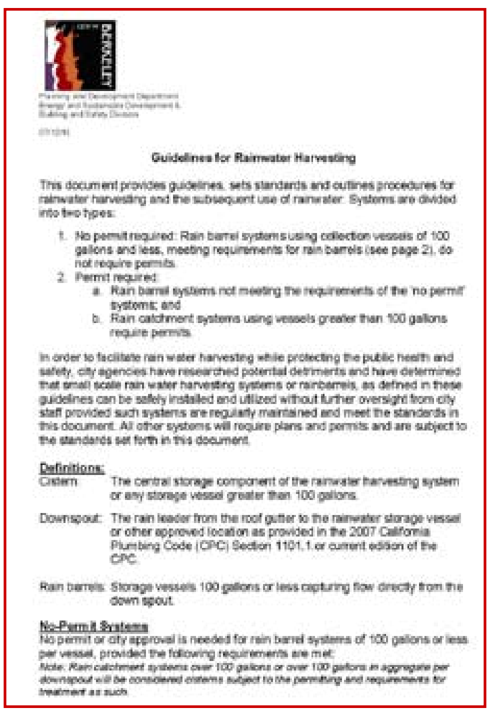
countries such as Australia (National Resource Management Ministerial Council, et al, 2009) have developed guidelines specifically for stormwater and larger applications of roof and ground runoff.

While there are different approaches and levels of guidance provided in the various guidelines for stormwater reuse – universal to each is the need to protect human health. Following this tenet, this guide applies point of use criteria to establish recommendations for the quality of water supplied by a stormwater reuse system. Given the water quality criteria for specific uses and the source water quality, the system components can then be defined.

### *Regulatory Requirements Assumed for this Guide*

Water quality criteria have been developed by various states and countries based on public health protection. Minnesota currently requires reclaimed wastewater to meet regulatory limits based on the California Water Recycling Criteria, Title 22 California Code of Regulations (California Title 22[2]). The complete list of criteria is included in **Table R.3b.1** (**Tool R.3b**). The Minnesota Pollution Control Agency (MPCA) handles permitting of recycled wastewater as part of the National Pollutant Discharge Elimination System (NPDES) permit process. The MPCA establishes recycled water quality criteria on a case-by-case basis and bases its assessment on the California Title 22 criteria.

This guide assumes the same public health criteria used for reclaimed wastewater for the supply of reclaimed stormwater, noting that there will be some differences associated with specific treatment technologies given the differences in the source characteristics.


Planning and Development Department
Energy and Sustainable Development & Building and Safety Division

**Guidelines for Rainwater Harvesting**

This document provides guidelines, sets standards and outlines procedures for rainwater harvesting and the subsequent use of rainwater. Systems are divided into two types:

1. No permit required: Rain barrel systems using collection vessels of 100 gallons and less, meeting requirements for rain barrels (see page 2), do not require permits.
2. Permit required:
   a. Rain barrel systems not meeting the requirements of the 'no permit' systems; and
   b. Rain catchment systems using vessels greater than 100 gallons require permits.

In order to facilitate rain water harvesting while protecting the public health and safety, city agencies have researched potential detriments and have determined that small scale rain water harvesting systems or rainbarrels, as defined in these guidelines can be safely installed and utilized without further oversight from city staff provided such systems are regularly maintained and meet the standards in this document. All other systems will require plans and permits and are subject to the standards set forth in this document.

Definitions:

Cistern: The central storage component of the rainwater harvesting system or any storage vessel greater than 100 gallons.

Downspout: The rain leader from the roof gutter to the rainwater storage vessel or other approved location as provided in the 2007 California Plumbing Code (CPC) Section 1101.1 or current edition of the CPC.

Rain barrels: Storage vessels 100 gallons or less capturing flow directly from the down spout.

No-Permit Systems

No permit or city approval is needed for rain barrel systems of 100 gallons or less per vessel, provided the following requirements are met:

*Note: Rain catchment systems over 100 gallons or over 100 gallons in aggregate per downspout will be considered cisterns subject to the permitting and requirements for treatment as such.*

Several U.S. cities have guidelines and permits for rainwater harvesting, such as the City of Berkely, CA.

In addition to the specific pathogen limits established by the California Title 22 criteria, which are characterized using the measurement of total coliform, there are also best practices that must be employed for specific uses. (Refer to **Tool R.1a** to learn more about pathogens in water)

This guide simplifies the health-based criteria as follows:

- ***Level 1*** *– provides a supply from a protected source/storage system (limited exposure to pathogens or conditions for biological growth)*
- ***Level 2*** *– provides a supply meeting a total coliform limit of 23/100 ml*
  - This is the same level of protection provided by secondary-23 recycled water under California Title 22.
  - To achieve this level, in most cases filtration will be required followed by disinfection. However, depending on the stormwater characteristics, it is possible that disinfection alone could meet the total coliform limit.
- ***Level 3*** *– provides a supply meeting a total coliform limit of 2.2/100 ml*
  - This is the same level of protection provided by tertiary recycled water under California Title 22.
  - This level of pathogen reduction will require filtration and disinfection. Additional treatment, such as chemical addition, may be needed to remove constituents that could interfere with pathogen removal.

### *Other Regulatory Guidelines*

There are health-based criteria developed for many different uses. **Tool R.3b** provides tables compiled for various uses of water as listed below:

- ***Table R.3b.2*** *- State Water Reuse Criteria for Irrigation of Parks, Playgrounds, Schoolyards, and Similar Areas*
- ***Table R.3b.3*** *- State Water Reuse Criteria for Selected Nonpotable Applications*
- ***Tables R.3b.4*** *– Industrial Water Use Health-Based Criteria*

[2] MPCA, Municipal Wastewater Reuse, March, 2010.

The specific water quality limits and required treatment practices listed in these tables are based on use of reclaimed wastewater. Given that the pathogen limits are based on the risk associated with human exposure, these limits can be applied to any SOURCE of water. However, applying recycled wastewater treatment requirements and other pollutant limits to stormwater sources is not always appropriate. Wastewater is typically measured by the strength of its organic content, measured as biochemical oxygen demand (BOD), and solids, measured as total suspended solids (TSS). Some states require meeting these parameter limits in addition to pathogens, measured as either fecal coliform, total coliform, or E. Coli. Use of the term "secondary" refers to the biological process where organics are treated, also called oxidation, which is the standard treatment process for wastewater treatment plants in the U.S, in addition to disinfection. Some facilities may have an additional step where chemicals are added (coagulation), possibly an additional sedimentation step, and then a final filtration process.

## Part 2 – Environmental and System Equipment-Based Criteria

In addition to health risks, there are environmental and equipment performance risks to consider in planning a stormwater reuse system. Regulations for wastewater reuse have only health risk-based criteria. One reason for this is that water discharged from a wastewater treatment plant already meets water quality goals established for discharge to either a waterway or a land disposal system. It is assumed that the supplier and receiver of reclaimed wastewater will evaluate their water quality needs and establish goals in their water supply agreements. It is up to the individual partners to determine what water quality parameters will ensure protection of the environment and system equipment.

Given the numerous USEs of water and the site specific characteristics associated with a stormwater reuse system, the water quality criteria can vary significantly with the USE. The water quality requirements for each USE should be researched during the planning stages. It is possible that the water quality of the SOURCE and requirements for USE may dictate if a stormwater reuse project is feasible. Feasibility can be influenced by the system cost, the required treatment or system components, and labor requirements for operation and maintenance of the system.

### *Environmental*

This guide restricts the environmental criteria assessment to irrigation USEs. Impacts associated with USE of the supply to wash down equipment and structures, as with car wash facilities and street sweeping, are discussed in the Equipment-Based Requirements subsection. Refer to the Reference links for water quality considerations for other USEs and for more detail than presented in this guide.

Water quality for irrigation should be assessed in terms of the plant or turf type, soil conditions, and supplements (fertilizer) added to the soil. **Table R.3b.5 – Recommended Limits for Constituents in Irrigation Water Supplies** summarizes considerations for some water quality constituents known for their toxicity to plants. Given that chlorine is a common disinfectant for stormwater reuse systems, the chlorine residual needs to be monitored and maintained below 1 mg/L. At higher levels chlorine can cause severe damage to most plants; some plants show toxic effects with residuals as low as 0.05 mg/L. Other constituents of concern are described in **Tool R.1a - Stormwater Quality Characteristics** and listed references.

Nitrogen and phosphorus should also be considered in context with existing soil properties, as well as the implications on system equipment issues associated with high nutrient levels. For some applications, higher nutrients may provide advantages by reducing the fertilizing practices for irrigated turf and crops; but this must be weighed against the potential equipment problems associated with collecting, storing, and distributing high nutrient waters. In addition, if the stormwater reuse system is intended to recharge the groundwater, then it is important to assess that the stormwater does not overload the soil such that nutrients are released.

***Equipment-Based Requirements***

There are water quality parameters to consider that affect the equipment and structures that are a part of the stormwater reuse system and also the components of any facilities that USE the water. As with the design of systems using traditional water supplies, an understanding of the water quality is necessary to provide a system that does not corrode, become clogged, or promote the growth of microorganisms that could spread disease. Table R.3b.6 in **Tool R.3b - Water Quality Criteria Tables**, lists some water quality parameters and concentration limits for stormwater reuse system performance.

It is important to identify the water quality requirements for the different USEs planned for the stormwater. Toilet flushing systems, vehicle and equipment wash down, structure/roadway cleaning, and various industrial applications include different types of materials that could corrode or be discolored. The water quality requirements for cooling water (Table R.3b.7) and boiler feed water (Table R.3b.8) are provided in **Tool R.3b - Water Quality Criteria Tables** as examples of the characteristics that should be monitored and the concentration limits for USEs requiring a higher quality supply.

## Use Quality Criteria Summary

Tables R.3c.1&2 in **Tool R.3c - Use Criteria Matrix** summarize the water quality characteristics to consider in planning a stormwater reuse system based on the USE of the supply.

## References (Sources & Links)


- *Metcalf & Eddy, Water Reuse: Issues, Technologies, and Applications, 2007*
- *Natural Resource Management Ministerial Council et al, Australian Guidelines for Water Recycling, Stormwater Harvesting and Reuse, 2009*
- *State of California, 2000*
- *U.S. EPA. Managing Wet Weather with Green Infrastructure, Municipal Handbook, Rainwater Harvesting Policies. 2008.*
- *U.S. EPA. Agricultural Reuse, Reclaimed Water Quality. Pages 22-26. Chapter 2, Subsection 2.3. 2004*
- *Metcalf & Eddy. Agronomics and Water Quality Considerations. Pages 954-971. Chapter 17 Subsection. 2007*
- *Natural Resource Management Ministerial Council et al, Environmental Risk Management. Pages 81-92. Appendix 4. 2009*
- *Carl J. Rosen, Peter M. Bierman, and Roger D. Eliason. Department of Soil, Water, and Climate, University of Minnesota. Soil Test Interpretations and Fertilizer Management for Lawns, Turfs, Gardens, and Landscape Plants. 2008*
- *Thomas F. Scherer, Bruce Seelig, David Franzen. North Dakota State University, Agricultural Extension. Soil, Water and Plant Characteristics Important to Irrigation. EB-66. February, 1996*
- *Rain Bird Sprinkler Manufacturing Corporation . Landscape Irrigation Design Manual. 2000*
- *University of Minnesota Soil Testing Laboratory - (612) 625-3101*
- *The University of Minnesota Extension Service website - www.extension.umn.edu*

TOOL Facts&Data R.3b

# Water Quality Criteria Tables

This tool contains tables for various health-based, environmental, and equipment/ operations criteria as listed below.

## Table R.3b.1

## California Water Recycling Criteria*

| Type of Use | Total Coliform Limits[a] | Treatment Required |
|---|---|---|
| Irrigation of fodder, fiber, and seed crops, orchards[b] and vineyards[b], processed food crops[c], nonfood-bearing trees, ornamental nursery stock[d], and sod farms[d]; flushing sanitary sewers | *None required* | ■ Oxidation |
| Irrigation of pasture for milking animals, landscape areas[e], ornamental nursery stock and sod farms where public access is not restricted; landscape impoundments; industrial or commercial cooling water where no mist is created; nonstructural fire fighting; industrial boiler feed; soil compaction; dust control; cleaning roads, sidewalks, and outdoor areas | ■ $\leq$23/100 ml[a]<br>■ $\leq$240/100 ml in no more than one sample in any 30-day period | ■ Oxidation<br>■ Disinfection |
| Irrigation of food crops[b]; restricted recreational impoundments; fish hatcheries | ■ $\leq$2.2/100 ml[a]<br>■ $\leq$23/100 ml in no more than one sample in any 30-day period | ■ Oxidation<br>■ Disinfection |
| Irrigation of food crops[f] and open access landscape areas[g]; toilet and urinal flushing; industrial process water; decorative fountains; commercial laundries and car washes; snow-making; structural fire fighting; industrial or commercial cooling where mist is created | ■ $\leq$2.2/100 ml[a]<br>■ $\leq$23/100 ml in no more than one sample in any 30-day period<br>■ 240/100 ml (maximum) | ■ Oxidation<br>■ Coagulation[h]<br>■ Filtration[i]<br>■ Disinfection |
| Nonrestricted recreational impoundments | ■ $\leq$2.2/100 ml[a]<br>■ $\leq$23/100 ml in no more than one sample in any 30-day period<br>■ 240/100 ml (maximum) | ■ Oxidation<br>■ Coagulation<br>■ Clarification[j]<br>■ Filtration[i]<br>■ Disinfection |
| Groundwater recharge by spreading | ■ Case-by-case evaluation | ■ Case-by-case evaluation |

* Based on treated wastewater effluent as the source supply

[a] Based on running 7-day median; daily sampling is required.

[b] No contact between reclaimed water and edible portion of crop.

[c] Food crops that undergo commercial pathogen-destruction prior to human consumption.

[d] No irrigation for at least 14 days prior to harvesting, sale, or allowing public access.

[e] Cemeteries, freeway landscaping, restricted access golf courses, and other controlled access areas.

[f] Contact between reclaimed water and edible portion of crop; includes edible root crops.

[g] Parks, playgrounds, schoolyards, residential landscaping, unrestricted access golf courses, and other uncontrolled access irrigation areas.

[h] Not required if the turbidity of influent to the filters is continuously measured, does not exceed 5 nephelometric turbidity units (NTU) for more than 15 minutes and never exceeds 10 NTU, and there is capability to automatically activate chemical addition or divert wastewater if the filter influent turbidity exceeds 5 NTU for more than 15 minutes.

[i] The turbidity after filtration through filter media cannot exceed an average of 2 NTU within any 24-hour period, 5 NTU more than 5 percent of the time within a 24-hour period, and 10 NTU at any time. The turbidity after filtration through a membrane process cannot exceed 0.2 NTU more than 5 percent of the time within any 24-hour period and 0.5 NTU at any time.

[j] Not required if reclaimed water is monitored for enteric viruses, Giardia, and Cryptosporidium.

Source: Adapted from State of California. 2000. Water Recycling Criteria. Title 22, Division 4, Chapter 3, California Code of Regulations. California Department of Health Services, Drinking Water Program, Sacramento, California.

## Table R.3b.2
## State Water Reuse Criteria for Irrigation of Parks, Playgrounds, Schoolyards, and Similar Areas[1]

| State | Water Quality Limits | Treatment Requirements |
|---|---|---|
| **Arizona** | ■ No detectable fecal coli/100 mL<br>■ 2 NTU turbidity | ■ Secondary<br>■ Filtration<br>■ Disinfection |
| **California** | ■ 2.2 total coli/100 mL<br>■ 2 NTU turbidity | ■ Secondary<br>■ Coagulation[2]<br>■ Filtration<br>■ Disinfection |
| **Colorado** | ■ 126 E. coli/100 mL<br>■ 3 NTU turbidity | ■ Secondary<br>■ Filtration<br>■ Disinfection |
| **Florida** | ■ No detectable fecal coli/100 mL<br>■ 20 mg/L BOD<br>■ 5 mg/L TSS | ■ Secondary<br>■ Filtration<br>■ Disinfection |
| **Georgia** | ■ 23 fecal coli/100 mL<br>■ pH = 6-9<br>■ 5 mg/L BOD<br>■ 5 mg/L TSS<br>■ 3 NTU turbidity | ■ Secondary<br>■ Filtration<br>■ Coagulation[3]<br>■ Disinfection |
| **Hawaii** | ■ 2.2 fecal coli/100 mL<br>■ 2 NTU turbidity | ■ Secondary<br>■ Coagulation<br>■ Filtration<br>■ Disinfection |
| **Nevada** | ■ 2.2 fecal coli/100 mL | ■ Secondary<br>■ Disinfection |
| **New Mexico** | ■ 100 fecal coli/100 mL<br>■ 30 mg/L BOD<br>■ 30 mg/L TSS | *Not specified*[4] |
| **North Carolina** | ■ 14 fecal coli/100 mL<br>■ 10 mg/L BOD<br>■ 5 mg/L TSS<br>■ 4 mg/L $NH_3$ | ■ Secondary<br>■ Filtration<br>■ Disinfection |
| **Oregon** | ■ 2.2 fecal coli/100 mL<br>■ 2 NTU turbidity | ■ Secondary<br>■ Coagulation & Clarification<br>■ Filtration<br>■ Disinfection |
| **Texas** | ■ 20 fecal coli/100 mL<br>■ 3 NTU turbidity<br>■ 5 mg/L BOD | *Not specified* |
| **Utah** | ■ No detectable fecal coli/100 mL<br>■ 2 NTU turbidity<br>■ 10 mg/L BOD | ■ Secondary<br>■ Filtration<br>■ Disinfection |
| **Washington** | ■ 2.2 total coli/100 mL<br>■ 2 NTU turbidity<br>■ 0.5 mg/L $Cl_2$ residual | ■ Secondary<br>■ Coagulation & Clarification<br>■ Filtration<br>■ Disinfection |
| **USEPA Guidelines**[5] | ■ No detectable fecal coli/100 mL<br>■ pH = 6-9<br>■ 10 mg/L BOD<br>■ 2 NTU turbidity<br>■ 1 mg/L $Cl_2$ residual | ■ Secondary<br>■ Filtration<br>■ Disinfection |

[1] Source: WateReuse Foundation, Irrigation of Parks, Playgrounds, and Schoolyards with Reclaimed, Water Extent and Safety, 2005.

[2] Not needed if filter effluent turbidity does not exceed 2 NTU, the turbidity of the influent to the filters is continually measured, the influent turbidity does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and there is capability to automatically activate chemical addition or divert the wastewater should the filter influent turbidity exceed 5 NTU for more than 15 minutes.

[3] Not needed if filter effluent turbidity requirements are met.

[4] Assumes a minimum of conventional secondary treatment and disinfection.

[5] Also applied to vehicle washing, toilet flushing, use in fire protection systems and commerical air conditioners, and other uses with similar access or exposure to the water.

## Table R.3b.3

## Examples of State Water Reuse Criteria for Selected Nonpotable Applications

| State | Fodder Crop Irrigation[1] | | Processed Food Crop Irrigation[2] | | Food Crop Irrigation[3] | | Restricted Recreational Impoundments[4] | |
|---|---|---|---|---|---|---|---|---|
| | Quality Limits | Treatment Required | Quality Limits | Treatment Required | Quality Limits | Treatment Required | Quality Limits | Treatment Required |
| **Arizona** | • 1,000 fecal coli/100 ml | • Secondary | *Not covered* | *Not covered* | • No detect. fecal coli/100 ml<br>• 2 NTU | • Secondary<br>• Filtration<br>• Disinfection | • No detect. fecal coli/100 ml<br>• 2 NTU | • Secondary<br>• Filtration<br>• Disinfection |
| **California** | *Not specified* | • Oxidation | *Not specified* | • Oxidation | • 2.2 total coli/100 ml<br>• 2 NTU | • Oxidation<br>• Coagulation[5]<br>• Filtration<br>• Disinfection | • 2.2 total coli/100 ml | • Oxidation<br>• Disinfection |
| **Colorado** | *Not covered* | *Not covered* | *Not covered* | *Not covered* | *Not covered* | *Not covered* | *Not covered* | *Not covered* |
| **Florida** | • 200 fecal coli/100 ml<br>• 20 mg/L CBOD[6]<br>• 20 mg/l TSS[7] | • Secondary<br>• Disinfection | • No detect. fecal coli/100 ml<br>• 20 mg/L CBOD<br>• 5 mg/L TSS | • Secondary<br>• Filtration<br>• Disinfection | *Use prohibited* | *Use prohibited* | • No detect. fecal coli/100 ml<br>• 20 mg/L CBOD<br>• 5 mg/L TSS | • Secondary<br>• Filtration<br>• Disinfection |
| **New Mexico (Policy)** | • 1,000 fecal coli/100 ml<br>• 75 mg/L TSS<br>• 30 mg/L BOD | *Not specified* | *Not covered* | *Not covered* | *Use Prohibited* | *Use Prohibited* | • 100 fecal coli/100 ml<br>• 30 mg/L BOD<br>• 30 mg/L TSS | *Not specified* |
| **Utah** | • 200 fecal coli/100 ml<br>• 25 mg/L BOD<br>• 25 mg/L TSS | • Secondary<br>• Disinfection | • No detect. fecal coli/100 ml<br>• 10 mg/L BOD<br>• 2 NTU | • Secondary<br>• Filtration<br>• Disinfection | • No detect. fecal coli/100 ml<br>• 10 mg/L BOD<br>• 2 NTU | • Secondary<br>• Filtration<br>• Disinfection | • 200 fecal coli/100 ml<br>• 25 mg/L BOD<br>• 25 mg/L TSS | • Secondary<br>• Disinfection |
| **Texas** | • 200 fecal coli/100 ml<br>• 20 mg/L BOD<br>• 15 mg/L CBOD | *Not specified* | • 200 fecal coli/100 ml<br>• 20 mg/L BOD<br>• 15 mg/L CBOD | *Not specified* | *Use prohibited* | *Use prohibited* | • 20 fecal coli/100 ml<br>• 3 NTU<br>• 5 mg/L BOD or CBOD | *Not specified* |
| **Washington** | • 240 total coli/100 ml | • Oxidation Disinfection | • 240 total coli/100 ml | • Oxidation<br>• Disinfection | • 2.2 total coli/100 ml<br>• 2 NTU | • Oxidation<br>• Coagulation<br>• Filtration<br>• Disinfection | • 2.2 total coli/100 ml | • Oxidation<br>• Disinfection |

[1] In some states more restrictive requirements apply where milking animals are allowed to graze on pasture irrigated with reclaimed water.

[2] Physical or chemical processing sufficient to destroy pathogenic microorganisms. Less restrictive requirements may apply where there is no direct contact between reclaimed water and the edible portion of the crop.

[3] Food crops eaten raw where there is direct contact between reclaimed water and the edible portion of the crop.

[4] Recreation is limited to fishing, boating, and other non-body contact activities.

[5] Not needed if filter effluent turbidity does not exceed 2 NTU, the turbidity of the influent to the filters is continually measured, the influent turbidity does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and there is capability to automatically activate chemical addition or divert the wastewater should the filter influent turbidity exceed 5 NTU for more than 15 minutes.

[6] CBOD – Carbonaceous biochemical oxygen demand; where BOD is the same as Total BOD

[7] TSS – total suspended solids

## Table R.3b.3

## Examples of State Water Reuse Criteria for Selected Nonpotable Applications (continued)

| State | Restricted Access Irrigation[1] | | Unrestricted Access Irrigation[2] | | Toilet Flushing[3] | | Industrial Cooling Water[4] | |
|---|---|---|---|---|---|---|---|---|
| | Quality Limits | Treatment Required | Quality Limits | Treatment Required | Quality Limits | Treatment Required | Quality Limits | Treatment Required |
| **Arizona** | • 200 fecal coli/100 ml | • Secondary<br>• Disinfection | • No detect. fecal coli/100 ml<br>• 2 NTU | • Oxidation<br>• Filtration<br>• Disinfection | • No detect. fecal coli/100 ml<br>• 2 NTU | • Oxidation<br>• Filtration<br>• Disinfection | *Not covered* | *Not covered* |
| **California** | • 23 total coli/100 ml | • Oxidation<br>• Disinfection | • 2.2 total coli/100 ml<br>• 2 NTU | • Secondary<br>• Coagulation[4]<br>• Filtration<br>• Disinfection | • 2.2 total coli/100 ml<br>• 2 NTU | • Oxidation<br>• Coagulation[4]<br>• Filtration<br>• Disinfection | • 2.2 total coli/100 ml<br>• 2 NTU | • Oxidation<br>• Coagulation[4]<br>• Filtration<br>• Disinfection |
| **Colorado** | • 126 E.coli/100 ml<br>• 30 mg/L TSS | • Secondary<br>• Disinfection | • 126 ***E.coli***/100 ml 3 NTU | • Secondary<br>• Filtration<br>• Disinfection | *Not covered* | *Not covered* | • 126 ***E.coli***/100 ml<br>• 30 mg/L TSS | • Secondary<br>• Disinfection |
| **Florida** | • 200 fecal coli/100 ml<br>• 20 mg/L CBOD[6]<br>• 20 mg/l TSS7 | • Secondary<br>• Disinfection | • No detect. fecal coli/100 ml<br>• 20 mg/L CBOD<br>• 5 mg/L TSS | • Secondary<br>• Filtration<br>• Disinfection | • No detect. fecal coli/100 ml<br>• 20 mg/L CBOD<br>• 5 mg/L TSS | • Secondary<br>• Filtration<br>• Disinfection | • No detect. fecal coli/100 ml<br>• 20 mg/L CBOD<br>• 5 mg/L TSS | • Secondary<br>• Filtration<br>• Disinfection |
| **New Mexico (Policy)** | • 200 fecal coli/100 ml<br>• 30 mg/L BOD<br>• 30 mg/L TSS | *Not specified* | If within 100 ft of dwelling:<br>• 5 fecal coli/100 ml<br>• 10 mg/L BOD<br>• 3 NTU | *Not specified* | • 100 fecal coli/100 ml<br>• 30 mg/L BOD<br>• 30 mg/L TSS | *Not specified* | *Not covered* | *Not covered* |
| **Utah** | • 200 fecal coli/100 ml<br>• 25 mg/L BOD<br>• 25 mg/L TSS | • Secondary<br>• Disinfection | • No detect. fecal coli/100 ml<br>• 10 mg/L BOD<br>• 2 NTU | • Secondary<br>• Filtration<br>• Disinfection | • No detect. fecal coli/100 ml<br>• 10 mg/L BOD<br>• 2 NTU | • Secondary<br>• Filtration<br>• Disinfection | • 200 fecal coli/100 ml<br>• 25 mg/L BOD<br>• 25 mg/TSS | • Secondary<br>• Disinfection |
| **Texas** | • 200 fecal coli/100 ml<br>• 20 mg/L BOD<br>• 15 mg/L CBOD | *Not specified* | • 20 fecal coli/100 ml<br>• 3 NTU<br>• 5 mg/L BOD or CBOD | *Not specified* | • 20 fecal coli/100 ml<br>• 3 NTU<br>• 5 mg/L BOD or CBOD | • Not specified | • 200 fecal coli/100 ml<br>• 20 mg/L BOD<br>• 15 mg/L CBOD | • Not specified |
| **Washington** | • 23 total coli/100 ml | • Oxidation<br>• Disinfection | • 2.2 total coli/100 ml<br>• 2 NTU | • Oxidation<br>• Coagulation<br>• Filtration<br>• Disinfection | • 2.2 total coli/100 ml<br>• 2 NTU | • Oxidation<br>• Coagulation<br>• Filtration<br>• Disinfection | • 2.2 total coli/100 ml<br>• 2 NTU | • Oxidation<br>• Coagulation<br>• Filtration<br>• Disinfection |

[1] Classification varies by state; generally includes irrigation of cemeteries, freeway medians, restricted access golf courses, and similar restricted access areas.

[2] Includes irrigation of parks, playgrounds, schoolyards, residential lawns, and similar unrestricted access areas.

[3] Not allowed in single-family residential dwelling units.

[4] Cooling towers where a mist is created that may reach populated areas.

[5] Not needed if filter effluent turbidity does not exceed 2 NTU, the turbidity of the influent to the filters is continually measured, the influent turbidity does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and there is capability to automatically activate chemical addition or divert the wastewater should the filter influent turbidity exceed 5 NTU for more than 15 minutes.

[6] CBOD – Carbonaceous biochemical oxygen demand; where BOD is the same as Total BOD

[7] TSS – total suspended solids

## Table R.3b.4
## Industrial Water Use Health-Based Criteria

| Type of Use | Criteria | Treatment Required |
|---|---|---|
| **California[1]** | | |
| • Cooling water where no mist created<br>• Process water where no worker contact<br>• Boiler feed | • ≤ 23 total coli/100 ml | • Secondary<br>• Disinfection |
| • Cooling water where mist created[2]<br>• Process water where worker contact likely | • ≤ 2.2 total coli/100 ml | • Secondary<br>• Coagulation[3]<br>• Filtration<br>• Disinfection |
| **Florida[4]** | | |
| • Wash water[5]<br>• Process water[5] | • ≤ 200 fecal coli/100 ml<br>• ≤ 30 mg/L BOD<br>• ≤ 30 mg/L TSS | • Secondary<br>• Disinfection |
| • Once through cooling in closed system | • ≤ 30 mg/L BOD<br>• ≤ 30 mg/L TSS | • Secondary |
| • Once through cooling where mist created (alternative requirements acceptable if certain conditions met) | • No detectable fecal coli/100 ml<br>• ≤ 20 mg/L BOD<br>• ≤ 5 mg/L TSS | • Secondary<br>• Filtration<br>• Disinfection[6] |

[1] California Code of Regulations, Water Recycling Criteria, 2000.

[2] Drift eliminator required; chlorine or other biocide required to treat cooling water to control *Legionella* and other microorganisms.

[3] Not required under certain conditions.

[4] Florida Department of Environmental Protection, Reuse of Reclaimed Water and Land Application, 1999.

[5] Manufacture or processing of food or beverage where the water will be incorporated into or come in contact with the product is prohibited.

[6] Reclaimed water must be sampled at least once every two years for *Giardia* and *Cryptosporidium*.

## Table R.3b.5 Recommended Limits for Constituents in Irrigation Water Supplies[1]

| Constituent | Long-Term Use (mg/l) | Short-Term Use (mg/l) | Considerations |
|---|---|---|---|
| **Aluminum** | 5 | 20 | Can cause nonproductiveness in acid soils, but soils at pH 5.5 to 8.0 will precipitate the ion and eliminate toxicity. |
| **Arsenic** | 0.1 | 2 | Toxicity to plants varies widely, ranging from 12 mg/L for Sudan grass to less than 0.05 mg/L for rice. |
| **Beryllium** | 0.1 | 0.5 | Toxicity to plants varies widely, ranging from 5 mg/L for kale to 0.5 mg/L for bush beans. |
| **Boron** | 0.75 | 2 | Essential to plant growth, with optimum yields for many obtained at a few-tenths mg/L in nutrient solutions. Boron can be toxic to some plants at low concentrations. |
| **Cadmium** | 0.01 | 0.05 | Toxic to beans, beets, and turnips at concentrations as low as 0.1 mg/L. Conservative limits recommended. |
| **Chromium** | 0.1 | 1 | Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on toxicity to plants. |
| **Cobalt** | 0.05 | 5 | Toxic to tomato plants at 0.1 mg/L. Tends to be inactivated by neutral and alkaline soils. |
| **Copper** | 0.2 | 5 | Toxic to a number of plants at 0.1 to 1.0 mg/L. |
| **Fluoride** | 1 | 15 | Inactivated by neutral and alkaline soils. |
| **Iron** | 5 | 20 | Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of essential phosphorus and molybdenum. |
| **Lead** | 5 | 10 | Can inhibit plant cell growth at very high concentrations. |
| **Lithium** | 2.5 | 2.5 | Tolerated by most crops at concentrations up to 5 mg/L; mobile in soil. Toxic to citrus at low concentrations - recommended limit is 0.075 mg/L. |
| **Manganese** | 0.2 | 10 | Toxic to a number of crops at a few-tenths to a few mg/L in acidic soils. |
| **Molybdenum** | 0.01 | 0.05 | Nontoxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high levels of available molybdenum. |
| **Nickel** | 0.2 | 2 | Toxic to a number of plants at 0.5 to 1.0 mg/L; reduced toxicity at neutral or alkaline pH. |
| **Selenium** | 0.02 | 0.02 | Toxic to plants at low concentrations and to livestock if forage is grown in soils with low levels of selenium. |
| **Tin, Tungsten, & Titanium** | - | - | Effectively excluded by plants; specific tolerance levels unknown |
| **Vanadium** | 0.1 | 1 | Toxic to many plants at relatively low concentrations. |
| **Zinc** | 2 | 10 | Toxic to many plants at widely varying concentrations; reduced toxicity at increased pH (6 or above) and in fine-textured or organic soils. |
| **pH** | 6 | - | Most effects of pH on plant growth are indirect (e.g., pH effects on heavy metals' toxicity described above). |
| **Total Dissolved Solids (TDS)** | 500 - 2,000 mg/l | - | Below 500 mg/L, no detrimental effects are usually noticed. Between 500 and 1,000 mg/L, can affect sensitive plants. At 1,000 to 2,000 mg/L, can affect many crops and careful management practices should be followed. Above 2,000 mg/L, water can be used regularly only for tolerant plants on permeable soils. |
| **Free Chlorine** | <1 mg/l | - | Concentrations greater than 5 mg/l causes severe damage to most plants. Some sensitive plants may be damaged at levels as low as 0.05 mg/l. |

[1] U.S. EPA, Guidelines for Water Reuse, 2004

## Table R.3b.6

## Typical Parameters and Limits of Concern Related to System Equipment Performance

| Parameter | Limit of Concern | Issue |
|---|---|---|
| **Debris and organic/soil particulates** | *Not applicable* | Blocks or clogs equipment |
| **Organic matter (measured as BOD, COD, TOC)** | BOD>30 mg/L | Reduced dissolved oxygen levels through decomposition; results in odors and release of pollutants from sediments |
| **Nitrogen and phosphorus** | TP > 0.2 mg/L<br>TKN varies with use | Supports algal growth in open storage facilities, which can lead to higher turbidity and/or create algal blooms with biofilm characteristics that can clog irrigation equipment |
| **Iron** | > 1.0 mg/L | Clogging of system, particularly irrigation equipment |
| **Hardness** | > 600 mg/L as CaCO3 | Clogging of system, particularly irrigation equipment |
| **Salts** | Chlorides > 500 mg/L<br>TDS > 500 mg/L | Causes corrosion of most metals |
| **Hydrogen sulfide** | > 10 mg/L | Gas released in anaerobic conditions that can corrode metal and concrete surfaces |

Sources: USEPA, Guidelines for Water Reuse, 2004

Metcalf & Eddy, Water Reuse, Issues, Technologies, and Applications , 2007

## Table R.3b.7
## Recommended Cooling Water Quality (Makeup for Recirculating Systems)

| Parameter | Recommended Limit (mg/L) |
|---|---|
| Alkalinity | 350 |
| Aluminum | 0.1 |
| Ammonia | 24 |
| Bicarbonate | 200 |
| Calcium | 50 |
| Chloride | 500 |
| Hardness | 650 |
| Iron | 0.5 |
| Manganese | 0.5 |
| Phosphorus | 1.0 |
| Silica | 50 |
| Total Suspended Solids | 100 |
| Sulfate | 200 |
| Total Dissolved Solids | 500 |

Sources: SEH, Inc. Adapted from Water Pollution Control Federation, Water Reuse (Second Edition) Manual of Practice SM-3, 1989.

SEH, Inc. Adapted from Goldstein, D.J., I. Wei, and R.E. Hicks, Reuse of Municipal Wastewater as Make-Up to Circulating Cooling Systems. In: Proceedings of the Water Reuse Symposium, Vol. 1, Published by the AWWA Research Foundation, Denver, Colorado. March 25-30, 1979.

## Table R.3b.8
## Recommended Industrial Boiler Feed Water Quality

| Parameter | Recommended Limit (mg/L) | | |
|---|---|---|---|
| | Low Pressure (<150 psig) | Medium Pressure (150-700 psig) | High Pressure (>700 psig) |
| Alkalinity | 350 | 100 | 40 |
| Aluminum | 5 | 0.1 | 0.01 |
| Ammonia | 0.1 | 0.1 | 0.1 |
| Bicarbonate | 170 | 120 | 48 |
| Calcium | * | 0.4 | 0.01 |
| Chemical Oxygen Demand | 5 | 5 | 1 |
| Copper | 0.5 | 0.05 | 0.05 |
| Dissolved Oxygen | 2.5 | 0.007 | 0.007 |
| Hardness | 350 | 1.0 | 0.07 |
| Iron | 1.0 | 0.3 | 0.05 |
| Magnesium | * | 0.25 | 0.01 |
| Manganese | 0.3 | 0.1 | 0.01 |
| Silica | 30 | 10 | 0.7 |
| Suspended Solids | 10 | 5 | 0.5 |
| TDS | 700 | 500 | 200 |
| Zinc | * | 0.01 | 0.01 |

Sources: SEH, Inc. Adapted from U.S. Environmental Protection Agency, Guidelines for Water Reuse. EPA/625/R-04/108, 2004.

Metcalf & Eddy, *Water Reuse, Issues, Technologies, and Applications*, 2007.

# Use Criteria Matrix

Identify the health and environmental/system criteria based on the type of water use.

## Table R.3c.1 Use Criteria Matrix

| Use/Application | Health Criteria* | Environmental / System Criteria |
|---|---|---|
| **Residential/Commercial/Public Property Areas** | | |
| Landscape irrigation (cemeteries, freeway buffers, restricted golf courses and other controlled access areas)<br><br>Utility washing (paths, fences, outdoor equipment/ areas) | Level 2 | Salts, metals, nutrients, hardness<br><br>*Refer to* **Table R.3b.5** *&* **Table R.3b.6** |
| Open access landscape irrigation (parks, athletic fields, unrestricted golf courses)<br><br>Food garden watering<br><br>Water features and systems (ponds, fountains, waterfalls)<br><br>Within buildings (toilet flushing)<br><br>Vehicle washing | Level 3 | Salts, metals, nutrients, organic toxics, hardness<br><br>*Refer to* **Table R.3b.5** *&* **Table R.3b.6** |
| **Municipal Uses** | | |
| Street cleaning<br><br>Roadmaking and dust control<br><br>Equipment and structure washing<br><br>Fire protection | Level 2 | Salts, metals<br><br>*Refer to* **Table R.3b.6** |
| Sanitary sewer flushing | Level 1 | --- |
| **Commercial Uses** | | |
| Nurseries, sod farms, tree farms<br><br>Pasture | Level 1 & 2 | Crop dependent<br><br>*Refer to* **Table R.3b.5** |
| Orchards, vegetables/fruit | Level 2 & 3 | Crop dependent<br><br>*Refer to* **Table R.3b.5** |
| **Industrial Uses** | | |
| Cooling water<br><br>Process water<br><br>Washdown water | Level 2 & 3 | Industry specific requirements<br><br>*Refer to* **Table R.3b.6**, **Table R.3b.7** & **R.3b.8** |

*Definitions on following table, Table R.3c.2

## Table R.3c.2 Use Criteria Matrix Health Criteria Definitions

| Health Criteria Definitions (Based on California Title 22, State of California, 2000) | Total Coliform Limit (No./100ml) | Sampling Basis[1] | Treatment Process Requirements [2] |
|---|---|---|---|
| **Level 1** | | | |
| ■ Provides a supply for use with limited human exposure<br>■ The supply is from a protected source and storage system where there is limited exposure to pathogens or conditions for biological growth | *None required* | *None required* | ■ Screening[3] |
| **Level 2** | | | |
| ■ Provides a supply that meets the California Recycling Criteria (State of California, 2000) for a secondary-23[5] recycled water | <23 | Running 7-day median | ■ Screening[3]<br>■ Disinfection |
| ■ Provides a supply for use with controlled access and limited human contact | <240 | Maximum in 30 days | |
| **Level 3** | | | |
| ■ Provides a supply that meets the California Recycling Criteria (State of California, 2000) for a tertiary recycled water | <2.2 | Running 7-day median | ■ Screening[3]<br>■ Chemical Addition[4]<br>■ Filtration<br>■ Disinfection |
| ■ Provides a supply for use with uncontrolled access and potential for human contact | <23 | Maximum in 30 days | |

[1] Daily sampling during period of use (State of California, Water Recycling Criteria, 2000).

[2] Assumes water does not contain oxygen demanding constituent; otherwise may need to remove constituent through oxidation or other process.

[3] Assumes use of a first-flush diverter and other pretreatment processes to minimize pollutants from initial part of storm events.

[4] Chemical addition, coagulation, and clarification may be required for some applications and water quality characteristics.

[5] Defined in California Rule 60301.225 as recycled water that meets 23/100 ml coliform limit.

Reference: State of California. Water Recycling Criteria, 2000

# Treatment Considerations

## Overview
Stormwater reuse systems will often have some level of treatment to meet public health standards and other criteria established to protect the environment, the system equipment, and structures. This tool provides general considerations for treatment of stormwater for beneficial uses and links to other tools that provide more detail regarding stormwater treatment.

## Treatment Goals
The goals of a treatment system for a stormwater reuse system can include:

- *Remove coarse materials through screening to prevent clogging of equipment.*
- *Reduce sediment and particulate material to prevent clogging of the distribution system.*
- *Prevent soluble constituents from causing problems, such as:*
  - Forming precipitants that clog the distribution system.
  - Providing a food source for microorganisms that grow as a biofilm, thereby clogging the system.
  - Toxicity to soils and plants in irrigation systems.
  - Toxicity to aquatic plants and animals.
  - Corrosion of reuse system equipment or end use facilities.
- *Remove organic matter and nutrients from storage systems to avoid odors and pollutant release from sediments in anaerobic conditions; and to avoid algal blooms that can clog equipment.*
- *Destroy pathogens that can affect human health.*

## Factors to Consider
The following factors should be considered when determining the level of treatment for a stormwater reuse system:

- *The quality of the* ***SOURCE*** *water – refer to* ***Tool A. 1-Source Water Quality*** *and resource* ***Tool R.1a*** *&* ***Tool R.1b*** *for supplemental information*
- *The quality required for the intended* ***USE****(s) – refer to* ***Tool A.5-Use Criteria*** *and resource* ***Tool R.3a****,* ***Tool R.3b*** *and* ***Tool R.3c*** *for supplemental information*
- *The ability to integrate the system with current on-site practices/conditions (if applicable)*
- *Regulatory requirements anticipated in the future*
- *Environmental issues*
- *Type of storage system to be used*
- *Distribution methods*
- *Operation and maintenance requirements*

## Related Tools and Links
**Tool R.4-Treatment** describes the different processes and treatment process combinations for a stormwater reuse system.

**Tool I.3-Treatment** provides the implementation steps to follow for selecting treatment components of a stormwater reuse system.

# Treatment

## Overview

This tool presents the different types of processes to treat stormwater for various uses. There are numerous combinations of processes that could be used given the range of pollutants in stormwater and the different end uses of the water. **Tool I.3 –Treatment** refers to this tool as part of the implementation phase of a stormwater reuse project. Other tools related to this one include: **Tool R.1a-Stormwater Quality Characteristics**, **Tool R.3a-Use Water Quality Characteristics**, and **Tool R.3d-Treatment Considerations**.

Given the site-specific water quality characteristics of water from a SOURCE, the quality required for different USEs, and the lack of regulations for stormwater reuse systems, there are no standardized treatment process systems for stormwater reuse. Treatment process requirements for reclaimed water can be categorized by the target parameter (adapted from Metcalf & Eddy, 2007):

- *Debris removal (trash and organic materials such as leaves)*
- *Enhanced suspended and dissolved solids removal (chemical addition/softening)*
- *Suspended solids removal (filtration)*
- *Colloidal solids removal (membrane filtration)*
- *Dissolved solids removal (demineralization/softening)*
- *Residual and specific trace constituent removal (multiple processes)*
- *Disinfection (microorganism removal/inactivation)*

The relationship of various treatment technologies available to achieve a desired reclaimed water quality is depicted in Figure R.4a (following page). The schematic shows how different treatment processes are sequenced for optimal constituent removal. The different treatment processes and key considerations are provided in Table R.4a. Residual and specific trace constituent removal processes are specialized treatments that are not likely to be used for stormwater. Manufacturers should be consulted for specific design, construction, and operation information.

Additional research is recommended for systems that are intended to operate through the winter. Treatment efficiencies may be reduced during periods when the influent water is below a specific threshold temperature. Additional heating or locating inside a building may be required to maintain the desired treatment.

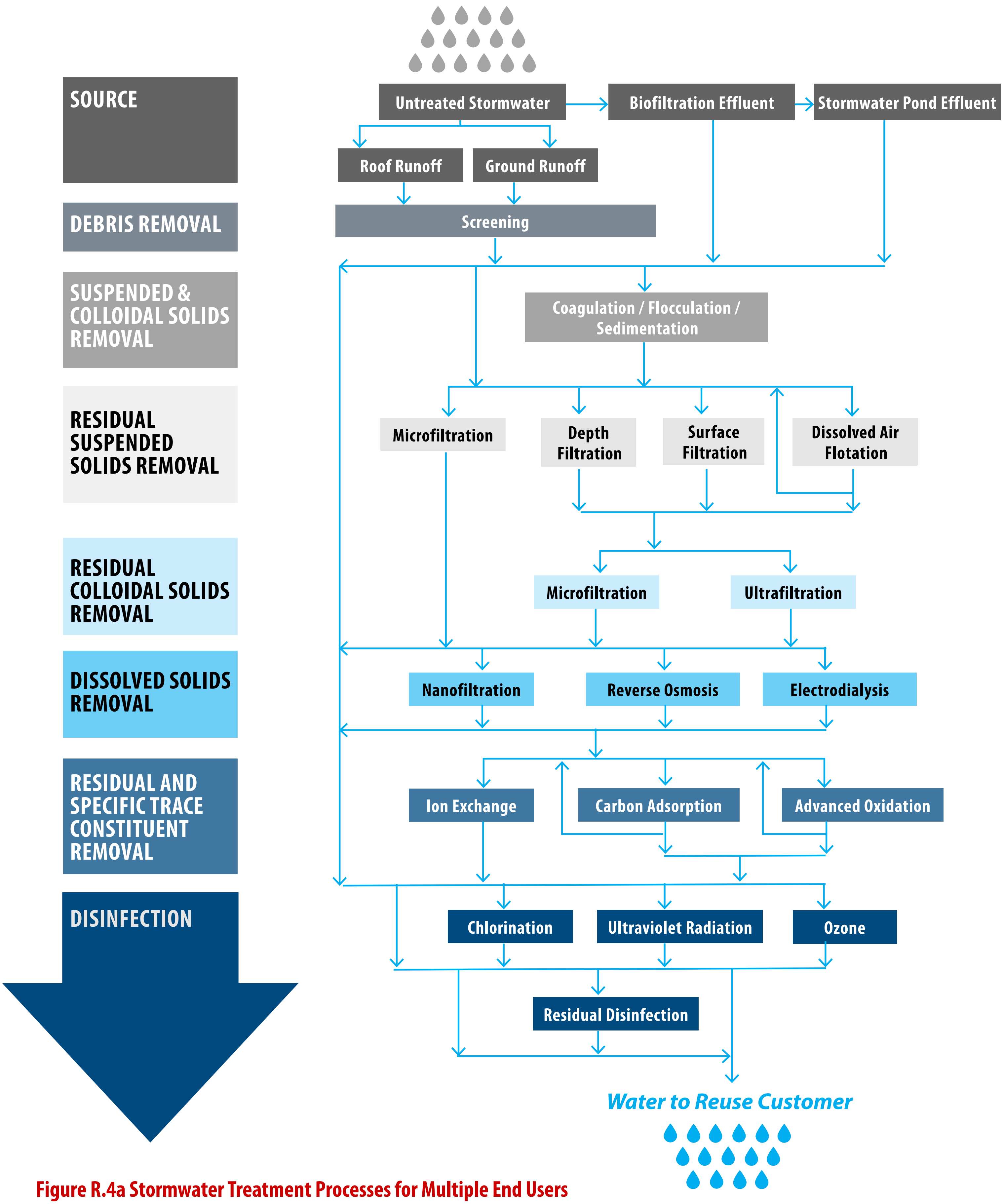



**Figure R.4a Stormwater Treatment Processes for Multiple End Users**

Source: Metcalf & Eddy, Water Reuse, Issues, Technologies, and Applications , 2007

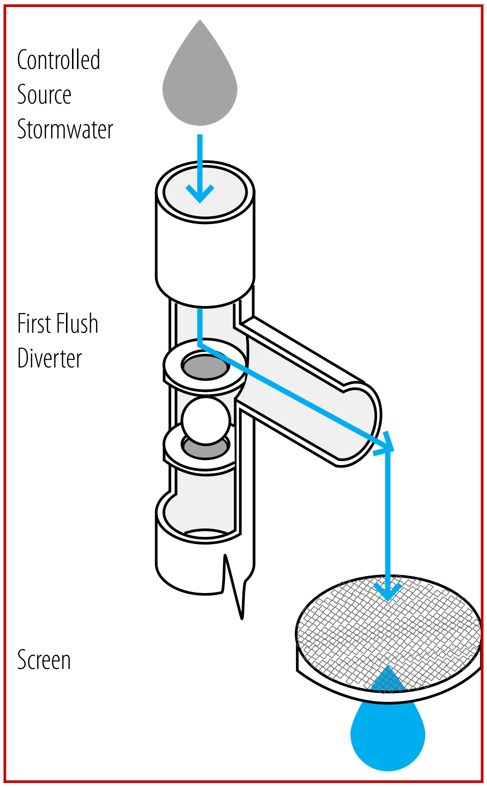



Figure R.4b Basic Treatment for Controlled Sources and Restricted Areas

Source: HKGi

Figure R.4b presents a system that requires the least amount of treatment. The SOURCE of the stormwater is from a controlled drainage area known to contain low levels of pollutants, and the water USE is for areas with limited human exposure. One example SOURCE is a rooftop free of animal feces, leaves, and materials that could degrade and release metals and hydrocarbons. This water could be stored in a rain barrel and then distributed on private property with drip irrigation. A first flush diverter would remove any particulates or debris, and then a screen would keep finer particulates from clogging the system and allowing organic matter and materials from settling in the barrel.

A common application for larger scale uses is the use of a stormwater pond to irrigate an adjacent athletic field. In Figure R.4c the USE requires treating to the Level 3 total coliform limit of 2.2/100 ml. Assuming the pond is designed so it does not ever go anaerobic, the treatment required is filtration followed by disinfection. Disinfection could be with sodium hypochlorite (with a required 90-minute contact time) or alternatively could be with ultraviolet radiation equipment designed in accordance with California Title 22.

More advanced treatment would be required if the stormwater in Figure R.4c is high in salts. As shown in Figure R.4d, to remove salts, a reverse osmosis system preceded by a microfiltration process is required. The reverse osmosis system also provides for pathogen removal and additional disinfection is only required to provide a chlorine residual for the distribution system.

## Resources (Sources and Links)


- *U.S. EPA, Ozone Disinfection Fact Sheet, 1999*
- *Metcalf and Eddy, Wastewater Engineering, Treatment, Disposal and Reuse, 2007*

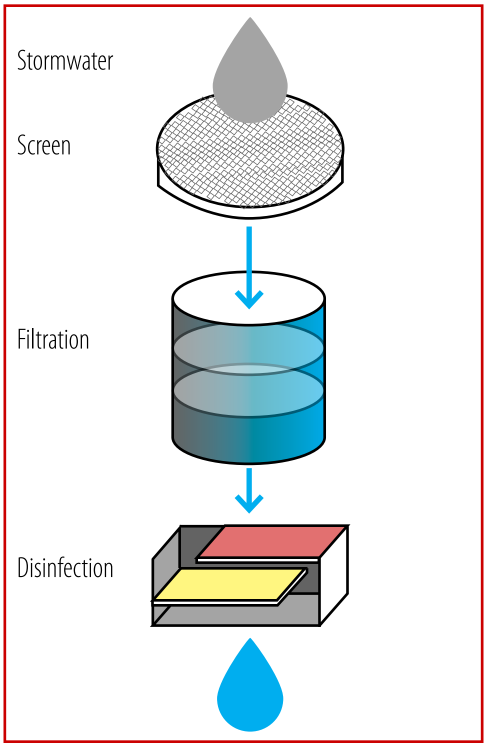




Figure R.4c Basic Treatment for Unrestricted Access Irrigation

Source: HKGi

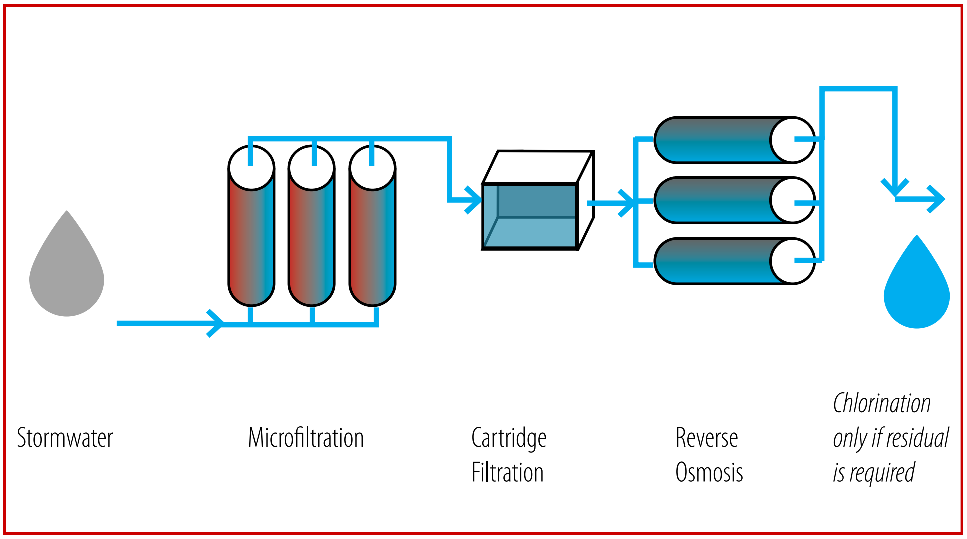



Figure R.4d Treatment Train for Unrestricted Uses Requiring Salt Removal

Source: HKGi

## Table R.4a Key Considerations for Treatment Processes

| Treatment | Used to Remove | What it Does | Design Considerations | O&M Considerations | Alternatives | Advantages over Alternatives | Disadvantages over Alternatives |
|---|---|---|---|---|---|---|---|
| **Suspended & Colloidal Solids Removal** | | | | | | | |
| **Coagulation**<br>**Flocculation**<br>**Sedimentation** | ■ high dissolved salt concentrations<br>■ suspended solids<br>■ phosphorus | ■ large basin allows particles to settle by gravity<br>■ chemicals may be added to cause particles of interest to precipitate and settle | ■ if stormwater basin is used, then add filters at basin exit to ensure settled particles do not leave | ■ allow for regular basin washing/ cleaning to eliminate sediments | ■ microfiltration with membrane softening<br>■ ion exchange unit | ■ lower overall O&M costs<br>■ stormwater basin serves dual purpose – water quantity and quality | ■ microfiltration may reduce disinfection requirements |
| **Residual Suspended Solids Removal** | | | | | | | |
| **Depth / Surface Filtration** | ■ suspended solids | ■ water is passed through filter media, thereby removing particulates<br>■ aids in the disinfection process | ■ add additional filters at basin exit | ■ inspect filters based on manufacturer's recommendations | ■ microfiltration | ■ lower overall O&M costs | ■ microfiltration may reduce disinfection requirements |
| **Dissolved Air Flotation** | ■ oil and grease<br>■ algae from pond water<br>■ low density floc particles | ■ microbubbles are formed by dissolving air under pressure<br>■ bubbles surround slow-settling particles and float them to the surface | ■ a mechanical skimming system will need to be designed to remove particles from the surface<br>■ discuss other design considerations with manufacturer | ■ discuss with manufacturer | ■ coagulation / flocculation / sedimentation<br>■ filtration | ■ removes more particulates than sedimentation and filtration<br>■ smaller footprint required | ■ higher energy costs |
| **Residual Colloidal Solids Removal** | | | | | | | |
| **Microfiltration**<br>**Ultrafiltration** | ■ suspended solids<br>■ microorganisms | ■ water passes over a membrane in lieu of a mesh filter | ■ may still require a level of pretreatment to prevent fouling<br>■ discuss other design considerations with commercial supplier | ■ will require membrane replacement (approximately every 5 years)<br>■ residual disposal | ■ sedimentation basins<br>■ depth / surface filters | ■ captures microorganisms in addition to suspended solids, smaller footprint required, may reduce disinfection requirements | ■ higher capital costs<br>■ higher O&M costs – including membrane replacement, energy, performance monitoring, residuals handling and disposal |

## Table R.4a Key Considerations for Treatment Processes (continued)

| Treatment | Used to Remove | What it Does | Design Considerations | O&M Considerations | Alternatives | Advantages over Alternatives | Disadvantages over Alternatives |
|---|---|---|---|---|---|---|---|
| **Dissolved Solids Removal** | | | | | | | |
| **Nanofiltration** | ■ dissolved salts<br>■ bacteria<br>■ viruses<br>■ proteins | ■ force stormwater under hydrostatic pressure through a semipermeable membrane | ■ requires a large amount of pretreatment to remove metals that can cause scaling and particulates that can cause biofouling<br>■ must include feature to dispose of particulates collected by membranes | ■ must check for scaling, biofouling | ■ reverse osmosis<br>■ electrodialysis | ■ removes more particulates than electrodialysis<br>■ requires less energy than both alternatives<br>■ produces a smaller waste stream than electrodialysis | ■ removes less particulates than reverse osmosis<br>■ removes less multivalent ions than electrodialysis<br>■ produces a larger waste stream than reverse osmosis. |
| **Reverse Osmosis** | ■ dissolved salts<br>■ TDS<br>■ nitrate<br>■ sulfates<br>■ nitrate<br>■ other ions<br>■ bacteria<br>■ viruses | ■ force stormwater under hydrostatic pressure through a semipermeable membrane | ■ requires a large amount of pretreatment to remove metals that can cause scaling and particulates that can cause biofouling (cartridge and pressure-driven filters are typically installed ahead of reverse osmosis membranes)<br>■ must include feature to dispose of particulates collected by membranes | ■ must check for scaling, biofouling | ■ nanofiltration<br>■ electrodialysis | ■ highest removal efficiency<br>■ most complete removal of multivalent ions<br>■ produces the smallest waste stream<br>■ commercially available | ■ requires more energy than nanofiltration |
| **Electrodialysis** | ■ charged ionic solutes including dissolved salts | ■ ions are removed from solution by passing stormwater through an ion-exchange membrane | ■ cartridge filters are generally required before the electrodialysis membrane<br>■ must design for waste stream disposal | ■ maintain supply of sulfuric acid, used to maintain low pH to minimize scaling | ■ nanofiltration<br>■ reverse osmosis | ■ requires the least amount of pretreatment<br>■ removes more multivalent ions than nanofiltration | ■ produces the largest waste stream<br>■ requires more energy than nanofiltration<br>■ removes the least amount of particulates between the three alternatives<br>■ make-up water is required to continuously wash membranes |

## Table R.4a Key Considerations for Treatment Processes (continued)

| Treatment | Used to Remove | What it Does | Design Considerations | O&M Considerations | Alternatives | Advantages over Alternatives | Disadvantages over Alternatives |
|---|---|---|---|---|---|---|---|
| **Disinfection** | | | | | | | |
| **Chlorination** | ■ pathogens | ■ injects chlorine into the stormwater, thereby killing bacteria | ■ design for an appropriate contact time--contact time increases with pH and decreases with temperature<br>■ determine type (sodium hypochlorite, calcium hypochlorite, etc) and quantity of chlorine required | ■ calibration of dosage control devices | ■ UV<br>■ ozone | ■ most common disinfection technology<br>■ least cost | ■ does not kill cysts<br>■ combines with decaying organic matter to form trihalomethanes, a possible carcinogenic byproduct |
| **Ultraviolet Radiation** | ■ pathogens | ■ stormwater is passed over an ultraviolet lamp | ■ requires cartridge filters ahead of the UV light | ■ routine cleaning of the cartridge filters<br>■ UV lamps must be periodically replaced | ■ chlorination<br>■ ozone | ■ no byproducts<br>■ minimal energy requirements | ■ unfiltered stormwater will cause shadows to be cast by particulates, allowing pathogens to pass |
| **Ozone** | ■ dissolved organic matter<br>■ pathogens | ■ diffused ozone is released through fine bubble diffuser located at bottom of tank | ■ ozone contact chamber must be deep to provide mixing and maximum ozone transfer<br>■ requires treatment of off-gases<br>■ corrosion protection required | ■ requires monitoring of influent to adjust dosage to accommodate changes in flow and concentration<br>■ routine checks for leaks | ■ chlorination<br>■ ultraviolet radiation | ■ more effective than chlorination for destroying bacteria and viruses | ■ treatment of off-gases required<br>■ more energy required |

# Construction Cost Development

This tool lists the components that must be included when developing cost estimates for a stormwater reuse project. It is set up as a checklist for the user to follow. Note that each project is unique. Other items may be needed that are not categorized here, while others can be scaled back for a preliminary estimate. Not all of these items may be required for each reuse project, while other items may already exist at the site.

This list does not include the items that are common to many construction projects, including mobilization, demolition, erosion and sediment control, traffic control, and construction management.

Treatment systems and pumping systems are described as fully contained units. Project owners and designers should contact manufacturers directly for component, sizing, layout and cost recommendations.

## Table R.5a Construction Cost Units

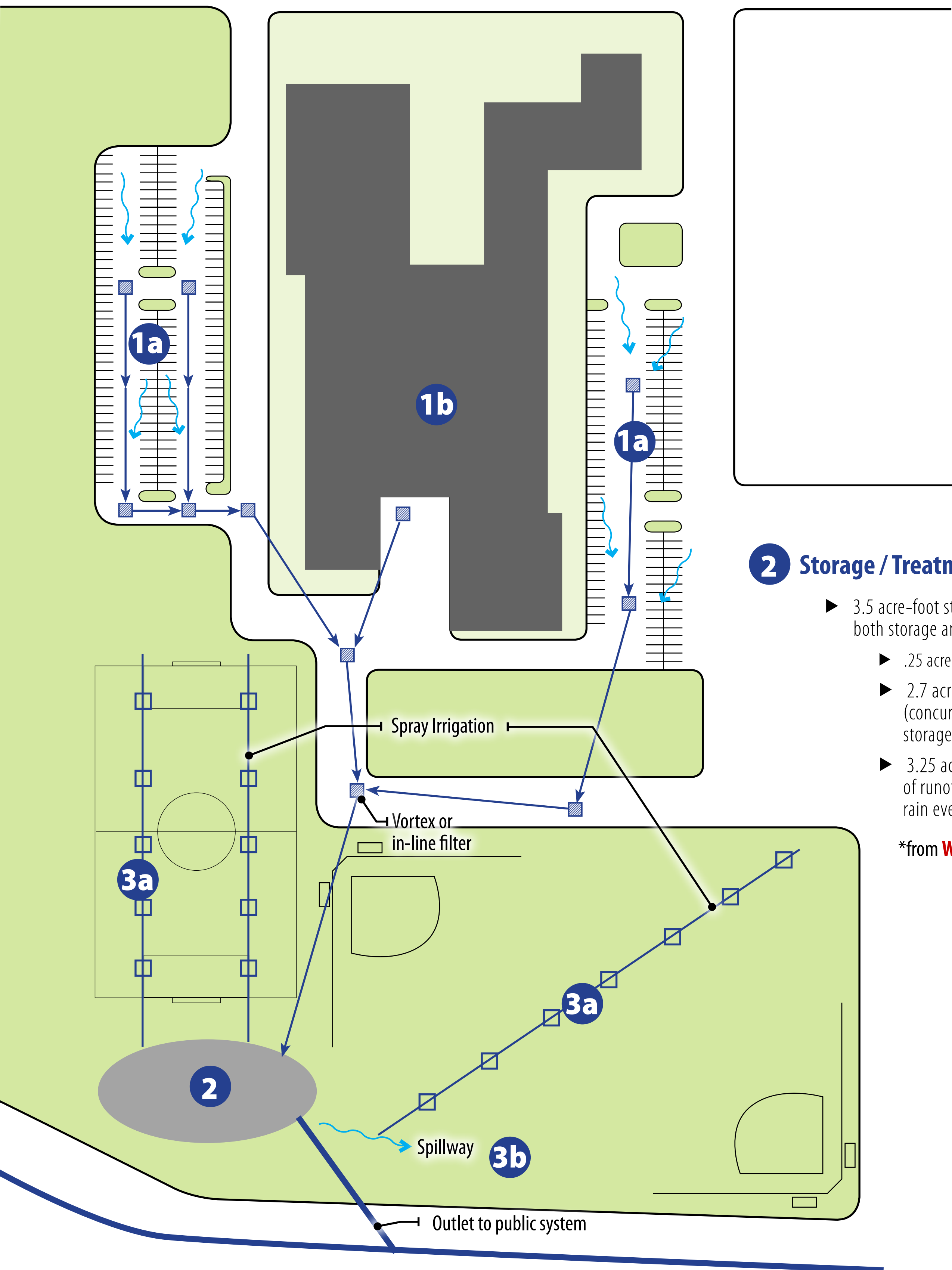
| Construction Activity | Unit |
|---|---|
| **Collection** | |
| Cleaning of roof (if retrofit project) | Square foot |
| Roof washing system | Each |
| Gutters | Linear foot |
| Gutter Screens | Linear foot |
| Downspouts | Linear foot |
| Scuppers | Each |
| Catch basins | Each |
| Catch basin filters | Each |
| Manholes | Each |
| Oil / water separators | Each |
| Storm sewers | Linear foot |
| Bypass valves | Each |
| First flush diverter | Each |

## Table R.5a Construction Cost Units (continued)

| Construction Activity | Unit |
|---|---|
| **Storage** | |
| **Ponds and basins** | |
| Site demolition | Varies |
| Excavation | Cubic foot |
| Disposal of excess soil | Cubic foot |
| Vegetation restoration | Square foot |
| Baffles at outlet | Linear foot |
| Filters at outlet | Each |
| Outlet structure | Each |
| Pumping system including pump, motor, valves, and pressure tank (for non-gravity and pressurized systems) | Varies |
| Aeration | Varies |
| Electrical supply (for pumps or aeration) | Varies |
| **Below-ground storage** | |
| Site demolition | Varies |
| Excavation and backfill | Cubic foot |
| Imported aggregate bedding material | Cubic foot |
| Disposal of excess soil | Cubic foot |
| Vegetation or pavement restoration | Square foot |
| Pre-fabricated tanks | Each |
| Baffles, calming inlet, and/or filters, if not supplied with pre-fabricated tank | Each |
| Cast-in-place concrete tank | Varies |
| Pumping system including pump, motor, valves, and pressure tank (for non-gravity and pressurized systems) | Varies |
| Maintenance access manhole | Each |
| Electrical supply (for pumps) | Varies |
| **Above-ground storage** | |
| Site demolition | Varies |
| Foundation – aggregate | Cubic foot |
| Foundation – concrete | Square yard |
| Pre-fabricated tanks with cover | Each |
| Baffles, calming inlet, and/or filters, if not supplied with pre-fabricated tank | Each |
| Cover, if not supplied with pre-fabricated tank | Each |
| Cast-in-place concrete tank | Varies |
| Pumping system including pump, motor, valves, and pressure tank (for non-gravity and pressurized systems) | Varies |
| Electrical supply (for pumps) | Varies |

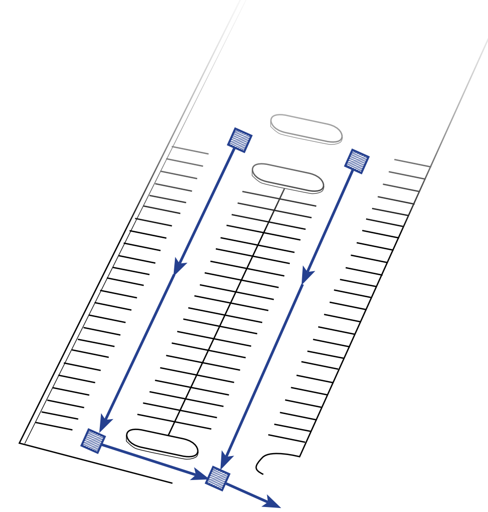
## Table R.5a Construction Cost Units (continued)

| Construction Activity | Unit |
|---|---|
| **Treatment** | |
| **All Treatment Systems** | |
| Piping | Linear foot |
| Valves | Each |
| Flow meter (when needed to regulate chemical feed) | Each |
| Electrical supply | Varies |
| Maintenance access manhole (if located underground) | Each |
| Backflow prevention valves (if connected to potable water for supplemental supply and/or for filter backwash) | Each |
| **Suspended & Colloidal Solids Removal Systems** | |
| Chemical feed | Varies |
| Tank with baffles or mixing device (if chemicals not fed into inline mixing device) | Varies |
| Settling basin with dewatering valves for solids removal | Varies |
| **Residual Suspended Solids Removal Systems** | |
| Filter chamber containing activated carbon or other filter media, including piping and valves for bypass and backwash (for filtration systems) | Varies |
| Tank with micro-bubble diffusion, dewatering valves, and surface skimmer (for dissolved air flotation systems) | Varies |
| **Residual Colloidal Solids Removal Systems** | |
| Filter chamber containing multi-media, including piping and valves for bypass and backwash (for ultrafiltration systems) | Varies |
| **Dissolved Solids Removal Systems** | |
| pH feed (for reverse osmosis systems) | Varies |
| Chemical feed (for electrodialysis systems) | Varies |
| Filter chamber containing semi-permeable membrane, including piping and valves for bypass and backwash (for all systems) | Varies |
| Solids disposal system | Varies |
| **Disinfection** | |
| Chemical feed (for continuous chlorine disinfection) | Varies |
| Tank with baffles or mixing device (for batch disinfection with chlorine) | Varies |
| Contact tank with UV lights and piping (for ultraviolet disinfection) | Varies |
| Tank with piping, valves, ozone diffuser (for ozone disinfection) | Varies |
| Off-gas ozone destructor tank (for ozone disinfection) | Varies |
| **Distribution** | |
| Pumping system including pump, motor, valves, and pressure tank | Varies |
| Piping for distribution | Linear foot |
| Valves for pressure control, and regulating flow | Each |
| Valve boxes | Each |
| Sprinkler nozzles – impulse, spray, rotating, bubbler, or drip | Each |
| Irrigation controllers with wiring to each sprinkler (for automated control systems) | Varies |
| Drain plug (for winterization) | Each |




## System Features

- Stormwater pond acts as sedimentation basin
- Fine filtration of pond effluent to prevent clogging and fouling of irrigation equipment
- Drip chlorination for disinfection



## 1a Collection - Ground Surface

- Total - 122,800 sf asphalt parking lots
- Storm sewer network collects runoff through series of catch basins and pipes
- Diverts stormwater to existing detention pond
- Weekly sweeping of parking lot to collect large debris and extend period between sediment removal from stormwater pond

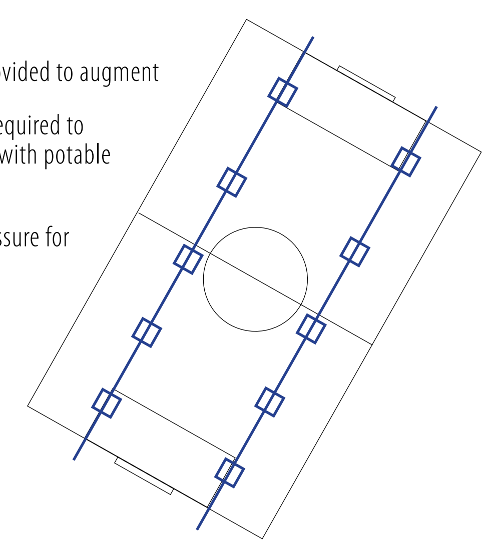
## 2 Storage / Treatment

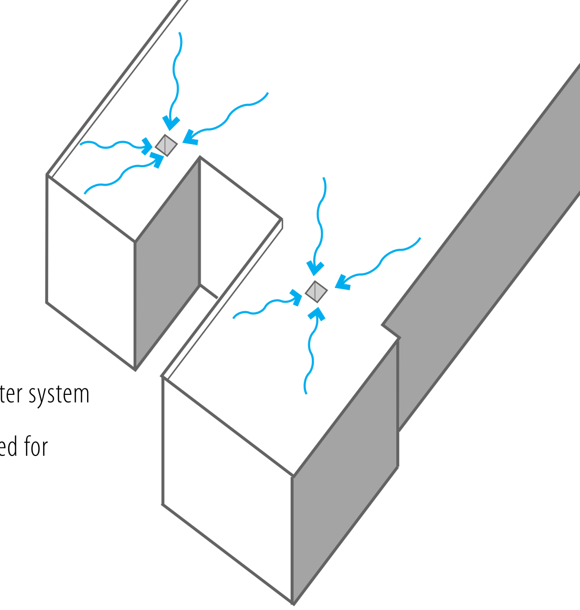
- 3.5 acre-foot stormwater pond provides both storage and treatment
  - .25 acre-foot for permanent pool
  - 2.7 acre-foot reuse volume (concurrent with total retention storage)*
  - 3.25 acre-foot detention for storage of runoff from 100-year, 24-hour rain event

*from **Water Balance Tool**

## 3a Distribution

- Spray irrigation
- Potable water connection provided to augment
- Backflow prevention valves required to prevent cross contamination with potable water supply
- Pump provides adequate pressure for irrigation
- Night irrigation to minimize human contact with chlorinated irrigation water



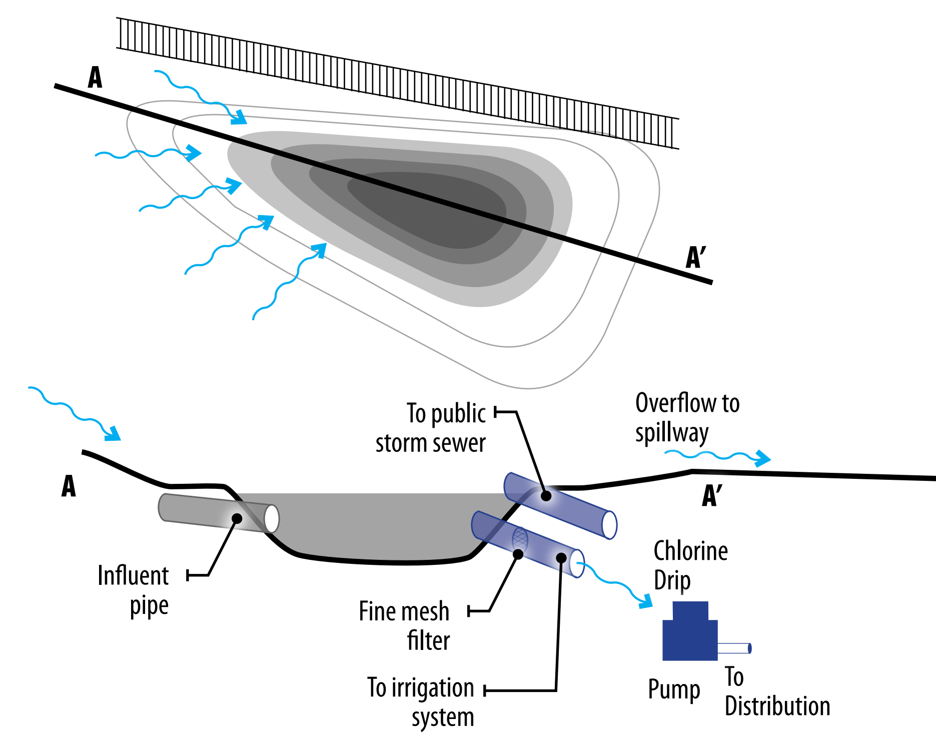


## 1b Collection - Roof

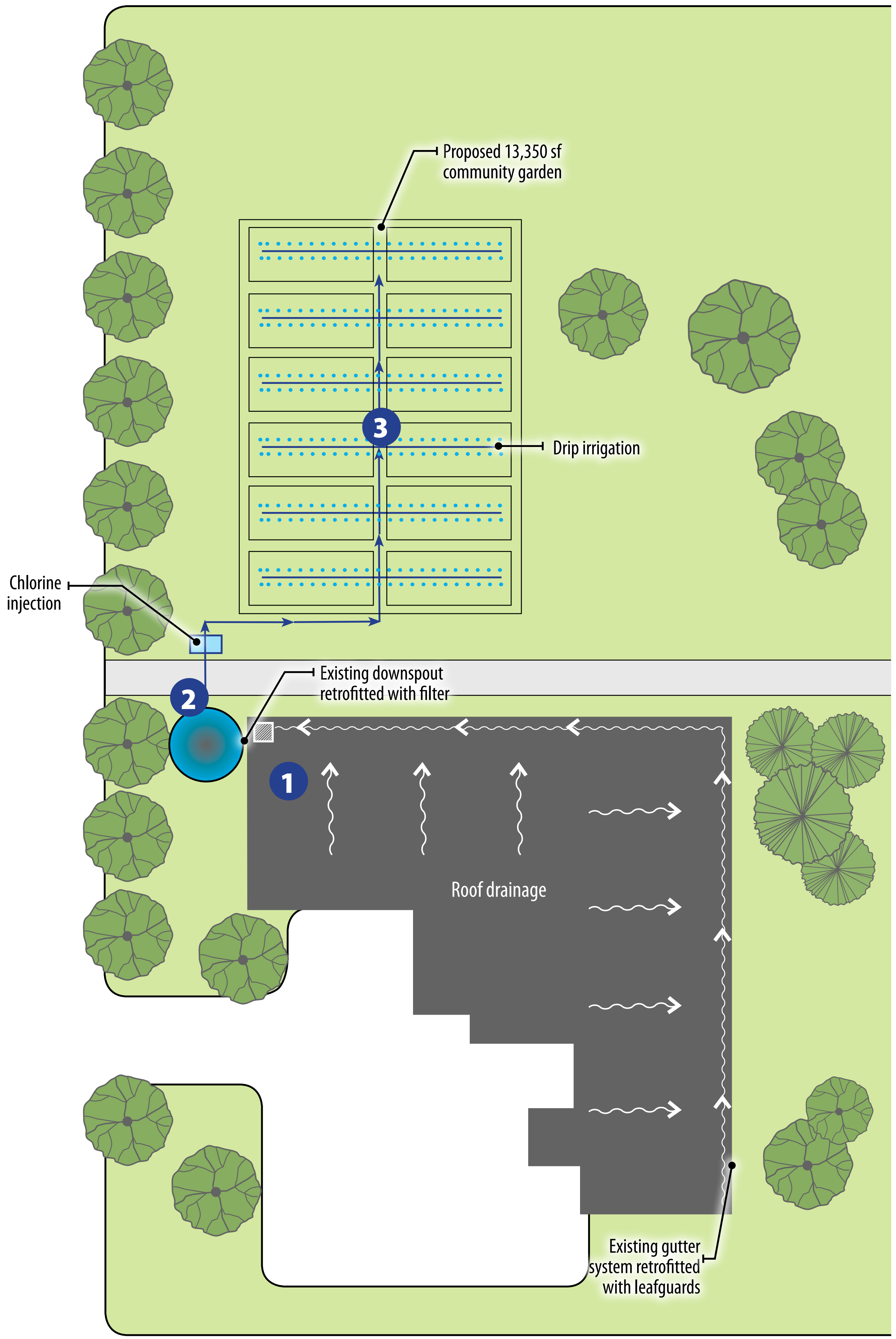
- 125,000 sf roof
- Leaders connect to on-site stormwater system
- Roofs routinely inspected and cleaned for pollutants

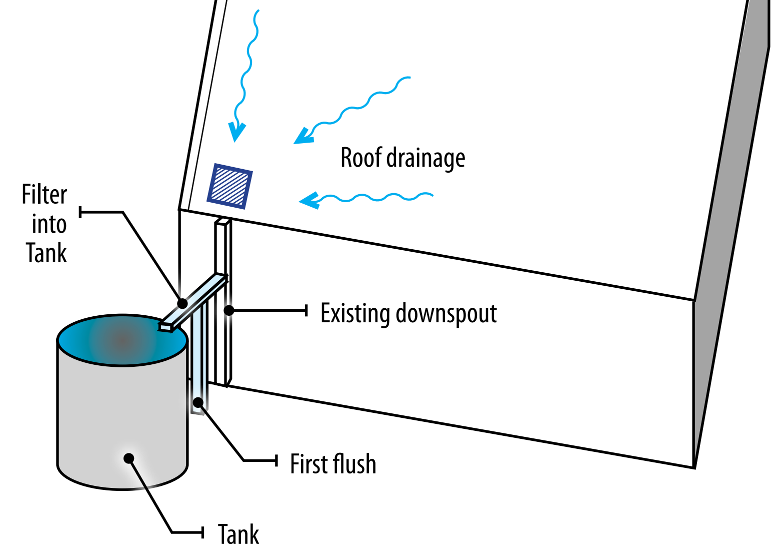
## 3b Emergency Spillway

- Fence separates athletic fields from stormwater pond
- Filter located at stormwater pond outlet
- Drip chlorination disinfection in pump manhole




*Diagrams Not To Scale*



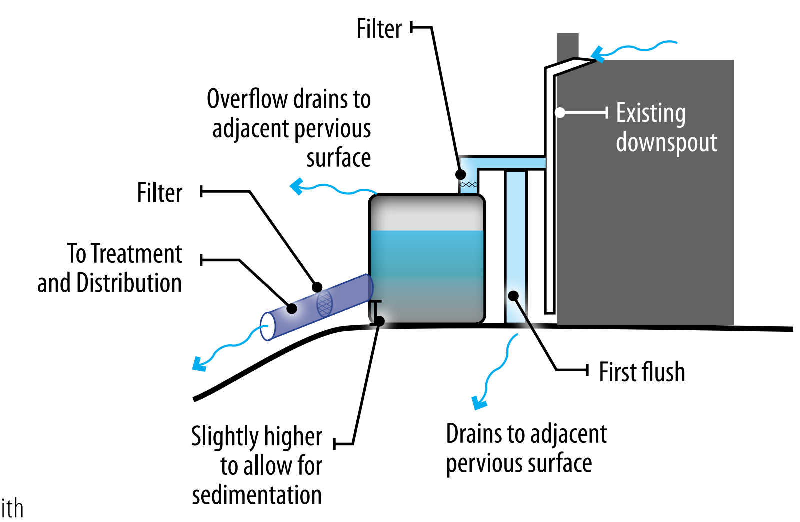




## 1 Collection

- Existing school building adjacent to property
  - 21,210 sf roof area
  - Existing collection system sized appropriately to convey storm event
  - Currently connected to public storm system
- Collection system modified to divert stormwater to one downspout location (ensure downspout is sized appropriately to drain entire roof)
- First-flush and Bypass systems installed before storage tank
  - Divert majority of stormwater from public storm system to storage tank
  - Direct first flush to adjacent pervious surface for infiltration
  - Keep connection with public storm system for bypass flows
- Filters and leafguards retrofitted onto existing rooftop collection on roof
- Monthly inspection of rooftop; Sweep, clean large debris and relocate bird/animal nests, as necessary

## 2 Storage / Treatment

- Use **Water Balance Tool**
  - Irrigation based on 1 inch per week
  - 5,000 gallons will meet demand 55% of seasonal demand
  - 15,000 gallon tank will meet 85% of seasonal demand
  - 100,000 gallon tank required to meet 100% of seasonal demand
- Tank features:
  - 15,000 gallon tank installed; Supplemental water supply provided from off-site
  - Gravity drainage (tank situated on high ground)
  - Outlet slightly higher than tank bottom to allow for sedimentation
  - Filters at tank entrance and exit
- Clean system in autumn when tank is winterized; Remove sediment, fill with water and disinfect with bleach, de-water, clean exterior
- Mark each 1,000 gallons for visual estimation of stored volume
- Each week, add 1/3 cup bleach for each 1,000 gallons of stored water for manual disinfection
- Sign attached to storage tank: 'Do not drink. Water used for irrigation, only'



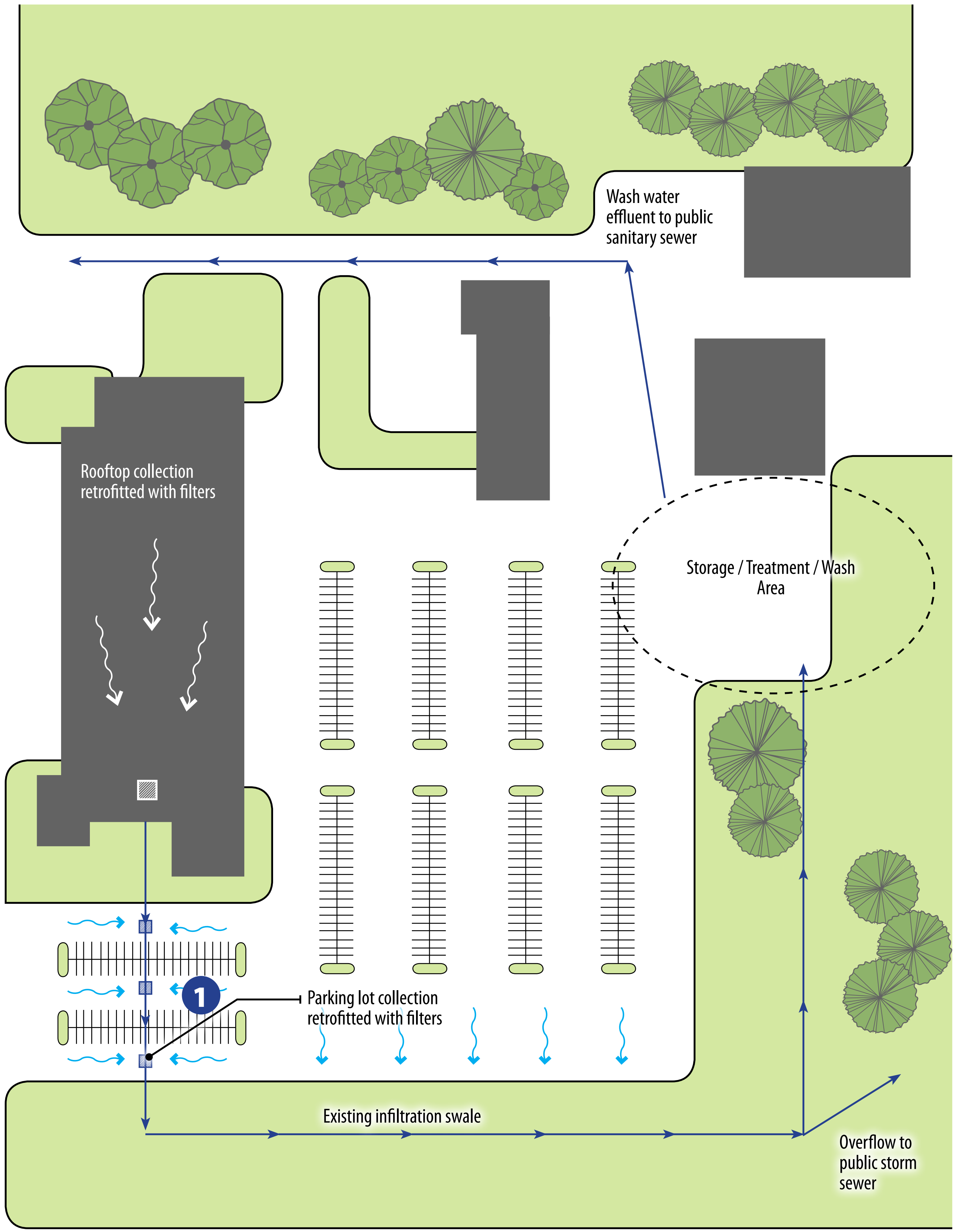

## 3 Distribution

- Manual valves to allow community control of irrigation
- Gravity control into distribution network
- Drip irrigation system, installed each spring and removed each autumn

## System Features

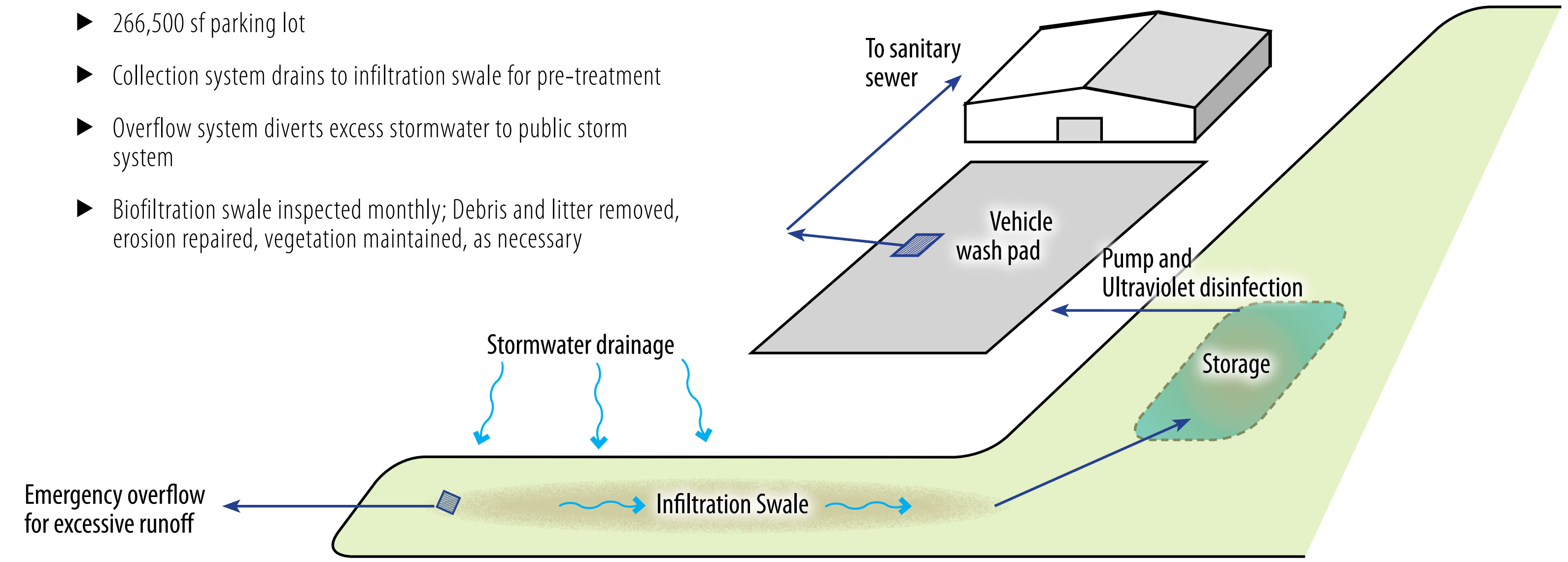
- First flush diversion
- Gravity system - no need for pumps
- Tank accessible for potable water augmentation / clean out / disinfection
- Filtration at both inlet and outlet of storage tank

*Diagrams Not To Scale*



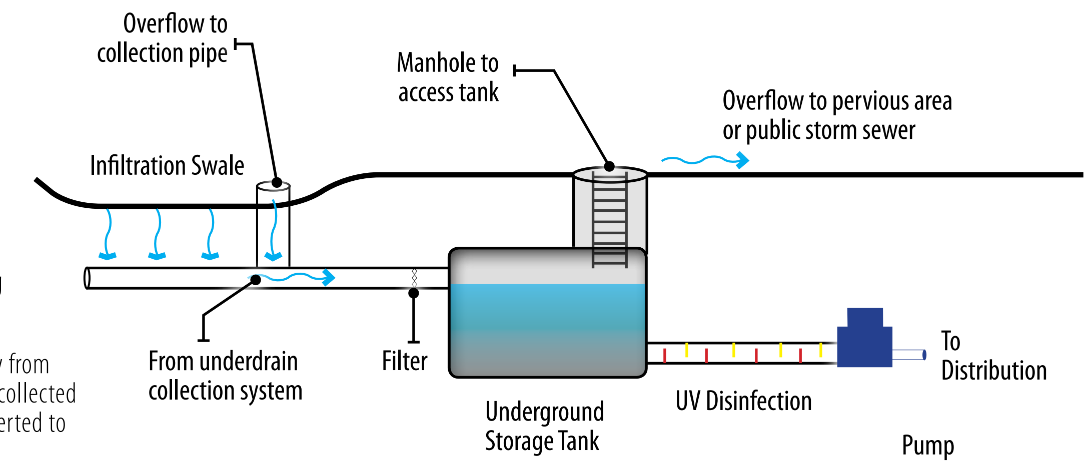

## 1 Collection

- 266,500 sf parking lot
- Collection system drains to infiltration swale for pre-treatment
- Overflow system diverts excess stormwater to public storm system
- Biofiltration swale inspected monthly; Debris and litter removed, erosion repaired, vegetation maintained, as necessary




## 2 Storage / Treatment

- Cars / Trucks in fleet: 200
- Gallons per wash: 40
- Washes per vehicle per week: 1
- Gallons required per week: 8,000
- 25,000 gallon storage tank will meet demand 75% of weeks in service during spring/summer/fall season
- Excess stormwater can be diverted away from storage and infiltrated into ground and collected by underdrain system; Excess runoff diverted to public storm sewer
- Underground tank to reduce pumping requirements
- Situate tank in grassy area such that no loads are placed on top
- Install filter at tank entrance and exit
- UV disinfection system



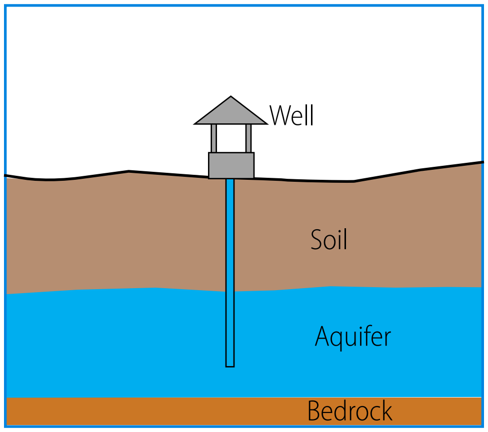

## 3 Distribution

- Power wash hoses
- Determine hose demands for pump sizing
- Wash water from vehicle wash pad to drain to sanitary sewer; Valves installed to prevent stormwater from draining to sanitary sewer when vehicle wash is not in use

*Diagrams Not To Scale*

# Glossary

def.




Aquifer

*Source: HKGi*

## Acre-foot

Enough water to cover an acre of land one-foot deep (i.e., 325,851 gallons, or 43,560 cubic feet).

## Application rate

The depth of water applied to a given area over time, usually measured in inches per hour.

## Applied water

The portion of water supplied by the irrigation system that reaches the soil surface.

## Aquifer

A saturated geologic formation that will yield a sufficient quantity of water to serve as a private or public water supply.

## Backflow prevention device

A safety device used to prevent contamination of the potable water supply from the reverse flow of water from an irrigation system or other customer activity back into the potable distribution system.

## Backwash

The use of water to clean filters. Water under high-pressure is pumped in reverse through filters, removing trapped sediment and other material.

## Beneficial rainfall

The portion of total rainfall that is available for use.

## Best Management Practices (BMP)

Recommendations pertaining to the development and maintenance of varied land uses, aimed at limiting the effects of development, such as soil erosion and stormwater runoff, on the natural environment. See *Metropolitan Council's Urban Small Sites Best Management Practices Manual* for specific examples of best management practices.

## Biochemical oxygen demand

Measure of the amount of oxygen required by bacteria to consume organic matter in water. Measured over a period of time, typically 5 days at 20°C.

## Bioretention system

Stormwater treatment method similar to a sand filter, in which vegetation is planted on the top of a soil filter medium; also known as biofiltration system.

### Bubbler
A type of sprinkler that delivers a relatively large volume of water to a level area where standing water gradually infiltrates into the soil. The flow rate is large relative to the area to which the water is delivered. Bubblers are used to irrigate trees and shrubs.

### Calcium
(element symbol Ca) An element that is commonly found in water. It contributes to the hardness of water.

### Capita
Latin for "person".

### Catch-can-test
Measurement of a sprinkler system's application rate. Test involves placing graduated containers at evenly spaced intervals throughout an irrigated area and measuring the depth of water collected in the cans over a given period of time.

### Central irrigation control system
A computerized system for programming irrigation controllers from a central location; using a personal computer and radio waves or hard wiring to send program information to geographically distant controllers.

### Check valve
A device that prevents drainage of water down to the low points of an irrigation system after the system is shut off. Also called an anti-drain valve. A valve that allows flow in only one direction, preventing backflow.

### Chemical oxygen demand
Measure of the amount of biologically or chemically oxidizable organic compounds in water.

### Chlorination
Process of adding chlorine to water as a method of water disinfection.

### Climate factor
Evapotranspiration minus precipitation. One of the four factors used to determine landscape water use.

### Coliform bacteria
Microorganisms (e.g., Escherichia coli) common to the intestinal tract of warm blooded animals. The organisms' presence in water is an indicator of the presence of pathogenic organisms.

### Colony-forming unit (CFU)
A measure of the number of viable bacteria in a sample.

### Commercial user
Customers that use water at a place of business, such as hotels, restaurants, office buildings, commercial businesses or other places of commerce. These do not include multi-family residences, agricultural users, or customers that fall within industrial or institutional classifications.

## Conductivity or electrical conductivity (EC)

A measure of the conduction of electricity through water; can be used to determine the total dissolved salts content. EC is measured in µS/cm.

## Conjunctive use

The coordinated use and storage of surface and ground water supplies to improve water supply reliability and potentially increase the overall availability of water.

## Contaminant

Any chemical, microbe, or other material that is not found in pure water and that can make water unsuitable for its intended use. Some contaminants only affect aesthetic qualities such as appearance, taste, or odor of the water, while others can produce adverse health effects.

## Cost-effectiveness

An analysis that compares the financial benefits of a project to the costs needed to complete that project.

## Crop coefficient (Kc)

A factor used to adjust reference evapotranspiration and calculate water requirements for a given plant species. (Also called plant factor or landscape coefficient).

## Cryptosporidium

Microorganism that is highly resistant to disinfection; commonly found in lakes and rivers. Cryptosporidium has caused several large outbreaks of gastrointestinal illness with symptoms such as diarrhea, nausea, and stomach cramps. People with severely weakened immune systems are likely to have more severe and more persistent symptoms than healthy individuals (adapted from United States Environmental Protection Agency).

## Curb stop

Shut-off valve between the customer meter and the street service line from the water main.

## Debris

A contaminant that you can see. Debris can include leaves and twigs, dust and dirt, bird and animal droppings, and insects.

## Desalination

The process of removing salt from brackish water or sea water, producing water suitable for fresh water uses, as well as concentrated brine.

## Design Peak-to-Average Flow

The ratio of the peak-hour flow used for hydraulic design divided by the design-average flow.

## Design Peak-Hour Flow

The design-average flow times the peak-to-average ratio.

### Discount rate
The financial rate used to calculate the present value of future benefits and costs.

### Disinfection
A process designed to kill most microorganisms, including essentially all pathogenic bacteria. There are several ways to disinfect; chlorine and ultraviolet radiation are most frequently used in water treatment.

### Dissolved Air Flotation
A water treatment process that clarifies wastewater (or other waters) by the removal of suspended matter such as oil or solids. Removal is achieved by dissolving air in the water or wastewater under pressure and then releasing the air at atmospheric pressure in a flotation tank or basin. The released air forms tiny bubbles which adhere to the suspended matter causing the suspended matter to float to the surface of the water where it may then be removed by a skimming device.

### Distribution facilities
Pipes, meters, storage, pumps and other facilities used to distribute water to end users.

### Distribution uniformity (DU)
An expression of how evenly water is applied to a landscape by an irrigation system. DU is calculated in the field by analyzing the results of catch-can tests.

### Drinking water
See "potable water."

### Drip irrigation
The slow, accurate application of water directly to plant root zones via a system of tubes and emitters usually operated under pressure.

### Dual and multiple programming
The capacity of an irrigation controller to schedule the frequency and duration of irrigation cycles to meet varying water requirements of plants served by a system. Grouping plants and laying out irrigation stations by similar water requirements facilitates multiple programming.

### E.coli
Escherichia coli; bacterium found in the intestinal tracts of warm blooded animals, including humans. Used as an indicator of the presence of pathogenic organisms.

### Effective precipitation (EP)
The portion of total rainfall that is available for use by the plant.

### Effluent
Wastewater, treated or untreated, that flows out of a wastewater treatment plant, or industrial outfall.

### End use
A fixture, appliance, or other specific object or activity that uses water.

### Estimated Water Use (EWA)
The amount of water estimated to be needed by the landscape during one year.

### ET factor
A factor used to set a landscape water efficiency goal. Also known as an "adjustment factor".

### Evapotranspiration (ET) Rate
The rate of water evaporated from soil surfaces and transpired by plants during a specific time.

### Fecal coliform
The coliform bacteria group, present in the intestinal tracts and feces of humans and other warm-blooded animals. Drinking water with fecal coliform can cause diarrhea and other gastrointestinal illnesses. Often reported in units of CFU/100 mL.

### Filtration
A water treatment process that involves water passing through sand or other media, where particles and other constituents are trapped and removed from the flow.

### First flush
The first runoff from a storm event, in which the concentrations of pollutants are higher than in subsequent runoff from the same storm event.

### Flow rate
The rate at which a volume of water flows through pipes, valves, etc in a given period of time. Often reported as cubic feet per second (cfs) or gallons per minute (gpm).

### Graywater
Untreated domestic wastewater from the hand basin, shower, bath, spa bath, washing machine, laundry tub, kitchen sink and dishwasher, not including toilets.

### Groundwater
Water that has seeped beneath the earth's surface and is stored in the pores and spaces between solid materials (e.g., sand, gravel or clay).

### Groundwater recharge
Percolating or pumping surface water into a groundwater basin to increase the available groundwater supply.

### Hardness
A common measurement of water quality which describes the concentration of dissolved calcium and magnesium and sometimes other divalent and trivalent metallic elements. Derived from the qualitative description of how "hard" it is to create soap suds.

### Hardscape
Landscaping that impedes the seepage of water into the ground, such as concrete, brick and lumber.

### Hardware efficiency

A percentage or fraction value that represents the portion of water applied by an irrigation system that is beneficial to the plants. See distribution uniformity.

### Heterotrophic Plate Count (HPC)

A procedure for estimating the total number of live non-photosynthetic bacteria in water. Colony forming units (CFU) are counted after spreading the sample over a membrane or spread plate and incubating in an appropriate growth medium (agar) and at an appropriate temperature.

### Historic basis

Past water consumption history.

### Hydraulic conductivity

Soil or rock property that describes the ease with which water can move through pore spaces or fractures.

### Hydrologic cycle

Movement of water as it evaporates from rivers, lakes or oceans, into the atmosphere, returns to earth as precipitation, flows into rivers to the ocean and evaporates again.

### Impact head

A type of single-stream irrigation device rotor that uses the impact of a stream of water to rotate a nozzle in a full or partial circle. Impact heads have large radii and relatively low precipitation rates and do not provide matched precipitation rates for varying arc patterns.

### Indicator organisms or indicator bacteria

Microorganisms whose presence is indicative of pollution or of more harmful microorganisms (e.g., E. coli can indicate the presence of pathogenic bacteria).

### Industrial user

Water users that are primarily manufacturers or processors of materials as defined by the NAICS Code numbers 2000 through 3999.

### Infiltration rate

The rate at which water permeates the soil surface, expressed as a depth of water per unit of time (inches per hour).

### Infrastructure

Fixed facilities, such as sewer lines and roadways, that serve existing and new development and redevelopment.

### Institutional user

Water-using establishment engaged in public service. This includes schools, churches, hospitals, and government facilities. All facilities serving these functions are considered institutional regardless of ownership.

### Irrigated area

The portion of a landscape that requires supplemental irrigation, usually expressed in square feet or acres.

### Irrigation controller
A mechanical or electronic clock that can be programmed to operate remote-control valves to control watering times.

### Irrigation cycle
A scheduled application of water by an irrigation station defined by a start time and its duration. Multiple cycles can be scheduled, separated by time intervals, to allow infiltration of applied water.

### Irrigation plan
A two-dimensional plan drawn to scale expressing the layout of irrigation components and component specifications. Layout of pipes may be depicted diagrammatically, but location of irrigation heads and irrigation schedules should be specified.

### Irrigation scheduling
The process of developing a schedule for an automatic irrigation system that applies the design volume of water, matched to the plant needs, and can vary daily, weekly and/or seasonally.

### Land Planning Act, Metropolitan Land Planning Act
The sections of Minnesota Statutes directing the Metropolitan Council to adopt long-range, comprehensive policy plans for transportation, airports. wastewater services, and parks and open space. It authorizes the Metropolitan Council to review the comprehensive plans of local governments.

### Landscape water budget (LWB)
A volume of applied irrigation water expressed as a monthly or yearly amount, based on ET and the plant materials being irrigated.

### Life-cycle analysis
Examines the costs and benefits of an action over its entire expected life span.

### Local Comprehensive Plan
Plans prepared by cities, townships and, in some cases, counties, for local land use and infrastructure.

### Local Government
Municipal units of government, such as counties, cities and townships.

### Meter (water)
An instrument for measuring and recording water volume.

### Metropolitan Area, Metro Area
See region.

### Metropolitan Urban Service Area (MUSA)
The area in which the Metropolitan Council ensures that regional services and facilities under its jurisdiction are provided.

### Microclimate

The climate of a specific place within a given area.

### Microfiltration

The separation or removal from a liquid of particles and microorganisms in the size range of 0.1 to 2.0 microns in diameter.

### Mulch

A protective covering of various substances, usually organic, such as wood chips, placed on the soil surface around plants to reduce weed growth and evaporation and to maintain even temperatures around plant roots.

### Multi-family (MF)

Residential housing with multiple dwelling units, such as apartments and condominiums.

### Multifamily housing

Residential structure with two or more separate dwelling units.

### Multiple start times

An irrigation controller's capacity to accept programming of more than one irrigation start-time per station per day.

### Municipal and industrial (M&I)

Water supplies utilized for non-agricultural uses.

### NAICS (formally SIC codes)

North American Industry Classification System. A consolidation of the Standard Industrial Classification (SIC) codes for the US, Canada and Mexico. Produced by the US Office of Management and Budget.

### Native and adopted plants

Plants indigenous to an area or from a similar climate that require little or no supplemental irrigation once established.

### NPDES

National Pollutant Discharge Elimination System.

### Nonpathogenic microbe

A bacteria, parasite, or virus that does not cause an infection or disease in humans.

### Nonpotable water

Water that is considered unsafe, unpalatable, or both, for drinking.

### Nutrient

Substance that provides nourishment for an organism – the key nutrients in stormwater runoff are nitrogen and phosphorus.

### O&M

Operations and Maintenance.

## Operating pressure

Distribution system water pressure measured in pounds per square-inch (psi). Municipal systems are generally maintained between 50 and 80 psi.

## Overspray

Application of water via sprinkler irrigation to areas other than the intended area.

## pH

Value taken to represent acidity or alkalinity of an aqueous solution, expressed as the logarithm of the reciprocal of the hydrogen ion activity in moles per litre at a given temperature.

## Pathogen

A disease-causing organism (e.g. bacteria, viruses, protozoa).

## Pathogenic microbe

A bacteria, parasite, and virus that can cause an infection or disease in humans.

## Peak use

The maximum demand occurring in a given period, such as hourly, daily or annually.

## Per capita use

Water used per person.

## Point of entry

The point (location) where water enters a home's plumbing system. A point of entry treatment unit treats all of the water entering the home rather than treating the water at the point where it is consumed. A whole-house water softener is an example of a common point of entry treatment unit.

## Point of use

A point (location) in a home where water is actually used.

## Potable water

Water that meets drinking water standards and is considered safe and satisfactory for drinking and cooking.

## Pound per square-inch (psi)

A unit measure of pressure. In this case, the pressure exerted by water in a distribution system.

## Precipitation rate

Rate of precipitation (rain/snow) generally measured in inches per hour or per day.

## Primary treatment

The first stage of a wastewater treatment process in which floating material and large suspended solids are removed by mechanical processes, such as screening or settling.

### Public user

Publicly owned water customers, such as schools, parks, and government buildings. Also referred to as institutional customers.

### Public water system

A public water system (PWS) is any system that serves at least 25 people per day for at least 60 days each year or that serves at least 15 service connections such as homes, apartments, or businesses.

### Rain shutoff device

A device connected to an irrigation controller that overrides scheduled irrigation when significant precipitation is detected.

### Rainwater

Precipitation that has not yet reached a roof or other surface.

### Raw water

Untreated water.

### Recirculating task

Water that is employed for the same task multiple times. For example, water can be used to carry heat away from a heat source, cooled by evaporation in a cooling tower, and returned to the heat source to repeat the task.

### Reclaimed water

Wastewater that has been treated and recovered for beneficial purposes.

### Recycled water

Used in California to describe reclaimed water.

### Record drawings

Site plans reflecting the actual constructed conditions of a landscape irrigation system or other facility installation.

### Reference evapotranspiration

The water requirements of a standardized landscape plot; specifically, the estimate of the evapotranspiration of a broad expanse of well-watered, 4-to-7 inch-tall cool-season grass.

### Remote control valve

An electric solenoid valve, wired to an irrigation controller, that controls the flow of water to an irrigation station.

### Retrofit

1) Replacement of existing water fixtures or appliances with new and more efficient ones.

2) Replacement of a portion of a water fixture or appliance to make the fixture more efficient.

### Reuse
As used in this stormwater guide, capture and use of stormwater runoff that is reclaimed for specific, direct, and beneficial uses. Term is also used to describe water that is captured on-site and utilized in a new application. Also called rainwater harvesting, rainwater recycling, or rainwater reclamation.

### Reverse osmosis (RO)
A process to remove dissolved solids, usually salts, from water. Salty water is forced through membranes at high pressure, producing fresh water and a highly concentrated brine.

### Roofwater
Water collected from the roofs of buildings.

### Runnel
A narrow channel used to convey water.

### Runoff
The rainfall, snowmelt, or irrigation water flow that has not evaporated or infiltrated into the soil, but flows over the ground surface.

### Secondary treatment
The second step in most wastewater treatment systems, which removes most of the oxygen-demanding substances (organics) and light suspended solids.

### Secondary wastewater treatment plant
A facility that employs secondary wastewater treatment.

### Sewage or wastewater
Material collected from internal household and other building drains. Includes fecal waste and urine from toilets, shower and bath water, laundry water and kitchen water.

### SIC Code (Standard Industrial Classification)
A system devised by the federal government to classify industries by their major type of economic activity. The code may extend from two to eight digits. This term has been superseded by the NAICS.

### Single-family (SF) unit
A residential dwelling unit built with the intent of being occupied by one family. It may be detached or attached (i.e., townhouses).

### SOC (synthetic organic chemical)
A type of organic molecule that is typically found in pesticides, herbicides, and similar man-made products.

### Soil amendment
Organic or inorganic materials added to soils to improve their texture, nutrient content, moisture holding capacity, or infiltration rates.

### Soil improvement
The addition of soil amendments.

### Soluble reactive phosphorus
A measure of orthophosphate, a filterable (soluble, inorganic) fraction of phosphorus.

### Spray head
A sprinkler irrigation nozzle installed on a riser that delivers water in a fixed pattern. Flow rates of spray heads are high relative to the area covered by the spray pattern.

### Spray irrigation
Sprinkler irrigation using spray heads on fixed or pop-up risers and having relatively high irrigation rates.

### Sprinkler irrigation
Overhead water delivery by spray heads, stream rotors, or impact heads. Delivery rates will vary depending on system layout and type of head used.

### Sprinkler run time
The minutes of irrigation per day, based on the weekly irrigation requirement and irrigation days per week.

### Sprinkler station
A group of sprinklers controlled by the same valve.

### Sprinkler valve
The on-off valve, usually electric, that controls an irrigation or sprinkler.

### Station
An irrigated area controlled by a single irrigation valve.

### Storage basin
A natural or artificial impoundment used to hold water before its treatment or distribution (e.g. tank, dam, reservoir).

### Stormwater
Precipitation that runs off urban surfaces such as roofs, pavement, parking lots, roads, gardens and open spaces.

### Subsurface drip irrigation
The application of water via buried pipe and emitters, with flow rates commonly measured in gallons per hour.

### Surface water
Water that remains on the earth's surface, in oceans, rivers, streams, lakes, wetlands or reservoirs.

### Suspended solids
Solids in suspension in water that can be removed by a filter with a nominal pore diameter of about 1.2 µm.

## Thatch

The buildup of organic material at the base of turfgrass leaf blades. Thatch repels water and reduces infiltration capacity.

## Total coliform

A total count or measure of the level of coliform bacteria in a water sample (often reported in units of CFU/100 mL)

## Total dissolved salts

A measurement of the total dissolved salts in a solution. Major salts in recycled water typically include: sodium, magnesium, calcium, bicarbonate, potassium, sulfate and chloride. Used as measure of water or soil-water salinity with units of mg/L.

## Total Dissolved Solids

The total weight of the solids that are dissolved in water, given in mass per unit volume of water (mg/L). TDS is determined by filtering a given volume of water (usually through a 0.45 micron filter), evaporating it at a defined temperature (usually 103 - 105 degrees Celsius) and then weighing the residue.

## Total Kjeldahl Nitrogen

The sum of organic nitrogen, ammonia ($NH_3$), and ammonium ($NH_4^+$) in the chemical analysis of soil, water, or wastewater.

## Total organic carbon

The amount of carbon bound in an organic compound that is often used as a non-specific measure of water quality.

## Total phosphorus

The total mass of soluble and particulate phosphorus in a volume of water.

Turfgrass is the most common vegetative ground cover for athletic fields and residential lawns.

*Source: HKGi*

## Total dissolved phosphorus

The mass of dissolved phosphorus in solution .

## Total Suspended Solids (TSS)

TSS are solid materials, organic and inorganic, that are suspended in the water, including silt and plankton.

## Transpiration

The passing of water through living plant membranes into the atmosphere.

## Treated water

Water that has been treated for a beneficial use.

## Turbidity

The amount of small particles of solid matter suspended in water as measured by the amount of scattering and absorption of light rays caused by the particles. Turbidity is measured in nephelometric turbidity units (NTU).

## Turfgrass

Hybridized grasses that, when regularly mowed, form a dense growth of leaf blades and roots.

### Ultrafiltration
A method of cross-flow filtration which uses a membrane to separate small colloids and large molecules from water and other liquids.

### Ultraviolet disinfection
A disinfection method using ultraviolet light.

### UPC (Uniform Plumbing Code)
The model plumbing code, prepared by the International Association of Plumbing and Mechanical Officials.

### Untreated water
Water that has not been treated in a treatment system.

St. Anthony Village Wastewater Treatment Plant

*Source: HKGi*

### Utility
Used alternately to describe a provided resource, such as water, gas, or electric as well as for the provider of the resource.

### Valve
Device to control the flow of water, other liquids or gases.

### VOC (volatile organic chemical)
A type of organic molecule that is typically found in refined organic products such as plastics, glues, and solvents, as well as gasoline, greases and oils.

### Wastewater
Water containing the wastes from households, commercial facilities, and industrial operations. It may be mixed with surface water, stormwater, or groundwater that infiltrated into the collection system.

### Wastewater treatment plant
A facility designed to remove contamination from municipal and industrial wastewater prior to discharge.

### Water allowance
The quantity of water needed to maintain plants and other features in an ornamental landscape.

### Water audit
1) An on-site survey of an irrigation system or other water use facility to measure hardware and management efficiency and generate recommendations to improve its efficiency. 2) For water distribution systems, a thorough examination of the accuracy of water agency records and system control equipment to identify, quantify, and verify water and revenue losses.

### Water budget
1) The calculated amount of water a household will require based on the size of the family, number and types of fixtures, and landscape needs. 2)Water budget approach: A method of establishing water efficiency standards by providing the water necessary to meet the water needs.

### Water conservation

The US Water Resources Council defines water conservation as activities designed to 1) reduce the demand for water, 2) improve efficiency in use and reduce losses and waste of water, and 3) improve land management practices to conserve water.

### Water-efficient landscape

A landscape that minimizes water requirements and consumption through proper design, installation, and management.

### Watershed

A land area defined by topography, soil and drainage characteristics that collects water that flows to a common point.

### Wetting area (pattern)

The soil area wetted by a sprinkler, bubbler or low volume emitter.

### Xeriscape

Landscaping and gardening techniques that reduce or eliminate the need for supplemental water from irrigation. Based on seven principles: proper planning and design; soil analysis and improvement; practical turf areas; appropriate plant selection; efficient irrigation; mulching; and appropriate maintenance.

### Zero footprint

The complete reduction and/or offset of the potable water demand of a purposed development project by conservation, use of recycled water, or other measures.

# Sources & Links

## Fact Sheet Resources

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## Case Studies Resources

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## **Case Studies Resources** (continued)

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| American National Standards Institute | 2010 | *Design, installation and performance of underground thermoplastic irrigation pipelines.* | Washington, D.C. | http://webstore.ansi.org/RecordDetail.aspx?sku=ANSI/ASAE+S376.2+JAN1998+(R2010) | Irrigation design |
| Cabell Brand Center | 2007 | *Virginia Rainwater Harvesting Manual* | Salem, VA | http://www.dcr.virginia.gov/documents/stmrainharv.pdf | Manual describing collection, storage, and treatment of rooftop runoff in Virginia |
| Center for Neighborhood Technology | 2004 | *Green Values Stormwater Management Calculator* | Chicago, IL | http://logan.cnt.org/calculator/calculator.php | Determine discharge from surface / roof runoff |
| City of Berkeley, Planning and Development Department, Energy and Sustainable Development & Building and Safety Division | 2010 | *Guidelines for Rainwater Harvesting* | Berkeley, CA | http://www.ci.berkeley.ca.us/uploadedFiles/Planning_and_Development/Level_3_-_Energy_and_Sustainable_Development/rainwater.pdf | Technical guidelines for installing rooftop rainwater collection systems in Berkeley, CA |
| College of Tropical Agriculture and Human Resources, University of Hawai'i | 2010 | *Guidelines for Rainwater Catchment Systems for Hawai'i* | Mānoa, HI | http://www.ctahr.hawaii.edu/oc/freepubs/pdf/RM-12.pdf | Manual describing collection, storage, and treatment of rooftop runoff in Hawai'i |
| Council on the Environment for New York City | 2008 | *Rainwater Harvesting 101* | New York, NY | http://www.raincollectionsupplies.com/v/vspfiles/assets/images/newyorkrwh.how.to.pdf | Practical guide to using rainwater for community gardens. |
| Emmons & Oliver Resources, Center for Watershed Protection | 2005 | *Issue Paper "G". Cold Climate Considerations for Surface Water Management* | St. Paul, MN | http://www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/stormwater-management/minnesota-s-stormwater-manual.html | Cold climate recommendations |
| Federal Highway Administration | 2001 | *Urban Drainage Design Manual* | Washington, D.C. | http://isddc.dot.gov/OLPFiles/FHWA/010593.pdf | Technical guidence on urban runoff collection. |
| German Institute for Standardization | 1989 | *Rainwater Harvesting Systems: Part I: Planning, Installation, Operation and Maintenance* | Germany | http://www.ecoagua.pt/sbo/files/DIN1989.pdf | Translation of 1989 German manual for harvest, treatment and use of rainwater harvested from rooftop collection areas; considered to be first manual developed |
| Jensen, M.E., ASABE | 1982 | *Design and operation of farm irrigation systems* | St. Joseph, MI | http://asae.frymulti.com/monographs.asp?confid=dos2007 | Technical manual developed by American Society of Agricultural and Biological Engineers |
| Metcalf & Eddy | 2007 | *Water Reuse* | | McGraw-Hill | Textbook |

## **Implementation Resources** (continued)

| Author | Year | Title | Location | Publisher/Web Link/ Other | Description |
|---|---|---|---|---|---|
| Metropolitan Council | 2011 | *Water Conservation Toolbox* | St. Paul, MN | http://www.metrocouncil.org/environment/WaterSupply/conservationtoolbox.htm | Links for water efficient irrigation practices |
| Midwestern Climate Center and Illinois State Water Survey | 1992 | *Rainfall Frequency Atlas of the Midwest* | Champaign, IL | http://www.isws.illinois.edu/pubdoc/B/ISWSB-71.pdf | IDF curves for the Midwest |
| Minnesota Climatology Working Group | 2011 | *Minneapolis / St. Paul Metro Area Climate Page* | St. Paul, MN | http://climate.umn.edu/doc/twin_cities/twin_cities.htm | Link to historic climate data |
| Minnesota Department of Labor and Industry | 2009 | *Minnesota Plumbing Code* | St. Paul, MN | https://www.revisor.mn.gov/rules/?id=4715&view=chapter | Rules for plumbing systems in Minnesota |
| Minnesota Department of Labor and Industry | 2007 | *Minnesota Provisions of the Building Code* | St. Paul, MN | https://www.revisor.mn.gov/rules/?id=1303 | Foundation requirements |
| Minnesota Department of Natural Resources | | *Water use permits* | St. Paul, MN | http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/permits.html | Link to DNR water use permits |
| Minnesota Department of Transportation | 2005 | *MNDOT Drainage Manual* | St. Paul, MN | http://www.dot.state.mn.us/bridge/hydraulics/drainagemanual/ | Hydraulic design for Minnesota highway drainage |
| Minnesota Pollution Control Agency | 2005 | *Minnesota Stormwater Manual* | Minnesota | http://www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/stormwater-management/minnesota-s-stormwater-manual.html | Stormwater management manual for the State of Minnesota |
| Minnesota Pollution Control Agency | 2011 | *Minimal Impact Design Standards (MIDS): Enhancing stormwater management in Minnesota* | St. Paul, MN | http://www.pca.state.mn.us/index.php/water/water-types-and-programs/stormwater/stormwater-minimal-impact-design-standards-mids.html | Web page containing information on status of development of Minimal Impact Design Standards |
| Montana State University Extension | 2006 | *Rainwater Harvesting Systems for Montana* | Bozeman, MT | http://msuextension.org/publications/AgandNaturalResources/MT199707AG.pdf | Rainwater harvesting fact sheet for rooftop collection in Montana |
| National Conference of the Stormwater Industry Association | 2010 | *Conference Proceedings of the 2010 Stormwater Industry Association National Conference* | Burwood, NSW, AU | http://www.gemsevents.com.au/stormwater2010/conference_papers.shtml | Papers presented at Australia 2010 stormwater conference; includes numerous papers on rainwater harvesting and reuse. |
| National Resource Management Ministerial Council, et al | 2009 | *Australian Guidelines for Water Recycling, Stormwater Harvesting and Reuse* | Australia | http://www.ephc.gov.au/taxonomy/term/39 | Manual decribing collection, storage, treatment and use of stormwater collected from rooftops and ground surfaces in Australia |

## Implementation Resources (continued)

| Author | Year | Title | Location | Publisher/Web Link/ Other | Description |
|---|---|---|---|---|---|
| National Resource Management Ministerial Council, et al | 2006 | *Managing Urban Stormwater: Harvesting and Reuse* | Australia | http://www.environment.nsw.gov.au/stormwater/pubs.htm | Regulatory and technical guidence for rooftop and ground runoff in Australia; includes case studies |
| National Sanitation Foundation | 2004 | *Home Water Treatment Devices* | Ann Arbor, MI | http://nsf.org/consumer/drinking_water/dw_treatment.asp?program=WaterTre#devices | Summary of small-scale water treatment technologies |
| National Sanitation Foundation | 2004 | *Rainwater Collection Systems* | Ann Arbor, MI | http://nsf.org/consumer/newsroom/fact_water_rainwater.asp?program=WaterTre | Introduction into rainwater collection |
| National Sanitation Foundation | 2011 | *NSF Certified Drinking Water System Components* | Ann Arbor, MI | http://www.nsf.org/business/water_distribution/performance.asp?program=WaterDistributionSys | Allows user to research products that pass NSF Standard 61 |
| National Sanitation Foundation | 2004 | *Rainwater Collection* | Ann Arbor, MI | http://nsf.org/consumer/rainwater_collection/index.asp | Introduction into rainwater collection |
| NOAA | | *Geodetic Bench Marks* | Washington, D.C. | http://www.ngs.noaa.gov/PUBS_LIB/GeodeticBMs/images/figure13.gif | Frost line determination |
| North American Rain Systems | 2011 | *Manuals for Rainwater Harvesting* | Lyman, SC | http://www.raincollectionsupplies.com/Rainwater_Harvesting_Manuals_s/31.htm | Links to rainwater harvesting manuals from municipalities around the world |
| North Carolina State University | 2011 | *Rainwater Harvesting at NCSU* | Raleigh, NC | http://www.bae.ncsu.edu/topic/waterharvesting/ | Web page for North Carolina State University, contains rainwater harvester computer model |
| North Dakota State University | 1996 | *Soil, Water and Plant Characteristics Important to Irrigation, EB-66* | Fargo, ND | http://www.ag.ndsu.edu/pubs/ageng/irrigate/eb66w.htm | Soil characteristics for successful irrigation in North Dakota |
| Rain Bird Sprinkler Manufacturing Corporation | 2000 | *Landscape Irrigation Design Manual* | Tucson, AZ | http://www.rainbird.com/documents/turf/IrrigationDesignManual.pdf | Design manual for drip and spray irrigation systems |
| State of California, Department of Natural Resources | 2009 | *Irrigation Scheduling* | Sacramento, CA | http://wwwcimis.water.ca.gov/cimis/infoIrrSchedule.jsp | Home page |
| State of California, Department of Natural Resources | 1981 | *Captured rainfall: small-scale water supply systems* | Sacramento, CA | http://www.archive.org/stream/capturedrainfall213calirich/capturedrainfall213calirich_djvu.txt | Paper introducing concept of collecting rooftop rainwater for small-scale use. |
| State of California, Division of Drinking Water and Environmental Management | 2007 | *Treatment Technology Report for Recycled Water* | Sacramento, CA | http://www.cdph.ca.gov/certlic/drinkingwater/Documents/DWdocuments/treatmenttechnology.pdf | Treatment technologies approved for use in California |
| Stryker | 1986 | *Drip Irrigation Design Guidelines* | Amsterdam | http://www.irrigationtutorials.com/dripguide.htm | Drip irrigation technical guidelines |

## **Implementation Resources** (continued)

| Author | Year | Title | Location | Publisher/Web Link/ Other | Description |
|---|---|---|---|---|---|
| Texas Commission on Environmental Quality | 2007 | *Harvesting, Storing, and Treating Rainwater for Domestic Indoor Use* | Texas | http://www.scribd.com/doc/34474136/Harvesting-Storing-and-Treating-Rainwater | Manual describing collection of rootop runoff and treatment to levels acceptable for indoor potable use in Texas |
| Texas Water Development Board | 2005 | *The Texas Manual on Rainwater Harvesting* | Texas | http://www.twdb.state.tx.us/publications/reports/rainwaterharvestingmanual_3rdedition.pdf | Manual describing collection, storage and treatment for water harvested from rooftops in Texas. |
| U.S. Department of Commerce | 1961 | *Rainfall Frequency Atlas of the United States* | Washington, D.C. | http://www.nws.noaa.gov/oh/hdsc/PF_documents/TechnicalPaper_No40.pdf | IDF curves for the United States |
| University of Florida, IFAS | 2009 | *Materials and Installation of Delivery Pipes for Irrigation Systems* | Arlington, VA | http://edis.ifas.ufl.edu/ch171 | Irrigation material selection and installation |
| University of Florida, IFAS | 1985 | *Drip-irrigation systems for small conventional vegetable farms and organic vegetable farms* | Gainsville, FL | http://edis.ifas.ufl.edu/hs388 | Drip irrigation recommendations for FL |
| University of Florida, IFAS Extension | 2009 | *"Publication #CIR1424, Materials and Installation of Delivery Pipes for Irrigation Systems "* | Gainsville, FL | http://edis.ifas.ufl.edu/ch171 | Irrigation piping materials |
| U.S. EPA | 2004 | *Guidelines for Water Reuse* | Washington, D.C. | http://www.epa.gov/nrmrl/pubs/625r04108/625r04108.pdf | Summarizes the different aspects of water reuse (primarily wastewater); case studies from U.S. and world |
| U.S. EPA | 2011 | *WaterSense (Home page)* | Washington, D.C. | http://www.epa.gov/watersense/ | Link to homepage; contains resources for water efficient practices |
| Virginia Department of Conservation and Recreation | 2011 | *Design Specification No. 6. Rainwater Harvesting* | Richmond, Virginia | http://vwrrc.vt.edu/SWC/april_22_2010_update/DCR_BMP_Spec_No_6_RAINWATER_HARVESTING_Final_Draft_v1-8_04132010.htm | Rainwater harvesting technical specification for Virginia |

## Statutes, Rules, Codes, Ordinances and Regulations Resources

| Author | Year | Title | Location | Publisher/Web Link/ Other | Description |
|---|---|---|---|---|---|
| City of Medina | 2007 | *Water Utility Ordinance* | Media, MN | http://www.ci.medina.mn.us/facts/Ordinances%20-%20Updated%202006/Chapter_7/710.pdf | Water Utility Ordinance - Section 710.75 regulates irrigation systems. Allows stormwater ponds to be used as irrigation source. |
| Ecker | 2007 | *Plumbing Engineer: Rainwater Harvesting and Plumbing Codes* | Northbrook, IL | http://www.harvesth2o.com/plumbing_codes.shtml | Article on rainwater harvesting requirements in various plumbing codes |
| HarvestH2O | 2011 | *Regulations and Statutes* | online | http://www.harvesth2o.com/statues_regulations.shtml | Links to current stormwater and rainwater harvesting codes |
| MN Office of the Revisor of Statutes | 2010 | *MN Statutues: Metropolitan Area Water Supply Planning Activities* | St. Paul, MN | https://www.revisor.mn.gov/statutes/?id=473.1565 | MN statute requiring water supply planning for the Twin Cities |
| MN Office of the Revisor of Statutes | 2010 | *MN Statutes: Public Water Supply Plans; Appropriation During Deficiency* | St. Paul, MN | https://www.revisor.mn.gov/statutes/?id=103g.291 | Requires water conservation plan for all public water supplier serving population greater than 1,000 |
| MN Department of Labor and Industry | 2009 | *Minnesota Plumbing Code* | St. Paul, MN | https://www.revisor.mn.gov/rules/?id=4715&view=chapter | Plumbing systems requirements for Minnesota |
| MN Department of Labor and Industry | 2007 | *Minnesota Provisions of the Building Code* | St. Paul, MN | https://www.revisor.mn.gov/rules/?id=1303 | Building requirements for Minnesota |
| MN Pollution Control Agency | 2010 | *Municipal Wastewater Reuse* | St. Paul, MN | http://www.pca.state.mn.us/index.php/view-document.html?gid=13496 | Fact sheet by MPCA recommending CA standards for wastewater reuse systems |
| Stark, Pushard | 2008 | *On Tap: The State of Rainwater Harvesting in the US* | Morgantown, WV | http://www.nesc.wvu.edu/pdf/dw/publications/ontap/magazine/OT_FA08.pdf | Article on status of rainwater harvesting policies as of 2008 |

## Resource Tool Resources

| Author | Year | Title | Location | Publisher/Web Link/Other | Description |
|---|---|---|---|---|---|
| Bannerman, et al, Wisconsin Department of Natural Resources | 1992 | *Sources of Pollutants in Wisconsin Stormwater* | Madison, WI | http://dnr.wi.gov/runoff/pdf/sources.pdf | Wisconsin study of runoff pollutants from unique sources |
| California Code of Regulations | 2000 | *Water Recycling Criteria, Title 22, Division 4, Chapter 3* | Sacramento, CA | http://www.cdph.ca.gov/certlic/drinkingwater/Documents/Lawbook/RWregulations-01-2009.pdf | California standards for application of treated recycled water |
| California Department of Transportation | 2000 | *Guidance Manual: Stormater Monitoring Protocols* | Sacramento, CA | http://www.dot.ca.gov/hq/env/stormwater/special/guidance_manual/one_file/GUIDANCE_MANUAL.pdf | Protocols for stormwater sampling and monitoring |
| Florida Department of Environmental Protection | 1999 | *Reuse of Reclaimed Water and Land Application* | Tallahassee, FL | http://www.dep.state.fl.us/legal/rules/wastewater/62-610.pdf | Rules on reuse of reclaimed water in Florida |
| Metcalf & Eddy | 2007 | *Water Reuse: Issues, Technologies, and Applications* | | | Textbook |
| Minnesota Department of Health | 2010 | *Environmental Laboratory Search* | St. Paul, MN | https://apps.health.state.mn.us/eldo/public/accreditedlabs/labsearch.seam | List of environmental laboratories certified by the Minnesota Department of Health |
| Minnesota Pollution Control Agency | 2008 | *Minnesota Rule 2050.0222, Specific Water Quality Standards for Class 2 Waters of the State* | St. Paul, MN | https://www.revisor.mn.gov/rules/?id=7050.0222 | Minnesota surface water standards |
| National Resource Management Ministerial Council, et al | 2009 | *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2)* | Australia | http://www.ephc.gov.au/taxonomy/term/39 | Manual decribing collection, storage, treatment and use of stormwater collected from rooftops and ground surfaces in Australia |
| Rosen, et al, Department of Soil, Water and Climate, University of Minnesota | 2008 | *Soil Test Interpretations and Fertilizer Management for Lawns, Turfs, Gardens, and Landscape Plants* | St. Paul, MN | http://www.extension.umn.edu/distribution/horticulture/DG1731.html | Soil testing for Minnesota site |
| University of Minnesota, College of Science and Engineering | 2010 | *Stormwater Treatment: Assessment and Maintenance* | Minneapolis, MN | http://stormwaterbook.safl.umn.edu/ | On-line stormwater treatment manual |
| University of Minnesota, Water Resources Center | 2008 | *Assessment of Stormwater Best Management Practices Manual* | St. Paul, MN | http://wrc.umn.edu/prod/groups/cfans/@pub/@cfans/@wrc/documents/asset/cfans_asset_115795.pdf | Procedures to assess the effectiveness of stormwater Best Management Practices |
| U.S. EPA | 2011 | *Current Drinking Water Standards* | Washington DC | http://water.epa.gov/drink/contaminants/index.cfm | Drinking Water Standards |

## **Resource Tool Resources** (continued)

| Author | Year | Title | Location | Publisher/Web Link/Other | Description |
|---|---|---|---|---|---|
| U.S. EPA | | *Secondary Drinking Water Regulations, Guidance for Nuisance Chemicals* | Washington DC | http://water.epa.gov/drink/contaminants/secondarystandards.cfm | Drinking Water Standards |
| U.S. EPA | 1999 | *Ozone Disinfection Fact Sheet* | Washington DC | http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_ozon.pdf | Ozone disinfection fact sheet |
| Water Environment Research Foundation | 1999 | *Urban and Highway Snowmelt: Minizing the Impact of Receiving Water* | Alexandria, VA | http://www.werf.org/AM/Template.m?Section=Search&Template=/CustomSource/Research/ResearchProfile.cfm&ReportId=94-IRM-2&ID=94-IRM-2 | Snowmelt sampling and analysis |
| Water Reuse Foundation | 2004 | *Irrigation of Parks, Playgrounds and Schoolyards with Reclaimed Water: Extent and Safety* | Alexandria, VA | http://www.watereuse.org/product/irrigation-parks-playgrounds-and-schoolyards-reclaimed-water-extent-and-safety-0 | Use of reclaimed water for parks and playgrounds |
| Brezonik, Staldman | 2002 | *Analysis and Predictive Models of Stormwater Runoff Volumes, Loads, and Pollutant Concentrations from Watersheds in the Twin Cities Metropolitan Area* | Minnesota | Water Research, Volume 36, Issue 7 | Summary of Models |
| Steuer etal | 1997 | *Sources of Contamination in an Urban Basin in Marquette, Michigan and an Analysis of Concentrations, Loadsm and data quality, Middleton, WI.* | Madison, WI | Water Resources Investigations Report 97-4242, USGS | |
| Washbusch etal | 1999 | *Sources of Phosphorus in Stormwater and Street Dirt from Two Urban Residential Basins in Madison, Wisconsin* | Madison, WI | Water Resources Investigations 99-4021, USGS | |
| Water Planning Division, USEPA | 1993 | *Results of the Nationwide Urban Runoff Program* | Washington DC | WH-554 | NURP study |

## Association Resources

| Association | Web Link |
|---|---|
| WateReuse Foundation | http://www.watereuse.org/foundation |
| Harvest H2O | http://www.harvesth2o.com/ |
| American Water Works Association | http://www.awwa.org/index.cfm |
| Water Environment Federation | http://www.wef.org/ |
| American Water Resources Association | http://www.awra.org/ |
| Association of Metropolitan Water Agencies | http://www.amwa.net/ |
| International Code Council | http://www.iccsafe.org/Pages/default.aspx |
| National Association of Clean Water Agencies | http://www.nacwa.org/ |
| US Green Building Council | http://www.usgbc.org/ |
| American Association of Agricultural and Biological Engineers | http://www.asabe.org/ |
| American Society of Civil Engineers | http://www.asce.org/ |
| American Society of Mechanical Engineers | http://www.asme.org/ |
| Building Industry Consulting Services International | https://www.bicsi.org/default.aspx |
| International Rainwater Harvesting Alliance | http://www.irha-h2o.org/ |
| American Rainwater Catchment Systems Association | http://www.irha-h2o.org/ |