# LOCAL GROUNDWATER LEVELS IN WISCONSIN

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## Introduction

In recent years, especially the past 10 years, there has been an alarming decline in groundwater and lake levels and reduced stream flows in the Wisconsin Sand Plains (WSP). This greatly impacts aquatic ecosystems, recreational uses of aquatic resources, and property values of riparian lands. It is clear that reduced stream flows are associated with reduced groundwater elevations. What is not clear is the cause of the lower groundwater level. However, there is a popular belief that the reduction in groundwater table elevations is associated with irrigation of agricultural land from high capacity irrigation wells. Wisconsin common law related to groundwater makes use of a "reasonable use standard" (Kent and Dudiak, 2001), so potential conflicts between lake riparian owners and groundwater-based irrigation indicates the urgency of developing an improved understanding of irrigation's impacts on groundwater quantity. There is ample evidence that groundwater fluctuations occur naturally because of drought and high rainfall periods (Heath, 1983), but accompanying this natural fluctuation in precipitation has been a tremendous growth in irrigated cropping in the humid parts of the U.S. in general, and particularly in the WSP (WDNR, 1970; Bajwa et al., 1992; Ellefson et al., 2002). At a broader scientific level, there is a need for understanding irrigation water use (evapotranspiration, ET) by crops with respect to native vegetation (including grass and forest) on WSP, and other sand plains in humid temperate regions with shallow depth to groundwater. Arguably irrigated crops should be viewed as simply another vegetation type on the landscape, with characteristic temporal patterns of evapotranspiration loss and groundwater recharge, albeit strongly driven by human manipulation of soil wetness through irrigation. Foster and Chilton (2003) note the heavy exploitation of groundwater in recent years. They suggest that most consumptive use of pumped groundwater is by irrigated agriculture. We initiated a research project in summer of 2007 to attempt to obtain quantitative data on the causes of changes in groundwater elevation relative to groundwater use for irrigated crop in comparison to natural vegetation on WSP over recent decades. Water use by the differences vegetations will be accomplished via computer model simulation and indirect measurements of groundwater recharge rates.

## Irrigation in Wisconsin

Irrigation in north central United States expanded eight-fold between 1970 and 1990 (Bajwa et al., 1992) and the expansion continues, though perhaps at a slower rate (USDA NASS, 2007). The majority of irrigated land in WSP is in Portage and Waushara counties, and the historical extent of the practice is reported in Table 1. Post World War II technology and cycles in the agricultural economy are reflected in the development of irrigated land area. Area of irrigated

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land in Portage County has increased over the 15-yr period between 1987 and 2002 by 48% (Table 1). While the increase in Waushara is more modest (at about 11%), our observations are that the wells and irrigation systems are being modernized and increased in capacity.

Table 1. Changes in irrigated land area in two counties in Wisconsin Sand Plain (US Census of Agriculture)

| Year | Portage County irrigated land area (ha) | Waushara County irrigated land area (ha) |
|---|---|---|
| 2002 | 37,365 | 19,796 |
| 1997 | 31,705 | 20,962 |
| 1992 | 27,599 | 17,312 |
| 1987 | 25,180 | 17,857 |
| 1982 | 20,179 | 14,806 |
| 1978 | 20,030 | 15,840 |
| 1974 | 11,875 | 11,821 |
| 1969 | 10,167 | 8,943 |
| 1964 | 6,983 | 5,330 |
| 1959 | 2,805 | 2,120 |
| 1954 | 1,134 | 111 |
| 1949 | 363 | 216 |

Hydrologic researchers in the 1960s and 1970s estimated the impacts of pumping for irrigation on surface water resources (e.g., Weeks et al., 1965; Weeks and Stangland, 1971) and warned of impending environmental harms if pumping was not managed (WDNR, 1970). These studies conceptualized pumping effects as an increase in evapotranspiration (ET) relative to nonirrigated land covers. Increased evapotranspiration comes at a cost to net groundwater recharge. Reduced net groundwater recharge in turn lowers lake and groundwater levels and reduces surface water flows. Irrigation might decrease net recharge by half or more over many years. In the vicinity of Plainfield, Weeks and Stangland (1971) estimated that a landscape cover consisting of one-fourth irrigated lands would average surface water flow losses of 25 to 30% and a water table decline of 0.15 m on top of natural water table declines.

Groundwater levels in parts of the Wisconsin Central Sand Plain area are at depths not observed in several decades, causing stream stretches to become dry during summer periods and drastically reducing the size of some lakes (Fig. 1). Quite understandably questions are being raised over the roles of irrigation and municipal wells in this drop in groundwater level. To our knowledge, a careful study of these contributions has never been made, in spite of the tremendous growth in irrigated acreage in the region (Table 1). Official measurements of the groundwater level near Hancock began in 1951 and continue to this day (Fig. 2). Water table fluctuations there pre-date the extensive irrigation development of the area (Table 1). However, this well is at an all-time historic low (http://groundwaterwatch.usgs.gov/CRNSites.asp?S=440713089320801; USGS, 2007).

Similar impacts in irrigated Sand Plains of neighboring states i.e., Michigan and Minnesota have not been observed (personal communication, Jerry Wright, Extension Irrigation Engineer, University of Minnesota, 2006; Jeff Andresen, Dept of Geography, Michigan State University, 2006; and Dave Mulla, Univ. of Minnesota, 2007). This is perhaps because of the relatively


Figure 1. Photograph of Long Lake (near Plainfield, Wisconsin) in August 2007.

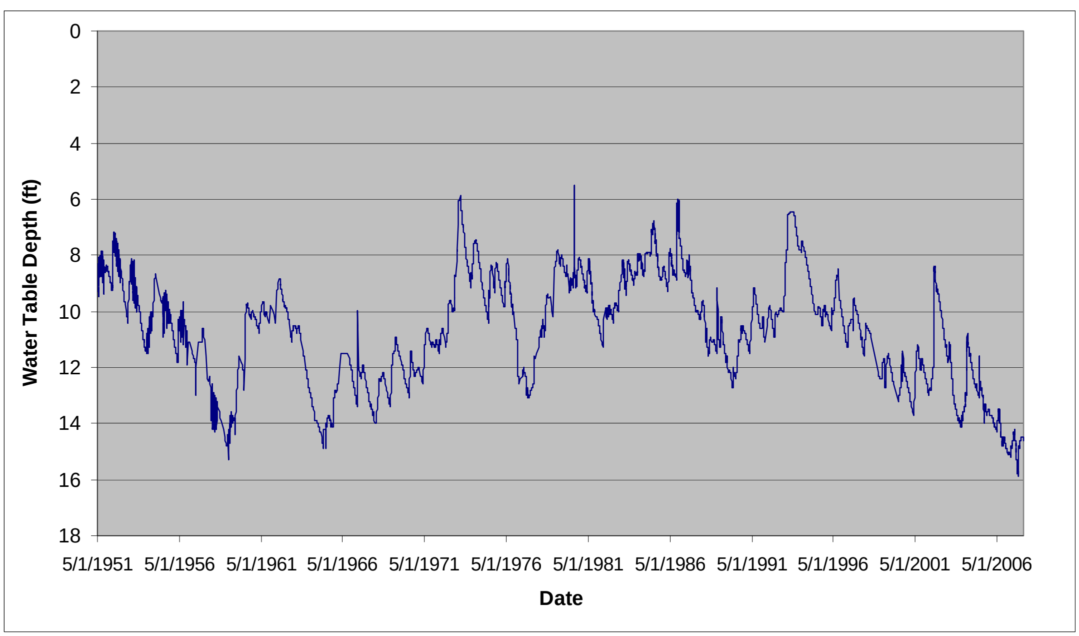


Figure 2. Depth to water table at the USGS monitoring well near Hancock, Wisconsin.

dispersed nature of irrigation in Minnesota, and the dense but topographically less complex land area composing the irrigated Sand Plains of Michigan (e.g., lack of glacial extensive melt water lakes and moraines). However, at a regional scale, both Lakes Michigan and Superior have seen record low surface water levels in recent years. The low water level negatively impacted the shipping industry on Lake Superior in 2006 and 2007.

## Evaluation of Water Balance in WSP

Fluctuations in the depth to groundwater come about from changes in the balance of water inputs (recharge) to outputs (discharge) (Jyrkama et al., 2002). Recharge is the fraction of precipitation (rain and snow melt) that percolates below the rootzone of plants, and this occurs, to some degree, everywhere in the region. The amount of recharge that occurs depends on both the amount of precipitation that falls and the amount of this water that enters the soil and drains past plant roots (Heath, 1983; Jyrkama et al., 2002). There does not seem to be a clear trend in precipitation in Central Wisconsin over the past four decades (Fig. 2), either in total or seasonal patterns. Heavy precipitation events have increased over this period of record (Kunkel et al., 1999), but the impacts of this increase on recharge are not yet obvious.

For WSP, the ultimate discharge is the Wisconsin River, as the groundwater moves slowly toward it. Streams, ditched streams, and drainage ditches act as groundwater discharge points. Distributed across the region there are other discharges, such as evaporation from lakes and streams, transpiration from vegetation with roots that reach groundwater (phreatophytic plants, Schwartz and Zhang, 2003), and pumping of wells. This extraction of groundwater by pumping of wells is the most important human intervention in the balance of groundwater recharge and discharge (Foster and Chilton, 2003). There are several kinds of wells in the region: irrigation, industrial, home, and municipal. Most of the water pumped by these wells is lost from the groundwater by evaporation in industrial processes (like electricity generation) or from vegetation. Some of the water used by households and industries is returned to rivers after cycling through a wastewater treatment plant. However, some of the water extracted at these wells finds its way back to the groundwater, for example through the septic system of a home, or when irrigation applications exceed water use by plants and the water holding capacity of the soil.

Estimating how much crop irrigation changes the groundwater balance of a region, and thereby the water table depth, is complicated. Agricultural development in a region such as WSP involves both the replacement of perennial vegetation (either native or replanted, e.g., tree plantations), and because of the low water-holding capacity of the soils, supplemental irrigation derived from groundwater. These two aspects of irrigated agriculture combine to *increase groundwater recharge* at some times of the year, but to *increase discharge* at others. Perennial vegetation is actively growing and so losing water by transpiration for more of the year than annual crops, because early and late in the growing season crop lands are bare and bare soil loses little water by evaporation, especially from sandy soils. As a result early and late season precipitation on crop lands largely becomes groundwater recharge; while the soil moisture (that is that used by plants) must first be refilled before there can be groundwater recharge beneath perennial vegetation. Global change should also be considered. There is a clear trend for spring to arrive earlier in North America and Europe (Manzel et al., 2006), thus many species of perennial vegetation begin using soil water earlier now than in the past. Additionally, even dead natural plant materials intercept precipitation and allow it to evaporate rather than enter the soil. These effects were demonstrated in a comparison of groundwater recharge in South Central Wisconsin by Brye et al. (2000). During the period from June 1995 and January 1998, native prairie yielded about 200 mm of recharge, compared with 560 mm from the no-tillage corn and 790 mm with conventional tillage (Brye et al., 2000). On the other hand, irrigated annual crops continue to evaporate water at the maximum rate (potential evapotranspiration) all summer long, because irirgators keep the soil moist with groundwater by the act of irrigating. Evaporation from unirrigated vegetation depends on whether or not soil moisture is present, and so becomes small once the soil moisture is depleted. Phreatophytes can extract groundwater from areas with natural vegetation (Schwartz and Zhang, 2003). In summary, our annual cropping pattern allows for greater recharge early and late in the season, but irrigation creates discharge that does not occur from natural areas.

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