CALCULATING A WETLAND WATER BUDGET

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OUTLINE

- Introduction
- Wetland Models
- Water Budget Model
  - Precipitation
  - Surface Water Runoff
  - Groundwater Inflow (Infiltration)
  - Evapotranspiration
  - Groundwater Outflow (Exfiltration)
  - Surface Water Outflow
Novitzki (1979, 1989) outlined 5 basic sets of hydrologic conditions that cause wetlands. Creating a wetland requires one to replicate one of these sets of characteristics:

1. Surface water depression wetlands
2. Ground water depression wetlands
3. Surface water slope wetlands
4. Ground water slope wetlands
5. Extensive wetlands on flat plains
Surface Water Depression

[Diagram showing precipitation, surface flow, evaporation, impermeable layer, and water table.]
Ground Water Depression
Surface Water Slope
Ground Water Slope
Water Budget Model

* Model of water depths and potential draw down for proposed wetland construction
  - Monthly estimates represented graphically
    - Water Depths vs. Time
* Reliable Water Source
  - Predict water inflows and outflows
  - All units converted to water depth over wetland design
  - All inputs conservatively estimated
  - All outputs generously estimated
Water Budget Components

**MASS BALANCE**

\[ \text{INFLOWS} - \text{OUTFLOWS} = \Delta \text{STORAGE} \]

- **INFLOWS** = Precipitation + Surface Water + Groundwater Inflows
- **OUTFLOWS** = Evapotranspiration + Surface Water Outflows + Groundwater Outflows

- All components measured in inches
- Volumes divided by area of wetland to obtain depth of water in inches.

- \( \Delta \text{Storage} = \) change in water level depth (inches)
Water Budget Components

Variables:
- Precipitation
  - Actual Rainfall - Amount/Distribution
- Surface Water Runoff
- Groundwater Inflow (infiltration)
  - assume zero to be conservative
- Potential Evapotranspiration
- Groundwater Outflow (exfiltration)
  - soil permeability (k)
- Surface Water Outflow
- Change in Storage or water level
- Watershed Changes Overtime
**Water Budget Components**

* Input/Output

<table>
<thead>
<tr>
<th>Type</th>
<th>Typical Data Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Precipitation</td>
<td>Historical Rainfall</td>
</tr>
<tr>
<td>2. Infiltration</td>
<td>Site Measurements</td>
</tr>
<tr>
<td>3. Direct Surface</td>
<td>TR-55</td>
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<tr>
<td>4. Overbank Flooding</td>
<td>TR-55, HEC-2, Stage</td>
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<td>5. Evapotranspiration</td>
<td>Pan Data, Thornthwaite</td>
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<td>6. Exfiltration</td>
<td>Soil Testing</td>
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<tr>
<td>7. Spillway Outflow</td>
<td>Weir Formula</td>
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</tbody>
</table>
Typical Water Budget Model
\[ \Delta S = P + RO - ET - GWO - SWO \]

Precipitation

- Daily precipitation data obtained from nearest weather station - Historical Rainfall
  - Precipitation selected from wet, dry, and typical years
    - Dulles or Washington National Airports
      - [http://205.156.54.206/er/lwx/iad/cliad.htm](http://205.156.54.206/er/lwx/iad/cliad.htm)
      - [http://tgsv5.nws.noaa.gov/er/lwx/dca/clidca.htm](http://tgsv5.nws.noaa.gov/er/lwx/dca/clidca.htm)
    - VA State Climatology Office
    - National Climatic Data Center
\[ \Delta S = P + RO - ET - GWO - SWO \]

Runoff

Surface Water Runoff

- SCS Runoff Curve Number Method - TR-55
- \[ Q = \frac{(P - I_a)^2}{(P - I_a) + S} \] Eq. 1
  - \( Q \) = runoff
  - \( P \) = rainfall
  - \( S \) = potential maximum retention after runoff begins
  - \( I_a \) = initial abstraction
    - units are inches
- \[ I_a = 0.2S \] Eq. 2
  - surface depressions, interception, evaporation, and infiltration
  - minimum precipitation to cause runoff
\[ \Delta S = P + RO - ET - GWO - SWO \]

*Runoff*

Substituting Eq.2 into Eq.1 gives:

\[ Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \]

- \( P \) = daily precipitation
- \( S \) = maximum retention potential
- \( S = \frac{1000}{CN} - 10 \)
  - related to soil and cover conditions of the watershed through the CN
  - determined by rainfall-runoff plots

Influenced by:
- rate of infiltration at soil surface
- rate of transmission in the soil profile
- water-storage capacity of the profile
\[ \Delta S = P + RO - ET - GWO - SWO \]

*CN = Curve Number - ranges from 0 - 100*

- hydrologic soil group (A - D) (Exhibit A-1)
  - A (high infiltration) - D (low infiltration)
- cover type (Tables 2-2)
  - vegetation, bare soil, impervious surfaces, residential, etc.
- hydrologic condition (Tables 2-2)
  - poor, fair, and good
- antecedent moisture condition (AMC I - III)
  - based on 5 day rainfall totals
    - I - dry periods
    - II - average moisture periods
    - III - wet periods
    - Assume II
\[ \Delta S = P + RO - ET - GWO - SWO \]

Runoff

* Calculate CN
  
  1. Delineate Watershed
  2. Locate hydrologic soil groups (A - D) from Soil Survey.
  3. Divide watershed into different cover types (woods, paved, etc) and conditions (good, fair, or poor).
  4. Overlay watershed, soils, and cover type maps and calculate area of each subgroup.
  5. Determine CN for Each subgroup (Tables 2.2 a-d)
  6. Calculate weighted CN (CNw)
     
     - CN x Area for each subgroup
     - \[ CNw = \frac{CN \times Area}{\sum \text{Areas}} \]
\[ \Delta S = P + RO - ET - GWO - SWO \]

*Calculate Runoff:*

1. Calculate \( S = \frac{1000}{CNw} - 10 \)
2. Using Daily Precipitation Data (P) calculate:
   - \( Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \) (inches of runoff over watershed)
   - Note that minimum size storm event that creates runoff = \( P_{min} = 0.2S \)
3. Volume \( RO = Q \times \text{Net Contributing Watershed Area} \)
4. Depth RO contributing to constructed wetland = \( \frac{\text{Volume RO}}{(\text{Constructed Wetland Area} + \text{Existing Pond/Wetland Area})} \)
5. Repeat steps 2 - 4 to for each daily storm event
6. Sum daily RO depths to determine RO depth for month.
\[ \Delta S = P + RO - ET - GWO - SWO \]

Runoff

Limitations

- \( I_a = 0.2S = 20\% \) of maximum retention
- developed by means of rainfall and runoff data from experimental small watersheds (< 10 acres).
- highly variable

Source:


Figure 10.2: Relationship of \( I_a \) and \( S \). Plotted points are derived from experimental watershed data.
\[ \Delta S = P + RO - ET - GWO - SWO \]

**Limitations**

- CNs describe average conditions.
- Time is not a factor, therefore rainfall duration nor intensity are accounted for.
- Does not take into account runoff from snowmelt or rain on frozen ground.
- CN is less accurate when runoff is < 0.5 inches.
- Applies only to direct subsurface runoff not subsurface flow or high groundwater levels that contribute to runoff.
- If CN < 40 use another method.
- Safety Factor - The opposite of Typical Civil Engineering SF's.
AMC II
- Source:
\[ \Delta S = P + RO - ET - GWO - SWO \]

**Potential Evapotranspiration (ET)**

- **Thornthwaite ET method**
  - empirical equation
  - mean monthly temperature \((T)\) degrees Celsius
  - \(ET = 1.6(10T/I)^a\)
  - \(I = \text{heat index} = \sum \left( \frac{T}{5} \right)^{1.514} \) (sum 12 months)
  - \(a = 0.49239 + 0.01792 (I) - 7.71 \times 10^{-5} (I^2) + 6.75 \times 10^{-7} (I^3)\)

- or
  - Obtain ET values from nearest weather station
  - Percentage of Pan Evaporation
  - Weighing Lysimeter
\[ \Delta S = P + RO - ET - GWO - SWO \]

*Groundwater Outflow (exfiltration)*

- **Darcy’s Equation** \( q = -k \frac{dh}{dl} \)
  - \( q = \) groundwater seepage rate (cm/day)
  - \( k = \) hydraulic conductivity of soil
  - \( \frac{dh}{dl} = \) vertical hydraulic gradient, assume = 1

- **Laboratory testing for K**
  - collect soil samples for testing

- **Estimate K based on soil texture**
  - **Sand**: \( >1 \times 10^{-3} \) cm/sec \((>0.002 \text{ ft/min})\)
  - **Silt**: \( 1 \times 10^{-3} \) to \( 1 \times 10^{-5} \) cm/sec \((0.002 \text{ to } 2 \times 10^{-5} \text{ ft/min})\)
  - **Clay**: \( < 1 \times 10^{-6} \) cm/sec \(<2 \times 10^{-6} \text{ ft/min})\)
\[ \Delta S = P + RO - ET - GWO - SWO \]

Surface water Outflow

* Outflow Control
  - Excess Runoff is your Safety Factor
  - Always provide a way to spill excess water and adjust water levels
  - Controlled with berms, dikes, dams, spillways, and weirs
Water Level = Initial Fill + P + RO - ET - GWO - SWO

Water budget model components and water level prediction for pond/wetland system.

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</tbody>
</table>

* expressed in depth (inches) over baseline elevation which is approximately the average distance from weir invert to average elevation of soil substrate in wetland.