Minnesota Pollution Control Agency

Baseline Water Quality of Minnesota's Principal Aquifers

Ground Water/May 1998

G W M A P

Ground Water Monitoring and Assessment Program

In March 1998, the Minnesota Pollution Control Agency (MPCA) released a report, “Baseline Water Quality of Minnesota’s Principal Aquifers,” that provides data about the quality of the state’s ground water resources. This fact sheet summarizes the study and provides contacts for more information.

What is the baseline study?

The baseline study is an assessment of ground water quality in Minnesota’s principal aquifers. The objectives of the study were to determine background water quality of the state’s principal aquifers and identify factors that affect ground water quality.

How was the study conducted?

Samples were collected from domestic wells using a statewide grid, with a distance of 11 miles between each grid node. Each aquifer identified at a grid node was sampled. Sampling included 47 inorganic chemicals and five field parameters, volatile organic compounds (VOCs), and some sampling for tritium (a radioactive isotope) and pesticides. A total of 954 wells were sampled statewide.

What information did the study generate?

Summary statistics were generated for each chemical in Minnesota’s principal aquifers. This includes mean, median, maximum, minimum, 95th percentile, and 95th percent confidence limit concentrations. For aquifers with more than 15 samples, these data serve as background concentrations.

Factors affecting water quality were identified for each chemical and aquifer. Some of the more important conclusions are listed below.

- Water quality in glacial drift aquifers was generally good but varied widely, with arsenic, manganese, iron, and nitrate concentrations locally being at high concentrations.
- Water quality in Cambrian and Ordovician aquifers of southeast Minnesota was good, except in those areas where the aquifers appeared to be poorly protected by overlying glacial deposits.
- Water quality in the Cretaceous and Sioux Quartzite aquifers generally was poor due to high concentrations of sulfates, boron, dissolved solids (including hardness), and, in some cases, nitrate and manganese.
- Water quality in Precambrian aquifers depends on the type of soil or bedrock and ranged from poor in North Shore Volcanics (high boron, manganese, and beryllium concentrations) to good in crystalline bedrock aquifers.

Concentrations of most chemicals were higher in the western part of the state. This reflects increased time that the water has been in the ground, decreased recharge, and differences in parent material toward the west. Similar but less significant relationships were observed in the southern part of the state. Nitrate, iron, manganese, arsenic, and boron were among the chemicals most strongly correlated with oxidation-reduction potential (redox) conditions in

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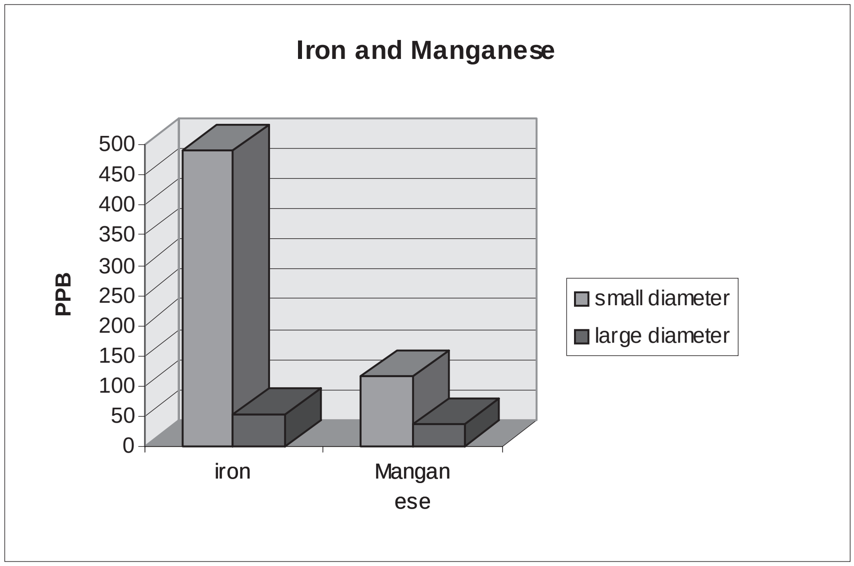
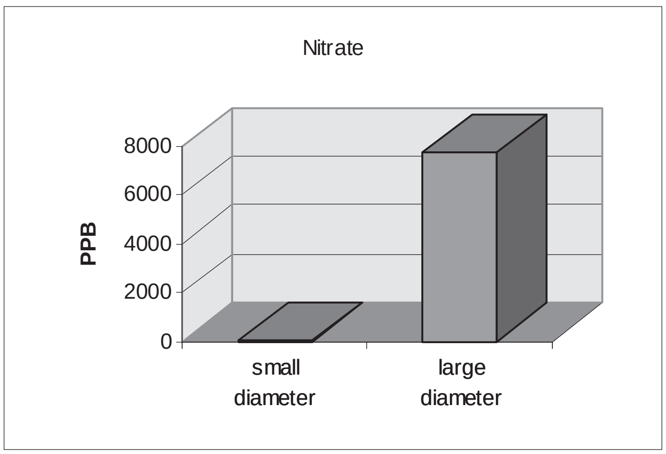
ground water. Nitrate concentrations were greatest in oxygen-rich, high redox waters, while iron, manganese, arsenic, and boron all increased as redox potential decreased.

Well diameter significantly affected water quality. The effect of well diameter was related to changes in redox conditions near large-diameter compared to small- diameter wells. Large-diameter wells had oxygen-rich, high redox water, which leads to elevated concentrations of nitrate and lower concentrations of iron and manganese compared to smaller-diameter wells. Large-diameter wells do not represent a major threat to an aquifer's water quality, despite these findings.





Risk to ground water users was low for most aquifers and chemicals. The percentage of samples exceeding health-based drinking criteria was 8.7, 4.1, 3.3, and 2.3 for boron, manganese (using a standard of 1000 ug/L), nitrate, and beryllium, respectively. The percentage of samples exceeding their Maximum Contaminant Level (MCL) or Secondary Maximum Contaminant Level (SMCL) was 67.9, 6.5, and 3.7 for iron, aluminum, and sulfate, respectively. VOCs were detected in 11 percent of the wells, but there were only four exceedances of health-based drinking water criteria. The most common VOCs were chloroform (47 detections), toluene (26), xylene and benzene (13 each), di-, tri-, and tetrachoroethene (3, 5, and 4, respectively), and various chlorofluorocarbons (10). Atrazine was detected in two wells at concentrations below the drinking water standard.

Analysis of individual parameters included an assessment of natural and anthropogenic sources for each chemical, the fate of chemicals in soil and ground water, factors affecting the observed distribution of chemicals in groundwater, and geochemical controls on distribution of chemicals in ground water.

Who can use information from this study?

The report is technical, but water planners can use the baseline information to better understand factors that may influence ground water quality. The 'Summary Statistics' and the 'Factors Affecting Ground Water Quality' sections of the report should help local water planners put what they already know about the local system into a larger context and determine if their area falls within expected ranges for parameters of concern. This document also contains information that should improve planners' understanding of the vulnerability and condition of their aquifer. This includes discussions of what parameters are of concern, which of those are naturally occurring, and which can be affected by human activity. This information can also be used to improve individual monitoring plans to get meaningful local information. Technical staff can use the baseline data to assess background conditions for aquifers and obtain information that may help make site decisions. The baseline document includes geochemical information that may help hydrogeologists to understand the conditions in certain aquifers. Another application is using the information to make risk-based decisions. Example scenarios of how this might be helpful are included in the full report in the summary and examples sections.

Managers can use the baseline data to better understand ground water quality issues. It also will help managers to understand potential risks to receptors and know what areas would benefit from ground water protection programs. The statistical summaries define background values for each aquifer, providing a context for particularly valuable data for managers at sites that are potentially contaminated. Thus, higher or lower values than background can be investigated and assessed. Also, chemicals with the greatest risk of exceeding the various drinking water criteria have been identified for the principal aquifers. This information will help managers make informed decisions about risk, aquifer use, and resource protection.

What doesn't the study tell us?

For aquifers in which less than about 15 wells were sampled, the summary data should not be used as background information unless additional data from other sources exist for the aquifer of concern.

Most sampled wells were completed in the middle and lower portions of aquifers. The data therefore do not provide a good picture of water quality in the upper portions of these aquifers. This will be of most concern for unconfined aquifers which receive direct recharge, such as unprotected areas of the Prairie du Chien and Jordan aquifers, fractured bedrock aquifers near the land surface, and surficial drift aquifers. GWMAP is conducting an increasing amount of monitoring in shallow systems to fill in these data gaps.

Samples were not filtered. The samples provide a good indication of what is being consumed by humans, but geochemical interpretations are difficult. The greatest concern is with chemicals which were highly correlated with suspended solids, such as iron and manganese.

Seasonal and spatial effects are unknown. Seasonal effects on water quality should be small, since most samples were from deeper portions of the aquifers. Assessing spatial patterns would require a denser sampling network and knowledge of geologic materials. Spatial effects are best studied in small geographic areas for naturally-occurring chemicals which pose a potential water quality concern.

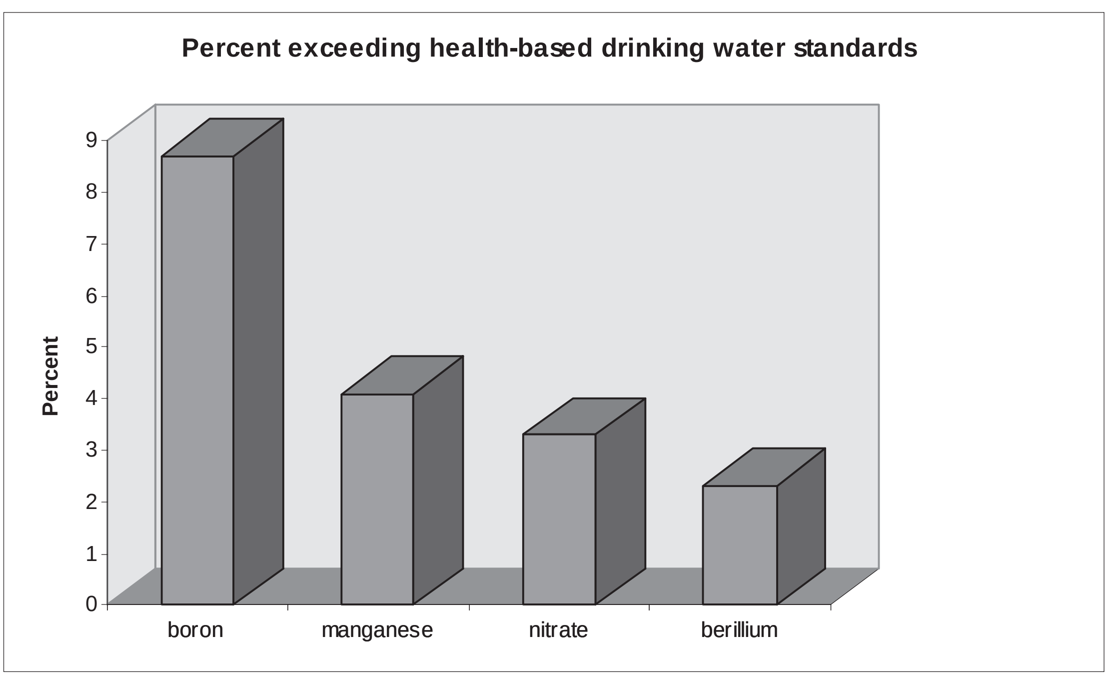
What is the future of the baseline study?

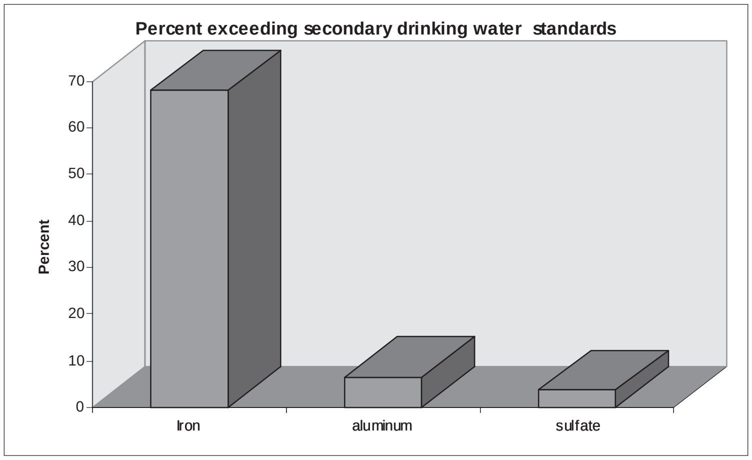
Because background water quality should not change over time, there is no need to continue the baseline program at the same level. However, the following components of a statewide baseline program should be established.

Additional samples should be collected from the Sioux Quartzite, Cedar Valley, Mt. Simon, Hinckley, St. Lawrence, and Franconia aquifers. The final sample size for these aquifers should be approximately 20. These samples do not need to be collected within GWMAP grids. Upon completion of the additional sampling, the data should be reanalyzed and new summary statistics generated.

A statewide baseline database should be established and maintained in a central location. Some of the key features of this database are listed below.

- Minimum quality assurance/quality control (QA/QC) criteria need to be established for data entered into the database.
- Additional fields should be created for the data, including land use.
- Data from non-GWMAP past and future studies should be entered. Other likely data sources include US Geological Survey investigations, Minnesota Geological Survey and Department of Natural Resources studies including county atlases and regional assessments, and regional data.
- Data from regulated sites should be entered when the data are considered to represent background (i.e. upgradient wells) water quality.





- Data should be reanalyzed at approximately 10-year intervals.

What is the difference between ambient and baseline data?

Baseline provides a snapshot of water quality at a particular point in time. It is used as a point of reference and can therefore be considered to represent a background condition. This concept works well for naturally-occurring chemicals, because concentrations of these chemicals in ground water should change slowly, if at all. For aquifers affected by human activity, a different approach is needed because water quality may change in response to human activity.

An ambient program also provides a snapshot of water quality at a particular point in time, but when measured over several different times, trends in water quality can be assessed. An ambient program therefore measures several "baselines" to determine if they are equal. If they are not, then ground water quality is changing. Another difference between baseline and ambient is that only chemicals which may be expected to change in response to human activity are sampled in an ambient design. Examples include nitrate and VOCs. If water quality is changing, the following questions need to be answered.

- Is water quality getting better or worse?
- What is the lateral and vertical extent of change within the aquifer?
- What will the water quality be when change ends?
- What factors are contributing to change?
- What human activities can be implemented to maintain or improve water quality at a sustainable level for human consumption?

The following aquifers are potentially sensitive to human activity.

- Surficial drift aquifers.
- Bedrock aquifers with thin cover of glacial materials.
- Karst bedrock.
- Fractured bedrock near the land surface.
- Deeper aquifers which are extensively pumped, thus inducing flow of ground water from more sensitive aquifers.

Ambient monitoring networks should be established in areas mapped as being hydrologically sensitive. The principal components of such networks are listed below.

- Wells should be completed at the water table and at receptor points. The shallow wells are designed to identify impacts in the most sensitive portions of the aquifer; the receptor wells identify the risk to humans.
- Monitoring points should be located so that spatial analysis of the data can be conducted. Separation distances between wells will vary with the sampling location and may require some preliminary sampling from temporary and existing wells.
- Conduct quarterly sampling for at least four years or until seasonal variations can be quantified. Sampling may then be reduced to once or twice a year.
- Sample parameters include the chemicals of concern for the aquifer being sampled and field parameters. Most monitoring programs will also include sampling for major cations and anions and the redox parameters (field Eh and dissolved oxygen, reduced iron and manganese, total and dissolved organic carbon, sulfate, and nitrate).
- Field sampling, laboratory QA/QC, data storage, and data analysis procedures must be documented
- Completion of an annual report is required.

Where can I get more information or data?

Additional reports, information, and presentations will be prepared during the ensuing months to reach all potential audiences.For further information, contact Tom Clark (project coordinator, 612-296-8580) or Mike Trojan (technical analyst, 612-297-5219). GWMAP reports and data can be mailed electronically or found on the MPCA web site at <http://www.pca.state.mn.us>.

GWMAP

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