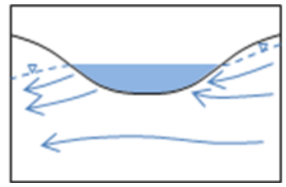
Flow-Through Lake/Wetland: Generalized Monitoring Strategy



General Hydrologic Characteristics of Flow-Through Lakes & Wetlands

Flow-through lakes are surface expressions of the water table and are in direct hydraulic connection with the water-table aquifer. They receive inflows from groundwater along the upgradient shore of the lake and discharge flow to groundwater along the downgradient shore. In general, the net contribution of groundwater to the overall lake water balance is zero (although some net loss of groundwater from evaporation may take place). Flow-through lakes can have contributions of surface-water runoff into the lake but if that contribution is large, a flow-through lake might better be classified as a recharge lake. If the lake has an outlet of significance, a better classification would be a discharge lake.

Many lakes in Minnesota are flow-through lakes. The stage elevation of the lake moves up and down with the regional water table. During prolonged dry periods, the lake may drop a few feet. During extended wet periods, lake stage will rise. Depending upon lake bathymetry, these changes in lake stage (responding to water-table fluctuations) can be visually dramatic and can change the surface-water area of the lake.

Because flow-through lakes are surface expressions of the water table, they are susceptible to regional groundwater pumping. Lakes have much higher storage properties than the surrounding aquifer media – therefore, lakes will dampen the effects of drawdown from pumping for a period of time and act as recharge sources to the aquifer. But over a longer period of time, the storage in the lake will be reduced in response to the overall lowering of the water table and the lake elevation will drop until a new hydraulic equilibrium is reached.

It is important to recognize that flow-through lakes are susceptible to climatic changes. A period of successive years of lower than average precipitation will tend to cause a drop in the water table and a corresponding drop in the lake stage. This drop in lake stage may have nothing to do with changes in regional pumping. However, regional pumping often increases in response to dry periods as more irrigation takes place. Differentiating the effects of pumping from climatic changes can be challenging.

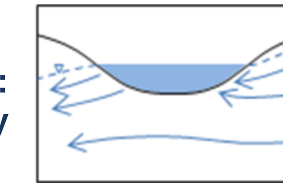
Generalized Monitoring Plan

Although every setting is unique – monitoring plans must take into account local conditions, existing monitoring programs, and coordination among overlapping governmental units – all monitoring should incorporate the following elements:

- Lake-stage monitoring
- Groundwater withdrawal rate monitoring
- Potentiometric level monitoring
- Monitoring of other parameters, as a local need is identified

Coordination and Reporting

Monitoring related to Flow-Through lakes/wetlands will require coordination with DNR, nearby water appropriators, WMO's (if applicable), lake associations, and Metropolitan Council (if applicable). Data should be compiled annually in a report to coordinating agencies. All monitoring data should be compiled in electronic form. Alternatives to annual reporting could be a dedicated web site where data can be downloaded.

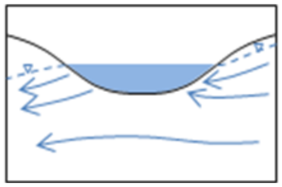


Typical Monitoring Costs

The following are approximate costs for a generalized monitoring program, as described above. It is important to recognize that local settings may differ from the generalized assumptions. For example, drilling costs for piezometers will vary, depending on the depth to the pumped aquifer (or if there is more than one pumped aquifer) and the need for well screens (instead of open hole intervals). There may be some cost savings realized if existing monitoring installations are already present (e.g., there is an established gauging station or a piezometer). These cost estimates should only be used as a starting point for estimating the actual cost of a particular monitoring program.

	Justification	Frequency	Equipment	Capitol Cost[1]	Variables	Annual Cost[1]	Variables
Lake Stage	Pumping may affect lake stage. Lake stage is crucial to habitat and recreational use	Hourly or less	A piezometer, pressure transducer, and data logger in a stilling well	$100 to $3,000	Assumes dedicated pressure transducers and data loggers. Remote telemetry estimated to cost additional $3,000 per piezometer.	$100- $1,000	Assumes that downloading of data would occur along with piezometer transducer downloading)
Groundwater Withdrawal - All pumped wells	Accurate and precise data are crucial to understand the relationship between pumping, changes in water level (i.e. drawdown).	5 minutes or less	SCADA-controlled data loggers in all pumped wells	$ 0 to $40,000 (assumes existing SCADA)	Electronic tabulation of flow rates for each well at 5-minute intervals may require modifications to existing system	$0 - $2,000	Cost dependent on SCADA system and requirements for manual formatting of tabulated data
Potentiometric Levels - Near lake, in direct line with pumped wells	Change in aquifer water level is a key indicator of potential effect on lake stage.	15 minutes or less	A piezometer, pressure transducer, and data logger at each site	$ 15,000 to $30,000	Depth of piezometers; need for well screens (assumes 2-inch diameter piezometers)	$1,500	Well maintenance fee to MDH,
Other Parameters	These data provide indicators of the overall health of the stream and its capability to support trout habitat	Hourly or less		$ 3,000 to $4,500	Assumes dedicated pressure transducers and data loggers. Remote telemetry estimated to cost additional $3,000 per piezometer.	$2,000	Assumes quarterly downloading of data by well-owner staff. Add $150 per piezometer for annual data from telemetry (if used)

[1]The above costs do not include costs for conducting aquifer testing (which may be a Water Appropriation Permit requirement for a new pumping well). Annual costs include an estimate of staff costs to the well owner for data handling and maintenance.



Flow-Through Lake/Wetland:
Generalized Monitoring Strategy

To facilitate the discussion of monitoring programs, a generalized hydrologic setting for a Flow-Through lake is presented.

The Flow-Through lake is assumed to:
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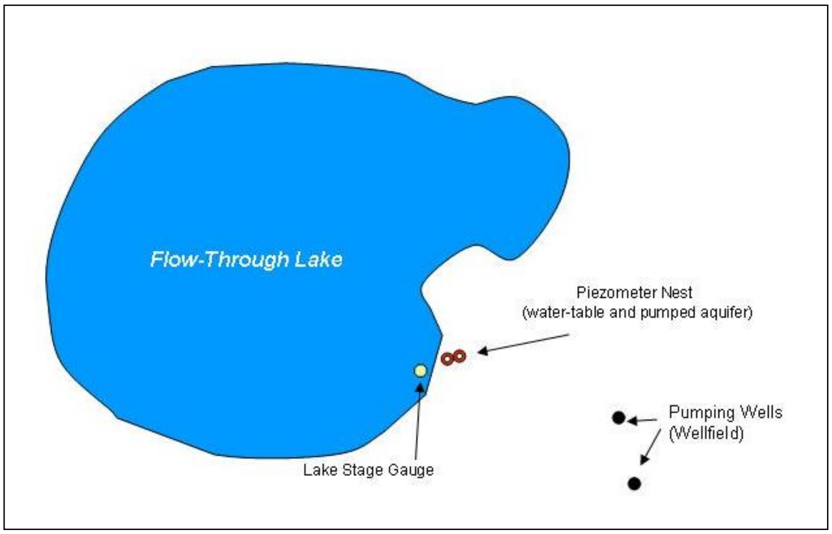
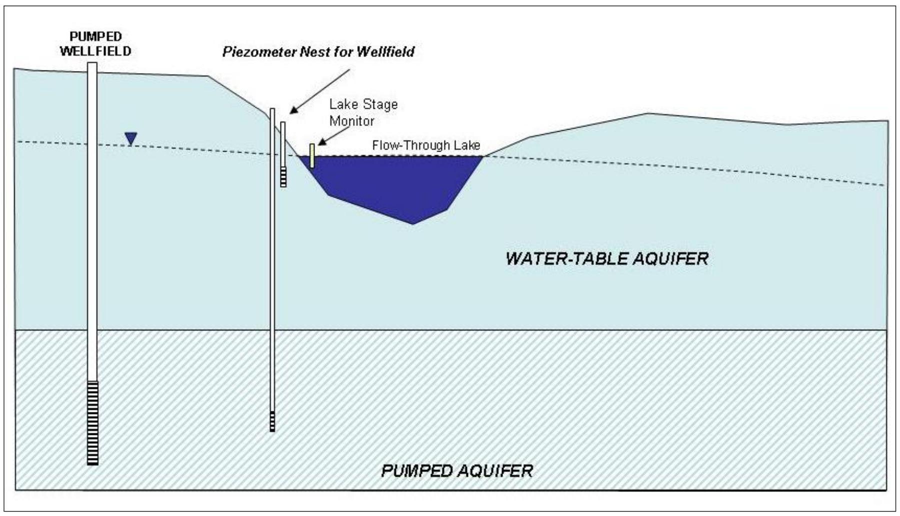
(1) no surface-water outlet;
(2) groundwater inflows that are approximately equal to groundwater outflows;
(3) have high-capacity groundwater pumping in the region near the lake; and
(4) pumping is from an aquifer deeper than the surficial water-table aquifer..





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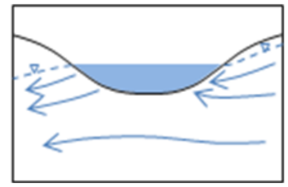

A generalized monitoring system and program consists of the following:

Groundwater Withdrawal Rates

Purpose

Accurate and precise pumping rate measurements for individual wells are crucial to understanding the relationship between pumping, changes in potentiometric levels in the aquifer (i.e. drawdown), and lake-wetlands stage. Before a causal link can be established, correlations need to be developed between pumping and responses in the aquifer and lake. These correlations cannot be relied upon unless the data are accurate, precise, and frequent. These types of data are important not only in establishing a potential causal effect but also to refute the existence of a hypothesized effect.

Location(s)

Each high-capacity pumped well

Measurement Frequency

Groundwater withdrawal rates must be accurately measured and recorded on a continuous basis for each high-capacity pumped well. At a minimum, measurements should be made every 5 minutes or less.

Equipment/Method(s)

SCADA systems should be capable of measuring and tabulating flow measurements on an interval of approximately 1 minute or less. Electronic tabulation (such as spreadsheets) should be developed and maintained for each well that provides a continuous record of pumping rate at the above interval. Each flow measurement should correspond with an accurate date and time.

Potentiometric Levels

Purpose

In general, high-capacity pumping will affect surface water bodies only if the pumping also affects potentiometric levels in the aquifer that is being pumped and the water-table aquifer. In other words, in order to affect stage elevation of surfacewater bodies, pumping must induce drawdown. But, it is important to understand that the absence of observed drawdown effects near surfacewater features is not, by itself, an indicator that pumping is not affecting the gaining feature. It is possible that pumping even far away from a gaining feature can capture groundwater that would otherwise flow into the feature without ever inducing measurable drawdown in the groundwater system at the gaining feature.

Data from piezometers located between pumping centers and the lake will provide an indication of how extensive the pumping center's cone of depression is and how it changes over the course of a year. The purpose of the well nests adjacent to the trout stream is to correlate changes in the potentiometric surface of both the pumped aquifer and the water table aquifer with stream flows. These data are useful in developing a causal relationship between pumping, potentiometric heads, and lake stage They are also useful in determining if changes in lake stage are in response to local pumping or to regional effects, such as regional pumping (many miles away) or climatic/meteorological conditions.

Location(s)
It is recommended that a nest piezometer be installed approximately next to the lake/wetland, in direct line with each pumping center (i.e. well field) and the lake/wetland and completed in the pumped aquifer. The piezometer nest should consist of one piezometer screened at approximately the same interval as pumping wells in the area and one piezometer screened across or just below the water table.

Measurement Frequency
Such systems are capable of recording head measurements at intervals of 15 minutes or less – a frequency level that is recommended. At a minimum, measurements should be made every 15 minutes or less.

Equipment/Method(s)
Piezometers in bedrock units (i.e. pumped aquifers) should have screens or open-hole intervals that span at least one transmissive zone (e.g., significant horizontal fracture) but should not span the entire aquifer. A screen or open hole interval of less than 20 feet would be preferred. The screen or open hole should preferably be at approximately the same stratigraphic horizon as the mid-point of the open hole portion of the pumped well(s). Water-table piezometers should have screens no longer than 10 feet. In all cases, piezometers should be equipped with pressure transducers and automated data logging systems. They are typically much more cost effective and precise than manual measurements. A system for a single piezometer is usually less than $2,000 and requires download of data on a quarterly basis. Remote telemetry and/or interface with SCADA systems is also possible.

Lake Stage Monitoring

Purpose
To a great extent, concerns over the effects of pumping will relate to lake/wetland stage because lake/wetland stage is a parameter that many users of the lake or wetland will be most keenly aware. Many lakes have a record of lake stage levels, collected usually by volunteers. Most wetlands do not. Some of these records are good and some are of uncertain quality. Most are not collected frequently enough. For lakes and wetlands near high-capacity pumping areas, reliably establishing the natural fluctuation of lake stage is very important..

Location(s)
The location for lake stage monitoring should be at a readily accessible but protected location (to minimize disturbance, accidental damage, and vandalism).

Measurement Frequency
Ideally, hourly measurements would be ideal. Daily measurement should be a minimum frequency.

Equipment/Method(s)
Lake stage should be recorded using stilling wells (to protect from wave action and other interferences) and automated pressure transducers (or other automated stage recorders). Manual staff gauge measurements could augment automated measurements on a bi-weekly to monthly schedule. If there is the capability to manual measure on a regular basis (e.g., there are volunteers from a lake association), manual measurements with a staff gauge could substitute for a stilling well with automated measurements.

Other Parameters
Purpose
Temperature, dissolved oxygen, and specific conductance data provide indicators of the overall health of the lake/wetland.

Aquifer test pumping of new wells can allow for quantification of aquifer parameters and regional drawdown effects.

Groundwater flow modeling is useful in evaluating the vast amount of data that will be collected over time.

Location(s)
Temperature, dissolved oxygen, and specific conductance data may be collected at stream gauging stations or lake stage monitoring locations.

Aquifer testing may be done on existing or new pumped wells.

Measurement Frequency
Temperature, dissolved oxygen, and specific conductance data may be collected using automated measuring equipment for relatively low cost.

Equipment/Method(s)
New wells should have some sort of aquifer (pumping) test performed to quantify aquifer parameters and regional drawdown effects.

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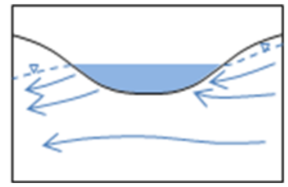
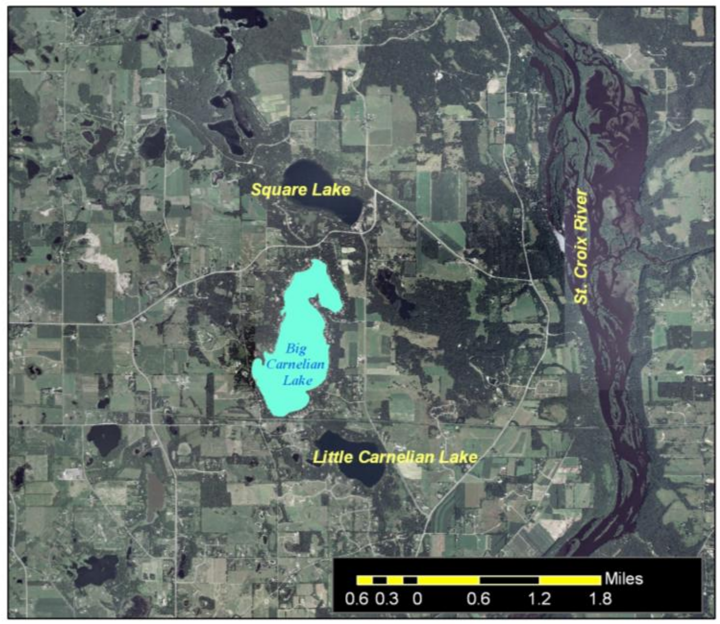
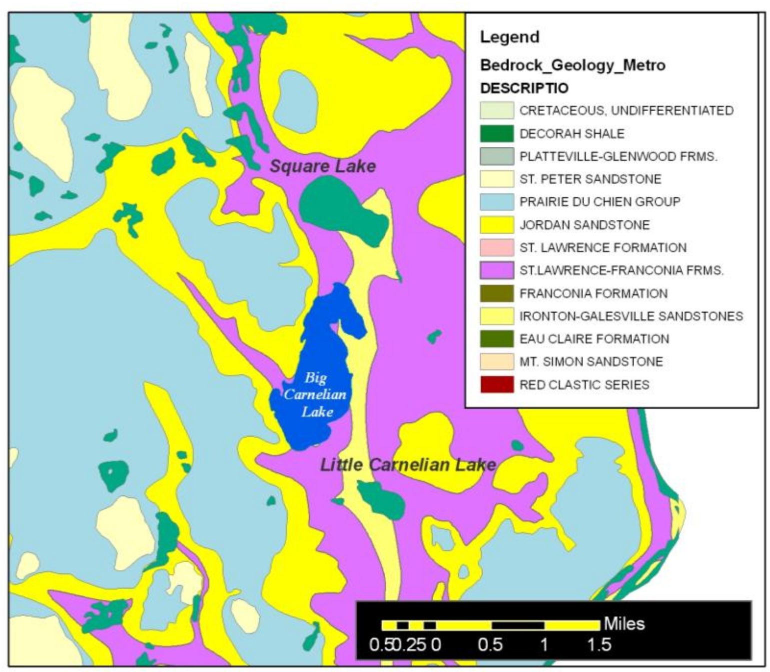


Monitoring Case Study/Example: Big Carnelian Lake, Washington County

Big Carnelian Lake in Washington County was identified as a lake that may meet the criteria for a Flow-Through lake – potentiometric heads in the water-table aquifer appear to be above the lake stage and the lake has does not have a significant outlet.



Big Carnelian Lake is located approximately 2 miles west of the St. Croix River. Square Lake is to the north and Little Carnelian Lake is to the south of Big Carnelian Lake. Little and Big Carnelian Lakes have approximately the same lake stage but Square Lake is about 10 feet higher in elevation. While there are many small capacity wells in the area, supplying individual homes and farmsteads, there are not many high-capacity wells (except for a few irrigation wells) and no municipal well fields nearby. Regional groundwater flow is expected to be east-southeast toward the St. Croix River (the regional discharge sink in the area).



Square, Big Carnelian and Little Carnelian Lakes are located above a buried bedrock valley that trends approximately north-south. The buried bedrock valley incises through the Prairie du Chien Group and the Jordan Sandstone – two units which make up the important Prairie du Chien-Jordan Aquifer. In the vicinity of Big Carnelian Lake, the Prairie du Chien-Jordan Aquifer discharges into the buried bedrock valley's deposits. Thus, the water table in the vicinity of Big Carnelian Lake would be controlled by the potentiometric surface and groundwater discharge of the Prairie du Chien-Jordan Aquifer.

System to Monitor Effects of Pumping on Big Carnelian Lake

The current monitoring system, if any, is unknown. A monitoring program might include the following:

Potentiometric Levels

Contouring of water levels from the County Well Index has been used, in part, to identify Big Carnelian Lake as a flow-through lake, along with the absence of a surface-water discharge pathway. These data suggest that lake stage is at about the same elevation as the surrounding regional water table and is a surface-expression of the water table. This means that changes in the water-table elevation could result in changes in groundwater flow into the lake. In particular, a lowering of the water table over time could result in decreases in lake stage.

For Big Carnelian Lake, the potentiometric surface of the Prairie du Chien Group and the Jordan Sandstone upgradient (west) of the lake should be better understood through the installation of a piezometer in one or both of these units (preferably paired with a water-table piezometer.

Lake Stage Monitoring

Continuous lake stage monitoring at a secure location should be initiated if not already underway. It is important to obtain an understanding of the natural fluctuation of the lake stage over time so that changes that are outside of normal fluctuation ranges can be identified. It is also important to obtain data that relate lake stage to water-table elevation. Changes in lake stage as a function of climatological conditions are important to understand.

Groundwater Withdrawal Rates

Groundwater withdrawals in the area do not appear to be significant at this point. If new high-capacity wells in the area are located, the pumping rates of these wells need to be monitored. Because the lake stage may be susceptible to changes in flow and the potentiometric surface of the Prairie du Chien-Jordan Aquifer, pumping rates in that aquifer for wells located to the west of the lake should be monitored.

Other Parameters

Lake quality parameters, such a temperature, turbidity, clarity, etc. are useful for many evaluations but are likely not necessary for the purposes described herein. Because of the complexity of hydrogeologic conditions in the area, a groundwater modeling approach may be necessary to understand the relationship between groundwater flow, pumping, climatological conditions and lake stage.