# HYDROLOGY TOOLS FOR WETLAND DETERMINATION

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## INTRODUCTION

In making wetland determinations, the Food Security Act of 1994 requires that the three criteria for wetlands (hydric soils, hydrophytic vegetation, and wetland hydrology) be determined separately. Hydric soils can be determined on site by use of the Field Indicators of Hydric Soils in the United States (USDA 1996), while vegetation can be observed on-site or if the site is disturbed on a near-by undisturbed site. However, hydrology often cannot be observed on-site. In order to establish wetland hydrology, the timing and duration of the inundation or saturation must be established. Therefore, acceptable methodologies had to be established that would be agreed upon by all wetland regulatory agencies to determine wetland hydrology by inundation or saturation.

The Natural Resources Conservation Service (NRCS) has recently published Hydrology Tools for Wetland Determination (USDA 1997). This document describes field-tested analytical procedures to assist in wetland hydrology determination. These procedures provide additional information about the duration and frequency of inundation or saturation of a site and hence are indicators of the hydrology of a potential wetland or of a restored wetland. These tools include: stream gage analysis, remote sensing, water balance, observation wells, state drainage guides, scope and effect equations, and the program DRAINMOD.

The Hydrology Tools for Wetland Determination (HTFWD) has been developed by a multidiscipline team from the NRCS in cooperation with the U.S. Army Corps of Engineers (COE), the U.S. Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (FWS), various regional, state, and local agencies, universities, and the private sector. These methodologies are now accepted by the various agencies for documenting the hydrology on potential wetland sites. These procedures can be used to support wetland determinations, to evaluate possible impacts to wetlands from planned activities, and to evaluate the potential hydrology of wetland restoration sites.

This paper describes each of the hydrology tools and gives a brief description of their use. Supporting information is described, including WETS tables that provide long-term weather data reporting stations for most counties across the nation. There can be multiple reporting stations in any one county. The WETS tables include precipitation normals as well as defining the growing season for the particular location. WETS tables can be downloaded from the Internet. Hard copies of WETS tables are available in Section I, Field Office Technical Guide in NRCS field offices.

The hydrology tools have proven successful in a wide variety of landscape settings in different regions of the United States. These tools have also proven effective using different lengths of time of continuous inundation or saturation. Hence, if the laws regarding critical duration of saturation or inundation to produce wetland hydrologic conditions were to change, the hydrology tools would remain valid procedures (Woodward and Warne 1997).

## WETLAND HYDROLOGY CRITERIA

The wetland hydrology criteria used by the USDA is defined by the National Food Security Act Manual (USDA 1996). The definition is subject to change but at present is as follows:

1. Inundation (flooding or ponding) occurs for 7 consecutive days or longer during the growing season in most years (50% chance or more); or

2. Saturation at or near the surface occurs for 14 consecutive days or longer during the growing season in most years (50% chance or more). Soils may be considered to be saturated to the surface when the water table is within:

   a. 0.5 ft of the surface for coarse sand, sand, or fine sandy soils; or

   b. 1.0 ft of the surface for all other soils.

There are different criteria for different types of wetland such as Farmed Wetlands, Wetlands and Farmed Wetlands that are potholes, playas, or pocosins. The differences are in the duration of saturation or inundation. However, in all these definitions it is necessary that the needed hydrology occur during the growing season. Therefore, the growing season must also be determined for the site. The growing season is represented by the period from the last 28 °F or lower air temperature in the spring to the first 28 °F or lower air temperature in the fall at a frequency of 5 years in 10. Growing season can be obtained from WETS tables.

For the purposes of wetland delineation under the Clean Water Act, the Corps of Engineers Wetlands Delineation Manual (Environmental Laboratory 1987) defines the hydrology criteria. The criteria are slightly different from that used by USDA and, therefore, a user must always be sure of which criteria are applicable and what are the latest criteria.

## WETS TABLES

WETS (WETS is not an acronym) Tables define the normal range of monthly precipitation and the normal growing season (Woodward and Pasteris 1995). This data is available from the NRCS National Water and Climate Center (NWCC) for approximately 6,700 weather stations across the country. The WETS Tables are available on the Internet at www.wcc.nrcs.usda.gov/water/wetlands.html. By selecting a state and county, available stations can be downloaded. In some cases, stations from adjoining counties must be used. Data available include monthly and yearly average maximum, minimum and daily temperature; monthly and annual average, 30% less than, and 30% greater than precipitation; and growing season beginning and ending dates and length. The WETS tables are used as supporting information in the use of many of the Hydrology Tools. STATS Tables are downloaded along with the WETS Tables. STATS Tables provide monthly rainfall from the beginning of the record to present (the STATS Tables lag the current year by approximately one year).

## FIELD INDICATORS OF HYDROLOGY

Indicators of wetland hydrology can be split into two types: recorded and field. Recorded wetland indicators of hydrology can include stream and lake gage data or historical data. Recorded indicators are sought first. As a matter of field expedience, both the FSA and COE Wetland Delineation Manual allow the use of on-site field indicators of hydrology, when used in combination with soils and vegetation parameters, for routine wetland determinations. The FSA Manual refers the user to the COE Wetland Delineation Manual for a description of the field indicators. The listed field indicators (only one needed to establish hydrology) are: inundation, saturation in the upper 12 inches, water marks, drift lines, sediment deposits, and drainage patterns in wetlands. Additional field indicators that may be used (two or more required) include oxidized root channels in upper 12 inches, water-stained leaves, local soil survey data (hydrologic regime), and the FAC-Neutral Test. In some situations, the field indicators may need supporting quantified information (ex. aerial photography) documenting the timing, duration, and extent of the hydrology. Such situations may include appeals of wetland determinations. The Hydrology Tools can be used independently of or in support of the field indicators of hydrology.

## TOOLS DESCRIPTION

### Stream Gage Analysis

Since inundation is a criteria for wetland hydrology, out of bank or backwater flooding from streams, rivers, and lakes can be analyzed to establish if the inundation criteria is met. By using available gage data (either discharge converted to stage or stage), the period of time that the water maintains a level that meets the duration (consecutive days) and timing (during growing season) for the required recurrence (50%) can be established. Data must be adjusted from the gage to the site. Interpolation between gages or water surface profile calculations can be used to establish water levels away from a gage.

The U.S. Geological Survey (USGS) and the U.S. Army Corps of Engineers (COE) are the two main sources for stream gage data (water.usgs.gov, www.usace.army.mil, respectively). The COE data is usually in stage and can be used directly after being adjusted to the gage datum. The USGS data is often in discharge and must be converted back to stage by the rating curve for the station. The rating curve may be requested from the USGS District Office or calculated from stage discharge data.

In Mississippi, the NRCS used gage data to establish dates that met the farmed wetland criteria (15 consecutive days of inundation during the growing season). These dates were then compared with available Landsat data to determine if satellite imagery was available to document the areas inundated. This process proved successful, so that satellite imagery data was used in the Mississippi Delta to make Farmed Wetland (FW) determinations. Each county office was provided overlays for quad maps designating areas of permanent water, catfish ponds, wooded areas, and Farmed Wetlands. By default, all other open areas were considered Prior Converted cropland. This methodology has proved very accurate and defensible.

### Remote Sensing

Remotely sensed data (aerial photographs, satellite imagery) is available for much of the landscape. Until the mid-1990s, USDA recorded aerial photographs of cropland for crop certification. Most areas were photographed twice per year. For USDA wetland determinations, aerial photography was already available in many counties. However, since these photographs represented only a snapshot in time, supporting information had to be added to the photographs to establish duration and recurrence. The WETS tables provide this information. In this procedure, a minimum of five years with normal precipitation (determined from the WETS tables) of aerial photography is used. The occurrence of wetland signatures in this photography is noted. If wet signatures occur in at least 50% of the years, the site is determined to have wetland hydrology. To establish if the image in question represents a wetter than, drier than, or normal year, the precipitation record for the three months prior to the date of the imagery is evaluated with the months weighted in relation to the image date (the most recent month weighted greatest). The procedure and forms (which can be easily converted into a spreadsheet) are documented in the HTFWD manual.

**Water Balance**

For depressional areas (prairie potholes, playas), a water balance for the site in question can establish the duration, frequency, and depth of ponding (or soil saturation). The depth-storage relationship of the depression must be known, as well as other variables in the water balance such as rainfall, runoff, stream inflow, surface outflow, deep percolation, soil moisture storage, and evapotranspiration. The balance can be run on a daily, weekly, or monthly basis to determine if wetland hydrology criteria are met. A weekly or shorter time frame is preferred.

Normally an individual or team will perform the necessary calculation in a particular region and develop a watershed to depression area ratio. If the ratio is above a determined level, there is sufficient watershed to inundate or saturate the depression to meet wetland hydrology criteria. If the ratio is too low, then the hydrology criteria cannot be met.

The water balance method can also be used to determine the predicted hydrology of a created, constructed, restored, or enhanced wetland. Design changes can be made until the predicted hydrology meets the hydrology goals of the wetland design.

**Observation Wells**

Shallow groundwater observation wells (as differentiated from piezometers) provide a direct measurement of the depth of the water table, duration, frequency, and timing. Manual measurements or recording wells can be utilized. Using observation well data alone, 10 years of measurement is required. However, by using the WETS table information as with the remote sensing procedure, less than 5 years of data can be used if wetland hydrology (water table depth) can be found in years of below or normal precipitation.

It is critical that the observation wells be installed and maintained properly to insure valid readings representative of the site conditions. Since the observation of a water table at 12" or less is being documented, wells should be screened no deeper than two feet. This method is costly and time consuming, thereby restricting its use to special circumstances.

**State Drainage Guides**

Many states developed drainage guides that provided information on the proper drain (both surface and subsurface) spacing to provide adequate drainage for crop production. These guides establish drainage system spacing requirements based upon the type of system and soil type. These guides can be used in cases that have existing drainage systems near or on potential wetland sites. It is reasoned that if a site has a drainage system in proper functioning condition (maintained) that meets the drainage guide criteria, then the hydrology of the site has been removed sufficiently to no longer meet the wetland hydrology criteria. This reasoning relates to areas affected by water tables, not to those areas subjected to surface inundation by out-of-bank or backwater flooding (ex. Farmed Wetlands).

**Scope and Effect Equations**

The term "Scope and Effect" is used to describe an analysis of the areal extent and magnitude of the effect of activities such as ditching, tiling, diking, etc. on the site hydrology. Scope and Effect equations are drainage design equations used to determine whether existing drainage systems (or planned installations or maintenance) are sufficient to remove wetland hydrology from a site.

While numerous water table drawdown equations are available, four have been determined to be applicable in evaluating a site for wetland hydrology. These equations are: the Ellipse equation, the Hooghoudt equation (modified Ellipse), the van Schilfgaarde equation, and Kirkham's equation. The first three equations evaluate subsurface hydrology only. Kirkham's equation is used only in evaluating the removal of ponded water by a tile drain. Often Kirkham's is used to evaluate the time required to remove the surface ponding, then one of the other equations is used to evaluate the drawdown of the water table in the soil profile. van Schilfgaarde's equation is the only transient equation, the others being steady state. The appropriate equation must be selected for the site conditions to be evaluated.

An Internet site (www.sedlab.olemiss.edu/java/tools.html) is available that has the equations already programmed. The site is interactive, so data is input directly and the calculations made without needing to download the programming (the site is fully NETSCAPE 3.01, IE 4.0 and higher compatible, other browsers and versions may not function fully).

Hydraulic conductivity and the drainable porosity of the soil are the data inputs that are the hardest to quantify. General soil parameters can be found in county soil surveys, while more detailed information may be available from local universities and federal or state agencies. Hydraulic conductivity and drainable porosity can be calculated from a program called MUUF. The National Water and Climate Center has made the MUUF program and data available as downloadable files on their server (ftp://ftp.wcc.nrcs.usda.gov/water_mgt/muuf/). Also available is the soil water characteristics program from SPAW (ftp://ftp.wcc.nrcs.usda.gov/water_mgt/soilwatr). There is no technical support for the MUUF program or its data.

In the Ellipse and Hooghoudt equations, drainage rate (q) is the normal input. In the original use of these equations, drainage rate is the rate at which water must be removed to prevent the water table from exceeding the desired depth for a time period, which would damage a crop (1 to 2 days). In drainage design, this value has been based on crop damage in humid regions. The drainage rate required has been published in state drainage guides specific to climate regions.

For wetland purposes, drainage rate is used as the average rate water must be removed for the water table to fall below 12" below the surface for more than 14 days, taking into account rainfall, evapotranspiration (ET), and soil water storage (12" and 14 days are specific to current soil saturation wetland criteria for non-sandy soils). Therefore, this value is often calculated from the drainable porosity, depth water table is lowered, time to lower water table, and the amount of water from rainfall that must be removed. The appropriate value to use for q should be based on

$$q = \frac{(f^{*}\text{depth water table lowered}) + \text{rainfall} - \text{evapotranspiration}}{\text{time to lower water table for most critical period during the growing season}}$$

The drainage rate is a function of climate and should be evaluated locally. Long-term continuous simulation models (DRAINMOD) could be used to evaluate area, state, or regional drainage rate values. Appropriate values for drainage rate need to be evaluated by climate region and soil type.

One guiding factor in the selection of the proper equation to use is in the relationship between the depth of the drain (d), the depth of the impermeable layer below the drain (a), and the calculated drain spacing (S). In general, the ellipse is used where a<=2d, Hooghoudt's equation (modified ellipse) is used where a>2d, but S/a>4, and if S/a<4 (infinite depth to impermeable layer) Figure 4-30 in Drainage of Agricultural Lands, Section 16, National Engineering Handbook (USDA 1971) can be used.

## DRAINMOD

DRAINMOD is a computer program that was developed to simulate the performance of drainage, subirrigation, and controlled drainage systems. DRAINMOD was developed by Dr. R.W. Skaggs of North Carolina State University (NCSU) to simulate the performance of water table management systems. DRAINMOD is licensed for use within NRCS and the USDA-SCS DRAINMOD User's Guide (USDA 1994) should be referenced for detailed instructions in running the program. Others should contact NCSU to obtain the program and to learn about formal training available.

For use in making wetland determinations, DRAINMOD (Ver 4.60a and higher) includes an option that will calculate the number of days during the growing season (user defined) that the water table is within a user defined depth to the surface for each year in the period simulated (Table 1). This information is used to determine if the site modeled meets the hydrology criteria for saturation duration and depth during the growing season (USDA 1996).

DRAINMOD is used to simulate long-term conditions and therefore requires significant input data (30 years of daily precipitation). This long-term simulation removes the problem of short-term climatic variation (drought, wetness) in the analysis of wetland hydrology. Currently, DRAINMOD accounts for offsite runoff by modifying the precipitation-input data for equivalent runoff.

DRAINMOD can be used to evaluate the appropriate drainage rates to use in the scope and effect equations to evaluate wetland situations. Reference Wetland Simulations developed using DRAINMOD can be used to evaluate short-term (less than one year) observation well data, making the use of observation wells in wetland determinations more viable.

## SUMMARY

The Hydrology Tools for Wetland Determination presents seven analytical procedures that can be used to document the saturation or inundation of a potential wetland site. These tools are: stream gage analysis, remote sensing, water balance, observation wells, state drainage guides, scope and effect equations, and the program DRAINMOD. These tools complement the on-site indicators of hydrology rather than replacing them. It is recommended that two or more of these tools be applied to any potential wetland site to improve the confidence and defensibility of any wetland determination made.

The NRCS National Water and Climate Center makes available the WETS tables to provide supporting information needed to use the hydrology tools. The dates and length of the growing season are defined as well as precipitation normals. The accompanying STATS tables provide monthly precipitation for the period of record.

**DISCLAIMER**

Within the NRCS, Engineering Job-Approval-Authority is used to limit the practice of engineering to those individuals who have been identified as having received training and have demonstrated the ability to perform the operations in question to the satisfaction of and under the supervision of the supervising engineer. Each engineering practice has its own range of practice limits and limits vary among individuals based upon their knowledge and experience. The Hydrology Tools for Wetland Determination are considered by NRCS to be the practice of engineering. Individuals outside the NRCS should be cautioned that some states might consider the use of these tools in wetland hydrology determination the practice of engineering. NRCS provides these tools (hardcopy, Internet, etc.) to be utilized by qualified individuals only.

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Table 1.
DRAINMOD – HYDROLOGY EVALUATION

Number of periods with water table closer than 30.00 cm
for at least 14 days. Counting starts on day
117 and ends on day 283 of each year

| Year | Number of Periods of 14 days or more with WTD < 30.00 cm | Longest Consecutive Period in Days |
|---|---|---|
| 1962 | 0. | 5. |
| 1963 | 0. | 2. |
| 1964 | 0. | 0. |
| 1965 | 0. | 6. |
| 1966 | 0. | 0. |
| 1967 | 0. | 7. |
| 1968 | 0. | 0. |
| 1969 | 0. | 3. |
| 1970 | 0. | 10. |
| 1971 | 0. | 6. |
| 1972 | 0. | 0. |
| 1973 | 0. | 13. |
| 1974 | 0. | 12. |
| 1975 | 0. | 0. |
| 1976 | 0. | 0. |
| 1977 | 0. | 0. |
| 1978 | 0. | 4. |
| 1979 | 0. | 10. |
| 1980 | 0. | 0. |
| 1981 | 0. | 0. |
| 1982 | 0. | 9. |
| 1983 | 1. | 24. |
| 1984 | 1. | 22. |
| 1985 | 0. | 0. |
| 1986 | 1. | 27. |
| 1987 | 0. | 0. |

Number of Years with at least one period = 3. out of 26 years.

(From: Hydrology Tools for Wetland Determination, Course Workbook, National Employee Development Center, Fort Worth, TX, 1996)