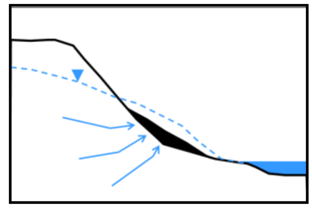
Calcareous Fen:
Generalized Monitoring Strategy



General Hydrologic Characteristics of Trout Streams

Fens are wetlands fed by groundwater. Calcareous fens are wetlands fed by groundwater containing high concentrations of dissolved calcium carbonate and rare calciphylic ("calcium loving") plants. Calcareous fens are characterized by sloping peat layers and peat domes that can be tens of feet thick. The peat overlies mineral soils. Potentiometric heads within the peat are typically artesian and spring heads form around peat domes, coalescing into rivulets and streams. These spring flows, along with upwelling groundwater associated with river bluff environments, also produce conditions where trout streams develop. Because of their unique ecology and hydrology, calcareous fens are afforded special protection under Minn. Rule Pt. 8420.1040 and statute. Calcareous fens are considered to be much more vulnerable to changes in groundwater flow because their special character is dependent on discharging groundwater. In particular, local and regional pumping may reduce upward vertical hydraulic gradients in the vicinity of the calcareous fens, resulting in diminishment of fen hydrology that may lead to compaction of peat, reductions in the area of upwelling, and the development of conditions conducive to invasive and woody species that choke out the habitat for fen plants.

There a several calcareous fens along the Minnesota River bluff in the metro area. The two best known calcareous fens in the metro area are the Savage Fen Wetland Complex (in Savage) and the Seminary Fen Wetland Complex (in Chaska). Both have been extensively studied but much remains unknown about the correlation between regional pumping and conditions at the fens. Other fens in the metro area include Black Dog Fen (Burnsville), Nichols Fen (Eagan), and Ft. Snelling Fen.

Calcareous fens are part of larger wetland complexes that contain features in addition to calcareous fens. The calcareous fen portions of the wetland complexes are very sensitive to disturbance, even by foot travel. Piezometers through the peat need to be placed by hand and must be regularly resurveyed because of peat movement. Permanent piezometers and wells must be installed at the peripheries of the fen areas.

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:

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

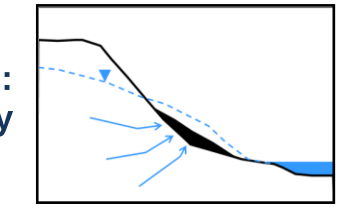
More than any other type of groundwater-dependent surface-water feature, calcareous fens depend on two levels of monitoring – on-site (i.e. in and around the fen and wetland complex) and far-field. A community with high capacity wells in the vicinity of a calcareous fen should focus on the far-field monitoring – i.e. the types of monitoring that concentrate directly on the effects of high-capacity well pumping. Within the fen wetland complex, state and local agencies with expertise in designing monitoring systems for calcareous fens should take the lead in implementation. Communities should participate where they can with local monitoring.

The elements of a calcareous fen monitoring plan may be a part of a broader effort of a Calcareous Fen Management Plan. In order to design a monitoring plan, extensive hydrologic and biologic characterization of the fen must first be undertaken. Characterization activities include:

- Biologic surveys of fen and wetland plants and habitats;
- Scoring of the fen using the calcareous fen criteria;
- Evaluation of peat thickness, stratigraphy, and surface-water hydrology;
- Evaluation of hydrochemical conditions.

Coordination and Reporting

Fen monitoring will require the input of the DNR, Metropolitan Council, WMO's and nearby communities. However, one entity should be responsible for compiling the local and regional data and evaluating trends. Local communities do not generally have the expertise to make these assessments. 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. These costs do not apply to monitoring directly associated with the fen wetland complex.

	Justification	Frequency	Equipment	Capitol Cost[1]	Variables	Annual Cost[1]	Variables
Groundwater Withdrawal • All pumped wells	Accurate and precise data are crucial to understand the relationship between pumping, changes in water level (i.e. drawdown), and stream/spring flows.	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 • Midway between wellfield and fen, in direct line with pumped wells	Change in aquifer water level is a key indicator of potential effect on stream flow.	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 fen	Hourly or less		$ 2,000 to $4,000	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.

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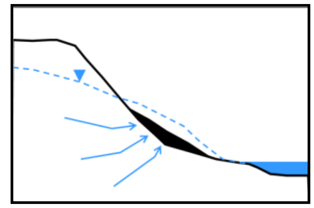
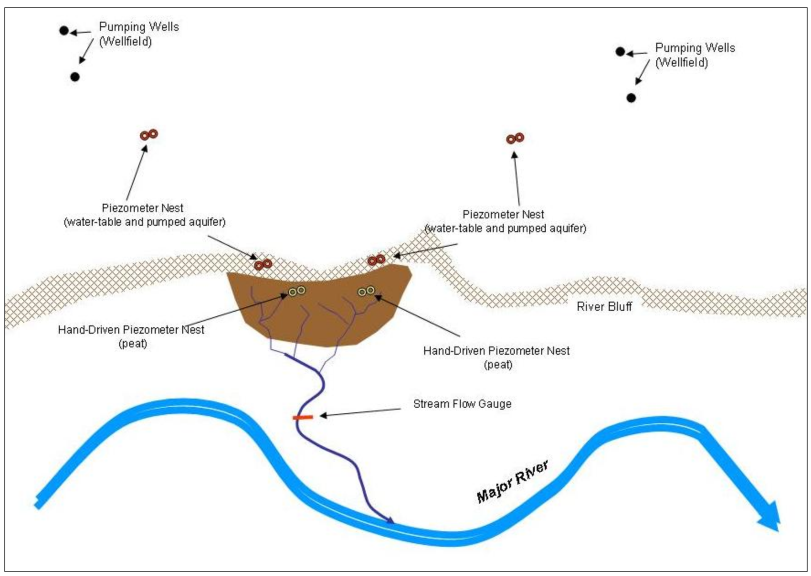
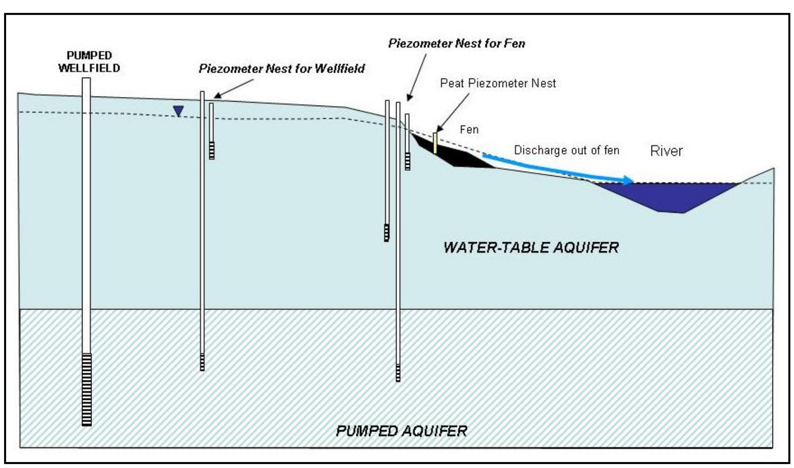
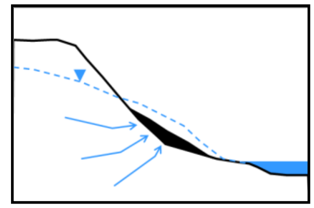


To facilitate the discussion of monitoring programs, a generalized hydrologic setting for a calcareous fen is presented. The fen is assumed to:

(1) be located along the bluffs of a major river, downgradient of the pumping centers;
(2) be characterized and monitored locally by state agencies or other local units of government familiar with fen hydrology and ecology;
(3) be supported by upwelling groundwater;
(4) have high-capacity groundwater pumping in the region near the fen; and
(5) pumping is from an aquifer deeper than the surficial water-table aquifer.







A generalized monitoring system and program consists of the following:

Spring-Flow Monitoring

Purpose

Reduction in the upward vertical gradients at calcareous fens will likely result in reductions in spring flows at the fens. Individual spring heads are difficult to monitor for flow and may naturally shift from year to year. A better monitoring approach is to identify a stable location downstream of the coalescence of spring heads into a single channel and monitoring flows at that location. Flow monitoring using a structure with continuous stage recording (e.g., a flume or weir) is the preferred method. Flow measurements should be in conjunction with potentiometric measurements. Flow measurements should be the responsibility of government agencies overseeing the fen.
Accuracy is important in stream-flow measurements.

Location(s)

Stable stream cross sections should be identified or established. Where a reliable rating curve (i.e. relationship between stage height and stream flow) can be developed, stage height can be monitored using manual staff-gauge readings. Periodic manual stream gauging should be conducted to verify the reliability of the rating curve. Other options include the use of automated devices to directly measure average stream flow (see Designated Trout Streams).

Measurement Frequency

Continuous measurement is important because correlations need to be developed between stream flow, meteorological influences, and pumping. At a minimum, measurements should be made hourly.

Equipment/Method

Both accuracy and precision are important in stream-flow measurements. Stable stream cross sections should be identified or established. Automated measurement devices should be used. Where a reliable rating curve (i.e. relationship between stage height and stream flow) can be developed, stage height can be monitored using bubblers or pressure transducers in stilling wells. Periodic manual stream gauging should be conducted to verify the reliability of the rating curve. Other options include the use of automated Doppler measurement devices to directly measure average stream flow.

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 stream flows. Before a causal link can be established, correlations need to be developed between pumping and responses in the aquifer and stream. 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

Groundwater levels at the fens and upgradient of the fens are considered to be of primary significance in maintaining the hydrologic health of calcareous fens. The fens formed along the slope of the river bluff because the abrupt change in topography results in artesian conditions (i.e. potentiometric heads above the ground surface) in the surficial deposits and in the underlying bedrock aquifers. Upward vertical gradients are present underneath the fen, resulting in upward groundwater flow. If these potentiometric heads are lowered, upwelling flows could diminish or cease. It is important to have measurements of potentiometric heads (i.e. groundwater levels) at multiple depths (i.e. well nests with wells screened at different depths and in different units) at and near the fens. Further upgradient from the fens, monitoring of potentiometric heads is important to characterize the effects of pumping on groundwater levels and evaluate a correlation, if any, with potentiometric head changes at the fens.

Location(s)

A piezometer nest, consisting 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 should be installed midway between each well field and the fen, approximately along a direct line between the well field and fen. The purpose of the well nest is to correlate changes in the potentiometric surface of both the pumped aquifer and the water table aquifer with potentiometric head and stream flows and the fen wetland complex. These data are useful in developing a causal relationship between pumping, potentiometric heads, and stream flow. They are also useful in determining if changes in heads and stream flow at the fen are in response to local pumping or to regional effects, such as regional pumping (many miles away) or climatic/meteorological conditions.

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.

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

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

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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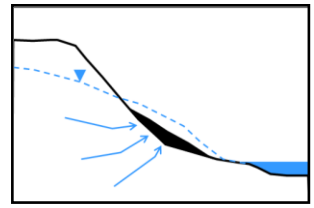
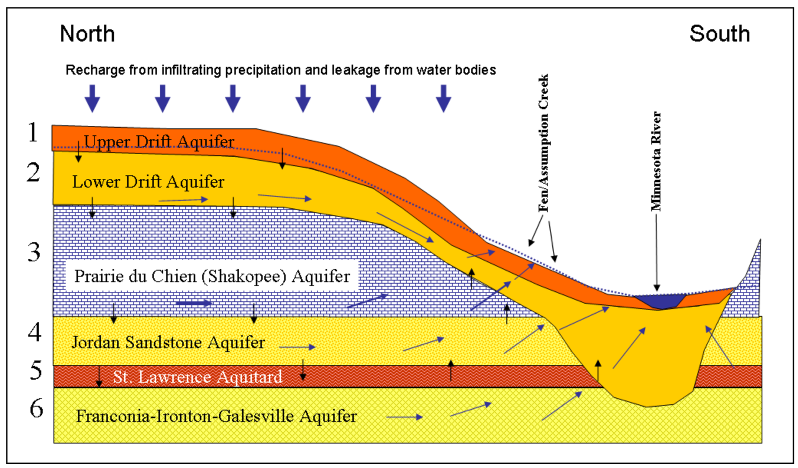


Monitoring Case Study/Example: Seminary Fen, Carver County

The upwelling conditions in the Seminary Fen Wetland Complex are the result of both local and regional groundwater flow conditions, including groundwater flow in bedrock aquifers. The calcareous fen portions of the wetland complex are situated on a gentle slope at the base of the Minnesota River bluff on top of lacustrine and terrace deposits. Beneath Seminary Fen, Quaternary and pre-Quaternary erosion has removed the Prairie du Chien Group and the Jordan Sandstone. The Prairie du Chien-Jordan aquifer system is heavily influenced by the Minnesota River, which is the major discharge zone. Groundwater flow is toward the Minnesota River (to the south in Carver County.



The fen area is a location where regional potentiometric heads are greater than the ground surface topography, resulting in upper vertical hydraulic gradients from bedrock, through unconsolidated deposits, and peat. The highest upward gradients (approximately four feet of difference between the water table well and the nested piezometer) were observed associated with a component of high quality calcareous fen. In these high quality calcareous fen areas, fen indicator plants abound, along with thick peat domes (as thick as 12 feet), turgid ground, and precipitating calcium carbonate.

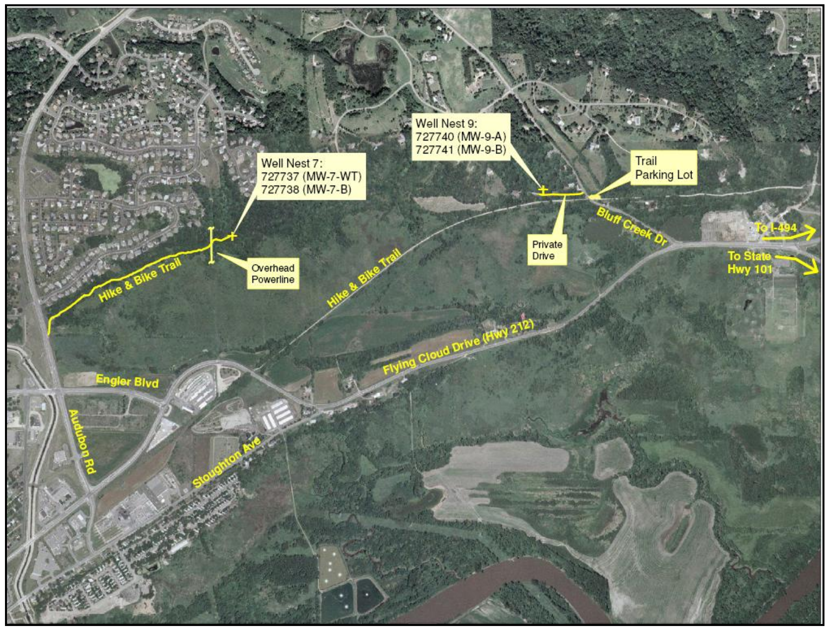
In addition to the calcareous fen areas, there are non-calcareous fen wetlands in the wetland complex. Spring heads are prevalent and coalesce in flows that reach Assumption Creek – a designated trout stream.

System to Monitor Effects of Pumping on Seminary Fen

A partial monitoring system and program are in place for Seminary Fen. This program includes the following:

<u>Potentiometric Levels</u>

Hand-driven piezometers were placed in and around the peat domes of the high-quality calcareous fens in 2007. These piezometers are still present but they likely are not monitored. Two well nests of two wells each were installed upgradient of the fen areas to measure hydraulic heads in unconsolidated deposits adjacent to the fen and monitor vertical hydraulic gradients. These wells are monitored by the Lower Minnesota River Watershed District. A temporary piezometer was installed through the stream bed of Assumption Creek (and showed hydraulic heads that were at least 2 feet above the stream's water surface, indicating strong vertical hydraulic gradients).



The City of Chanhassen is required to install a well nest in the Prairie du Chien-Jordan Aquifer between its wells and Seminary Fen as a requirement to receive a Water Appropriations Permit for a new well. Water levels in this well nest will be monitored by the City. As additional appropriations are permitted in the area, well nests should be added to the monitoring system between the pumping center and the fen area for the purpose of characterizing the potentiometric responses to pumping

Stream-Flow and Spring-Flow Monitoring

Stream flows in Assumption Creek are monitored irregularly and infrequently. Flows from springs are not monitored.

Groundwater Withdrawal Rates

Nearby cities monitor flow rates using SCADA systems and report monthly rates on a per well basis to the DNR as part of the Water Appropriations Permit requirements. It is absolutely critical that ALL high capacity wells in the cities of Chanhassen, Chaska, Eden Prairie, Minnetonka, Victoria, and areas amongst these communities accurately and continuously measure the pumping rates of each well and maintain these records. Flow rates are necessary – not power use or on-off records. In the absence of good pumping records it will be nearly impossible to understand the effects of pumping on the fen.

Other Parameters

An extensive hydrologic and biologic evaluation was conducted on behalf of MnDOT in 2006-2008 as part of a Draft Environmental Impact Statement alternatives evaluation for the Highway 41 Reroute. It was through this study that the site piezometers and well nests were installed. A local groundwater flow model was also developed to evaluate the effects of dewatering during road-bridge construction on the fen hydrology.

The effects of regional pumping on upwelling conditions and groundwater levels at the fen are poorly understood because of the lack of regional data. The installation and monitoring of additional monitoring wells (such as those being installed by the City of Chanhassen) will be important in better understanding cause-effect relationships between pumping and fen hydrology parameters. A key factor will be to begin collecting detailed records of individual well pumping in Chaska, Chanhassen, Eden Prairie and Shakopee. Automated flow gauging of selected spring heads may also prove useful. Continuous water-level measurements in the permanent monitoring well nests at the fen are recommended. The piezometer nest in the high-quality fen/peat dome area should be instrumented with continuous water-level/water pressure recorders.