US Army Corps of Engineers ®

Lake Winnebago: Fox-Wolf River Basin

BUILDING STRONG®

Table of Contents

Index of Figures

The purpose of this booklet is to acquaint the public with basic information on Lake Winnebago and the Fox-Wolf River drainage basin as well as to inform them about the U.S. Army Corps of Engineers regulation activities and responsibilities.

Location and Physical Characteristics

The Fox-Wolf River drainage basin is located in east-central Wisconsin and has an area of 6,430 square miles. The basin is comprised of the Wolf River, the Upper Fox River, the Lake Winnebago pool and the Lower Fox River. The Lake Winnebago pool consists of Lakes Winnebago, Poygan, Winneconne and Butte Des Morts *(see Figure 1).*

Figure 1. Fox-Wolf River System

The Wolf River originates in the central part of Forest County, Wisconsin, and flows in a southerly direction through several small lakes, Lake Poygan, Lake Winneconne and Lake Butte des Morts. The Wolf River joins the Upper Fox River in Lake Butte des Morts.

The Upper Fox River flows through flat marshy areas, many with poor drainage. The higher grounds surrounding the floodplain are generally good quality agricultural lands, chiefly devoted to dairy farming.

Lake Winnebago, located between the Upper and Lower Fox Rivers, is the largest inland lake in the state of Wisconsin and one of the largest freshwater inland lakes in the United States. A federal dam at Menasha (see Figure 2) and a private dam at Neenah (See Figure 3) control the outflows from Lake Winnebago. At the elevation of the crest of the Menasha Dam, Lake Winnebago has a surface area of about 206 square miles, a length of about 28 miles, a width of about 10 miles and a maximum depth of about 21 feet.

Figure 2. Menasha Dam

Figure 3. Neenah Dam

The Lower Fox River, connecting Lake Winnebago and Green Bay, is 39 miles long and its width varies from about 500 to 1,000 feet. The vertical drop from Lake Winnebago to Green Bay (Lake Michigan) is about 168 feet (see Figure 4). The river generally flows between high clay banks with frequent areas of exposed limestone. The average drop of the Lower Fox River is about 5 feet per river-mile. Most of the properties adjacent to the riverbank consist of either municipal buildings or highly industrialized facilities such as paper mills, hydroelectric power plants or other factories. In recent years, there has been increased residential development along the Lower Fox River. The remainder of the drainage basin below Lake Winnebago is primarily agricultural.

Water Level Regulation Strategy

Since 1959, the U.S. Army Corps of Engineers has regulated the levels of Lake Winnebago. Water levels, weather forecasts, river flows and winds are reviewed on a daily basis to balance the needs of all users of the basin's water resources. This is accomplished through frequent coordination, discussion and correspondence with the user communities. The Corps also conducts an annual regulation meeting which is open to the public.

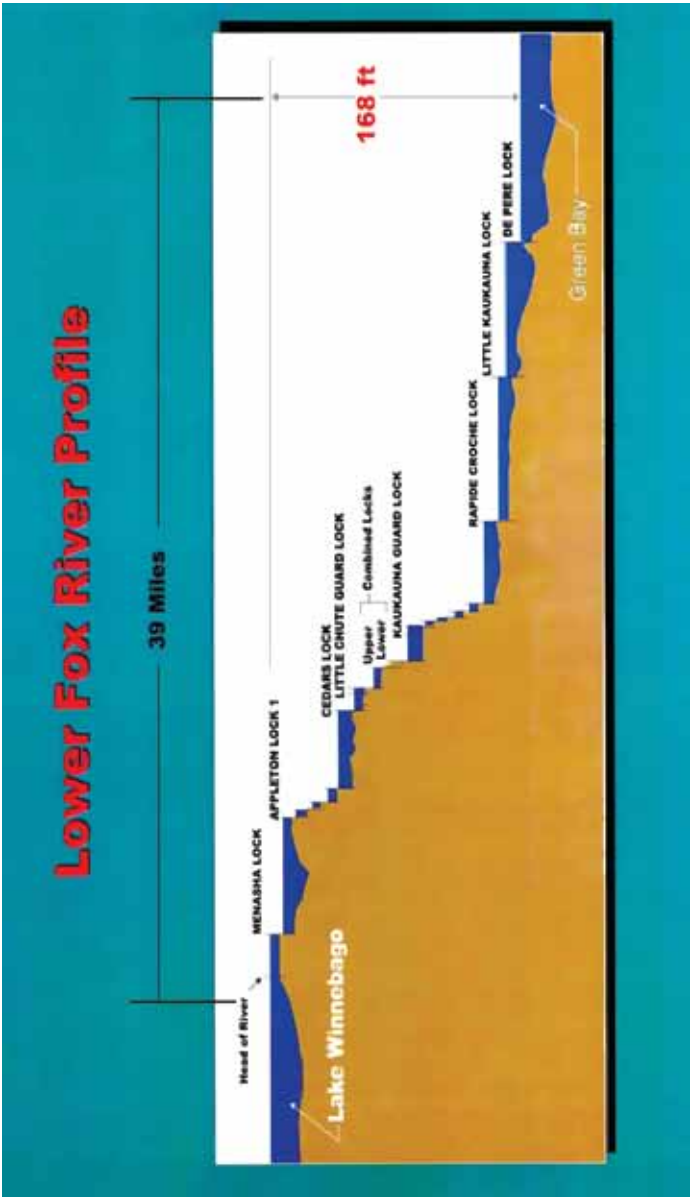

Figure 4. Lower Fox River Profile

An important objective of lake operations is to reduce downstream flooding during spring snowmelt and heavy rains. The lake is drawn down in the winter in anticipation of spring rains and snowmelt. The lake's storage capacity allows it to be used to reduce the incidence of downstream floods.

After the threat of spring flooding has passed, the lake level is gradually raised during the spring season to its summer target for navigation and recreational boating.

All regulation strategies are based on limits defined under the Marshall Order. The Marshall Order was established in 1886 to “maintain the level of Lake Winnebago at or below” flood stage (3.45 feet Oshkosh Datum). Oshkosh Datum is a local datum referenced to the crest of the Menasha Dam from which all Lake Winnebago water surface elevations are derived. In 1920, the Marshall Order was modified to address navigation needs on Lake Winnebago. This Order set forth that “(the) ...limits of regulation for Lake Winnebago under existing laws, orders, rules and permits are from 21-1/4 inches above the crest of Menasha Dam (3.45 feet Oshkosh Datum) down to the crest during the navigation season (1.68 feet Oshkosh Datum). The navigation season presently extends from about May 1 to early October. During the years the Corps has regulated the lake, water levels have remained predominately within the limits of the Marshall Order. Figure 5 shows the various water levels of Lake Winnebago during the last 5 years of operation using past regulation strategies and comparing them to limits of the Marshall Order.

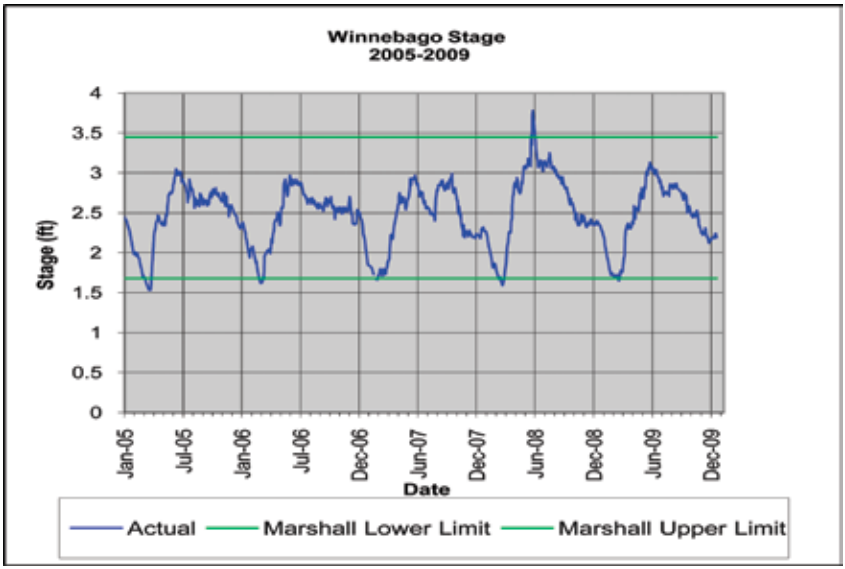

Figure 5. Lake Winnebago Target vs. Stage

The Great Lakes Hydraulics and Hydrology Office (H&H) of the Detroit District oversees the water control activities for the Fox-Wolf River basin. H&H staff work closely with local personnel at the Corps field office in Kaukauna, Wisconsin in making daily regulation decisions. Staff from the Kaukauna office adjust the flow control gates at the Menasha Dam, make downstream pool adjustments at other flow control structures along the Lower Fox, and monitor all the telemetered gauges. The Kaukuana personnel do not make adjustments at the Neenah Dam since this dam is privately owned by Neenah Paper Incorporated. All adjustments at the Neenah Dam are handled by private contractors of Neenah Paper in coordination with Corps staff.

Current Regulation Objectives

The current regulation strategy for Lake Winnebago is divided into five periods. They are described as follows (see Figure 6).

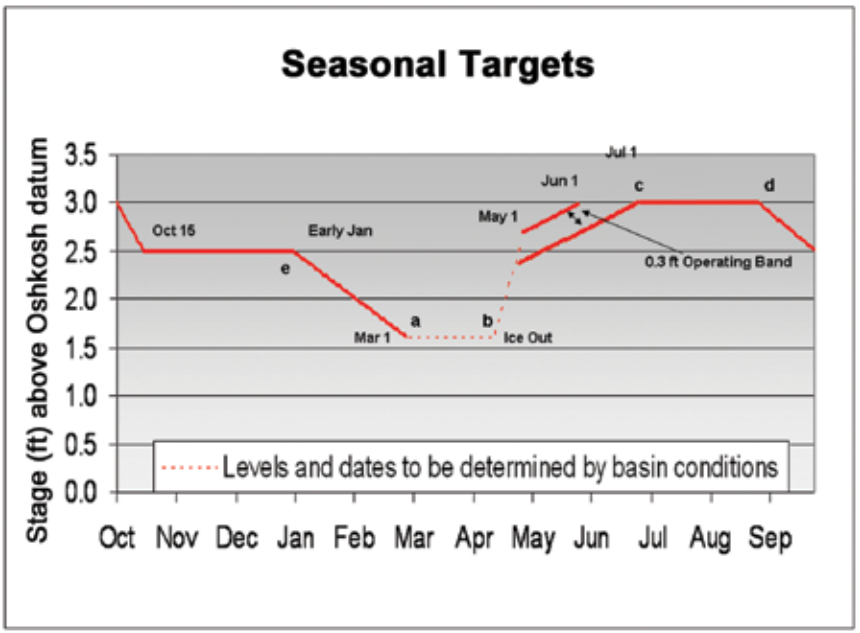

Figure 6. Seasonal Targets

(1) Winter Drawdown (segment e-a on Figure 6):
After solid ice cover forms, the lake is slowly drawn down. The upper pool regions of Lakes Poygan, Winneconne and Butte des Morts contain the majority of the sensitive wetland habitat which is susceptible to ice damage. A sudden increase in water level during the winter may damage

rooted aquatic plants locked in the ice. For the sake of fish and other aquatic life such as muskrats, frogs and turtles, the water level should not be drawn down before a solid ice cover develops. Fish can generally avoid dewatering, but other animals cannot. These animals may survive a winter drawdown under a sheet of ice, but not likely if their over-wintering sites are exposed and/or frozen. For these reasons, it is important to the Winnebago pool environment to avoid significant water level increases when ice is present, and to draw down after a stable ice cover has formed in the upper regions. Close contact with the Wisconsin Department of Natural Resources (WDNR) is maintained during this time for advice on ice cover conditions. If no solid ice cover forms by early January, drawdown must begin regardless.

The drawdown provides capacity to contain spring flooding. Flooding in the Lake Winnebago pool and/or the Lower Fox River is likely to occur when the ice cover on Lake Winnebago and the existing snowpack melts and the Lake Winnebago pool capacity is not sufficient to contain the additional runoff. If the lake level is reduced too far, spring outflows may have to be severely restricted in order to achieve the required navigation stage when the pool is refilled. The drawdown target level is determined during an annual Drawdown Conference Call between the Corps and interested parties in early January. Typically, a target level of 1.68 feet by March 1 is selected, but the target level and date is flexible depending on conditions that develop during the spring. As the winter progresses, the District Office consults the National Weather Service (NWS) and field personnel to develop an outlook for the spring runoff. For example, if below average snow is recorded, little spring runoff will occur and it could be difficult to achieve the summer target by June 1. In this situation, it would be best to increase the March 1 target level to ensure we achieve 3.0 feet by June 1. Since 1990, the drawdown has averaged about 1.45 feet which is 0.5 feet above the average historical drawdown level.

The drawdown may require multiple gate changes, especially during mild winters when inflows remain high. Winter outflows can create problems with frazil (anchor) ice, which is a type of ice that is formed when fast moving water comes in contact with air below 25° F. Frazil ice forms into slushy balls dispersed through the water column. This frazil ice can clog hydropower and process water intakes, causing plants to shut down. When a plant shuts down, ice jams usually occur because the intake is no longer drawing from the pool above the dam. The water level rises and ice piles on top of itself, blocking flow. Flooding is likely upstream of the problem, and flow is reduced for awhile downstream. If downstream companies are not alerted in time, their intakes may fail to shut off automatically, drawing the water below the crest of the dam and interrupting flow in the river. It

is therefore important to avoid the formation of frazil ice. If a complete ice cover has not developed on the river, analyses by the Corps Engineer Research and Development Center's Cold Regions Research and Engineering Laboratory (CRREL) show that flows must be limited to about 4,000 cubic feet per second (cfs) when the air temperature falls below 25° F. Limiting flows to 4,000 cfs during cold periods will keep the velocities in the river low enough so frazil ice cannot form. If the river has frozen over completely, there will be no contact with the air and frazil ice formation is unlikely.

These constraints sometimes make frequent, temporary gate movements necessary to take advantage of short periods of mild weather. As a courtesy to Neenah Paper Incorporated, which owns the Neenah Dam, such short-term movements are made at the federally operated Menasha Dam. This is the more practical option since Neenah gate movements require a full day's advance notice for work crews to be mobilized.

(2) Between Drawdown and Ice-out (see segment a-b of Figure 6):
Once the drawdown target is achieved, basin conditions are evaluated to determine how quickly the lake level can be allowed to rise before the ice cover in the Winnebago upper pool region breaks up and starts moving out. This period can vary greatly from year to year depending on how much snow remains in the basin and the spring weather conditions. As stated before, large water level increases can cause considerable ice damage to wetlands and shoreline structures. Close contact with the WDNR and Kaukauna Utilities is maintained in late March or early April for input on when the ice cover has broken up. During normal conditions the water level is raised very slowly and gradually through the early spring as the snow melts, but no major increases in level are allowed at this point.

(3) Spring Refill (see segment b-c of Figure 6):
When the upper pool ice cover is in such a deteriorated state that a lake level rise would not adversely affect adjacent shoreline, the lake can be refilled. The start of the refill changes each year but typically occurs near the start of April. As shown in the satellite photos (see Figures 7 & 8), the condition of the ice on the Lake can change very quickly during the spring. Figure 8 shows that even though most of Lake Winnebago can appear to be ice-free along most of the shoreline, large masses of ice can remain. It is important to wait until this ice is almost completely melted before raising the level up substantially. This delay helps minimize the risk of shoreline damage as was discussed earlier. A conference call is scheduled before the refill begins, much like the drawdown conference call, to discuss the possible strategies for refilling the lake. As shown in Figure 6, the lake level during the refill is maintained between an operating band. If there

Figure 7. Winnebago Ice Cover on March 30, 2009

Figure 8. Winnebago Ice Cover on April 6, 2009

was a dry winter with very little snowpack and the basin remains dry throughout the spring, the level may be increased more quickly to ensure the summer navigational target is hit. If there is a lot of snow remaining in the basin and a very wet outlook for the spring, the lower half of the band may be followed to reduce the potential for flooding and minimize negative impacts on the aquatic vegetation throughout the basin. The summer target of 3.0 feet is usually hit between June 1 and July 1. The magnitude of the outflows varies significantly from year to year, depending on inflow and extent of the drawdown. The hydropower generators on the Lower Fox River operate best when flows are about 4,000 to 4,500 cfs. Energy production tails off significantly when flows are less than 2,500 to 3,000 cfs. Hydropower production, protection of the ecosystem, navigation and flood control are all important issues to consider during spring fill.

(4) Summer Season (see segment c-d on Figure 6):
During the summer portion of the navigation season, the level of Lake Winnebago will be held as close as possible to a target level of 3.0 feet above Oshkosh Datum. Water levels above 3.0 feet result in high water levels in the upstream lakes and can result in substantial environmental damage over time. While water levels will rise above 3.0 feet at various times during the late spring and summer, the Corps attempts to keep the level from spending sustained periods of time over 3.0 feet. Since the year's lowest inflows occur during the summer, it is not always possible to maintain Lake Winnebago's level at 3.0 feet. Stream flow into the Winnebago pool will often fall below 2,000 cfs. Evaporation losses, combined with lack of precipitation, sometimes result in negative net inflows. Consequently, the water level may fall three or four-tenths below target by the time of the fall regulation meeting, even with all gates at the Menasha and Neenah Dams remaining closed.

(5) Between Navigation Season and Freeze-up (see segment d-e on Figure 6):
As the navigation season draws to a close, the level of Lake Winnebago will be gradually reduced to a freeze-up level determined at the fall regulation meeting. During this time period it is important from an environmental standpoint to avoid large changes in water level from around Oct. 1 through freeze-up of the lake. Large changes in the water level during this time can impact over-wintering habits of animals around the lake. For this reason the lake level is lowered as gradually as possible starting in mid September all the way through freeze-up. Ice formation varies greatly from year to year but can start as early as mid-November or as late as the end of December. The date of the freeze-up target will shift each year based on the temperatures throughout the region. Typically, the regulation targets are proposed at the annual regulation meeting. This meeting is usually held in October, at or around the time of the closing of the Lake Winnebago navigation season.

Flooding Problems

Floods have occurred in the adjacent reaches of the Fox River and along the shores of Lake Winnebago during all seasons of the year, with the most extensive flooding occurring in spring. The Wolf and Upper Fox Rivers generally require several days of precipitation or snowmelt to reach flood stage. Inflows to Lake Winnebago from these rivers during flood stage can result in gradual and sustained rises in the lake level for a week or more. More abrupt rises in the level of Lake Winnebago are primarily due to heavy localized precipitation on the lake's surface.

Floods can occur from rainfall, rainfall accompanied by snowmelt or snowmelt only. The temporary storage of floodwaters in Lake Winnebago reduces the peak flows along the Lower Fox River. However, the duration of the high water can extend over a period of several weeks. In addition, strong winds can cause the lake level to increase on one side of the lake (wind setup) increasing the potential for flooding and erosion along the shoreline of Lake Winnebago. In fact, over the past five years, the maximum wind setup from east-west storms have caused water levels on one shore to be 0.50 feet higher than the opposite shoreline. North-south storms have caused differences of up to 1.25 feet. Easterly winds also have an impact on the upriver areas. Winds push the water up the Fox River at Oshkosh into Lake Poygan and cause high water levels and the potential for flooding on the shoreline around Lake Poygan. Conversely, westerly winds can also have the opposite effect and push the water into Lake Winnebago causing high lake levels and lowering water levels in the upriver areas which impacts recreational boating and fishing activities in both areas.

Seasonal Fluctuations

Seasonal fluctuations reflect variations in Lake Winnebago and the upriver area water levels. Typically, from late November to early March, most of the Wisconsin landscape is snow-covered, with streams and rivers ice-covered. During the winter, the existing snowpack and frost layer remain frozen. When temperatures rise above freezing, both the snow and frost layer are thawed and allow the resulting runoff to flow into the lake. The greatest rise in water levels occurs in the spring due to a combination of snowmelt and precipitation. Another factor contributing to fluctuations in lake levels is evaporation. About 80 percent of the year's total evaporation occurs during the period May through October. Evaporation rates equivalent to daily outflows as high as 1,500 cfs can be experienced over the summer. To put this in perspective, outflows from the lake into the Lower Fox River are typically 1,500 to 2,500 cfs during the summer, so

evaporation can substantially increase the amount of water leaving the lake. A high evaporation rate along with the lack of precipitation could cause the level of Lake Winnebago to drop below the desired levels for this time of year as well as decrease the flows along the Lower Fox River.

Ice Concerns

Lake Winnebago is usually ice-covered from early December through April of any given year. Ice thicknesses greater than 25 inches are commonly measured around the lake during this time. The ice provides recreational opportunities over the winter for ice fishing and sturgeon spearing on the lake. Although the ice layer has benefits, it can also pose problems for shoreline property owners. Typically, in the early winter and beginning of spring, the ice layer near the shore is very thin. Strong winds can push the ice around the lake and cause the ice to pile up against the shoreline. These shoves can pile up higher than 10 feet (see Figure 9) and can cause damage to docks or other structures near the shore. Damage can also be caused due to ice expansion. Throughout the winter there can be periods of varying temperatures where warm weather can follow periods of extremely cold weather. Sometimes when the temperature changes drastically enough, the ice can expand.The expanding ice will eventually crack and form pressure ridges where ice will pile up. As shown in Figure 10, ice expansion formed a pressure ridge near the shore which damaged a dock on Lake Winnebago.

Figure 9. Ice shoves in Spring 2009

Figure 10. Ice Expansion Winter 2009

Through regulation of the lake level, the Corps attempts to minimize the risk of ice damage by keeping the level as low as possible when the ice layer is weak. However, regardless of the level of the lake, shoreline damage due to ice will always be a potential risk and property owners should plan accordingly.

Industrial, Commercial & Municipal Users

The Lower Fox River is part of the most important industrialized region in the basin. The greatest concentration of Wisconsin's pulp and paper industry exists within this area. Extensive use is made of the river by this industry. The river also provides water for navigation, hydropower, municipalities and other industries along the Lower Fox River. Each user affects the quantity and quality of water available as a resource.

Hydroelectric Power

The Lower Fox River from Lake Winnebago to De Pere has a fall of 168 feet in a distance of 39 miles, making it a valuable source of hydropower. Historically, the generation of hydropower at dam sites along the Fox River has been an important factor in the development of the region. Currently, there are nine hydropower generating stations along the Lower Fox River. They utilize the power to operate numerous paper mills, factories and municipalities in the immediate vicinity of the Lower Fox River.

Domestic and Industrial Water Supplies

About 20 percent of the water withdrawn in the basin is used by public water utilities and local governments for domestic water supplies, commercial and industrial uses, and for other purposes such as firefighting and street washing. The four communities of Appleton, Oshkosh, Neenah and Menasha depend on water supplies from Lake Winnebago; others depend primarily on groundwater.

The rivers and lakes within the basin are also used for discharging waste water from municipalities and industries. The most intensive use of the region's water resources for these purposes is along the Lower Fox River. The Corps maintains a working relationship with the WDNR and cooperates with the WDNR and industry representatives about expected outflows from Lake Winnebago down the Lower Fox River.

Recreational Users

The water resources of the region are extensively used for recreational activities such as fishing, hunting and boating. These activities are increasing the demands on the region's lakes and streams. The majority of boating use, primarily for fishing, pleasure cruising and water skiing, is concentrated around the lakes having adequate access, water depths and launching facilities. Because of its size and character, Lake Winnebago provides the widest range of boating opportunities. The heavy concentration of boaters will continue to increase in the future, bringing increased demands for mooring facilities and associated services.

Fish & Wildlife and Wetland Habitat Concerns

Since the dams at Menasha and Neenah were built in the 1850's, the natural water level fluctuations of Lake Winnebago and the upstream pools have certainly changed. Figure 11 shows a comparison of how an uncontrolled lake level would fluctuate versus a regulated lake level similar to Lake Winnebago. The Corps regulation strategy takes environmental affects into consideration and attempts to minimize negative impacts to the environment.

High water levels, wave and ice energy, and land use practices in the watershed have caused the loss of many acres of wetland habitat. The losses have had a direct impact on the abundance and diversity of desirable fish and wildlife and water quality.

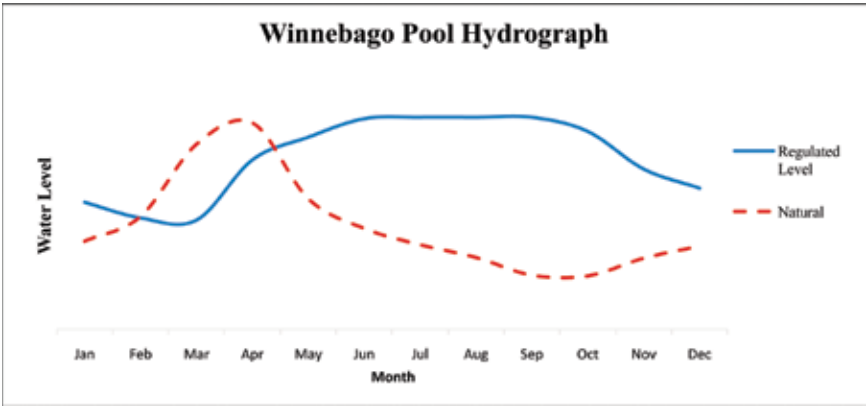

Figure 11. Winnebago Pool Hydrograph (provided by WDNR)

Data Collection

Hydrologic and meteorological data are continuously collected and assessed by the Corps from a network of gauges and rainfall stations. Of primary importance in the day-to-day regulation of Lake Winnebago are the nine satellite Data Collection Platforms (DCPs) (See Figure 12) and the United States Geological Survey's (USGS) acoustic velocity meters (AVM) at Lutz Park and Oshkosh. These are all equipped to relay real time hydrologic data to the Corps offices in Detroit, Michigan and Kaukauna, Wisconsin. The AVM's provide real time inflows and outflows for Lake Winnebago. Inflow data from the upper reaches of the watershed can be estimated from DCP stage data at the communities of New London, Royalton, Berlin and Waupaca. Lake Winnebago's stage is taken as the average of the levels at Oshkosh, Stockbridge, Menasha and Fond du Lac. The historical daily mean, maximum and minimum lake levels for the period 1988-2008, are shown on Figure 13. The DCP data is received via satellite, disseminated and displayed on the District's website. See the back page of this booklet for the website address.

Regulation Meetings

Regulation meetings are held on an annual basis to adjust regulation strategies in accordance with the Marshall Order directives and to address local issues. Since circumstances change from year to year and situations arise, the meetings are necessary in order to set the target stages and dates for the upcoming regulation season. Representatives of the Corps, WDNR, industrial users, hydropower users and other interested parties

Figure 12. Typical Data Collection Platform

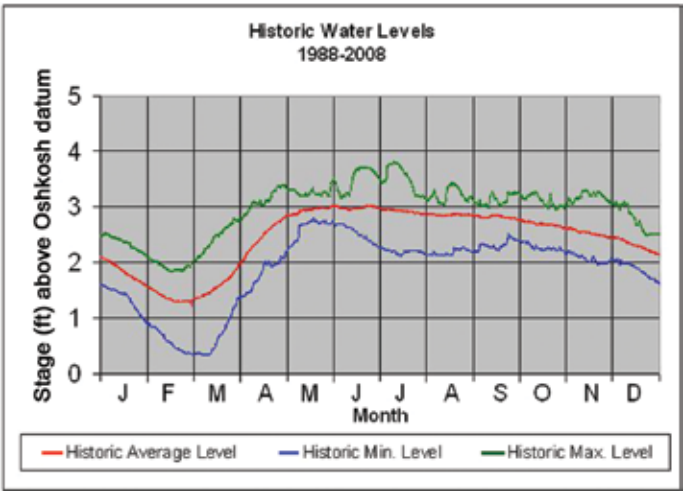

Figure 13. Historical Lake Levels

meet in the fall to discuss any issues that arose during the year and provide feedback on a specific regulation strategy for the next year. The meetings allow local interests, authorities and members of the general public to have a say in how the lake is regulated. This promotes public cooperation, increases understanding of all the various, and sometimes conflicting, uses within the basin and provides a forum to discuss regulation strategies with all stakeholders. Cooperation between private companies, the Corps, WDNR, various citizens groups and local agencies is important because Lake Winnebago and the Lower Fox River are integrally related. These meetings are organized and hosted by the Corps and are usually held in October in the Appleton area. Several public conference calls are also held throughout the year. One call is held in early January to discuss the strategy for drawing the level of the lake down for the winter. The second call is held later in the spring to discuss the strategy for refilling the lake. Other conference calls have been held throughout the years, and a notice for these calls are mailed out, emailed and posted on the Corps' Winnebago website. The Corps welcomes all interested parties to participate in these meetings and conference calls.

Published: October 2010
Designed by: ACE-IT, IPSD-Detroit

For more information contact:
USACE, Detroit District
Public Affairs Office
477 Michigan Avenue
Detroit, MI 48226

www.lre.usace.army.mil

Follow the Detroit District on
Facebook and Twitter.

For further questions and/or comments concerning the
Fox-Wolf River Drainage Basin, please address inquires to:

Chief, Watershed Hydrology Branch
USACE, Detroit District
477 Michigan Avenue
Detroit, MI 48226
Phone: (313) 226-2137

U.S. Army Corps of Engineers
Fox River Sub-Office
1008 Augustine Street
Kaukauna, WI 54130
Phone: (920) 766-3531

USACE Lake Winnebago Website:
www.lre.usace.army.mil/greatlakes/hh/lakewinnebago