Current Topics Web Review for Minnesota Ground-Water Projects

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This document was developed to help readers find a select (limited) subset of web pages and online documents that address topics considered to be special, emerging, important or otherwise popular within the category of ‘Minnesota ground water’. It features study approaches, example projects, selected contaminants, issues, concepts, and best management practices for ground-water projects, including planning and management. It was not developed to feature ground-water data or location-specific information. Instead, it was developed as a complement to the Minnesota Ground Water Information Resources component of this guide. This document will not be updated frequently.

IMPORTANT DISCLAIMER
The mention of particular references, procedures, study approaches, etc., within this document does not mean they are approved or recommended by any particular organization. Please refer to the appropriate organizations to determine what they require or recommend.

Several hypertext links below point to documents in Adobe Portable Document Format (PDF). Please download the most recent (free) Adobe Reader® software for viewing PDF documents.

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ESTIMATING SURFACE WATER CONTRIBUTION TO GROUND WATER RECHARGE... (MPCA)

The Minnesota Pollution Control Agency (MPCA) conducted a study (report is in PDF format) in 2000 and 2001 to determine the contribution of Spring Creek to recharge of the Verdi aquifer in southwest Minnesota. The Verdi aquifer is in a designated source water management area. The management area includes a large portion of the Spring Creek watershed because the creek may contribute to ground water recharge. Three methods were used to estimate recharge from Spring Creek: water mass balance, chloride mass balance, and distribution of stable isotopes of oxygen and hydrogen. Estimated recharge was about 16 percent with water mass balance, 27 percent with chloride mass balance, and 13 percent using stable isotopes.

SISEEBAKWET LAKE GROUND WATER AND SURFACE WATER INTERACTION STUDY (MPCA)

Lake Conditions In 1999 and Historical Trends in Lake Characteristics with an Emphasis on the Impacts of Ground Water and Surface Water Interactions on a Marl Lake.

This detailed report (in PDF format) answers questions such as the following:

- How can you calculate what % of lake water comes directly from ground water?
- How can local hydrogeology and climate change control lake transparency?
- What else besides algae can cause lakes to change color?
- What is a marl lake and how is it created?

GROUND WATER DISCHARGE TO SURFACE WATER AT CONTAMINATION SITES (MPCA)

This web page outlines several existing methods to assess the zone of interaction between ground and surface water. These methods measure temperature and head differences between surface and ground water, and determine seepage between the two.

GROUND-WATER RECHARGE AND DISCHARGE (MPCA, GWMAP)

This report (in PDF format) features ground-water recharge and discharge (including ground water-surface water interactions). A brief discussion, links and summary of two studies. Text prepared by the MPCA Ground-Water Monitoring and Assessment Unit (GWMAP), undated.
DNR GROUND WATER TECHNICAL ANALYSIS PROGRAM

The DNR Ground Water Technical Analysis Program conducts ground water-surface water investigations. Ground water withdrawals can decrease water levels and decrease flow in springs, streams, lakes and wetlands. Such impacts usually take a much longer time to become evident than do water level changes within the pumped aquifer itself.

CALCAREOUS FEN STUDIES (DNR)

Minnesota Department of Natural Resources Ground Water Technical Analysis Program.

LAKE-GROUND WATER INTERACTION AT WHITE BEAR LAKE, MINNESOTA

A 1998 publication, Lake-Ground Water Interaction at White Bear Lake, Minnesota, is a 93-page, detailed report that includes data presentation, in-depth analysis, photos and numerous charts and figures.

WASHINGTON COUNTY STUDIES.

Visit the Groundwater page of the Washington County website to access study results of a groundwater and surface water project or open the document directly here: Integrating Groundwater & Surface Water Management -Northern Washington County, 2003 (PDF format). In addition Washington County has a Groundwater/Surface Water Management web page.

LAKES IN THE HYDROLOGIC SYSTEM -- THEIR RELATION TO GROUND-WATER (USGS)

This web page by the United States Geological Survey National Research Program is about the “Role of Lakes in the Hydrologic System, with Emphasis on Their Relation to Ground-Water”. The major objective of the problem of lake hydrology research is to gain understanding of the basic principles controlling the interaction of lakes and ground water, including associated chemical fluxes. The project emphasizes integration of theoretical and experiment field work. Although research emphasis is on ground water, the project includes state-of-the-art studies of the atmospheric and surface-water components of lake hydrology, as needed in the evaluation of the ground-water component.

This web page features a substantial list of recent publications, many of which include links to online abstracts or reports. Some of these online publications address Minnesota locations:

- The significance of ground water to the accumulation of iron and manganese in the sediments of two hydrologically distinct lakes in North-Central Minnesota
- Exchange of water, solutes, and nutrients (in PDF format) at the sediment-water interface affects a northern Minnesota watershed at multiple scales
- Characterization of lake and ground water movement in the littoral zone of Williams Lake, north-central Minnesota
- Mid-Holocene hydrologic model of the Shingobee watershed, Minnesota [the link to this abstract is only valid on the main web page: go to the main page and search, find or look for the abstract title to find the link]
- Malformed frogs in Minnesota
- Plants as indicators of focused ground water discharge to a northern Minnesota Lake
INTERACTION OF GROUND WATER AND STREAMS IN MINNESOTA (USGS)

This United States Geological Survey web page presents a very brief discussion on interaction of ground water and streams in Minnesota. (This content was reportedly circa 1996 at the time of this writing; see previous USGS entries for more recent information.) The quantity and quality of streamflows in most of Minnesota are controlled by ground water during periods of low rainfall. State and local agencies are concerned about the effects of ground-water withdrawals on streamflow and stream-water quality. There also is concern that contamination within the aquifers or the streams could adversely affect public water supplies. Water managers can benefit from additional information about how streams are affected by ground-water withdrawals from adjacent aquifers and about how poor water quality in these aquifers affects streams.

BENTHIC-FLUX CHAMBER FOR MEASUREMENT OF SEEPAGE RATES AND WATER SAMPLING (USGS)

This web page begins with an abstract of "Development of a Benthic-Flux Chamber for Measurement of Ground-Water Seepage Rates and Water Sampling for Mercury Analysis at the Sediment-Water Interface". Scroll down the web page for a hypertext link to the full report. The benthic-flux chamber was successfully used to measure the rate of ground water seeping to surface water or surface water seeping to ground water, and to collect water samples for mercury analysis from the sediment/water interface in a lake setting.

GROUND-WATER/SURFACE-WATER HYDROLOGY - CURRENT STUDIES IN MINNESOTA (USGS)

This web page provides brief overviews of current United States Geological Survey studies in Minnesota that emphasize “Ground-Water/Surface-Water hydrology”.

SELECTED GENERAL REFERENCES

GROUND WATER AND SURFACE WATER A SINGLE RESOURCE (USGS)

This is a highly recommended 1998 publication by T.C. Winter, J.W. Harvey, O.L. Franke and W.M. Alley. "Surface water commonly is hydraulically connected to ground water, but the interactions are difficult to observe and measure"

As the Nation's concerns over water resources and the environment increase, the importance of considering ground water and surface water as a single resource has become increasingly evident. Issues related to water supply, water quality, and degradation of aquatic environments are reported on frequently. The interaction of ground water and surface water has been shown to be a significant concern in many of these issues.

GROUND-WATER AND SURFACE-WATER INTERACTIONS (USGS)

This part of the USGS Ground Water Information Pages focuses on ground-water and surface-water interactions. Traditionally, management of water resources has focused on surface water or ground water as if they were separate entities. As development of land and water resources increases, it is apparent that development of either of these resources affects the quantity and quality of the other. Nearly all surface-water features (streams, lakes, reservoirs, wetlands, and estuaries) interact with ground water.
HYDROCHEMICAL PROCESSES AT THE GROUND WATER-SURFACE WATER INTERACTION ZONE  
(US EPA)

This United States Environmental Protection Agency (US EPA) web page provides links to 
several studies that focus on ground-water and surface-water interactions. Ground-water discharge to surface water is recognized as an important process governing contaminant fate and transport and ecosystem viability within watersheds. Reliable assessment of long-term patterns of the chemistry and hydrology in watersheds under the influence of ground water discharge is dependent on establishing a monitoring strategy that captures both the spatial and temporal dynamics of processes occurring at the ground water-surface water (GW-SW) interaction zone.

KNOW YOUR WATERSHED CAMPAIGN

The Know Your Watershed campaign, coordinated by the Conservation Technology Information Center Presents a very nice online guide for watershed partnerships entitled Groundwater & Surface Water: Understanding the Interaction. Groundwater is a hidden resource. At one time, its purity and availability were taken for granted. Now contamination and availability are serious issues. Some interesting facts to consider …

- Scientists estimate groundwater accounts for more than 95% of all fresh water available for use.
- Approximately 50% of Americans obtain all or part of their drinking water from groundwater.
- Nearly 95% of rural residents rely on groundwater for their drinking supply.
- About half of irrigated cropland uses groundwater.
- Approximately one third of industrial water needs are fulfilled by using groundwater.
- About 40% of river flow nationwide (on average) depends on groundwater.

GROUND-WATER/SURFACE-WATER INTERACTIONS WORKSHOP (U.S. EPA, JULY 2000)


- Part 1
- Part 1
- Part 3

PLEASE NOTE: Some references in the Ground-Water Supply and Sustainability section overlap with this topic; in particular, you might want to review Ground-Water Withdrawals On The Rock River & Valley Aquifer (USGS) further below.
Karst is an efficiently drained landscape that forms on soluble rock. Karst is characterized by caves, sinkholes, a lack of surface drainage and other climatically controlled features, and is mainly, but not exclusively, formed on limestone. Karst features arise when rain falls and infiltrates the soil -- where the availability of carbon dioxide causes the formation of weak carbonic acid. If the slightly acidic soil water never reaches soluble bedrock, nothing happens. But if is able to move into contact with soluble carbonate rocks, dissolution occurs, with calcium, magnesium and bicarbonate ions as byproducts.

Karst characteristics make southeastern Minnesota water resources most challenging to protect. Petroleum and other chemicals released from underground storage can quickly move into ground water supplies. Manure released from agricultural spills can cause fish kills many miles from the release point. Chemicals used on the landscape can reappear at unexpected times and in unexpected locations. Read more about Karst in Minnesota.

Ground Water Investigations In Karst Areas (MPCA Petroleum Remediation Program)

This guidance document (in PDF format.) outlines procedures and techniques that should be used to implement accurate, reliable, and cost-effective ground water investigations in karst areas. Hydrogeologic characteristics depart significantly from those of porous media in karst aquifers. Variances from conventional hydrogeologic site characterization practices are therefore necessary in karst areas, due to the presence of hydrogeologic features and properties that cannot be characterized by porous media approximations.

SOUTHEAST MINNESOTA WATER RESOURCES BOARD

Navigation note: You may have to click on the ‘Karst’ link in the left margin of this web page to view the material related to karst and karst features. This web site has hypertext links to other web pages with good information about karst, ground water, geology and more.
This web site is about Karst Features of Minnesota. Southeastern Minnesota is part of the Upper Mississippi Valley Karst (Hedges and Alexander, 1985) that includes southwestern Wisconsin and northeastern Iowa. Karst lands in Minnesota are developed in Paleozoic carbonate and sandstone bedrock. A significant sandstone karst has developed in Pine County. Most surficial karst features such as sinkholes are found only in those areas with less than fifty feet of sedimentary cover over bedrock surface.

Since the early 1980s, the Minnesota Geological Survey and Department of Geology and Geophysics at the University of Minnesota have been mapping karst features and publishing various versions of their results in County Geologic Atlases. Now, a karst feature database of Southeastern Minnesota has been developed that allows sinkhole and other karst feature distributions to be displayed and analyzed across existing county boundaries in a GIS environment.

This web site features The Karst Campaign for Clean Water, Productive Soil, and Profitable Farms. The overall goal of the "Karst Campaign" is to promote clean water, productive soil, and profitable farms through a comprehensive educational strategy targeted for the karst region of southeastern Minnesota. The objectives of this project would help local units of government build local capacity to educate agricultural audiences about farming impacts on surface and drinking water in the karst region, and voluntary ways of reducing these impacts consistent with profitable farming.

NATIONAL REFERENCES

U.S. GEOLOGICAL SURVEY - KARST

This part of the USGS Ground Water Information Pages focuses on Karst. Karst is a special type of landscape that is formed by the dissolution of soluble rocks, including limestone and dolomite. Karst regions contain aquifers that are capable of providing large supplies of water. Common geological characteristics of karst regions that influence human use of its land and water resources include ground subsidence, sinkhole collapse, groundwater contamination, and unpredictable water supply.

KARST WATERS INSTITUTE

The Karst Waters Institute (KWI) is a 501 (c)(3) non-profit institution whose mission is to improve the fundamental understanding of karst water systems through sound scientific research and the education of professionals and the public.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Ground-Water Monitoring in Karst Terranes (in PDF format). The hydrology of karst terranes is significantly different from that of non-karst terranes. Accordingly, the monitoring techniques necessary for reliable, accurate assessment of their ground-water quality are significantly different. In this light, Dr. James F. Quinlan wrote ‘Ground-Water Monitoring in Karst Terranes, Recommended Protocols & Implicit Assumptions’ in 1989. This document discusses these
techniques, recommends ways to solve the special problems posed by monitoring in karst terranes, calls attention to possible regulatory problems, discusses the assumptions made when monitoring, and makes recommendations throughout the text.

OCCURRENCE, FATE, AND TRANSPORT OF CHLORINATED SOLVENTS IN KARST REGIONS (USGS)

This web site features a USGS report on “Preliminary Conceptual Models of the Occurrence, Fate, and Transport of Chlorinated Solvents in Karst Regions of Tennessee”. Published and unpublished reports and data from 22 contaminated sites in Tennessee were reviewed to develop preliminary conceptual models of the behavior of chlorinated solvents in karst aquifers. Chlorinated solvents are widely used in many industrial operations. High density and volatility, low viscosity, and solubilities that are low in absolute terms but high relative to drinking-water standards make chlorinated solvents mobile and persistent contaminants that are difficult to find or remove when released into the ground-water system. In karst aquifers, chemical dissolution has enlarged joints, bedding planes, and other openings that transmit water. Because the resulting karst conduits are commonly too large to develop significant capillary pressures, chlorinated solvents can migrate to considerable depth in karst aquifers as dense nonaqueous-phase liquids (DNAPL's). Once chlorinated DNAPL accumulates in a karst aquifer, it becomes a source for dissolved-phase contamination of ground water. A relatively small amount of chlorinated DNAPL has the potential to contaminate ground water over a significant area for decades or longer.

GROUND-WATER POLLUTION SENSITIVITY AND TIME OF TRAVEL

MINNESOTA DEPARTMENT OF NATURAL RESOURCES

The Minnesota Department of Natural Resources (DNR) defines a sensitive area as a geographic area characterized by natural features where there is significant risk of ground-water degradation from activities conducted at or near the land surface. Sensitivity assessments are based on the geologic and hydrogeologic factors that affect the ability of geologic materials to restrict the downward migration of contaminants to the ground water of interest. This approach is called geologic sensitivity.

The pollution sensitivity of an aquifer is assumed to be inversely proportional to the time of travel which is the approximate time that elapses from when a drop of water infiltrates the land surface until it enters an aquifer or reaches a specific target such as a spring. Shorter travel times may indicate higher sensitivity and longer travel times may indicate lower sensitivity. Very High sensitivity indicates that water moving downward from the surface may reach the ground-water system within hours to months. In these areas, there is little time to respond to and prevent aquifer contamination.
MINNESOTA POLLUTION CONTROL AGENCY

In 1999, the Minnesota Pollution Control Agency (MPCA) published a brief report entitled *Estimating Ground Water Sensitivity to Nitrate Contamination* (in PDF format). They studied how ground-water geochemistry affects the occurrence and mobility of nitrate. The data suggest a chemical process called denitrification is important in determining whether or not nitrate contamination of ground water is likely to occur in a particular area. Denitrification reduces potential negative effects on drinking water or surface water receptors by reducing nitrate. Therefore it appears that assessment of ground water chemistry for denitrification potential (called “geochemical sensitivity” in this report) can be a more useful tool for aquifer management than simple estimates of hydrologic sensitivity -- at least when attempting to predict the fate of nitrate.

UNITED STATES GEOLOGICAL SURVEY

To read about the use of chlorofluorocarbons (manmade freons used mainly as refrigerants) as environmental tracers in conjunction with geologic and hydrologic information to provide a better understanding of the link between land use and the water quality in an underlying surficial sand and gravel aquifer, see the following 1997 report in PDF format: *Ground-Water Age Dating and Other Tools Used to Assess Land-Use Effects on Water Quality*.

WELLHEAD PROTECTION

MDH SOURCE WATER PROTECTION PROGRAM

*Wellhead protection* is part of the *Source Water Protection program* at the Minnesota Department of Health (MDH). You can also read about *Security Assessment of Public Water Supplies* and keeping our drinking water supplies safe from terrorists and other vandals.

MDA DRINKING WATER PROTECTION

The Minnesota Department of Agriculture (MDA) has a web page featuring *Drinking Water Protection in Agricultural Areas*. This page includes wellhead protection case studies, drinking water protection fact sheets and numerous hypertext links to Resources for wellhead Teams and agricultural advisors.

EPA SOURCE WATER PROTECTION

This United States Environmental Protection Agency (EPA) *Source Water Protection* website has basic information about the water used for drinking water and the federal, state, and local programs that assess and manage potential public health risks, including a Web Guide - an annotated guide to EPA source water resources.

The EPA also offers a *Source Water Web Guide*. This web-guide is a selected and very partial collection of available source water protection tools for community planners, public water supply operators, members of local source water protection teams, and anyone interested in protecting their sources of drinking water.
METHODS FOR DELINEATING WELLHEAD PROTECTION AREAS (EPA)

This United States Environmental Protection Agency web page features a literature review of methods for delineating wellhead protection areas.

THE GROUND WATER PROTECTION COUNCIL

The Ground Water Protection Council (GWPC) is a national association of state ground water and underground injection control agencies whose mission is to promote the protection and conservation of ground water resources for all beneficial use, recognizing ground water as a critical component of the ecosystem.

GROUND-WATER SUPPLY AND SUSTAINABILITY

MINNESOTA DEPARTMENT OF NATURAL RESOURCES (DNR)

SUSTAINABILITY OF MINNESOTA'S GROUND WATER (DNR)

Much of Minnesota is naturally endowed with good supplies of ground water. However, those supplies are not evenly distributed in the state nor are they limitless. Overpumping of wells causes continued declines of ground water levels in aquifers, local impacts on streams and wetlands, and the potential that needed ground water resources would not be available for future use. Ground water withdrawal that results in unacceptable impacts on the resource is not sustainable.

This web page includes hypertext links to a (June 2005) “Statement of Issues and Needs” and a series of supporting fact sheets about the sustainability of Minnesota’s ground water.

MINNESOTA’S WATER SUPPLY (DNR)

The DNR publication Minnesota’s Water Supply: Natural Conditions and Human Impacts, published in 2000, highlights the following topics:

- current water budget and human impacts;
- an overview of water resource management concerns that are being addressed statewide and by geographic and hydrogeologic areas;
- current strategies for water supply management, and planning and development suggestions.

DROUGHT OF 1988 (DNR)

A publication entitled, Drought of 1988, published in 1999 by the DNR, provides a useful perspective on the limitations of Minnesota’s water supply.
GROUND WATER TECHNICAL ANALYSIS PROGRAM (DNR)

The DNR Ground Water Technical Analysis Program conducts studies of ground-water availability and ground-water supply and investigates disputes about use of ground water. http://www.dnr.state.mn.us/waters/groundwater_section/tech/index.html.

STATE POLICY, PLANNING AND PRIORITIES FOR WATER RESOURCE ISSUES (EQB)

The Environmental Quality Board (EQB) is charged with coordinating state policy on water resource management issues. Their Water Resources web page includes a description of the EQB’s statutory water resources planning duties including ground water policy; this page also has hypertext links to important documents such as the following:

- Minnesota Water Marks 2000 - 2010 (10-year State Water Plan)
- Protecting Minnesota’s Waters (Biennial water priority report)

Additional publications, including older publications and media releases, etc. can be found on their Water Policy web page.

METROPOLITAN COUNCIL

BEFORE THE WELLS RUN DRY

The Metropolitan Council’s web page entitled Before the Wells Run Dry includes a discussion about water supply and demand, an aquifer map, a generalized regional hydrogeologic cross section and a sidebar featuring Water Supply Facts.

WATER RESOURCES MANAGEMENT POLICY PLAN - WATER SUPPLY SECTION

From this web page, you should be able to access the ‘Water Supply’ section of the ‘Water Resources Management Policy Plan’. As of May 2005, this web page featured the 1998 Water Resources Management Policy Plan but had a link (see note with link near the top of the page) to a draft version of the 2004 plan which also included a ‘Water Supply’ section.

An excerpt from the 1998 version of the Water Supply section follows. Blessed with large rivers and a natural underground water system 1,000 feet thick, the Twin Cities metropolitan area has water in abundance. But if the region's resources are great, so too are its needs. It uses nearly a billion gallons of water daily - a volume of water equal to two and a half Metrodomes for cooling power plants, for drinking and other personal uses, and for commercial and industrial needs. Providing water to areas that will need it presents a long-term challenge facing this rapidly growing metropolitan area. Plentiful, clean water is essential to sustain the region and secure its future growth.

According to an excerpt from the 2004 draft, regional water demand in 2003 totaled over 1.3 billion gallons per day (BGD). Modeled projections for residential, commercial, industrial, institutional and “unaccounted for” water use show a rise of about 29 percent—or about 112 million gallons per day—from 2000 to 2030 due to increases in population and associated economic activity.
WATER SUPPLY PLANNING

The Metropolitan Council is responsible for planning for the regional water supply for the seven-county metropolitan region that includes Minneapolis and St. Paul (Minnesota Statutes Chapter 473.156). The Council has developed short-term and long-term plans for existing and expected water use and supply in the metropolitan area. The Water Supply Planning web page has links to these plans and additional related information. You can also link directly to the selected plans and web pages that are highlighted immediately below.

Water Demand and Planning in the Twin Cities Metropolitan Area (May 2004)

This sixty-eight page report (in PDF format) analyzes water demand, issues and planning conducted for the region, and serves as an update of the water use and supply element of the Council’s Long-Term Water Supply Plan. In 2002, an average of 292 million gallons per day (mgd) of water was used for municipal supply. Other uses, not including power generation, accounted for another 97 mgd. An additional 774 mgd were appropriated for power generation in 2002; however, most of this water was used for cooling and returned to the source at a slightly higher temperature so it is not considered a consumptive use.

Potential limitations on the region’s water supply include lack of access to the Prairie du Chien-Jordan aquifer, adverse impacts of withdrawals and contamination. A thorough assessment of the ability of supplies to meet demands is typically conducted only where a problem has occurred or is likely to occur. Additional studies are necessary to determine the full limitations of the region’s water supply system.

Projected Water Demand for the Twin Cities Metropolitan Area (February 2001)

For an estimate of future water-supply demands in the Twin Cities area, see the 2001 report by the Metropolitan Council entitled Projected Water Demand for the Twin Cities Metropolitan Area in PDF format.

SOUTHWEST METRO GROUNDWATER WORK GROUP

During the early-mid 1990s the communities in the southwest metro area were facing difficulties obtaining regulatory approval for additional appropriation of groundwater to supply their growing needs. The central issue was the potential impact of groundwater withdrawals on sensitive surface water features in the southwest metro area, primarily the Savage Fen, Boiling Springs, and Eagle Creek. In 1997, the Southwest Metro Groundwater Work Group (SMGWG) was formed to address these issues.

UNITED STATES GEOLOGICAL SURVEY (USGS)

WATER AVAILABILITY IN MINNESOTA (USGS)

This United States Geological Survey web page presents a very brief discussion about water availability in Minnesota. Water is a significant economic and recreational resource of Minnesota, making the State well known as “The Land of 10,000 Lakes.” During 1995, about 79 percent of all Minnesotans obtained their domestic supplies from ground water and nearly 750 million gallons of ground water were withdrawn every day. During the past 20 years, ground-water
withdrawals from glacial and bedrock aquifers in Minnesota have increased, particularly for irrigation in areas of sandy soils. Irrigated acreage in many sandy areas increased by a factor of 10 during the 1970's, according to the soil and water conservation districts. Anticipated future changes in land use, population, and economic development also will increase ground-water withdrawals.

GROUND-WATER WITHDRAWALS ON THE ROCK RIVER & VALLEY AQUIFER (USGS)

This report by the United States Geological Survey states that “Increased demand for ground water in southwestern Minnesota has resulted in increased withdrawals from surficial aquifers. The Rock River Valley aquifer is currently the only viable water source for the City of Luverne and the Rock County Rural Water District. Ground-water flow in the aquifer is integrally linked to flow in the Rock River.” This is a 114-page detailed technical report in PDF format: Effects Of Ground-Water Withdrawals On The Rock River And Associated Valley Aquifer, Eastern Rock County, Minnesota.

SUSTAINABILITY OF GROUND-WATER RESOURCES (USGS)

Today, many concerns about the Nation's ground-water resources involve questions about their future sustainability. The sustainability of ground-water resources is a function of many factors, including depletion of ground-water storage, reductions in streamflow, potential loss of wetland and riparian ecosystems, land subsidence, saltwater intrusion, and changes in ground-water quality. Each ground-water system and development situation is unique and requires an analysis adjusted to the nature of the existing water issues. The purpose of this Circular is to illustrate the hydrologic, geologic, and ecological concepts that must be considered to assure the wise and sustainable use of our precious ground-water resources. The report is written for a wide audience of persons interested or involved in the protection and sustainable use of the Nation's water resources.

Resource sustainability has proved to be an elusive concept to define in a precise manner and with universal applicability. In this report, we define ground-water sustainability as development and use of ground water in a manner that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences. The definition of "unacceptable consequences" is largely subjective and may involve a large number of criteria. Furthermore, ground-water sustainability must be defined within the context of the complete hydrologic system of which ground water is a part.

WATER USE IN THE UNITED STATES (USGS)

This web page includes hypertext links to national and regional water use information, guidelines and a handbook for collecting water use information, a water use bibliography for Minnesota and more.

Estimates of water use in the United States indicate that about 408 billion gallons per day (one thousand million gallons per day, abbreviated Bgal/d) were withdrawn for all uses during 2000. This total has varied less than 3 percent since 1985 as withdrawals have stabilized for the two largest uses—thermoelectric power and irrigation. Fresh ground-water withdrawals (83.3 Bgal/d) during 2000 were 14 percent more than during 1985. Fresh surface-water withdrawals for 2000 were 262 Bgal/d, varying less than 2 percent since 1985.
The renewable water supply is the sum of precipitation and imports of water, minus the water not available for use through natural evapotranspiration and exports. Renewable water supply is a simplified upper limit to the amount of water consumption that could occur in a region on a sustained basis. Requirements to maintain minimum flows in streams leaving the region for navigation, hydropower, fish, and other instream uses limit the amount of the renewable supply available for use. Also, total development of a surface-water supply is never possible because of increasing evaporative losses as more reservoirs are used. Nevertheless, the renewable supply compared to consumptive use is an index of the degree to which the resource has already been developed.

**LAND SUBSIDENCE (USGS)**

*Land subsidence* is a gradual settling or sudden sinking of the Earth's surface owing to subsurface movement of earth materials. Subsidence is a global problem and, in the United States, more than 17,000 square miles in 45 States, an area roughly the size of New Hampshire and Vermont combined, have been directly affected by subsidence. The principal causes are aquifer-system compaction, drainage of organic soils, underground mining, hydrocompaction, natural compaction, sinkholes, and thawing permafrost. More than 80 percent of the identified subsidence in the Nation is a consequence of our exploitation of underground water, and the increasing development of land and water resources threatens to exacerbate existing land-subsidence problems and initiate new ones.

**SUSTAINABLE USE - AWWA RESEARCH FOUNDATION**

The Awwa Research Foundation (AwwaRF) is a member-supported, international, nonprofit organization that sponsors research to enable water utilities, public health agencies, and other professionals to provide safe and affordable drinking water to consumers. Foundation-sponsored research has provided guidance to utilities in their efforts to achieve sustainable use. The concept of sustainability – sustainable water supplies, treatment and storage practices, and service – guides the Foundation's research in this area. Sustainability involves both sides of the supply-and-demand equation; utilities must manage their sources, treatment, storage, delivery, and service, while understanding, anticipating, and influencing demand and end uses.

Sustainability on the supply side can mean managing short-term, seasonal fluctuations in supply, planning for extended periods of drought, or a rotation among disparate source waters. On the demand side, sustainability can involve defining end uses, understanding seasonal or demographic variables in demand, as well as crafting conservation rates that achieve predictable results.

**STORMWATER**

**MINNESOTA REFERENCES**

The Minnesota Pollution Control Agency’s (MPCA) Stormwater Program is designed to reduce the pollution and damage caused by stormwater runoff. Mandated by Congress under the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) Stormwater Program is a comprehensive national program for addressing polluted stormwater runoff. Minnesota regulates the disposal of stormwater through State Disposal System (SDS) permits. The MPCA
issues combined NPDES/SDS permits for construction sites, industrial facilities and municipal separate storm sewer systems (MS4s).

The Minnesota Pollution Control Agency has developed a manual, *Protecting Water Quality in Urban Areas*, to help local government officials, urban planners, developers, contractors and citizens prevent stormwater-related pollution.

You might also find the Minnesota Stormwater Steering Committee web page helpful; it includes a list of approximately 30 public and private Member Organizations. Some of the committee’s goals include the following:

- Provide technical expertise and recommendations for education, inspection, enforcement and training programs
- Create guidance for coordination between governmental units to reduce regulatory overlap and promote permit simplification
- Act as liaisons with their respective agencies/organizations in promoting and supporting the statewide stormwater effort

This web page also includes a link to the Minnesota Stormwater Manual RFP which (in Appendix B beginning on page 24) includes an extensive list of links to online manuals, guides and plans for stormwater management from a wide variety of organizations.

The Metropolitan Council’s Urban Small Sites Best Management Practice Manual provides information on tools and techniques to assist Twin Cities municipalities and WMOs in guiding development and redevelopment. The manual includes detailed information on 40 BMPs that are aimed at managing stormwater pollution for small urban sites in a cold-climate setting. The goal of the manual is to support the principles of accommodating growth while preserving the environment.

The Minnesota Board of Water and Soil Resources (BWSR) has an Urban Stormwater Management web page with links to several websites they recommend for additional information. As the level of human activity increases, the potential for water quality impacts also increases. Humans are especially active in urban areas with construction projects, industrial processes, transportation of materials and people, and densely settled business, commercial, and residential areas. The result of this activity has been increased stormwater runoff and flooding, and damage to rivers and lakes from runoff of nutrients, sediment, toxic materials, and bacteria.

**NATIONAL REFERENCES**

The United States Environmental Protection Agency Stormwater Program website provides an overview of current topics and has many useful links to publications, regulations, FAQs and a glossary. Stormwater discharges are generated by runoff from land and impervious areas such as paved streets, parking lots, and building rooftops during rainfall and snow events that often contain pollutants in quantities that could adversely affect water quality. Most stormwater discharges are considered point sources and require coverage by an NPDES permit. The primary method to control stormwater discharges is through the use of best management practices.

STATE AND FEDERAL MONITORING ACTIVITIES

(STATE) INTEGRATED GROUND WATER QUALITY MONITORING SYSTEM

In 2004, the Minnesota Department of Health, Minnesota Department of Agriculture, and the MPCA completed a Memorandum of Agreement that describes monitoring responsibilities for each agency.

MINNESOTA DEPARTMENT OF AGRICULTURE

The Monitoring and Assessment for Agricultural Chemicals in the Environment web page includes links to numerous information resources related to monitoring for agricultural chemicals. The Minnesota Department of Agriculture (MDA) is the lead state agency for all aspects of pesticide and fertilizer environmental and regulatory functions.

MINNESOTA DEPARTMENT OF HEALTH

General information and links related to ground-water quality monitoring can be found on the Ground Water Background web page. A discussion about how the Minnesota Department of Health cooperates with other agencies on ground water monitoring work is located further down the page. Reports on routine testing done on public water supplies, emerging issues, and other related topics are also available through annual reports.

MINNESOTA DEPARTMENT OF NATURAL RESOURCES

Since 1944, DNR Waters has managed a statewide network of water level observation wells (obwells). Data from these wells are used to assess ground water resources, determine long term trends, interpret impacts of pumping and climate, plan for water conservation, evaluate water conflicts, and otherwise manage the water resource.

MINNESOTA POLLUTION CONTROL AGENCY

The main Ambient Ground Water Monitoring and Assessment web page provides an overview of current monitoring activities and many links to summaries and publications of previous studies, data sets and maps. In general, these activities focus on monitoring ground-water quality but some water-level data is available. Some data sets and publications are extensive in scope. An example is the 1992 - 1996 statewide baseline study wherein nearly 1000 ground water samples were collected throughout the state and analyzed for a detailed suite of chemical parameters.

UNITED STATES GEOLOGICAL SURVEY

The USGS collects and archives water-resources data including: streamflow, ground-water levels, and water-quality data at hundreds of locations throughout Minnesota. These hydrologic data
are used in research and hydrologic studies to describe the quantity, quality, and location of Minnesota's water resources. The collection, analysis, and interpretation of these data are done in cooperation with other Federal, State and local agencies, tribal governments, universities, and research centers. Use the menus on this web page to link to studies, water data, publications, etc., related to ground water monitoring. One good example, under the “Studies>Research and Regional Studies menu” is a hypertext link to a web page that features National Water-Quality Assessments (NAWQA). Another (data rich) example, under the “water data” menu, is the hypertext link to the Minnesota “Ground Water Data” page.

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**ARSENIC**

**ARSENIC IN WELL WATER (MDH)**

Many Minnesotans are surprised to learn that they have arsenic in their drinking water. Despite its reputation as a deadly poison, arsenic is like any toxic substance: its effects depend on how much and how long people are exposed to it. Arsenic is a part of the earth’s crust and occurs naturally in some soil and rock. Arsenic from soil and rock can leach into groundwater. Groundwater is the primary source of drinking water for much of Minnesota. Almost all arsenic in drinking water is from these underground deposits of naturally occurring arsenic.

**ARSENIC IN MINNESOTA’S GROUND WATER (MPCA)**

The former Ground Water Monitoring and Assessment Program (GWMAP) of the Minnesota Pollution Control Agency collected arsenic concentration data for ground water throughout Minnesota. Much information from the former GWMAP program can still be found on the main page of a related MPCA website. The following web pages are recommended for arsenic information:

- Arsenic Concentrations in Minnesota’s Ground Water (statewide map)

**ARSENIC IN MINNESOTA GROUNDWATER (USGS)**

As of March 2005, a study entitled “Arsenic in Minnesota Groundwater and its Impact on the Drinking Water Supply” was underway by the United States Geological Survey. An (interim) progress report for this study was also available in March 2005.

**ARSENIC IN MINNESOTA GROUND WATER: RECENT RESEARCH AND IMPLICATIONS**

This article in PDF format by Melinda L. Erickson, Water Resources Science, University of Minnesota, and Randal J. Barnes, Civil Engineering, University of Minnesota appeared in the March 2004 edition of the Minnesota Ground Water Association Newsletter. The article begins on page 10 of the newsletter.
ENVIRONMENTAL OCCURRENCE OF ARSENIC (EPA)

Arsenic is a naturally occurring element, generally found at higher concentrations in sedimentary rocks than in other rock types. Major anthropogenic sources of arsenic in the environment include smelting operations and chromated copper arsenate (CCA), a variety of pesticide used in pressure treating wood for construction purposes. Arsenic is listed as the highest priority contaminant on the ASTDR/EPA list of hazardous substances at Superfund sites (ASTDR 2001 list). This site includes many links to other websites with information about arsenic in ground water.

ARSenic IN DRINKING WATER (EPA)

[March 2005 excerpt] The Safe Drinking Water Act requires EPA to revise the existing 50 parts per billion (ppb) standard for arsenic in drinking water. On January 22, 2001 EPA adopted a new standard, and public water systems must comply with the 10 ppb standard beginning January 23, 2006. EPA also provides links to additional arsenic information.

ARSenic IN DRINKING WATER & GROUNDWATER (WISCONSIN DNR)

This web site contains general information about arsenic, arsenic occurrence, recommendations, articles and studies about arsenic in Wisconsin ground water, related website links and contact information.

ARSenic, WHAT YOU NEED TO KNOW (NGWA)

This one-page article about arsenic in private well water (in PDF format) answers questions such as “What do you do if your water contains arsenic, and can it be removed?”. The article is published by the National Ground Water Association (NGWA).

THE ARSENIC SITE

The goal of The Arsenic Site is to build a community of responsible individuals who are generous with accurate perspectives on the matter of reducing arsenic levels in drinking water. It includes many links to web sites about arsenic-related research, treatment (of water for reduction of arsenic), seminars, conferences and more.

MECHANISM OF ARSENIC RELEASE TO GROUNDWATER

This 1999, eleven-page article (in PDF format) focuses geographically on Bangladesh and West Bengal but contains information that should be useful for understanding arsenic in ground water elsewhere. “The [arsenic] (As) derives from reductive dissolution of Fe oxyhydroxide and release of its sorbed As. The Fe oxyhydroxide exists in the aquifer as dispersed phases, such as coatings on sedimentary grains. Recalculated to pure FeOOH, As concentrations in this phase reach 517 ppm. Reduction of the Fe is driven by microbial metabolism of sedimentary organic matter, which is present in concentrations as high as 6% C. Arsenic released by oxidation of pyrite, as water levels are drawn down and air enters the aquifer, contributes negligibly to the problem of As pollution.”
NITRATE

WATER TESTING FOR NITRATE (MDA)

Nitrate is a common contaminant found in many wells throughout Minnesota. Shallow wells, dug wells, and wells with damaged or leaking casings are the most vulnerable to nitrate contamination. Major sources of nitrate contamination can be from fertilizers, animal waste, and human sewage. It is highly recommended to test your drinking water supply on an annual basis.

Elevated levels of nitrate in drinking water can cause Blue Baby Syndrome in infants under six months of age. Long term health effects to older children and normal healthy adults exposed to elevated levels of nitrate in their drinking water are not yet known or agreed upon in the scientific community. However, the National Cancer Institute suggests a link between elevated levels of nitrate in drinking water and an increased risk of non-Hodgkin’s lymphoma (a cancer of the lymphatic system).

Visit this Minnesota Department of Agriculture web page to find out more about nitrate and topics such as the following:

- Details of the Nitrate Water Testing Program
- How do I get my water tested?
- What if I find nitrate in my drinking water?

NITRATE IN WELL WATER (MDH)

Nitrate is a common contaminant found in many wells in Minnesota. Too much nitrate in drinking water can cause serious health problems for young infants. This brochure provides a basic explanation of nitrate in wells and gives steps that you as a well owner can take to protect your family and visitors from illness.

NITRATE AND SOURCE WATER PROTECTION (MDH)

This web page includes the following topics:

- Guidance for Mapping Nitrate Concentrations
- Nitrate Probability Maps and Reports
- Nitrate Web Links

LABORATORIES CERTIFIED FOR NITRATE ANALYSES (MDH)

The US Environmental Protection Agency administers the Safe Drinking Water Program (SDWP), which regulates many contaminants in public drinking water supplies. For example public water supplies are tested routinely for nitrates. However, private wells are only required to
be tested for bacteria and nitrate when they are newly constructed, and any water testing after that is the responsibility of the well owner.

The State of Minnesota requires that laboratories which perform water, soil, and waste testing for government agencies for regulatory purposes must be certified by the Environmental Laboratory Certification Program, administered by the Minnesota Department of Health.

**NITRATE IN MINNESOTA GROUND WATER (MPCA)**

This web page has links to five publications about nitrate in Minnesota ground water. Search or browse this “Ambient Ground Water Monitoring and Assessment - Publications” web page of the former Ground Water Monitoring and Assessment Program of the Minnesota Pollution Control Agency (MPCA) to link to the publications. A map indicating the distribution of nitrate concentrations (magnitude) in Minnesota is also available. The main page for Ambient Ground Water Monitoring and Assessment at the MPCA contains links to additional studies. One example is the 2004 Condition Monitoring study web page which includes a summary report and maps that present nitrate data for domestic wells and monitoring wells.

**NITRATE IN GROUND WATER (MN DEPT. OF ADMIN.)**

This web page features nitrate in ground water as a Minnesota Milestones indicator. Ground water is a vital source of drinking water for more than 75 percent of Minnesotans and 98 percent of the state’s nearly 1,000 community water systems. Less than half a percent of public water supply systems in Minnesota had average nitrate-nitrogen concentrations above the drinking water standard during a two-year period from 1999 to 2000. The U.S. Environmental Protection Agency has established a public drinking water standard for nitrate-nitrogen (nitrate) concentrations at 10 parts per million (ppm). Many experts consider nitrate levels above one part per million to be a sign of human influence on water quality. Sources of nitrate include fertilizer, crop residue, manure, septic systems and deposits from the atmosphere.

**NITRATE IN DRINKING WATER (WATER RESOURCES CTR. - U. OF M.)**

Nitrate occurs naturally in soil, or may be derived from nitrogen fertilizers, crop residues, human and animal wastes, and some other industrial wastes. All are possible sources of nitrate, which is soluble and moves with surface and ground water. In Minnesota, the biggest cause of nitrate-contaminated drinking water is improper waste water treatment. This often results from feedlot runoff and septic systems that are not built to code or are not maintained properly.

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**PESTICIDES**

**MONITORING AND ASSESSMENT FOR AGRICULTURAL CHEMICALS (MDA)**

The Minnesota Department of Agriculture (MDA) is the lead state agency for all aspects of pesticide and fertilizer environmental and regulatory functions. This web site provides a description of MDA agricultural chemical monitoring and assessment programs, links to numerous information resources including pesticide monitoring reports, the Interagency Integrated Ground Water Quality Monitoring Strategy and links to related information.
PESTICIDE BEST MANAGEMENT PRACTICES (MDA)

The Minnesota Department of Agriculture (MDA) is responsible for the development, promotion and evaluation of voluntary Best Management Practices (BMPs) for pesticide use. BMPs are practicable voluntary practices that are capable of preventing and minimizing degradation of ground water and surface water, considering economic factors, availability, technical feasibility, implementability, effectiveness, and environmental effects. This web site has hypertext links to numerous Pesticide BMPs and related information.

NATURAL ATTENUATION OF CONTAMINATED SOIL AND GROUND WATER (MDA)

The MDA is committed to considering proposals for natural attenuation of agricultural chemicals at suitable incident sites. The guidance document on this web site outlines MDA's approach for natural attenuation of contaminated soil and ground water at agricultural chemical incident sites in Minnesota. Attenuation of pesticides and fertilizers can occur naturally in the environment, however, the process may be limited by local environmental conditions, high concentrations of the pesticides and/or fertilizers and mixtures of different chemicals. While much is known about the attenuation of individual pesticides at label application rates in agricultural field use settings, there is limited information available on the attenuation of individual agricultural chemicals or mixtures of agricultural chemicals above label rates in non-field settings.

THE MINNESOTA PESTICIDE MANAGEMENT PLAN (MDA)

The Pesticide Management Plan (PMP) is a guidance document for the prevention, evaluation and mitigation of occurrences of pesticides or pesticide breakdown products in groundwaters and surface waters of the state, and is a requirement of the Pesticide Control Law (Minn. Stat. chapter 18B). The PMP must include components promoting prevention, developing appropriate responses to the detection of pesticides or pesticide breakdown products in groundwater and surface waters, and providing responses to reduce or eliminate continued pesticide movement to groundwater and surface water.

PESTICIDES - MINNESOTA DEPARTMENT OF HEALTH

On their Pesticides web page, the Minnesota Department of Health (MDH) explains that pesticides are substances used to prevent, destroy, repel or mitigate any pest ranging from insects, animals and weeds to microorganisms such as fungi, molds, bacteria and viruses. Pesticides may be toxic and harmful to the environment and to people if they are used improperly. At the same time, they help to manage and prevent pests that spread disease, that damage crops, buildings, and other property, and that are a public nuisance. The MDH also provides assistance on “Evaluating Your Pesticide Risk”.

NAWQA PESTICIDE NATIONAL SYNTHESIS PROJECT (USGS)

This web site features the United States Geological Survey's (USGS) national assessment of pesticides in the streams, rivers, and ground water of the United States. The Pesticide National Synthesis Project is part of the U. S. Geological Survey's National Water Quality Assessment Program (NAWQA). The program began in 1991 with the purpose of producing a long-term assessment of the status of and trends in the quality of the Nation's water resources. Pesticides
are one of the highest-priority issues for the National Water Quality Assessment (NAWQA). This web site includes hypertext links to detailed reports and data about pesticides in ground water and much more.

NATIONAL PESTICIDE INFORMATION CENTER

The National Pesticide Information Center (NPIC) is a cooperative effort of United States Environmental Protection Agency and Oregon State University. This NPIC web site is an especially good source of hypertext links to other high quality pesticide-related web sites. For example, their ‘technical’ web page has links to other web sites in the following topic areas:

- Toxicology & Active Ingredient Fact Sheets
- Health Information Databases
- Environmental & Chemical Properties Databases
- Product, Label, & MSDS Databases
- Statistics

PESTICIDES IN DRINKING WATER (NPTN)

This four-page National Pesticide Telecommunications Network (NPTN) fact sheet is designed to answer questions by the general public about pesticides that are regulated by the United States Environmental Protection Agency.

PESTICIDES AND WATER QUALITY (PURDUE UNIVERSITY)

This 60-page document in PDF format, “Pesticides and Water Quality Principles, Policies, and Programs”, is well-written and well-illustrated. Even though it provides ample detail for technical readers, many non-technical readers will appreciate the style of the document. It was prepared by contributors representing Purdue University, the United States Environmental Protection Agency and Environmental Chemistry Laboratory, DowElanco. Examples of chapter titles include the following:

- The Fate of Pesticides in the Environment
- Regulatory Evaluation of Environmental Fate Data for Water Quality Concerns
- Risk Assessment of Pesticides for Water Quality Concerns
- Public Policy, Pesticides, and Water Quality

PROPERTIES OF PESTICIDES

Caution: Please remember that these hypertext links are provided for your convenience only. Use your own judgment regarding the reliability of information you find on these web pages; check the web pages to see when they were last updated.
PESTICIDE INFORMATION PROFILES (EXTOXNET)

This web site allows searching or browsing for detailed information about individual pesticides. EXTOXNET is a cooperative effort of University of California-Davis, Oregon State University, Michigan State University, Cornell University, and the University of Idaho. Primary files are maintained and archived at Oregon State University.

PRODUCT LABEL INFORMATION AND MATERIAL SAFETY DATA SHEETS (CDMS)

This web page allows you to enter a “crop protection product” (such as a pesticide) brand name into a search box to obtain detailed information about the product. CDMS, Inc. is a privately held corporation located in Marysville, CA. Founded in 1983, the company provides America’s premier software service to access crop protection product label, MSDS, WPS and DOT information. Over 100 crop protection product manufacturers support CDMS by supplying and approving all information in the CDMS databases. There are over 1,600 crop protection product labels and 4,200+ MSDSs in the CDMS databases.

SOLVENTS AND OTHER ORGANIC CHEMICALS

Cross Reference Tip: If you don’t find what you are looking for in this section, you might want to visit the Site Remediation: Investigation and Cleanup section in the Technical Reference List for Minnesota Ground Water Projects. It includes some references that address organic chemicals.

VOLATILE ORGANIC COMPOUNDS IN MINNESOTA’S GROUND WATER (MPCA)

Volatile organic compounds (VOCs) are carbon-containing compounds that readily evaporate at normal air temperature. Fuel oils, gasoline, industrial solvents, paints, and dyes are all sources of VOCs. A brief two-page overview of VOCs in Minnesota ground water is available in PDF format. More detailed publications and extensive VOC data sets for Minnesota ground water can be found on the Ambient Ground Water Monitoring and Assessment web site at the Minnesota Pollution Control Agency. See their Baseline Report on Minnesota’s principal aquifers for background information about their largest single VOC data set (found near the bottom of the page) and a statewide map displaying VOC detections in Minnesota ground water.

VOLATILE ORGANIC CHEMICALS IN PRIVATE DRINKING WATER WELLS (MDH)

This Minnesota Department of Health (MDH) web page provides answers for many of the most common questions that private well owners have regarding volatile organic compounds (VOCs) in their well water. MDH also provides information about children’s health risks from exposure to VOCs.

Most VOCs found in the environment result from human activity. When VOCs are spilled or improperly disposed of, a portion will evaporate, but some will soak into the ground. In soil, VOCs may be carried deeper by rain, water or snow melt and eventually reach the ground-water table. When VOCs migrate underground to nearby wells, they can eventually end up in drinking water supplies. The U.S. Environmental Protection Agency (EPA) estimates that Volatile Organic Chemicals are present in one-fifth of the nation’s water supplies. Minnesota Department
of Health (MDH) studies suggest that 3 - 6% of public water supplies and about 2 - 4% of all water supplies in Minnesota contain detectable amounts of VOCs.

**DRINKING WATER CONTAMINANTS (EPA)**

View details on individual volatile organic contaminants or synthetic organic contaminants, including pesticides & herbicides.

**NATIONAL ASSESSMENT OF VOLATILE ORGANIC COMPOUNDS (USGS)**

This United States Geological Survey web site features the National Assessment of Volatile Organic Compounds (VOCs) in Water Resources of the United States. It includes hypertext links to numerous publications. The three major topics addressed in the National Assessment are VOCs in ground water, VOCs in source water and drinking water and VOCs in urban streams.

The Objectives of this effort are as follows:

- Determine the occurrence, status, distribution, major natural and anthropogenic factors, and probable sources of VOCs in the Nation's ground water
- Determine the occurrence and status of VOCs in aquifers and rivers that serve as public and domestic drinking water supplies
- Determine the occurrence, status, geographical distribution, and probable sources of VOCs in urban streams

**FATE OF ORGANIC CHEMICALS IN SUBSURFACE ENVIRONMENTS (USGS)**

Release of various synthetic organic compounds to the environment has caused soil and groundwater pollution in many places. The processes which control the persistence and movement of these materials are not well understood. A better understanding is necessary to aid in construction of models to predict movement and fate of pollutants in the subsurface and for design of control and abatement techniques. Project objectives are to determine the transformation pathways of selected organic compounds using a combination of field observations and laboratory simulations of environmental conditions; assess the relative importance of physical, chemical, and biochemical processes in the transformation of these compounds under ambient conditions; and study relevant biotransformation processes occurring in the subsurface. Visit this United States Geological Survey web site for links to the project home page and numerous investigation reports.

**MIGRATION OF CHLORINATED SOLVENTS IN FRACTURED SEDIMENTARY ROCK (USGS)**

This United States Geological Survey web site features “Geochemical and Microbiological Processes that Affect Migration and Natural Attenuation of Chlorinated Solvents in Fractured Sedimentary Rock -- Naval Air Warfare Center (NAWC) Research Site, West Trenton, NJ”. It includes numerous hypertext links to related information.

Toxic chemicals such as chlorinated solvents in fractured rock aquifers pose a serious threat to the Nation's ground-water resources. Improper disposal methods, leaking tanks and pipes, and chemical spills have contaminated fractured rock aquifers in and around many industrial centers.
The restoration and protection of ground-water quality depend on knowledge of the physical, chemical, and microbiological processes that affect the fate of these toxic chemicals in fractured rock aquifers. The intent of this investigation is to help develop the knowledge needed to create practical and cost-effective methods to clean up and protect ground-water resources in fractured rock aquifers.

NATURAL ATTENUATION OF CHLORINATED SOLVENTS IN GROUND WATER (MPCA)

This Minnesota Pollution Control Agency document (1999 guidelines) in PDF format provides guidance on the selection of natural attenuation as a remedy for chlorinated solvents in ground water at sites regulated under the Minnesota Environmental Response and Liability Act (MERLA), including the Minnesota Superfund and Voluntary Investigation and Cleanup (VIC) Programs. It is part of the Risk-Based Site Evaluation Manual that outlines the process for making decisions at sites on the basis of risk to human health and the environment.

The document emphasizes the subtle though important distinction between intrinsic biodegradation of contaminants in ground water and the process of selecting natural attenuation as a remedy for a particular site. As defined in this document, natural attenuation is “the demonstration that intrinsic degradation will reduce the concentrations of the contaminants before they pose unacceptable levels of risk to human health or the environment, or exceed ground water criteria at established points of compliance”.

NATURAL ATTENUATION OF CHLORINATED SOLVENTS IN GROUNDWATER (ITRC)

The term "natural attenuation” refers to naturally-occurring processes in soil and groundwater environments that act without human intervention to reduce the mass, toxicity, mobility, volume or concentration of contaminants in those media. These in-situ processes include biodegradation, dispersion, dilution, adsorption, volatilization and chemical or biological stabilization or destruction of contaminants.

This 123-page 1999 publication in PDF format, ‘Natural Attenuation of Chlorinated Solvents in Groundwater: Principles and Practices’, was prepared by the Interstate Technology and Regulatory Cooperation Work Group In Situ Bioremediation Work Team and the Industrial Members of the Remediation Technologies Development Forum (RTDF). The RTDF is a public and private sector collaboration to develop innovative solutions to complex hazardous waste problems. The mission of the RTDF Bioconsortium is to accelerate the development of cost-effective bioremediation processes for degrading chlorinated solvents and to achieve public and regulatory acceptance that these processes are safe and effective.

NON-AQUEOUS PHASE LIQUID (NAPL) CLEANUP ALLIANCE

The Non-Aqueous Phase Liquid (NAPL) Cleanup Alliance was created by the U.S. Environmental Protection Agency (EPA). It includes representatives from the petroleum industry, federal and state government, and academia who share an interest in pursuing aggressive technologies for removing large-scale non-aqueous phase liquid (NAPL) contamination.
ORGANIC CHEMICALS - REMEDIATION RESEARCH (NIEHS/EPA)

Chlorinated solvents, dense non-aqueous phase liquids (DNAPLs), polynuclear aromatic hydrocarbons (PAHs), dioxins, and volatile organic compounds (VOCs) are common organic (carbon-containing) environmental contaminants. Low and high exposure levels can lead to a variety of human health affects and often result in remediation difficulties at Superfund sites due to their varying chemical backgrounds. Research available from this web page looks at advanced remediation methods for these compounds thus resulting in a profound effect on the EPA Superfund program and the restoration of organic-contaminated sites.

EMERGING CONTAMINANTS

EMERGING CONTAMINANTS IN THE ENVIRONMENT (USGS)

The United States Geological Survey (USGS) Toxic Substances Hydrology Program has a wealth of information on its Emerging Contaminants In the Environment web page.

Research is documenting with increasing frequency that many chemical and microbial constituents that have not historically been considered as contaminants are present in the environment on a global scale. These "emerging contaminants" are commonly derived from municipal, agricultural, and industrial wastewater sources and pathways. These newly recognized contaminants represent a shift in traditional thinking as many are produced industrially yet are dispersed to the environment from domestic, commercial, and industrial uses. The major goal of the Emerging Contaminants Project is to provide information on these compounds for evaluation of their potential threat to environmental and human health.

For Minnesota-related studies on this topic, see the USGS web page entitled Emerging Contaminant and Endocrine Studies in Minnesota.

"EMERGING" CONTAMINANTS IN U.S. WATER SUPPLIES

This informative article by the Academy of Natural Sciences presents a good overview of the breadth and depth of issues related to “emerging contaminants” in U.S. Water Supplies.

Scientific studies over the past few years have begun to indicate that small amounts of previously unsuspected substances may be present in America's waters. These chemicals are often called "emerging" contaminants, and include a variety of synthetic substances (as well as a few natural products) that are not normally expected to be present in aquatic systems. Many of these substances enter waterways as part of municipal, industrial, and agricultural wastewater systems, so they are also often referred to collectively as "organic wastewater contaminants" (OWCs).

Labeling these contaminants as "emerging" may suggest, erroneously, that they are the result of some new products or practices. For the most part though, these are not new chemicals; in fact, some them have been used for decades. What is new is our awareness of these substances as possible pollutants. Technologies now allow scientists to detect them in very low concentrations, and to ask questions as to the possible effects--if any--of this trace contamination; in this sense they are emerging as objects of scientific examination and public policy debate.
WATER ANALYSIS: EMERGING CONTAMINANTS AND CURRENT ISSUES (EPA - NERL)

This web page features a content-rich four-page research abstract from EPA’s National Exposure Research Laboratory. This invited review for the journal Analytical Chemistry (June 2003) covers developments from 2001-2002 in water analysis. The author focuses on new, emerging contaminants and environmental issues that are driving most of the current research. Dr. Richardson also discusses new research on drinking water disinfection by-products (DBPs); pharmaceuticals, hormones, and endocrine disrupting compounds; chiral contaminants; methyl-tert-butyl ether (MTBE); algal toxins; organotins; perchlorate; arsenic; natural organic matter; and microorganisms.

ENDOCRINE DISRUPTERS AS A PUBLIC HEALTH ISSUE (MDH)

The question of whether or not certain chemical pollutants affect endocrine system functioning in humans and animals has been of concern and controversy in the past 10 to 15 years. Environmentalists passionately proclaim the potential for harm to humans and wildlife and provide examples of situations where they feel impacts are already apparent; representatives from industry downplay the possible effects and suggest that the risks posed by naturally occurring endocrine active chemicals in our diet far outweigh any presented by endocrine-modulating environmental pollutants. The truth probably lies somewhere between the two views.

This January 2003 article by the Minnesota Department of Health, and published in ‘Minnesota Medicine’, explains that an endocrine disrupter is an exogenous agent that interferes with the synthesis, secretion, transport, binding, action, or elimination of natural hormones in the body that are responsible for the maintenance of homeostasis, reproduction, development, and/or behavior.

ENDOCRINE DISRUPTORS (EPA)

On this web page, developed in 1997, the EPA discusses the “Potential of Chemicals to Affect the Endocrine System”. In recent years, increasing scientific and public attention has been focused on the potential effects of synthetic chemicals on the hormone system. In March 1996, Theo Colborn, Dianne Dumanoski, and John Peterson Myers published a book entitled Our Stolen Future that addressed this issue. According to the book, hormone disrupting chemicals are widespread and can cause adverse effects even at low levels, resulting in potentially serious risks to the environment and public health. This document summarizes EPA’s understanding of this issue and the action it is taking, as well as discussing some of the book’s recommendations.

From the Endocrine Disruptors Research Initiative web page: Evidence suggests that environmental exposure to some anthropogenic chemicals may result in disruption of endocrine systems in human and wildlife populations. A number of the classes of chemicals suspected of causing endocrine disruption fall within the purview of the U.S. Environmental Protection Agency’s (EPA) mandates to protect both public health and the environment. Although there is a wealth of information regarding endocrine disruptors, many critical scientific uncertainties still remain.

From the Endocrine Disruptor Screening Program web page: This site provides you information about endocrine disruptors and EPA’s approach and progress for screening and testing chemicals for potential endocrine disruption. You will also find information about EDSP’s program
activities and upcoming meetings. In recent years, some scientists have proposed that certain chemicals might be disrupting the endocrine system of humans and wildlife. A variety of chemicals have been found to disrupt the endocrine systems of animals in laboratory studies, and compelling evidence shows that endocrine systems of certain fish and wildlife have been affected by chemical contaminants, resulting in developmental and reproductive problems.

**PHARMACEUTICALS AND PERSONAL CARE PRODUCTS (EPA)**

The full title of this website is “Pharmaceuticals and Personal Care Products (PPCPs) as Environmental Pollutants -- Pollution from Personal Actions, Activities, and Behaviors”. It is hosted by the United States Environmental Protection Agency, National Exposure Research Laboratory.

This website is dedicated to the scientific issues associated with the occurrence of Pharmaceuticals and Personal Care Products (PPCPs) in the environment. It serves as a central location to learn about the topic and to initiate searches for further information.

**USE OF PPCPS IN THE ENVIRONMENT AS ANALYTICAL "TOOLS" (EPA)**

Most of the focus on pharmaceuticals and personal care products (PPCPs) in the environment regards their presence as pollutants -- with the attendant questions regarding potential toxicological consequences. Their very existence as environmental contaminants, however, provides a number of opportunities to accomplish other purposes unrelated to any concern regarding their occurrence. These opportunities relate to the use of PPCPs as tools for probing or measuring other, unrelated factors. Four examples are presented on this web page which also includes links to other publications and web sites.

**NON-REGULATED WATER CONTAMINANTS: EMERGING RESEARCH (EPA)**

This 22-page paper was authored by Christian G. Daughton, Environmental Chemistry Branch, Environmental Sciences Division, National Exposure Research Laboratory, U.S. EPA and published on the Internet on September 8, 2004. This paper includes links to numerous other publications.

Those chemical pollutants that are regulated under various international, federal, and state programs represent but a small fraction of the universe of chemicals that occur in the environment as a result of both natural processes and human influence. Although the number of these targeted chemicals might be minuscule compared with the universe of both known and yet-to-be identified chemicals, an implicit assumption is that these selective lists of chemicals are responsible for the most significant share of risk with respect to environmental or economic impairment or to human health. This paper examines some of the less-discussed aspects of the background and assumptions that underlie society's relationship with chemical pollutants in water, particularly with respect to the need for a more holistic understanding of exposure and risk.
PHARMACEUTICALS AND PERSONAL CARE PRODUCTS AS POLLUTANTS (EPA)

This detailed color poster illustrates how and where many pharmaceuticals, personal care products and other potentially harmful chemicals are released into the environment. It features the following topic. Pharmaceuticals and Personal Care Products (PPCPs) as Pollutants: Pharmaceuticals and Personal Care Products (PPCPs) as Pollutants: Origins, Fate, and Control in the Environment. Major Products Under Task 6980 (PPCPs) U.S. EPA, Office of Research and Development, National Exposure Research Laboratory, Environmental Chemistry Branch, Environmental Sciences Division, NERL-Las Vegas.

DISINFECTION BYPRODUCTS (EPA)

This web page includes a brief comment on disinfection byproducts by the United States Environmental Protection Agency. Details about microbes and disinfection byproducts and links to additional web sites that focus on disinfection byproducts are also available. For reference, you can read a brief EPA discussion of disinfectants.

SUMMARY TABLE OF EMERGING CONTAMINANTS (KOMEX)

Komex Environmental Ltd., an environmental consulting and engineering firm, provides a summary table of emerging ground-water contaminants with their major environmental pathways, their sources, contaminant mobility, remediation complexity, examples of regulatory levels and more.

GROUND WATER MONITORING AND REMEDIATION® ABSTRACTS

This web page features nine abstracts of articles that address pharmaceuticals and endocrine disruptors in ground water published in the journal Ground Water Monitoring and Remediation® Vol. 24, No. 2, Spring 2004.

CONTAMINANTS IN GROUNDWATER TASK GROUP (ECOS)

The Contaminants in Groundwater Task Group of the Environmental Council of the States (ECOS) Sustainability Workgroup has focused on issues related to emerging constituents, such as perchlorate. In 2004 the task group created an Emerging Contaminants in Groundwater Strategic Plan. And on February 2-3, 2005, the task group met in Washington, DC as part of a larger ECOS-DOD Sustainability Work Group Meeting. Both the plan and the meeting summary can be accessed from their web site.
SELECTED GROUND-WATER PUBLICATIONS LISTS

The web pages under this heading have been selected because they include hypertext links to numerous Minnesota ground-water publications. However, some of these web pages may also include other topics that do not fit this category. For more specific topics, please see the other headings (above).

DNR DIVISION OF WATERS PUBLICATIONS

Division of Waters Publications

Go directly to the 1990 Minnesota Ground Water Bibliography in PDF format.

MINNESOTA GEOLOGICAL SURVEY

Current Publications

Minnesota at a Glance

MINNESOTA POLLUTION CONTROL AGENCY PUBLICATIONS

Ambient Ground Water Monitoring and Assessment Publications

More Ground-Water Publications

USGS MINNESOTA OFFICE - STUDIES AND PUBLICATIONS

Browse Publications of the USGS Minnesota Science Center 1946 to Present -- organized alphabetically by senior author’s name. To ‘search’ these publications by title, use your Internet browser’s ‘find’ or ‘search’ function.

Search the USGS Publications Warehouse -- for all areas of the United States.

Browse summaries of USGS Minnesota Water Resources Activities.

MINNESOTA GROUND WATER ASSOCIATION NEWSLETTER

The current issue of the Minnesota Ground Water Association (MGWA) Newsletter is only available to (MGWA) members, however, ‘back issues’ are available to everyone.

RESEARCH BRIEFS - NIEHS/EPA SUPERFUND BASIC RESEARCH PROGRAM

The Research Brief is a monthly email series highlighting individual research projects supported by the NIEHS/EPA Superfund Basic Research Program. Each Brief provides a synopsis of the research and a contact for more detailed information.
THE GROUNDWATER FOUNDATION

This “Get Informed” web page includes links to numerous web pages and publications designed for students and teachers interested in ground-water education. Materials are available for both youth education and community education. Content ranges from basic concepts in ground water hydrology and hands on learning activities to workshops for source water assessments and protection.

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