2C-13 Water Balance Calculations

A. Introduction

Water balance calculations help determine if a drainage area is large enough or if it has the right characteristics to support a permanent pool of water during average or extreme conditions. A water balance calculation should be completed for wet detention basins (stormwater ponds) and constructed stormwater wetland design. The details of a rigorous water balance are beyond the scope of this manual. However, a simplified procedure is described to provide an estimate of permanent pool viability and point to the need for more rigorous analysis. Water balance can also be used to help establish planting zones in a wetland design.

B. Basic equations

Water balance is defined as the change in volume of the permanent pool resulting from the total Inflow, minus the total outflow (actual or potential):

$\Delta V = \sum \text{Inflow} - \sum \text{Outflow}$ **Equation 1**

where:
ΔV = change in the permanent pool (ac-ft)
$\sum$ Inflow = sum of all inflows over a period of time
$\sum$ Outflow = sum of all outflow over a period time, including losses to infiltration and evaporation

The inflows consist of rainfall (P), runoff (R), and baseflow (Bf) into the pond. The outflows consist of infiltration (I), evaporation (E), evapotranspiration (Et), and surface overflow (O) out of the pond or wetland. These changes are reflected in Equation 2:

$\Delta V = [P + R + B_f] - [I + E + Et + O]$ **Equation 2**

1. **Rainfall (P).** Monthly values are commonly used for calculation of values over a season. Rainfall is the direct amount falling on the surface of the pond for the time period being studied. Historical monthly rainfall totals are available for most all locations in Iowa in various formats for a number of gauge stations across Iowa and summary data can be accessed at http://mesonet.agron.iastate.edu/climodat/index.phtml. Hourly (TD3240) and 15 minute (TD3260) rainfall data are available from the National Climate Data Center at http://www.ncdc.noaa.gov/oa/ncdc.html for the NWS Coop recording gauge stations in Iowa. The office of the State of Iowa climatologist is another source of monthly rainfall and other climate data (i.e. temperature, evaporation, etc.) http://www.agriculture.state.ia.us/climatology.htm.

2. **Runoff (R).** Runoff is equivalent to the rainfall for the period times the efficiency of the watershed, which is equal to the ratio of runoff to rainfall. In lieu of gauge information, Q/P can be estimated one of several ways. The best method would be to perform long-term simulation modeling using rainfall records and a watershed model. Two other methods have been proposed.

   The ratio of runoff to rainfall volume for a particular storm can be determined using Equation 3. It is assumed that if the average storm that produces runoff has a similar ratio, then the Rv value can serve as the ratio of rainfall to runoff. Not all storms produce runoff in an urban setting.

Typical initial losses (often called initial abstractions) are normally taken between 0.1 and 0.2 inches. For Iowa, about 8-9% of all storms in a year are less than 0.1 inches. Thus a factor of 0.9 can be applied to the calculated Rv value to account for storms that produce no runoff. Equation 3 reflects this approach. Total runoff volume is then simply the product of runoff depth (Q) times the drainage area to the pond.

$Q = 0.9\ PRv$ **Equation 3**

where:
P = precipitation (in)
Q = runoff volume (in)
Rv = volumetric runoff coefficient for the watershed

The WINTR-55 program can be used to model a range of storms using the CN method to predict the individual storm runoff. These values can be plotted by rainfall depth and applied to monthly rainfall to create a monthly runoff model.

Most stormwater ponds and wetlands have little, if any, baseflow, as they are rarely placed across perennial streams. If so placed, baseflow must be estimated from observation or through theoretical estimates. Methods of estimation and baseflow separation can be found in most hydrology textbooks.

3. **Infiltration (I).** Infiltration is a very complex subject and cannot be covered in detail here. More detailed information is included in Part 2E, including data on nominal infiltration rates and soil water capacity. The amount of infiltration depends on soils, water table depth, rock layers, surface disturbance, the presence or absence of a liner in the pond, and other factors. The infiltration rate is governed by the Darcy equation as:

   $I = AkhGh$ **Equation 4**

   where:
   I = infiltration (ac-ft/day)
   A = cross-sectional area through which the water infiltrates (ac)
   K_h = saturated hydraulic conductivity or infiltration rate (ft/day)
   G_h = hydraulic gradient = pressure head/distance

   G_h can be set equal to 1.0 for pond bottoms and 0.5 for pond sides steeper than about 4:1. Infiltration rate can be established through testing, though not always accurately.

4. **Evaporation (E).** Evaporation is from an open lake water surface. Evaporation rates are dependent on differences in vapor pressure, which in turn depend on temperature, wind, atmospheric pressure, water purity, and shape and depth of the pond. It is estimated or measured in a number of ways, which can be found in most hydrology textbooks. Monthly evaporation data for Iowa is available form the National Climate Data Center (NCDC) at http://www.ncdc.noaa.gov/oa/ncdc.html. In Iowa, evaporation data is reported as monthly averages for May through September, and as 10-day averages for the last days of April and first days of October. Evaporation data is not recorded between October 11 and April 20, due to sub-freezing weather conditions.

5. **Evapotranspiration (Et).** Evapotranspiration consists of the combination of evaporation and transpiration by plants. The estimation of Et for crops in Iowa is well-documented and has become standard practice. However, for wetlands, the estimating methods are not documented, nor are there consistent studies to assist the designer in estimating the demand wetland plants

would put on water volumes. Estimating Et only becomes important when wetlands are being designed, and emergent vegetation covers a significant portion of the pond surface. In these cases, conservative estimates of lake evaporation should be compared to crop-based Et estimates, and a decision made. Crop-based Et estimates can be obtained from typical hydrology textbooks or from the websites mentioned above. The climate website at Iowa State University in the Department of Agronomy can provide additional information: http://mesonet.agron.iastate.edu/climodat/index.phtml.

6. **Overflow (O).** Overflow is considered as excess runoff. In water balance design, overflow is either not considered, since the concern is for average values of precipitation; or is considered lost for all volumes above the maximum pond storage. Obviously, for long-term simulations of rainfall runoff, large storms would play an important part in pond design.