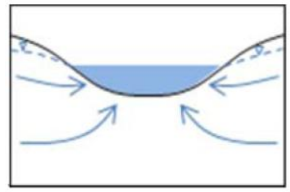
Designated Trout Stream:
Generalized Monitoring Strategy



General Hydrologic Characteristics of Trout Streams

Stream flows in most trout streams in the metro area are predominantly due to groundwater inflows, and the base flow of the stream is equated with the groundwater contribution to the stream's flow. Thus, trout streams are a special type of gaining stream.

The headwaters of these streams are typically formed by the coalescing of flows from several spring heads (e.g., Eagle Creek in Scott County) or concentrated flow from a few discrete springs (e.g., South Branch of Valley Creek). Because groundwater is typically cooler than surface runoff and because the groundwater contribution to baseflow is relatively constant, conditions that are conducive to trout habitat are present.

There are a small number of designated trout streams in the metro area. Examples include: portions of the Vermillion River in Dakota County, Eagle Creek in Scott County, Browns Creek in northern Washington County, Assumption Creek in Carver County, and the South Branch of Valley Creek in southern Washington County.

Minnesota Rule 6264.0050 Subpart 4 lists the reaches of designated trout streams in Minnesota. The "current, course, or cross section" of a trout stream cannot be affected by a water appropriation unless approved by the Commissioner of the DNR. A groundwater appropriation (i.e. pumping) that reduces the baseflow of a trout stream can be (and has been) interpreted as changing the current of the trout stream.

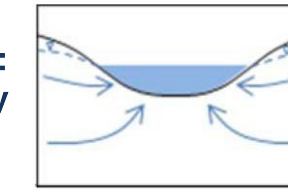
Generalized Monitoring Plan

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

Coordination and Reporting

Monitoring related to trout streams will require coordination with DNR, nearby water appropriators, WMO's (if applicable), 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.

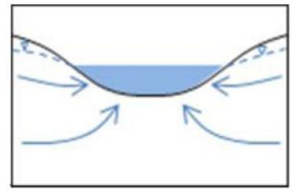


Typical Monitoring Costs

The following are approximate costs for a generalized monitoring program, as described below. 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
Stream Flow □ Headwater site □ Mouth site	Change in stream flow is a key indicator of potential effect on trout habitat.	Hourly or less	2 stream gauging sites	$10,000 to $30,000	Availability of suitable cross-sections; access; stage vs. Doppler measurements	$3,000-$10,000	Need for cross-section maintenance; site maintenance; Manual measurement verification of flow rate
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 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 pumped well(s) and stream □ At headwater stream site	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	$ 25,000 to $80,000	Depth of piezometers; need for well screens (assumes 2-inch diameter piezometers)	$150	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)

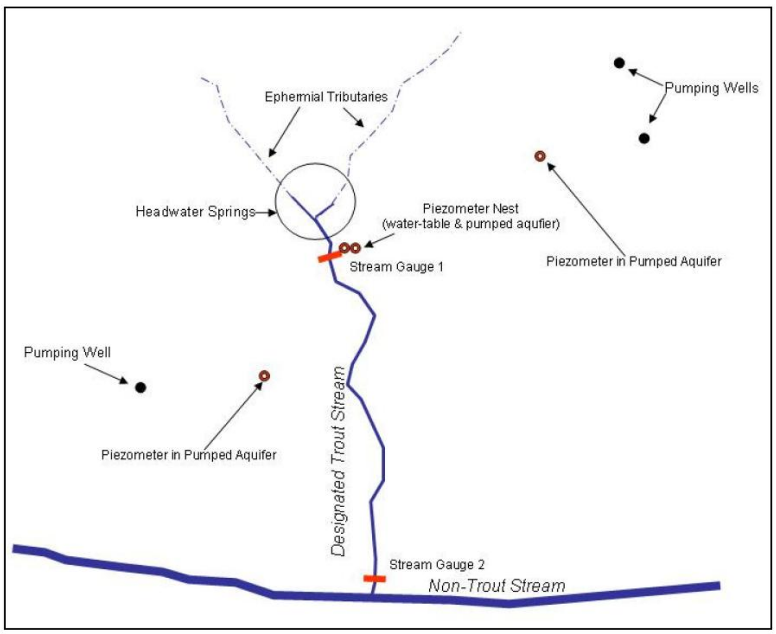
[1]The above costs do not include costs for conducting aquifer testing (which may be a Water Appropriation Permit requirement for a new pumping well). Annual costs include an estimate of staff costs to the well owner for data handling and maintenance.

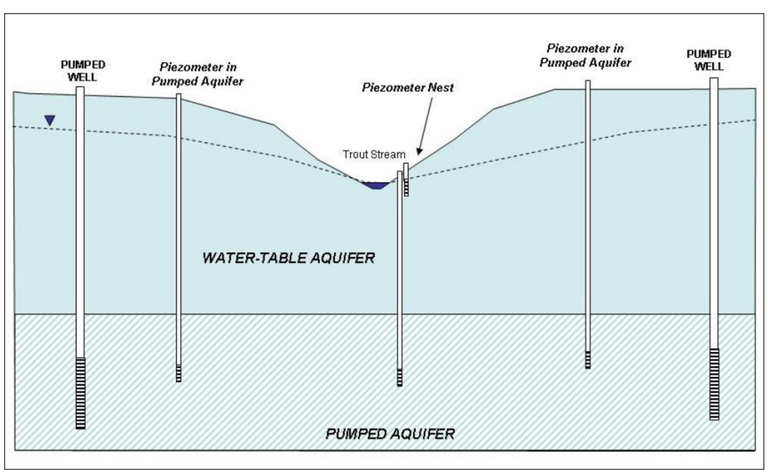


Designated Trout Stream: Generalized Monitoring Strategy

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

(1) Originate as headwater springs where groundwater discharges to the surface and makes up most or all of the baseflow;
(2) Flow toward a larger river that is not a trout stream;
(3) Continue to gain flow (both groundwater and surface water runoff) between the headwaters and the confluence with the larger stream;
(4) Have high capacity groundwater pumping in the region near the trout stream (in this example, pumping wells on either side of the trout stream); and
(5) Pumping is from an aquifer deeper than the surficial water-table aquifer.





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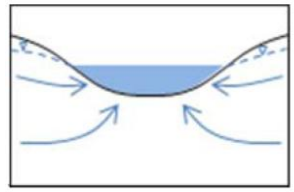

A generalized monitoring system and program consists of the following:

Stream-Flow Monitoring
Purpose
Gauging at appropriate locations will generate data on: (1) headwater spring contribution to baseflow (and temporal variability); (2) groundwater contribution to baseflow along the remainder of the trout stream reach; (3) relative contribution of groundwater from headwaters and remainder of stream reach; and (4) contribution of surface-water inflows and duration of hydrograph influence. Long-term collection of this data provides information on changes in stream flow, a key indicator of potential effect on trout habitat.

Location(s)
Continuous stream flows measurements should be made at two gauging locations: below the headwaters spring area and near the confluence with the larger stream.

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
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 and/or flows into/out of surface-water bodies, pumping must induce drawdown. But, it is important to understand that the absence of observed drawdown effects near gaining surface-water 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 gaining feature without ever inducing measurable drawdown in the groundwater system at the gaining feature.

Data from piezometers located between pumping centers and the trout stream 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 from the headwaters springs. 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 stream flow 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 piezometer be installed approximately midway between each pumping center (i.e. well field) and the trout stream and completed in the pumped aquifer.

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 near the up-stream gauging station. While multiple piezometer nests would be desirable, a single nest located on either side of the stream should be sufficient, no matter how many pumping centers are near the trout stream.

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 stream and its capability to support trout habitat.

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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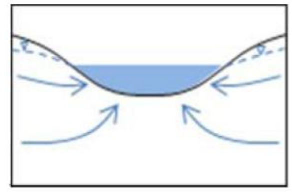
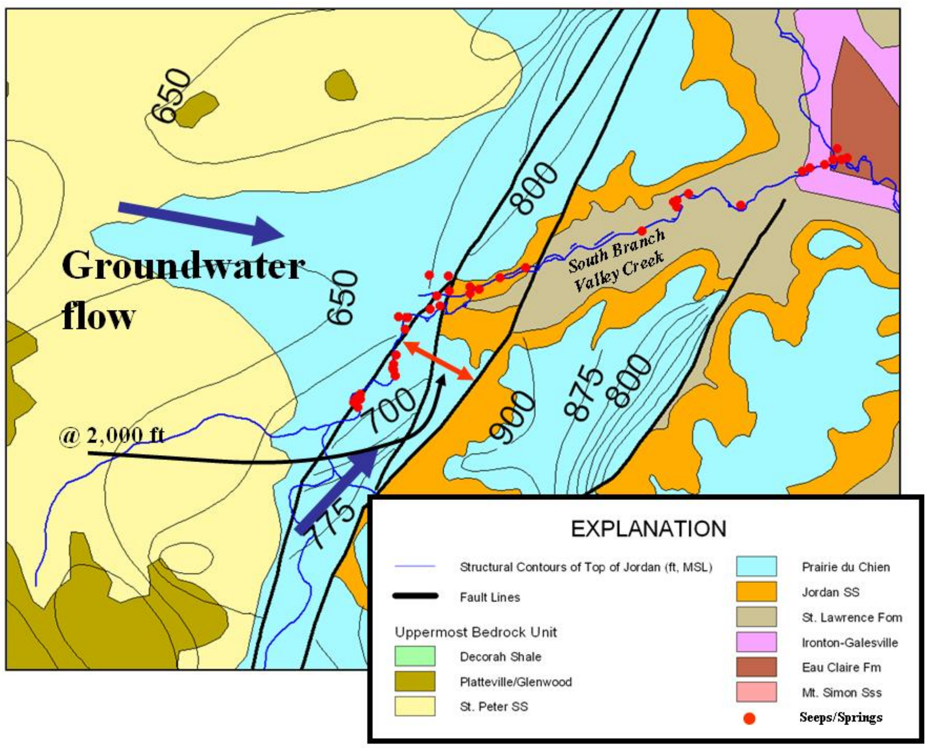


Monitoring Case Study/Example: South Branch of Valley Creek

The headwaters of the South Branch of Valley Creek originate as springs in a pond and bank seepage over a short distance (less than about ¼ mile) downstream of the pond. Baseflow below these seeps and springs is about 4 to 4.5 cubic feet per second. There is very little additional baseflow contributing to the South Branch along the remainder of the reach, downstream to the confluence with the North Branch of Valley Creek.



Stream-flow monitoring by Valley Branch Watershed District, the Science Museum of Minnesota, and by Bonestroo for the City of Woodbury indicates that stream flow is almost entirely baseflow from groundwater except during storm events and spring runoff. Hydrograph peaks during storm events are short-lived due to the small watershed area.

Bedrock in the vicinity of the South Branch of Valley Creek is relatively shallow (5 to 20 feet below ground surface). Recent mapping and borehole interpretations by the Minnesota Geological Survey have delineated northeast-southwest trending fault zones in the bedrock, causing vertical off-sets of geologic units. There appears to be a correlation between the location of the fault zones, the presence of more-permeable bedrock units, and the location of the majority of springs and seeps at the headwaters of Valley Creek. One interpretation is that groundwater is flowing from west to east in the more permeable Prairie du Chien Group and Jordan Sandstone, encountering the fracture zones (and lower permeability rocks, such as the St. Lawrence Formation), and discharging as springs along the fault lines. Additional groundwater contributions to the stream flow may be coming from deeper permeable units (such as the Ironton-Galesville Sandstones and the Mt. Simon-Hinckley Sandstones) up through the fault zones.

System to Monitor Effects of Pumping on Valley Creek

A monitoring system and program is already in place for the South Branch of Valley Creek. This program includes the following:

<u>Stream-Flow Monitoring</u>

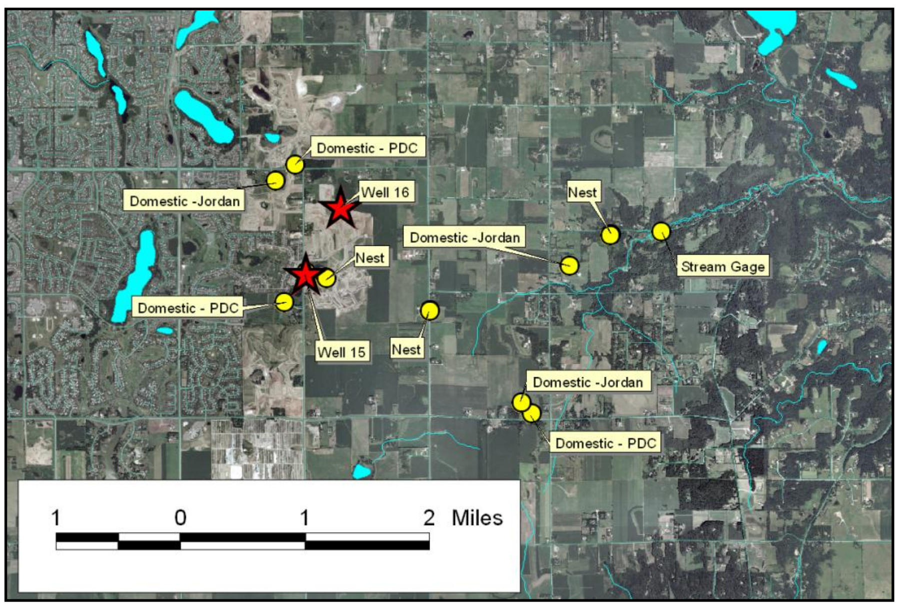
Stream flows are monitored by recording river stage and periodic stream-flow monitoring with hand-held meters at a cross section downstream of the major spring-seep area. A record of approximately three years has been established. Recent review of the monitoring program has determined that more precise (and automated) stream-flow measurements are needed, along with a more stable stream cross section. Doppler flow measurement devices are being evaluated.

<u>Groundwater Withdrawal Rates</u>

The City of Woodbury's municipal wells are closest to the headwaters of Valley Creek. The City of Woodbury has a SCADA system to monitor pumping rates of individual wells in real time.

<u>Potentiometric Levels</u>

Several well nests have been installed between the City of Woodbury's East Wellfield and the headwaters of Valley Creek. Well nests include wells completed at the water table, in the Prairie du Chien Group, and in the Jordan Sandstone (the pumped aquifer unit). Continuous water-level recorders are installed in these wells.



<u>Other Parameters</u>

The City of Woodbury conducted two long-term (greater than 30-day duration) aquifer tests at high pumping rates using two wells (Wells 15 and 16), accompanied by groundwater-level measurements in monitoring wells, groundwater level measurements in selected domestic wells, and stream-flow measurements in Valley Creek. The data from these tests were used to construct groundwater flow models, which continue to evolve as new data are collected. The groundwater flow models are used to assist in the interpretation of data and to plan new data collection activities. To date, there has been no established correlation between observed stream-flow reductions and pumping.