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TECHNICAL MEMORANDUM

TO: Stephanie McNamara, Administrator Vadnais Lake Area Water Management

FROM: Rebecca Kluckhohn, P.E.

DATE: May 19, 2009

SUBJECT: Gilfillan Lake- Water Balance & Quality Context

BACKGROUND:

Recent low water levels in Gilfillan Lake have prompted concern from area residents (Figure 1). Gilfillan Lake levels have fallen in each of the past three years (2006-2008), and are almost four feet lower than the value reported in 1994. As the result the Vadnais Lake Area Water Management Organization (VLAWMO) requested this technical memo to guide the process of preparing a Sustainable Lake Management Plan.

The report is not a policy memo, but a technical memo to lay out the water balance and set a framework for the citizen group to select water quality goals for the lake. The technical memo is meant to support the development of policy by reporting on native and existing conditions and provide recommendations for future monitoring and evaluation.

Gilfillan Lake, located in North Oaks, Minnesota was augmented with groundwater starting in 1951 to raise it from its 1950's elevation of 906 ft NGVD to 910 ft NGVD (Tolz, King and Day Engineers and Architects, May 1950).

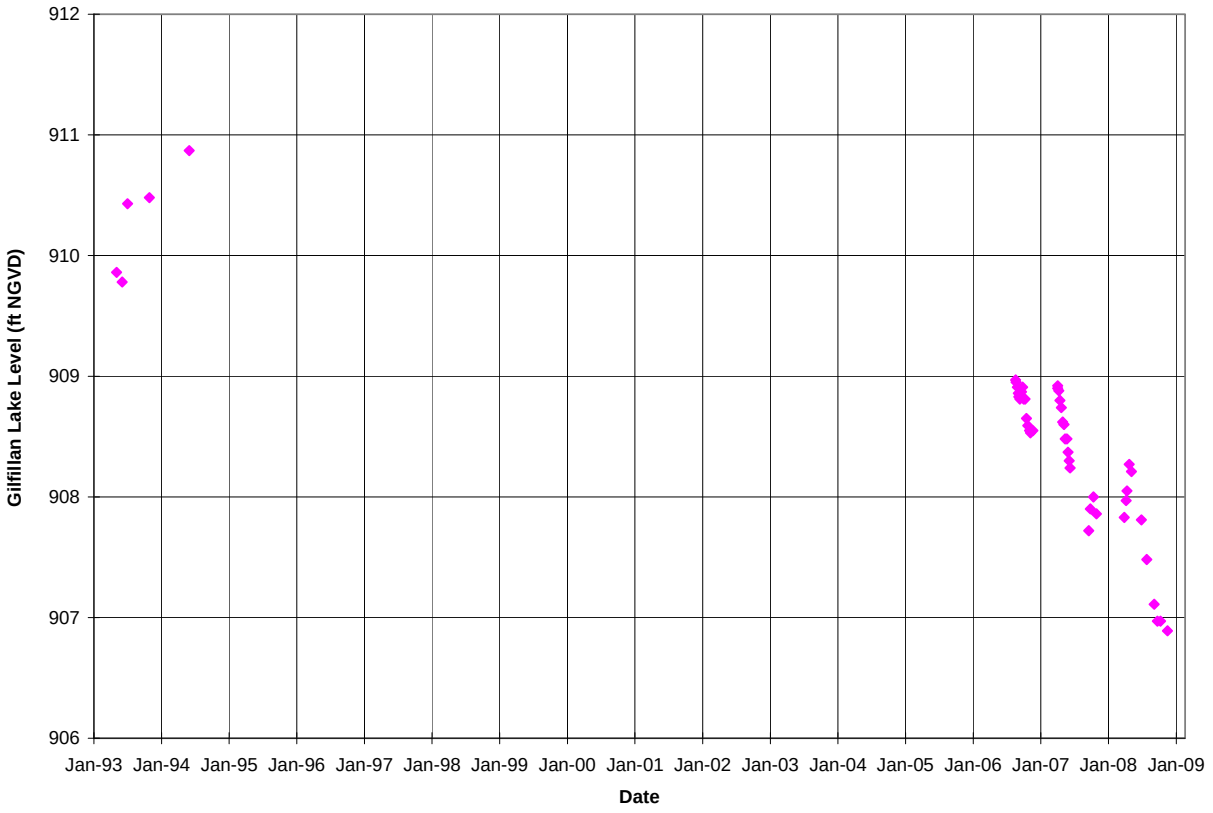
Homeowners pumped Gilfillan Lake dry in 1950, cleared trees and brush and dredged the lake basin to its present depth. They installed a well and pumping station and refilled the basin in 1951 (personal communication with Brian Corcoran, VLAWMO).

Estimates of groundwater augmentation levels based on power usage were available between 1974 and 1989. During that period, on average about 17 inches over the lake surface was added to the lake annually. No corresponding lake levels were available for review in preparation of this memo. In 1988 the DNR revoked all permits for lake augmentation through groundwater. Augmentation ceased in 1989 (CRA 1992).

Citizen concerns over low lake levels observed between 1989 and 1990 prompted evaluations by two consultants to evaluate the cause of low water levels. CRA retained by Reynolds and Whirlpool and Professional Engineering Consultants retained by the City of North Oaks. CRA was originally retained to investigate and remediate a contaminated site located west of Gilfillan Lake.

Both reports concluded that cessation of augmentation, coupled with dry weather between 1987 and 1989 caused the low water levels in Gilfillan Lake. A subsequent wet year in 1991 temporarily abated the low water issues as evidenced by the 1993 and 1994 water level data (909.87 to 910.87 ft NGVD).

Figure 1. Gilfillan Lake Elevation



This technical memo presents the following:

- A rough water balance for Gilfillan Lake based on existing lake level data and watershed data, as well as recommendations to improve quantification of the components of the water balance
- A water quality context for Gilfillan Lake. This consists of an inverted Canfield-Bachmann model based on existing in lake water quality. This model allows

stakeholder groups to get a sense for nutrient load reductions required to achieve various in-lake water quality goals and assists in setting goals.

WATER BALANCE:

The information reviewed for the water balance includes:

- A limited set of lake elevation data available from the DNR (Figure 1)
- Local precipitation data from White Bear Lake (Figure 2)
- Land use & topography to determine drainage area (Figure 3)
- Historical records:
  - *Report on Lake Level Control by Well Water Supply for the L.W. Hill Farm Property Commission No. 3118* by Toltz, King and Day, Inc. Engineers and Architects, May 1950
  - City of St. Paul plans for the improvements for Hwy 96 in the vicinity of Gilfillan Lake
  - *2008 Annual Monitoring Report Highway 96 Site White Bear Township, Minnesota,* CRA 2008
  - *Evaluation of Groundwater Remediation (Impact) on Local Pond and Lake Levels Highway 96 Site White Bear Township, Minnesota* CRA 1992

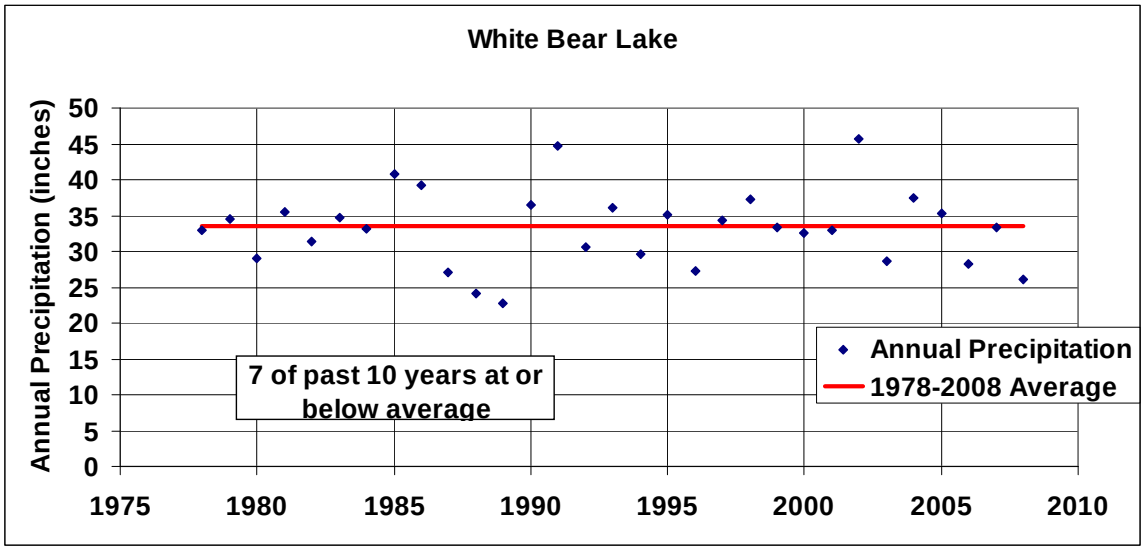
The elements that impact lake water levels include precipitation, watershed runoff, lake inflows, lake outflows, groundwater contribution, losses to groundwater, evaporation, and evapotranspiration. Precipitation, watershed runoff, lake inflows and occasionally groundwater are sources of water to a lake. Evaporation off a lake surface, evapotranspiration, lake outflows and occasionally losses to groundwater are all sinks of water, ie they subtract water volume from the lake. The section below will quantify each component of the water balance using existing data.

Precipitation, Evaporation and Evapotranspiration

Local precipitation has been at or below average for seven of the past ten years (Figure 2). Precipitation contributions are considered roughly equal to evaporation on an annual basis thus evening the two out. Average annual precipitation is about 33.5 inches at the White Bear Lake Station (ranging from 22.8 to 45.7 inches between 1978 and 2008). Annual evaporation is generally equal to precipitation.

Residents reported only one small bay had significant emergent vegetation, therefore, for the purpose of this report, evapotranspiration is lumped into evaporation levels. A vegetative survey for emergent vegetation would provide the area impacted by evapotranspiration.

Figure 2. White Bear Lake Precipitation



Periods of reported citizen concerns in 1989-1991 and 2006-present have followed dry periods in terms of precipitation.

Watershed Runoff

A percentage of the precipitation that falls over the land draining to Gilfillan Lake will runoff and eventually end up in Gilfillan Lake. The amount of runoff depends on land use, soil type and topography as well as drainage area. These factors combine to determine the amount of runoff available to replenish water to Gilfillan Lake.

Land use in the area is predominantly residential. The area is well vegetated with a full canopy of mature trees. With the exception of Highway 96 and the development in the southeast corner of the drainage area, the small amount of impervious area within the drainage area, about 17%, is not very well connected.

Further the topography of the land creates significant casual depressional storage areas within the drainage area. These areas collect and infiltrate runoff in most precipitation events rather than allowing it to migrate downstream, thus reducing the effective size of the watershed for most precipitation events. Therefore, the resulting drainage area to Gilfillan Lake is variable. The maximum potential watershed is 630.6 acres. The potential land areas that drain to the lake are shown in Figure 3.

The potential runoff based on current landuse and topography ranges between 10 to 20 inches per year for an average year. However, as noted, in 7 of the past 10 years, local precipitation has been average or below average.

Figure 3. Drainage area to Gilfillan Lake

Groundwater

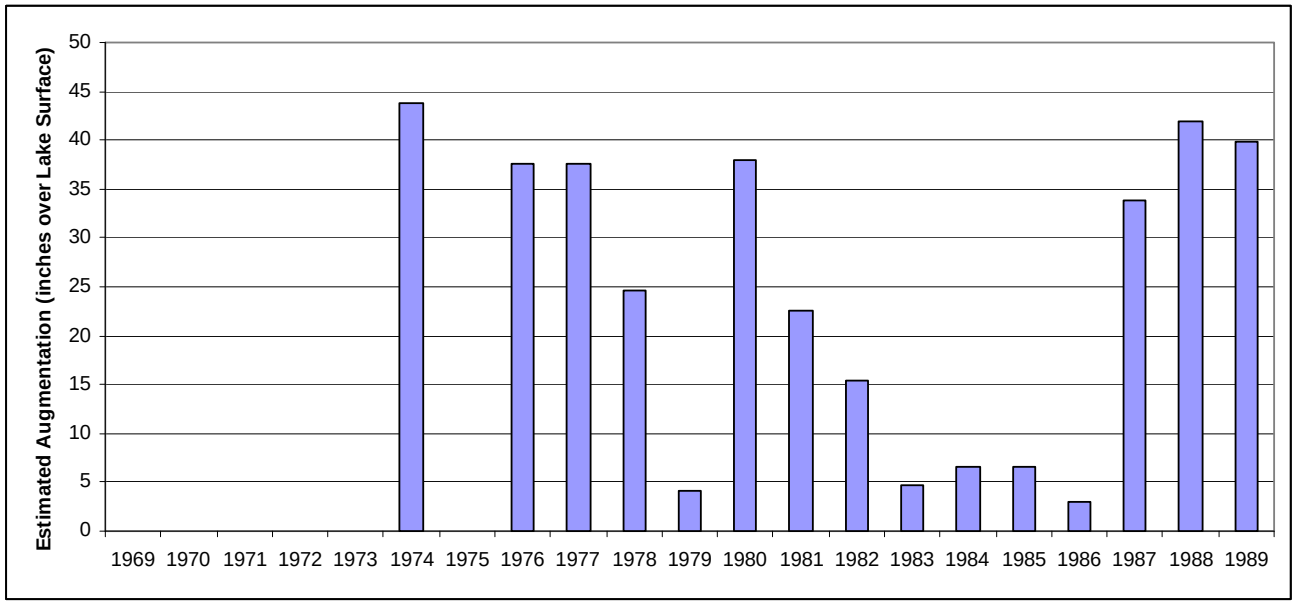
Historically, Gilfillan Lake was augmented with groundwater until the DNR disallowed the use of groundwater for lake level control in 1988. An historical report on lake level control for Gilfillan Lake and four other unnamed ponds indicated that at of the time of the report, May 1950, the elevation of Gilfillan Lake was 906 ft NGVD compared with the recent measurement of 906.98 ft NGVD. The report documented a proposal to raise the elevation of the lake from 906 to 910 ft NGVD through augmentation with pumped well water.

At the time of the report, the normal precipitation for Ramsey County was 27.17 inches compared with a current 30-year average of 33.5 inches.

The report documented that the drainage area to Gilfillan Lake was 110 acres with 8.83 inches of runoff. No map was provided to compare with existing drainage area. Based on

that report, we may actually have more area draining to Gilfillan Lake compared with historical levels.

Figure 4. Estimated Augmentation in Inches over Lake Surface*



* Source for figures x and x is the CRA 1992 Report

Figure 5. Relationship between Augmentation and Precipitation

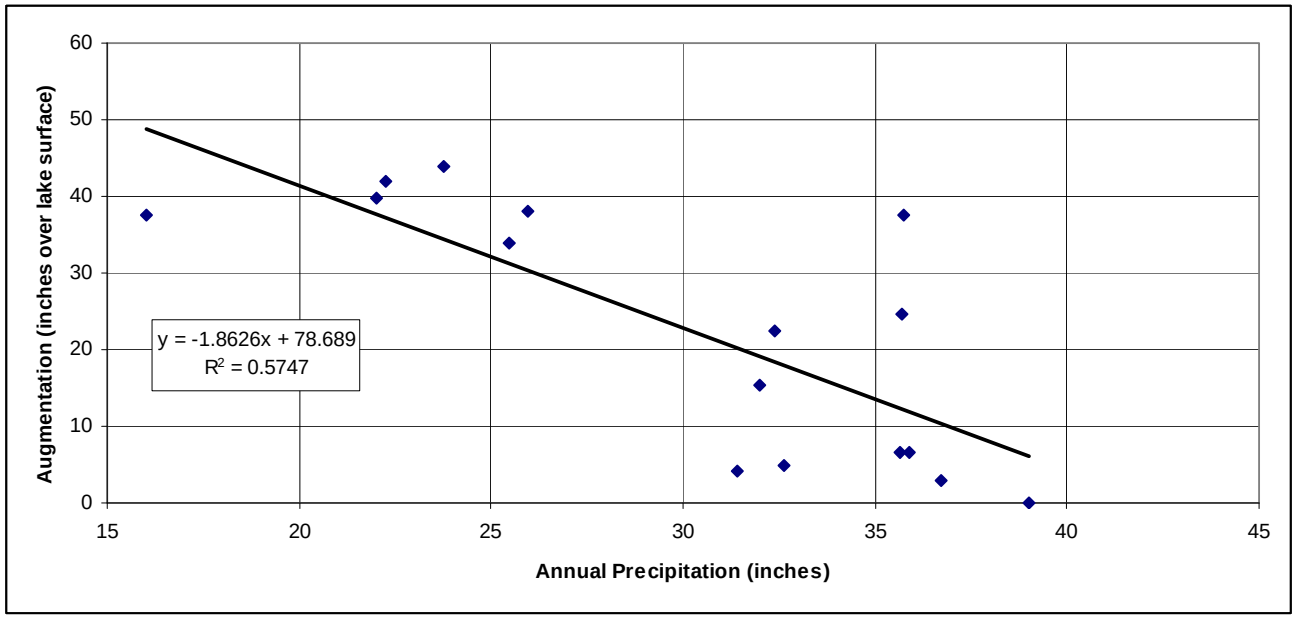


Figure 5 shows an inverse relationship between precipitation and augmentation indicating that augmentation was used to offset years with low precipitation.

Shallow groundwater in the vicinity of Gilfillan Lake has been studied to some extent due to a contaminated site in the southeast corner of the drainage area. The contaminated groundwater plume migrating from the site is reported to be migrating well under the lake in the sand aquifer above the St. Peter Sandstone formation.

Gilfillan Lake is perched well above the static water level which is about 900 feet NGVD in the area based on historic records. The lake does not appear to be in connection with this aquifer.

Review of a 1992 CRA report shows a perched shallow aquifer in the area of the contaminated site southeast of Gilfillan Lake that may or may not extend under Gilfillan Lake. Based on wells just east of Robb Farm Road, the gradient of the perched groundwater aquifer is about 0.0026 ft/ft. Applying that to the distance Gilfillan Lake lies from these wells, if the shallow aquifer persists under the lake, it may have an elevation of around 906 to 907 ft NGVD in the area of Gilfillan Lake. This is consistent with pre-augmentation water levels reported for the lake. It is important to note however that it is unknown if this shallow perched aquifer extends below the lake or not. Confirmation with area well logs would be necessary to determine this. The CRA reports are focused on the contaminated deeper aquifer.

If the shallow perched water table extends under the lake, water levels in the lake are likely fluctuating with it adding water to the lake in some years, extracting water in other years depending on the lake elevation.

In addition to well logs, measuring water levels in the small lakes and ponds around Gilfillan might also assist in determining groundwater influence on the lake.

Water Balance Results:

Based on the review of existing data, the low water levels in Gilfillan Lake as compared to historically maintained water surface elevations of about 910 ft NGVD are the result of

- A small drainage area, rich with casual depressional storage and a minimum of connected impervious areas
- The cessation of groundwater augmentation
- Below normal precipitation

Table 1 shows the estimated range of annual contributions to and subtractions from Gilfillan Lake for an average year. Groundwater contributions are estimated based on precipitation and estimated runoff and likely have an even wider variation.

Table 1. Annual Water Balance (in inches over lake surface):

Water Balance Component	Inches over Lake Surface
Precipitation	+33.5
Evaporation	-33.5
Inflows	+0
Outflows (recent)	-0
Watershed Runoff*	+10 to 20
Groundwater	-10 to 24
Net	0 to -4

*Watershed runoff is based on largest potential drainage area.

The values reported in Table 1 are very rough estimations based on available data and should be verified through collection of additional data for the purpose of designing any implementation projects.

However, while there is uncertainty in the exact breakdown of these values, the major conclusion that declining water levels are the result of cessation of augmentation, dry weather, and a small watershed is still valid.

Another issues raised by the citizen group was the potential of increasing losses to groundwater beneath the lake through the proposed installation of groundwater monitoring wells under the lake. It is our understanding the proposed wells are for monitoring alone and will not impact lake levels.

Citizens also hypothesized that improvements to Hwy 96 south of Gilfillan Lake have impacted water levels. Based on the information provided, it was not possible to compare the original condition to present condition. However, it does appear several ponds were installed, adding storage area and connecting areas that were previously disconnected. Additional drainage area (and therefore additional water) could be gained by lowering outlets of the Highway 96 ponds to redirect stormwater directly to Gilfillan Lake. This however may adversely impact nutrient concentrations to the lake.

Hydrologic Data Collection Recommendations:

Existing data available was reviewed for preparation of this memo. During this review of data, additional data needs were identified in terms of existing data, and data that should be collected in the future.

- Record water levels at Gilfillan Lake weekly during the summer

- Record inflows and outflows if any
- A shallow groundwater well to evaluate the presence of perched water and it's interaction with the lake would better quantify the groundwater.
- Measure lake water levels in Lilly Pond and the other smaller ponds in the vicinity of Gilfillan Lake
- Pull CRA's well logs in the vicinity of Gilfillan Lake to confirm if the shallow perched groundwater extends under the lake.
- Baseline and on-going fish and vegetation surveys to track the impact of water levels on biota

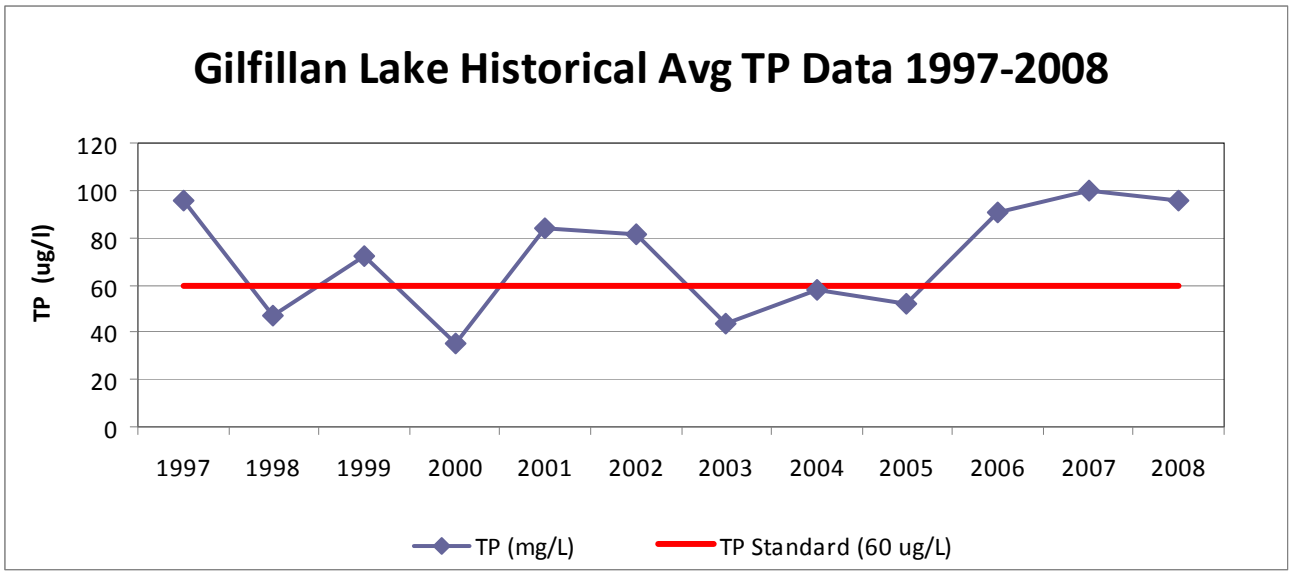
Existing Data to Collect:

- A 1992 CRA Report identifies historical lake water levels for Gilfillan Lake that are not available through DNR or VLAWMO. These records should be located and evaluated.
- Pumping records for augmentation
- Individual well logs from CRA (with permission)
- Water levels at smaller ponds in the area of Gilfillan (Lilly, etc).

WATER QUALITY:

In-lake TP for Gilfillan Lake has ranged from 35 to 100 ug/L TP since 1997, with high concentrations occurring in all of the past the last three years. The average concentration is 71 ug/L. The lake has exceeded state water quality standards for TP in 7 of the past 12 years (Figure 6).

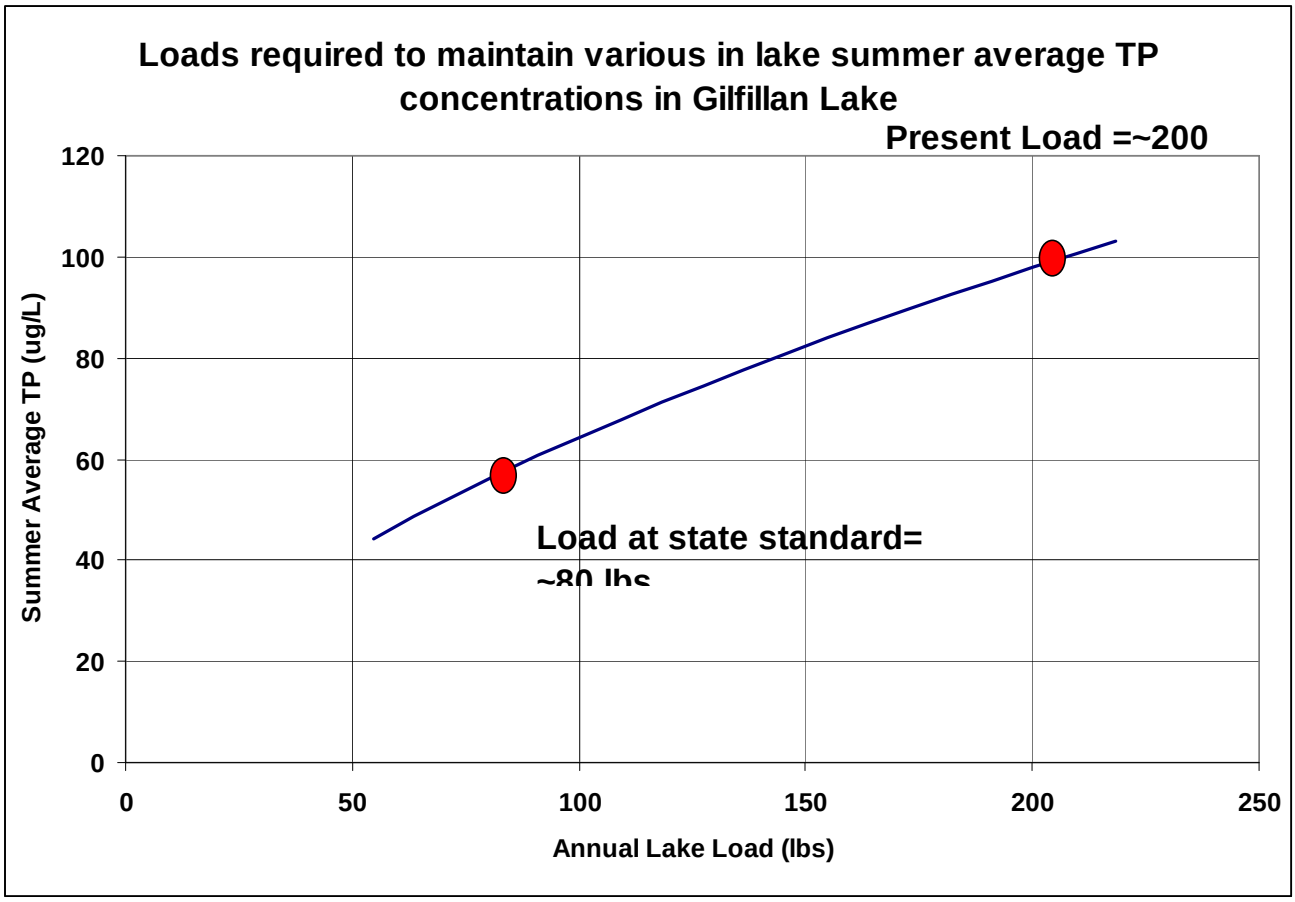
Figure 6. TP Concentrations in Gilfillan Lake Compared with State Standard



A nutrient load reduction is necessary to meet state standards. Figure 7 shows the approximate relationship between in lake concentrations and loads based on lake morphometry and watershed characteristics. This is a rough evaluation to give an idea of the order of magnitude of load reductions necessary to meet state standards, and to give a sense for what is achievable in the lake.

This evaluation is based on the Canfield-Bachmann equation and shows that a load reduction of approximately 120 lbs is needed to achieve state standards.

Figure 7. Loads required to maintain in-lake summer average TP concentrations


Loads required to maintain various in lake summer average TP concentrations in Gilfillan Lake
Present Load =~200
Load at state standard=
~80 lbs
Summer Average TP (ug/L)
120
100
80
60
40
20
0
0
50
100
150
200
250
Annual Lake Load (lbs)