User Manual

for

Water Balance Spreadsheet

Version 1.2

Prepared for:

The City of Calgary

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WBSCC – Version History

WBSCC V1.0 (July 2011)	The beta version of WBSCC; presented to the City of Calgary staff, and consulting industry.
WBSCC V1.1 (July 2011)	Some errors detected in Version 1.0 were fixed, and tested for a variety of application scenarios
WBSCC V1.2 (November 2011)	The precision of variables included in the calculations was increased to remove small cumulative errors and to fix one potential error detected in the pond volume calculations of sheet SD.

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1.0 INTRODUCTION

Welcome to the **Water Balance Spreadsheet for the City of Calgary** (**WBSCC**).

The purpose of this spreadsheet is to enable users to:

- Simulate the precipitation-runoff process for urban catchment areas.
- Evaluate the performance of various source control practices and stormwater management facilities.

Such modeling is required for City of Calgary applications.

This tool was originally developed in support of the Theoretical Residential Low Impact Development (LID) Subdivision Project for the City of Calgary. It was used to determine the reduction of annual runoff volumes discharged to either Nose creek or West Nose Creek, by implementing various source control practices. Back then, the City of Calgary Water Resources committed to distribute this tool to the consulting industry for use in support of Master Drainage Plan (MDP), Staged Master Drainage Plan (SMDP), Pond Report and Stormwater Management Report submissions to the City of Calgary.

The WBSCC addresses urban stormwater management issues. It features the following aspects which may not be included in conventional urban drainage modeling software:

- Full flexibility for re-direction of flows from hard surfaces into permeable landscaping, absorbent landscaping or bioretention /bioswale media.
- Full flexibility with the representation of rainwater harvesting and re-use of stormwater accumulated in stormwater management facilities for irrigation (during summer months) or other uses.
- Representation of the replenishment of soil moisture due to irrigation, either from harvested rainwater or stormwater.

- Improved representation of the reduced infiltration during the winter months.
- Reduction of the infiltration capability as a function of clogging over time
- Enhanced statistics and graphical representation of the performance of all source control practices and stormwater management facilities

1.1 Overview of Capabilities

Developed using Microsoft® Excel, the current version of WBSCC can perform continuous simulation of the precipitation-runoff process for an urbanized catchment area -- using a daily time step. Furthermore, the WBSCC allows simulation of the water balance of stormwater storage facilities receiving runoff produced by the catchment area. Pertinent capabilities of the WBSCC includes:

- The WBSCC enables users to characterize the catchment's variability in land use. The catchment is modeled using up to five sub-catchment areas and two central storage facilities -- which can be dry ponds, wet ponds or (constructed) wetlands (see Figure 1).
- Each sub-catchment is comprised of up to five cover types; representing different characteristics for runoff generation. These cover types includes impervious surfaces, pervious surfaces, absorbent landscaping, green roof media, and bioretention/bioswales media.
- Each sub-catchment can be optionally drained to a storage facility (tank) for water re-use.
- Runoff generated from each cover type in a sub-catchment can be routed to other cover types within the same sub-catchment, the local storage facility or to one of the central storage facilities. The current version of the WBSCC has restrictions on which cover types can be routed to other cover types. No loops are allowed in the routing.

- Water re-use can be set for each sub-catchment in the form of irrigation for pervious surfaces, absorbent landscaping and green roof media. In addition, a constant (user defined) rate demand for other uses can be provided.
- Climate data such as daily precipitation, mean daily temperature and monthly evaporation are in the form of time series, which are vital for the current version of WBSCC. For the current version of this spreadsheet, the climate data has been taken from the Calgary International Airport Station for the period 1960-2010.
- The WBSCC simulates precipitation-runoff processes and flow routing using a daily time step; automatically generating an annual summary of results.

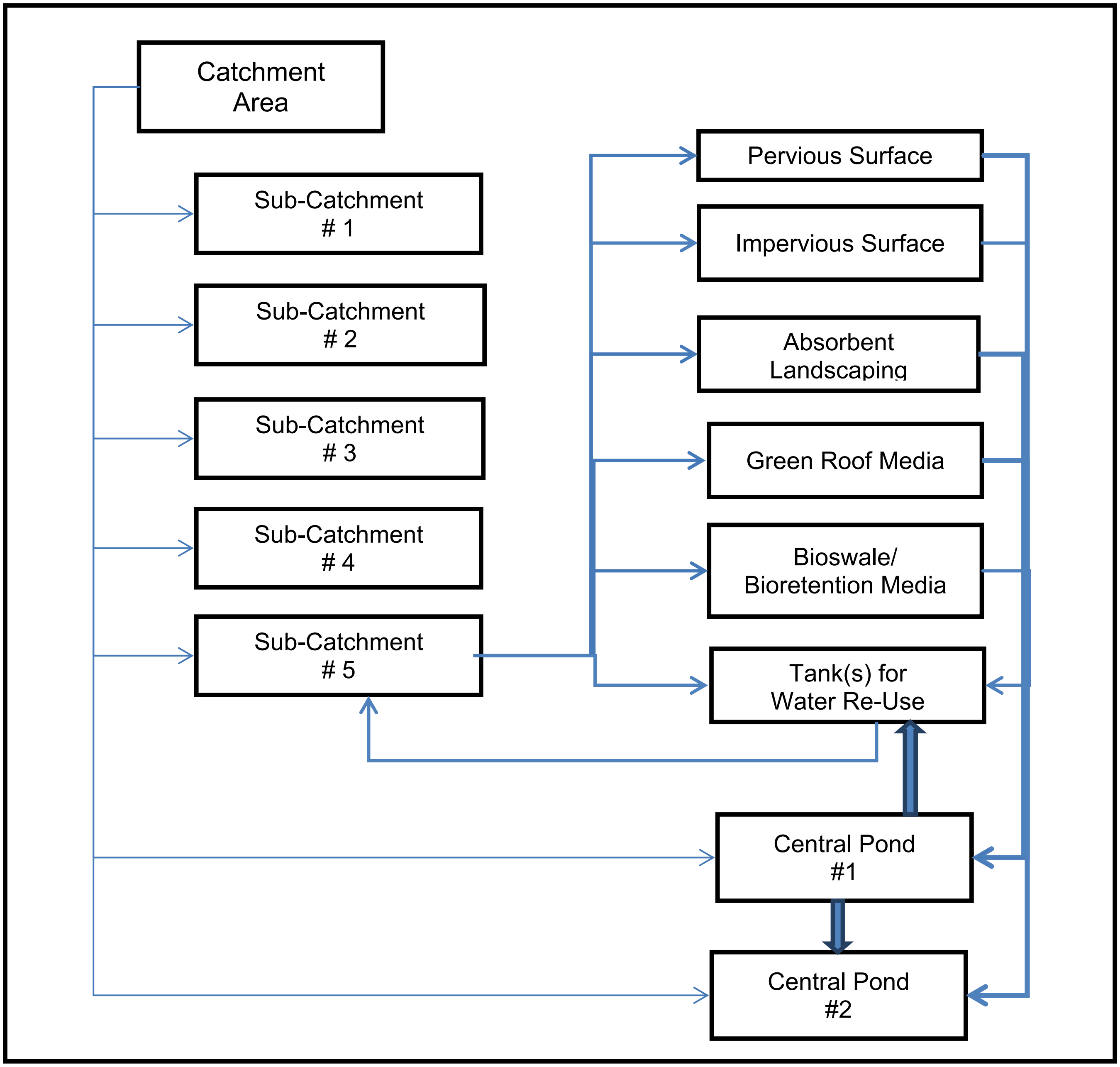

Figure 1: Water Balance Spreadsheet Overview

1.2 Using this Manual

1.2.1 User Background

This manual is for users with a working knowledge of stormwater management principles and urban drainage modeling – focused on Source Control BMPs and LID. Users are advised to be proficient in Microsoft® Excel.

1.2.2 Organization of Manual

This manual is organized into the following sections:

Section 1: Introduction, concepts and limitations of the WBSCC including scientific background of the catchment area model in the WBSCC.

Section 2: Technical overview illustrating data requirements and the mathematical representation of the modeling process in the WBSCC.

Section 3: Installing the WBSCC

Section 4: Organization of worksheets in the WBSCC.

Section 5: Instructions for the WBSCC including data management, computation and viewing of results.

Section 6: References.

Appendix A: An application example of the WBSCC.

Appendix B: Glossary of technical terms.

Appendix C: Steps involved in estimating the hydraulic properties of soils/media using the software SPAW.

Appendix D: Design tables and graphs

1.2.2.1 CATCHMENT AREA DESCRIPTION

This section describes the catchment area model used by WBSCC. It is comprised of up to five sub-catchment drainage areas and up to two central water storage facilities (see *Figure 2).* Central water storage facilities can include wet/dry ponds and/or (constructed) wetlands. In the majority of cases, the central water storage facilities will be ponds. Consequently, in the WBSCC, central water storage facilities are generically referred to as ponds.

Runoff from each sub-catchment is calculated based on the land use and related parameters. Both central storage facilities can be modeled to receive runoff from the sub-catchments and discharge excess runoff through an outfall to a receiving water body. One of the facilities can be modeled to discharge into the other facility. Furthermore, water can be re-used from either facility.

The footprint of each central storage facility is composed of the inundated area of the pond and the surrounding dry area, which is assumed to have a pervious cover type similar to the five sub-catchments. While the total footprint area of each central storage facility is fixed, the size of the inundated area can increase and decrease as a function of the amount of runoff entering the facility and water being re-used or discharged. As the inundated area increases in size, the size of the adjacent pervious dry area decreases and vice versa. The benefit of this approach is that it allows for the appropriate representation of evaporation facilities.

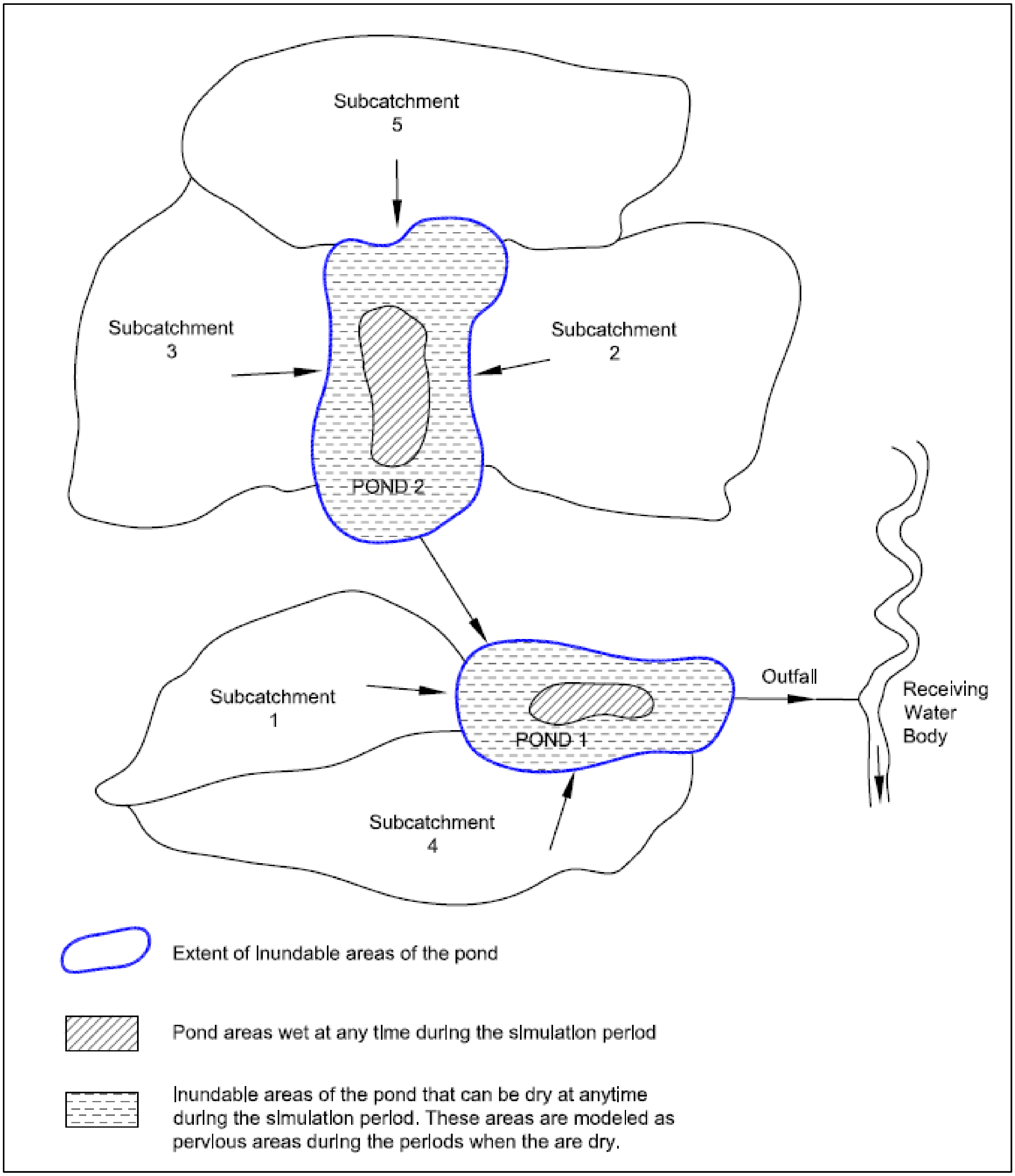

Figure 2: Sub-catchment Sketch

1.3 Sub-catchment Model

Section 1.3 describes the sub-catchment model and land use set up.

1.3.1 Sub-catchment Concept

Figure 3 *Sub-Catchment Schematic Diagram* illustrates the dynamics for possible water movements across the various cover types of a sub-catchment and into a tank for water re-use. It is possible to include up to five cover types: an impervious surface, a pervious surface, an absorbent landscaping, a green roof media, and a bioretention/bioswale media.

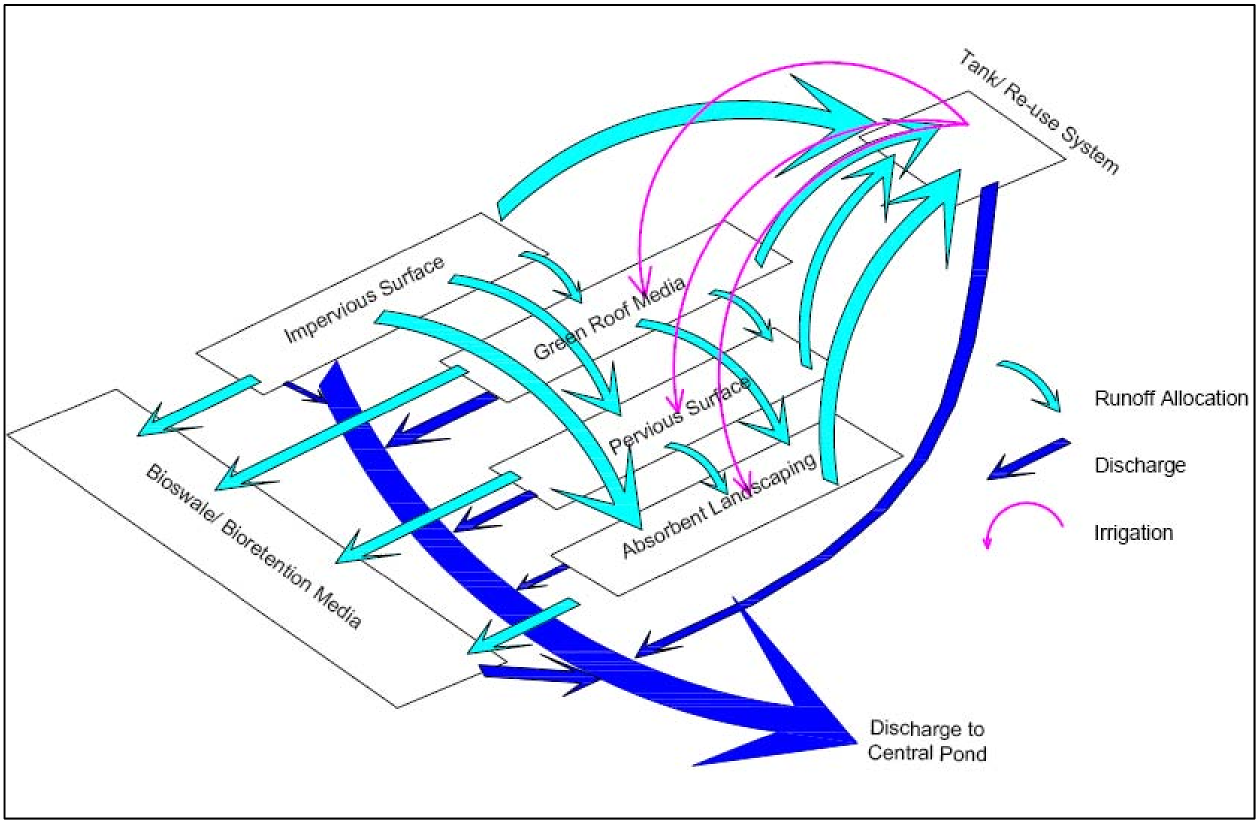

Figure 3: Sub-catchment Schematic Diagram

Runoff generated from each cover type can be partially or fully allocated to other cover types or storage tank. Water collected in the storage tank can be used for supplementing irrigation and other demands. The remaining portion of runoff, if any, is assumed to drain directly into one of the two central ponds or water storage facilities (i.e. dry pond or (constructed) wetland). It cannot drain into both central ponds.

Table **1** shows the allocation rules pertaining to each sub-catchment area and the central ponds. A check mark means yes and the “x” means no. The impervious surfaces can drain to any sub-catchment, while the pervious surfaces can drain to all sub-catchments; except for the impervious surfaces and green roof media. Absorbent landscaping cannot drain to pervious surfaces and green roof media. Runoff from the bioretention/bioswale media can only drain to the ponds, whereas water accumulated in the ponds can only be directed to storage tanks for water re-used and to other pond. Pond to pond redirection indicates the discharge from one pond to the other.

Table 1: Runoff Allocation Rules for LID Projects

Source of Runoff/Planned Discharge	**Destination**					
	Pervious Surface	Absorbent Landscaping	Green Roof Media	Bioretention /Bioswale Media	Tank for Re-use	Pond
Impervious Surface	√	√	√	√	√	√
Pervious Surface	N/A	√	X	√	√	√
Absorbent Landscaping	X	N/A	X	√	√	√
Green Roof Media	√	√	N/A	√	√	√
Bioretention /Bioswale Media	X	X	X	N/A	X	√
Municipal Make-up/Tank Re-use	√	√	√	X	N/A	X
Central Ponds	X	X	X	X	√	√

Check mark means yes. The “x” means no.

1.3.2 Sub-catchment Cover Types

In the real world, the surface of a sub-catchment area is comprised of a mixture of various land uses, including roofs, roadways, driveways, landscaped green areas, natural green areas, absorbent landscaping, green roof media, bioretention areas, bioswale areas, etc. For purposes of modelling the sub-catchment areas using WBSCC, users measure areas on land uses from actual plans or aerial photos and aggregate them in the available cover types.

Section 1.3.2.1 to 1.3.2.7 describe the characteristics of each sub-catchment cover type and storage tanks in detail.

1.3.2.1 Impervious Surfaces

This idealized area combines all impervious surfaces within each sub-catchment. The area size corresponds to the total of all the impervious surfaces within the sub-catchment. Impervious surfaces are made of (or paved with) materials that prevent the infiltration of water; they include roads, gutters, driveways, roofs, etc. There is no need for the impervious surfaces within each sub-catchment to be connected. However, the setup of the WBSCC requires that they have similar characteristics defined by the parameters as described in Section 2.2. Runoff from impervious surfaces can be partially or fully allocated to any other sub-catchment unit as seen in Figure 3, or described in Table 1.

1.3.2.2 Regular Pervious Surfaces

Regular pervious surfaces are areas that allow infiltration of water and are not part of absorbent landscaping, green roofs or bioretention areas/bioswales. Regular pervious surfaces within each sub-catchment do not need to be connected, but they must have similar characteristics represented by the required parameters as described in Section 2.2. Runoff from pervious surfaces can be partially or fully allocated to other sub-catchment areas as seen in Figure 3, or described in Table 1. Such allocation is only possible to absorbent landscaping, bioretention areas/bioswales or to the tank. Allocation to impervious surfaces or green roofs is not permitted.

1.3.2.3 Absorbent Landscaping

Absorbent landscaping are surfaces designed to enhance water retention. Absorbent landscaping within each sub-catchment do not need to be connected but they must have similar characteristics represented by the required parameters as described in Section 2.2. Runoff from absorbent landscaping can be allocated to bioretention /bioswale media and to the storage tank for water re-use. Allocation into impervious surfaces, green roof media or regular pervious surfaces is not permitted. Absorbent landscaping is treated identical to regular pervious surfaces, except for the differences in allocation.

1.3.2.4 Green Roof Media

Green roof media consists of soil/permeable medium placed on the roofs of buildings, partially or fully, covered with vegetation and are provided with appropriate drainage facilities. Green roof media within each sub-catchment do not need to be connected but they must have similar characteristics represented by the required parameters as described in Section 2.2. Runoff from green roof media can be allocated to absorbent landscaping, bioretention bioswale media, regular pervious surfaces and to the storage tank for water re-use; allocation to impervious areas is not permitted.

1.3.2.5 Bioretention and Bioswale Media

Bioretention /bioswales media are depressed landscaped areas underlain by a soil medium that may percolate into the sub-soils and/or discharge via a sub-drain. Various bioretention/bioswale media may exist in the sub-catchment but they must share similar characteristics as described in Section 2.2. Runoff from bioretention/bioswale media is not allowed to be redirected to any other cover types; it is assumed to drain directly into one of the central ponds.

1.3.2.6 Storage Units for Water Re-use

The storage unit for water re-use is a tank with a constant surface area (i.e., with vertical walls) which does not receive direct precipitation but collects runoff from other units. Irrigation from the storage tank can be provided to green roof media, absorbent landscaping and regular pervious surfaces. In addition, supply for a constant-rate non-potable water demand is supported.

1.3.2.7 Discharge

The total runoff from the entire subcatchment into the central facilities, for the purpose of the WBSCC and this user manual, will be referred to as Discharge.

This variable aggregates runoff from all cover types not internally allocated to other cover types. It also includes spills from the storage tank, when the tank capacity is exceeded.

1.4 Central Storage Facilities Model

Two central storage facilities (also referred to as storm ponds, dry ponds or (constructed) wetlands) can be included to receive runoff from the various sub-catchment areas. The combined runoff from each sub-catchment can be directed to only one of the two central storage facilities, typically a stormwater pond. Each pond can receive runoff from one or more sub-catchments.

Runoff collected in these central facilities can be allocated for water re-use to tanks in one or more sub-catchment areas for particular days when the water demand is not covered by the amount of water available within the storage tanks.

Water discharges from these facilities, namely the off-site discharges, can be directed via a control structure (or overflow) to an outfall or the other storage facility. Loops are not allowed; discharges from Pond #1 can be directed to Pond #2 and from Pond #2 to Pond #1 but not simultaneously.

2.0 TECHNICAL OVERVIEW

2.1 Climate Data

2.1.1 Precipitation

The daily precipitation (total) data from the Environment Canada – Weather Office database is used for the period 1960-2010 for the station 3031093 – Calgary International Airport, Alberta. Total precipitation is defined by Environment Canada as the sum of the total rainfall and the water equivalent of the total snowfall observed during each day of the record.

2.1.2 Temperature

The mean daily temperature is in degrees Celsius (C) from the Environment Canada – Weather Office database for the station 3031093 – Calgary International Airport, Alberta is used for the period 1960-2010.

2.1.3 Evaporation and Evapotranspiration

Monthly lake evaporation data was obtained for the period 1960-2001 from the *Evaporation and Evapotranspiration in Alberta 1912 to 1985* report and addendums issued by Alberta Environment (Hydrology Branch). Monthly values of potential evapotranspiration rates were retrieved from these reports for the period 1960-2001. Beyond 2001, average values from 1960 to 2001 were used for each month.

2.1.4 Effective Precipitation

Effective Precipitation represents accumulation of non-liquid precipitation. It is defined as the potential amount of snow on the ground that is assumed to be melted in a single day when the daily temperature reaches a defined threshold. Non-liquid precipitation is reduced by sublimation losses based on a user-defined factor. Residual precipitation is accumulated on the ground until the day when the temperature threshold for melting is reached.

2.2 Water Balance and Runoff Modeling

2.2.1 General Runoff Model

The General Runoff model for all cover types is based on a simplified water balance approach where the change in soil moisture over time is computed as a function of inflows (i.e., precipitation, run-on, irrigation, etc.) and outflows (i.e., evapotranspiration, groundwater flux, sub-drain flow, runoff, etc.), representing the water storage within soil or media as a simple reservoir. The moisture level in this reservoir varies between the wilting point, below which there is no moisture available for evapo-transpiration, and saturation where all pore spaces are completely filled with water. Seepage starts when the moisture level exceeds the field capacity (Appendix C provides an illustration of various soils/media properties used in the WBSCC). If ponding is allowed on the surface, additional water retention beyond the porosity is possible.

Various inflow and outflow variables involved with the general runoff model are shown in

Figure 4, while the water balance computation is expressed by Equation 1.

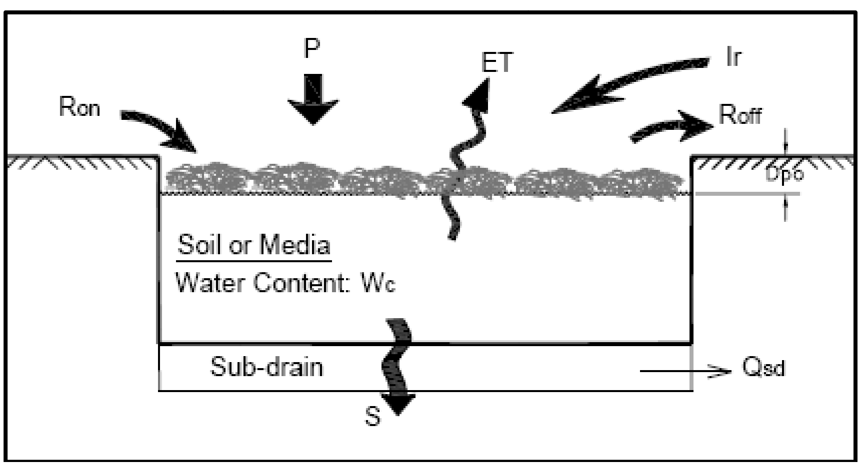

Figure 4: General Runoff Model

Equation 1: Change in Water Content of the Soil in One Day

$$\frac{\Delta W_C}{\Delta t} = P + R_{on} + Ir - ET - S - R_{off} - Q_{sd}$$

Where:

W_C	Soil water (mm)
Δt	Time interval (1 day)
P	Precipitation (mm)
R_{on}	Run-on (mm)
Ir	Irrigation supply (mm)
ET	Evapo-transpiration (mm)
S	Seepage (mm)
Q_{sd}	Sub-drain flow (mm)

The inflow and outflow variables are expressed in mm, assuming that these variables consider a unit area of catchment. Equation 1 is valid over a time period in which the inflow and outflow components can be considered to be constant.

2.2.2 Runoff from Impervious Surfaces

Runoff from impervious surfaces can flow to green roof media, pervious surfaces, absorbent landscaping, bioswale/bioretention media or into a tank for water re-use. The user determines where the surface runoff ends up.

The runoff from impervious surfaces is determined by subtracting the depression storage of the catchment area from the total precipitation. Run-on from external areas can be incorporated in calculation by providing values for the entire period of modelling. Figure 5 shows the relevant variables involved in the water balance for the impervious surfaces.

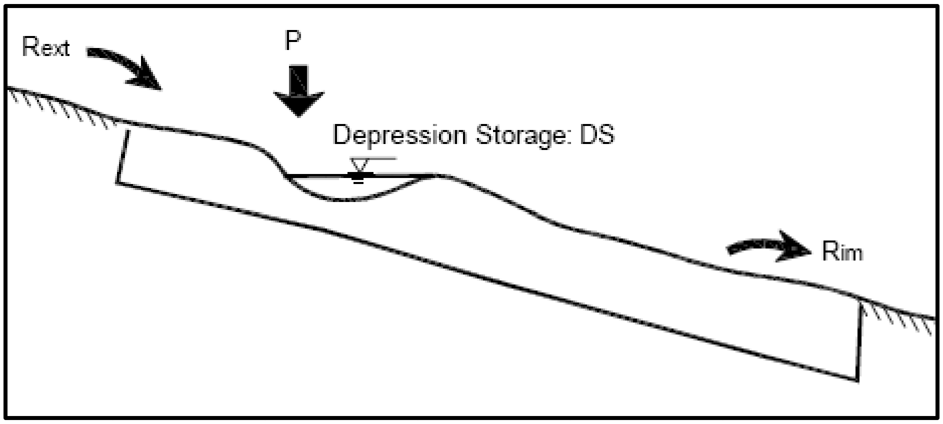

Figure 5: Variables of Water Balance for Impervious Surfaces

The runoff from impervious surfaces is determined using Equation 2 in a time step indicated by *i.* This variable represents any day out of the 18,628 days in the model (1960-2010).

Equation 2 Runoff from Impervious Areas

Where:

R_{im}	Runoff from impervious area (mm)
R_{ext}	Run-on from external areas (mm)
D_s	Depression storage (mm)
	Precipitation (mm)

The following assumptions ensure the validity of Equation 2:

- The travel time of flow on the impervious areas is much smaller than the time step of 24 hours. This is usually met as the travel time is typically in the order of few minutes in urban areas

- Precipitation is assumed to be liquid. For snowmelt events, the effective precipitation (as described in section 2.1.4) is used.

2.2.3 Water Balance from Regular Pervious Surfaces

Runoff generated from pervious surfaces can flow to bioswale/bioretention media and absorbent landscaping prior to discharge into a central storage facility; or collected and stored in tanks for water re-use.

Variables involved in the water balance for regular pervious surfaces are shown in Figure 6.

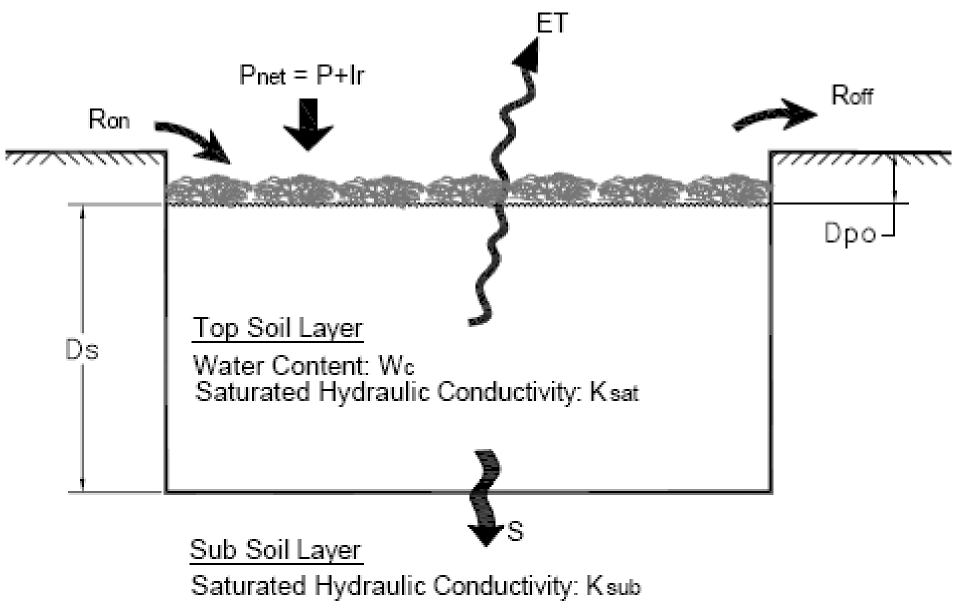

Figure 6: Variables of Water Balance for Pervious Surfaces

The change in soil water content, during time step ***i,*** is determined using the relationships expressed by Equation 3.

Equation 3 Change in Soil Water Content

$$W_c(i+1) = Max \begin{bmatrix} W_c(i) + P_{net}(i) + R_{on}(i) - S(i) - ET(i) - R_{off}(i), \\ D_S * W_p \end{bmatrix}$$

Where:

$W_c(i+1)$	Soil water at the beginning of period i+1 (mm)
$P_{net}(i)$	Net precipitation including irrigation during period i (mm)
$R_{on}(i)$	Run-on during period i (mm)
$S(i)$	Seepage during period i (mm)
$R_{off}(i)$	Run-off during period i (mm)
D_s	Depth of soil (mm)
W_P	Wilting point

In Equation 3, all inflow and outflow volumes, as well as the amount of soil water are expressed in mm for a unit base area. The minimum effective water content of the soil mass considered is D_s*W_p. The field capacity of soil limits the seepage as expressed by Equation 4. The soil water content varies between the wilting point and the porosity under normal conditions. If ponding is allowed, additional water retention beyond porosity is possible. The initial soil water content, for the very first day of simulation, is assumed to be the average of the wilting point and the field capacity. The seepage loss during period ***i*** is determined using Equation 4.

Equation 4 Seepage through the Soil

$$S(i) = Min\begin{bmatrix} Max\{W_c(i) - D_S * F_c, 0\}, \\ C_t * 1000 * Min\{F_\theta * K_{sat}, K_{sub}\} \end{bmatrix}$$

Where:

F_c	Field capacity
C_t	Constant to convert day to seconds (86400)
K_{sat}	Saturated hydraulic conductivity for the soil (m/s)
K_{sub}	Saturated hydraulic conductivity for the sub-soil (m/s)
F_θ	Factor to account for the reduction in hydraulic conductivity for the soil when the moisture content in the soil is less than porosity.

F_θ is determined based on Saxton's formula (Saxton and Rawls, 2006) as shown by Equation 5:

Equation 5

$$F_\theta = Max\left[1, \left(\frac{W_C(i)}{\eta}\right)^{3+\frac{2}{\lambda}}\right]$$

Where:

$1/\lambda$	Inverse slope of the logarthimic tension moisture curve (See Appendix C)
η	Porosity of the soil//medium; numerically equivalent to the volumetric water content at saturation.

The maximum water that can be stored in the soil matrix and ponding area above ground is determined using Equation 6.

Equation 6 Maximum Water Stored in Soil Matrix

$$\boldsymbol{MaxWat} = \eta * \boldsymbol{D_s} + \boldsymbol{D_{po}}$$

Where,

MaxWat maximum amount of water in the soil and the ponding area (mm)

D_{po} Average ponding depth above the soil surface (mm)

Finally, runoff is determined using Equation 7.

Equation 7

$$R_{off}(i) = Max \begin{bmatrix} W_c(i) + P_{net}(i) + R_{on}(i) - S(i) - ET(i) - MaxWat, \\ 0 \end{bmatrix}$$

2.2.4 Water Balance from Absorbent landscaping

The methodology to determine the water content, seepage and the runoff for absorbent landscaping is identical to that of the regular pervious surfaces, as described in Section 2.2.3.

Runoff from absorbent landscaping can find its way into bioswale/bioretention media prior to discharge into a central storage facility; or into a water tank for water re-use.

2.2.5 Water Balance from Green Roof Media

The determination of water content and runoff for green roof media is similar to that of the regular pervious surfaces. For seepage, the procedure is slightly different to account for the lack of any subsoil. Runoff from green roof media can flow onto pervious surfaces, absorbent landscaping and bioswale/bioretention media prior to discharge into a central storage facility; or into a tank for water re-use. The Variables involved in the determination of water balance from green roof media are shown in Figure 7.

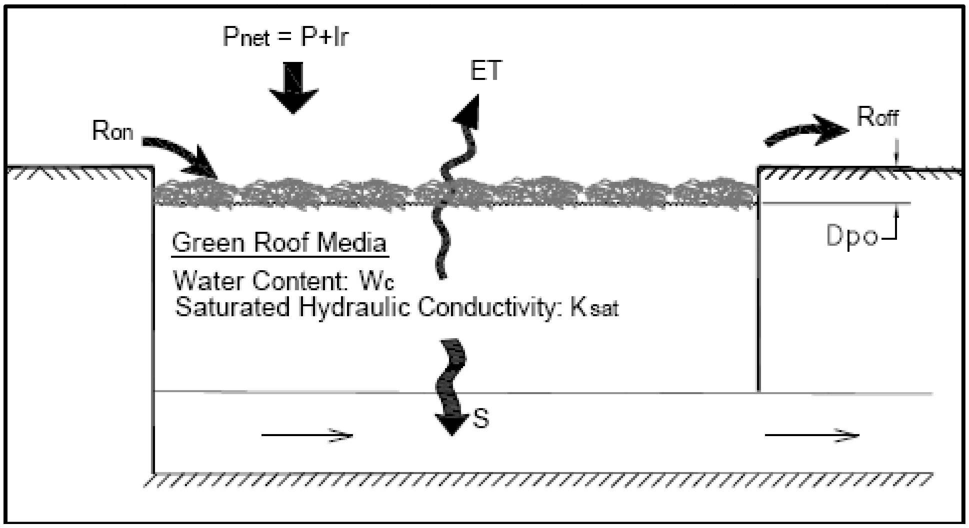

Figure 7: Variables of Water Balance for Green Roof Media

Equation 8 is used to determine seepage.

Equation 8 Seepage

F_c	Field capacity
C_t	Constant to convert day to seconds (86400)
K_{sat}	Saturated hydraulic conductivity for the soil (m/s)
F_θ	Factor to account for the reduction in hydraulic conductivity for the soil when the moisture content in the soil is less than porosity.

2.2.6 Water Balance from Bioswale/Bioretention Media

The variables involved in the water balance for bioretention/bioswale media are shown in Figure 8. Runoff from bioswale/bioretention media is released to discharge to a central storage facility.

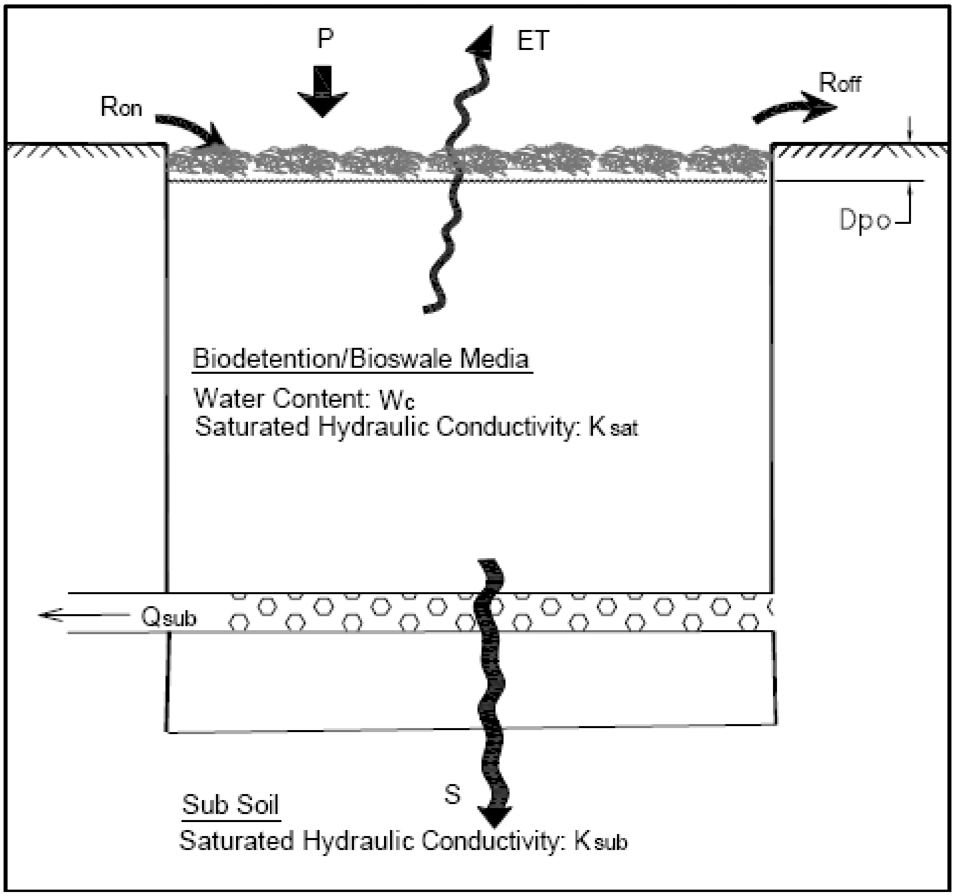

Figure 8: Variables of Water Balance for Bioswale/Bioretention Media

The determination of water content in bioretention/bioswales media is similar to that of the pervious surfaces, and is accomplished by using Equation 3.

As bioretention/bioswale media can have a subdrain located at any elevation above the bottom of the soil media, a new variable, $WL(i)$, is introduced to determine the surface water elevation assuming that during the time step (1 day) the water level in the trench must first reach the elevation of the subdrain holes before water actually exits through subdrain. $WL(\mathrm{i})$ is determined using Equation 9.

Equation 9

$$WL(i) = \frac{W_c(i) - D_s * F_c}{\eta - F_c}$$

Seepage through the soil media during period i depends on the invert elevation of sub-drain (I_{sub}) in relation to $WL(i)$. If $WL(i)$ is greater than I_{sub} then a sub-drain flow term is included in the estimation of seepage. This is expressed by Equation 10.

Equation 10

$$\boldsymbol{S(i) = Min\begin{bmatrix} Max\{(W_c(i) - D_S * F_C), 0\}, \\ C_t * 1000 * K_{sat} * F_\theta * F_{ip}, \\ C_t * \begin{Bmatrix} \dfrac{Q_{sub}}{10 * A_{bi}}, if\ WL(i) > I_{sub} \\ 0, \quad if\ WL(i) < I_{sub} \end{Bmatrix} + C_t * 1000 * K_{sub} \end{bmatrix}}$$

Where:

F_{ip}	Factor to account for a reduction due to clogging of the soil media based on the ratio of impervious to pervious surface area
A_{bi}	Area draining into the subdrain (ha)
Q_{sub}	sub-drain capacity (m^3/s)

The maximum amount of water that can be stored in the soil matrix and ponding area above the ground is determined using Equation 6.

The runoff from the bioretention/bioswales media is determined using Equation 11.

Equation 11

$$R_{off}(i) = Max\begin{bmatrix} W_c(i) + P_{net}(i) + R_{on}(i) - S(i) - ET(i) - MaxWat, \\ 0 \end{bmatrix}$$

2.2.6 Storage for On-Site Water Re-use Units

Variables involved in the water balance for on-site water re-use units are shown in Figure 9.

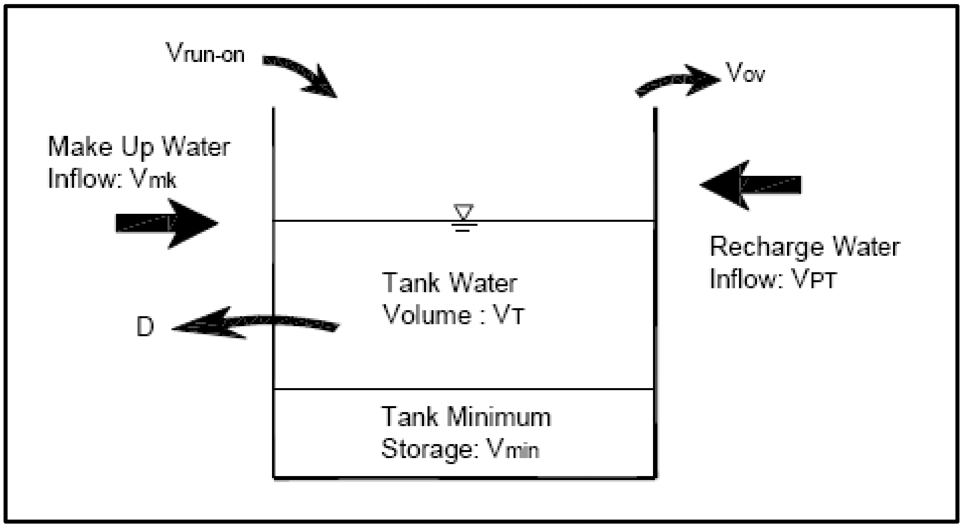

Figure 9: Variables of Water Balance for Storage for Re-use System

Overflow volume from the tank to the central ponds is determined using Equation 12.

Equation 12

$$\boldsymbol{V_{ov}(i) = Max\begin{bmatrix} V_T(i-1) + V_{run-on}(i) + V_{mk}(i) - D(i) + V_{PT}(i) - V_{Tmax}, \\ 0 \end{bmatrix}}$$

Where:

$V_{ow}(i)$	Overflow volume during period i (m^3)
$V_T(i-1)$	Water volume at the beginning of period i (end of period i-1) (m^3)
$V_{run-on}(i)$	Total run-on volume during period i (m^3)
$V_{mk}(i)$	Total make-up volume during period i (m^3)
$D(i)$	Total demand during period i (m^3)
$V_{PT}(i)$	Total recharge volume from the central ponds during period i (m^3)
V_{Tmax}	Maximum storage capacity over which overflow occurs (m^3)

If desired, the user may choose to use municipal make-up water to fully cover the demand during each day of the simulation. The demand includes both irrigation and other constant non-potable water demands.

If the storage tank overflows, the end-of-time step volume will be V_{Tmax}; otherwise, it will be calculated by Equation 13.

Equation 13

$$V_T(i) = V_T(i-1) + V_{run-on}(i) + V_{mk}(i) - D(i) + V_{PT}(i) - V_{ov}(i)$$

2.3 Central Storage Ponds

The water balance calculations for the two central storage ponds are conducted to estimate pond variables such as water elevation, storage volume, discharges and overflow volumes. Variables involved in the water balance for the central storage ponds are shown in Figure 10.

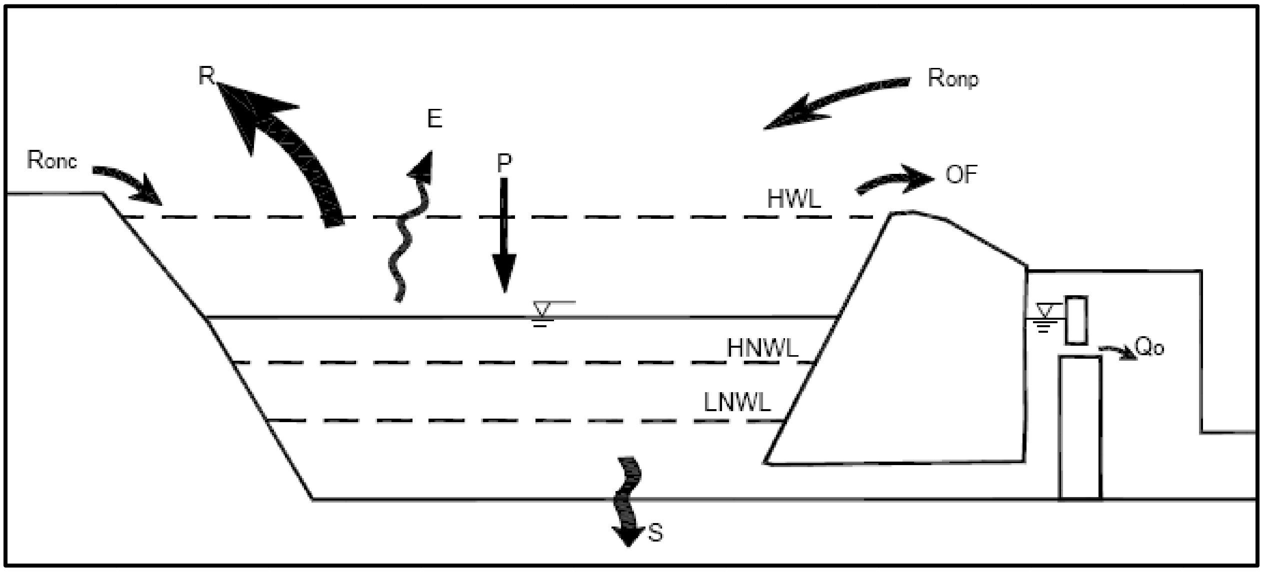

Figure 10: Variables of Water Balance for Central Ponds

The change in volume in the central storage ponds is determined during each time step using Equation 14.

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Equation 14 Change in Volume in Central Pond for each Time Step

$$V(i) = V(i-1) + P(i) + R_{onc}(i) + R_{onp}(i) - R(i) - E(i) - S(i) - OF(i) - Q_o(i)$$

Where:

V(i)	Pond water volume at the end of period i (m^3)
P(i)	Volume of direct precipitation during period i (m^3)
$R_{onc}(i)$	Run-on volume from sub-catchment areas during period i (m^3)
$R_{onp}(i)$	The volume of water received from other ponds during period i (m^3)
R(i)	Recharge volume sent to re-use tanks during period (i)
E(i)	Total evaporation loss during period i (m^3)
S(i)	Total seepage loss during period i (m^3)
OF(i)	Total overflow during period i (m^3)
$Q_O(i)$	Total flow via control structure (m^3)

The total volume of direct precipitation, evaporation and discharge over a simulation time step depend on the pond surface area and elevation. Ideally, the average values of area and elevation over a simulation time step (i.e., the average of the start-of-time step and the end-of-time step values) should be used in estimating direct precipitation, evaporation and discharge. However, the end-of-time step values of pond area and elevation are not known explicitly, until the end-of-time step volume is determined. A predictor-corrector iterative approach is used to arrive at a better solution of the variables involved.

The predictor-corrector iterative approach involves with the following steps:

1. Determine the direct precipitation, evaporation and discharge for a time step using the pond area and elevation of the previous time step.
2. Determine the end-of-time step pond volume using the flow quantities derived from Step 1.
3. Determine the end-of-step pond area and elevation using the volume computed in Step 2.
4. Determine the averages of pond area and elevation based on the values in the previous time step and in Step 3.
5. Determine the direct precipitation, evaporation and discharge using the average values of pond area and elevation found in step 4.
6. Determine the end-of-time step volume using the direct precipitation, evaporation and discharge found in Step 5.

2.4 WBSCC Simulation

The simulation span for the WBSCC is from January 1, 1960 to December 31, 2010, which corresponds to the climate data span. The columns in the worksheets for computation represent distinct variables and the cells in these columns contain Excel-based formulas representing intermediate or final steps of computation. The *WBSCC Simulation* represents re-computation of cells that contain formulas, based on the user input data. This operation updates the values of formula-resident cells and generates the daily time series of the relevant variables. The annual summaries and statistics of selected variables are automatically developed along with re-computation.

2.5 Summary of Assumptions

The following assumptions are made in modeling the runoff from an urbanized catchment area using the WBSCC:

- The effective precipitation is assumed as the potential amount of snow on the ground that is assumed to be melted in a single day when the daily temperature reaches a defined threshold.
- Non-liquid precipitation is reduced by sublimation losses based on a user defined factor.
- Residual precipitation is accumulated on the ground until the day when the temperature threshold for melting is reached.
- Inflow and outflow variables in water balance modeling are assumed constants within the computational time step (i.e. 1 day).
- The travel time of flow on the impervious areas is much smaller than the time step, which is 24 hours. This is usually met as the travel time is typically in the order of few minutes.

3.0 INSTALLING WBSCC

3.1 General

The WBSCC can be copied to any folder during installation. The computer should be equipped with Microsoft® Excel Version 2007 or a later version. When the WBSCC is opened, a new ribbon named WBSCC will appear in *Excel*. Buttons in this panel will assist the user with performing various operations.

3.2 Hardware Requirements

The WBSCC requires about 165 MB hard disk space for each application saved. In addition, in view of the computations performed, sufficient physical memory (4GB or higher) should be available to minimize the computational time.

4.0 ORGANIZATION OF WBSCC

The WBSCC is composed of a collection of worksheets that fall under three categories: (1) Information, (2) Computation and, (3) Results. In addition, a user friendly wizard is provided to develop customizable graphics of computational results. Figure 11 shows the organization of the worksheets in the WBSCC.

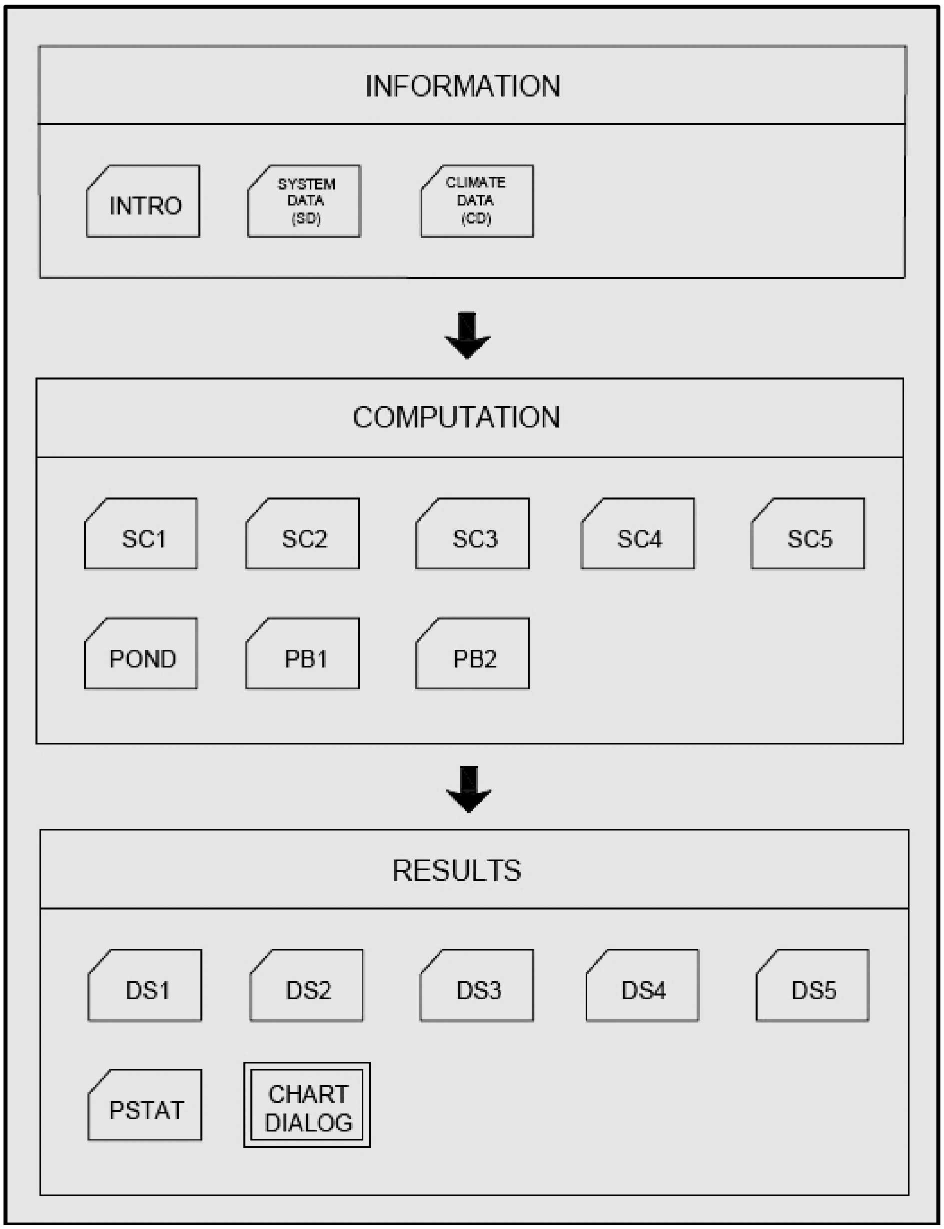


Figure 11 : WBSCC Organization

4.1 Information Worksheets

4.1.1 INTRO Sheet

The INTRO worksheet provides general information about the various worksheets in the WBSCC. A statement of the liability limitation as well as the contact information is also provided in INTRO.

4.1.2 System Data

The System Data (SD) worksheet contains the general information of the site, tabulated data sets for the five sub-catchments and two storm ponds, crop profiles for selected cover types, and the irrigation schedules. This worksheet also contains information such as the desired runoff allocation between the various cover types within each sub-catchment as well as the discharge routing information between the storm ponds. The user needs to enter all relevant catchment data through this worksheet. Additional data such as the annual clogging factor (which limits the amount of seepage) based on the impervious to pervious area ratios, as well as the external Run-on time series are provided in Worksheet SD1.

4.1.3 Climate Data

The Climate Data (CD) worksheet contains time series of historical daily precipitation, mean daily temperature, and monthly potential evaporation/evapo-transpiration data. Tables to convert the potential evaporation/evapo-transpiration data to the actual watershed conditions are also provided in this worksheet.

4.2 Computation Worksheets

The internal computational results are presented for the various sub-catchments and ponds. These results are in the form of daily time series, over the computational time domain.

4.2.1 Sub-catchment Computation

Worksheets Sub-catchment (SC1) through SC5 show the computational details for Sub-catchments 1 through 5. In each worksheet, variables involved in the water balance computation regarding each cover type and the storage/re-use tank are provided in the form of daily time series. An annual summary table, highlighting the statistics of pertinent variables is also provided.

Worksheets Pond Boundary (PB1) and PB2 show the water balance computation involved with the non-submerged areas surrounding Ponds 1 and 2, respectively. As discussed in Section 2.0, these areas are assumed to have a pervious surface cover type, and the runoff generated by these areas is allocated to the respective pond.

4.2.2 Ponds Computation

Variables in the water balance computation of Ponds 1 and 2 are provided in Worksheet POND. This worksheet also contains additional variables used in the predictor-corrector computation of the pond capacity, surface area and stage. An annual summary table, highlighting the statistics of pertinent variables is also provided.

4.3 Results Worksheets

4.3.1 Sub-catchment Statistics

Worksheets DS1 through DS5 (Detailed Statistics) show the summary statistics and the aggregated results of pertinent variables for each sub-catchment.

4.3.2 Pond Statistics

Worksheet PSTAT shows the summary statistics as well as the aggregated results of pertinent variables involved in the water balance computation of the two ponds.

4.4 Chart Dialog User Interface

A user-customizable dialog is provided to create graphs based on the available time series.

5.0 WORKING WITH WBSCC

5.1 Security Settings for WBSCC

It is required that the standard security settings of Microsoft® Excel are relaxed so that the macro-enabled WBSCC application can be opened in Microsoft® Excel 2007 or a later version. This can be achieved by accessing the Excel Options, then the Trust Center and then the Macro Settings. Select *Enable all macros* and check off "Trust access to the VBA project object model"(see Figure 12. Note: Figure 12 shows the settings for Microsoft® Excel 2010).

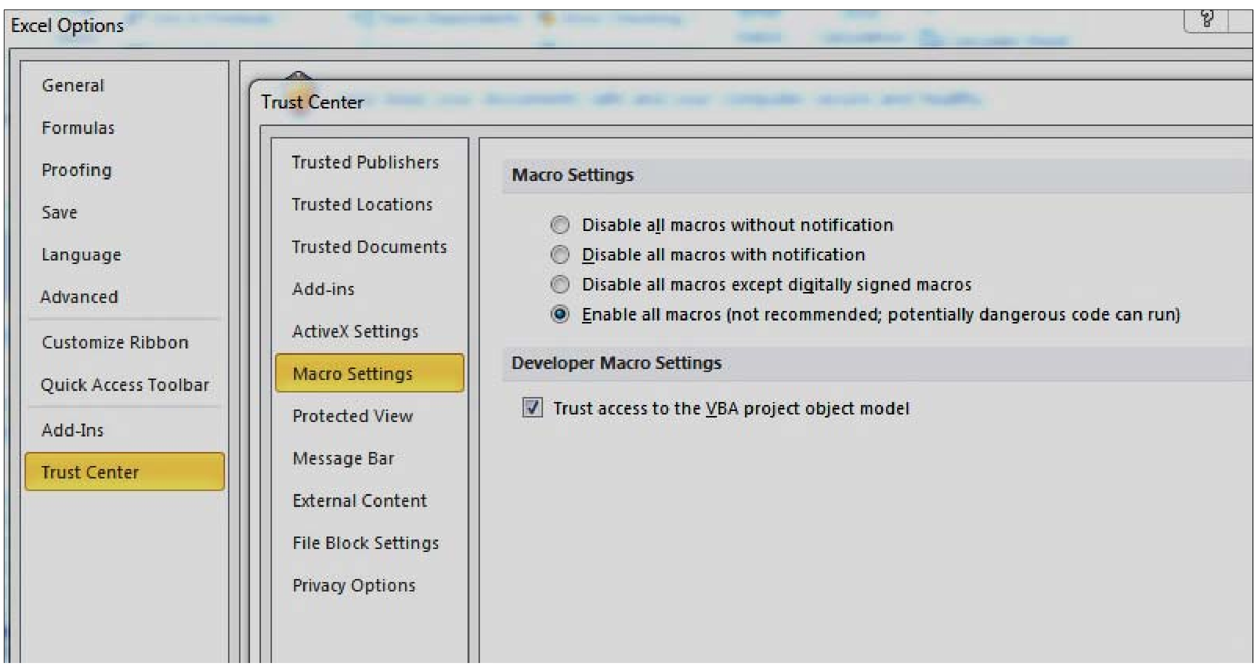


Figure 12: Security Settings for WBSCC

5.2 Entering Data

The data required to complete the modeling process is provided through Worksheets CD and

SD. The current version of the WBSCC prevents any modifications to the climate data by the user. However, the user may view the climate data from Worksheet CD.

The system data is entered in the cells with blue background in Worksheet SD. It is important that Worksheet SD is viewed using the “Page Layout View”, with the page size set to Letter sized (8.5 x 11 inches) and orientation set to Landscape to follow the steps below. In total, there are 24 pages in the Page View, with Pages 20,21, 23 and 24 intentionally left blank.

Page 1 (Figure 13) may be populated with the project summary information. Provide information such as Project Name, Project Description, Location, Date, Designer (Modeller) and Reviewer (See Data Block 1[1]). Data on this sheet is optional.

[1] Data blocks are shown in Figures 13 to 20 as red squares labeled with a yellow square

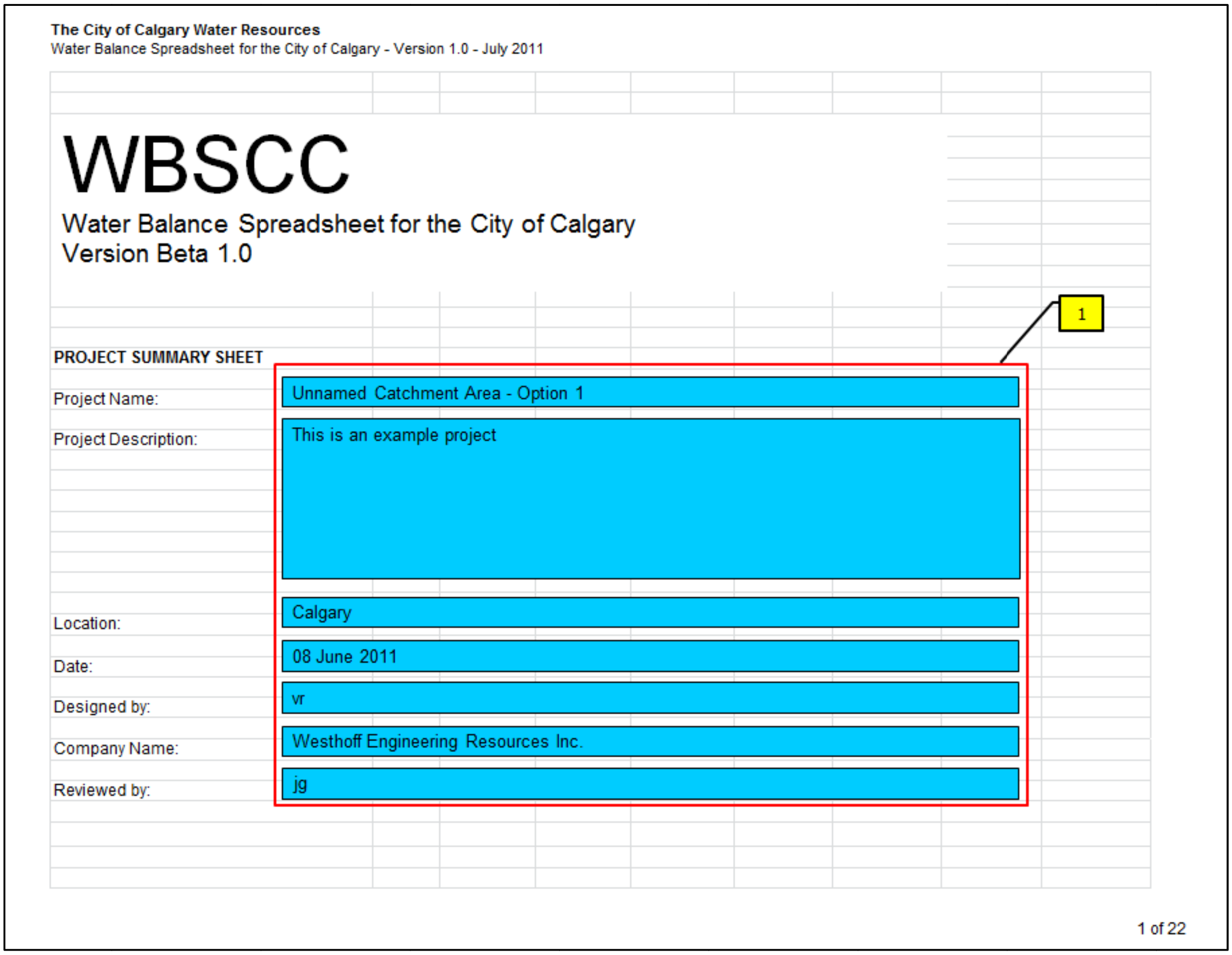


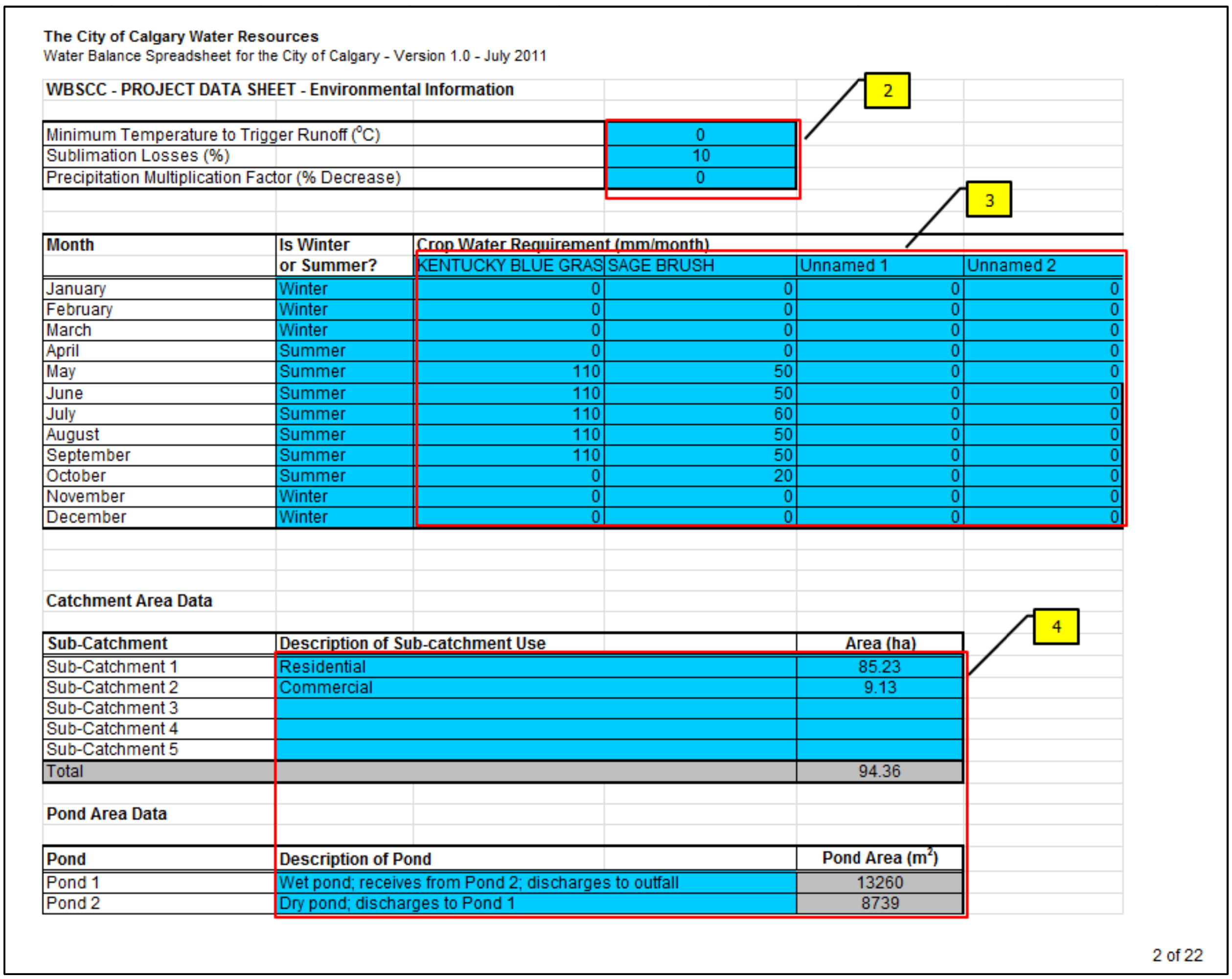
Figure 13 : System Data – Project Summary Information (Page 1)

Page 2 (Figure 14) should be populated with pertinent environmental information and the catchment area data through the following steps:

1. Enter environmental information as follows (see Data Block 2 – Figure 14)
    a. Minimum temperature to trigger runoff (^{o}C)
    b. Sublimation losses in % (to account for sublimation during winter)
    c. Precipitation multiplication factor (% reduction) to analyse sensitivity.
2. Enter the crops used, and their monthly crop water requirements (mm) (see Data Block 3 – Figure 14).

3. Enter the usage of sub-catchments and their extents (ha) (see Data Block 4 – Figure 14). The foot-print areas of ponds is calculated based on the ponds data, however, the user needs to enter the description of ponds.

The information on the monthly crop water requirement is used if the user chooses to turn on irrigation using a crop cover demand approach rather than an actual irrigation supply approach (see Figure 17 for the latter).



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WBSCC - PROJECT DATA SHEET - Environmental Information

Minimum Temperature to Trigger Runoff (^oC)	0
Sublimation Losses (%)	10
Precipitation Multiplication Factor (% Decrease)	0

Month	Is Winter or Summer?	Crop Water Requirement (mm/month)			
		KENTUCKY BLUE GRAS	SAGE BRUSH	Unnamed 1	Unnamed 2
January	Winter	0	0	0	0
February	Winter	0	0	0	0
March	Winter	0	0	0	0
April	Summer	0	0	0	0
May	Summer	110	50	0	0
June	Summer	110	50	0	0
July	Summer	110	60	0	0
August	Summer	110	50	0	0
September	Summer	110	50	0	0
October	Summer	0	20	0	0
November	Winter	0	0	0	0
December	Winter	0	0	0	0

Catchment Area Data

Sub-Catchment	Description of Sub-catchment Use	Area (ha)
Sub-Catchment 1	Residential	85.23
Sub-Catchment 2	Commercial	9.13
Sub-Catchment 3		
Sub-Catchment 4		
Sub-Catchment 5		
Total		94.36

Pond Area Data

Pond	Description of Pond	Pond Area (m^2)
Pond 1	Wet pond; receives from Pond 2; discharges to outfall	13260
Pond 2	Dry pond; discharges to Pond 1	8739

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Figure 14: System Data – Environmental Information and Catchment Area Data (Page 2)

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WBSCC - PROJECT DATA SHEET - Environmental Information (Cont'd.)

Actual to Potential Evapotranspiration Modification Factors

5

Sand		Silt		Clay		Custom	
AW/AWC	F	AW/AWC	F	AW/AWC	F	AW/AWC	F
0	0	0	0	0	0	0	0
0.2	1	0.2	0.1	0.2	0.05	0.2	0.1
0.4	1	0.4	0.8	0.4	0.3	0.4	0.5
0.6	1	0.6	1	0.6	0.6	0.6	0.7
0.8	1	0.8	1	0.8	0.95	0.8	0.9
1	1	1	1	1	1	1	1
50	1	50	1	50	1	50	1
100	1	100	1	100	1	100	1

AW: Available Water Content (mm)
AWC: Available Water Capacity (mm)

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Figure 15 Potential to Actual Evapotranspiration Modification Factors

Page 3 (Figure 15) shows the multiplication factors to derive the actual evapotranspiration from the potential evapotranspiration based on the ratio of the available water content to the available water capacity. (See Data Block 5 – Figure 15).

Page 4 (Figure 16) shows the data entry tables for sub-catchment parameters and run-off allocation plan, as an example for Sub-catchment 1. The following data should be entered:

1. Areas (ha) for various cover types (See Data Block 6 – Figure 16).
2. Depression loss (mm), for impervious cover type only (See Data Block 7 – Figure 16).
3. Soil mixture (% of soils, 0 to 100) for various cover types, except for impervious surface (See Data Block 8 – Figure 16).

4. Depth of soil or media (mm) for various cover types (See Data Block 9 – Figure 16).
5. Soil or media porosity for various cover types (See Data Block 10 – Figure 16).
6. Field capacity and wilting point for various cover types (See Data Block 11 – Figure 16).
7. Saturated and sub-soil hydraulic conductivity values (m/s) for the various cover types (See Data Block 12 – Figure 16).
8. Ponding depth (mm) (See Data Block 13 – Figure 16).
9. Subdrain invert elevation (mm) and subdrain capacity associated with the bioretention/bioswale media (See Data Block 14 – Figure 16).

In the runoff allocation table on Page 4 (Figure 16), enter the appropriate fractional runoff allocation (%, 0 to 100) between appropriate cover types (See Data Block 15 – Figure 16). Cover types that cannot receive water from a particular type are in grey. Discharge is to be routed to either Pond #1 or Pond #2 by selecting from the drop-down list.

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WBSCC - PROJECT DATA SHEET - Sub-Catchment 1: Parameters, Runoff Allocation
Usage: Residential

Sub-catchment Parameters		Cover Type: Impervious Surface	Pervious Surface	Absorbent Landscaping	Green Roof Media	Bioretention/ Bioswale Medium	Unassigned Area
Area (Total: 85.23)	(ha)	43	36.71	4.9	0.02	0.6	0
Depression Loss	(mm)	1.6					
Soil Type: Sand	(%)				100	90	
Silt			100	100	0	10	
Clay	(%)						
Custom	(%)						
Unassigned	(%)		0	0	0	0	
Soil or Media Depth			300	300	200	600	
Porosity	(-)		0.46	0.46	0.512	0.469	
Field Capacity	(-)		0.271	0.271	0.132	0.092	
Wilting Point	(-)		0.126	0.126	0.057	0.038	
Saturated Hydraulic Conductivity	(m/s)		5.00E-06	5.00E-06	2.50E-05	3.50E-05	
Sub-soil Hydraulic Conductivity	(m/s)		1.00E-08	1.00E-08		5.00E-08	
Ponding Depth	(mm)		0	0	0	300	
Inv. Slope of Log. Tension Moisture Curve	(-)		4.98	4.98	4.55	4.32	
Subdrain Invert (above bottom of media)	(mm)					100	
Subdrain Capacity	(m^3/s)					0.001	

% of Runoff Allocated To:		Runoff Allocated from Cover Type/ Facility: Impervious Surface	Pervious Surface	Absorbent Landscaping	Green Roof Media	Bioretention/ Bioswale Media	Storage/ Reuse Tank	Discharge
Pervious Surface	(%)	50			0			
Absorbent Landscaping	(%)	30	0		0			
Green Roof Media	(%)	0						
Storage/ Reuse Tank	(%)	0.1	60	50	0			
Bioretention/Bioswale Media	(%)	10	40	50	0			
Discharge	(%)	9.9	0	0	100	100	100	
Pond 1/Pond 2								POND #1

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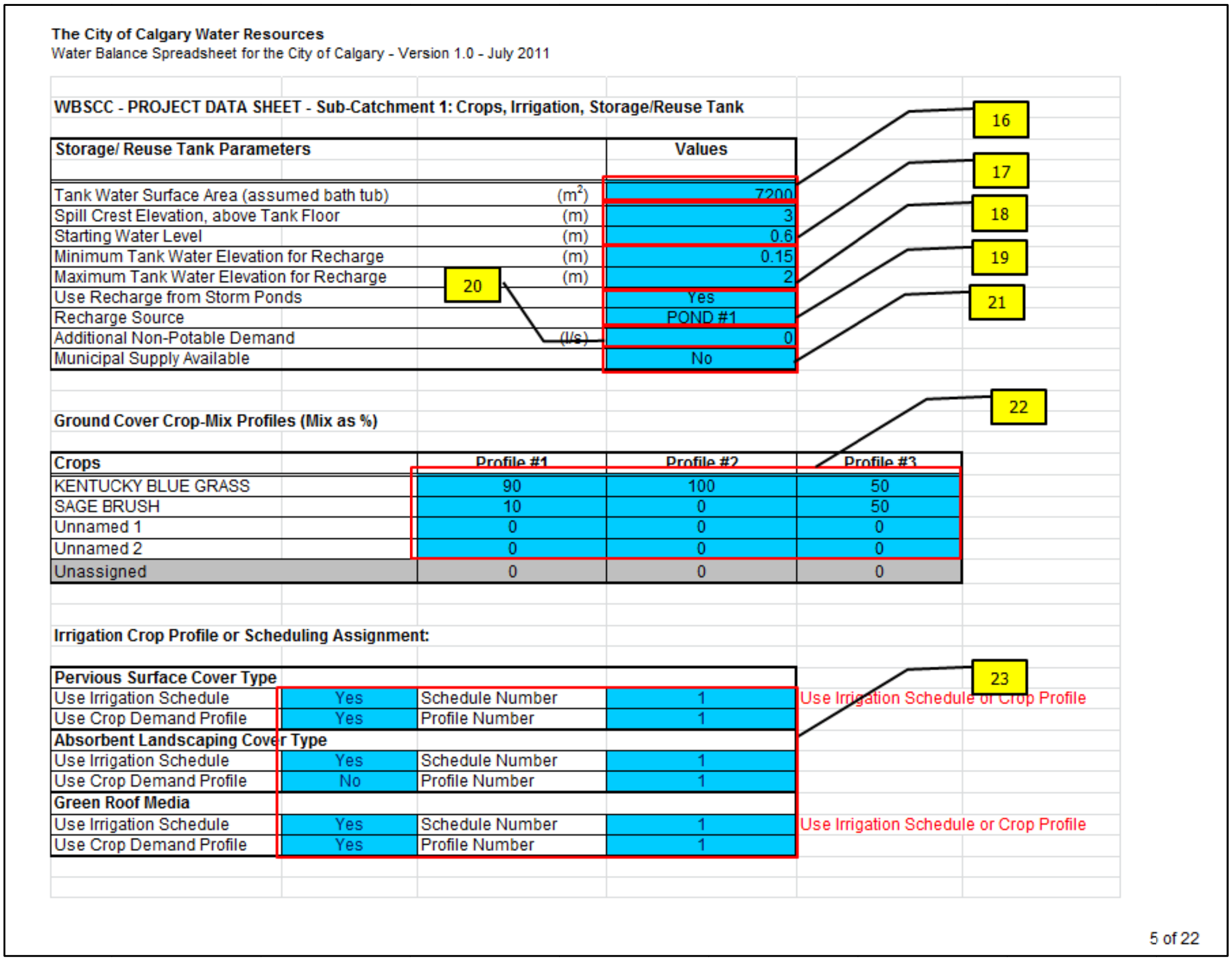
Figure 16 : System Data – Sub-Catchment Parameters and Runoff Allocation (Page 4)

Page 5 (Figure 17) shows the set of parameters for the storage/Re-use tank, ground cover mix profiles and irrigation/crop profile assignment. The following data needs to be entered for the storage/re-use tank.

1. Area of tank (sq.m) (See Data Block 16 – Figure 17).
2. Spill crest elevation and starting water elevation (m above tank floor) (See Data Block 17 – Figure 17).
3. Minimum and maximum tank water elevations for recharge (m above tank floor) (See Data Block 18 – Figure 17).
4. In the next row, select *Yes* (from the drop-down list) if recharge is to be received from a storm pond, and in the next row select the appropriate storm pond from which the recharge water is sourced. (See Data Block 19 – Figure 17).
5. Enter constant potable water demand (l/s) (See Data Block 20 – Figure 17).
6. Select *Yes* or *No* for the availability of municipal supply (See Data Block 21 – Figure 17).

In the table for the ground cover crop-mix profiles, appropriate portions (%, 0 to 100) of selected crops for each profile should be entered (See Data Block 22 – Figure 17).

In the table for irrigation crop profile or scheduling assignment, use either an irrigation schedule or crop demand profile (or none) with appropriate profiles, for the purpose of irrigation. Do not use both (see Data Block 23 – Figure 17).



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WBSCC - PROJECT DATA SHEET - Sub-Catchment 1: Crops, Irrigation, Storage/Reuse Tank

Storage/ Reuse Tank Parameters		Values
Tank Water Surface Area (assumed bath tub)	(m^2)	7200
Spill Crest Elevation, above Tank Floor	(m)	3
Starting Water Level	(m)	0.6
Minimum Tank Water Elevation for Recharge	(m)	0.15
Maximum Tank Water Elevation for Recharge	(m)	2
Use Recharge from Storm Ponds		Yes
Recharge Source		POND #1
Additional Non-Potable Demand	(l/s)	0
Municipal Supply Available		No

Ground Cover Crop-Mix Profiles (Mix as %)

Crops	Profile #1	Profile #2	Profile #3
KENTUCKY BLUE GRASS	90	100	50
SAGE BRUSH	10	0	50
Unnamed 1	0	0	0
Unnamed 2	0	0	0
Unassigned	0	0	0

Irrigation Crop Profile or Scheduling Assignment:

Pervious Surface Cover Type				
Use Irrigation Schedule	Yes	Schedule Number	1	Use Irrigation Schedule or Crop Profile
Use Crop Demand Profile	Yes	Profile Number	1	
Absorbent Landscaping Cover Type				
Use Irrigation Schedule	Yes	Schedule Number	1	
Use Crop Demand Profile	No	Profile Number	1	
Green Roof Media				
Use Irrigation Schedule	Yes	Schedule Number	1	Use Irrigation Schedule or Crop Profile
Use Crop Demand Profile	Yes	Profile Number	1	

Figure 17 : System Data – Storage/Re-use Tank Parameters, Crops and Irrigation Assignment

(Page 5)

Page 6 (Figure 18) is populated with two types of irrigation schedules with potential daily irrigation supplies in mm. As an example, in Figure 18, Schedule 1 shows a week-day irrigation scheme (See Data Block 24 – Figure 18), and Schedule 2 shows a week-end irrigation scheme (See Data Block 25 – Figure 18).

A precipitation threshold (mm) can be entered, which is deducted from the irrigation demand if there was precipitation in the preceding two days. Consider case of Schedule 2, if the total precipitation from Thursday through Saturday exceeds 10 mm, the actual irrigation applied on Saturday can be less than 25 mm (See Data Block 26 – Figure 18).

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WBSCC - PROJECT DATA SHEET - Sub-Catchment 1: Weekly Watering Schedule

Weekly Watering Schedule #1 (Depth of Irrigation) (mm) 24

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Jan							
Feb							
Mar							
Apr							
May						10	
Jun			10			15	
Jul		10		10		15	
Aug		10		10		15	
Sep			10			15	
Oct							
Nov							
Dec							

Weekly Watering Schedule #2 (Depth of Irrigation) (mm) 25

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Jan							
Feb							
Mar							
Apr							
May							25
Jun							25
Jul							25
Aug							25
Sep							25
Oct							
Nov							
Dec							

26

Precipitation treshold (mm) during the irrigation day and the preceding two days: 10

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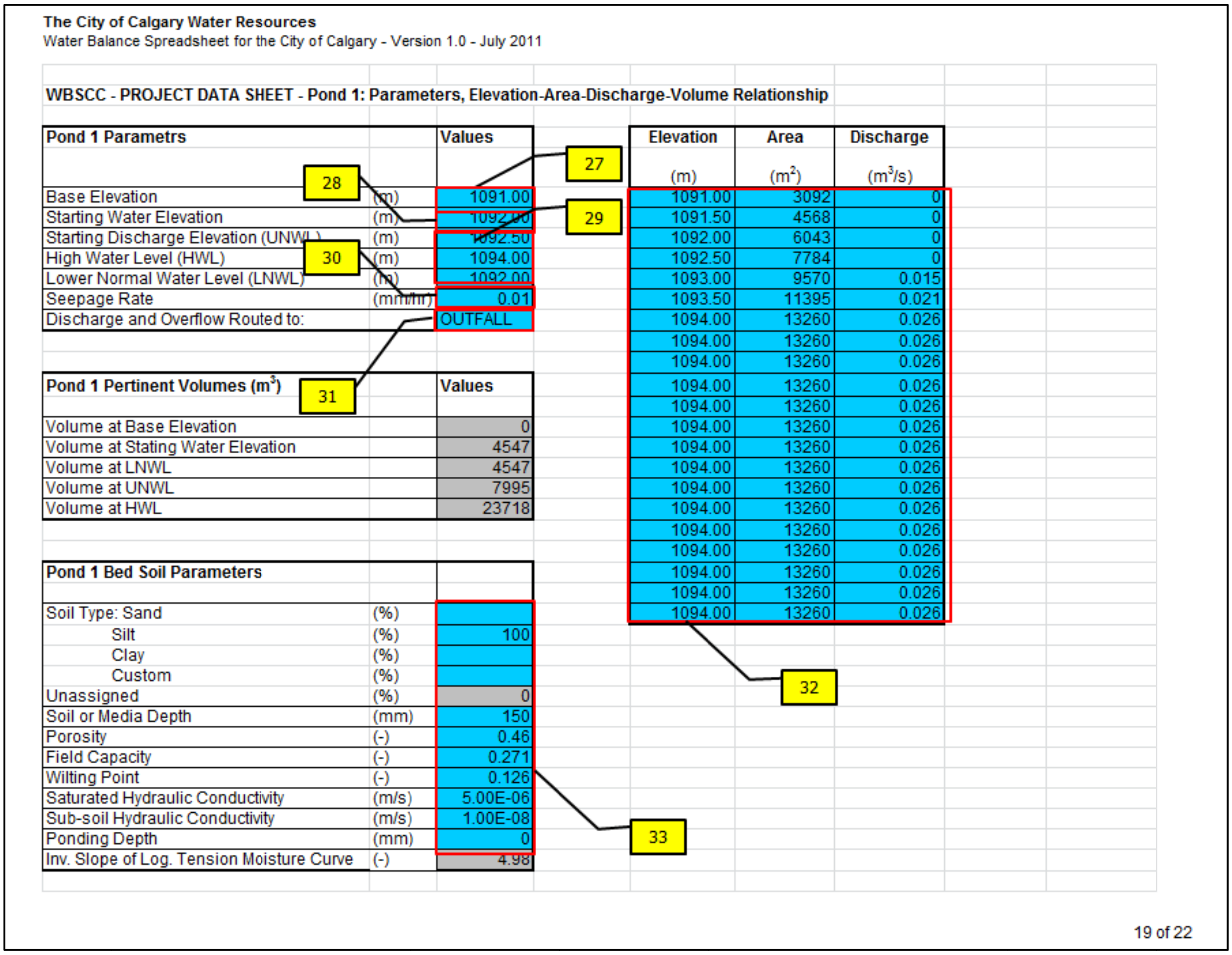
Figure 18: System Data – Weekly Irrigation Schedules (Page 6)

Page 19 (Figure 19) shows the storm pond parameters, in this case for Pond #1. The following data need to be entered for the ponds.

1. Base elevation of pond (m) (see Data Block 27 – Figure 19).
2. Starting water level (m) (see Data Block 28 – Figure 19).
3. The starting discharge elevation, which is equal to the upper normal water level (UNWL) (m), the high water level (HWL) and the lower normal water level (LNWL) (see Data Block 29 – Figure 19).
4. Seepage rate (mm/hr) (see Data Block 30 – Figure 19)
5. The outflow option from a drop-down list (see Data Block 31 – Figure 19).

The adjacent table in Page 19 is populated with elevation – area – discharge relationship (see Data Block 32 – Figure 19). Values in this table should be provided in an increasing order.

Data Block 33 – Figure 19 shows the soil parameters of the assumed pervious cover type around the pond. Instructions to enter data in this data block resemble that of the soil data for any sub-catchment.



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WBSCC - PROJECT DATA SHEET - Pond 1: Parameters, Elevation-Area-Discharge-Volume Relationship

Pond 1 Parametrs		Values
Base Elevation	(m)	1091.00
Starting Water Elevation	(m)	1092.00
Starting Discharge Elevation (UNWL)	(m)	1092.50
High Water Level (HWL)	(m)	1094.00
Lower Normal Water Level (LNWL)	(m)	1092.00
Seepage Rate	(mm/hr)	0.01
Discharge and Overflow Routed to:		OUTFALL

Pond 1 Pertinent Volumes (m^3)	Values
Volume at Base Elevation	0
Volume at Stating Water Elevation	4547
Volume at LNWL	4547
Volume at UNWL	7995
Volume at HWL	23718

Pond 1 Bed Soil Parameters		
Soil Type: Sand	(%)	
Silt	(%)	100
Clay	(%)	
Custom	(%)	
Unassigned	(%)	0
Soil or Media Depth	(mm)	150
Porosity	(-)	0.46
Field Capacity	(-)	0.271
Wilting Point	(-)	0.126
Saturated Hydraulic Conductivity	(m/s)	5.00E-06
Sub-soil Hydraulic Conductivity	(m/s)	1.00E-08
Ponding Depth	(mm)	0
Inv. Slope of Log. Tension Moisture Curve	(-)	4.98

Elevation (m)	Area (m^2)	Discharge (m^3/s)
1091.00	3092	0
1091.50	4568	0
1092.00	6043	0
1092.50	7784	0
1093.00	9570	0.015
1093.50	11395	0.021
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026

Figure 19 : System Data – Pond Parameters (Page 19)

Figure 20 shows the additional data sheet. The following data is entered

1. Enter the possible range of values of ratios of the impervious to pervious surface areas (i/p ratio) pertaining to the bioretention/ bioswales media (Data Block 34 – Figure 20). Note that these ratios are to be entered in an increasing order to facilitate interpolation
2. Enter the set of clogging factors under various i/p ratios over the simulation period on an annual basis. (Data Block 35 – Figure 20).
3. Enter the daily time series of Run-on to impervious surfaces from external sources. (See Data Block 36 – Figure 20).

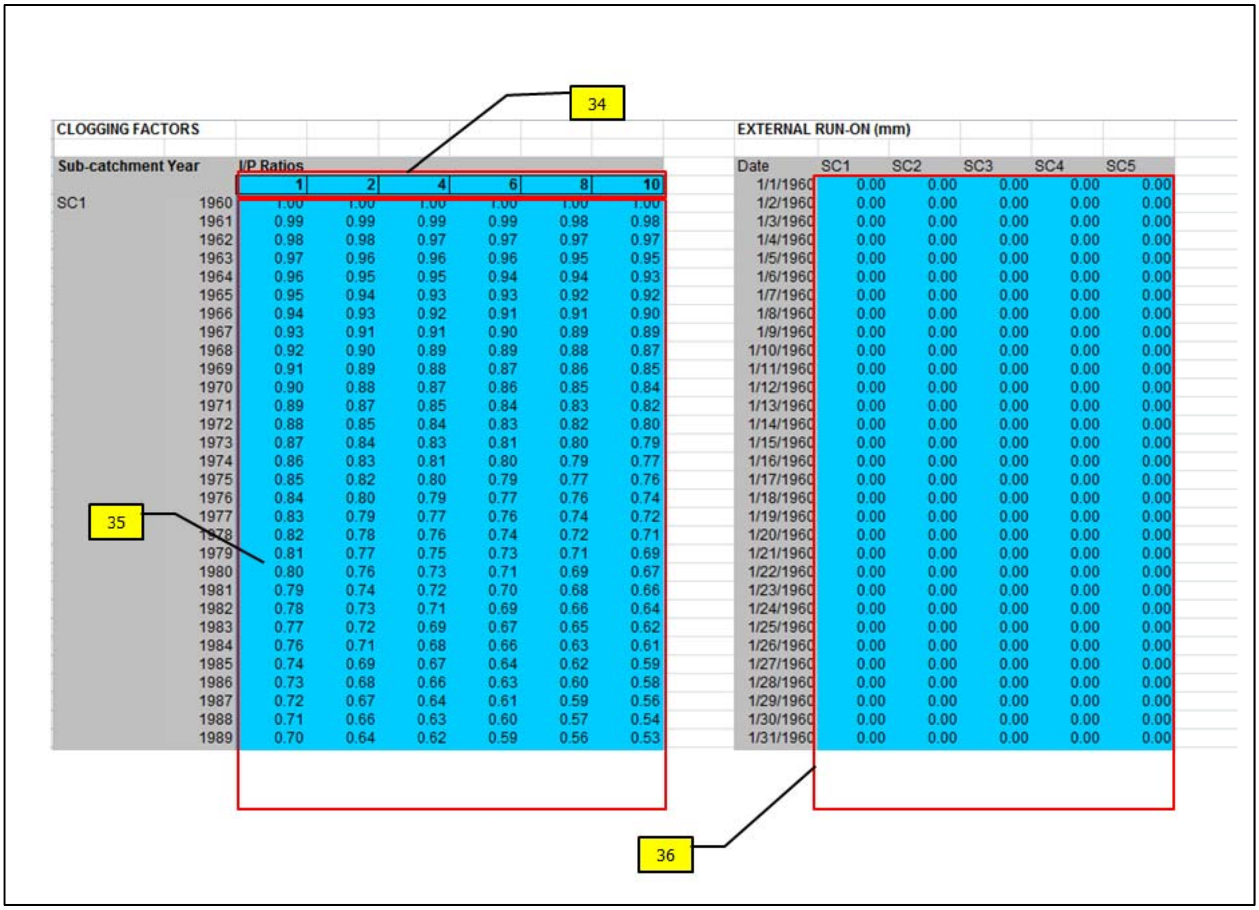


Figure 20: Additional Data

5.3 Performing Calculations

A customized ribbon element, which contains a set of buttons to perform various tasks, is provided in WBSCC (see Figure 21).

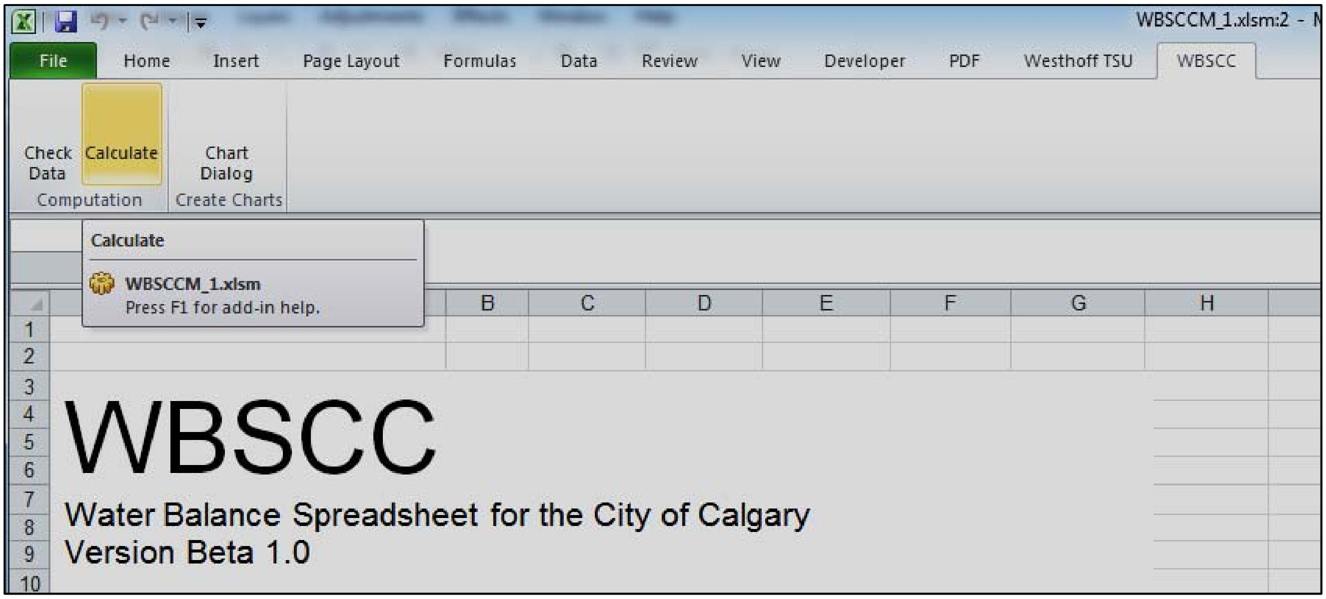


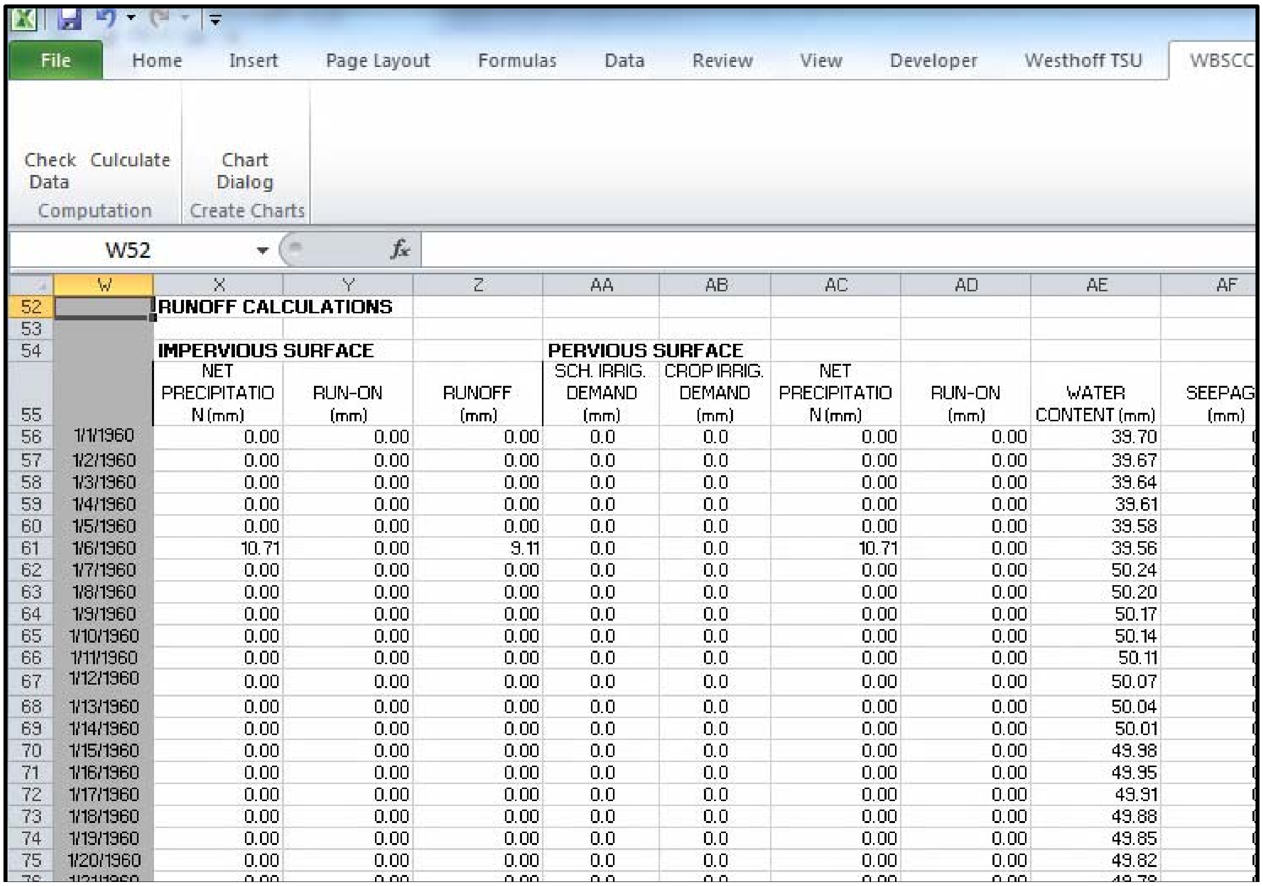
Figure 21 : WBSCC Custom Ribbon

After the user has completed entering the relevant catchment data, an intermediate step should be performed to check the integrity of the data entered. This is done by clicking on the ***Check Data*** button of the WBSCC ribbon. Various cells in Worksheet SD are provided with unassigned values (e.g. cover type surfaces, runoff allocation percentages, etc). The user needs to confirm that there are no unassigned quantities across Worksheet SD.

The actual simulation can subsequently be performed by clicking on the ***Calculate*** button of the WBSCC ribbon. The computational time depends on the hardware resources of the user's computer. The task bar at the bottom of Excel window shows the progress of the computation.

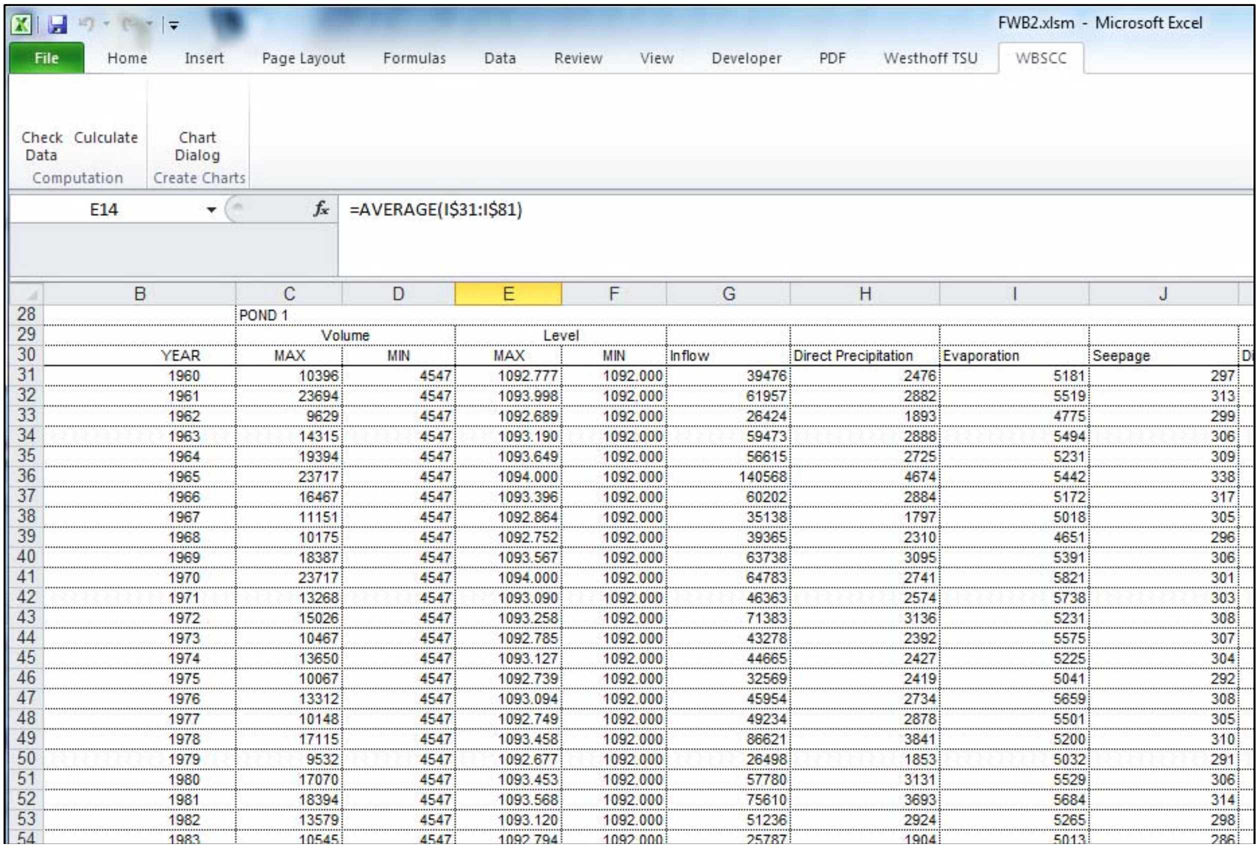
5.4 Viewing Results

The user can display daily or annual time series results, or generate a custom graph. Typical daily and annual time series results are shown in Figure 22 and 23. Worksheets SC1 through SC5 (for sub-catchments) and POND (for ponds) show the daily time series of all variables involved in the calculations. Worksheets DS1 through DS5 and PSTAT show the annual time series of the sub-catchments and ponds, respectively. Summarized results for sub-catchments and ponds are also available in these worksheets (see Figure 24 and Figure 25 for typical summarized results).



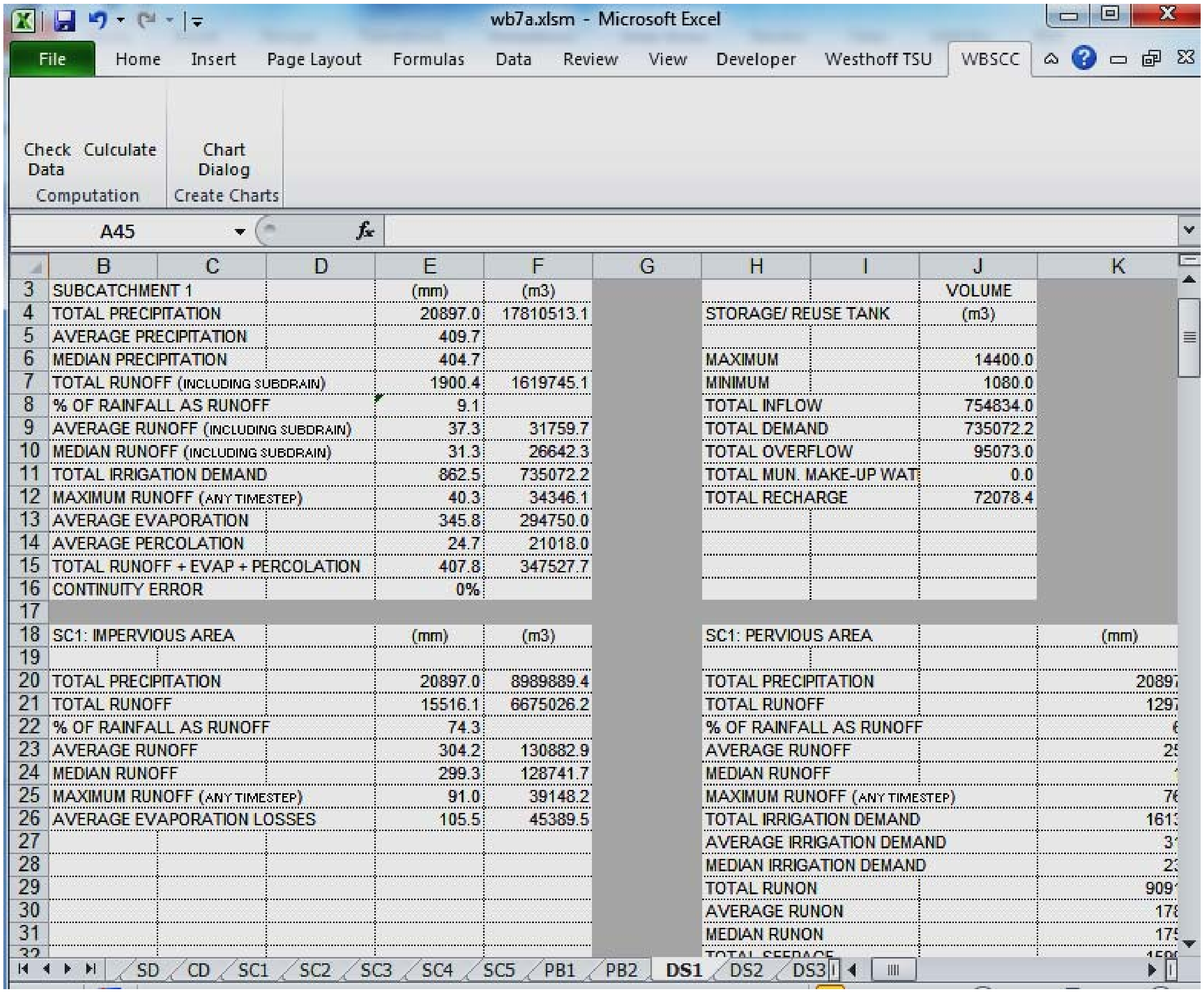
	W	X	Y	Z	AA	AB	AC	AD	AE	AF
52		RUNOFF CALCULATIONS								
53										
54		IMPERVIOUS SURFACE			PERVIOUS SURFACE					
55		NET PRECIPITATION (mm)	RUN-ON (mm)	RUNOFF (mm)	SCH. IRRIG. DEMAND (mm)	CROP IRRIG. DEMAND (mm)	NET PRECIPITATION (mm)	RUN-ON (mm)	WATER CONTENT (mm)	SEEPAG (mm)
56	1/1/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	39.70	
57	1/2/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	39.67	
58	1/3/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	39.64	
59	1/4/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	39.61	
60	1/5/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	39.58	
61	1/6/1960	10.71	0.00	9.11	0.0	0.0	10.71	0.00	39.56	
62	1/7/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	50.24	
63	1/8/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	50.20	
64	1/9/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	50.17	
65	1/10/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	50.14	
66	1/11/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	50.11	
67	1/12/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	50.07	
68	1/13/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	50.04	
69	1/14/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	50.01	
70	1/15/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	49.98	
71	1/16/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	49.95	
72	1/17/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	49.91	
73	1/18/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	49.88	
74	1/19/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	49.85	
75	1/20/1960	0.00	0.00	0.00	0.0	0.0	0.00	0.00	49.82	

Figure 22: Daily Time Series Results



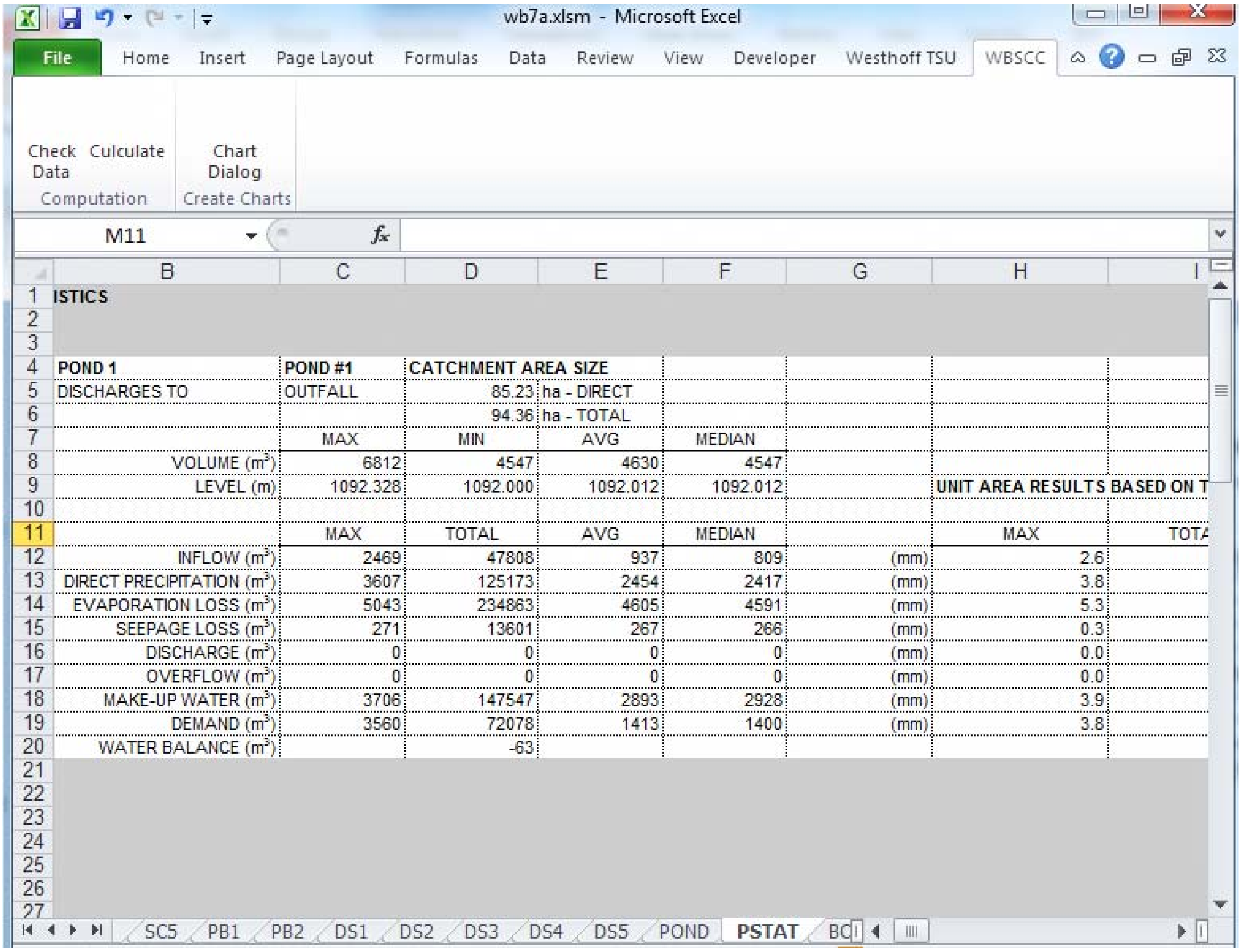
	B	C	D	E	F	G	H	I	J
28		POND 1							
29		Volume		Level					
30	YEAR	MAX	MIN	MAX	MIN	Inflow	Direct Precipitation	Evaporation	Seepage
31	1960	10396	4547	1092.777	1092.000	39476	2476	5181	297
32	1961	23694	4547	1093.998	1092.000	61957	2882	5519	313
33	1962	9629	4547	1092.689	1092.000	26424	1893	4775	299
34	1963	14315	4547	1093.190	1092.000	59473	2888	5494	306
35	1964	19394	4547	1093.649	1092.000	56615	2725	5231	309
36	1965	23717	4547	1094.000	1092.000	140568	4674	5442	338
37	1966	16467	4547	1093.396	1092.000	60202	2884	5172	317
38	1967	11151	4547	1092.864	1092.000	35138	1797	5018	305
39	1968	10175	4547	1092.752	1092.000	39365	2310	4651	296
40	1969	18387	4547	1093.567	1092.000	63738	3095	5391	306
41	1970	23717	4547	1094.000	1092.000	64783	2741	5821	301
42	1971	13268	4547	1093.090	1092.000	46363	2574	5738	303
43	1972	15026	4547	1093.258	1092.000	71383	3136	5231	308
44	1973	10467	4547	1092.785	1092.000	43278	2392	5575	307
45	1974	13650	4547	1093.127	1092.000	44665	2427	5225	304
46	1975	10067	4547	1092.739	1092.000	32569	2419	5041	292
47	1976	13312	4547	1093.094	1092.000	45954	2734	5659	308
48	1977	10148	4547	1092.749	1092.000	49234	2878	5501	305
49	1978	17115	4547	1093.458	1092.000	86621	3841	5200	310
50	1979	9532	4547	1092.677	1092.000	26498	1853	5032	291
51	1980	17070	4547	1093.453	1092.000	57780	3131	5529	306
52	1981	18394	4547	1093.568	1092.000	75610	3693	5684	314
53	1982	13579	4547	1093.120	1092.000	51236	2924	5265	298
54	1983	10545	4547	1092.794	1092.000	25787	1904	5013	286

Figure 23: Annual Time Series Results



Row	B–D	E	F	H–I	J	K
3	SUBCATCHMENT 1	(mm)	(m3)		VOLUME	
4	TOTAL PRECIPITATION	20897.0	17810513.1	STORAGE/ REUSE TANK	(m3)	
5	AVERAGE PRECIPITATION	409.7				
6	MEDIAN PRECIPITATION	404.7		MAXIMUM	14400.0	
7	TOTAL RUNOFF (INCLUDING SUBDRAIN)	1900.4	1619745.1	MINIMUM	1080.0	
8	% OF RAINFALL AS RUNOFF	9.1		TOTAL INFLOW	754834.0	
9	AVERAGE RUNOFF (INCLUDING SUBDRAIN)	37.3	31759.7	TOTAL DEMAND	735072.2	
10	MEDIAN RUNOFF (INCLUDING SUBDRAIN)	31.3	26642.3	TOTAL OVERFLOW	95073.0	
11	TOTAL IRRIGATION DEMAND	862.5	735072.2	TOTAL MUN. MAKE-UP WAT	0.0	
12	MAXIMUM RUNOFF (ANY TIMESTEP)	40.3	34346.1	TOTAL RECHARGE	72078.4	
13	AVERAGE EVAPORATION	345.8	294750.0			
14	AVERAGE PERCOLATION	24.7	21018.0			
15	TOTAL RUNOFF + EVAP + PERCOLATION	407.8	347527.7			
16	CONTINUITY ERROR	0%				
17						
18	SC1: IMPERVIOUS AREA	(mm)	(m3)	SC1: PERVIOUS AREA		(mm)
19						
20	TOTAL PRECIPITATION	20897.0	8989889.4	TOTAL PRECIPITATION		20897
21	TOTAL RUNOFF	15516.1	6675026.2	TOTAL RUNOFF		1297
22	% OF RAINFALL AS RUNOFF	74.3		% OF RAINFALL AS RUNOFF		6
23	AVERAGE RUNOFF	304.2	130882.9	AVERAGE RUNOFF		25
24	MEDIAN RUNOFF	299.3	128741.7	MEDIAN RUNOFF		
25	MAXIMUM RUNOFF (ANY TIMESTEP)	91.0	39148.2	MAXIMUM RUNOFF (ANY TIMESTEP)		76
26	AVERAGE EVAPORATION LOSSES	105.5	45389.5	TOTAL IRRIGATION DEMAND		161
27				AVERAGE IRRIGATION DEMAND		3
28				MEDIAN IRRIGATION DEMAND		2
29				TOTAL RUNON		909
30				AVERAGE RUNON		17
31				MEDIAN RUNON		17

Figure 24: Summarized Sub-Catchment Results (partial)



	B	C	D	E	F	G	H	I
1	ISTICS							
2								
3								
4	POND 1	POND #1	CATCHMENT AREA SIZE					
5	DISCHARGES TO	OUTFALL	85.23	ha - DIRECT				
6			94.36	ha - TOTAL				
7		MAX	MIN	AVG	MEDIAN			
8	VOLUME (m^3)	6812	4547	4630	4547			
9	LEVEL (m)	1092.328	1092.000	1092.012	1092.012		UNIT AREA RESULTS BASED ON T	
10								
11		MAX	TOTAL	AVG	MEDIAN		MAX	TOTA
12	INFLOW (m^3)	2469	47808	937	809	(mm)	2.6	
13	DIRECT PRECIPITATION (m^3)	3607	125173	2454	2417	(mm)	3.8	
14	EVAPORATION LOSS (m^3)	5043	234863	4605	4591	(mm)	5.3	
15	SEEPAGE LOSS (m^3)	271	13601	267	266	(mm)	0.3	
16	DISCHARGE (m^3)	0	0	0	0	(mm)	0.0	
17	OVERFLOW (m^3)	0	0	0	0	(mm)	0.0	
18	MAKE-UP WATER (m^3)	3706	147547	2893	2928	(mm)	3.9	
19	DEMAND (m^3)	3560	72078	1413	1400	(mm)	3.8	
20	WATER BALANCE (m^3)		-63					

Figure 25: Summarized Pond Results (partial)

A user interface to create custom graphs can be started by clicking on the ***Chart Dialog*** button of the WBSCC ribbon. The user interface is shown in Figure 26.

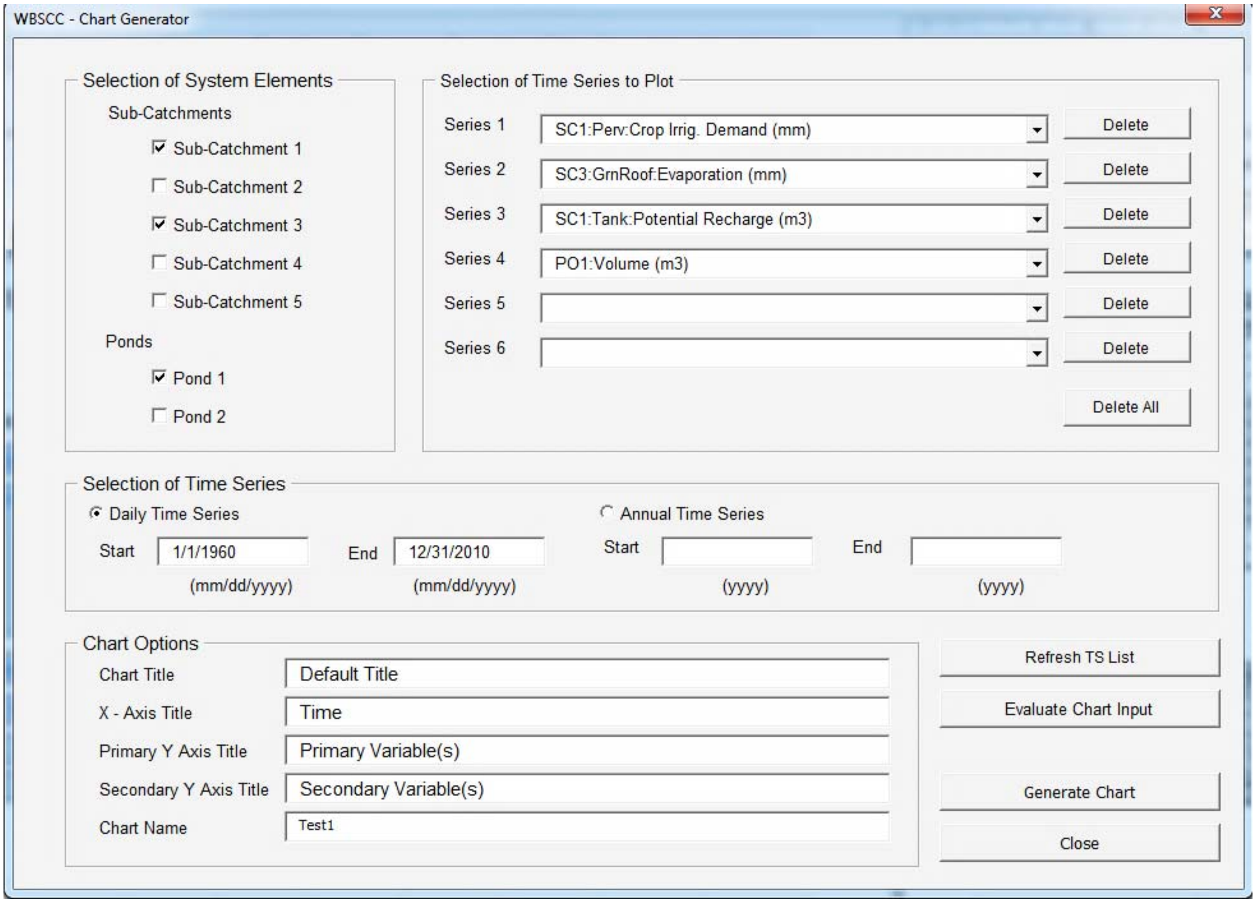


Figure 26 : Chart Dialog User Interface

The following steps are involved in generating a custom graph:

1. Select the sub-catchments and/or ponds in the Selection of System Elements group to get the time series.
2. Select either daily or annual time series in the selection of Time Series group, and set the appropriate time window. The start and end dates for daily time series should be set in accordance with the regional clock setting of the user's computer. The WBSCC automatically detects the current setting of the user's computer and provides appropriate date format under the date entry fields, i.e. mm/dd/yyyy or dd/mm/yyyy. Failure to follow the suggested format will generate an overflow error.
3. Click on the Refresh TS List button to load the time series names in the selection drop-down list boxes.
4. Select at most six time series to plot.
5. Click on the Evaluate Chart Input button and make sure that there is no error message.

6. Provide appropriate titles and a name for the chart in the chart option group, and click on the Generate Chart button.

A typical chart generated is shown in Figure 27. Note that this chart is generated using generic format options. User needs to modify these options to improve the quality of the chart.

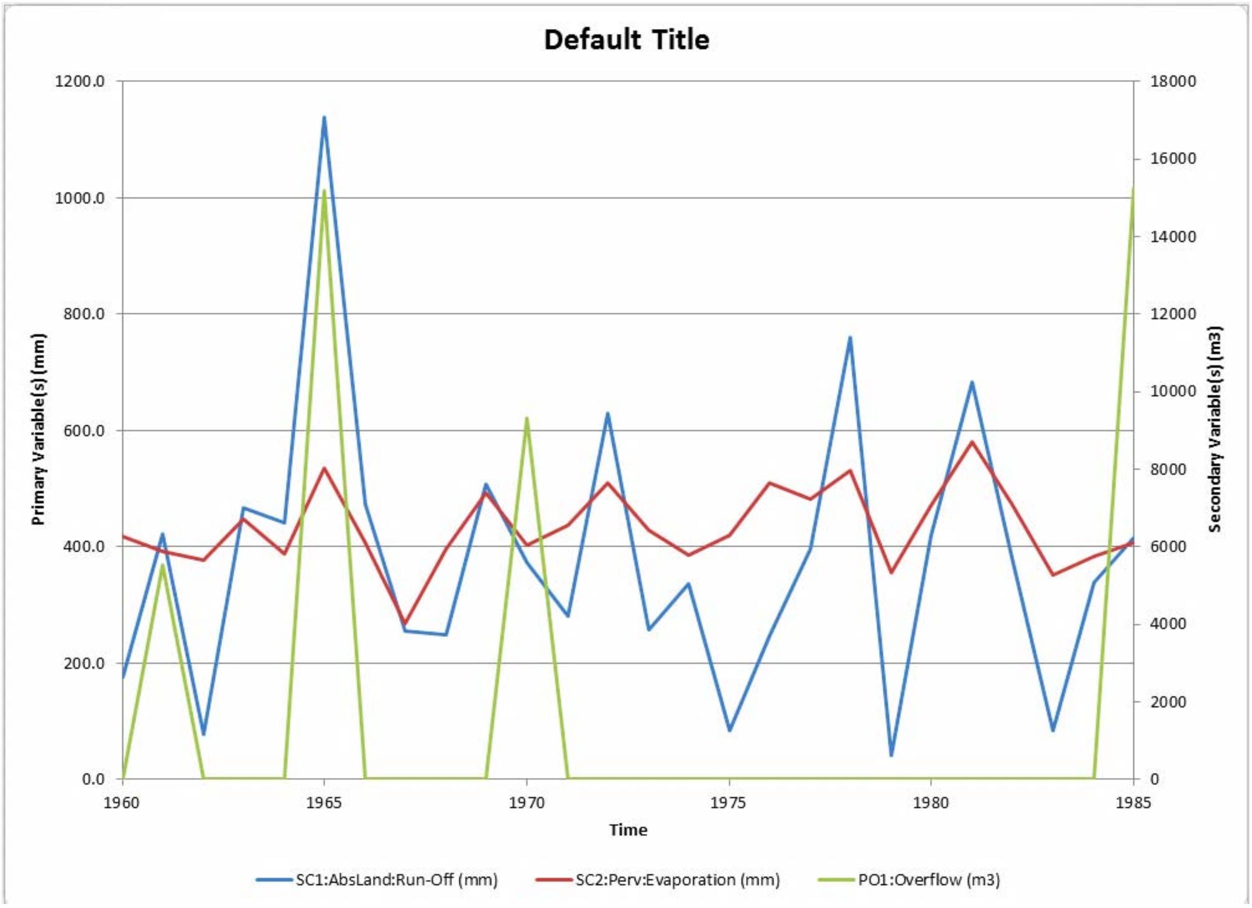


Figure 27 : Chart Generated using the Chart Dialog User Interface

6.0 REFERENCES

Saxton, K. E., and Rawls, W. J. (2006). “Soil Water Characteristics Estimates by Texture and Organic Matter for Hydrologic Solutions.” Soil Sci. Soc. Am. J. 70: 1569 – 1578.

APPENDIX – A

WBSCC APPLICATION EXAMPLE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

This Appendix provides an example application of the WBSCC for an urbanized catchment area. One of the objectives of source control BMPs is to control discharges from various land cover types to the conveyance system. Planned construction of elements, such as, bioretention/bioswale media, green roof media and storm ponds, would help control storm water discharge from urbanized areas. The WBSCC can be used to assess the amount of discharge from various cover types of a catchment area. The WBSCC can also be used to estimate variations in the drainage flows due to change in cover types. In the example, portions of building roofs are hypothetically converted to green roof media and the variation in drainage flows is examined.

2 SITE DESCRIPTION

Figure A- 1 shows the selected urbanized catchment area, with two sub-catchments. Sub-catchment 1, with a total area of 85.23 ha, constitutes a residential area with houses, roads, school building, playground and a wet storm pond. A constructed bioswale is used in the collection of drainage flows and discharge to the storm pond. Sub-catchment 2, with a total area of 9.13 ha, constitutes a commercial area with a shopping complex, parking lot and dry storm pond. For the purpose of this example, it is assumed that the storm pond in Sub-catchment 2 drains to the pond in Sub-catchment 1.

Figure A- 2 shows a detailed view of the selected sub-catchments, indicating various sub-catchment elements and the surface areas associated with them.

2.1 Characteristics of Sub-Catchment 1

Sub-catchment 1 is dominantly covered by impervious and pervious surfaces. The impervious surfaces cover a total area of 43 ha comprised of roofs on houses, roads and school buildings' roofs. Pervious surfaces, arising from residential lawns, have a total area of 36.71 ha. Playgrounds near the school building have a total surface area of 4.90 ha and these are the planned landscaped surfaces to promote infiltration. A constructed green roof media with a surface area of 0.02 ha is assumed to be on top of the school building. The constructed bioretention/bioswale media, has a total surface area of 0.6 ha, and is located within this sub-catchment.

Sub-catchment 1 has three over-head tanks on the roof of the school buildings. In this example, these tanks are aggregated into a single tank with a surface area of 7200 m^2 and a spill crest level of 3.0 m above the tank floor.

A constructed wet pond (POND #1) is located within Sub-catchment 1. Table 1 shows the elevation – surface area relationship for POND #1. An orifice of diameter 100 mm, with an invert elevation of 1092.5 m (UNWL) is assumed. The LNWL and HWL are 1092.0 m and 1094.0 m, respectively.

Table 1: POND #1: Elevation – Area Relationship

Elevation (m)	Surface Area (m^2)
1091.00	3092
1092.00	6043
1092.50	7784
1093.00	9570
1093.50	11395
1094.00	13260

2.2 Characteristics of Sub-Catchment 2

Sub-catchment 2 is originally covered by 6.53 ha of impervious surfaces and 2.6 ha of pervious surfaces. The impervious surfaces include the roof tops of buildings and a parking lot, while the pervious surfaces constitute land around the dry pond (POND #2). There are no storage tanks within this sub-catchment, however, a nominal (artificial) storage tank with a capacity of 500 m^3 is provided to facilitate irrigation water supply from POND #2. The elevation – surface area relationship for POND #2 is shown in Table 2. POND #2 is assumed to have an orifice of diameter 100 mm with the invert elevation at 1109.5 m. The HWL of POND #2 is at 1112.5 m.

Table 2: POND #2: Elevation – Area Relationship

Elevation (m)	Surface Area (m^2)
1109.50	0
1109.60	570
1109.70	1529
1109.80	2012
1109.90	2935
1110.00	3501
1110.50	4891
1111.00	5763
1111.50	6702
1112.00	7700
1112.50	8739

3 WBSCC DATA INPUT AND ANALYSIS OF RESULTS

To demonstrate how the WBSCC can be applied, two options are analyzed:

1. No green roof media is present.
2. Green roof media are present on top of the commercial buildings in sub-catchment 2 (1.01 ha), and on top of the school building (0.02 ha), as shown in Figure A- 2.

3.1 Data Input for Option 1

Figure A- 3 through Figure A- 12 shows the project information and data entered for option 1. Some of this data is applicable to option 2. Figure A- 4 shows the default environmental information and two types of crops (Kentucky Blue Grass and Sage Brush) and their monthly irrigation water requirement. In the catchment area table, 85.23 ha is entered for Residential usage, and 9.13 has is entered for Commercial usage.

Parameters and flow routing information for Sub-catchment 1 are entered as shown in Figure A-5. The total residential area of 85.23 ha is divided into appropriate cover type based on the areas measured from Figure A- 2. Soil mixtures for various cover types are assumed. Miscellaneous physical properties of soil are taken from the work of Saxton and Rawls (Saxton and Rawls, 2006). The bioswale media is assumed with a ponding depth of 300 mm, along with the sub-drain pipe located at 100 mm from the assumed bottom of the bioswale layer. The sub-drain capacity is assumed 0.0001 m^3/s. Runoff from the impervious surface is assumed to be routed to pervious surfaces (50%), absorbent landscaping (30%), storage/reuse tank (0.1%) and bioretention/bioswale media (10%). Runoff from pervious surfaces is assumed to be routed to storage/reuse tank (60%) and bioretention/bioswale media (40%). Runoff from absorbent landscaping is equally divided between storage/reuse tank and bioretention/bioswale media.

For the overhead storage, recharge is required when the water head falls between 0.15 m and 2.0 m. Tank gets recharged from POND #1.

Three ground cover crop mix profiles are developed using the assumed crop types. Figure A- 6 shows these profiles. Profile #1 has 90% of Kentucky Blue Grass and 10% of Sage Brush; Profile #2 has 100% of Kentucky Blue Grass; and, Profile #3 has 50% of Kentucky Blue Grass and 50% of Sage Brush. Figure A- 7 shows the weekday and weekend irrigation schedules. Crops in pervious surfaces, absorbent landscaping and green roof media will be irrigated by assuming an irrigation profile or a crop profile as shown in the last table in Figure A- 6.

Figure A- 8 illustrates assignment of parameters for sub-catchment 2. Soil parameters are assumed to be the same as with sub-catchment 1. When the area under a cover type is zero, the underlying soil parameters have no contribution to the runoff calculations. Sub-catchment 2 has no storage/re-use tank. However, a nominal tank with a capacity of 500 m^3 is assumed for flow routing purpose. As the catchment area is small, all runoff from various cover types are routed to discharge, and then to POND #2. Crop mix and irrigation profiles are not effective as additional irrigation from a tank is not possible.

Figure A- 11 and Figure A- 12 show the pond parameters. POND #1 is routed to Outfall, whereas, POND #2 is routed to POND #1.

3.2 Simulation Results for Option 1

Figure A- 13 through Figure A- 17 shows the simulation results for option 1. Figure A- 13 shows the overall summary of runoff for sub-catchment 1. The source control measures in Sub-catchment 1, by means of pervious surfaces, absorbent landscaping, bioretention/bioswale media, and water reuse, results in 10.3% of precipitation converted into runoff. The irrigation demand is mostly looked after by tank water reuse, and the tank is recharged from POND #1. This process illustrates efficient rain harvesting. Summarized runoff results for various cover types in Sub-catchment 1 are also presented in Figure A- 13 and Figure A- 14.

Figure A- 15 shows the overall summary of runoff for sub-catchment 2. From the source control point of view, only the pervious surfaces in sub-catchment 2 help in reducing runoff, hence about 55.5% of precipitation is converted into runoff. Figure A- 15 also shows the summary of runoff resulting from the impervious and pervious surfaces.

Figure A- 17 shows the summary of water volumes involved with POND #1 and POND #2. In POND #1 discharge through orifice when the water level is above the UNWL is observed. Considerable overflow, when the water level is above the HWL is also observed. There is no overflow observed from POND #2.

3.3 Data Input for Option 2

Option 2 is merely a duplication of Option 1 with a portion of pervious cover types converted to green roof media. Figure A- 18 shows the changes in cover type areas, with 0.02 ha of green roof media and 43 ha of impervious surfaces can be found. Figure A- 19 shows 1.01 ha of new cover green roof media with impervious surfaces reduced to 5.52 ha.

3.4 Simulation Results for Option 2

Figure A- 20 through Figure A- 24 illustrate the simulation results for Option 2. Significant changes in runoff can be found in Sub-catchment 2, where the percentage of precipitation converted to runoff reduces from 55.5 mm (option 1) to 48.1 mm (option 2).

4 REFERENCES

Saxton, K. E., and Rawls, W. J. (2006). "Soil Water Characteristics Estimates by Texture and Organic Matter for Hydrologic Solutions." Soil Science Society of America Journal. 70: 1569 – 1578.

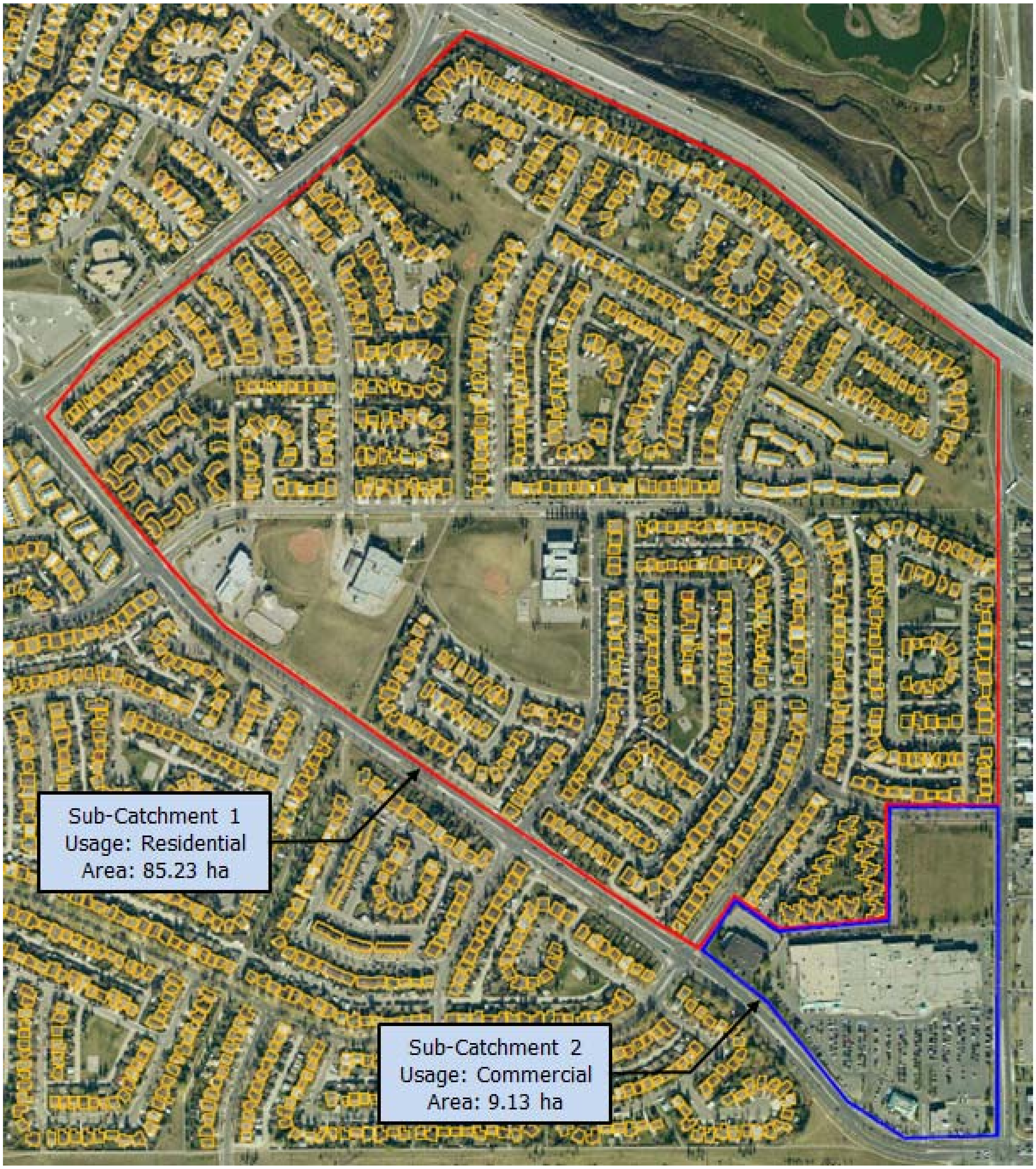


Figure A- 1: Urbanized Catchment Area

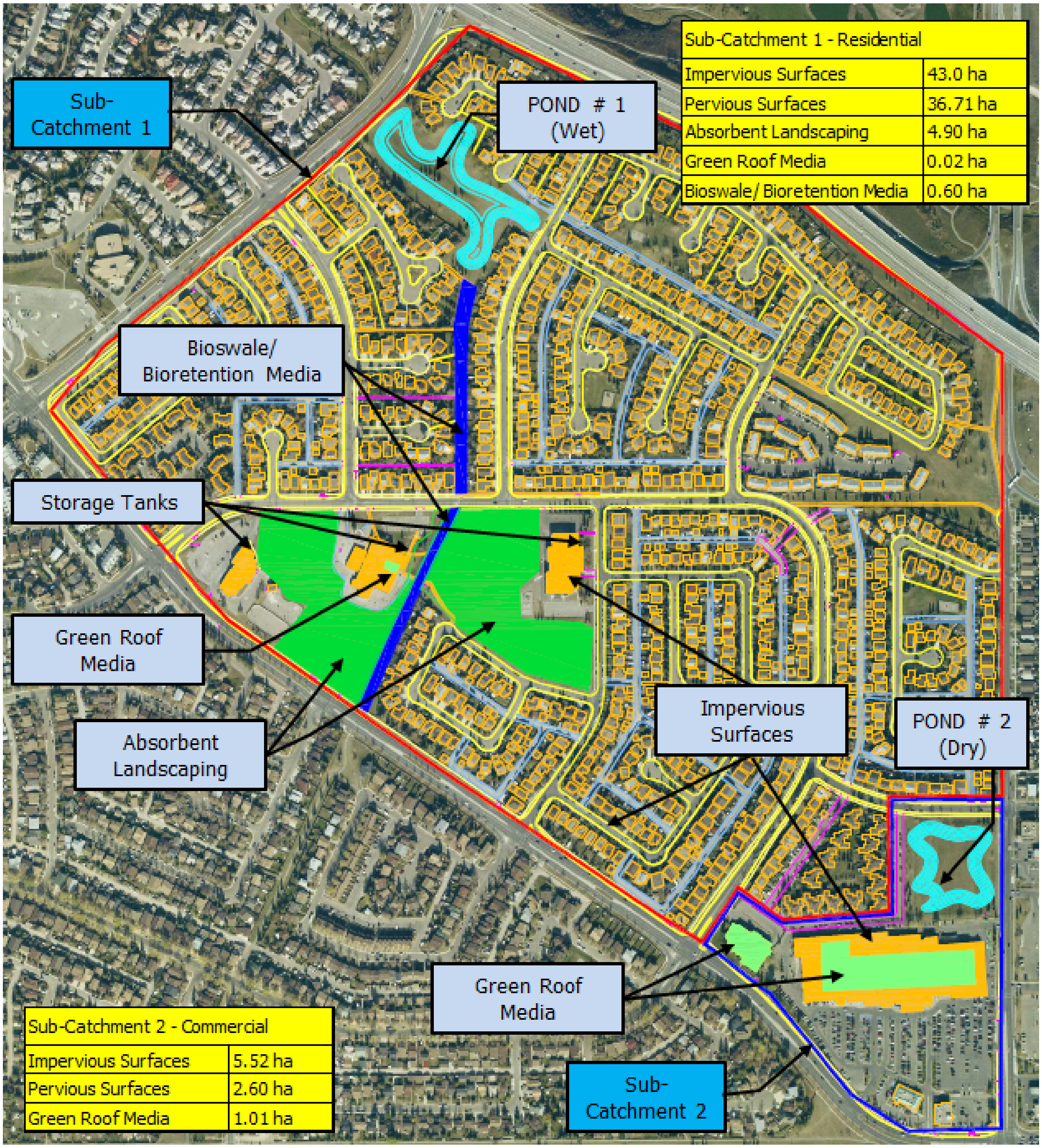
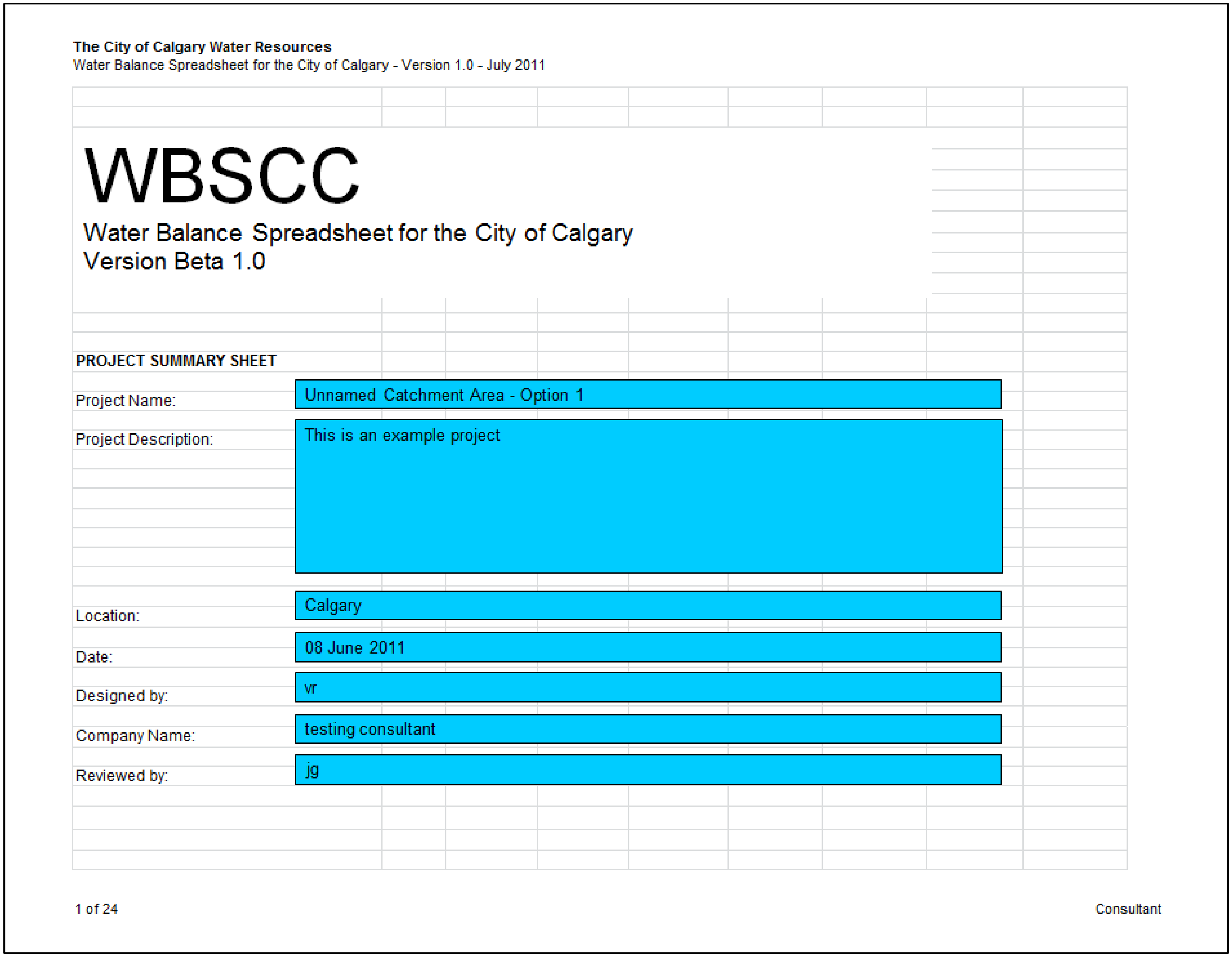


Figure A- 2: Detailed View of Catchment Area


The City of Calgary Water Resources
Water Balance Spreadsheet for the City of Calgary - Version 1.0 - July 2011

WBSCC
Water Balance Spreadsheet for the City of Calgary
Version Beta 1.0

PROJECT SUMMARY SHEET

Project Name:	Unnamed Catchment Area - Option 1
Project Description:	This is an example project
Location:	Calgary
Date:	08 June 2011
Designed by:	vr
Company Name:	testing consultant
Reviewed by:	jg

1 of 24 Consultant

Figure A- 3: Project Information (Option 1)

WBSCC - PROJECT DATA SHEET - Environmental Information

Minimum Temperature to Trigger Runoff (^oC)	0
Sublimation Losses (%)	10
Precipitation Multiplication Factor (% Decrease)	0

Month	Is Winter or Summer?	Crop Water Requirement (mm/month)			
		KENTUCKY BLUE GRAS	SAGE BRUSH	Unnamed 1	Unnamed 2
January	Winter	0	0	0	0
February	Winter	0	0	0	0
March	Winter	0	0	0	0
April	Summer	0	0	0	0
May	Summer	110	50	0	0
June	Summer	110	50	0	0
July	Summer	110	60	0	0
August	Summer	110	50	0	0
September	Summer	110	50	0	0
October	Summer	0	20	0	0
November	Winter	0	0	0	0
December	Winter	0	0	0	0

Catchment Area Data

Sub-Catchment	Description of Sub-catchment Use	Area (ha)
Sub-Catchment 1	Residential	85.23
Sub-Catchment 2	Commercial	9.13
Sub-Catchment 3		
Sub-Catchment 4		
Sub-Catchment 5		
Total		94.36

Pond Area Data

Pond	Description of Pond	Pond Area (m^2)
Pond 1	Wet pond; receives from Pond 2; discharges to outfall	13260
Pond 2	Dry pond; discharges to Pond 1	8739

Figure A- 4: Environmental Information and Catchment Area (Option 1 and Option 2)

WBSCC - PROJECT DATA SHEET - Sub-Catchment 1: Parameters, Runoff Allocation

Usage: Residential

Sub-catchment Parameters		Cover Type: Impervious Surface	Pervious Surface	Absorbent Landscaping	Green Roof Media	Bioretention/ Bioswale Medium	Unassigned Area
Area (Total: 85.23)	(ha)	43.02	36.71	4.9	0	0.6	0
Depression Loss	(mm)	1.6					
Soil Type: Sand					100	90	
Silt			100	100	0	10	
Clay							
Custom							
Unassigned			0	0	0	0	
Soil or Media Depth	(mm)		300	300	200	600	
Porosity			0.46	0.46	0.512	0.469	
Field Capacity			0.271	0.271	0.132	0.092	
Wilting Point			0.126	0.126	0.057	0.038	
Saturated Hydraulic Conductivity	(m/s)		5.00E-06	5.00E-06	2.50E-05	3.50E-05	
Sub-soil Hydraulic Conductivity	(m/s)		1.00E-08	1.00E-08		5.00E-08	
Ponding Depth	(mm)		0	0	0	300	
Inv. Slope of Log. Tension Moisture Curve			4.98	4.98	4.55	4.32	
Subdrain Invert (above bottom of media)	(mm)					100	
Subdrain Capacity	(m^3/s)					0.001	

% of Runoff Allocated To:	Runoff Allocated from Cover Type/ Facility: Impervious Surface	Pervious Surface	Absorbent Landscaping	Green Roof Media	Bioretention/ Bioswale Media	Storage/ Reuse Tank	Discharge
Pervious Surface	50			0			
Absorbent Landscaping	30	0		0			
Green Roof Media	0						
Storage/ Reuse Tank	0.1	60	50	0			
Bioretention/Bioswale Media	10	40	50	0			
Discharge	9.9	0	0	100	100	100	
Pond 1/Pond 2							POND #1

Figure A- 5: Sub-Catchment 1 - Parameters and Runoff Allocation (Option 1)

WBSCC - PROJECT DATA SHEET - Sub-Catchment 2: Crops, Irrigation, Storage/Reuse Tank

Storage/ Reuse Tank Parameters		Values
Tank Water Surface Area (assumed bath tub)	(m^2)	500
Spill Crest Elevation, above Tank Floor	(m)	1
Starting Water Level	(m)	0.5
Minimum Tank Water Elevation for Recharge	(m)	0
Maximum Tank Water Elevation for Recharge	(m)	1
Use Recharge from Storm Ponds		Yes
Recharge Source		POND #2
Additional Non-Potable Demand	(l/s)	0
Municipal Supply Available		No

Ground Cover Crop-Mix Profiles (Mix as %)

Crops	Profile #1	Profile #2	Profile #3
KENTUCKY BLUE GRASS	90	100	50
SAGE BRUSH	10	0	50
Unnamed 1	0	0	0
Unnamed 2	0	0	0
Unassigned	0	0	0

Irrigation Crop Profile or Scheduling Assignment:

Pervious Surface Cover Type			
Use Irrigation Schedule	No	Schedule Number	1
Use Crop Demand Profile	Yes	Profile Number	1
Absorbent Landscaping Cover Type			
Use Irrigation Schedule	No	Schedule Number	1
Use Crop Demand Profile	No	Profile Number	1
Green Roof Media			
Use Irrigation Schedule	No	Schedule Number	1
Use Crop Demand Profile	No	Profile Number	1

 Consultant

Figure A- 6: Sub-Catchment 1 - Storage Tank Parameters; Crops and Irrigation Profile Assignment (Option 1 and Option 2)

WBSCC - PROJECT DATA SHEET - Sub-Catchment 2: Weekly Watering Schedule

Weekly Watering Schedule #1 (Depth of Irrigation) (mm)

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Jan							
Feb							
Mar							
Apr							
May						10	
Jun			10			15	
Jul		10		10		15	
Aug		10		10		15	
Sep			10			15	
Oct							
Nov							
Dec							

Weekly Watering Schedule #2 (Depth of Irrigation) (mm)

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Jan							
Feb							
Mar							
Apr							
May							25
Jun							25
Jul							25
Aug							25
Sep							25
Oct							
Nov							
Dec							

Precipitation treshold (mm) during irrigation day and preceding two days: 10

Figure A- 7: Sub-Catchment 1 - Irrigation Schedules (Option 1 and Option 2)

WBSCC - PROJECT DATA SHEET - Sub-Catchment 2: Parameters, Runoff Allocation
Usage: Commercial

Sub-catchment Parameters		**Cover Type**					
		Impervious Surface	**Pervious Surface**	**Absorbent Landscaping**	**Green Roof Media**	**Bioretention/ Bioswale Medium**	**Unassigned Area**
Area (Total: 9.13)	(ha)	6.53	2.6	0	0	0	0
Depression Loss	(mm)	1.6					
Soil Type: Sand					100	90	
Silt			100	100	0	10	
Clay							
Custom							
Unassigned			0	0	0	0	
Soil or Media Depth	(mm)		100	50	200	600	
Porosity			0.46	0.46	0.512	0.469	
Field Capacity			0.271	0.271	0.132	0.092	
Wilting Point			0.126	0.126	0.057	0.038	
Saturated Hydraulic Conductivity	(m/s)		5.00E-06	5.00E-06	2.50E-05	3.50E-05	
Sub-soil Hydraulic Conductivity	(m/s)		1.00E-08	1.00E-08		5.00E-08	
Ponding Depth	(mm)		0	0	0	300	
Inv. Slope of Log. Tension Moisture Curve			4.98	4.98	4.55	4.32	
Subdrain Invert (above bottom of media)	(mm)					100	
Subdrain Capacity	(m^3/s)					0.001	

% of Runoff Allocated To:	**Runoff Allocated from Cover Type/ Facility:**						
	Impervious Surface	**Pervious Surface**	**Absorbent Landscaping**	**Green Roof Media**	**Bioretention/ Bioswale Media**	**Storage/ Reuse Tank**	**Discharge**
Pervious Surface	0			0			
Absorbent Landscaping	0	0		0			
Green Roof Media	0						
Storage/ Reuse Tank	0	0	0	0			
Bioretention/Bioswale Media	0	0	0	0			
Discharge	100	100	100	100	100	100	
Pond 1/Pond 2							POND #2

 Consultant

Figure A- 8: Sub-Catchment 2 - Parameters and Runoff Allocation (Option 1)

WBSCC - PROJECT DATA SHEET - Sub-Catchment 2: Crops, Irrigation, Storage/Reuse Tank

Storage/ Reuse Tank Parameters		Values
Tank Water Surface Area (assumed bath tub)	(m^2)	500
Spill Crest Elevation, above Tank Floor	(m)	1
Starting Water Level	(m)	0.5
Minimum Tank Water Elevation for Recharge	(m)	0
Maximum Tank Water Elevation for Recharge	(m)	1
Use Recharge from Storm Ponds		Yes
Recharge Source		POND #2
Additional Non-Potable Demand	(l/s)	0
Municipal Supply Available		No

Ground Cover Crop-Mix Profiles (Mix as %)

Crops	Profile #1	Profile #2	Profile #3
KENTUCKY BLUE GRASS	90	100	50
SAGE BRUSH	10	0	50
Unnamed 1	0	0	0
Unnamed 2	0	0	0
Unassigned	0	0	0

Irrigation Crop Profile or Scheduling Assignment:

Pervious Surface Cover Type			
Use Irrigation Schedule	No	Schedule Number	1
Use Crop Demand Profile	Yes	Profile Number	1
Absorbent Landscaping Cover Type			
Use Irrigation Schedule	No	Schedule Number	1
Use Crop Demand Profile	No	Profile Number	1
Green Roof Media			
Use Irrigation Schedule	No	Schedule Number	1
Use Crop Demand Profile	No	Profile Number	1

Figure A- 9: Sub-Catchment 2 - Storage Tank Parameters; Crops and Irrigation Profile Assignment (Option 1 and Option 2)

WBSCC - PROJECT DATA SHEET - Sub-Catchment 2: Weekly Watering Schedule

Weekly Watering Schedule #1 (Depth of Irrigation) (mm)

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Jan							
Feb							
Mar							
Apr							
May						10	
Jun			10			15	
Jul		10		10		15	
Aug		10		10		15	
Sep			10			15	
Oct							
Nov							
Dec							

Weekly Watering Schedule #2 (Depth of Irrigation) (mm)

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Jan							
Feb							
Mar							
Apr							
May							25
Jun							25
Jul							25
Aug							25
Sep							25
Oct							
Nov							
Dec							

Precipitation treshold (mm) during irrigation day and preceding two days: 10

Figure A- 10: Sub-Catchment 2 - Irrigation Schedules (Option 1 and Option 2)

WBSCC - PROJECT DATA SHEET - Pond 1: Parameters, Elevation-Area-Discharge-Volume Relationship

Pond 1 Parametrs		Values
Base Elevation	(m)	1091.00
Starting Water Elevation	(m)	1092.00
Starting Discharge Elevation (UNWL)	(m)	1092.50
High Water Level (HWL)	(m)	1094.00
Lower Normal Water Level (LNWL)	(m)	1092.00
Seepage Rate	(mm/hr)	0.01
Discharge and Overflow Routed to:		OUTFALL

Pond 1 Pertinent Volumes (m^3)	Values
Volume at Base Elevation	0
Volume at Stating Water Elevation	4547
Volume at LNWL	4547
Volume at UNWL	7995
Volume at HWL	23718

Pond 1 Bed Soil Parameters		
Soil Type: Sand		
Silt		100
Clay		
Custom		
Unassigned		0
Soil or Media Depth	(mm)	150
Porosity		0.46
Field Capacity		0.271
Wilting Point		0.126
Saturated Hydraulic Conductivity	(m/s)	5.00E-06
Sub-soil Hydraulic Conductivity	(m/s)	1.00E-08
Ponding Depth	(mm)	0
Inv. Slope of Log. Tension Moisture Curve		4.98

Elevation (m)	Area (m^2)	Discharge (m^3/s)
1091.00	3092	0
1091.50	4568	0
1092.00	6043	0
1092.50	7784	0
1093.00	9570	0.015
1093.50	11395	0.021
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026
1094.00	13260	0.026

Figure A- 11: POND #1 Parameters (Option 1 and Option 2)

WBSCC - PROJECT DATA SHEET - Pond 2: Parameters, Elevation-Area-Discharge Relationship

Pond 2 Parametrs		Values
Base Elevation	(m)	1109.50
Starting Water Elevation	(m)	1109.50
Starting Discharge Elevation (UNWL)	(m)	1109.50
High Water Level (HWL)	(m)	1112.50
Lower Normal Water Level (LNWL)	(m)	1109.50
Seepage Rate	(mm/hr)	0.01
Discharge and Overflow Routed to:		POND #1

Pond 2 Pertinent Volumes (m^3)	Values
Volume at Base Elevation	0
Volume at Stating Water Elevation	0
Volume at LNWL	0
Volume at UNWL	0
Volume at HWL	16426

Pond 2 Bed Soil Parameters		
Soil Type: Sand		
Silt		100
Clay		
Custom		
Unassigned		0
Soil or Media Depth	(mm)	150
Porosity		0.46
Field Capacity		0.271
Wilting Point		0.126
Saturated Hydraulic Conductivity	(m/s)	5.00E-06
Sub-soil Hydraulic Conductivity	(m/s)	1.00E-08
Ponding Depth	(mm)	0
Inv. Slope of Log. Tension Moisture Curve		4.98

Elevation (m)	Area (m^2)	Discharge (m^3/s)
1109.50	0	0
1109.60	570	0.0005
1109.70	1529	0.0008
1109.80	2012	0.0010
1109.90	2935	0.0012
1110.00	3501	0.0015
1110.50	4891	0.0021
1111.00	5763	0.0026
1111.50	6702	0.0030
1112.00	7700	0.0033
1112.50	8739	0.0036
1112.50	8739	0.0036
1112.50	8739	0.0036
1112.50	8739	0.0036
1112.50	8739	0.0036
1112.50	8739	0.0036
1112.50	8739	0.0036
1112.50	8739	0.0036
1112.50	8739	0.0036
1112.50	8739	0.0036
1112.50	8739	0.0036

Figure A- 12: POND #2 Parameters (Option 1 and Option 2)

SUBCATCHMENT 1	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	17810513.1
AVERAGE PRECIPITATION	409.7	
MEDIAN PRECIPITATION	404.7	
TOTAL RUNOFF (INCLUDING SUBDRAIN)	2148.4	1831067.3
% OF RAINFALL AS RUNOFF	10.3	
AVERAGE RUNOFF (INCLUDING SUBDRAIN)	42.1	35903.3
MEDIAN RUNOFF (INCLUDING SUBDRAIN)	33.6	28672.8
TOTAL IRRIGATION DEMAND	2512.6	2141498.2
MAXIMUM RUNOFF (ANY TIMESTEP)	47.8	40761.4
AVERAGE EVAPORATION	370.8	316004.2
AVERAGE PERCOLATION	25.4	21663.5
TOTAL RUNOFF + EVAP + PERCOLATION	438.3	373571.0

SUBCATCHMENT 1	
OVERALL WATER BALANCE OVER 51 YEARS	(m3)
TOTAL PRECIPITATION	17,810,513
TOTAL EXTERNAL RUNON	-
TOTAL RUNOFF (INCLUDING SUBDRAIN)	1,831,067
TOTAL EVAPORATION IMPERVIOUS AREAS	2,314,863
TOTAL EVAPOTRANSP PERVIOUS AREAS	13,801,352
TOTAL RECHARGE FROM PONDS TO STORAGE TANK	1,399,332
TOTAL PERCOLATION	1,104,836
SUBLIMATION LOSSES	308,848
SNOW PACK AT THE END OF SIMULATION PERIOD	5,063
WATER BALANCE	(156,185)
CONTINUITY ERROR	-0.9%

SC1: IMPERVIOUS AREA	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	8989889.4
TOTAL RUNOFF	15516.1	6675026.2
% OF RAINFALL AS RUNOFF	74.3	
AVERAGE RUNOFF	304.2	130882.9
MEDIAN RUNOFF	299.3	128741.7
MAXIMUM RUNOFF (ANY TIMESTEP)	91.0	39148.2
AVERAGE EVAPORATION LOSSES	105.5	45389.5

SC1: PERVIOUS AREA	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	7671288.7
TOTAL RUNOFF	1591.0	584040.1
% OF RAINFALL AS RUNOFF	7.6	
AVERAGE RUNOFF	31.2	11451.8
MEDIAN RUNOFF	9.8	3589.5
MAXIMUM RUNOFF (ANY TIMESTEP)	76.4	28043.0
TOTAL IRRIGATION DEMAND	5125.2	1881465.9
AVERAGE IRRIGATION DEMAND	100.5	36891.5
MEDIAN IRRIGATION DEMAND	97.7	35872.4
TOTAL RUNON	9091.6	3337513.1
AVERAGE RUNON	178.3	65441.4
MEDIAN RUNON	175.3	64370.8
TOTAL SEEPAGE	1955.1	717716.0
AVERAGE SEEPAGE	38.3	14072.9
MEDIAN SEEPAGE	35.2	12918.3
TOTAL EVAPORATION	31193.5	11451135.5
AVERAGE EVAPORATION	611.6	224532.1
MEDIAN EVAPORATION	606.3	222568.5
WATER BALANCE (OVER PERIOD OF RECORD)	5.8	mm

Figure A- 13: Sub-Catchment 1 – Summarized Runoff Results Part 1 (Option 1)

SC1: ABSORBENT AREA	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	1023953.0
TOTAL RUNOFF	20225.2	991035.3
% OF RAINFALL AS RUNOFF	96.8	
AVERAGE RUNOFF	396.6	19432.1
MEDIAN RUNOFF	382.9	18764.1
MAXIMUM RUNOFF (ANY TIMESTEP)	311.6	15270.8
TOTAL IRRIGATION DEMAND	5306.8	260032.3
AVERAGE IRRIGATION DEMAND	104.1	5098.7
MEDIAN IRRIGATION DEMAND	104.2	5105.9
TOTAL RUNON	40867.5	2002507.9
AVERAGE RUNON	801.3	39264.9
MEDIAN RUNON	788.2	38622.5
TOTAL SEEPAGE	4770.3	233743.1
AVERAGE SEEPAGE	93.5	4583.2
MEDIAN SEEPAGE	89.2	4370.0
TOTAL EVAPORATION	41662.9	2041480.7
AVERAGE EVAPORATION	816.9	40029.0
MEDIAN EVAPORATION	828.3	40586.8
WATER BALANCE (OVER PERIOD OF RECORD)	-0.1	mm

SC1: GREENROOF	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	0.0
TOTAL RUNOFF	2.0	0.0
% OF RAINFALL AS RUNOFF	0.0	
AVERAGE RUNOFF	0.0	0.0
MEDIAN RUNOFF	0.0	0.0
MAXIMUM RUNOFF (ANY TIMESTEP)	2.0	0.0
TOTAL IRRIGATION DEMAND	0.0	0.0
AVERAGE IRRIGATION DEMAND	0.0	0.0
MEDIAN IRRIGATION DEMAND	0.0	0.0
TOTAL RUNON	0.0	0.0
AVERAGE RUNON	0.0	0.0
MEDIAN RUNON	0.0	0.0
TOTAL SEEPAGE	1121.7	0.0
AVERAGE SEEPAGE	22.0	0.0
MEDIAN SEEPAGE	7.4	0.0
TOTAL EVAPORATION	19403.4	0.0
AVERAGE EVAPORATION	380.5	0.0
MEDIAN EVAPORATION	378.8	0.0
WATER BALANCE (OVER PERIOD OF RECORD)	-0.1	mm

SC1: BIOSWALE	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	125382.0
TOTAL SURFACE RUNOFF	108643.9	651863.6
% OF RAINFALL AS SURFACE RUNOFF + SUBD	842.7	
AVERAGE SURFACE RUNOFF	2130.3	12781.6
MEDIAN SURFACE RUNOFF	1162.9	6977.3
MAXIMUM RUNOFF (ANY TIMESTEP)	3337.4	20024.4
TOTAL RUNON	232772.7	1396636.3
AVERAGE RUNON	4564.2	27385.0
MEDIAN RUNON	3909.1	23454.5
TOTAL PERCOLATION	25562.9	153377.3
AVERAGE PERCOLATION	501.2	3007.4
MEDIAN PERCOLATION	497.7	2985.9
TOTAL EVAPORATION	51456.0	308736.1
AVERAGE EVAPORATION	1008.9	6053.6
MEDIAN EVAPORATION	1020.6	6123.4
TOTAL SUBDRAIN	67449.8	404698.6
AVERAGE SUBDRAIN	1322.5	7935.3
MEDIAN SUBDRAIN	1236.2	7417.0
WATER BALANCE (OVER PERIOD OF RECORD)	-3.0	mm

SC1: STORAGE / REUSE	(m3)
MAXIMUM VOLUME OVER RECORD	14400.0
AVERAGE MAX. VOLUME	7969.1
MEDIAN MAX. VOLUME	6280.6
MINIMUM VOLUME OVER RECORD	1080.0
AVERAGE MIN. VOLUME	1080.0
MEDIAN MIN. VOLUME	1080.0
TOTAL INFLOW	852616.7
AVERAGE INFLOW	16718.0
MEDIAN INFLOW	9990.1
TOTAL DEMAND	2141498.2
AVERAGE DEMAND	41990.2
MEDIAN DEMAND	41419.6
TOTAL OVERFLOW	113677.4
AVERAGE OVERFLOW	2229.0
MEDIAN OVERFLOW	0.0
TOTAL MUN. MAKE-UP WATER	0.0
AVERAGE MUN. MAKE-UP WATER	0.0
MEDIAN MUN. MAKE-UP WATER	0.0
TOTAL RECHARGE FROM PONDS	1399332.1
AVERAGE RECHARGE FROM PONDS	27437.9
MEDIAN RECHARGE FROM PONDS	26692.3
WATER BALANCE (OVER PERIOD OF RECORD)	0.7

Figure A- 14: Sub-Catchment 1 – Summarized Runoff Results Part 2 (Option 1)

SUBCATCHMENT 2	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	1907896.1
AVERAGE PRECIPITATION	409.7	
MEDIAN PRECIPITATION	404.7	
TOTAL RUNOFF (INCLUDING SUBDRAIN)	11591.6	1058309.6
% OF RAINFALL AS RUNOFF	55.5	
AVERAGE RUNOFF (INCLUDING SUBDRAIN)	227.3	20751.2
MEDIAN RUNOFF (INCLUDING SUBDRAIN)	220.5	20131.1
TOTAL IRRIGATION DEMAND	2798.0	255454.7
MAXIMUM RUNOFF (ANY TIMESTEP)	85.5	7802.6
AVERAGE EVAPORATION	228.0	20816.4
AVERAGE PERCOLATION	7.2	661.0
TOTAL RUNOFF + EVAP + PERCOLATION	462.5	42228.6

SUBCATCHMENT 2	
OVERALL WATER BALANCE OVER 51 YEARS	(m3)
TOTAL PRECIPITATION	1,907,896
TOTAL EXTERNAL RUNON	-
TOTAL RUNOFF (INCLUDING SUBDRAIN)	1,058,310
TOTAL EVAPORATION IMPERVIOUS AREAS	351,373
TOTAL EVAPOTRANSP PERVIOUS AREAS	710,264
TOTAL RECHARGE FROM PONDS TO STORAGE TANK	255,205
TOTAL PERCOLATION	33,712
SUBLIMATION LOSSES	33,084
SNOW PACK AT THE END OF SIMULATION PERIOD	542
WATER BALANCE	(24,184)
CONTINUITY ERROR	-1.3%

SC2: IMPERVIOUS AREA	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	1364574.1
TOTAL RUNOFF	15516.1	1013201.3
% OF RAINFALL AS RUNOFF	74.3	
AVERAGE RUNOFF	304.2	
MEDIAN RUNOFF	299.3	
MAXIMUM RUNOFF (ANY TIMESTEP)	91.0	5942.3
AVERAGE EVAPORATION LOSSES	105.5	6889.7

SC2: PERVIOUS AREA	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	543322.0
TOTAL RUNOFF	1734.9	45108.2
% OF RAINFALL AS RUNOFF	8.3	
AVERAGE RUNOFF	34.0	884.5
MEDIAN RUNOFF	26.5	689.2
MAXIMUM RUNOFF (ANY TIMESTEP)	71.6	1860.3
TOTAL IRRIGATION DEMAND	9825.2	255454.7
AVERAGE IRRIGATION DEMAND	192.7	5008.9
MEDIAN IRRIGATION DEMAND	191.4	4976.9
TOTAL RUNON	0.0	0.0
AVERAGE RUNON	0.0	0.0
MEDIAN RUNON	0.0	0.0
TOTAL SEEPAGE	1296.6	33711.7
AVERAGE SEEPAGE	25.4	661.0
MEDIAN SEEPAGE	23.6	612.7
TOTAL EVAPORATION	27317.9	710264.4
AVERAGE EVAPORATION	535.6	13926.8
MEDIAN EVAPORATION	552.9	14374.4
WATER BALANCE (OVER PERIOD OF RECORD)	5.7	mm

Figure A- 15: Sub-Catchment 2 – Summarized Runoff Results Part 1 (Option 1)

SC2: ABSORBENT AREA	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	0.0
TOTAL RUNOFF	3868.2	0.0
% OF RAINFALL AS RUNOFF	18.5	
AVERAGE RUNOFF	75.8	0.0
MEDIAN RUNOFF	70.5	0.0
MAXIMUM RUNOFF (ANY TIMESTEP)	77.0	0.0
TOTAL IRRIGATION DEMAND	0.0	0.0
AVERAGE IRRIGATION DEMAND	0.0	0.0
MEDIAN IRRIGATION DEMAND	0.0	0.0
TOTAL RUNON	0.0	0.0
AVERAGE RUNON	0.0	0.0
MEDIAN RUNON	0.0	0.0
TOTAL SEEPAGE	1165.5	0.0
AVERAGE SEEPAGE	22.9	0.0
MEDIAN SEEPAGE	21.6	0.0
TOTAL EVAPORATION	16051.9	0.0
AVERAGE EVAPORATION	314.7	0.0
MEDIAN EVAPORATION	316.3	0.0
WATER BALANCE (OVER PERIOD OF RECORD)	-562.1	mm

SC2: GREENROOF	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	0.0
TOTAL RUNOFF	2.0	0.0
% OF RAINFALL AS RUNOFF	0.0	
AVERAGE RUNOFF	0.0	0.0
MEDIAN RUNOFF	0.0	0.0
MAXIMUM RUNOFF (ANY TIMESTEP)	2.0	0.0
TOTAL IRRIGATION DEMAND	0.0	0.0
AVERAGE IRRIGATION DEMAND	0.0	0.0
MEDIAN IRRIGATION DEMAND	0.0	0.0
TOTAL RUNON	0.0	0.0
AVERAGE RUNON	0.0	0.0
MEDIAN RUNON	0.0	0.0
TOTAL SEEPAGE	1121.7	0.0
AVERAGE SEEPAGE	22.0	0.0
MEDIAN SEEPAGE	7.4	0.0
TOTAL EVAPORATION	19403.4	0.0
AVERAGE EVAPORATION	380.5	0.0
MEDIAN EVAPORATION	378.8	0.0
WATER BALANCE (OVER PERIOD OF RECORD)	-0.1	mm

SC2: BIOSWALE	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	0.0
TOTAL SURFACE RUNOFF	0.0	0.0
% OF RAINFALL AS SURFACE RUNOFF + SUBD	0.0	
AVERAGE SURFACE RUNOFF	0.0	0.0
MEDIAN SURFACE RUNOFF	0.0	0.0
MAXIMUM RUNOFF (ANY TIMESTEP)	0.0	0.0
TOTAL RUNON	0.0	0.0
AVERAGE RUNON	0.0	0.0
MEDIAN RUNON	0.0	0.0
TOTAL PERCOLATION	0.0	0.0
AVERAGE PERCOLATION	0.0	0.0
MEDIAN PERCOLATION	0.0	0.0
TOTAL EVAPORATION	20546.1	0.0
AVERAGE EVAPORATION	402.9	0.0
MEDIAN EVAPORATION	395.9	0.0
TOTAL SUBDRAIN	0.0	0.0
AVERAGE SUBDRAIN	0.0	0.0
MEDIAN SUBDRAIN	0.0	0.0
WATER BALANCE (OVER PERIOD OF RECORD)	-11.4	mm

SC2: STORAGE / REUSE	(m3)
MAXIMUM VOLUME OVER RECORD	250.0
AVERAGE MAX. VOLUME	4.9
MEDIAN MAX. VOLUME	0.0
MINIMUM VOLUME OVER RECORD	0.0
AVERAGE MIN. VOLUME	0.0
MEDIAN MIN. VOLUME	0.0
TOTAL INFLOW	0.0
AVERAGE INFLOW	0.0
MEDIAN INFLOW	0.0
TOTAL DEMAND	255454.7
AVERAGE DEMAND	5008.9
MEDIAN DEMAND	4976.9
TOTAL OVERFLOW	0.0
AVERAGE OVERFLOW	0.0
MEDIAN OVERFLOW	0.0
TOTAL MUN. MAKE-UP WATER	0.0
AVERAGE MUN. MAKE-UP WATER	0.0
MEDIAN MUN. MAKE-UP WATER	0.0
TOTAL RECHARGE FROM PONDS	255204.7
AVERAGE RECHARGE FROM PONDS	5004.0
MEDIAN RECHARGE FROM PONDS	4976.9
WATER BALANCE (OVER PERIOD OF RECORD)	0.0

Figure A- 16: Sub-Catchment 2 – Summarized Runoff Results Part 2 (Option 1)

POND 1	POND #1	CATCHMENT AREA SIZE		
DISCHARGES TO	OUTFALL	85.23	ha - DIRECT	
		94.36	ha - TOTAL	
	MAX	MIN	AVG	MEDIAN
VOLUME (m^3)	23745	2607	6063	5603
LEVEL (m)	1093.000	1091.633	1092.204	1092.204
	MAX	TOTAL	AVG	MEDIAN
INFLOW (m^3)	128744	2653980	52039	44383
DIRECT PRECIPITATION (m^3)	4749	142496	2794	2778
EVAPORATION LOSS (m^3)	5573	252826	4957	4884
SEEPAGE LOSS (m^3)	335	15126	297	296
DISCHARGE (m^3)	86704	991003	19431	14410
OVERFLOW (m^3)	34763	137703	2700	0
MAKE-UP WATER (m^3)	0	0	0	0
DEMAND (m^3)	46438	1399332	27438	26692
WATER BALANCE (m^3)		-1		

POND 2	POND #2	CATCHMENT AREA SIZE		
DISCHARGES TO	POND #1	9.13	ha - DIRECT	
		9.13	ha - TOTAL	
	MAX	MIN	AVG	MEDIAN
VOLUME (m^3)	11295	0	436	1
LEVEL (m)	1109.900	1109.500	1109.699	1109.699
	MAX	TOTAL	AVG	MEDIAN
INFLOW (m^3)	35286	1061767	20819	20131
DIRECT PRECIPITATION (m^3)	1932	48816	957	943
EVAPORATION LOSS (m^3)	2360	67927	1332	1321
SEEPAGE LOSS (m^3)	154	4632	91	88
DISCHARGE (m^3)	28837	819617	16071	15329
OVERFLOW (m^3)	0	0	0	0
MAKE-UP WATER (m^3)	0	0	0	0
DEMAND (m^3)	7595	255205	5004	4977
WATER BALANCE (m^3)		-36798		

Figure A- 17: Ponds – Summarized Results (Option 1)

WBSCC - PROJECT DATA SHEET - Sub-Catchment 1: Parameters, Runoff Allocation

Usage: Residential

Sub-catchment Parameters		**Cover Type**					
		Impervious Surface	**Pervious Surface**	**Absorbent Landscaping**	**Green Roof Media**	**Bioretention/ Bioswale Medium**	**Unassigned Area**
Area (Total: 85.23)	(ha)	43	36.71	4.9	0.02	0.6	0
Depression Loss	(mm)	1.6					
Soil Type: Sand					100	90	
Silt			100	100	0	10	
Clay							
Custom							
Unassigned			0	0	0	0	
Soil or Media Depth	(mm)		300	300	200	600	
Porosity			0.46	0.46	0.512	0.469	
Field Capacity			0.271	0.271	0.132	0.092	
Wilting Point			0.126	0.126	0.057	0.038	
Saturated Hydraulic Conductivity	(m/s)		5.00E-06	5.00E-06	2.50E-05	3.50E-05	
Sub-soil Hydraulic Conductivity	(m/s)		1.00E-08	1.00E-08		5.00E-08	
Ponding Depth	(mm)		0	0	0	300	
Inv. Slope of Log. Tension Moisture Curve			4.98	4.98	4.55	4.32	
Subdrain Invert (above bottom of media)	(mm)					100	
Subdrain Capacity	(m^3/s)					0.001	

% of Runoff Allocated To:		**Runoff Allocated from Cover Type/ Facility:**						
		Impervious Surface	**Pervious Surface**	**Absorbent Landscaping**	**Green Roof Media**	**Bioretention/ Bioswale Media**	**Storage/ Reuse Tank**	**Discharge**
Pervious Surface		50			0			
Absorbent Landscaping		30	0		0			
Green Roof Media		0						
Storage/ Reuse Tank		0.1	60	50	0			
Bioretention/Bioswale Media		10	40	50	0			
Discharge		9.9	0	0	100	100	100	
Pond 1/Pond 2								POND #1

Figure A- 18: Sub-Catchment 1 - Parameters and Runoff Allocation (Option 2)

WBSCC - PROJECT DATA SHEET - Sub-Catchment 2: Parameters, Runoff Allocation
Usage: Commercial

Sub-catchment Parameters		Cover Type					
		Impervious Surface	Pervious Surface	Absorbent Landscaping	Green Roof Media	Bioretention/ Bioswale Medium	Unassigned Area
Area (Total: 9.13)	(ha)	5.52	2.6	0	1.01	0	0
Depression Loss	(mm)	1.6					
Soil Type: Sand					100	90	
Silt			100	100	0	10	
Clay							
Custom							
Unassigned			0	0	0	0	
Soil or Media Depth	(mm)		100	50	200	600	
Porosity			0.46	0.46	0.512	0.469	
Field Capacity			0.271	0.271	0.132	0.092	
Wilting Point			0.126	0.126	0.057	0.038	
Saturated Hydraulic Conductivity	(m/s)		5.00E-06	5.00E-06	2.50E-05	3.50E-05	
Sub-soil Hydraulic Conductivity	(m/s)		1.00E-08	1.00E-08		5.00E-08	
Ponding Depth	(mm)		0	0	0	300	
Inv. Slope of Log. Tension Moisture Curve			4.98	4.98	4.55	4.32	
Subdrain Invert (above bottom of media)	(mm)					100	
Subdrain Capacity	(m^3/s)					0.001	

% of Runoff Allocated To:		Runoff Allocated from Cover Type/ Facility:						
		Impervious Surface	Pervious Surface	Absorbent Landscaping	Green Roof Media	Bioretention/ Bioswale Media	Storage/ Reuse Tank	Discharge
Pervious Surface		0			0			
Absorbent Landscaping		0	0		0			
Green Roof Media		0						
Storage/ Reuse Tank		0	0	0	0			
Bioretention/Bioswale Media		0	0	0	0			
Discharge		100	100	100	100	100	100	
Pond 1/Pond 2								POND #2

Figure A- 19: Sub-Catchment 2 - Parameters and Runoff Allocation (Option 2)

SUBCATCHMENT 1	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	17810513.1
AVERAGE PRECIPITATION	409.7	
MEDIAN PRECIPITATION	404.7	
TOTAL RUNOFF (INCLUDING SUBDRAIN)	2139.9	1823818.3
% OF RAINFALL AS RUNOFF	10.2	
AVERAGE RUNOFF (INCLUDING SUBDRAIN)	42.0	35761.1
MEDIAN RUNOFF (INCLUDING SUBDRAIN)	33.6	28632.9
TOTAL IRRIGATION DEMAND	2394.0	2040442.6
MAXIMUM RUNOFF (ANY TIMESTEP)	47.8	40746.6
AVERAGE EVAPORATION	369.0	314484.4
AVERAGE PERCOLATION	25.2	21487.7
TOTAL RUNOFF + EVAP + PERCOLATION	436.2	371733.3

SUBCATCHMENT 1	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	17810513.1
AVERAGE PRECIPITATION	409.7	
MEDIAN PRECIPITATION	404.7	
TOTAL RUNOFF (INCLUDING SUBDRAIN)	2139.9	1823818.3
% OF RAINFALL AS RUNOFF	10.2	
AVERAGE RUNOFF (INCLUDING SUBDRAIN)	42.0	35761.1
MEDIAN RUNOFF (INCLUDING SUBDRAIN)	33.6	28632.9
TOTAL IRRIGATION DEMAND	2394.0	2040442.6
MAXIMUM RUNOFF (ANY TIMESTEP)	47.8	40746.6
AVERAGE EVAPORATION	369.0	314484.4
AVERAGE PERCOLATION	25.2	21487.7
TOTAL RUNOFF + EVAP + PERCOLATION	436.2	371733.3

SC1: IMPERVIOUS AREA	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	8985710.0
TOTAL RUNOFF	15516.1	6671923.0
% OF RAINFALL AS RUNOFF	74.3	
AVERAGE RUNOFF	304.2	130822.0
MEDIAN RUNOFF	299.3	128681.8
MAXIMUM RUNOFF (ANY TIMESTEP)	91.0	39130.0
AVERAGE EVAPORATION LOSSES	105.5	45368.4

SC1: PERVIOUS AREA	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	7671288.7
TOTAL RUNOFF	1569.9	576302.3
% OF RAINFALL AS RUNOFF	7.5	
AVERAGE RUNOFF	30.8	11300.0
MEDIAN RUNOFF	7.1	2599.7
MAXIMUM RUNOFF (ANY TIMESTEP)	76.4	28037.2
TOTAL IRRIGATION DEMAND	4884.8	1793195.6
AVERAGE IRRIGATION DEMAND	95.8	35160.7
MEDIAN IRRIGATION DEMAND	91.0	33414.7
TOTAL RUNON	9087.3	3335961.5
AVERAGE RUNON	178.2	65411.0
MEDIAN RUNON	175.3	64340.9
TOTAL SEEPAGE	1934.4	710124.7
AVERAGE SEEPAGE	37.9	13924.0
MEDIAN SEEPAGE	35.0	12865.2
TOTAL EVAPORATION	30990.6	11376645.2
AVERAGE EVAPORATION	607.7	223071.5
MEDIAN EVAPORATION	602.0	221005.8
WATER BALANCE (OVER PERIOD OF RECORD)	5.8	mm

Figure A- 20: Sub-Catchment 1 – Summarized Runoff Results Part 1 (Option 2)

SC1: ABSORBENT AREA	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	1023953.0
TOTAL RUNOFF	20088.1	984317.1
% OF RAINFALL AS RUNOFF	96.1	
AVERAGE RUNOFF	393.9	19300.3
MEDIAN RUNOFF	379.1	18578.2
MAXIMUM RUNOFF (ANY TIMESTEP)	309.1	15144.4
TOTAL IRRIGATION DEMAND	5025.3	246242.0
AVERAGE IRRIGATION DEMAND	98.5	4828.3
MEDIAN IRRIGATION DEMAND	100.9	4942.4
TOTAL RUNON	40848.5	2001576.9
AVERAGE RUNON	801.0	39246.6
MEDIAN RUNON	787.8	38604.5
TOTAL SEEPAGE	4743.2	232416.1
AVERAGE SEEPAGE	93.0	4557.2
MEDIAN SEEPAGE	88.6	4339.7
TOTAL EVAPORATION	41526.6	2034805.6
AVERAGE EVAPORATION	814.2	39898.1
MEDIAN EVAPORATION	824.0	40374.6
WATER BALANCE (OVER PERIOD OF RECORD)	-0.1	mm

SC1: GREENROOF	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	4179.4
TOTAL RUNOFF	12.5	2.5
% OF RAINFALL AS RUNOFF	0.1	
AVERAGE RUNOFF	0.2	0.0
MEDIAN RUNOFF	0.0	0.0
MAXIMUM RUNOFF (ANY TIMESTEP)	6.9	1.4
TOTAL IRRIGATION DEMAND	5025.3	1005.1
AVERAGE IRRIGATION DEMAND	98.5	19.7
MEDIAN IRRIGATION DEMAND	100.9	20.2
TOTAL RUNON	0.0	0.0
AVERAGE RUNON	0.0	0.0
MEDIAN RUNON	0.0	0.0
TOTAL SEEPAGE	1661.2	332.2
AVERAGE SEEPAGE	32.6	6.5
MEDIAN SEEPAGE	22.7	4.5
TOTAL EVAPORATION	23878.8	4775.8
AVERAGE EVAPORATION	468.2	93.6
MEDIAN EVAPORATION	464.9	93.0
WATER BALANCE (OVER PERIOD OF RECORD)	-0.1	mm

SC1: BIOSWALE	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	125382.0
TOTAL SURFACE RUNOFF	107792.5	646755.2
% OF RAINFALL AS SURFACE RUNOFF + SUBD	837.6	
AVERAGE SURFACE RUNOFF	2113.6	12681.5
MEDIAN SURFACE RUNOFF	1157.5	6945.2
MAXIMUM RUNOFF (ANY TIMESTEP)	3275.5	19652.9
TOTAL RUNON	231645.3	1389871.8
AVERAGE RUNON	4542.1	27252.4
MEDIAN RUNON	3840.9	23045.5
TOTAL PERCOLATION	25500.2	153001.1
AVERAGE PERCOLATION	500.0	3000.0
MEDIAN PERCOLATION	496.9	2981.6
TOTAL EVAPORATION	51448.6	308691.5
AVERAGE EVAPORATION	1008.8	6052.8
MEDIAN EVAPORATION	1020.6	6123.4
TOTAL SUBDRAIN	67244.1	403464.7
AVERAGE SUBDRAIN	1318.5	7911.1
MEDIAN SUBDRAIN	1227.1	7362.9
WATER BALANCE (OVER PERIOD OF RECORD)	-3.0	mm

SC1: STORAGE / REUSE	(m3)
MAXIMUM VOLUME OVER RECORD	14400.0
AVERAGE MAX. VOLUME	7922.8
MEDIAN MAX. VOLUME	6129.3
MINIMUM VOLUME OVER RECORD	1080.0
AVERAGE MIN. VOLUME	1080.0
MEDIAN MIN. VOLUME	1080.0
TOTAL INFLOW	844611.9
AVERAGE INFLOW	16561.0
MEDIAN INFLOW	9974.3
TOTAL DEMAND	2040442.6
AVERAGE DEMAND	40008.7
MEDIAN DEMAND	39186.3
TOTAL OVERFLOW	112743.3
AVERAGE OVERFLOW	2210.7
MEDIAN OVERFLOW	0.0
TOTAL MUN. MAKE-UP WATER	0.0
AVERAGE MUN. MAKE-UP WATER	0.0
MEDIAN MUN. MAKE-UP WATER	0.0
TOTAL RECHARGE FROM PONDS	1305347.2
AVERAGE RECHARGE FROM PONDS	25595.0
MEDIAN RECHARGE FROM PONDS	25035.9
WATER BALANCE (OVER PERIOD OF RECORD)	0.7

Figure A- 21: Sub-Catchment 1 – Summarized Runoff Results Part 2 (Option 2)

SUBCATCHMENT 2	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	1907896.1
AVERAGE PRECIPITATION	409.7	
MEDIAN PRECIPITATION	404.7	
TOTAL RUNOFF (INCLUDING SUBDRAIN)	10054.5	917976.0
% OF RAINFALL AS RUNOFF	48.1	
AVERAGE RUNOFF (INCLUDING SUBDRAIN)	197.1	17999.5
MEDIAN RUNOFF (INCLUDING SUBDRAIN)	187.3	17104.0
TOTAL IRRIGATION DEMAND	3217.1	293723.4
MAXIMUM RUNOFF (ANY TIMESTEP)	76.4	6979.1
AVERAGE EVAPORATION	265.9	24273.9
AVERAGE PERCOLATION	10.6	969.8
TOTAL RUNOFF + EVAP + PERCOLATION	473.6	43243.2

SUBCATCHMENT 2	
OVERALL WATER BALANCE OVER 51 YEARS	(m3)
TOTAL PRECIPITATION	1,907,896
TOTAL EXTERNAL RUNON	-
TOTAL RUNOFF (INCLUDING SUBDRAIN)	917,976
TOTAL EVAPORATION IMPERVIOUS AREAS	297,026
TOTAL EVAPOTRANSP PERVIOUS AREAS	940,943
TOTAL RECHARGE FROM PONDS TO STORAGE TANK	293,473
TOTAL PERCOLATION	32,264
SUBLIMATION LOSSES	33,084
SNOW PACK AT THE END OF SIMULATION PERIOD	542
WATER BALANCE	(20,466)
CONTINUITY ERROR	-1.1%

SC2: IMPERVIOUS AREA	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	1153514.4
TOTAL RUNOFF	15516.1	856488.7
% OF RAINFALL AS RUNOFF	74.3	
AVERAGE RUNOFF	304.2	
MEDIAN RUNOFF	299.3	
MAXIMUM RUNOFF (ANY TIMESTEP)	91.0	5023.2
AVERAGE EVAPORATION LOSSES	105.5	5824.0

SC2: PERVIOUS AREA	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	543322.0
TOTAL RUNOFF	1696.3	44103.4
% OF RAINFALL AS RUNOFF	8.1	
AVERAGE RUNOFF	33.3	864.8
MEDIAN RUNOFF	26.5	689.3
MAXIMUM RUNOFF (ANY TIMESTEP)	70.9	1843.1
TOTAL IRRIGATION DEMAND	7837.9	203786.7
AVERAGE IRRIGATION DEMAND	153.7	3995.8
MEDIAN IRRIGATION DEMAND	150.2	3904.4
TOTAL RUNON	0.0	0.0
AVERAGE RUNON	0.0	0.0
MEDIAN RUNON	0.0	0.0
TOTAL SEEPAGE	1240.9	32264.5
AVERAGE SEEPAGE	24.3	632.6
MEDIAN SEEPAGE	23.0	598.7
TOTAL EVAPORATION	25425.6	661065.9
AVERAGE EVAPORATION	498.5	12962.1
MEDIAN EVAPORATION	508.0	13207.4
WATER BALANCE (OVER PERIOD OF RECORD)	5.1	mm

Figure A- 22: Sub-Catchment 2 – Summarized Runoff Results Part 1 (Option 2)

SC2: ABSORBENT AREA	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	0.0
TOTAL RUNOFF	3868.2	0.0
% OF RAINFALL AS RUNOFF	18.5	
AVERAGE RUNOFF	75.8	0.0
MEDIAN RUNOFF	70.5	0.0
MAXIMUM RUNOFF (ANY TIMESTEP)	77.0	0.0
TOTAL IRRIGATION DEMAND	0.0	0.0
AVERAGE IRRIGATION DEMAND	0.0	0.0
MEDIAN IRRIGATION DEMAND	0.0	0.0
TOTAL RUNON	0.0	0.0
AVERAGE RUNON	0.0	0.0
MEDIAN RUNON	0.0	0.0
TOTAL SEEPAGE	1165.5	0.0
AVERAGE SEEPAGE	22.9	0.0
MEDIAN SEEPAGE	21.6	0.0
TOTAL EVAPORATION	16051.9	0.0
AVERAGE EVAPORATION	314.7	0.0
MEDIAN EVAPORATION	316.3	0.0
WATER BALANCE (OVER PERIOD OF RECORD)	-562.1	mm

SC2: GREENROOF	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	211059.7
TOTAL RUNOFF	18.8	190.2
% OF RAINFALL AS RUNOFF	0.1	
AVERAGE RUNOFF	0.4	3.7
MEDIAN RUNOFF	0.0	0.0
MAXIMUM RUNOFF (ANY TIMESTEP)	11.2	112.8
TOTAL IRRIGATION DEMAND	8904.6	89936.7
AVERAGE IRRIGATION DEMAND	174.6	1763.5
MEDIAN IRRIGATION DEMAND	176.9	1786.9
TOTAL RUNON	0.0	0.0
AVERAGE RUNON	0.0	0.0
MEDIAN RUNON	0.0	0.0
TOTAL SEEPAGE	1702.3	17193.7
AVERAGE SEEPAGE	33.4	337.1
MEDIAN SEEPAGE	17.1	172.7
TOTAL EVAPORATION	27710.6	279877.1
AVERAGE EVAPORATION	543.3	5487.8
MEDIAN EVAPORATION	555.4	5609.0
WATER BALANCE (OVER PERIOD OF RECORD)	-0.1	mm

SC2: BIOSWALE	(mm)	(m3)
TOTAL PRECIPITATION	20897.0	0.0
TOTAL SURFACE RUNOFF	0.0	0.0
% OF RAINFALL AS SURFACE RUNOFF + SUBD	0.0	
AVERAGE SURFACE RUNOFF	0.0	0.0
MEDIAN SURFACE RUNOFF	0.0	0.0
MAXIMUM RUNOFF (ANY TIMESTEP)	0.0	0.0
TOTAL RUNON	0.0	0.0
AVERAGE RUNON	0.0	0.0
MEDIAN RUNON	0.0	0.0
TOTAL PERCOLATION	0.0	0.0
AVERAGE PERCOLATION	0.0	0.0
MEDIAN PERCOLATION	0.0	0.0
TOTAL EVAPORATION	20546.1	0.0
AVERAGE EVAPORATION	402.9	0.0
MEDIAN EVAPORATION	395.9	0.0
TOTAL SUBDRAIN	0.0	0.0
AVERAGE SUBDRAIN	0.0	0.0
MEDIAN SUBDRAIN	0.0	0.0
WATER BALANCE (OVER PERIOD OF RECORD)	-11.4	mm

SC2: STORAGE / REUSE	(m3)
MAXIMUM VOLUME OVER RECORD	250.0
AVERAGE MAX. VOLUME	4.9
MEDIAN MAX. VOLUME	0.0
MINIMUM VOLUME OVER RECORD	0.0
AVERAGE MIN. VOLUME	0.0
MEDIAN MIN. VOLUME	0.0
TOTAL INFLOW	0.0
AVERAGE INFLOW	0.0
MEDIAN INFLOW	0.0
TOTAL DEMAND	293723.4
AVERAGE DEMAND	5759.3
MEDIAN DEMAND	5791.0
TOTAL OVERFLOW	0.0
AVERAGE OVERFLOW	0.0
MEDIAN OVERFLOW	0.0
TOTAL MUN. MAKE-UP WATER	0.0
AVERAGE MUN. MAKE-UP WATER	0.0
MEDIAN MUN. MAKE-UP WATER	0.0
TOTAL RECHARGE FROM PONDS	293473.4
AVERAGE RECHARGE FROM PONDS	5754.4
MEDIAN RECHARGE FROM PONDS	5791.0
WATER BALANCE (OVER PERIOD OF RECORD)	0.0

Figure A- 23: Sub-Catchment 2 – Summarized Runoff Results Part 2 (Option 2)

POND 1	POND #1	CATCHMENT AREA SIZE		
DISCHARGES TO	OUTFALL	85.23	ha - DIRECT	
		94.36	ha - TOTAL	
	MAX	MIN	AVG	MEDIAN
VOLUME (m^3)	23745	2617	5938	5409
LEVEL (m)	1093.000	1091.635	1092.185	1092.185
	MAX	TOTAL	AVG	MEDIAN
INFLOW (m^3)	124615	2503743	49093	41365
DIRECT PRECIPITATION (m^3)	4716	141466	2774	2763
EVAPORATION LOSS (m^3)	5519	251184	4925	4862
SEEPAGE LOSS (m^3)	332	14986	294	293
DISCHARGE (m^3)	84180	938099	18394	14487
OVERFLOW (m^3)	34507	135449	2656	0
MAKE-UP WATER (m^3)	0	0	0	0
DEMAND (m^3)	42541	1305347	25595	25036
WATER BALANCE (m^3)		-1		

POND 2	POND #2	CATCHMENT AREA SIZE		
DISCHARGES TO	POND #1	9.13	ha - DIRECT	
		9.13	ha - TOTAL	
	MAX	MIN	AVG	MEDIAN
VOLUME (m^3)	10366	0	317	0
LEVEL (m)	1109.900	1109.500	1109.659	1109.659
	MAX	TOTAL	AVG	MEDIAN
INFLOW (m^3)	31726	921579	18070	17104
DIRECT PRECIPITATION (m^3)	1731	43955	862	844
EVAPORATION LOSS (m^3)	2001	55057	1080	1060
SEEPAGE LOSS (m^3)	129	3855	76	73
DISCHARGE (m^3)	23942	676605	13267	12713
OVERFLOW (m^3)	0	0	0	0
MAKE-UP WATER (m^3)	0	0	0	0
DEMAND (m^3)	9357	293473	5754	5791
WATER BALANCE (m^3)		-63457		

Figure A- 24: Ponds – Summarized Results (Option 2)

APPENDIX – B

GLOSSARY OF TERMS AND ABBREVIATIONS

1 Terms

Absorbent Landscaping

Absorbent landscaping consists of surfaces designed to enhance water retention, allowing only nominal overland flows.

Bioretention/Bioswales Media

Bioretention/bioswales media consists of depressed landscaped areas, underlain by a soil medium that may percolate into the sub-soils and/or discharge via a sub-drain.

Field Capacity

The field capacity is defined as the minimum amount of soil moisture above which pore water starts draining by gravity. Thus, it cannot be held in the pore space by capillary forces and begins to flow through the porous medium. (this doesn't make sense???)

Green Roof Media

Green roof media consist of soil/ permeable medium placed on the roofs of buildings, partially or fully, covered with vegetation and provided with appropriate drainage facilities.

Impervious Surfaces

Impervious surfaces are made of, and or paved with materials that prevent infiltration of water; including roads, gutters, driveways, roofs, etc.

Maximum Water Content

The maximum water content is the amount of water filled in the entire pore spaces of soil; and also, referred to as the saturated water content. In a volumetric measure, the maximum water content is equivalent to the porosity.

Pervious Surfaces

Pervious surfaces are natural loose soils surfaces or paved with gravel, wood chips or any other permeable material to allow infiltration of water.

Ponding Depth

The ponding depth is the depth of free-standing water above the soil or media surface.

Porosity

The porosity of soil is to the volumetric fraction of void space within a soil mass.

Saturated Hydraulic Conductivity

The saturated hydraulic conductivity is the conductivity of soil or media in a saturated condition.

Soil or Media Depth

The soil or media depth is the depth of soil or media, over which vegetative roots extract water for evapo-transpiration.

Wilting Point

The wilting point is the amount of soil moisture below which plants cannot extract water for evapo-transpiration.

2 Abbreviations

BMP – Best Management Practises

CD - Climate Data

HWL - High Water Level

LID – Low Impact Development

LNWL - Lower Normal Water Level

MDP – Master Drainage Plan

PB – Pond Bed

SC - Sub-Catchment

SD - System Data

SMDP – Staged Master Drainage Plan

UNWL - Upper Normal Water Level

WBSCC - Water Balance Spreadsheet for the City of Calgary

APPENDIX – C

ESTIMATION OF HYDRAULIC PROPERTIES OF SOIL/ MEDIA

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1 HYDRAULIC PROPERTIES OF SOILS/ MEDIA

A number of hydraulic properties of soils/ media is used in WBSCC in estimating the seepage loss to the sub-surface layers. The hydraulic properties used are as follows:

1. Porosity - The porosity of soil/ media is to the volumetric fraction of spaces within the soil mass. In numeric value, this is equivalent to the Saturated Water Content.
2. Saturated Water Content: Water content at which all pore spaces of soil matrix are filled with water, and dependent only on the soil texture and unaffected by salinity or gravel.
3. Field Capacity (F_c or θ_{33}) - The water content of the soil matrix approximating the water content of a saturated soil that has been allowed to freely drain. The field capacity is estimated at a hydraulic tension of 33 kPa (0.33 Bar) and dependent only on the soil texture and unaffected by salinity or gravel.
4. Wilting Point (W_p or θ_{1500}) - The water content below which plants are generally unable to extract water from the soil. The wilting point is estimated at a hydraulic tension of 1500 kPa (15 Bar) and dependent only on the soil texture and unaffected by salinity or gravel.
5. Hydraulic Conductivity (surface and sub-surface layers) - The capability of water to move within the soil matrix driven by matrix and gravitational potentials, dependent on soil texture and moisture content. When the soil/ media is at saturated condition, the hydraulic conductivity is referred to as the Saturated Hydraulic Conductivity (K_S).

The hydraulic conductivity of soils/ media for conditions other than saturation depends on the corresponding water content. A factor, based on the water content at field capacity and wilting point, termed as the *Inverse Slope of Logarithmic Tension Moisture Curve* is used in estimating the hydraulic conductivity at non-saturated conditions.

1.1 Soil Classification by Texture

All of the hydraulic properties of soils/ media used in WBSCC depend basically on the texture of soil described by the weight fractions of sand, silt, and clay particles. Additionally, the amount of organic matter and salinity present in the soils/ media and the degree of compaction influence the hydraulic properties by a marginal amount. Figure C-1 illustrates the soil texture triangle developed by the United States Department of Agriculture (USDA).

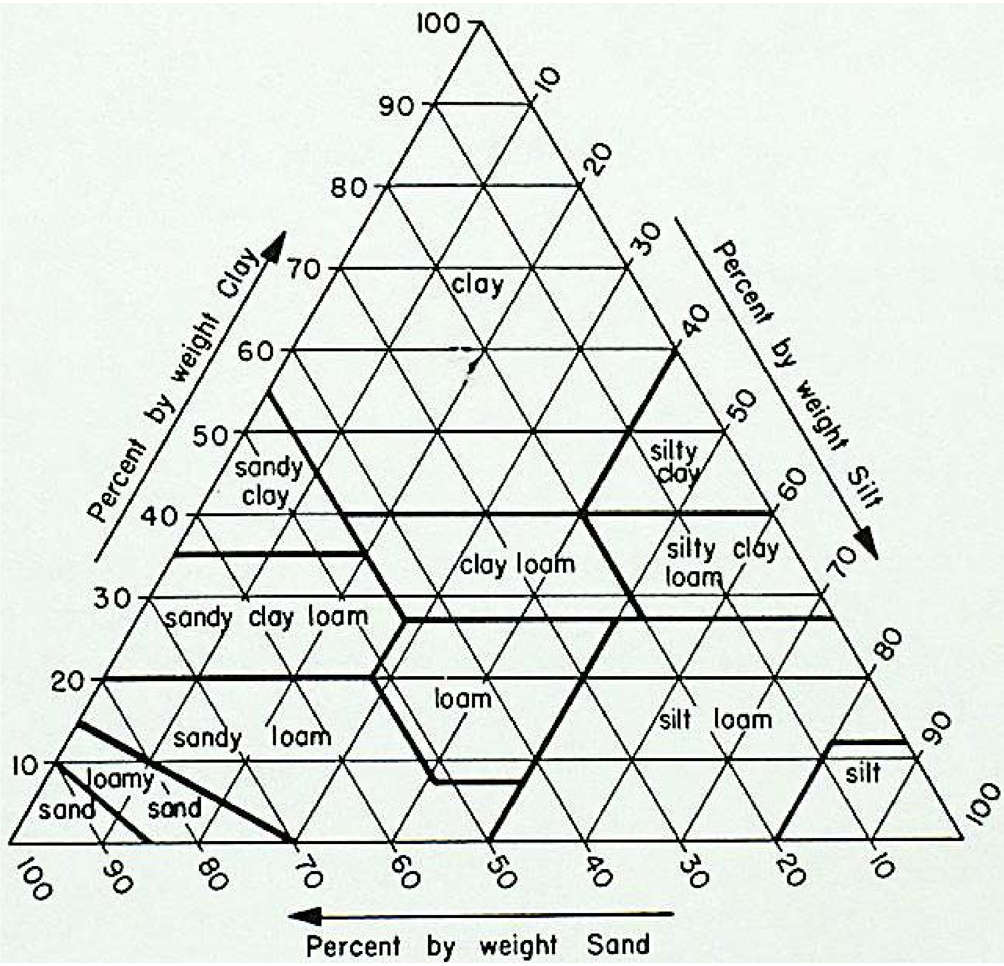

Figure C - 1   USDA Soil Triangle

The soil triangle classifies various soil types found in agricultural and urban lands. Based on the particle size, the constituents of soils are categorized as sand (0.05 to 2.0 mm), silt (0.002 to 0.05 mm) and clay (<0.002 mm).

1.2 Soil Water Potential and the Limits on Soil Water Availability

The soil water potential (also termed as matric potential or hydraulic tension) is the potential of soil water being held within the interstices of soil particles by capillary forces. This is dependent on soil texture and water content. Assume that a land segment is initially saturated and allowed to drain freely. This happens until the water content reaches the field capacity, at which point the soil water potential will be 33 kPa. Reduction of water content below this limit is only possible due to evapotranspiration by plants. However, evapotranspiration cannot be continued when the water content reaches the wilting point. At this point, the soil water potential will be 1500 kPa. Figure C – 2 illustrates the relationship between soil water potential and water content for selected soil samples.

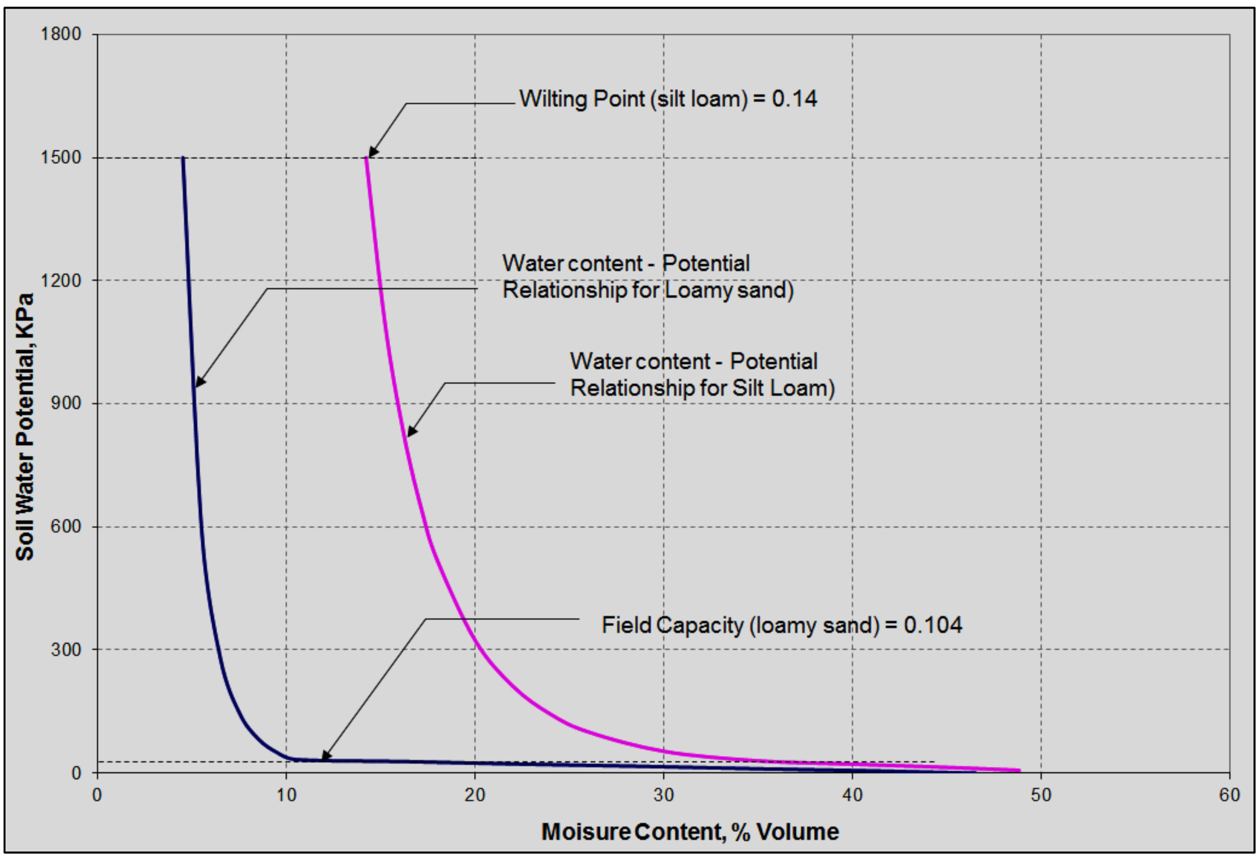

Figure C - 2 Soil Water Potential and Water Content

Moreover, Figure C – 3 illustrates the nature of water availability from soils/ media with reference to water content.

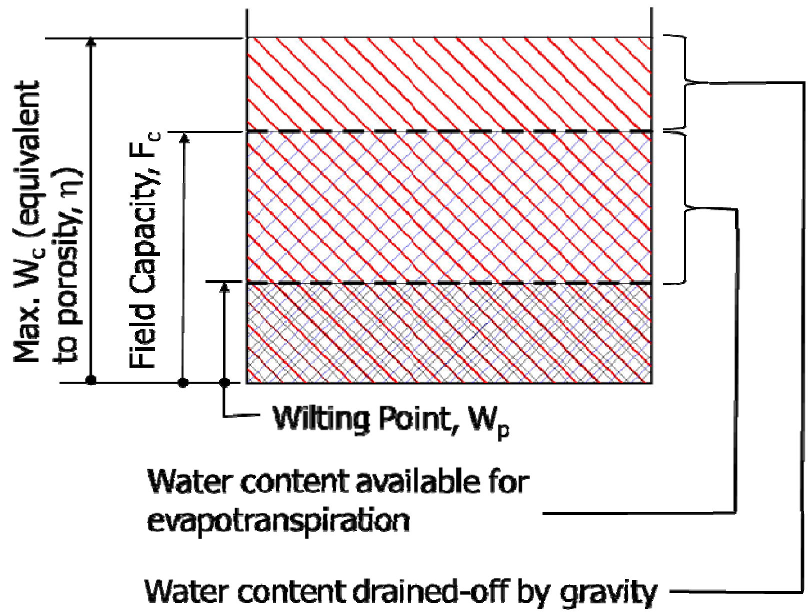

Figure C - 3   Soils/ Media Water Availability

2 ESTIMATION OF HYDRAULIC PROPERTIES BY USING SPAW

The hydraulic properties of soils/ media can be assessed from field tests or by using the software SPAW (Soil-Plant-Air-Water) developed by Dr. Keith E. Saxton (USDA - Agriculture Research Service) and Dr. Walter Rawls (USDA – ARS, Hydrology and Remote Sensing Laboratory) in cooperation with the Department of Biological Systems Engineering, Washington State University. Figure C – 4 shows the soil properties computation interface of SPAW.

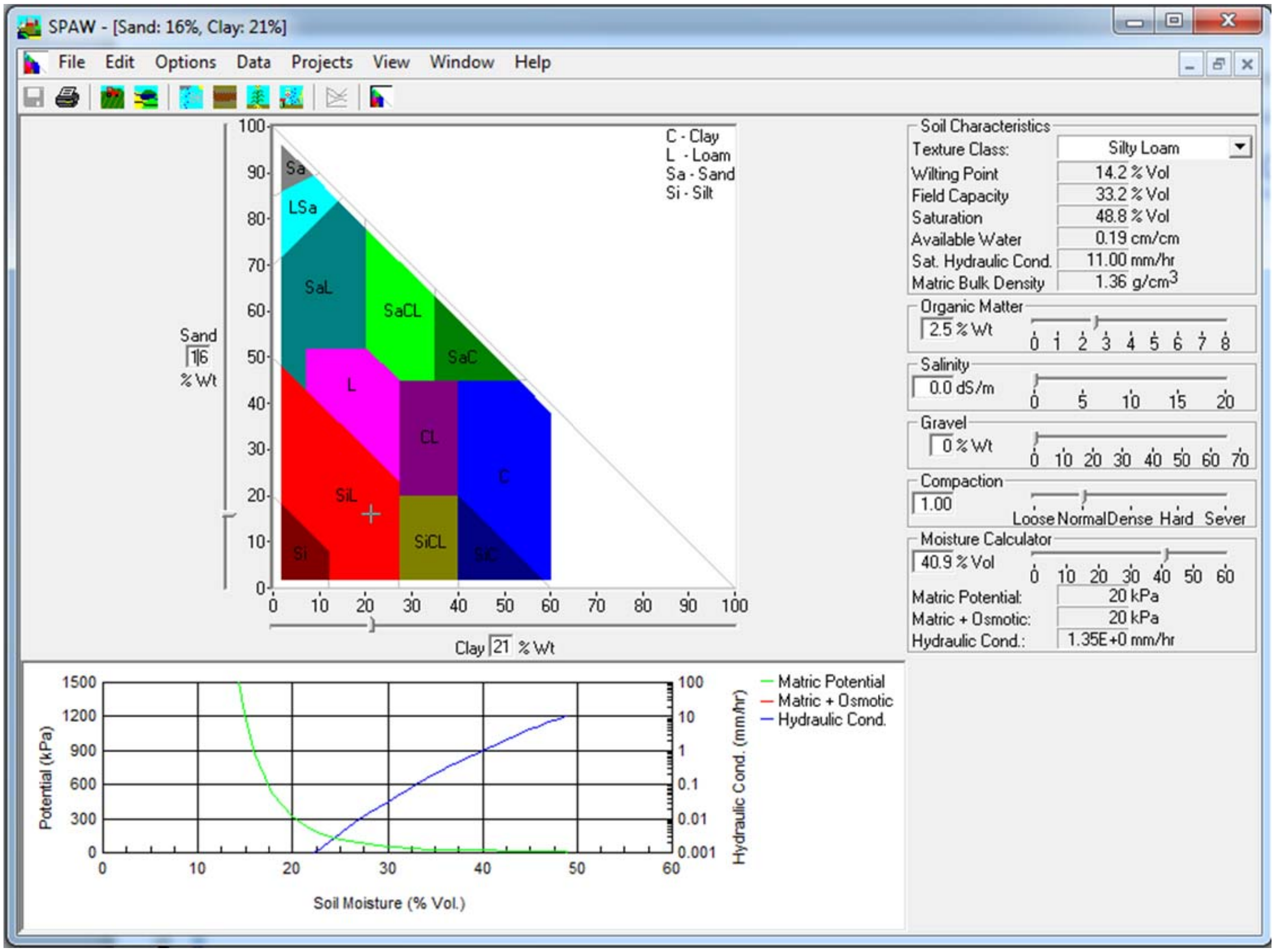

Figure C - 4 SPAW Software Interface

SPAW accepts the soil texture as weight percentages of sand and clay, determines the texture class, and computes the hydraulic parameters such as the wilting point, field capacity, saturation (i.e. porosity) and the saturated hydraulic conductivity. Other factors such as the organic matter, salinity, percentage of gravel and the level of compaction are set to default values. The variations of soil potential and hydraulic conductivity against water content are plotted. A slider tool to change the water content and to determine the soil potential and the hydraulic conductivity is also provided.

Typical parameters estimated from SPAW are provided in Table 1.

Table 1 Soil/ Media Hydraulic Parameters for Selected Soil Texture

Texture Class †	Sand	Clay	Wilt pt.	Field cap	Saturation	Plant avail.	Saturated conductivity	Matric density
			1500 kPa	33 kPa	0 kPa			
	------ %w -----		---------------------------- %v ------------------------				mm h^{-1}	g cm^{-3}
Sa	88	5	5	10	46	5	108.1	1.43
LSa	80	5	5	12	46	7	96.7	1.43
SaL	65	10	8	18	45	10	50.3	1.46
L	40	20	14	28	46	14	15.5	1.43
SiL	20	15	11	31	48	20	16.1	1.38
Si	10	5	6	30	48	25	22.0	1.38
SaCL	60	25	17	27	43	10	11.3	1.50
CL	30	35	22	36	48	14	4.3	1.39
SiCL	10	35	22	38	51	17	5.7	1.30
SiC	10	45	27	41	52	14	3.7	1.26
SaC	50	40	25	36	44	11	1.4	1.47
C	25	50	30	42	50	12	1.1	1.33

† Sa, sand; L, loam; Si, silt; C, clay.

2.1 Estimation of Hydraulic Conductivity

WBSCC uses the saturated and unsaturated hydraulic conductivity of soils/ media for computation. The saturated hydraulic conductivity is a direct output from SPAW, however, the unsaturated hydraulic conductivity is computed using inverse slope of logarithmic tension moisture curve. This approach follows the Brooks-Corey and van Genuchten model (van Gcnuchten, 1980):

$$K = K_S \left\{\frac{\theta}{\theta_S}\right\}^{3+2/\lambda} \quad \text{.......} \quad (1)$$

Where, K_S is the hydraulic conductivity at saturation;

θ_S is the water content at saturation;

θ is the water content at which hydraulic conductivity K is estimated; and

$1/\lambda$ is the inverse slope of logarithmic tension moisture curve.

The inverse slope of logarithmic tension moisture curve is estimated from the following relationship (Saxton and Rawls, 2006):

$$\frac{1}{\lambda} = \frac{\ln(1500) - \ln(33)}{\ln(\theta_{33}) - \ln(\theta_{1500})} \quad (2)$$

Where, θ_{33} is the Field Capacity (i.e. water content at matric potential of 33 kPa); and,

θ_{1500} is the Wilting Point (i.e. water content at matric potential of 1500 kPa);

Figure C – 5 illustrates the computation of $1/\lambda$ for a sample of loamy sand (sand 85% and clay 4% by weight).

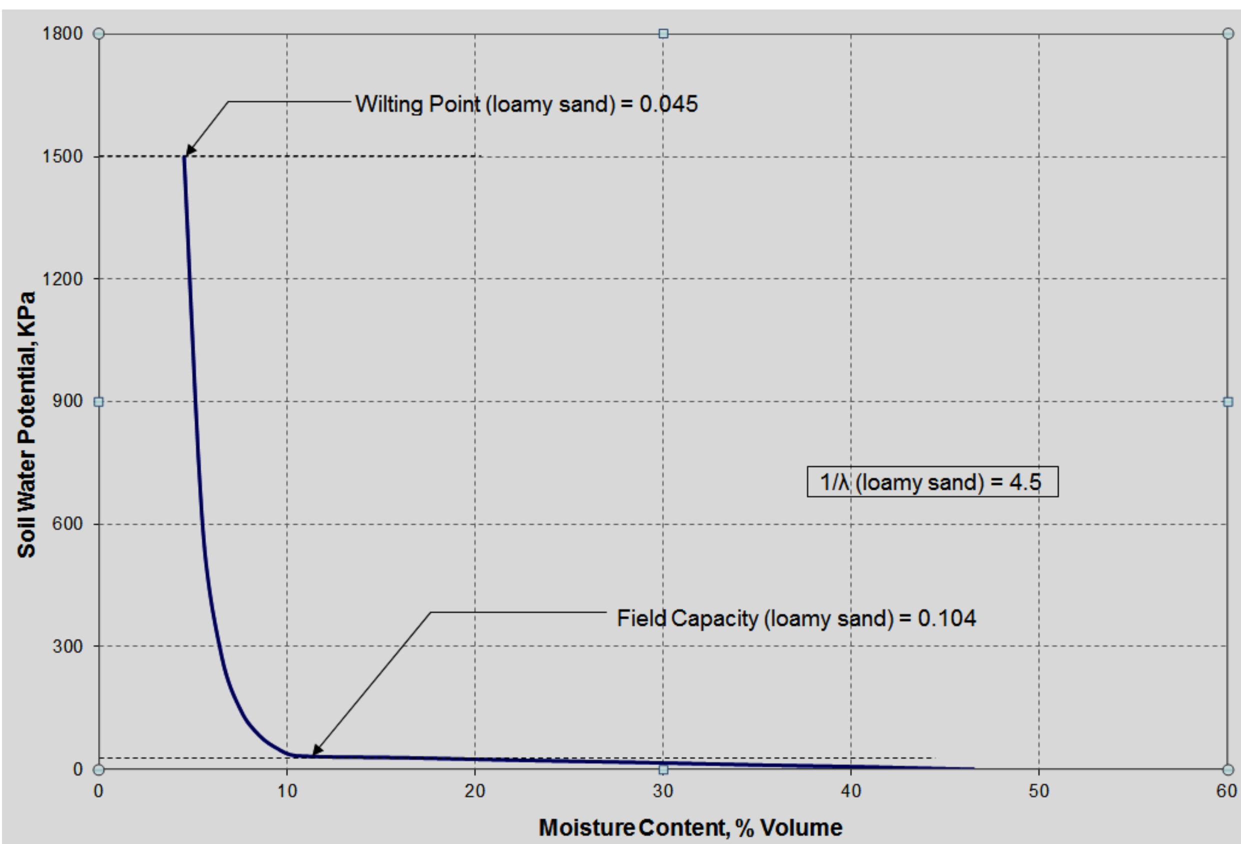

Figure C - 5 Computation of Inverse Slope of Logarithmic Tension Moisture Curve

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Saxton, K. E. and W. J. Rawls. (2006). Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. Soil Sci. Soc. Am. J. 70:1569–1578.

Van Genuchten, M.Th. (1980). A closed-form equation for predicting the hydraulic conductivity of unsaturated soils. Soil Sci. Soc. Am. J. 44:892–898.

APPENDIX – D

DESIGN TABLES AND FIGURES

Table D.1 Average Annual Runoff Volume as function of Directly Connected Imperviousness Ratio and Absorbent Landscaping (1960-2010)

Directly Connected Imperviousness Ratio	Average annual runoff volume (mm) for landscaping scenario (silty clay loam)			
	Base Case No Absorbent Landscaping	200 mm absorbent landscaping	300 mm absorbent landscaping	400 mm absorbent landscaping
0	32.5	5.7	0.7	0.0
10	60.4	36.2	31.7	31.1
20	88.2	66.7	62.7	62.2
30	116.0	97.2	93.7	93.3
40	143.9	127.8	124.8	124.4
50	171.7	158.3	155.8	155.5
60	199.6	188.8	186.8	186.6
70	227.4	219.3	217.8	217.6
80	255.2	249.9	248.9	248.7
90	283.1	280.4	279.9	279.8
100	310.9	310.9	310.9	310.9

Table D.2 Median Annual Runoff Volume as function of Directly Connected Imperviousness Ratio and Absorbent Landscaping (1960-2010)

Directly Connected Imperviousness Ratio	Median annual runoff volume (mm) for landscaping scenario (silty clay loam)			
	Base Case No Absorbent Landscaping	200 mm absorbent landscaping	300 mm absorbent landscaping	400 mm absorbent landscaping
0	26.1	0.0	0.0	0.0
10	50.0	31.3	30.8	30.7
20	81.0	61.7	61.6	61.4
30	112.3	92.5	92.4	92.1
40	137.7	123.3	123.2	122.8
50	164.8	154.2	153.5	153.5
60	192.7	185.0	184.2	184.2
70	220.1	215.8	214.9	214.9
80	250.4	246.4	245.6	245.6
90	278.0	276.3	276.3	276.3
100	307.0	307.0	307.0	307.0

Table D.3 Average Runoff Volume as function of Imperviousness Ratio and No Absorbent Landscaping Scenario – 100 mm soil depth

Directly Connected Imperviousness Ratio	Average annual runoff volume (mm) for landscaping scenario (silty clay loam)										
	Directly Connected Imperviousness										
	0	10	20	30	40	50	60	70	80	90	100
0	32.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	40.6	60.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20	50.8	68.5	88.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
30	64.0	79.2	96.5	116.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
40	79.9	93.1	107.8	124.5	143.9	N/A	N/A	N/A	N/A	N/A	N/A
50	100.4	110.5	122.6	136.6	152.6	171.7	N/A	N/A	N/A	N/A	N/A
60	126.3	133.9	142.5	152.9	165.7	180.9	199.6	N/A	N/A	N/A	N/A
70	158.6	163.3	169.1	176.1	184.6	195.4	209.4	227.4	N/A	N/A	N/A
80	198.5	201.1	204.3	208.0	212.5	218.6	226.7	238.3	255.2	N/A	N/A
90	248.3	249.1	250.0	251.2	252.7	254.7	257.6	261.7	268.8	283.1	N/A
100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	310.9

Table D.4 Median Runoff Volume as function of Imperviousness Ratio and No Absorbent Landscaping Scenario – 100 mm soil depth

Directly Connected Imperviousness Ratio	Median annual runoff volume (mm) for landscaping scenario (silty clay loam)										
	Directly Connected Imperviousness										
	0	10	20	30	40	50	60	70	80	90	100
0	26.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	30.5	50.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20	40.9	59.7	81.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
30	59.0	71.4	92.5	112.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
40	77.5	92.0	104.6	122.8	137.7	N/A	N/A	N/A	N/A	N/A	N/A
50	96.8	106.6	118.5	134.0	147.6	164.8	N/A	N/A	N/A	N/A	N/A
60	121.2	129.0	138.1	150.0	162.8	174.6	192.7	N/A	N/A	N/A	N/A
70	153.7	155.9	162.3	169.9	180.3	191.1	204.2	220.1	N/A	N/A	N/A
80	197.1	198.6	200.8	204.0	208.2	212.8	220.7	233.5	250.4	N/A	N/A
90	242.2	243.1	244.3	245.7	247.8	249.9	252.6	256.2	264.5	278.0	N/A
100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	307.0

Table D.5 Average Runoff Volume as function of Imperviousness Ratio and No Absorbent Landscaping Scenario – 300 mm soil depth

Directly Connected Imperviousness Ratio	Average annual runoff volume (mm) for landscaping scenario (silty clay loam)										
	Directly Connected Imperviousness										
	0	10	20	30	40	50	60	70	80	90	100
0	0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	1.9	31.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20	3.8	33.0	62.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
30	7.6	35.1	64.0	93.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
40	15.3	39.9	66.4	95.1	124.8	N/A	N/A	N/A	N/A	N/A	N/A
50	29.8	49.8	72.5	98.1	126.2	155.8	N/A	N/A	N/A	N/A	N/A
60	52.4	68.3	86.0	106.4	130.2	157.3	186.8	N/A	N/A	N/A	N/A
70	87.4	97.3	109.7	124.8	142.2	163.1	188.7	217.8	N/A	N/A	N/A
80	142.1	146.6	152.1	159.1	168.5	181.6	198.5	220.6	248.9	N/A	N/A
90	216.9	218.0	219.3	221.0	223.3	226.5	231.5	239.7	254.7	279.9	N/A
100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	310.9

Table D.6 Median Runoff Volume as function of Imperviousness Ratio and No Absorbent Landscaping Scenario – 300 mm soil depth

Directly Connected Imperviousness Ratio	Average annual runoff volume (mm) for landscaping scenario (silty clay loam)										
	Directly Connected Imperviousness										
	0	10	20	30	40	50	60	70	80	90	100
0	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	0.0	30.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20	0.0	30.8	61.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
30	0.0	31.3	61.7	92.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
40	4.5	32.3	62.6	92.5	123.2	N/A	N/A	N/A	N/A	N/A	N/A
50	19.9	38.2	64.2	93.9	123.3	153.5	N/A	N/A	N/A	N/A	N/A
60	42.6	56.5	74.7	98.4	125.2	154.2	184.2	N/A	N/A	N/A	N/A
70	83.6	89.2	103.3	116.3	136.2	156.5	185.8	214.9	N/A	N/A	N/A
80	140.9	144.1	147.5	156.1	164.1	175.1	191.9	219.0	245.6	N/A	N/A
90	211.6	212.5	213.4	214.8	217.6	220.8	224.1	233.1	250.1	276.3	N/A
100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	307.0

Table D.7 Average Runoff Volume as function of Imperviousness Ratio and Absorbent Landscaping Scenario – 300 mm absorbent landscaping - With irrigation by municipal water supply

Directly Connected Imperviousness Ratio	Average annual runoff volume (mm) for landscaping scenario (silty clay loam)										
	Directly Connected Imperviousness										
	0	10	20	30	40	50	60	70	80	90	100
0	0.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	1.9	31.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20	3.8	33.0	62.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
30	7.6	35.1	64.0	93.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A
40	15.3	39.9	66.4	95.1	124.8	N/A	N/A	N/A	N/A	N/A	N/A
50	29.8	49.8	72.5	98.1	126.2	155.8	N/A	N/A	N/A	N/A	N/A
60	52.4	68.3	86.0	106.4	130.2	157.3	186.8	N/A	N/A	N/A	N/A
70	87.4	97.3	109.7	124.8	142.2	163.1	188.7	217.8	N/A	N/A	N/A
80	142.1	146.6	152.1	159.1	168.5	181.6	198.5	220.6	248.9	N/A	N/A
90	216.9	218.0	219.3	221.0	223.3	226.5	231.5	239.7	254.7	279.9	N/A
100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	310.9

Table D.8 Median Runoff Volume as function of Imperviousness Ratio and Absorbent Landscaping Scenario – 300 mm absorbent landscaping - With irrigation by municipal water supply

Directly Connected Impervioussness Ratio	Average annual runoff volume (mm) for landscaping scenario (silty clay loam)										
	Directly Connected Imperviousness										
	0	10	20	30	40	50	60	70	80	90	100
0	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	0.0	30.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20	0.0	30.8	61.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
30	0.0	31.3	61.7	92.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
40	4.5	32.3	62.6	92.5	123.2	N/A	N/A	N/A	N/A	N/A	N/A
50	19.9	38.2	64.2	93.9	123.3	153.5	N/A	N/A	N/A	N/A	N/A
60	42.6	56.5	74.7	98.4	125.2	154.2	184.2	N/A	N/A	N/A	N/A
70	83.6	89.2	103.3	116.3	136.2	156.5	185.8	214.9	N/A	N/A	N/A
80	140.9	144.1	147.5	156.1	164.1	175.1	191.9	219.0	245.6	N/A	N/A
90	211.6	212.5	213.4	214.8	217.6	220.8	224.1	233.1	250.1	276.3	N/A
100	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	307.0

Table D.9 Median Annual Runoff Volume as function of Bioretention (I/P) Ratio and 300 mm Absorbent Landscaping Scenario

I/P Ratio	Median annual runoff volume (mm) for 300 mm absorbent landscaping scenario (silty clay loam)										
	Directly Connected Imperviousness 50% of Total Imperviousness										
	Varying Total Imperviousness Ratio										
	0	10	20	30	40	50	60	70	80	90	100
2	N/A	17.8	35.3	52.5	69.2	85.4	101.4	117.3	133.2	N/A	N/A
5	N/A	23.1	44.9	66.4	87.6	108.1	128.5	148.4	168.3	187.9	N/A
10	N/A	27.1	53.1	78.0	103.1	127.6	152.1	176.4	200.2	223.9	N/A
20	N/A	29.2	57.9	85.8	113.1	140.9	168.6	196.0	223.6	251.2	N/A
25	N/A	29.7	58.5	87.6	115.5	144.1	171.8	199.8	228.6	256.3	N/A
50	N/A	30.1	60.3	90.3	119.9	149.3	179.5	207.9	236.5	265.9	N/A

Table D.10 Median Annual Runoff Volume as function of Bioretention (I/P) Ratio and 100 mm Absorbent Landscaping Scenario

I/P Ratio	Median annual runoff volume (mm) for 100 mm absorbent landscaping scenario (silty clay loam)										
	Directly Connected Imperviousness 50% of Total Imperviousness										
	Varying Total Imperviousness Ratio										
	0	10	20	30	40	50	60	70	80	90	100
2	N/A	36.0	51.7	66.1	78.4	93.5	106.9	119.7	133.2	N/A	N/A
5	N/A	41.3	62.9	84.8	103.0	119.7	134.5	150.4	169.3	188.0	N/A
10	N/A	45.7	70.5	96.9	119.8	140.4	160.1	182.4	205.0	224.7	N/A
20	N/A	48.1	76.2	106.2	129.7	151.9	176.8	202.6	226.4	252.3	N/A
25	N/A	48.4	77.5	108.0	130.6	154.5	180.6	206.4	232.1	258.6	N/A
50	N/A	49.2	79.5	110.4	134.1	160.3	187.2	214.3	241.7	268.6	N/A

Table D.11 Evaporation Pond Area as function of Imperviousness Ratio

Imperviousness Ratio (100% Directly Connected)	% of Pond Over Total Area Including Pond
10	31%
20	39%
30	43%
40	46%

Table D.12 Average Runoff Volume as function of Imperviousness Ratio and % of Area for Irrigation – 400 mm Annual Irrigation

Imperviousness Ratio %	Average annual runoff volume (mm) - 400 mm annual irrigation				
	% of Total Area for Irrigation				
	0	10	20	30	40
10	28.3	5.7	2.0	0.9	0.9
20	57.3	29.5	9.0	4.5	3.0
30	86.4	58.2	30.7	13.3	8.2
40	115.5	87.3	58.9	33.9	19.9
50	144.6	116.3	87.8	60.5	40.0

Table D.13 Median Runoff Volume as function of Imperviousness Ratio and % of Area for Irrigation – 400 mm Annual Irrigation

Imperviousness Ratio	Median annual runoff volume (mm) - 400 mm annual irrigation				
	% of Total Area for Irrigation				
	0	10	20	30	40
10	19.2	0.0	0.0	0.0	0.0
20	48.8	19.9	0.0	0.0	0.0
30	80.5	50.8	20.1	0.0	0.0
40	109.3	80.5	50.2	20.5	7.8
50	139.5	110.2	83.4	52.7	29.5

Table D.14 Average Runoff Volume as function of Imperviousness Ratio and % of Area for Irrigation – 500 mm Annual Irrigation

Imperviousness Ratio	Average annual runoff volume (mm) - 500 mm annual irrigation				
	% of Total Area for Irrigation				
	0	10	20	30	40
10	28.3	4.4	1.1	0.9	0.8
20	57.3	22.8	6.2	3.3	2.4
30	86.4	51.3	19.8	9.3	6.3
40	115.5	80.2	45.5	22.4	14.4
50	144.6	109.3	74.0	44.5	28.8

Table D.15 Median Runoff Volume as function of Imperviousness Ratio and % of Area for Irrigation – 500 mm Annual Irrigation

Imperviousness Ratio	Median annual runoff volume (mm) - 500 mm annual irrigation				
	% of Total Area for Irrigation				
	0	10	20	30	40
10	19.2	0.0	0.0	0.0	0.0
20	48.8	11.4	0.0	0.0	0.0
30	80.5	44.2	7.0	0.0	0.0
40	109.3	73.4	34.9	10.1	2.7
50	139.5	102.3	66.1	31.7	19.6

Table D.16 Average Runoff Volume as function of Imperviousness Ratio and % of Area for Irrigation – 600 mm Annual Irrigation

Imperviousness Ratio	Average annual runoff volume (mm) - 600 mm annual irrigation				
	% of Total Area for Irrigation				
	0	10	20	30	40
10	28.3	3.6	0.9	0.9	0.8
20	57.3	17.0	4.8	2.7	2.2
30	86.4	44.5	13.8	7.3	5.3
40	115.5	73.3	34.5	17.2	12.0
50	144.6	102.3	61.1	34.1	23.7

Table D.17 Median Runoff Volume as function of Imperviousness Ratio and % of Area for Irrigation – 600 mm Annual Irrigation

Imperviousness Ratio	Median annual runoff volume (mm) - 600 mm annual irrigation				
	% of Total Area for Irrigation				
	0	10	20	30	40
10	19.2	0.0	0.0	0.0	0.0
20	48.8	5.9	0.0	0.0	0.0
30	80.5	35.0	0.0	0.0	0.0
40	109.3	67.2	20.9	4.1	0.0
50	139.5	94.3	53.2	25.6	14.2