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Wetland Surface Water Processes

PURPOSE: This technical note summarizes hydrologic and hydraulic (H&H) processes and the related terminology that will likely be encountered during an evaluation of the effect of surface water processes on wetland function. The technical note provides general guidance to personnel in the field who lack specific expertise in H&H processes but are still faced with the regulatory responsibility of wetland permit evaluation. Future technical notes will provide detailed information on data sources and methods of analyses associated with individual H&H processes.

BACKGROUND: The hydrologic and hydraulic characteristics of a wetland influence all wetland functions and, consequently, should be an initial focus of a wetland evaluation. The processes by which water is introduced, temporarily stored, and removed from a wetland are commonly known as the water budget. Water is introduced to a wetland through direct precipitation, overland flow (or runoff), channel and overbank flow, groundwater discharge, and tidal flow. Temporary storage includes channel, overbank, basin, and groundwater storage. Water is removed from the wetland through evaporation, plant transpiration, channel, overland and tidal flow, and groundwater recharge.

The relative importance of the above processes varies with wetland type (i.e. riverine, tidal, depressional), which depends on regional factors such as climate, geology, and physiography. In particular, the physiography or the topographic and bathymetric variation in and around a wetland affects the residence time within a wetland, which can either increase or reduce the relative impact of the H&H process. For example, the water budget of riverine wetlands with residence times on the order of hours to days is controlled primarily by differences in channel and overbank inflow and outflow. Depressional wetlands, on the other hand, which can have residence times ranging from weeks to seasons, have water budgets that depend for the most part on direct precipitation, evaporation, transpiration, and groundwater interaction. A flow chart illustrating the interaction between wetland H&H processes is provided as Figure 1.

- Wetland Basin Characteristics. The physiography or basin characteristics of a wetland and its surrounding watershed influence both the interaction and relative importance of individual H&H processes. Basic information on geometric features (basin length, width, depth, upstream drainage area), location and physical characteristics of hydraulic structures, and land use is essential to understand the water budget within a wetland. Initial estimates of these physical features can be derived from U.S. Geological Survey (USGS) topographic maps, aerial photography, wetland inventory maps, and National Ocean Service (NOS) charts for tidal areas. Refinements to the initial estimates can be made from data collected during a field visit. Useful spatial relationships that can be derived using these data are stage-area and stage-volume curves, which allow one to quickly estimate the extent of areal flooding given point surface elevation measurements.

- Precipitation. Surface water processes within a wetland are tied to both local and regional precipitation patterns. Precipitation can influence a wetland water budget directly through rain and snowfall within the physical boundaries of the wetland and the associated runoff, or indirectly through inflows from upstream watersheds. Information required to estimate the influence of precipitation ranges from general regional and seasonal variability to the frequency and magnitude of individual storm events. Complete daily records and statistical summaries of regional meteorological conditions are available through the National Weather Service (NWS).

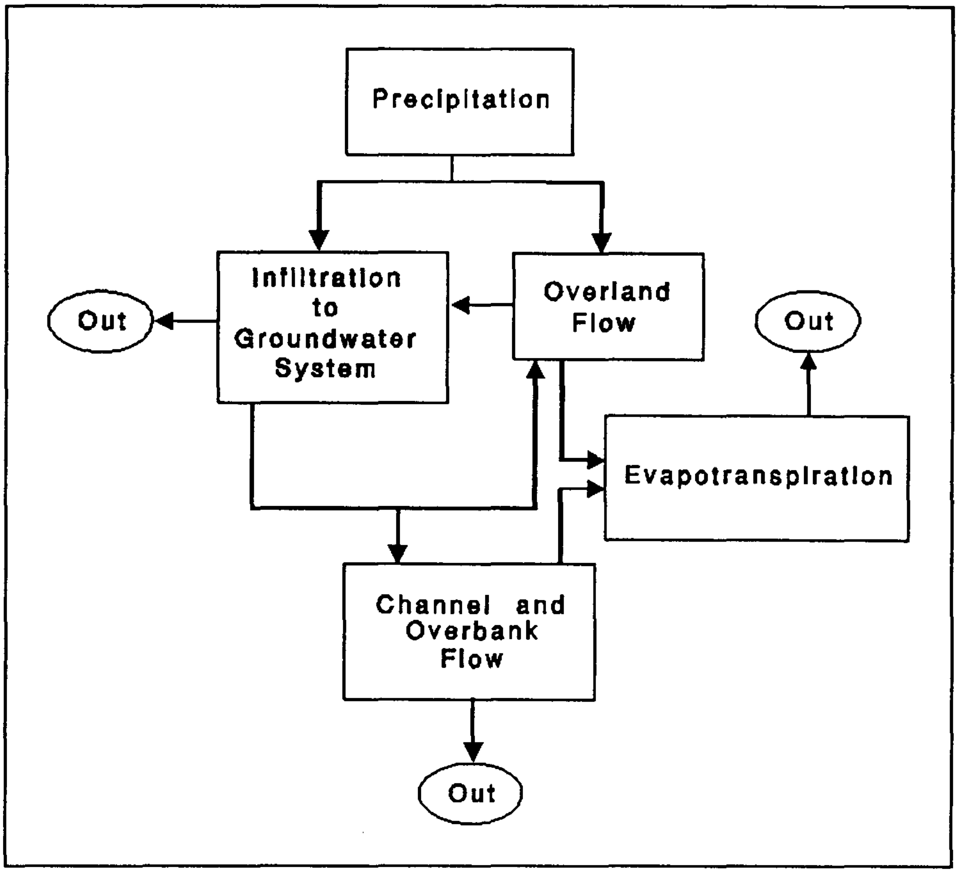

Figure 1. Flowchart of surface water H&H processes

- Evaporation and Transpiration. Evaporation is the process by which water in a liquid or solid state is converted to water vapor and lost to the atmosphere. Surface water loss due to evaporation depends on meteorological conditions, such as air temperature, humidity, and wind speed, and ground conditions such as vegetative cover and soil moisture content. Regional estimates of evaporation rates are obtained by pan, lake, and reservoir evaporation studies and are available through the NWS. Pan evaporation rates are higher than for lakes and reservoirs, so as a rough rule, pan evaporation rates should be reduced by 30% when applied to open water within a wetland (Kohler 1952).

  Transpiration results from root uptake by emergent plants and the subsequent loss through leaf surface area. Estimates of transpiration rates are related to vegetative density, soil moisture content, and depth to the deep root zone. These data are available through state agricultural extensions. Often the effects of evaporation and transpiration on a wetland water balance are combined into a single estimate of water loss called evapotranspiration. A number of empirical methods for estimating evapotranspiration are available in the literature (Christiansen 1968; Kadlec, Williams, and Scheffe 1986).

- Channel and Overbank Flow. Channel and overbank flow is the downgradient response of accumulated surface water to gravity. Channel and overbank flow can significantly impact the introduction, temporary storage, and removal of water within all types of wetlands. Flow rates are closely linked to net precipitation and the resulting processes, such as watershed runoff, ice and snowmelt, and flood flows from upstream watersheds. Discharge estimates can be obtained from USGS stage-discharge relationships derived for gaged rivers. The influence of channel and overbank flow varies seasonally to yearly in magnitude, duration, and frequency. As a consequence, care should be exercised in the use of measured flow rate and stage data to determine the areal extent and duration of flooding within the bounds of a wetland. The USGS publishes mean annual peak flow rates and flood flow events for selected return intervals (Barnes and Golden 1966) that can be used to view limited field data in a proper statistical perspective. In addition, much of the data compiled on river stage, discharge, and reservoir volumes are available through data systems, such as the USGS WATSTORE (National Water Data Storage and Retrieval System), that provide daily observations and statistical summaries.

- Overland Flow. Overland flow occurs when the infiltration capacity of the soil is exceeded. The resulting runoff follows topographic gradients until it either enters a channel or accumulates in a local depression where it ponds, infiltrates, or evaporates. Estimates for overland flow can be obtained from methods such as the Rational Formula (Bedient and Huber 1988), which relates discharge to rainfall intensity, watershed area, losses such as infiltration and detention storage. Data on runoff coefficients for various land coverage types can be obtained from standard reference handbooks (Chow 1964) and the SCS Engineering Field Handbook (1992).

- Groundwater Recharge and Discharge. Differences between surface water elevations and the groundwater table can result in either groundwater recharge or discharge. Recharge occurs when the surface water elevation exceeds the groundwater table, and discharge when the opposite occurs. Given that the surface water elevation within a wetland usually varies more rapidly than the groundwater table, the soils and sediment within a wetland can act as both a source or sink of surface water. Estimates of the volume flow rate of groundwater discharge can be obtained by applying Darcy's Law (Freeze and Cherry 1979). The data required to evaluate this process include surface water elevations, groundwater elevations, and the hydraulic conductivity of the soil or sediment. These data can be obtained from state offices of the USGS and the SCS. Regional groundwater level information is also available through WATSTORE.

- Tidal and Related Flow. The impact of the tides on the water budget of a coastal or estuarine wetland varies temporally and regionally. This is because both tidal periods and amplitudes exhibit a wide variation from one location to another. Tide tables, tidal current tables, and tidal current charts can be obtained from the NOS. Daily information on high and low tides is available in local newspapers. In addition, related flows such as freshwater inflows and wind-driven currents and waves can radically alter periodic volume balance and salinity distribution within a tidal wetland. Estimates of freshwater inflow should include upstream flows gaged at the fall line and runoff from watershed area below the fall line. Methods of estimating variations in water level due to wind forcing is provided in the Shore Protection Manual (USAEWES 1984).

CONCLUSION: This technical note provides a framework for examining surface water processes within a wetland. The information and supporting references presented can be used by field personnel as a guide to identifying the H&H processes that significantly influence wetland function, understanding the interrelationships among the various H&H processes, and identifying the data required to determine the relative importance of individual H&H processes. In general, the overview provided by this technical note should be used to avoid the omission or misinterpretation of specific H&H mechanisms and their role in determining the overall water budget of a wetland.

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