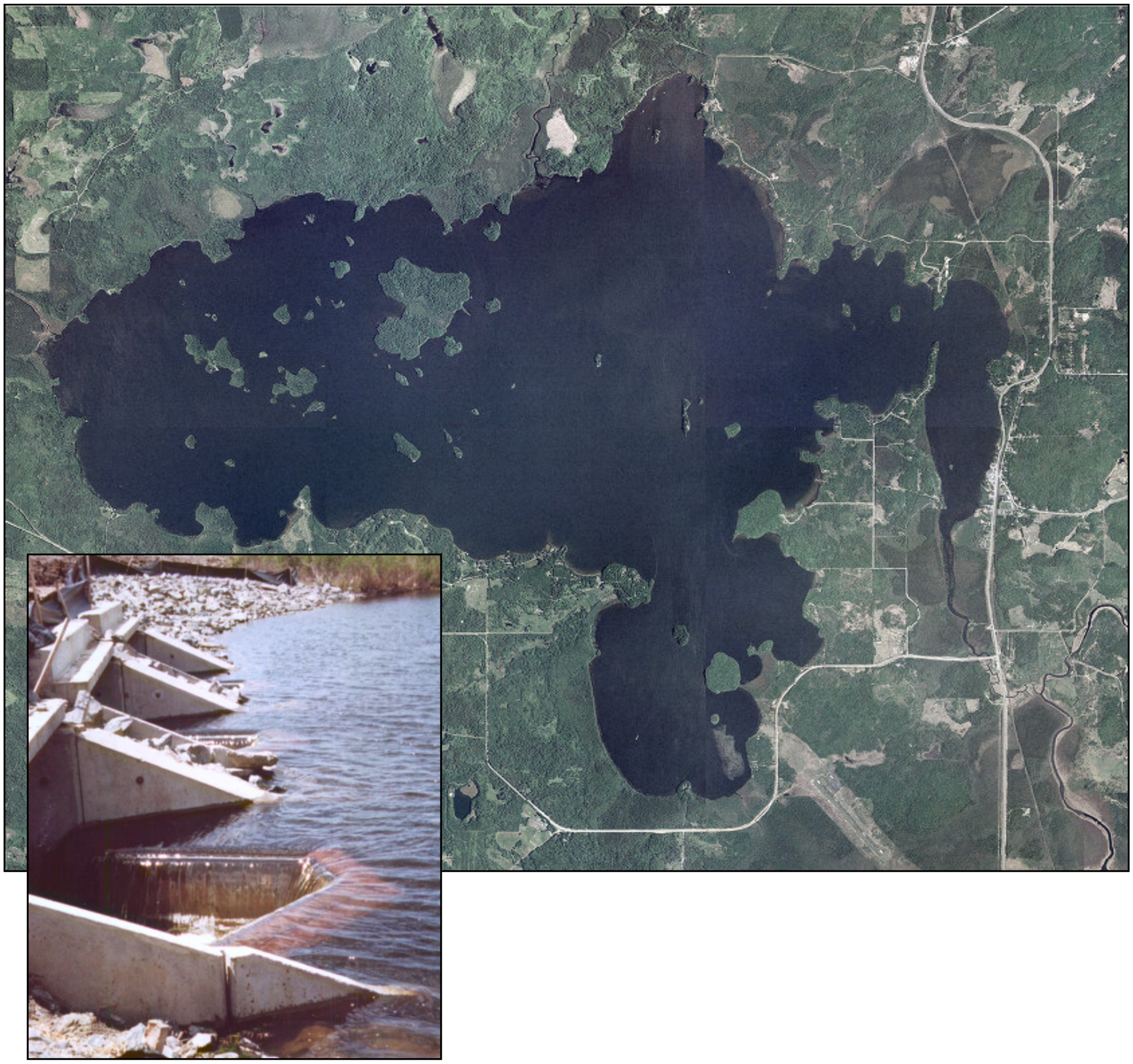
Hydrologic Evaluation of the Pelican Lake (69-841) Dam

St. Louis County



DNR Waters

February 10, 2009

Appendices D, E & F added February 23, 2009

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St. Louis County reconstructed the Pelican Lake dam as part of a larger highway improvement project in 2002. Lakeshore owners have expressed concern regarding recent low levels on Pelican Lake, and consider the new dam to be contributing to the problem. This report details a hydrologic and hydraulic investigation of the Pelican Lake dam in response to these concerns regarding low lake levels.

Pelican Lake is located in the northwestern portion of St. Louis County near the city of Orr. Pelican Lake is one of Minnesota's larger lakes at 11,500 acres in size; the lake contains many islands, and has a maximum depth of 38 feet. While there is considerable recreational development around the lake, much of the lakeshore is in public ownership and remains undeveloped. Pelican Lake is considered a high-quality bass fishery; northern pike and panfish are also an important part of the lake's sport fishery. Pelican Lake is also popular with waterfowl hunters.

Pelican Lake is located within the Vermilion River watershed. The lake outlets at its southeast end near the city of Orr into the Pelican River, which in turn flows into the Vermilion River. Compared to its size, the contributing watershed area of Pelican Lake (69.4 square miles) is relatively small, with a contributing watershed area to lake area ratio of 3.8:1 (Figure 2).

An outlet dam located at St. Louis County Highway 23 controls lake levels on Pelican Lake. The earliest report of a dam was by the county highway engineer who reported that, circa 1918-23, a "rock and brush dam [had been] constructed by timber operators or local residents for purpose of holding the lake level at a higher stage during dry periods. Some time prior to construction of the 1938 bridge and dam, the old timber dam had deteriorated to such an extent that it no longer was effective. Boats negotiated from the river out into the lake over this old dam without difficulty."

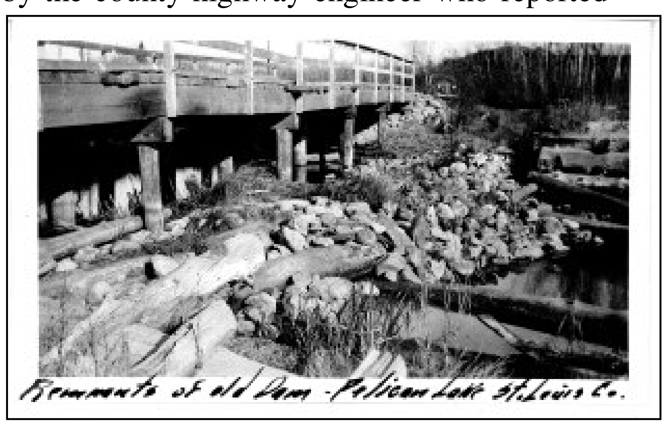

Figure 1. Original rock and brush dam

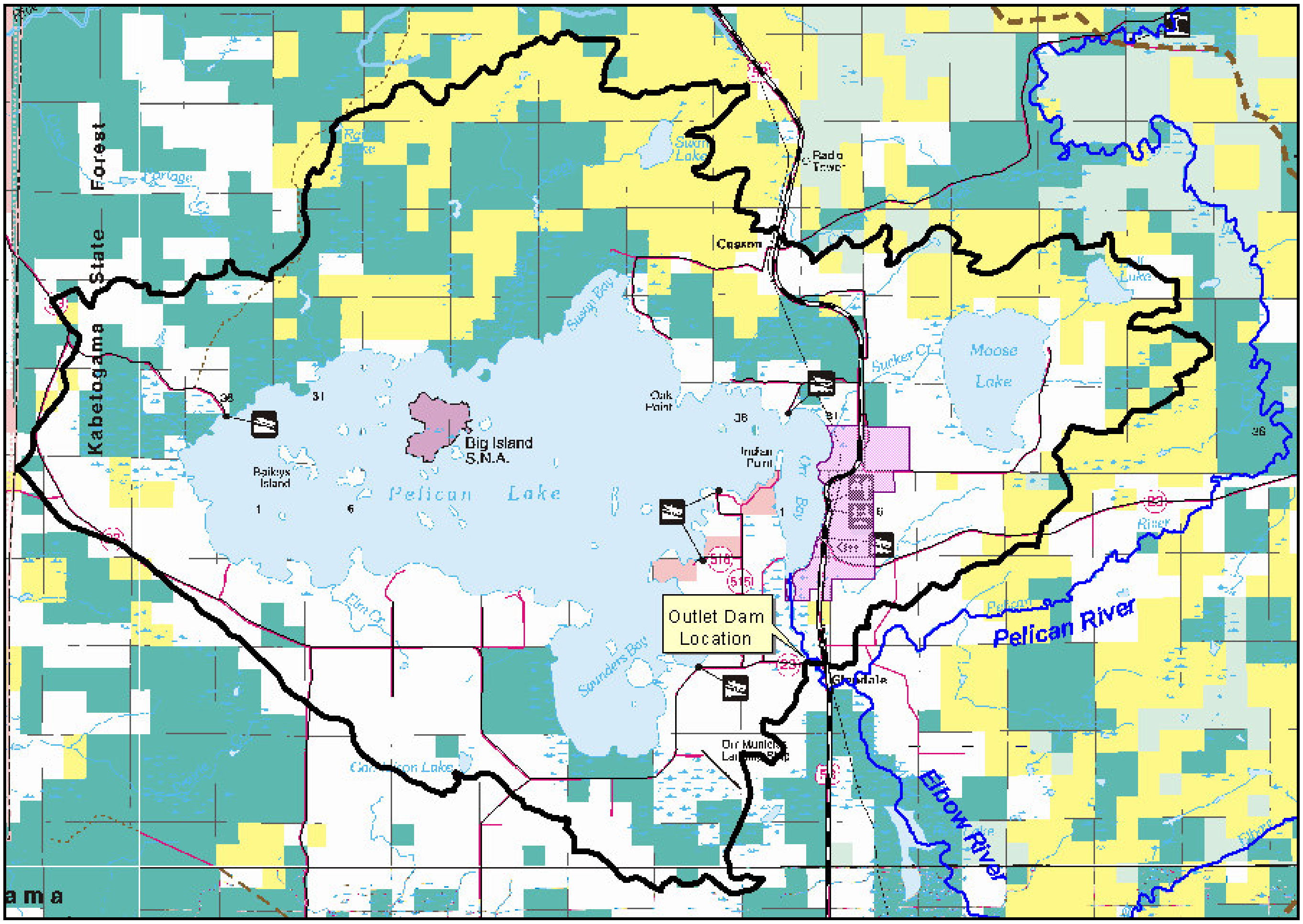

Figure 2. Pelican Lake watershed

Numerous lakes throughout Minnesota had fallen to very low levels as a result of the 1930s drought. During the late-1930s, the Works Progress Administration constructed over 300 dams in Minnesota, including one at Pelican Lake (completed in 1938). These dams were constructed and largely paid for by the WPA with a state/local cost-share. Once completed, ownership of the dams was transferred to the state of Minnesota - then the Department of Conservation (DOC), now the DNR. Easements were obtained for construction and access to the structure; flowage easements were not obtained.

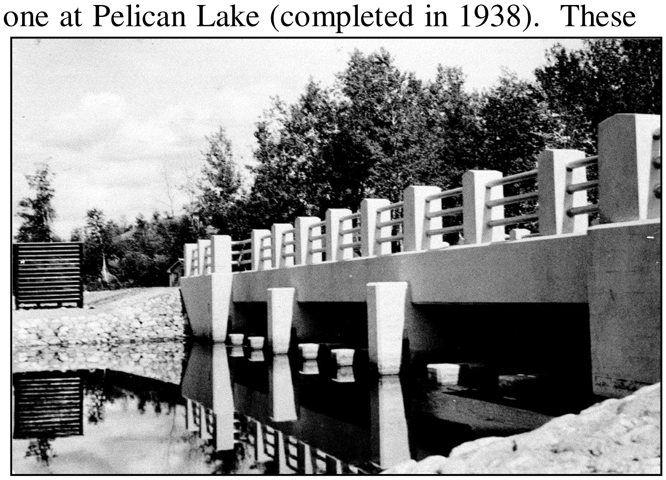

Figure 3. Pelican Lake dam shortly after construction

The general design philosophy for these structures was to restore, and then maintain "normal" lake levels throughout the summer months. The outlet streams were intended to function in a "state of nature" during high flows, i.e., the dam would have no impact on lake levels.

Most of the WPA dams consisted of one or more stop log bays; the Pelican Lake dam was constructed with nine - five foot wide bays. The number of stop log bays in any given dam was generally based on the size of the lake and respective watershed. A local operator was hired to add and remove stop logs from the dam to maintain "desirable" levels, and record the actual lake levels.

The concept of adding and removing stop logs to maintain desired lake levels works better in theory, than practice. Climate conditions are the predominant factor affecting lake levels. Unless the dam operator can control the amount and timing of precipitation, it's generally not possible to maintain a given level, much less a level that all affected parties agree is appropriate. Perhaps due to Murphy's Law and/or bad luck, heavy snowfall and spring rains fell in 1938. There were complaints regarding high lake levels within one week of the completion of the Pelican Lake dam. During the next several years the dam operator frequently reported that there were missing and broken stop logs, and that unauthorized tampering of the dam had occurred. The same issues and complaints were common on most of the other 300 plus lakes with newly constructed WPA dams.

A hearing before the Deputy Commissioner of Conservation was held in December 1944 to determine a natural ordinary high water level (NOHW) of Pelican Lake, and to determine a summer control elevation. As a result of the hearing, the DOC set the NOHW at an elevation equivalent to a lake gage reading of 4.6 feet, and the summer control elevation at 3.4 feet gage height. The dam operator was instructed to remove sufficient stop logs to lower and maintain a lake level of 3.4 on the lake gage.

Disputes regarding lake levels continued. The decision was made by the DOC to eliminate operation of the WPA dams. On October 2, 1946, the stop logs were fitted and wedged to an elevation of 3.4 feet gage height in the Pelican Lake dam; no further manipulation of the dam was authorized. In March of 1948, the shorter intermediate piers were cut down to the same 3.4-foot gage height to increase the hydraulic capacity of the dam and to facilitate passage of floating bog and debris. The wood stop logs were also replaced with concrete planks.

DNR staff has periodically inspected the Pelican Lake dam since that time; the stop logs have occasionally been adjusted to restore the authorized 3.4-foot setting. There have been periodic complaints regarding low lake level, but no documented high water complaints in recent years.

St. Louis County reconstructed the dam in 2002 as part of project to improve County Highway 23. The existing dam/bridge was replaced with 3 culverts and an integral weir in the upstream end of the culverts (see cover photograph). The design called for the top of the center weir to be constructed to the authorized runout elevation (1287.3) with the weirs in outer two bays 0.1 foot higher. A 10-inch by 12-inch slot was incorporated into the center weir to replicate leakage in the old dam and thereby maintain water supply to the downstream channel. This slot also facilitates fish movement between Pelican Lake and the Pelican River.

There have been numerous recent complaints from lakeshore owners regarding low lake levels. A DNR survey crew established that the weir was 0.08 feet below the design elevation on May 28, 2003. St. Louis County resurveyed the dam in 2007 and found that the top of the weir was 0.15 feet below the plan elevation. The county and DNR have agreed to restore the weir to the original design elevation, or some variation thereof. The majority of lakeshore owners seek to have the weir established at an elevation higher than designed to help minimize low summer lake levels.

A limited hydrologic study/report of the outlet dam was completed in October 2007. This report contained minimal discussion and did not address key concerns of lakeshore owners. DNR wildlife biologists have also raised concerns regarding potential negative impacts to natural resource values of the lake, in particular to wild rice. These concerns prompted the additional technical evaluation of the outlet dam and this expanded report.

Recorded Lake Level & Climate Data

The first step is to examine the available recorded lake level and climate data. Fortunately we have a good record of lake levels for two time periods: 1938 through 1947 and 1982 through the present. Figure 4a is a plot of all available lake level readings for Pelican Lake; Figures 4b and 4c show expanded views of the data collected since 1982. (Recorded lake level data are available for download using the "lake finder" option from the DNR website: http://www.dnr.state.mn.us/lakefind/index.html.)

The total range of recorded lake levels is three feet, but most years the lake level fluctuation is on the order of one foot. These data suggest that Pelican Lake fluctuated more while the dam was operated (1938 – 1946) than during the past 20 years with a fixed crest dam. This is likely due to a more complete record of lake levels as well as weather patterns during the earlier time period. Nevertheless this record does suggest that manipulating of a lake outlet does not guarantee stable lake levels.

The highest recorded lake level was from June 1944 (1289.7), in part caused by bog and debris blocking the outlet dam and downstream river channel. There was a second highwater period in August of 1944 with a peak recorded elevation of 1289.6. A field survey conducted in September 1944 found general highwater conditions throughout the area with the Pelican River free flowing for 6 miles to a downstream set of rapids, i.e., the highwater was not the result of debris blockage. It was concluded at that time that high flows on the Elbow River were contributing to the high levels on Pelican Lake.

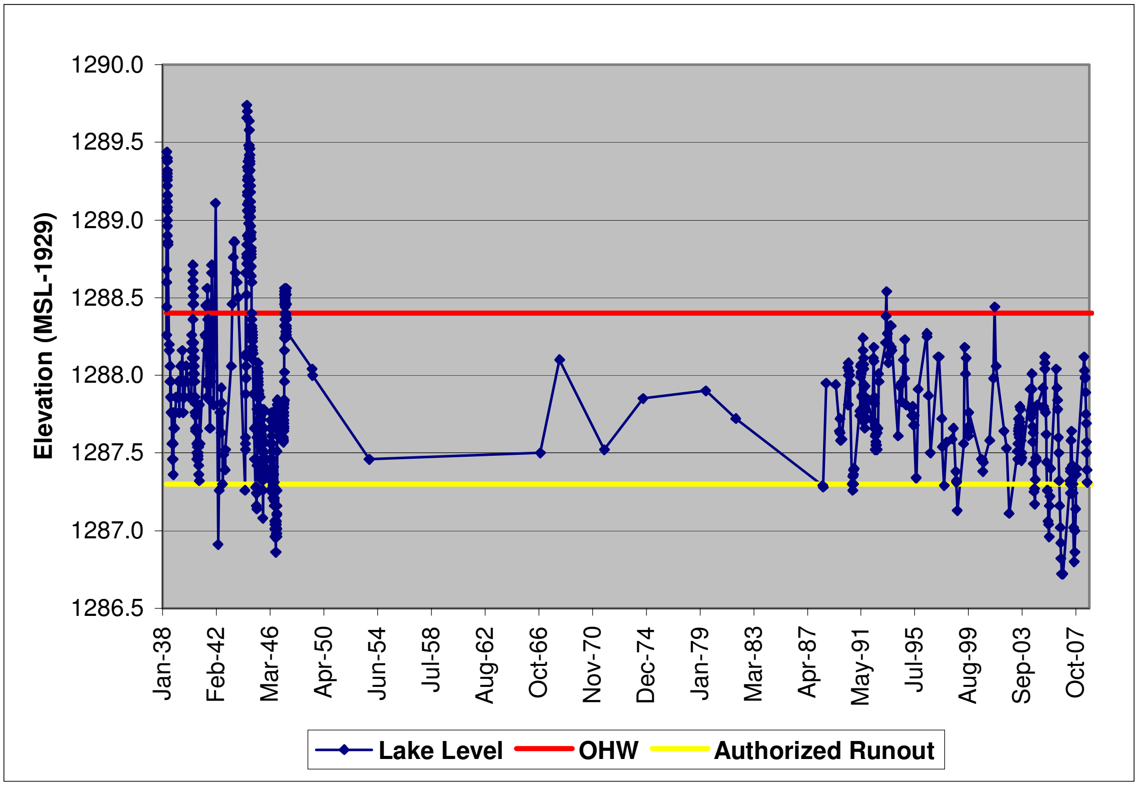

Figure 4a. Pelican Lake recorded lake level data (1938 – 2008)

Figure 4b is a plot of the available recorded lake levels for the last twenty years. During this period there have been no significant recorded high water events. The lowest recorded levels since 1938 occurred during the summers of 2006 and 2007.

This more focused view of lake levels provides a better picture of the yearly fluctuation of Pelican Lake – generally 1 to 1.5 feet. Lake level bounce following a specific snowmelt or heavy rainfall event has generally been less than 1 foot, as would be expected due to the small watershed to lake area ratio. Lake levels have exceeded the OHW at least twice during this time, spring 1993 and summer 2001.

The final lake level plot (Figure 4c) is included to illustrate the seasonal water level trend of most all Minnesota lakes and wetlands. The generally large volume of runoff from snowmelt and spring rainfall fills the basin, with the highest yearly lake level often occurring in April or May. During the summer months, lake levels fall as evaporation often far exceeds direct rainfall and runoff to the lake. The summer decline can be temporarily reversed following heavier summer rainfall, such as occurred in June 2004 and June 2005. No such temporary reversal is evident during the summers of 2006 through 2008. The summer decline is slowed and often reversed during the fall, due largely to lower evaporation rates and autumn rainfall.

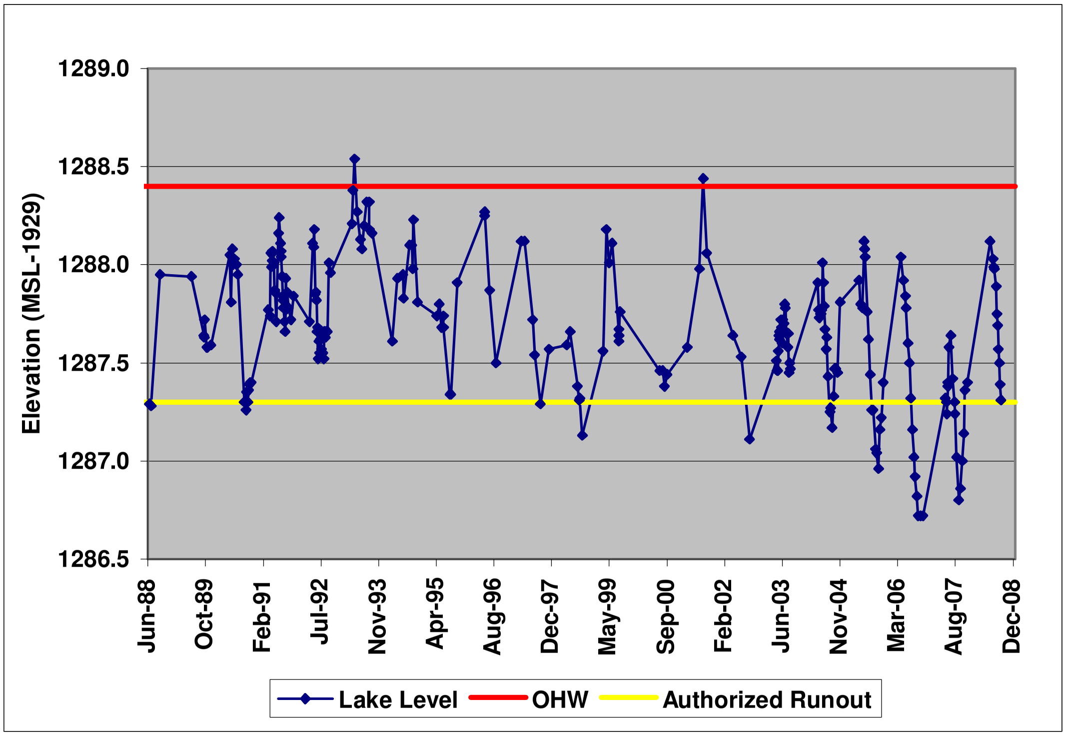

Figure 4b. Pelican Lake recorded lake levels (1988 – 2008)

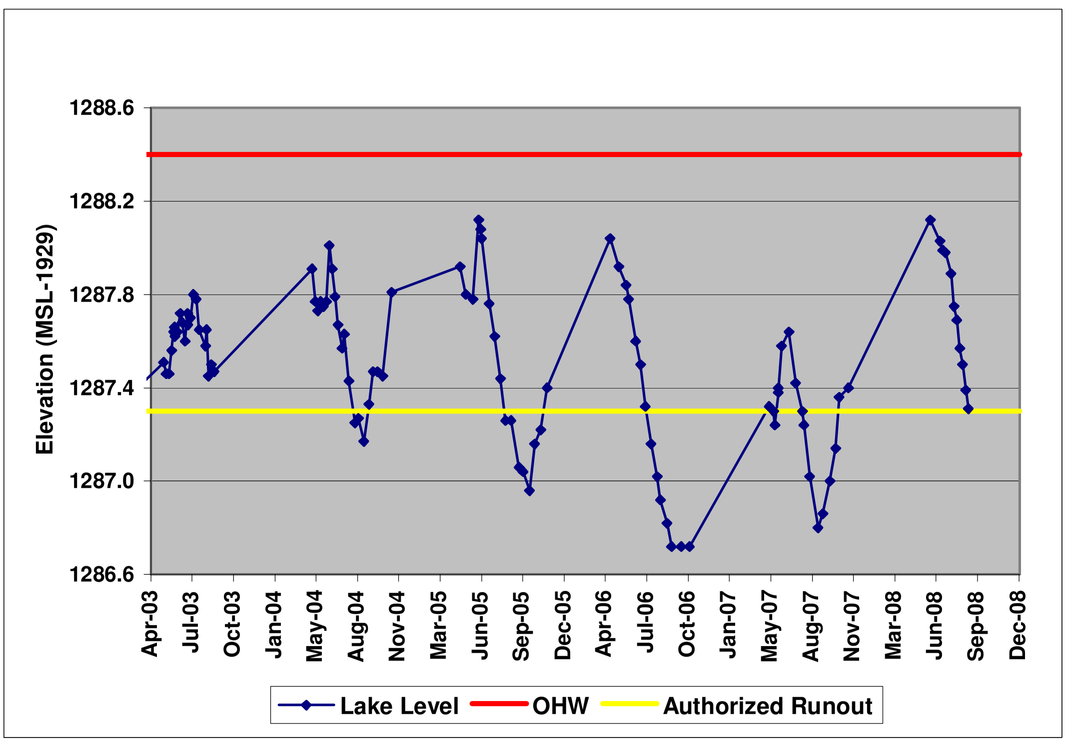

Figure 4c. Pelican Lake recorded lake levels (2003 – 2008)

Data available from the state climatology office (http://www.climate.umn.edu/) provides a perspective on the role that climate, primarily precipitation patterns, may have had on recent lake levels. Pecipitation data for the Pelican Lake area are presented in Figures 5a and 5b.

As expected, annual precipitation totals (Figure 5a) are highly variable, ranging from 18 to 37 inches per year during the past four decades. The very low precipitation total for 2006 helps explain low lake levels that year; but annual precipitation for 2005 and 2007 was near normal. Yearly precipitation totals provide a reasonable indicator, but the distribution of the rainfall/snowmelt within any given year is also important.

Figure 5b shows summer rainfall totals that - also highly variable from year to year. Of particular interest is that summer rainfall during the past several years has been well below normal. There has been no comparable period during the past four decades in which so many consecutive years have been below normal. Near normal annual precipitation, along with below-normal summer totals is the key factor in the record low lake levels of the last few years.

It is of course not known whether this weather pattern will persist, whether it's a product of climate change or just an anomaly, or whether it's another example of Murphy's Law (in contrast to 1938, well-below normal rainfall following construction of a new dam).

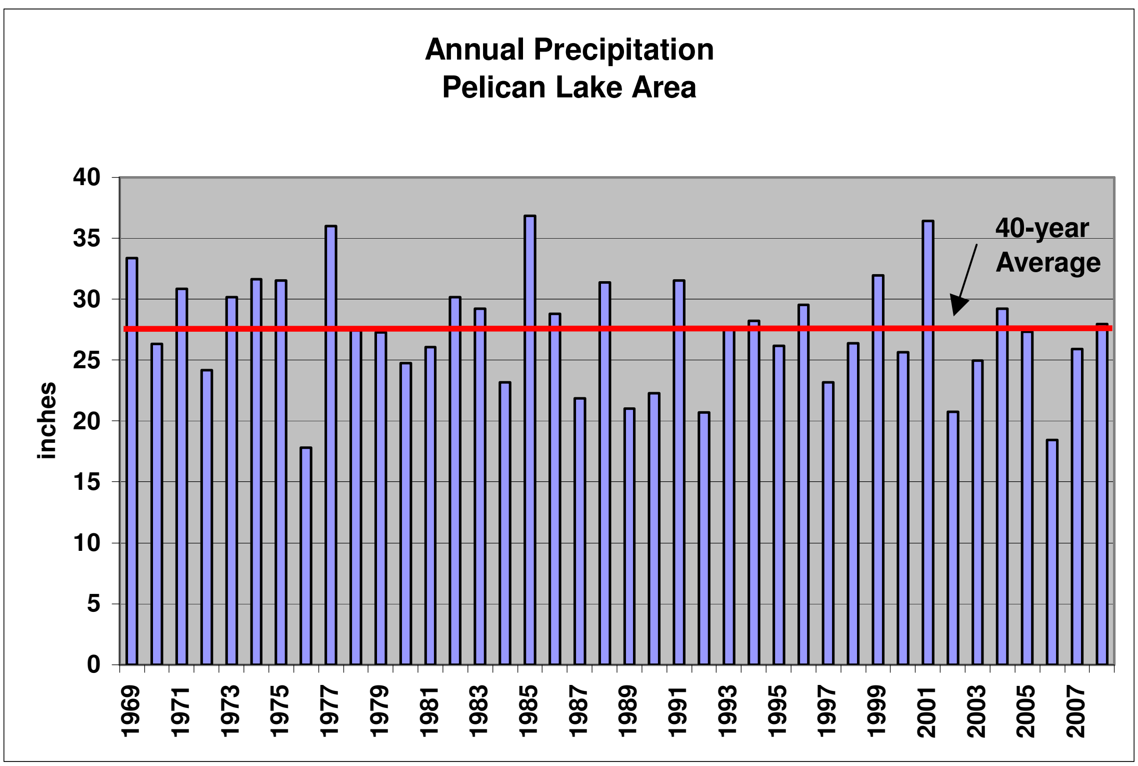

Figure 5a. Annual Precipitation – Pelican Lake area (1969 – 2008)

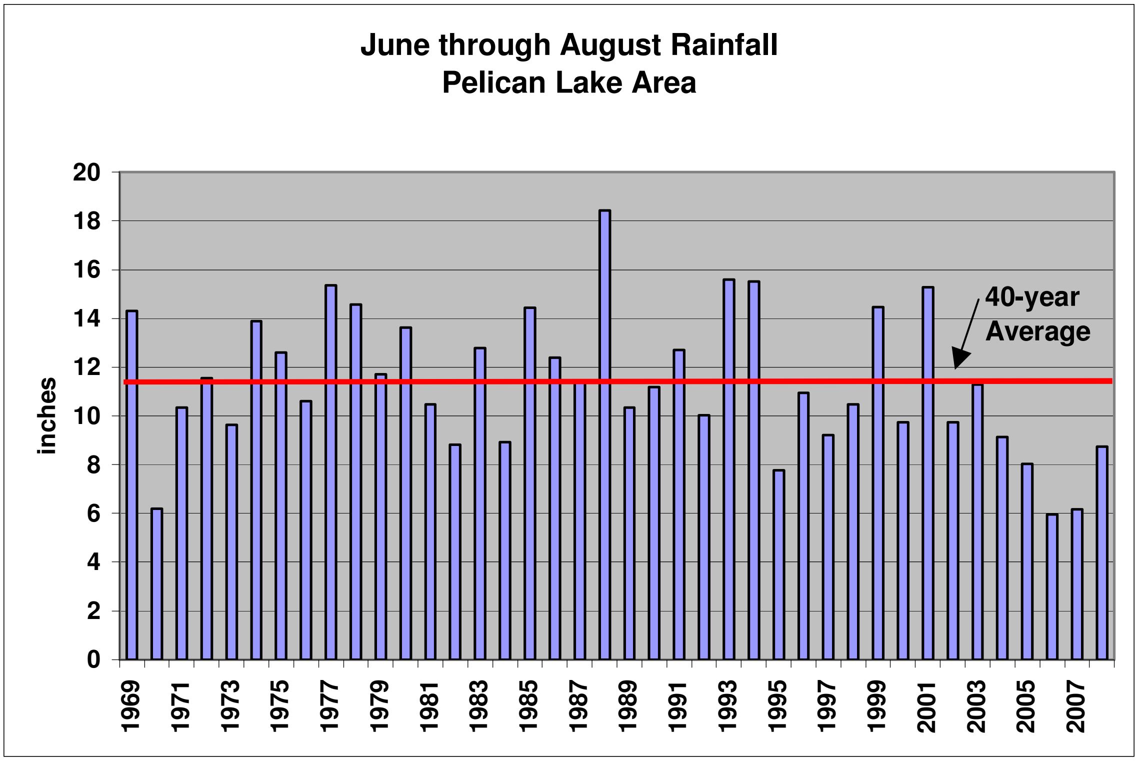

Figure 5b. June through August rainfall – Pelican Lake area (1969 through 2008)

Considerations regarding outlet dam modifications

Changing the elevation of a lake outlet dam can have unintended consequences. State statute and rules require careful consideration and engineering analysis of the potential impacts of future dam modifications. This assessment must take a long-term view of the impact throughout the full range of possible climate conditions, consider the interests of all affected parties, and evaluate the impact to the natural environment.

Recreation – a frequent concern of lakeshore owners is in regard to shallow near-shore water depths that hinder boat access. Maintaining stable late-summer lake levels is seen as a better option then repositioning or extending a dock. Navigation may also be an issue of concern for recreational users of a lake.

Flooding - Raising a dam to enhance the recreational use of a lake has the potential to increase the flood risk. In addition, higher "normal" levels can affect the use of low lying lands around a lake.

The Federal Emergency Management Agency regulations would not allow an increase to an established 100-year flood level on a lake or stream of more than 0.01 feet, if that higher flood level would increase the flood damage potential. FEMA has not established a regulatory flood elevation for Pelican Lake. In similar situations, the DNR has taken a less stringent approach and implemented dam modifications such that the potential increase in the 100-year flood levels is less than or equal to 0.1 foot.

Wild Rice – A key concern of DNR biologists in regard to raising the outlet dam is the potential impact to existing stands of native wild rice on Pelican Lake. (Much of the following discussion is taken from a 2008 DNR report to the MN legislature titled *Natural Wild Rice in Minnesota* http://files.dnr.state.mn.us/fish_wildlife/legislativereports/20080215_wildricestudy.pdf).

Wild rice is a very important food source and provides habitat for fish and migrating and resident birds. It also provides a valuable water quality benefit by sequestering phosphorus and nitrogen from the water column.

Wild rice is a shallow water plant and therefore very sensitive to changes in water levels. Wild rice is known to grow well at depths of 0.5 to 3 feet of water; deeper water depths can stress the plants and limit seed production. Water levels that are relatively stable or decline gradually during the growing season are preferred. Although wild rice may occur in a variety of lake bottoms, the most consistently productive stands are those with soft, organic sediment. Natural wild rice is particularly susceptible to uprooting during its floating-leaf stage, which occurs in early summer. At this stage, any rapid increase in water level can cause damage to natural stands. Plants can be significantly stressed even when they remain rooted.

The 2008 DNR report indicates that there are 119 acres of native wild rice on Pelican Lake and the Pelican River. The two prominent stands on Pelican Lake are located in Saunders Bay and near the mouth of Swan Creek. Even though Pelican Lake has a large littoral zone, wild rice is not widely found elsewhere likely due to combination of water depth, substrate and fetch. Water depths at the Saunders Bay stand have been measure at 3.5 to 4 feet deep. Since wild rice is already growing in this lake beyond its normal depth range, DNR biologists are concerned that even small changes in water levels could have large impacts on the abundance of this plant in Pelican Lake.

Ordinary High Water level (OHW) – It's often very difficult to quantify the potential environment impacts of a proposed dam modification. The OHW is therefore often used as a surrogate metric for natural resource concerns. The often stated objective is that the OHW must not change as a result of a dam modification. A very practical consideration is that shoreland zoning standards are based on the OHW, in particular building setback requirements. If a future survey found a higher OHW elevation, then existing structures may no longer meet those requirements.

An OHW is determined by a field survey, so there are no analytical means to predict how the OHW may change over time following an outlet modification. Qualitatively we typically seek to maintain roughly the same frequency of occurrence and duration of each event of when a lake would equal and/or exceed its OHW.

Hydrologic Evaluation of Alternatives

Reviewing the available lake level and climate data is a very important first step when contemplating a dam modification. However these data by themselves do not provide a complete picture of all hydrologic factors affecting a lake. A technical evaluation is needed in order to gain a better understanding of the hydrologic system of a given lake/watershed, including the various components of the lake water budget. We can then hopefully do a better job predicting the potential impacts of alternative outlet configurations during a full range of climatic conditions.

Outlet Discharge Rating Curve

The rate of water flowing over a lake outlet dam at any given point in time is a function of the:

- height of the dam;
- lake level; and
- height of the water on the downstream side of the dam (hereafter termed "tailwater").

That third bullet – tailwater – is a very important component of this phase of the study. A primary reason why we have been able to modify other WPA-constructed dams is that during high flow conditions, high water levels in the downstream channel often submerge (is higher than) the outlet dam. When this happens, the height of the dam often has little impact on the rate of outflow. The downstream channel is said to "control" outflow from the lake. It becomes more likely that a portion of a dam can be raised to help maintain higher summer lake levels, without adversely affecting flood levels, if it can be demonstrated the downstream channel significantly affects outflow from the lake.

As discussed earlier in this report, historical data from the 1940s indicate that the Pelican River has affected outflow from Pelican Lake. However tailwater submergence has not been documented in recent years – suggesting a relatively rare occurrence for Pelican Lake.

Since there's limited recorded tailwater data, we must rely on computer modeling to help assess how often the Pelican Lake dam becomes submerged and the extent to which submergence will affect lake levels. The U.S. Army Corps of Engineers HEC-RAS (**H**ydrologic **E**ngineering **C**enter – **R**iver **A**nalysis **S**ystem) model was used to develop elevation-discharge relationships for the existing dam, the "as designed" dam, and several alternative dams. A DNR 1998 survey of the Pelican River from the dam to the downstream railroad bridge provided the primary data source for this model. DNR Waters staff also measured flow in the Pelican River immediately downstream of the dam on three occasions to help calibrate the HEC-RAS model.

Additional data in the Pelican Lake correspondence file, in particular same-day measurements of water levels on the up- and downstream sides of the dam, helped refine previous analyses. The majority of time, low tailwater conditions exist at the Pelican

Lake dam, i.e., outflow is not impacted (Figure 6a). Outflow rating curves were also developed assuming higher tailwater conditions (Figure 6b). Both sets of curves were used in the subsequent lake water budget analysis. Separate sets of curves were also developed based on whether the 10" x 12" slot in the center weir was assumed open or closed.

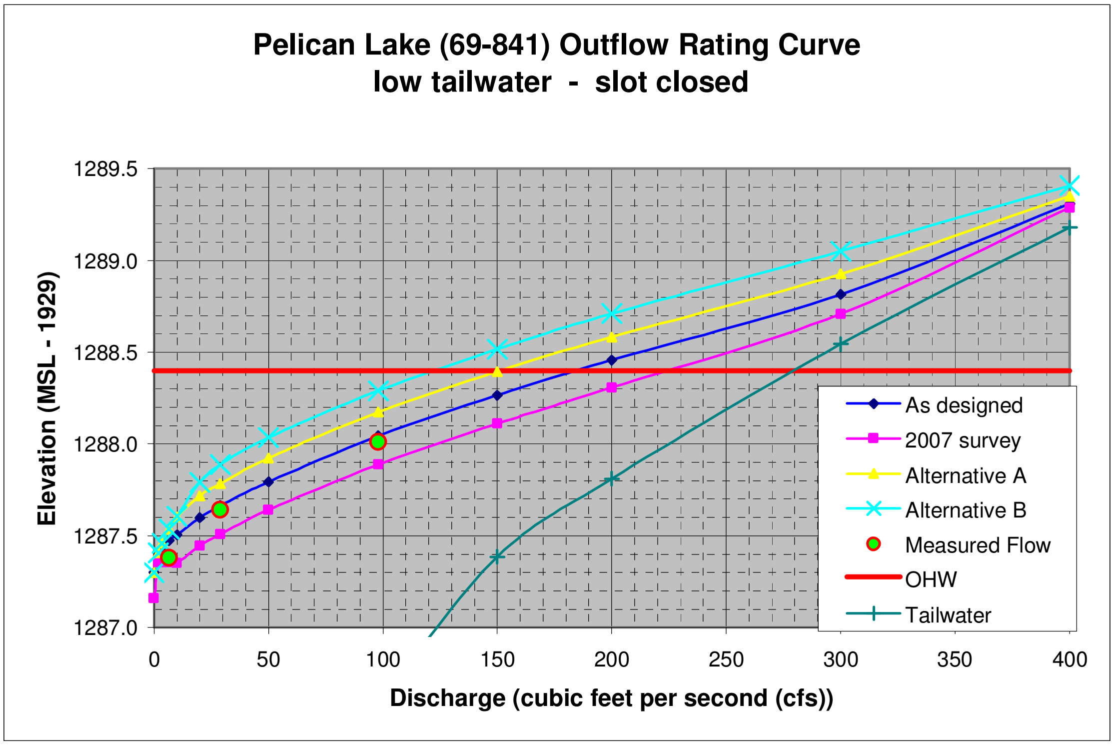

Figure 6a. Outflow rating curves – low tailwater conditions and slot assumed closed.

Description of Alternatives

Numerous potential dam configurations were evaluated as part of the October 2007 study. In that earlier study, Alternative B was found to be the maximum change possible without affecting the computed 100-year flood by more than 0.1 feet. Updated outflow rating curves were developed for four different dam configurations:

1. New Dam - As Designed
2. New Dam – as surveyed in 2007
3. Alternative A – outer two weirs raised 0.2 feet above the "as designed" dam
4. Alternative B – outer two weirs raised 0.4 feet above the "as designed" dam.

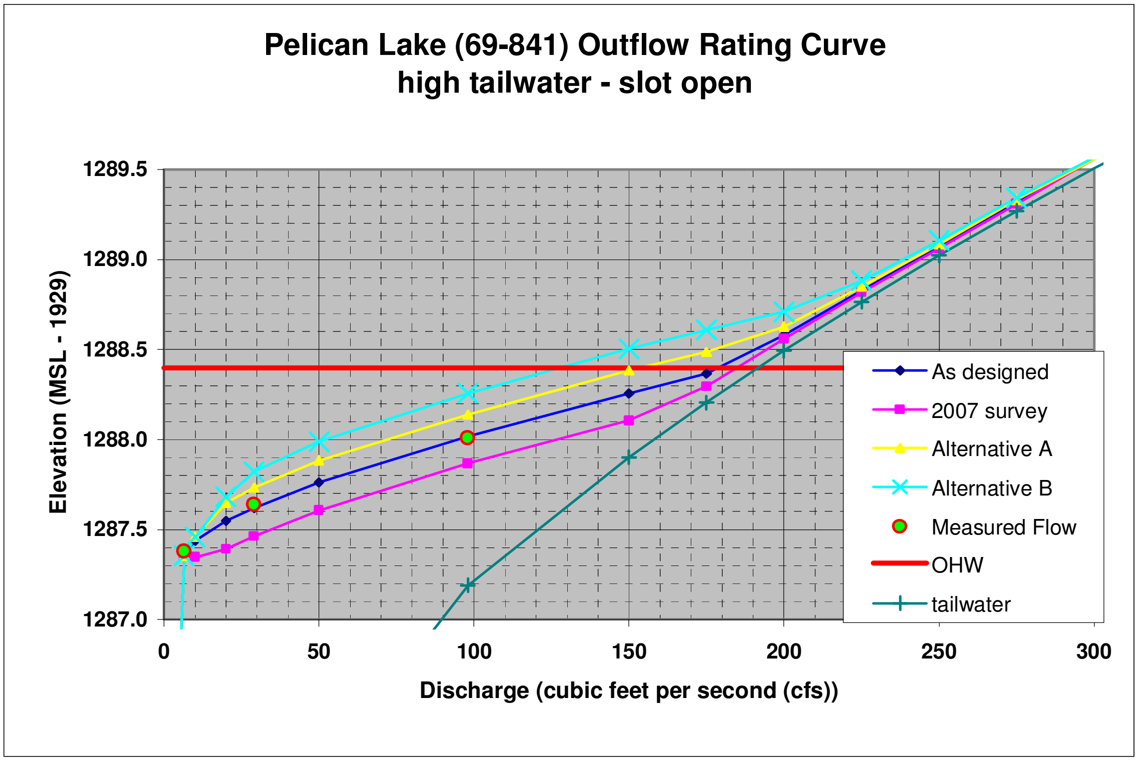

Figure 6b. Outflow rating curves – high tailwater conditions and slot assumed open

Pelican Lake Water Budget

A water budget was computed for Pelican Lake using a program developed by DNR Waters – WATBUD. WATBUD (a contraction for WATer BUDget) is a physically-based parameter model capable of optimizing and estimating selected water balance parameters, such as snowmelt, surface runoff, evaporation, and interchange with the ground water, by comparing computed lake levels to recorded lake levels. This model has been used in numerous studies to help identify causes of lake level fluctuation, whether natural or artificial, and in quantifying water balance components for use in water quality/quantity models. Additional information regarding WATBUD may be found at: http://climate.umn.edu/tools/wb.htm.

The primary input data include:

- Climate: historic daily precipitation and minimum/maximum temperatures for selected time periods. Temperature data are used in the calculation of lake evaporation, and also in the snow accumulation and melt computations.
- Watershed area: used to estimate the amount of runoff reaching the lake for a given amount of rainfall;
- Lake area: used in determining the volume of rain falling directly on the lake surface, and the volume of water evaporating off of the lake;
- Lake level – outflow relationship: (discussed above); and
- Recorded lake level data: used for model calibration.

Computations for evaporation, watershed runoff amounts, and flow over a dam can be readily accomplished using commonly used equations and parameters. There are no readily available methods to directly compute, nor measure, the interchange of ground water with the lake. The WATBUD model optimizes a net groundwater interchange parameter by comparing the computed lake levels with the recorded lake levels.

The WATBUD model was first calibrated to the recent period of 2005 through 2008. The outlet rating curve for the calibration run was based on the dam as surveyed by St. Louis County in 2007. It was assumed that the low-flow slot was blocked, as has been typically observed by DNR field staff.

The WATBUD model calibration process resulted in a reasonably good match between the computed and recorded lake level data (Figure 7). While the model does not perfectly replicate every small lake level fluctuation, it does a very good job of matching the overall lake level trend during the last four years.

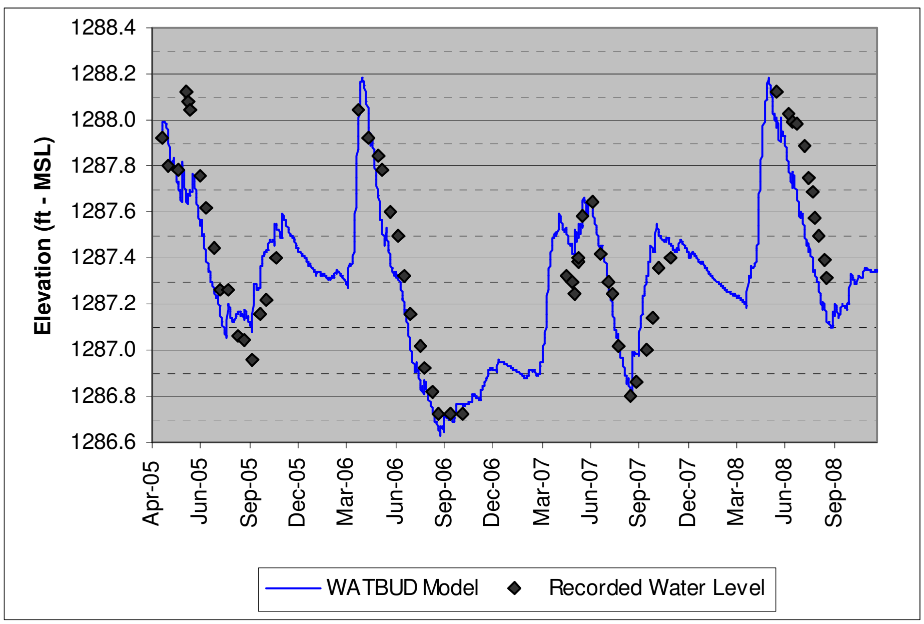

Figure 7. WATBUD model calibration results (April 2005 through November 2008)

One of the findings of the calibration process was that during the relatively dry climatic conditions of this simulation period, there was essentially no <u>net</u> ground water effect on Pelican Lake. That is, the ground water discharge to Pelican Lake was essentially the same as the water in Pelican Lake recharging (outflow) the groundwater aquifer.

Figure 8 shows the computed monthly volumes of the key water budget components for two months. The April 2006 values show the result of a typical spring runoff event. Watershed runoff from snowmelt and early season rainfall far exceeds the other components. The net spring inputs are greater than the outflows resulting in a higher lake level at the end of the month, than the beginning of the month.

July 2006 was very dry; evaporation becomes the predominant component of the water budget for Pelican Lake. During July 2006 there was still a trickle of water flowing over the dam, but that volume of water was negligible compared to the amount of water lost to evaporation.

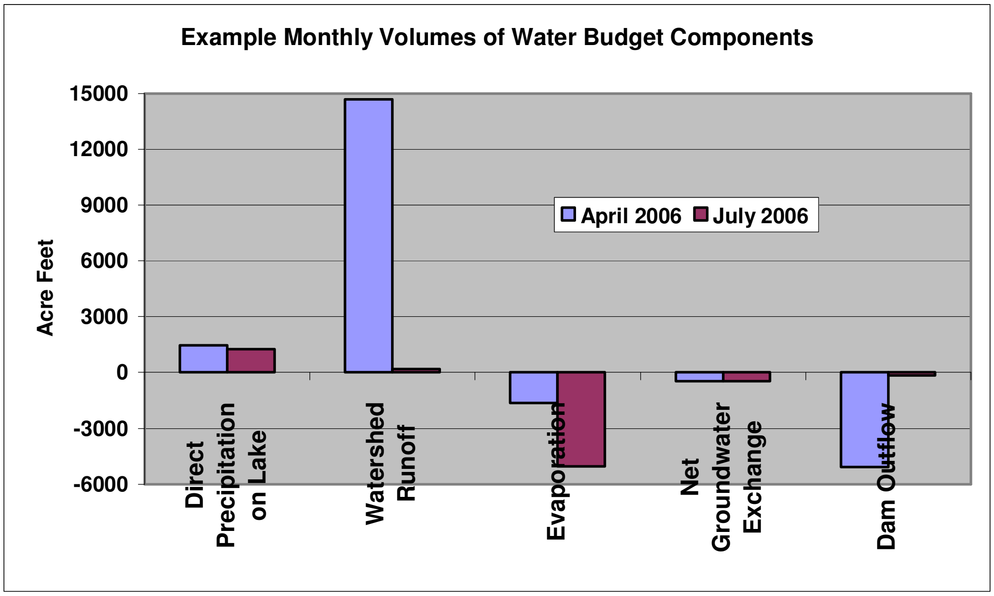

Figure 8. Pelican Lake water budget components for two selected months. (Note: 3,000 acre feet is roughly equivalent to a volume of three inches of water on Pelican Lake.)

The calibrated WATBUD model was rerun for the same time period using the outflow rating curves for the other dam configurations. The resulting lake level hydrographs are shown in Figure 9. Had the "as designed" dam been in place during the last four years, Pelican Lake would have been approximately 0.15 feet higher than what actually occurred. Alternatives A and B would have raised lake levels an additional 0.1 and 0.2 feet, respectively. The same relative difference in lake levels would have occurred throughout the year – spring, summer, fall and winter.

During dry summers, lake levels would potentially fall below their respective runout elevations with any of the dam configurations. But as a portion of the dam is raised and the difference between the elevation of the outside weirs and the center weir becomes greater, the number of "zero flow" days is reduced (assuming the low flow slot is blocked). This is illustrated by looking at the computed results for the summer of 2007.

WATBUD Model Results for 2007

	2007 Dam	As designed	Alt. A	Alt. B
Runout Elevation	1287.16	1287.3	1287.3	1287.3
Day runout reached				
(declining lake levels)	Aug. 1	Aug. 2	Aug. 12	Aug. 19
(rising lake levels)	Sept. 25	Sept. 22	Sept. 18	Sept. 7
Number of zero flow days (assuming slot is closed)	55	51	37	19

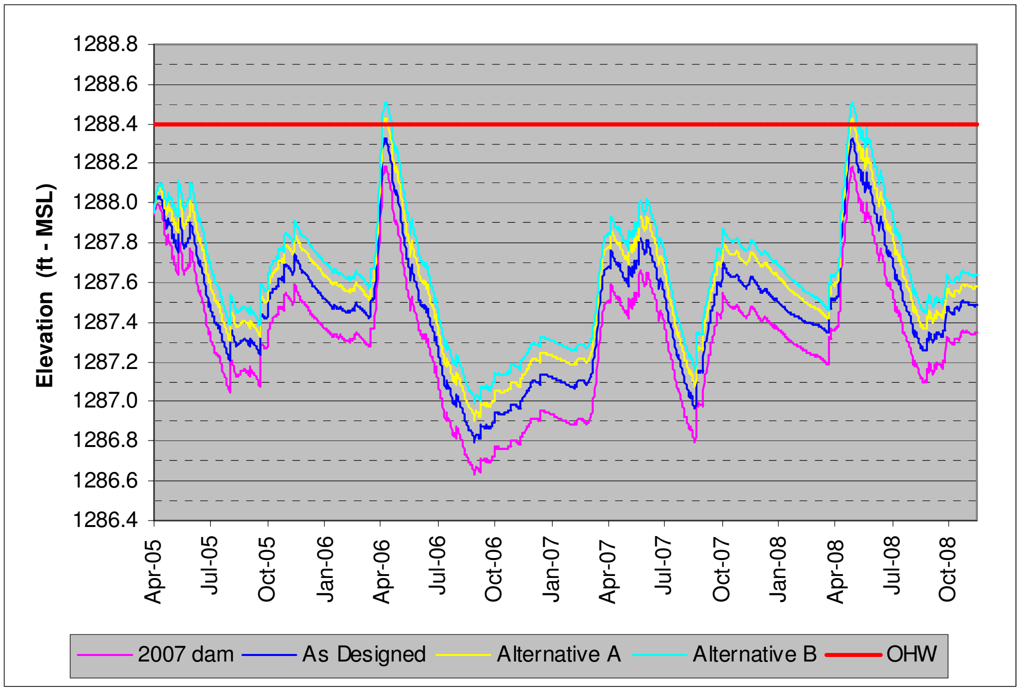

Figure 9. WATBUD model results: comparison of computed lake levels for outlet dam alternatives (2005 – 2008).

The same exercise was completed for wetter climatic conditions (fall 1999 through summer 2002) using the outflow rating curves assuming higher tailwater conditions. Once again, the calibration results were reasonably good (Figure 10). Only minor adjustments were made to the input parameters during the calibration process. One difference is that model results suggest that there was a small net positive groundwater contribution to the lake during this wetter period.

In order to simulate a severe flood event, two 25-year summer storms (4.1 inches each), three days apart, were added to the July 1999 climate record. The peak level reached is approximately the same as the computed 100-yr flood using a standard engineering design storm for the October 2007 report. Results are shown in Figure 11 and the following table.

	July 1999			Spring 2001		
	As Designed	Alt. A	Alt. B	As Designed	Alt. A	Alt. B
Lake level at start of heavy runoff	1287.75	1287.89	1287.98	1287.49	1287.62	1287.68
Peak lake level	1289.19	1289.29	1289.36	1288.64	1288.76	1288.84
Lake Level "Bounce" (ft)	1.44	1.40	1.38	1.15	1.14	1.16
Number of days @ or above the OHW	61	79	85	34	48	63

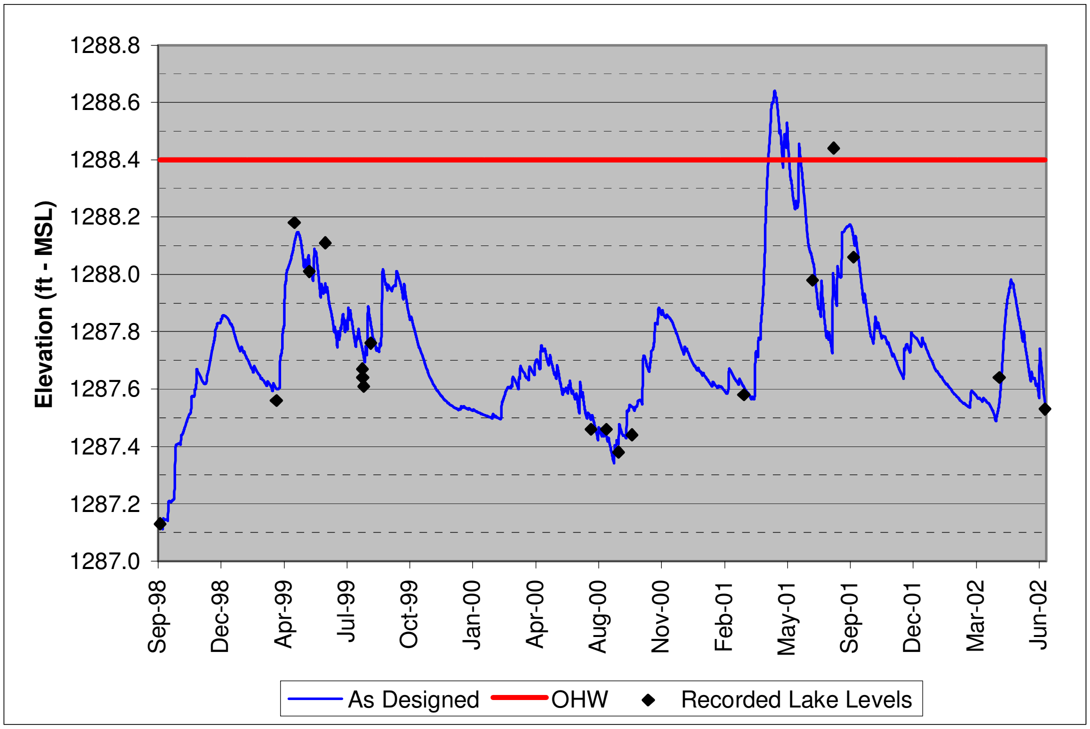

Figure 10. WATBUD model calibration results (September 1998 through June 2002).

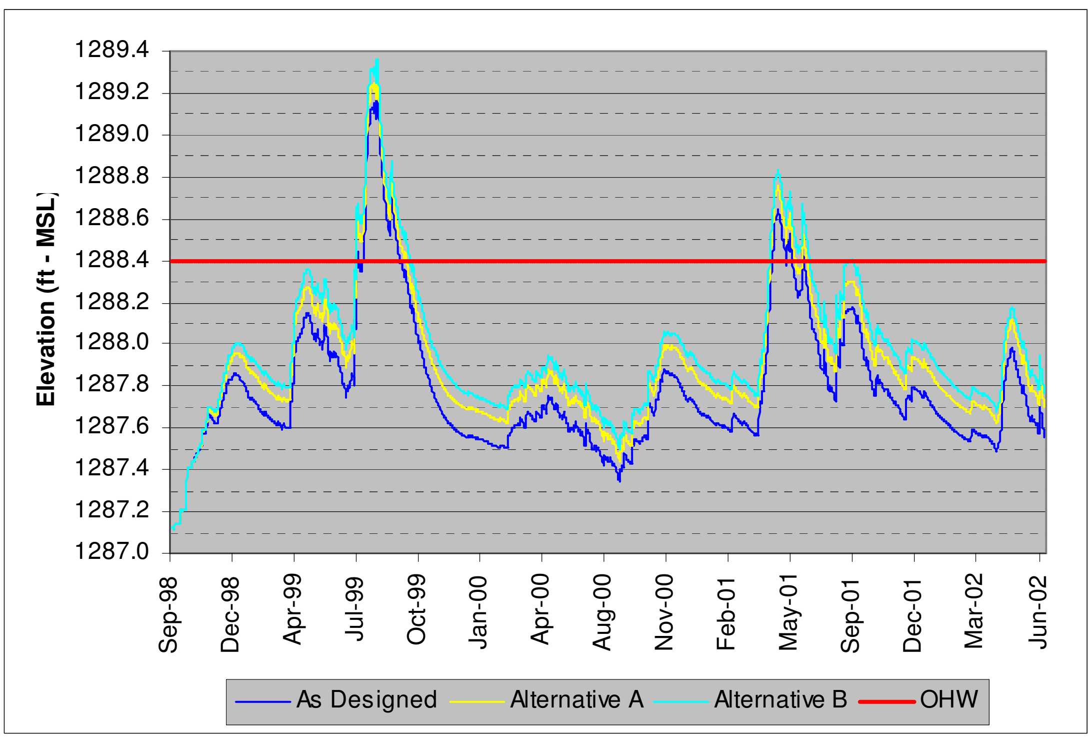

Figure 11. WATBUD model results: comparison of computed lake levels for outlet dam alternatives (1998 – 2002). Heavy rainfall added during July 1999 to simulate a severe flood event.

Impact of the low flow slot

The rate of flow through the low flow slot is primarily dependent on the difference between the water levels immediately upstream and downstream of the dam. The maximum flow out of the slot, occurring during lower lake level conditions, is approximately six cubic feet per second (cfs). This flow rate is equivalent to a volume of 12 acre feet of water per day, or 0.012 inches off of the lake each day. During higher lake levels conditions, the rate of flow out of slot is one to two cfs.

The impact of the slot on lake levels was evaluated using the WATBUD model for the 2005 through 2008 time period (Figure 12). The slot does have an impact on lake levels – yearly average of 0.12 feet, half that amount during the summer months. The impact of slot is not additive, i.e., it's not one inch the first year, two inches the second year, etc. The impact of the slot is largely negated during periods of heavier runoff.

Figure 12. WATBUD model results: computed lake levels for the 2007 dam assuming either the slot was closed or open throughout the simulation period.

A primary objective of the low flow slot is to provide an opportunity for fish movement across the dam for nearly all flow conditions. If the slot is plugged then that objective is obviously not achieved. There are other alternatives to promote fish migration. One option is evaluated in Appendix C. This alternative would not address the second objective of the low flow slot, namely maintaining a small rate of flow to the Pelican River during low lake levels.

Conclusions

Overall climate trends and specific weather patterns and events are the primary factors affecting levels on Pelican Lake. Lower than normal summer rainfall amounts were the leading cause of recent low late-summer lake levels.

The height of the new outlet dam is a much lesser, but still contributing factor to the lower than normal recent lake levels. With the same climate conditions during the past several years, the "as designed" dam would have resulted in lake levels being 0.15 feet - almost two inches – higher what actually occurred.

It is not possible to say what effect the low flow slot had on the recent low lake levels since it's not known how often, and when the slot was blocked by a piece of plywood. But apples-to-apples comparison indicates that an open slot would reduce lake levels by as much as one inch. Permanently closing slot would eliminate flow to the upper reach of the Pelican River during extended dry conditions.

Raising the Pelican Lake dam would affect long-term lake levels. Higher lake levels would occur throughout the year, and during all climatic conditions. It is not possible with a fixed-crest dam to only impact low lake levels on Pelican Lake without also affecting higher levels.

Raising the dam higher than the design elevation will not result in higher lake level "bounce" resulting from a particular rainfall or snowmelt event.

Either Alternatives A or B would supply slightly more flow to the downstream channel during an extended dry period as the number of zero flow days (assuming the low flow slot is blocked) would be less than the as designed dam.

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Appendix A: Definitions and Acronyms

All elevation data in this report are measured in feet above mean sea level, using the National Geodetic Vertical Datum, 1929 adjustment. Add 1.01 to these elevations to convert to NAVD-1988.

CFS: measure of flow in cubic feet per second

DOC: Department of Conservation, predecessor to the Department of Natural Resources

FEMA: Federal Emergency Management Agency

MSL: Mean Sea Level

Murphy's Law: "If anything can go wrong, it will."

NOHW: Natural Ordinary High Water level – Estimated OHW prior to construction of a lake outlet dam.

OHW: Ordinary High Water level, defined as an elevation delineating the highest water level that has been maintained for a sufficient period of time to leave evidence upon the landscape, commonly the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial.

Runout: Low point on the crest of the weir. Elevation where water just starts flowing over the outlet dam

Tailwater: Water level on the downstream side of a dam.

WATBUD: Name of a lake water budget computer model developed by DNR Waters.

WPA: Works Progress Administration

Appendix B: Authorized Elevation of the Pelican Lake Dam – an annotated history

While preparing this report, the author identified that various numbers have been used over the last six decades to specify the authorized elevation of the Pelican Lake dam. A chronology of the known events, interpretations, recent surveys of the new dam and a recommendation follow.

1. The 1944 Commissioners Order specified that the summer control elevation, i.e, lake level, is to be equivalent to 3.4 feet gage height. The zero elevation of the gage then, and now remains 1283.86, so the control elevation in feet above mean sea level is determined as follows:

Gage "zero" =	1283.86
Gage reading =	+ 3.4

Summer control elevation =	1287.26

2. In 1946, the DOC issued an order to permanently fix the top of the stop logs to 3.4 ft gage height. Note the difference - the Commissioners' Order specified a water surface elevation, this order specified the top of stop logs.

3. A first reference to an authorized stop log setting of 3.5 feet gage height was found in correspondence from 1968. No justification for this change was found in the correspondence file. Both the 3.4 and 3.5-foot gage height references were used in subsequent correspondence.

4. The top of each stop log has been measured during periodic inspections of the Pelican Lake dam since 1946. The stop logs were typically at, or slightly higher than the 3.4 foot gage height. It's not practical to precisely set all stop logs to an exact elevation. These dam inspections generally seek to ensure that the stop logs within a couple of tenths of the authorized setting.

5. A DNR August 1998 survey found that the top of the nine stop logs in the old dam ranged from 1287.19 to 1287.50, with an average elevation of 1287.35.

6. Recent correspondence (including the 2007 hydrologic report) indicated an authorized runout of 1287.35. Presumably this number came from the 1998 survey report.

7. The construction plans for the new dam specific the dam runout (the top of the weir in the center culvert) = 1287.3. The design elevation of top of weir in the outside two culverts was 0.1 foot higher than the center weir. Establishing reasonable construction tolerances was the justification for rounding from hundreds to tenths of a foot.

8. On May 28, 2003, a DNR survey crew obtained as-built elevations of the new dam. The average elevation of five shots on the left, center and right (looking downstream) weirs was 1287.32, 1287.23, and 1287.32, respectively.

9. St. Louis County re-surveyed the new dam on July 20, 2007 and found the left, center and right weirs at 1287.25, 1287.16, and 1287.25, respectively.

10. **It is recommend that hereafter, 1287.3 be used as the authorized runout elevation for Pelican Lake.**

Appendix C: Fish Passage Option

A shorter weir was also constructed in the downstream end of the center culvert and designed to work in conjunction with the low flow slot in the Pelican Lake dam. The top of this downstream weir is at elevation 1285.2. The weir also includes a one-foot by one-foot notch, giving it a runout elevation of 1284.2. During low flow conditions, the downstream weir creates a deeper water pool having lower flow velocities within the center culvert to facilitate fish movement.

The following figures show computed water surface profiles over the as designed dam and through the new County Highway 23 center culvert. Figure C1 plots the model results that assume the low flow slot is open. Note that the lake level for the lowest modeled flow rate, 3.5 cubic feet per second (cfs), is near the top of the slot. That is, all of the flow is going through the slot. For flow rates at and above 6 cfs there is water flowing over the dam as well as through the slot. Also note that only for the lowest two flow rates, 3.5 and 6 cfs, is there a drop in water surface elevation across the downstream weir.

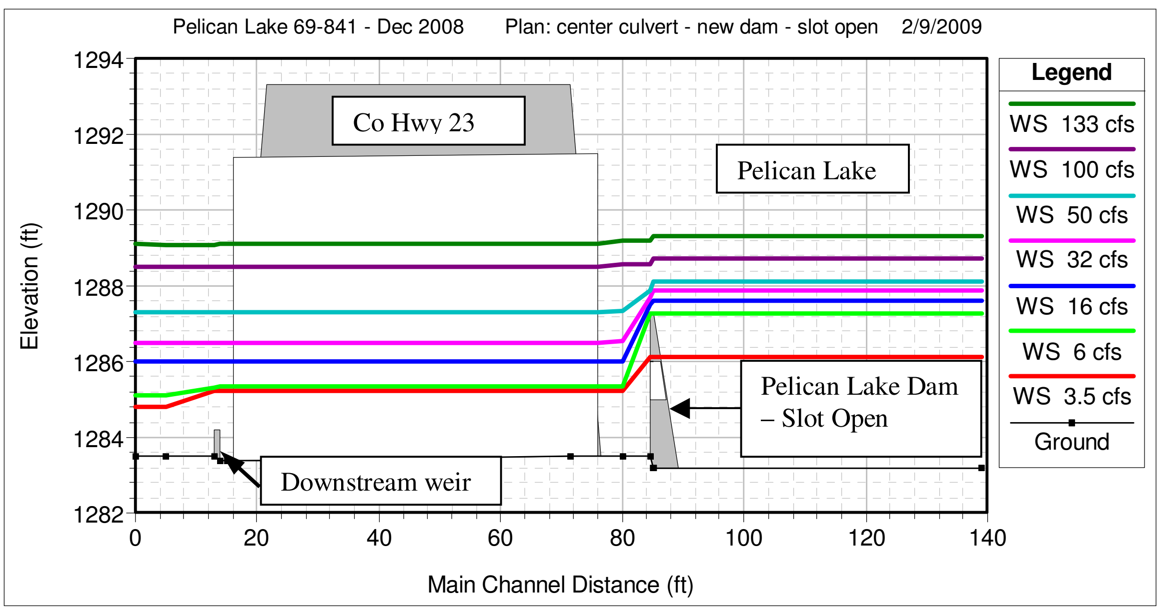

Figure C1. Computed water surface profiles for through the County Highway 23 center culvert for various flow rates assuming the low flow slot is **open**.

Figure C2 shows the computed water surface elevations with the as designed dam assuming the low flow slot is blocked. Note that the computed lake elevations for all flows rates are above the runout of the dam. The maximum difference in water surface elevation from the upstream to downstream side of the dam is over two feet.

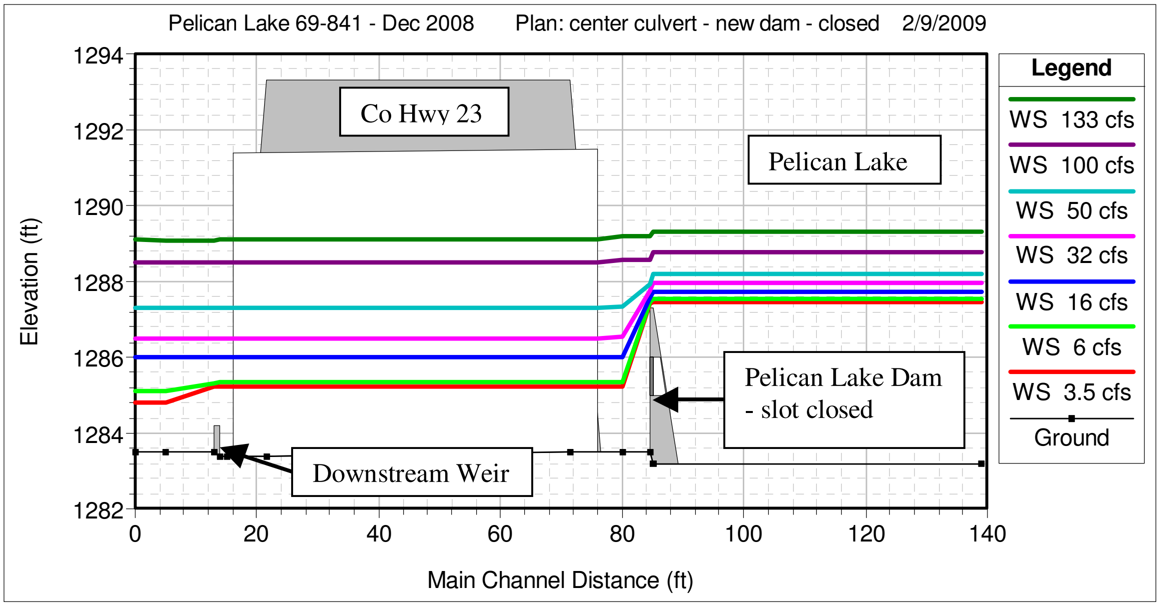

Figure C2. Computed water surface profiles for through County Highway 23 center culvert for various flow rates assuming the low flow slot is **closed**.

Figure C3 shows the effect of raising the downstream weir 0.6 feet and also eliminating the 1-foot by 1-foot notch. The intent of this possible change is to more evenly distribute the drop in water levels between the upstream dam and the shorter downstream weir. With a modest rise in the downstream weir there does not appear to be a reduction in flow capacity at higher flow rates. This alternative is not presented as a final design, but merely a suggestion that there may be other alternatives to provide for fish movement across this structure than the low flow slot.

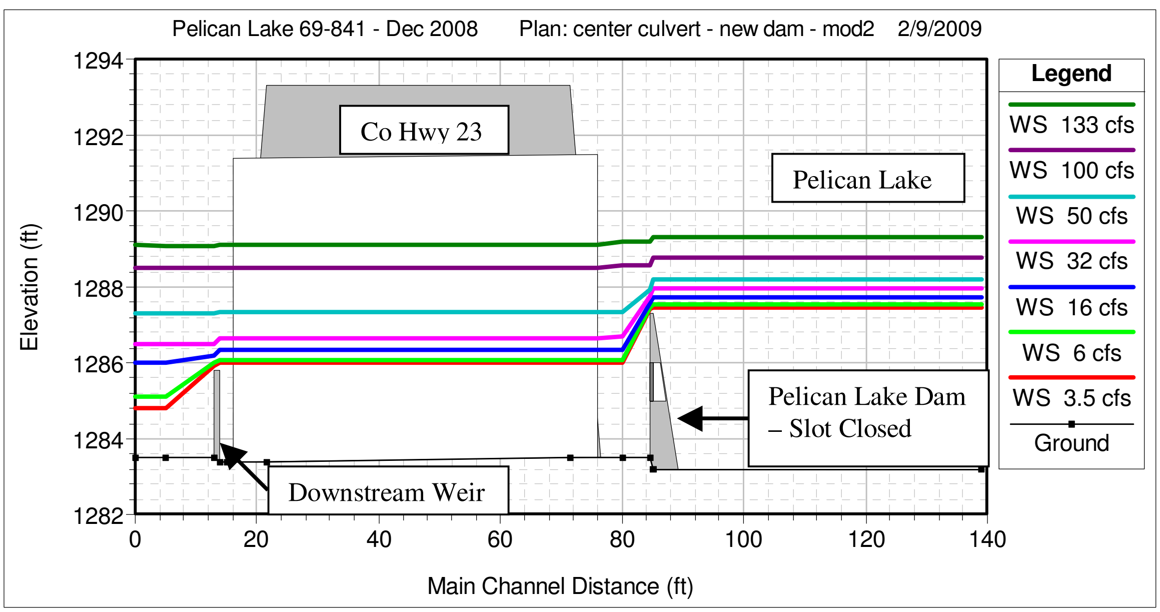

Figure C3. Computed water surface profiles through the County Highway 23 center culvert for various flow rates assuming the low flow slot is **closed,** and the downstream weir is raised 0.6 feet and the 1'x1' notch is eliminated.

Appendix D: Excerpts from DNR Waters St. Paul file on Pelican Lake

October 23, 1953	Wood stop logs replaced by concrete "logs" to an authorized height of 3.4 feet gage height.
March 29, 1954	DNR dam inspection report: "…conc. stop logs to top of piers in all bays."
April 9, 1963	Note regarding phone call w/ a shoreland owner: "Lake is 14 inches lower than usual… Biologist & Warden removed stop logs ….Want level higher."
August 28, 1963	Note regarding visit to dam: …bog and logs had floated into and hung up on the stop logs obstructing outflow. There was some overflow the water level was about 0.2' above the piers. A lift gate has been placed in the center bay. Logs in all bays to top of piers." *(Note: this was the first reference to a lift gate in the old dam. It was not installed by the DNR, nor was a permit ever found authorizing its construction. Presumably its purpose was to periodically draw down lake levels. The gate was removed in 1971.)*
February 22, 1966	Letter from the Orr-Pelican Lake Civic Club: "Our organization is interested in having marking buoys installed on our lake where navigational hazards exist, such as reefs, large rocks and similar hazards. Countless numbers of tourists staying at our resorts come to grief each summer running onto such objects, and whether the damage is to their equipment or that of the resort operators, the results are still unfortunate and unnecessary. An added complication, of course, is that in periods of high water on our lake, a boat can pass over a hidden rock or reef without notice, but when the water is low, these same rocks will ruin a motor."
March 24, 1966	Letter from the Orr-Pelican Lake Civic Club: "A high water condition on Pelican Lake is causing some concern among area residents. The lake has been unusually high all winter and if some action could be instituted within the next ten days serious flooding late in the spring might be avoided."
April 18, 1968	Memo in file regarding phone conversation with local resident who is "….concerned about the water level in Pelican Lake at Orr. He said that there are two planks missing in the dam at the outlet of the lake and for that reason the lake levels are down. He spoke about the legal lake elevation, but it was not clear to me whether this is being maintained now or not. If the lake is now at its legal elevation, it is nevertheless a foot or two lower than the people up there apparently want. I told him that we would check it out and do what should be done about the planks."

April 29, 1968	Letter from the Orr-Pelican Lake Civic Club: "Due to the increasingly serious problem of below normal precipitation and falling water levels in our area, our organization feels it desirous to have the dam at the Pelican River at Glendale maintained at the highest level possible."
May 8, 1968	DNR dam inspection report: "I checked dam and took picture, nothing was wrong, all stop logs in place, only bog on two bays and some wood." Stop log measurements: 3.7 feet gage height in all bays; lake gage reading = 4.24 ft.
February 4, 1969	Letter from the Orr-Pelican Lake Civic Club: "The members of this organization are understandably concerned about the high waters inevitable this coming spring…… We would appreciate the cooperation of your department in opening the dam at Pelican River at Glendale early enough to allow a runoff ahead of the usual time for this."
March 3, 1969	Memo in file authorizing the DNR Conservation Officer to gradually remove stop logs from the Pelican Lake dam.
July 14, 1969	Note in file regarding conversation with lakeshore owner: "He was in to speak for himself and the Pelican Lake Assoc. They would like to see no change in the setting of the stop logs in the dam except possibly to draw it down in the winter or early spring"
September 1971	Letter from the Orr Area Civic Club: "I am writing in regards to the dam in Pelican River, located at Glendale. It is in very bad disrepair, and needs extensive work done on it. Since it is a state owned and controlled dam, we feel that we should not have to maintain it. This past summer as well as a year ago, our lake was at a very low water level because of this."
October 6, 1971	DNR dam inspection report: "We put in $10^1/_2$ stop logs in different bays. Also the bay with lift out gate was broken and leaking very bad, because when open two years ago it wouldn't go back in stop log slots. So we filled that bay with wooden stop log. We also removed large long logs in front of dam." Stop log measurements = 3.7 feet gage height in all bays; lake gage reading = 3.66.
September 25, 1974	DNR dam inspection report: stop logs = 3.6 feet gage height all bays; lake gage reading = 3.99.
January 10, 1975	Letter from the resort owner: "I am seeking direction regarding a problem with the dam in the Pelican River that controls the level of Pelican Lake. A large section of bog has been lodged against the dam since last May, effectively blocking the flow of water over the dam for about 50% of its width. Runoff and what looks like high water conditions during the coming spring will cause a number of people, problems."
July 11, 1979	Dam inspection report: "Dam in good condition." Stop logs at 3.5 feet gage height all bays; lake gage reading = 4.04.

October 27, 1981	Dam inspection report: stop logs at 3.6, 3.3, 3.5, 3.7, 3.4, 3.6, 3.5, 3.5, 3.6 feet gage height; lake gage reading = 3.86.
November 19, 1982	Memo by DNR Area Hydrologist: "Owner of resort on Pelican Lake …. Agreed that the condition of the piers did not appear critical. He emphasized that his concern is to the leakage of water between the concrete stoplogs in the dam, and wishes to go on record as desiring that these stoplogs be replaced or sealed to prevent leakage. Although the regional files indicate no history of tampering with this dam, the resort owner stated that he is aware of occasions when downstream property owners have opened spaces between stoplogs in order to maintain some flow of water during dry periods when lake levels have receded below the top lf the stop logs. He gave no specifics concerning such tampering other than to suggest that it was farmers who desired to maintain a flow of water for cattle watering."
June 9, 1988	Letter from the Pelican Lake-Orr Resort Association: "The dam on the Pelican River near Orr, is in sad need of repair. The lake has dropped precipitously. Upon examination, we discovered two of the cement retainers were broken. Boards were put in place to keep the lake level at dam high. Many of the retainers are old and crumbling; some are missing and replaced with boards which are rotting. What we need are new retainers."
June 14, 1988	DNR dam inspection report: "there's some seepage; stop logs are approximately at pier height; -6.6 to top of low piers (3.4 feet gage height). I dragged a large log from the upstream side of the dam to the right bank." Stop logs measured at 3.55, 3.45, 3.46, 3.64, 3.4, 3.4, 3.48, 3.55, 3.5 feet gage height; lake gage reading = 3.44.
June 5 and 6, 1989	DNR survey of the dam: top of stop logs surveyed at 3.59, 3.46, 3.52, 3.68, 3.46, 3.48, 3.53, 3.60, 3.54. Lake gage reading = 4.08; tailwater 1.45 feet below the lake level.
September 1, 1993	DNR dam inspection report: "Removed bog and beaver cuttings from dam." Stop log measurements: 3.6, 3.5. 3.5, 3.6, 3.4, 3.5, 3.5, 3.5, 3.6 feet gage height; lake gage reading before removal of bog = 4.46; after bog removal = 4.32.
May & July, 1996	DNR dam inspection report: "found heavy timbers (RR ties) nailed together forming a timber dock? Removed same from dam as well as pilings post etc. and bog. Replaced a broken stoplog with a makeshift one from the available pilings." Stop log measurements: 3.5, 3.5, 3.5, 3.7, 3.4, 3.5, 3.4, 3.5, 3.5 feet gage height; lake gage reading (May 29, 1996) = 4.40, (July 11, 1996) = 4.02.
August 12, 1998	DNR Survey of the dam (see appendix B)

August 4, 1999	DNR dam inspection report. "Flowing; put a log in bay 4." Stop log measurements: 3.5, 3.5, 3.5, 2.9 (prior to adding log), 3.4, 3.5, 3.3, 3.5, 3.5; lake gage reading = 3.78.
May 28, 2003	DNR survey of new dam (see appendix B)

Note: gage "zero" = 1283.86 feet above mean sea level, NGVD 1929 adjustment. Add any reference to "gage height" to the gage zero to obtain the actual elevation in sea level datum.

High lake levels have been a periodic concern of lakeshore owners. However the correspondence file contains no documentation of structural damage due to high water.

It's very unlikely that at any given point in time, all stop logs in the old dam were at the exact same elevation. Prior to 1981, the dam inspector likely measured one stop log, and then visually checked the others to see that they were at roughly the proper height, i.e., equal to the top of the cut-off intermediate piers.

Even though there were several references to missing stop logs, only once has DNR dam inspector found that to be true (1999). Despite several references to leakage by concerned citizens, only once (1971) in regard to the lift gate did is there a specific reference to significant leakage through the dam in the dam inspection report.

There's a consistent element to the past concerns regarding low lake levels – an element certainly not unique to Pelican Lake. It's often assumed that low lake levels are somehow due to problems with a lake's outlet dam. Subsequent inspections in response to concerns regarding the Pelican Lake dam found that stop logs in the old dam were at the proper level. No doubt that leakage through the dam has had a minor effect on lake levels. But climate conditions, specifically the lack of rainfall and snowmelt – is the primary cause of low lake level conditions.

Appendix E: DNR Waters' surveys of the Pelican Lake Dam (1989 – 2003)

- John Scherek was the crew chief for all three surveys.
- All elevations are feet above mean sea level (NGVD, 1929 adjustment)

June 5 & 6, 1989

Vertical Control:	United States Coast & Geodetic Survey (USC & GS) benchmark "T21" at Orr. Elevation = 1304.25 MnDOT benchmark "6922 P" - disk in southeast abutment of County Road 23 bridge at Pelican Lake dam. Elevation = 1293.90
Selected Measurements:	Headwater @ dam = 1287.94 Tailwater @ dam = 1286.49 Average top of nine stop logs = 1287.40 Gage Zero = 1283.86 Top bridge abutment above gage = 1293.85

August 12, 1998

Vertical Control:	MnDOT benchmark "6922 P" Elevation = 1293.90
Selected Measurements:	Headwater @ dam = 1287.38 Tailwater @ dam = 1285.31 Average top of nine stop logs = 1287.35

May 28, 2003

Vertical Control:	MnDOT Benchmark "Glendale GPS 65 1972" Elevation = 1298.274
Selected Measurements:	Headwater @ dam = 1287.66 Tailwater @ dam = 1285.64 Average top of left weir = 1287.32 Average top of center weir = 1287.23 Average top of right weir = 1287.32

These three surveys were reviewed with Mr. Scherek. A different benchmark was used for the 2003 survey of the new dam, and the USC&GS benchmark used in the 1989 was not tied in during the 2003 survey. We did review the current DOT information for the Glendale benchmark. DOT has resurveyed that benchmark since 2003 and the elevation remained unchanged. There's no reason to believe that the Glendale benchmark is in error.

Appendix F: Headwater vs. Tailwater Relationships

The water level on the downstream side of the dam has been infrequently measured. All such data are plotted in Figure F1. These data provide a valuable confirmation of the elevation of the new dam compared to the old dam.

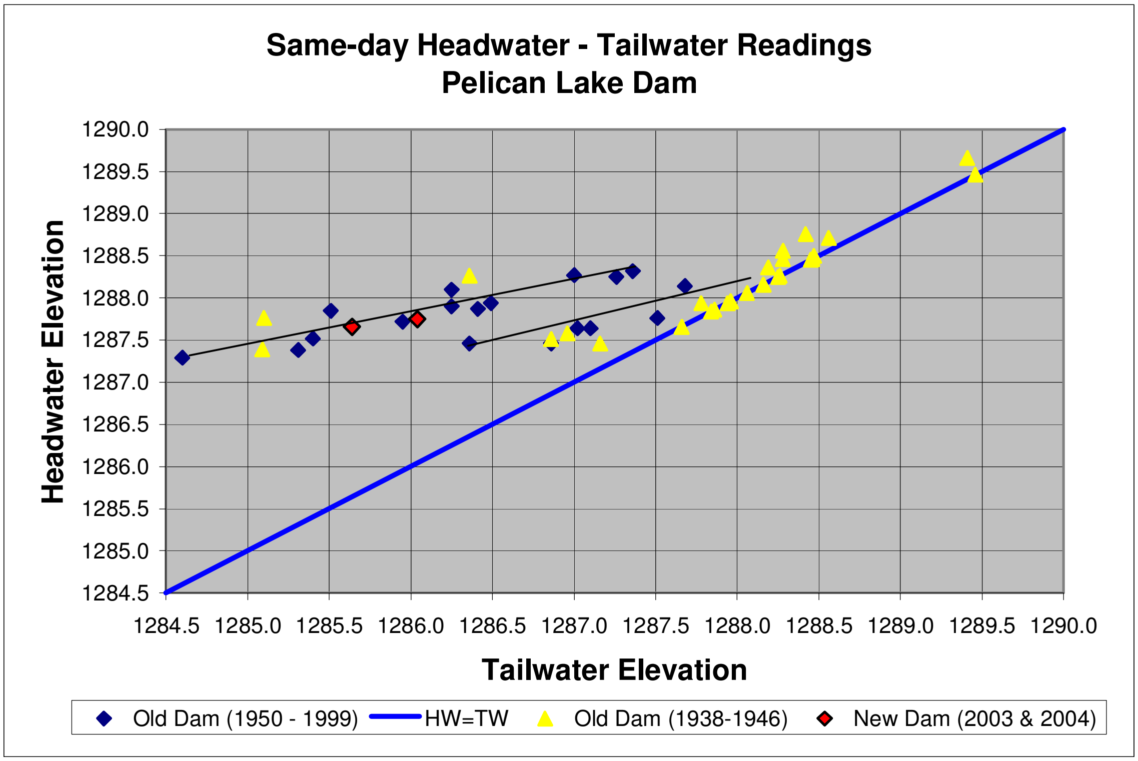

Figure F1. Same-day headwater and tailwater readings at the Pelican Lake dam.

The difference between the water levels on the upstream side of the dam (headwater) and the downstream side of the dam (tailwater) ranges from as much as three feet during very low lake level conditions to essentially no difference with high lake levels.

For a given flow rate, the elevation of the water on the downstream side of the dam is dependent on conditions in downstream reach of the Pelican River. Flow conditions on the Pelican River can range from free flowing, or potentially influenced by high flows on the Elbow River or debris jams. For a given flow rate the tailwater elevation is not dependent on the height of the Pelican Lake dam. If the new dam were in fact 1 to 1.5 feet too low, then the differential between the headwater – tailwater elevations would be reduced by a similar amount.

Headwater and tailwater elevations at the new dam have been measured on two occasions. Those two data points are depicted by the red diamonds in Figure F1 and are consistent with the data for the old dam. **These data provide very sound evidence that the new dam was not constructed 1 to 1.5 feet too low.**