A Study of Natural and Restored Wetland Hydrology

The U.S. Geological Survey and the U.S. Environmental Protection Agency are jointly studying the hydrology of a long-existing natural wetland and a recently restored wetland in the Kankakee River Valley in northwestern Indiana. In characterizing the two wetlands, project investigators are testing innovative methods to identify the analytical tools best suited for evaluating the success of wetland restoration. Investigators also are examining and comparing the relations between hydrology and restored wetland vegetation.

Introduction

Wetlands recently have received political and scientific attention because of their known benefit to the environment. For example, wetlands decrease the effects of flooding by storing large quantities of water in porous streambank sediments and low-lying areas. Extensive flooding in some areas of the United States has been attributed in part to the loss of wetlands (Fretwell and others, 1996). Wetlands also have been shown to improve water quality by filtering out fertilizers and pesticides. The organic-rich sediments of wetlands, produced by decaying plant mass, attract and bind other contaminants as well; many communities nationwide are constructing wetlands to enhance sewage-treatment systems.

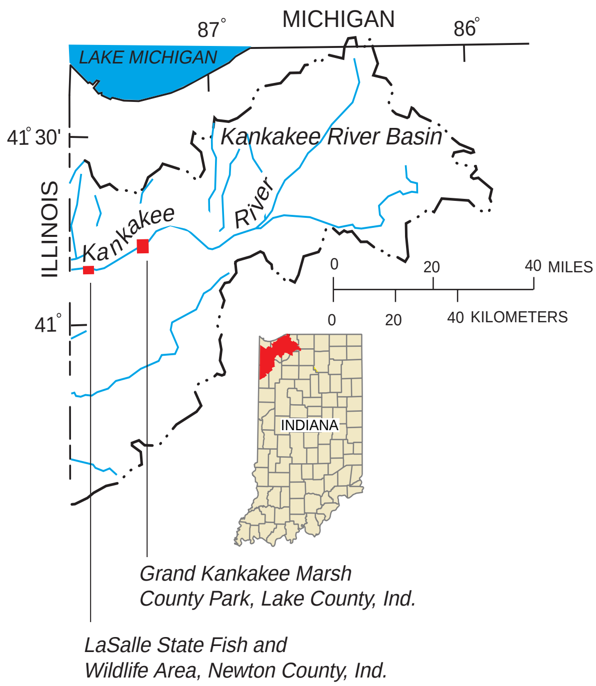


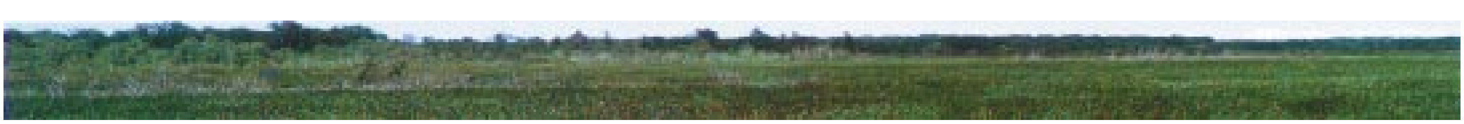
Figure 1. Location of the study area in northwestern Indiana.

As part of a U.S. Environmental Protection Agency Ecosystem Restoration Initiative grant, a joint U.S. Geological Survey (USGS)/U.S. Environmental Protection Agency (USEPA) study is looking at the hydrology of a natural wetland (the LaSalle Fish and Wildlife Area) and a restored wetland (the Grand Kankakee Marsh County Park) (fig. 1). Project investigators are examining and comparing the relations between hydrology and vegetation in the natural and restored wetlands while testing innovative methods to identify the analytical tools best suited for evaluating the success of wetland restoration.

Background

Prior to European settlement, wetlands in the Kankakee River Basin formed a continuous ecosystem from north-central Indiana to north-central Illinois. The Kankakee River system was then the largest wetland in the midwestern United States and gained international recognition during the 1800's for its diverse wildlife and excellent hunting and fishing opportunities. With European settlement, the flat valley floor became highly desired as farmland. A vast tile and ditch network was developed to lower ground-water levels beneath low-lying lands adjacent to the Kankakee River to make those lands agriculturally productive. An extensive levee system also was built to reduce flooding near the river. As a result, the hydrologic conditions that had sustained the wetlands in the Kankakee River Basin were altered. Today, only 13 percent of the original wetlands of the Kankakee River Basin remain intact, and the populations of many species of fish, plants, and wildlife have declined steadily in response to reduced and degraded wetland habitat.

In 1998, the U.S. Fish and Wildlife Service proposed restoration of 30,000 acres of the historical wetland over the next 30 years, and the U.S. Army Corps of Engineers began examining techniques to minimize the effects of periodic flooding. The purpose of the restoration would be to conserve, protect, and enhance fish and wildlife habitat in the Kankakee River Basin. One plan to accomplish this goal is to



plug and remove parts of the extensive tile and ditch network to allow ground water to return to historical levels.

Goals of the Study

The USGS/USEPA study will (1) determine the applicability of various naturally occurring isotopes of chemical elements (many of which have not commonly been applied in wetlands investigations) to discriminate between ground- and surface-water-flow paths, recharge and discharge areas, water residence times, and source areas in natural and restored wetlands; (2) develop a method to assess the hydrology of natural, constructed/relocated, and restored wetlands; (3) use computer-based models to simulate ground- and surface-water flow and chemical transport through the studied wetlands to corroborate the isotope results, as well as to forecast the effects of wetland restoration on adjacent properties; (4) characterize general water quality at both sites to differentiate between the natural and restored wetlands; and (5) develop statistical relations between established plant communities and wetland hydrology.

Information gained from this study may be applicable to wetlands investigations nationwide. In many parts of the country, destruction of natural wetlands is permitted if a wetland is constructed at another location. Constructed or relocated wetlands, unlike restored wetlands, commonly are built where a wetland has not existed previously. Research by USGS/USEPA scientists has found that wetland functions, such as water-quality improvement and decreased flooding intensity, partially are reconstituted in restored wetlands but probably are not reestablished in constructed or relocated wetlands (Hunt, 1996). The USGS/USEPA study will provide additional information describing the hydrology of restored wetlands. General observations in this study also may be applicable in other studies of manmade wetlands.

State of the Science

Recent research has focused on the details of wetland functions such as water-quality improvement, floodwave suppression, and ground-water/surface-water interactions (Krabbenhoft and Webster, 1995; Anderson and Cheng, 1993; Mills and Zwarich; 1986). These studies have shown that these wetland functions are correlated with recharge and discharge areas, ground-water-flow paths and rates, and soil-profile development. The location of recharge and discharge areas can change in response to seasonal or weather-related factors and can affect ground-water-flow direction. As a result, ground- and surface-water quality are affected. The presence of various wetland-plant communities may reflect these changing conditions.

Computer simulations of ground-water flow through wetlands may not be as useful as once believed (Hunt, 1996; Hunt and others, 1996, 1997). Accurate simulations of wetland-flow systems require detailed measurements of hydrologic properties at finer scales and frequencies than commonly are made.

The use of naturally occurring isotopes can be superior to traditional water-quality analyses for elucidating the details of wetland hydrology (Hunt and others, 1998; Kehew and others, 1998). In addition, the conjunctive use of isotope analyses and computer simulations results in more accurate predictive capabilities than can be achieved without the isotopic information.

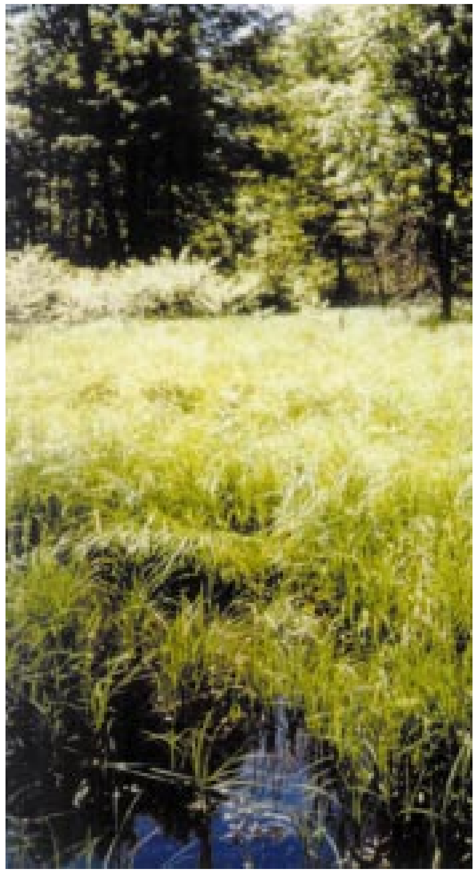


Figure 2. A sedge meadow within the oak savanna at LaSalle State Fish and Wildlife Area.

Study Sites

Sites for the USGS/USEPA study are at the Grand Kankakee Marsh County Park in Lake County, Ind., and at the LaSalle State Fish and Wildlife Area in Newton County, Ind. Both study sites are adjacent to the Kankakee River. At both sites, the geology consists of unconsolidated sand, underlain by clay-rich glacial-lake deposits and a basal bedrock. A previous USGS hydrologic investigation provided some background information (Arihood and Basch, 1994).

The Grand Kankakee Marsh County Park is a wetland-restoration project managed by the Lake County Parks Department. Wetland restoration began in 1979 and the Parks Department continually is adding new property to its boundaries; the total area is currently 1,900 acres. The restored wetland provides refuge and nesting areas for migratory waterfowl and hunting opportunities for local enthusiasts.

The wetland at Grand Kankakee Marsh County Park had been cultivated prior to wetland restoration. A system of pumps, drains, and ditches is used to manage water levels in the wetland. Water from the Kankakee River and the Brown Levee Ditch is used to flood low-lying areas within the wetland. The Kankakee River and the Brown Levee Ditch form the south and the north boundaries of the Park.

The LaSalle Fish and Wildlife Area, which was dedicated in 1964, includes approximately 3,700 acres of land. The USGS/USEPA study site is a remnant of the historical wetlands of the Kankakee River Basin and includes sloughs and sedge meadows in a matrix of upland oak savannas (fig. 2). There are no artificial controls on water levels at the LaSalle study site, and parts of the site are seasonally inundated.

Instrumentation and Data Collection

The geologic simplicity at the study sites along the Kankakee River, the quantity and precision of hydrologic information collected, and the extensive data base of isotope and water-quality analyses help provide a clear conceptualization of the hydrologic and water-quality processes occurring in the wetlands. An accurate conceptualization and a data base of precisely measured hydrologic properties are required for computer simulations of wetland hydrology.

At both sites, a transect was selected that parallels the local ground-water-flow direction and is perpendicular to the Kankakee River. Wells were installed along each transect in nests of two or three wells, and each well was drilled to a different depth. All of the wells drilled for this project were completed in the surficial sand aquifer. Existing wells belonging to private landowners, the LaSalle Fish and Wildlife Area, and the Lake County Parks Department were completed in bedrock and were included in the study-site well transects.

Additional instrumentation installed at the Grand Kankakee Marsh County Park (fig. 3) measures rainfall, humidity, atmospheric pressure, air temperature, ground-water temperature, and surface- and ground-water levels. Water samples collected at more than 60 points at the two sites represent rainfall, saturated- and unsaturated-zone ground water, ditch and stream water, and seepage into shallow wetland ponds. The water samples are being analyzed for about 40 constituents, including major ions, trace elements, and nutrients.

In addition to the continuous measurements made by site instrumentation, ancillary hydrologic data have been collected. Ancillary data include detailed topographic maps of the land surface and records of pumping and other park-managed controls on water flow into and out of the restored wetland.

Aquifer and streambed permeability, which strongly affect the rate at which water flows into and out of the wetlands, are being estimated by use of aquifer pump-and-recovery tests and floodwave-response analyses (Barlow and Moench, 1998; Duffield, 1998). These estimated values, which are used as input to the computer models of the wetland flow system, can in turn strongly affect the accuracy of the simulations (described below).

Isotope Studies

Atoms of an element that have the same number of protons but a different number of neutrons are isotopes of that element. Naturally occurring isotopes of many chemical elements exist in ground and surface water and can provide information about the hydrologic and geochemical history of the water in a wetland (Sidle, 1998). Samples for isotopic analysis usually are collected with the same techniques and tools that are used to collect samples for general water-quality analysis, although some require specialized devices.

Figure 3. Aerial view of the restored wetlands at Grand Kankakee Marsh County Park. The photo was taken from above the Kankakee River, looking toward the northeast. (Photograph by Marc Robertson, Lake County Parks Department.)

Most wetland studies have made use of a few basic isotopes, such as those of oxygen and hydrogen. This study is examining the use of the isotopes of oxygen, hydrogen, carbon, nitrogen, sulfur, strontium, lead, and chloride (table 1). In other studies these isotopes have been used to calculate the contribution of ground water to streams and lakes, to estimate the residence time of water in an aquifer, to indicate specific rock-water interactions, to differentiate between agricultural and naturally occurring nutrients, and to infer biologically mediated reactions occurring in ground water (Clark and Fritz, 1997). Isotopic analyses for this study are being done at the USEPA National Risk Management Laboratory in Cincinnati, Ohio, and at Purdue University in Lafayette, Ind.

Table 1. Naturally occurring isotopes used in this study

[1, provides information about ground-water sources; 2, provides information about the ground-water-flow-path history; 3, provides data for estimating ground-water residence times; 4, provides information about biochemical modifications to water chemistry]

Compounds	Isotopes	Uses
Oxygen	$^{18}O/^{16}O$	1, 2
Hydrogen	$^{2}H/^{1}H$	1, 2
Carbon	$^{13}C/^{12}C$	1, 2, 3, 4
Nitrogen	$^{15}N/^{14}N$	1, 2, 4
Sulfur	$^{34}S/^{32}S$	1, 2, 4
Strontium	$^{87}Sr/^{86}Sr$	1, 2
Lead	$^{206}Pb/^{204}Pb$	1, 2
Chloride	^{36}Cl/total Cl	3

Computer Simulations of Wetland Hydrologic Processes

The accuracy of a computer simulation of a hydrologic system such as a wetland depends on the quality of data used as input for the computer program. Through the study-site instrumentation, the USGS and USEPA are making detailed measurements of many of the variables necessary to characterize accurately a wetland hydrologic system.

The simulations of wetland hydrology will be done using the computer code commonly known as MODFLOW (McDonald and Harbaugh, 1988). This code uses the field-measured data and the researcher's conceptualization of the flow system to solve a set of mathematical equations and produce a three-dimensional array of ground-water-flow rates and directions. The effects of various restoration activities on local ground-water levels will be simulated by adjusting the model input and conceptualization. The computer simulations developed from this information will be used to predict the effects of wetland restoration on the existing hydrology of the wetlands and adjacent farmlands and to suggest residence times and transport pathways of surface water and ground water.

Vegetation and Hydrology

Relations between hydrologic variables and wetland vegetation are being examined at both study sites. The composition and richness of the vegetation are being sampled at 10 plots adjacent to ground-water observation wells where information exists to describe the hydrology. Relations between hydrology and vegetation will be derived by statistical analysis of the data.

Study Results

The USGS/USEPA study described here began in October 1997 and is scheduled to extend through September 2000. Analysis of data collected since the study's inception is underway; initial results are scheduled for publication in 1999. Additional results will be published throughout the study period as more data become available. Professional journals are the targeted outlets for publication of these results.

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