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# Groundwater Hydrology of a Population of Lindera melissifolia in Arkansas


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# GROUNDWATER HYDROLOGY OF A POPULATION OF *LINDERA MELISSIFOLIA* IN ARKANSAS

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**ABSTRACT**

Groundwater hydrology was monitored from October through August in and around a bottomland forest pond containing *Lindera melissifolia*, pondberry. The study site exhibited a series of low ancient dunes and depressions, with seasonal ponds in the depressions. Ponds showed no surface inlets or outlets. Shallow wells were made and soil cores removed along a transect from the top of one dune across the pond to a lower dune. Piezometers were installed in the wells and groundwater levels monitored. Soil core samples were analyzed to determine particle size distribution at soil profile positions selected during field analysis. It was shown that a subsurface hydrologic gradient exists between surrounding dune slopes and the pond bottom, delivering groundwater to the pond during the season when precipitation exceeds evapotranspiration. The hydrologic gradient was shown to be substrate-dependent.

## INTRODUCTION

*Lindera melissifolia* has been declared a federally threatened species by the U.S. Fish and Wildlife Service and endangered in Arkansas. The U.S. Forest Service considers it a "rare" species and included it in a study of rare plants in the southeastern states (Kral, 1982). In Arkansas, only a few populations of pondberry in three areas of the northeastern part of the state are known. These populations only occur in association with temporary ponds in depressions between dunes formed from glacial outwash (Saucier, 1978). Ponds are typically well isolated from each other, due to natural topography and to agricultural modification of the landscape (Wright, 1989). Survival of the species requires that existing stands maintain themselves and if possible spread to other ponds.

Knowledge of the groundwater hydrology of wetland areas in which pondberry is found in Arkansas, as well as other freshwater wetlands is limited (Good, *et al.*, 1978; Pomeroy, 1979). Despite the recognized importance of the hydrologic regime to the survival of all species occupying the wetland habitat, groundwater hydrology is often the component of the wetland ecosystem not thoroughly investigated. The importance of the hydrologic regime to the survival of all species occupying the wetland habitat is now being realized (LaBaugh, 1986; Clairaiu Jr. and Kleiss, 1989).

Three most common assumptions concerning groundwater movement relative to ponds are: 1) the water table is a subdued replica of the land surface, 2) the water table in areas between ponds has a uniform slope, and 3) ponds recharge groundwater (Winter, 1986). However, studies of groundwater flow relative to topographic depressions by Meyboom (1966) and Freeze (1969) indicate that groundwater flow systems are much more complex than these assumptions indicate. Each depression in the landscape has a local flow system that is superimposed on the regional system (Mills and Zwarich, 1986).

The primary source of recharge in many wetland areas is from infiltration of precipitation (Bedinger, 1980). Surface flows may be too slow to observe easily (Hammer and Kadlec, 1986). Subsurface flow is then generated by rapid infiltration of rain and the associated increase in soil hydraulic conductivity (Pearce, *et al.*, 1986). The nature and properties of the soils in and surrounding the wetland, as well as those of underlying deposits, are important because of the relationship between soil characteristics and the movement of water (Carter, 1986).

Because it is a wetland species, pondberry is subject to alterations in hydrology. At present, little is known about the hydrological characteristics of the areas in which it is found. In order for existing stands of pondberry to maintain themselves and spread to other ponds, the hydrologic elements of their present habitat must be determined. The purpose of this study was to determine the groundwater hydrology of one such location in Arkansas. From these data, other possible areas can be located to find additional stations suitable for supporting the species. More importantly, acquisition and management decisions may be guided by the hydrological findings.

## STUDY SITE

The site for this study is located in Woodruff County, Arkansas. The area exhibits a series of low, sandy dunes and depressions. The depressions form natural ponds, which are seasonal. No surface inflows or outflows were evident for the pond studied.

Soil series classifications for the area are Tuckerman, Beulah, and Bruno fine sandy loams. These soils are classified as hydric, meaning they remain saturated too far into the growing season to permit cropping (Wright, 1989). Bedding of the subsoil is such that well drillers indicate they go through various clay bands for the first 10 meters of depth (Neal Harris, United States Soil Conservation Service, personal communication).

The pondberry stand at this site is about 75 $m^2$ in area with an average density of 5 stems $m^{-2}$ (Wright, 1988). It is located on the southeast berm of the depression and extends into the pond approximately 2 m. The pond is approximately 59,000 $m^2$ in area, and is vegetated by a closed-canopy bottomland hardwood forest.

Soil characteristics in and around the pond contribute to acquisition and retention of pond water. Although there was no evidence of surface drainage into the pond, abrupt transition to lenses of finer particle size, along with the presence of considerable clay and silt, would be expected to contribute to ponding (H. Don Scott, personal communication cited in Wright, 1989). Preliminary exploratory cores to 90 cm taken in 1988 by Larry Ward of the U.S. Soil Conservation Service in Little Rock, Arkansas indicated some banding of layers according to particle size, including bands with considerable clay content. Mottling and concretions in the lower parts of the cores were indications of frequent flooding (Wright, 1988).

The pond margin showed no evidence of disturbance, but the fields surrounding the depression were planted in crops until March 1989. At that time, the landowner abandoned tillage around the site area and planted a buffer of pine trees around the depression containing the study site.

## MATERIALS AND METHODS

Since the principal hypothesis was that the pond could be recharged by groundwater from higher ground, a transect was established from the top of a dune on the west side of the pond to the pond bottom. Five wells were drilled along this transect. Two additional wells were drilled on the pond bottom. Relative well depths and locations are shown in Figure 1. Wells 1-7 were drilled in August 1988.

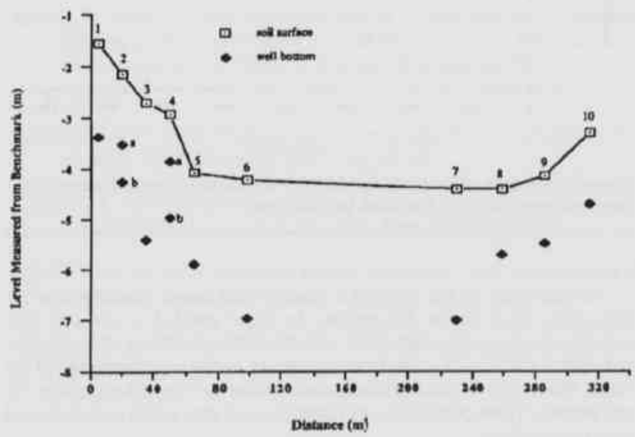


Figure 1. Depth of placement of wells in and around the pond relative to each other. Wells #5-7 are on the pond bottom.

After the soil core sample had been taken, piezometers were installed in the wells to allow for groundwater level monitoring throughout the wet season. PVCpipe having an outside diameter of 3.8 cm was used to construct the piezometers. A small amount of 2-3 cm gravel was placed in the bottom of each well prior to installing the piezometer. The piezometer was fitted with a removable cap to prevent entry of extraneous material. The piezometers allowed the level of the water table to be determined at intervals throughout the wet season (Reeve, 1986). Rainfall data for the area were obtained from the National Oceanic and Atmospheric Administration (NOAA, 1988; NOAA, 1989). The weather station is located approximately 4 km southwest of the study site.

The pond perimeter was then surveyed with a builder's level to determine the lowest point. After the lowest point was determined, another transect was established on the lowest (east) side of the pond. Three more wells numbered 8-10 were drilled along this transect (Fig. 1) in January 1989.

Water levels in the wells were monitored from October 1988 to August 1989 to determine groundwater fluctuations. Pond surface levels were also monitored during the same time period. Visual analysis of the soil at the time the soil cores were taken at well #2 and well #4 suggested the presence of perched water tables. At these two locations, an additional piezometer was installed to the depth of these suspected perched water tables, and next to the original piezometer. The original piezometers were designated B, and the new ones A.

The core samples were analyzed at the site by the United States Soil Conservation scientists. Cores of soil were also analyzed in the lab by screening and soil hydrometry (Brower and Zar, 1984) to determine particle size distribution at profile positions determined during field analysis.

## RESULTS

Soils were primarily fine sandy loam, with bands of increased clay content (Fig. 2). These bands of increased clay content will be referred to as lenses. Wells #5, 6, and 7 showed evidence of strong gleying. These three wells were located on the bottom of the pond.

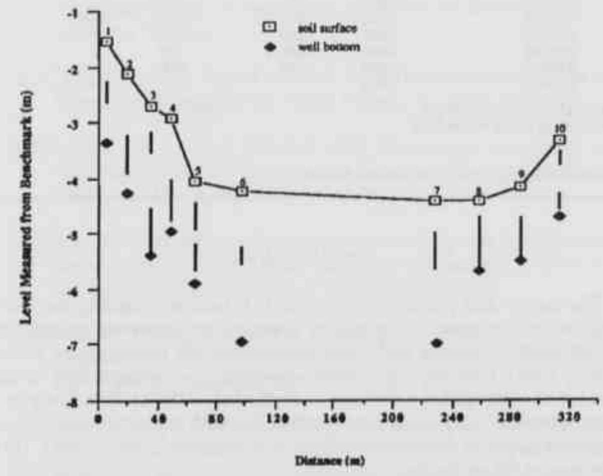


Figure 2. Abrupt increases in the clay content of the soil in each well are shown relative to each other. The depth below the soil surface of these layers is also shown. These layers of increased clay content in the soil were determined by soil particle size analysis.

Wells #2a and #4a had a high clay content at the depths they were placed, as hypothesized. The clay content at the bottom of these two wells was higher than in the soil above or below them. This was verified by the soil particle size analysis of these two wells. When correlated with monthly rainfall data, water was shown to perch above these layers with increased clay content after a rain. A layer with increased clay content was also found to be present in the samples taken from under the pond itself. Well #7 demonstrated one layer that was primarily clay.

Groundwater levels were also recorded. The soil at well#8 was saturated from February 13, 1989 through May 27, 1989, with standing water extending as much as 15 m. up the dune slope away from the pond bottom. As the pond water level dropped, saturation at well #8 decreased.

The pond contained water by November 26, 1988. While the water level had decreased, there was still water in the pond at well #7 on July 22, 1989.

### STATISTICAL ANALYSIS

Depth to the groundwater level from the surveyed benchmark was regressed with the distance between wells. Regressions were calculated for each date that groundwater levels were measured. Only those dates on which sufficient data were collected were used in the analysis. The slope of the regression line indicated the direction of groundwater flow and hydraulic gradient (Table 1). The correlation coefficient was also determined to describe the tendency for distance between wells and depth to the water table to covary. The absolute value of the coefficient indicated the strength of that tendency to covary.

Table 1. Hydraulic gradient and correlation coefficient analysis for sample dates with sufficient data.

| Date | Hydraulic Gradient wells 1-5 | Hydraulic Gradient wells 8-10 | Correlation Coefficient wells 1-5 | Correlation Coefficient wells 8-10 |
|---|---|---|---|---|
| 11/26/88 | -.020 | | | |
| 12/18/88 | -.009 | | .599 | |
| 1/03/89 | .006 | -.008 | .559 | |
| 1/16/89 | -.008 | -.030 | .778 | |
| 1/30/89 | -.010 | -.020 | .964* | |
| 2/13/89 | -.020 | -.001 | .865 | .386 |
| 2/27/89 | -.020 | .00 | .974* | .386 |
| 3/13/89 | -.010 | .002 | .935* | .397 |
| 3/27/89 | -.010 | .003 | .945* | .280 |
| 4/07/89 | -.020 | .005 | .957* | .400 |
| 4/15/89 | -.010 | -.002 | .817 | .650 |
| 4/29/89 | -.006 | -.002 | .634 | .240 |
| 5/13/89 | -.005 | -.001 | .559 | .046 |
| 5/20/89 | -.010 | -.004 | .620 | .274 |
| 5/27/89 | -.005 | .00 | .396 | |
| 6/10/89 | -.003 | -.001 | .274 | .984* |
| 6/17/89 | -.008 | -.020 | .721 | |
| 6/24/89 | -.010 | -.020 | .783 | |
| 7/08/89 | -.006 | -.020 | .500 | |
| 7/22/89 | -.010 | | | |
| Soil Surface Slope Wells 1-5 | | | -.040 | |
| Soil Surface Slope Wells 8-10 | | | .020 | |

* Statistically significant at 95% confidence level

## DISCUSSION

The nature and properties of the soils in and surrounding the wetlands, as well as those of underlying deposits, are important because of the relationship between soil characteristics and the movement of water (Carter, 1986). One important factor modifying soil permeability is the presence of permeability variations at depths below the surface. The presence of permeability variations directly beneath the depressions also affects the nature of depression focused flow systems (Lissey, 1971). This is the case at the study site.

Field soil data indicated the presence of primarily fine sandy loam soil with a clay content of 0-4%. However, clay lenses were present in soil samples from all ten wells (Fig. 2). The clay content in these samples increased to as much as 15% at several depths. These clay lenses were at a higher elevation outside the depression edge than in the depression. The clay lens under the pond itself appeared to be continuous across the pond bottom at about 5 m below the benchmark. The clay lens below the depression would be an effective aquiclude (Johnson, 1942). As water enters the depression, the slower permeability of the clay lens would cause the water to pond above it.

In the late fall and winter months, rainfall is much higher than evapotranspiration. This results in a greater input (rainfall) than output (evapotranspiration plus internal drainage) causing the soil profile to become wet and water to pond on the clay lens. Since the depth in the profile to the clay lens increases toward the pond, the water ponded above the clay lens establishes a horizontal pressure gradient. As a result of this gradient and the more rapid saturated hydraulic conductivity in the coarser textured horizon, saturated flow of water occurs above the clay lens toward the pond (Lissey, 1971; Pearce, *et al.*, 1986). This groundwater exchange must be primarily lateral rather than vertical (Schalles and Shure, 1989). Water flow was lateral into the pond from the west side during the late fall and winter. Statistical analysis of regression for the sample dates also indicates this (Table 1). Some groundwater outflow is also shown at well #8.

During the late spring months, water loss becomes greater than input as evapotranspiration increases. As the depth of ponded water decreases, transport of water to the pond is reduced. When flow has become significantly reduced, the soil above the clay lens becomes largely unsaturated and the hydraulic gradient will be low. This pattern was demonstrated at the study site.

Clay lenses closer to the surface allow for the formation of perched water tables. Wells #2a and #4a were placed at depths where the field soil analysis indicated clay lenses existed. At these two locations perched water tables formed after a rain due to the infiltration of the water through the soil vertically and perching of the water on the layer of soil with increased clay content (Fig. 3). Water remained perched several days. These perched water tables delivered water by lateral movement into the pond. Data also indicated a clay lens that was a possible perched water table at well 10. These shallow clay lenses were approximately 0.44 m thick.

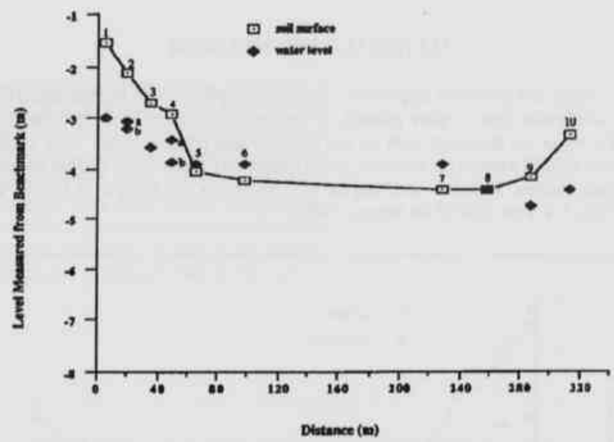


Figure 3. Groundwater levels for 2/27/89 are shown. Perched water tables were present at wells 2A and 4A at this time.

Groundwater in the study site area should move laterally into the depression. Once in the depression, the water ponded on the clay lens under the depression surface. This contributed to the filling of the depression. Some outflow of groundwater occurred on the low (east) side of the pond. Water also formed perched water tables on clay lenses nearer the soil surface. These perched water tables formed after a rain and dissipated after several days.

While groundwater hydrology of this area appears evident on a local scale, the total flow system of the area may be much more complex. Further studies on how the regional flow system affects this local system are necessary before a complete analysis of the groundwater hydrology of the area in which *Lindera melissifolia* is located can be made.

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