The Subcommittee on Ground Water of The Advisory Committee on Water Information

National Ground-Water Monitoring Network—Results of Pilot Studies

September 2011

Cover photographs (clockwise from top)—

A 105-ft deep dedicated monitoring well in Beaverhead County, southwest Montana, monitored to create a water-level record for Tertiary-age sand and gravel in the Northern Rocky Mountains Intermontane Basins aquifer systems
(by Michael Richter, Montana Bureau of Mines and Geology).

Observation well in Sussex County, New Jersey, in the winter *(U.S. Geological Survey New Jersey Water Science Center).*

A 68-ft deep dedicated monitoring well in Sheridan County, northeast Montana, monitored to create a water-level record for Pleistocene outwash gravel in the sand and gravel aquifers (glacial regions) principal aquifer
(by Clarence Schwartz, Montana Bureau of Mines and Geology).

A "nested" set of dedicated monitoring wells with open-interval tops between 14 and 191 feet below land surface in Powell County, western Montana. The wells are monitored to create water-level records for Tertiary-age sand and gravel in the Northern Rocky Mountains Intermontane Basins aquifer systems. Data from the site are transmitted through cell-phone telemetry to the Montana Bureau of Mines and Geology's Ground Water Information Center about 35 miles distant *(by Thomas Patton, Montana Bureau of Mines and Geology).*

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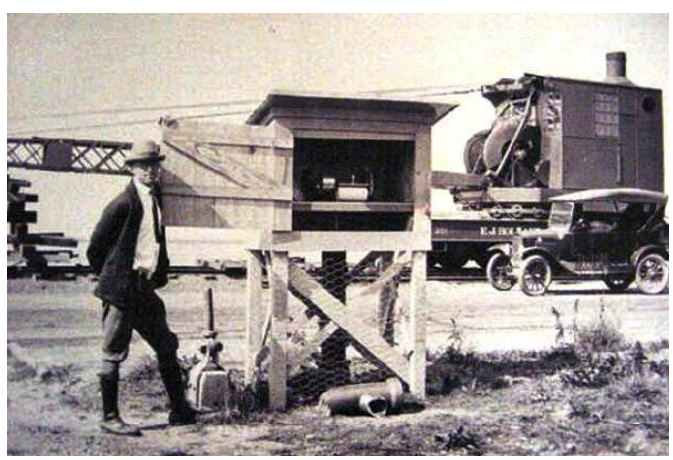

USGS New Jersey Water Science Center

Water-level monitoring near Atlantic City, New Jersey (circa 1920)

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National Ground-Water Monitoring Network—Results of Pilot Studies

Executive Summary

Ground water is a critical natural resource for the Nation. It is the source of drinking water for nearly 130 million Americans each day. About 39 percent of the Nation's irrigation water supply is obtained from ground water, and that percentage is increasing. Although overall water use in the United States has been relatively steady for more than 20 years, ground-water use has continued to increase. In addition to human uses, many ecosystems are dependent on ground-water discharge to streams, lakes, and wetlands.

In 2007, the Federal Advisory Committee on Water Information (ACWI) formed the Subcommittee on Ground Water (SOGW) to develop and encourage implementation of a nationwide, long-term ground-water quantity and quality monitoring framework. The SOGW is a collaboration of scientists, engineers, and managers from private industry, nongovernmental organizations, Federal, State, and local governments, and academia. The SOGW issued a June 2009 report entitled A National Framework for Ground-Water Monitoring in the United States (*http://acwi.gov/sogw/pubs/tr/sogw_tr1_Framework_june_2009_Final.pdf*). The report, referred to as the "Framework Document" in this report, describes a framework for the establishment and long-term operation and use of a National Ground-Water Monitoring Network (NGWMN). The NGWMN is envisioned as a voluntary, integrated system of data collection, management, and reporting that provides the data needed to help address present and future ground-water management questions raised by Congress, Federal, State, and Tribal agencies, and the public.

As a developmental step in establishing a NGWMN, the SOGW selected five volunteer pilot projects to test the concepts outlined in the Framework Document: Illinois-Indiana, Minnesota, Montana, New Jersey, and Texas. The five pilot projects were conducted through cooperative efforts between the State monitoring network managers, the SOGW, and U.S. Geological Survey (USGS) staff. The five pilot projects developed both a water-level monitoring network and a water-quality monitoring network. The 1-year pilot studies began in January 2010 to test the proposed network design and implementation concepts.

The five volunteer pilot projects (Illinois-Indiana, Minnesota, Montana, New Jersey, and Texas) identified selected wells within their own monitoring networks that met the NGWMN criteria. These five projects documented (reports available at *http://acwi.gov/sogw/pubs*) their network, evaluated the process, evaluated the framework design, evaluated gaps in meeting the framework design, and documented the associated costs of participating in the NGWMN and in meeting the defined gaps. These pilot projects have successfully demonstrated the feasibility of a collaborative national ground-water monitoring network that could provide information necessary for the planning, management, and development of ground-water supplies to meet current and future water needs.

After a thorough evaluation of the monitoring program in their selected principal or major aquifers, each pilot study provided a "gap analysis" by defining the changes that would need to be made to their existing program in order to meet all of the requirements of the Framework Document. These "gaps" were identified for both the water-level and water-quality networks. The gaps are summarized in this document in four categories: (1) Spatial Gaps, which identify additional monitoring points needed to provide an adequate areal distribution of wells or springs, (2) Temporal Gaps, which identify needs for increases in the frequency of measurements to meet the requirements of the Framework Document, (3) Field Practice Gaps, which identify changes in water-level measurement techniques or documentation needed to meet the requirements of the Framework Document, and (4) Data-Management Gaps, which identify missing data elements required by the Framework Document or other data-handling issues.

Individual States evaluated their monitoring programs and networks to determine what the costs would be to meet the specifications of the NGWMN framework in four principal areas: (1) Well Network, (2) Field Practices, (3) Data Management, and (4) Monitoring Program. Each area may have incremental framework (gap) costs that are one-time ("start-up" or "front-end") expenses as well as capital expenditures and annual operation and maintenance outlays. No limits, financial or otherwise, were placed on the pilot studies for this exercise. The network design selected by each

pilot study drives any cost estimates for full implementation of the NGWMN. Actual implementation may be more or, in fact, less that those cited in this report, depending on the final network design. If the NGWMN relied only on existing wells, the capital and one-time costs primarily would include some limited well logging and instrumentation, modification of field practices and data standards, and automated data collection totaling $865,384, an average of $173,077, for the five State pilot projects. Pilot studies also proposed new well installation and monitoring, which increased the cost of their proposed networks.

One of the objectives of the pilot process was to identify possible changes to the Framework Document that were identified through the experiences gained as the pilot networks were implemented. These recommendations identified requirements that are impractical, expensive, or that present other barriers to participation. Pilots were encouraged to provide feedback to the SOGW on any suggested changes to the Framework Document. Recommendations are grouped by network design, classification of wells, and required data elements.

The development of a NGWMN Web-based data portal (*http://cida.usgs.gov/gw_data_portal/*) was a key element of the pilot process. This pilot data portal was developed by the USGS using state-of-the-art informatics processes to unify data provided from the five volunteer pilot projects. The NGWMN Web portal aggregates and disseminates network ground-water monitoring data from participating organizations to interested parties, including policy makers, scientists, and the general public. The goal of the portal is to create a single location (Web site) that is publically accessible for compiling and relaying ground-water levels, ground-water-quality data, and associated metadata from distributed databases located within participating agencies through a map-based graphical user interface. It was determined through the pilot portal effort that even though States recorded data differently and used different database platforms, States typically included nearly all of the data needed for comparable reporting from their existing databases. The Information Technology work accomplished by the Pilot Studies was certainly significant; however, the Data Portal is designed to minimize the work required by the data providers. Thus, making adjustments in those systems was not foreseen as a major cost impediment to participation in a collaborative NGWMN.

A nationwide collaboration for ground-water monitoring has been considered for decades. The NGWMN Framework Document and five successful pilot projects have illustrated that a convergence of information technology improvements, increased information needs, and interest in collaboration make this the ideal time to pursue a NGWMN.

Introduction

Ground water is the source of drinking water for nearly 130 million Americans each day. Of the 79,600 million gallons per day (Mgal/d) of ground water used in 2005, about 67 percent was used for irrigation, about 23 percent was used for public supply and domestic use, 4 percent was used for industrial use, and the remainder was used for livestock, aquaculture, mining, and power generation (Kenny and others, 2009). About 39 percent of the Nation's irrigation water supply is obtained from ground water, and that percentage is increasing. Although overall water use in the United States has been relatively steady for more than 20 years, ground-water use has continued to increase, primarily as a percentage of public supply and irrigation. In addition to human uses, many ecosystems are dependent on ground-water discharge to streams, lakes, and wetlands.

The Nation's ground-water resources are under stress, and increased interstate and national attention are needed to assure sustainable use of the resource. Federal, State, and local agencies have documented substantial effects to ground-water resources throughout the Nation. Impacts include declining water levels and contamination of ground water from chemical use and waste disposal. Increased ground-water demand is expected in all sectors of the economy, including the heavy-use sectors of agriculture, drinking water, and energy production. Increased biomass production will increase demand on ground water for water supply to produce fuels and may further degrade water quality as a result of increased agrichemical application and residuals disposal. These activities threaten the aquifers directly as well as ground-water-dependent ecosystems and the base flow of streams supported by ground-water discharge. Proposals for geologic sequestration of carbon dioxide present the potential to acidify ground water if migration of the carbon dioxide to adjacent aquifers occurs. Additionally, brackish and saline ground waters are likely to be increasingly developed and treated in water-deficient areas and may compete as locations for carbon sequestration. As ground-water use increases, it is imperative to improve the overall management of the resource. An integrated local, State, Tribal, and Federal partnership approach is needed to accommodate multijurisdictional issues, effect management of transboundary aquifers, and promote stakeholder involvement.

The need for a national ground-water monitoring network (NGWMN) has been recognized by numerous governmental and nongovernmental agencies. To address this concern, the Subcommittee on Ground Water (SOGW) was established in 2007 as an ad-hoc committee under the Federal Advisory Committee on Water Information (ACWI). The SOGW and its working groups, which include more than 70 people representing 55 different organizations, was charged with developing a framework that establishes and encourages implementation of a long-term ground-water-quantity and quality monitoring network. The network is intended to provide data and information necessary for the planning, management, and development of ground-water resources in a sustainable manner. The SOGW issued a June 2009 report entitled A National Framework for Ground-Water Monitoring in the United States (*http://acwi.gov/sogw/pubs/tr/sogw_tr1_Framework_june_2009_Final.pdf*).

The report, referred to as the "Framework Document" in this report, describes a framework for the establishment and long-term operation and use of a NGWMN.

The NGWMN is envisioned as a voluntary, integrated system of data collection, management, and reporting that provides the data needed to help address present and future ground-water management questions raised by Congress, Federal, State, and Tribal agencies, and the public. The NGWMN will be made up of a compilation of selected wells from existing State, Federal, and Tribal ground-water monitoring programs. The focus of the network will be on assessing the baseline conditions and long-term trends in water levels and water quality. As proposed, the NGWMN will include two monitoring subnetworks: a subnetwork that focuses on monitoring unstressed parts of principal aquifers and aquifer systems, and a subnetwork that targets areas of concern within aquifers and aquifer systems (typically areas where water-quality degradation or water-level declines are of concern). Monitoring within the NGWMN will include four different categories: baseline monitoring, trend monitoring, surveillance monitoring, and special studies monitoring.

Ground-water-level monitoring has been conducted for many decades in many States. Data from these networks have been used to help identify, develop, and manage ground-water supplies at the local and State level. Ground-water-quality monitoring programs have been developed more recently in response to the focus on water quality that resulted from passage of the Safe Drinking Water Act; the Clean Water Act; the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and other environmental laws. As of 2007, 37 States operated statewide or regional ground-water monitoring networks, and 33 States have at least one active ground-water-quality monitoring program. The State monitoring networks are funded using a combination of State and Federal funds. The networks are operated by a variety of State agencies, many of them in cooperation with the U.S. Geological Survey (USGS). The networks operate under a variety of specific State/Tribal/local goals and objectives, which do not necessarily focus on all of the important aquifers within a State or reservation. As a result, it is very difficult to use these ground-water monitoring programs to evaluate water availability, rates of use, and sustainability on a regional or national basis. Because many aquifers support multiple political jurisdictions, the concept of monitoring at the scale of an aquifer rather than political subdivision is critical to facilitate sustainable ground-water use.

After evaluating statements of interest from numerous States, the SOGW selected five volunteer pilot projects to test the concepts outlined in the Framework Document: Illinois-Indiana, Minnesota, Montana, New Jersey, and Texas. These five pilot projects vary in scale from an intrastate monitoring network that covers a portion of an individual State to an interstate network where two States share the same aquifer. Information provided by the pilot projects will help to better understand the current status, range of coverage, and level of coordination of ground-water monitoring networks in the United States and will serve as a foundation for developing an estimate of the number and type of resources needed for full-scale implementation of the proposed national monitoring network. The five pilot projects were conducted through cooperative efforts between the State monitoring network managers, the SOGW, and USGS staff. The pilot projects completed their 1-year effort in December 2010.

Pressure transducer used for continuous water-level monitoring.

Purpose of Study

One of the three key recommendations included in A National Framework for Ground-Water Monitoring Network in the United States is to develop and conduct a limited number of pilot studies to (a) test the NGWMN concepts and approaches detailed in the Framework Document, (b) evaluate the feasibility and resources necessary to implement a national network, and (c) produce recommendations leading to full-scale implementation. The pilot projects were initiated in early 2010 and have been completed (2011). Each of the pilot projects has addressed the following objectives to:

1. Evaluate the feasibility of designing network segments within one or more principal, major, or other important aquifers within their State or States using conceptual ground-water flow models as the primary network design element,
2. Determine methods to establish unstressed and targeted subnetworks within the target aquifer(s),
3. Test the design of the NGWMN and its ability to provide water-level and quality data to large-scale assessments of the ground-water resource,
4. Determine the feasibility and design elements of a central, Web-based data portal that will allow NGWMN to gather and disseminate data, as well as promote data sharing among data providers and the public,

5. Test and assess the effectiveness of coordination, cooperation, and collaboration mechanisms among Federal, State, regional, local, and Tribal data collectors, providers, and managers,
6. Investigate methods to ensure that data collected by the data providers and, therefore, the NGWMN as a whole are comparable. Evaluate data elements, including site characteristics, well construction and details, the frequency of water-level measurements, water-quality analytes, water-level measurement procedures, water-quality sampling procedures, and written standard operating procedures, and
7. Determine the timeframe and costs associated with adding, upgrading, or developing a State, Tribal, or local well network and data-management system that meet the criteria and needs of the NGWMN and its ongoing implementation.

Each pilot study has evaluated potential monitoring points within selected principal, major, or other important aquifers for possible inclusion in the NGWMN and identified a subset of proposed monitoring points as meeting NGWMN's "stressed" or "unstressed" subnetwork design criteria and as a "surveillance" or "trend" dataset. These designations are explained in the Framework Document, and their relation is shown in figure 1. In addition, each pilot study identified all costs of potential participation in a NGWMN that are specific to the particular pilot State on a total and per well basis, as appropriate, including historical costs for the development and maintenance of their existing network; one-time start-up costs; and capital, operational, and maintenance costs associated with filling pilot-defined data gaps. Each pilot study has interfaced with the NGWMN pilot data portal that is under development by the USGS.

This report is designed to provide a summary of the reports produced by the individual pilot projects and the pilot NGWMN portal. The individual reports provide many more details on the State-based networks and describe their experience with the pilot process and their recommendations for implementation of the NGWMN. This summary report borrows heavily from the individual pilot reports. For additional details on the individual pilot projects, including the NGWMN portal, the reports can be obtained at the SOGW Web site at *http://acwi.gov/sogw/pubs*.

Pilot Studies

The five pilot projects to test the framework for a National Ground Water Monitoring Program are Illinois-Indiana, Minnesota, Montana, New Jersey, and Texas. The location of the pilot projects and their relation to the principal aquifers of the United States is shown in figure 2. Each pilot study completed a report that documented the developed network and their experiences with the Framework Document.

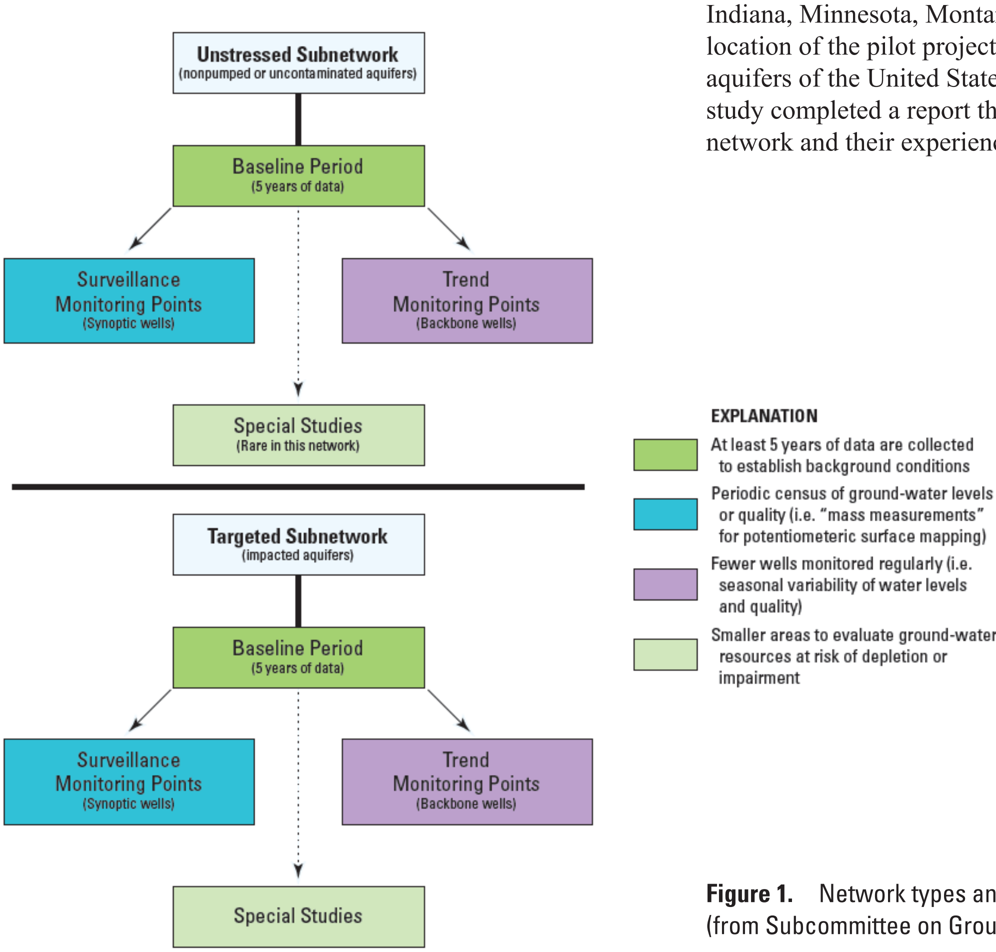

Figure 1. Network types and relation among networks (from Subcommittee on Ground Water, 2009).

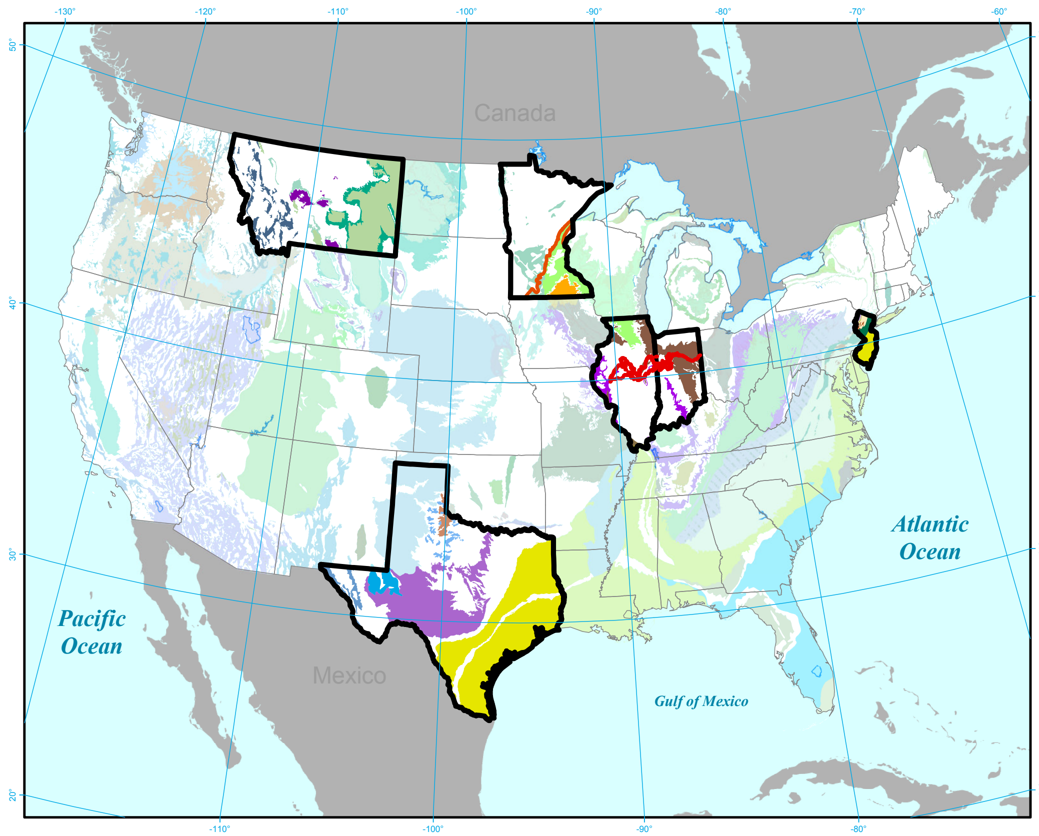

Figure 2. Locations of the pilot projects and their relations to the principal aquifers of the United States.

Illinois-Indiana

The Illinois-Indiana Pilot Study (Wehrmann and others, 2011) evaluated a network for two sand and gravel aquifers that cover the central part of these two States—the Mahomet-Teays aquifer and the Glasford and Mason aquifers. This system is a regionally important Quaternary sand and gravel aquifer (part of the unconsolidated and semiconsolidated sand and gravel aquifers) that extends beneath portions of 11 counties in east-central Illinois and beneath portions of 12 counties in north-central Indiana. Known as the Mahomet-Teays aquifer (or simply as the Mahomet aquifer) in Illinois and as the Teays-Mahomet aquifer in Indiana, the aquifer occupies portions of the buried Teays-Mahomet bedrock valley (also called the Lafayette (Teays) bedrock valley in Indiana) detailed within the regional portion (HA-730-K) of the USGS Ground Water Atlas of the United States (Lloyd and Lyke, 1995).

As a multistate pilot study, collaboration and coordination for the Illinois-Indiana Pilot Study were extensive. Key participants in the study included the Illinois State Water Survey (ISWS), the Indiana Department of Natural Resources (InDNR) Division of Water, Indiana Department of Environmental Management (InDEM) Office of Water Quality, Illinois Environmental Protection Agency (IEPA), and the Illinois State Geological Survey (ISGS). Additional support was provided by the USGS Illinois and Indiana Water Science Centers, the Illinois Department of Agriculture (IDA), the Imperial Valley Water Authority (IVWA), and the Mahomet Aquifer Consortium. The success of this multistate effort was important in showing the feasibility of the multistate collaborative efforts needed for the NGWMN to become operational.

Minnesota

The Minnesota Department of Natural Resources (DNR) and the Minnesota Pollution Control Agency (MPCA) collaborated in the Minnesota Pilot Study for the NGWMN. The DNR and the MPCA tested the NGWMN concepts and approaches in the Framework Document with regard to water-level and water-quality monitoring, respectively. This collaborative effort was necessary because Minnesota uses a multiagency approach to ground-water monitoring and protection. As part of this multiagency approach, the DNR is responsible for assessing and managing the State's ground-water supply and availability. Three State agencies, including the MPCA, are charged with assessing and managing the quality of the State's ground water. Only the MPCA worked on the water-quality aspects of the pilot study because this agency maintains the largest network of wells within the study area. Full implementation of the NGWMN in Minnesota likely will include collaboration and cooperation from several other State and Federal agencies, including the Minnesota Department of Agriculture (MDA), Minnesota Department of Health (MDH), Metropolitan Council, and the USGS.

The Minnesota Pilot Study (MacDonald and Kroening, 2011) focused on the Cambrian-Ordovician aquifer system within southeastern Minnesota. This system consists of four local aquifers and covers an area of approximately 15,000 square miles, including the seven-county Minneapolis-St. Paul metropolitan area (TCMA). The aquifers within the Cambrian-Ordovician system are an important water-supply source for this part of Minnesota, and most of the ground water abstracted within this part of the State is from the Cambrian-Ordovician system.

Montana

The Montana Bureau of Mines and Geology (MBMG) evaluated sites within its statewide ground-water monitoring network for potential inclusion in a NGWMN. Montana's network is a strongly coordinated effort among State and local agencies. The Montana Ground Water Assessment Steering Committee includes representatives from the Montana Department of Natural Resources and Conservation, Department of Environmental Quality, Department of Agriculture, and the State Library as voting members. The committee has the responsibility to review and approve ground-water monitoring sites selected by the MBMG. The MBMG operates some wells and also receives data from other groups, including the Gallatin Valley Water Quality District, the Lewis and Clark County Water Quality Protection District, the Missoula Valley Water Quality District, the Confederated Salish and Kootenai Tribes, and the Montana Department of Natural Resources and Conservation. The Gros Ventre and the Assiniboine Tribes (Fort Belknap Reservation) and the Assiniboine and Sioux Tribes (Fort Peck Reservation) allow MBMG to operate water-level recorders on their land.

Clarence Schwartz, Montana Bureau of Mines and Geology

A 180-foot deep dedicated monitoring well in Dawson County in eastern Montana monitored to create a water-level record for coal in the Fort Union Formation in the Lower Tertiary aquifers.

The Montana Pilot Study (Patton and Buckley, 2011) evaluated a network for seven principal aquifers in Montana: alluvial aquifers, glacial aquifers, the Northern Rocky Mountains Intermontane basin aquifer system, Lower Tertiary aquifers, Upper Cretaceous aquifers, Lower Cretaceous aquifers, and Paleozoic aquifers.

New Jersey

The New Jersey Pilot Study's primary partners include the New Jersey Geological Survey (NJGS) and the USGS New Jersey Water Science Center (USGS-NJ). Because NJGS is part of the New Jersey Department of Environmental Protection, other divisions within the Department participate in the ground-water monitoring network design, funding, and data utilization. These divisions include the Division of Water Supply, the Division of Water Quality, and the Division of Watershed Management. The New Jersey Pilot Study area encompasses the entire State of New Jersey, which includes the Coastal Plain Physiographic Province in the southern part of the State and the Valley and Ridge, Highlands, and Piedmont Physiographic Provinces in the northern part of the State.

The New Jersey Pilot Study (Domber and others, 2011) evaluated a network for eight principal or major aquifers/aquifer systems as defined by the USGS in the Ground Water Atlas of the United States (HA-730, Miller, 1999; and HA-730-L, Trapp and Horn, 1997). These systems include the sand and gravel aquifers, the Early Mesozoic basin aquifers, the Piedmont and Blue Ridge crystalline-rock aquifers, the Piedmont and Blue Ridge carbonate-rock aquifers, the New York and New England carbonate-rock aquifers, the Valley and Ridge aquifers, the Valley and Ridge carbonate-rock aquifers, and the Northern Atlantic Coastal Plain aquifer system. New Jersey divides the Northern Atlantic Coastal Plain aquifer system into several different aquifers that are regionally important and hydrologically distinct from each other. These divisions are finer scale delineations than either the principal or major aquifer definitions of the USGS, which resulted in a pilot study with 13 local aquifer names.

Texas

The Texas Water Development Board (TWDB) evaluated sites within its statewide ground-water monitoring network for potential inclusion in a NGWMN. TWDB's water-level information includes data from cooperating entities that have contributed water-level data for decades. The primary data contributors to the TWDB water-level database are the TWDB, local ground-water conservation districts, and the USGS.

The Texas Pilot Study (Hopkins and others, 2011) evaluated a network for six principal aquifers, which are made up of eight local aquifers. The study chose to omit the Ogallala aquifer in order to focus more attention on aquifers not as thoroughly studied. The six principal aquifers evaluated are the Coastal lowlands aquifer system (Gulf Coast aquifer), Texas Coastal uplands aquifer system (Carrizo-Wilcox aquifer), Seymour aquifer, Pecos River Basin alluvial aquifer, Rio Grande aquifer system (including the Hueco-Mesilla Bolsons), and Edwards-Trinity aquifer system (Trinity, Edwards, and the Edwards-Trinity Plateau aquifers).

Water-Level Monitoring Network

Network Designs

The NGWMN is designed to answer questions at the national, regional interstate, and statewide scales. The Framework Document provides general guidelines that can be used to characterize wells for individual subnetworks and to select adequate spatial and temporal coverage of wells within a principal or major aquifer. Pilot projects were asked to evaluate their existing ground-water-level networks within the target aquifers and were given the freedom to work within those general guidelines. The Framework Document provides a broad definition for unstressed and targeted subnetworks. The SOGW did not provide detailed criteria to the pilot projects on how to define the subnetwork to which a well or spring is assigned, instead allowing the pilot study the freedom to design their own criteria. Moreover, the SOGW provided no specific guidance on a minimum or maximum number of wells for any subnetwork. Pilot projects selected wells from among their existing networks and identified spatial and temporal gaps using their interpretation of the goals of the NGWMN as provided in the Framework Document.

Illinois-Indiana

The Illinois-Indiana Water-Level Monitoring Network consists of 28 wells (table 1). The network covers two local aquifers that are part of the sand and gravel principal aquifer that exists in both Illinois and Indiana. A total of nine targeted wells and 19 unstressed wells are distributed throughout the aquifer (fig. 3). The method of classifying trend and surveillance wells was not defined.

Table 1. Summary of Illinois and Indiana water-level wells for the National Ground-Water Monitoring Network by principal aquifer, local aquifer, well type, and well status.

Principal aquifer	Illinois-Indiana aquifer	Well type	Targeted count	Unstressed count	Total
Sand and gravel aquifers	Mahomet-Teays	Trend	4	4	8
		Surveillance	2	9	11
	Glasford and Mason	Trend	2	4	6
		Surveillance	1	2	3
Subtotal trend			6	8	14
Subtotal surveillance			3	11	14
TOTAL			9	19	28

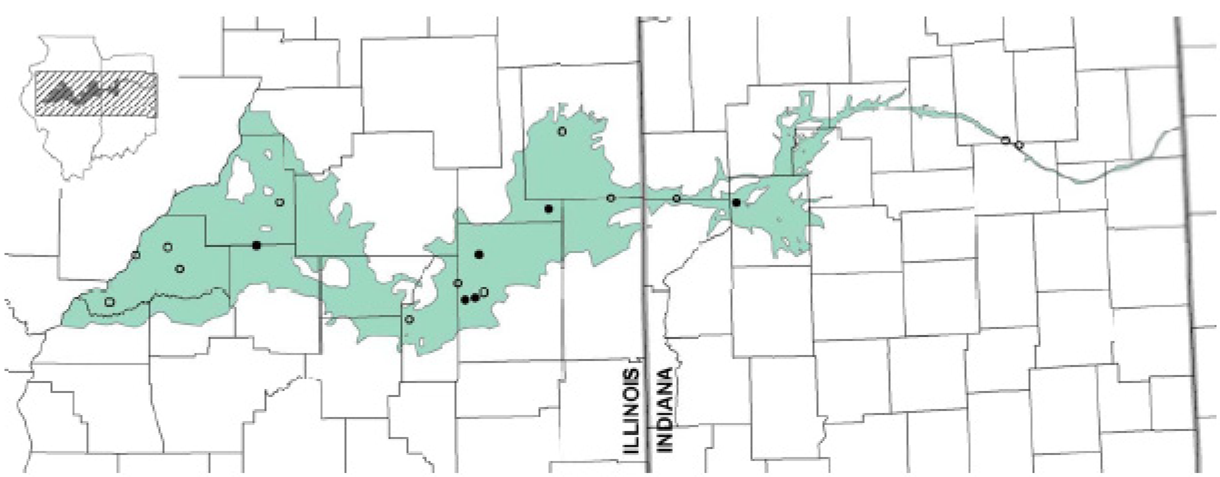

Figure 3. Locations of water-level wells in the ground-water-level network in Illinois and Indiana.

Unstressed and targeted wells were classified on the basis of stress. The unstressed subnetwork includes monitoring wells from areas not affected by pumping and anthropogenic contamination. Targeted wells were wells that showed a long-term response to a changed or changing environment. The hydrographs of all wells were examined, and the appropriate classification was selected.

Minnesota

The Minnesota Water-Level Monitoring Network consists of 52 wells (table 2). The pilot network is designed to monitor four aquifers in the Cambrian-Ordovician aquifer system. Minnesota identified 43 targeted wells and 9 unstressed wells. The locations of the aquifers being monitored are shown in figure 4. The locations of the NGWMN water-level monitoring wells for the Prairie du Chien-Jordan aquifer are shown in figure 5.

All wells in the Minnesota Water-Level Monitoring Network were identified as trend wells. Wells selected had at least 5 years of existing data. Most wells are measured once a month from June through November and twice during the months of March through May for a total of eight measurements annually. A definition of surveillance wells was not provided.

Wells were classified as targeted if the available data showed a long-term downward trend in water levels or the well was in the vicinity (within 5 miles) of a known high-volume pumping well (a well that pumps over 10,000 gallons a day or over 1,000,000 gallons a year); all other wells were classified as unstressed.

Table 2. Summary of Minnesota water-level wells for the National Ground-Water Monitoring Network by principal aquifer, local aquifer, well type, and well status.

Principal aquifer	Minnesota aquifer	Well type	Targeted count	Unstressed count	Total
Cambrian-Ordovician aquifer system	Upper Ordovician aquifer	Trend	0	2	2
		Surveillance			
	Prairie du Chien/Jordan aquifer	Trend	25	4	29
		Surveillance			
	Tunnel City/Wonewoc aquifer	Trend	9	2	11
		Surveillance			
	Mount Simon aquifer	Trend	9	1	10
		Surveillance			
Subtotal trend			43	9	52
Subtotal surveillance					
TOTAL			43	9	52

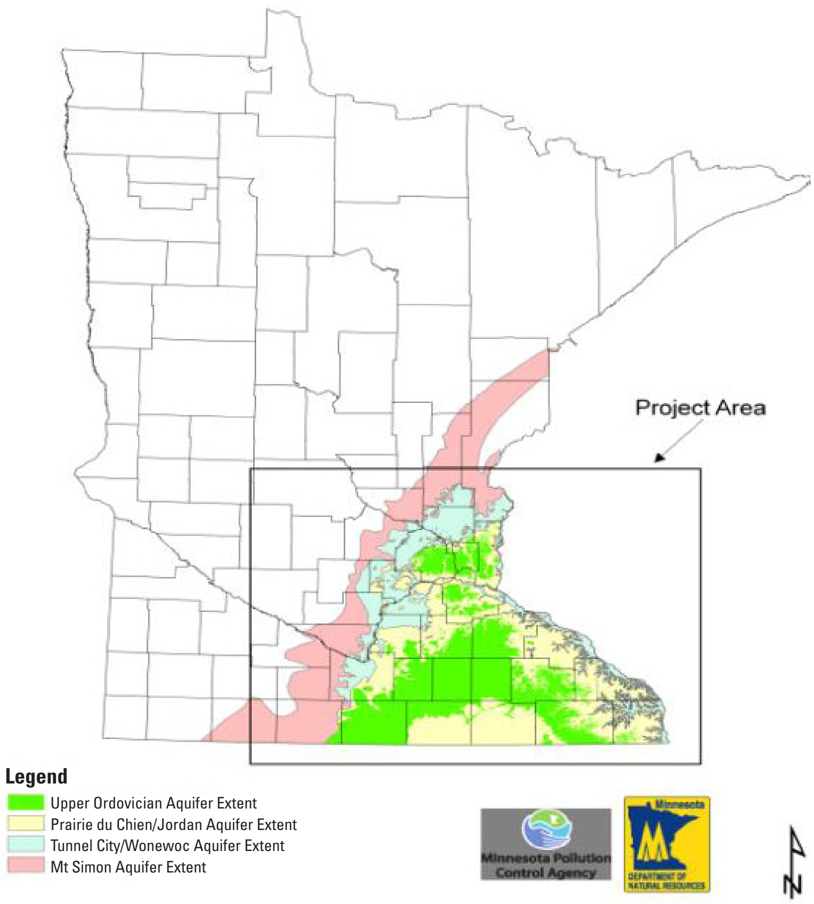

Figure 4. The Cambrian-Ordovician aquifer system in Minnesota.

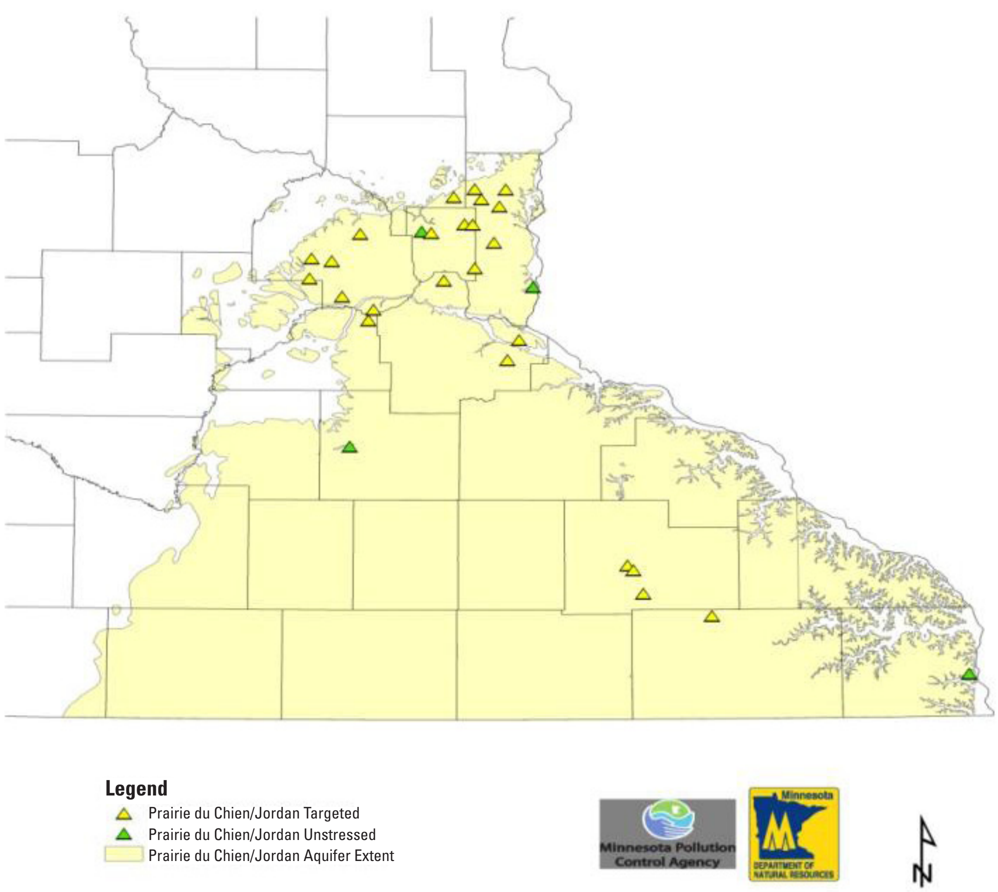

Figure 5. Locations of the National Ground-Water Monitoring Network water-level monitoring wells for the Prairie du Chien-Jordan aquifer.

Montana

The Montana Pilot Study selected sites including 271 wells for the NGWMN (table 3). The pilot network is for seven principal aquifers. The locations of the 45 targeted wells and 226 unstressed wells are shown in figure 6.

The Montana Pilot Study stated that all wells met the criteria for the surveillance classification; however, depending on the purpose of the well, the site could be considered a "trend" site. Wells with installed water-level recording instruments by default were classified as trend sites. A few newly constructed dedicated monitoring wells, installed for the purpose of monitoring water-level trends, also were classified as trend sites despite the lack of a baseline record.

The Montana pilot project attempted to follow the definitions of "targeted" and "unstressed" as used in the Framework Document in conjunction with guidance provided by the SOGW during the project period. That guidance suggested that the pilot project define targeted from a water-level or water-quality perspective, and then further define unstressed as not being targeted.

The Framework Document (section 1.4.3.2) reserved the targeted flag for aquifers (or segments of aquifers) that

1. Are known to be heavily influenced by pumping,
2. Have experienced substantial recharge-altering land-use changes,
3. Are located in areas of managed ground-water resources (for example, artificial recharge or enhanced storage and recovery, or controlled withdrawals),
4. Are known to have degraded water quality as a result of human activities, or
5. Are in an area expected to soon be developed.

However, even though most of Montana's intermontane basins have undergone "recharge-altering land-use changes" (because of surface-water irrigation), for the purposes of the Montana pilot project, wells in these 19 basins were not flagged as targeted unless one of the other factors outlined in the Framework Document applied.

Table 3. Summary of Montana water-level wells for the National Ground-Water Monitoring Network by principal aquifer, local aquifer, well type, and well status.

Principal aquifer	Montana aquifer	Well type	Targeted count	Unstressed count	Total
Alluvial aquifers	Many specific local geologic codes describing Quaternary sediments. Excludes glacial aquifers but does include sediments of Miocene/Pliocene age in northern Montana.	Trend	7	9	16
		Surveillance	2	12	14
Glacial aquifers	Many specific local geologic codes describing glacial aquifers.	Trend	0	3	3
		Surveillance	2	8	10
Northern Rocky Mountains Intermontane basin aquifer system	Many specific local geologic formation and materials codes that describe the basin-fill materials in and surrounding bedrock of intermontane basins.	Trend	6	38	44
		Surveillance	3	92	95
Lower Tertiary aquifers	Many specific local geologic formation and materials codes describing the Fort Union Formation.	Trend	21	10	31
		Surveillance	1	38	39
Upper Cretaceous and Lower Cretaceous aquifers	Many specific local geologic formation and materials codes for regional aquifers in rocks of Cretaceous age (Fox Hills-Hell Creek, Judith River, Eagle, Kootenai Formation aquifers).	Trend	1	1	2
		Surveillance	2	6	8
Paleozoic aquifers	Almost entirely corresponds to the Mississippian Madison Group.	Trend	0	3	3
		Surveillance	0	6	6
Subtotal trend			35	64	99
Subtotal surveillance			10	162	172
TOTAL			45	226	271

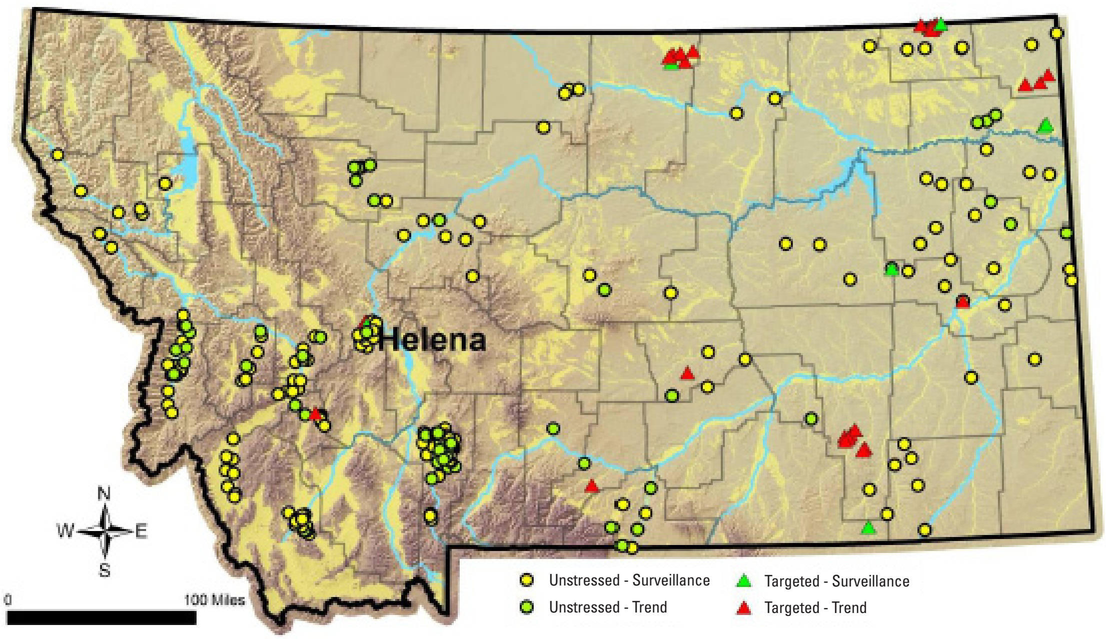

Figure 6. Locations of the National Ground-Water Monitoring Network ground-water-level monitoring wells in Montana.

Clarence Schwartz, Montana Bureau of Mines and Geology

A 600-foot deep stock water well in Musselshell County in central Montana monitored to create a water-level record for sandstone in the Judith River Formation in the Upper Cretaceous principal aquifer.

New Jersey

The New Jersey Water-Level Monitoring Network consists of 982 wells (table 4). The pilot network is for seven principal aquifers, which includes 13 of the major New Jersey aquifers. The network includes a total of 623 targeted wells and 359 unstressed wells (fig. 7).

Trend and surveillance wells were classified on the basis of their measurement frequencies. The trend wells all have at least 5 years of continuous daily value water-level data. The surveillance wells are wells in the New Jersey Network that are measured approximately every 5 years.

Unstressed and targeted wells were classified on the basis of water-level declines. The water-level decline was calculated

Table 4. Summary of New Jersey water-level wells for the National Ground-Water Monitoring Network by principal aquifer, local aquifer, well type, and well status.

Principal aquifer	New Jersey aquifer	Well type	Targeted count	Unstressed count	Total
Sand and gravel aquifers	same	Trend	1	12	13
		Surveillance	0	0	0
Early Mesozoic basin aquifers	same	Trend	0	12	12
		Surveillance	0	0	0
Piedmont and Blue Ridge crystalline-rock aquifers and Piedmont and Blue Ridge carbonate-rock aquifers	same	Trend	0	2	2
		Surveillance	0	0	0
Valley and Ridge aquifers, Valley and Ridge carbonate rock aquifers, and New York and New England carbonate-rock aquifers	same	Trend	0	4	4
		Surveillance	0	0	0
Northern Atlantic Coastal Plain aquifer system	Kirkwood-Cohansey aquifer system	Trend	1	34	35
		Surveillance	0	39	39
	Atlantic City 800-foot sand aquifer	Trend	4	5	9
		Surveillance	76	21	97
	Piney Point aquifer	Trend	3	1	4
		Surveillance	29	19	48
	Vincentown aquifer	Trend	0	2	2
		Surveillance	0	23	23
	Wenonah-Mount Laurel aquifer	Trend	6	5	11
		Surveillance	68	51	119
	Englishtown aquifer	Trend	8	3	11
		Surveillance	55	21	76
	Upper Potomac-Raritan-Magothy aquifer system	Trend	8	3	11
		Surveillance	167	36	203
	Middle Potomac-Raritan-Magothy aquifer system	Trend	13	4	17
		Surveillance	110	44	154
	Lower Potomac-Raritan-Magothy aquifer system.	Trend	6	1	7
		Surveillance	69	16	85
Subtotal trend			49	89	138
Subtotal surveillance			574	270	844
TOTAL			623	359	982

as the difference between recent water levels in the well and the predevelopment water level. Confined wells with water-level declines of 40 feet (ft) or greater were designated as targeted wells. Unconfined wells with water-level declines of 25 ft or greater were designated at targeted wells. In addition, two Critical Areas are designated in New Jersey. Wells within the boundaries of the Critical Areas are also designated as targeted wells. All wells that were not designated as targeted wells because of the magnitude of water-level decline or inclusion in a water-supply Critical Area were designated as unstressed wells.

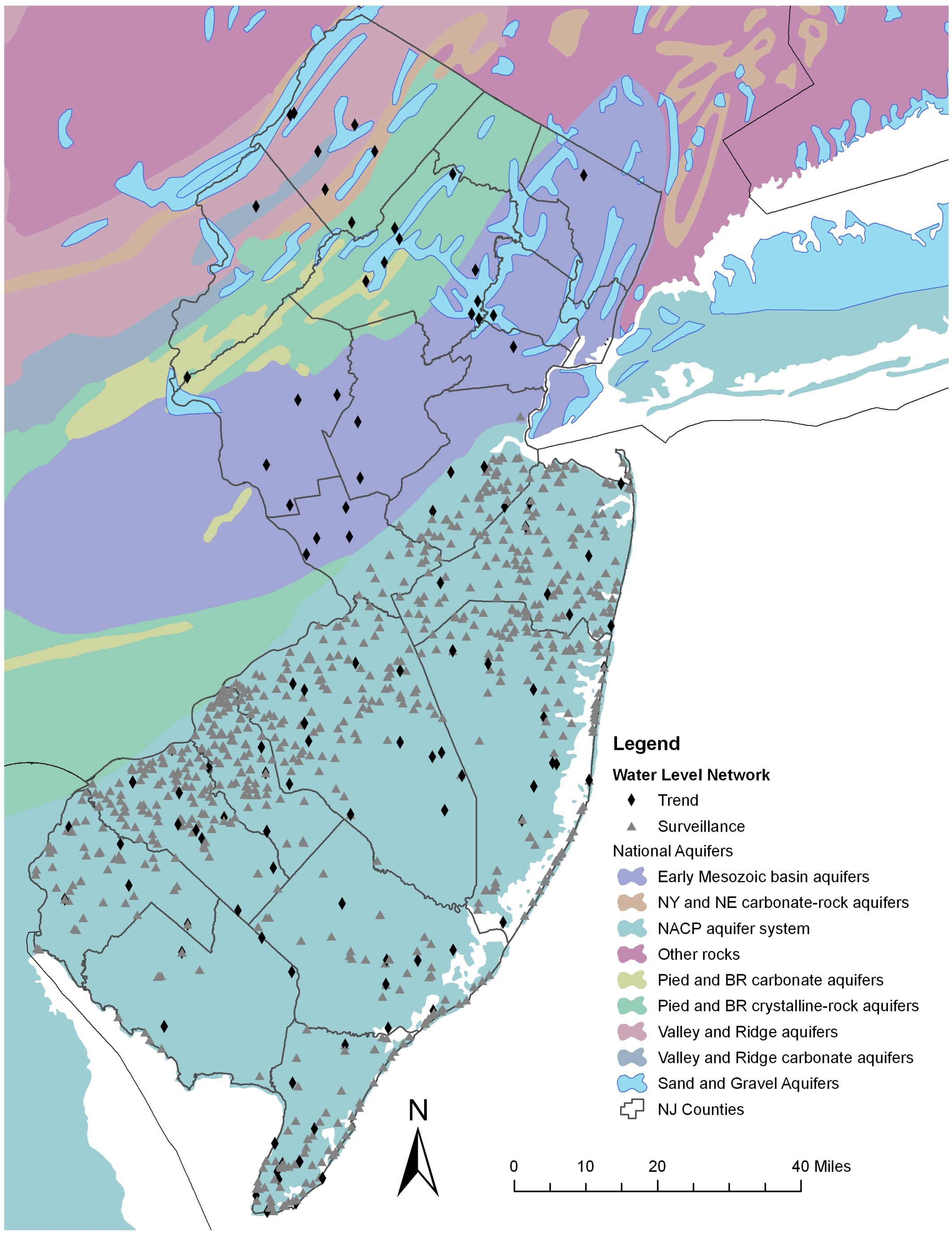

Figure 7. Locations of the ground-water-level monitoring network wells and the principal aquifers in New Jersey.

Texas

The Texas Water-Level Monitoring Network consists of 425 wells (table 5). The pilot network is for six principal aquifers, which cover eight of the major Texas aquifers (fig. 8). The network includes a total of 197 targeted wells and 228 unstressed wells (fig. 9).

According to its Pilot Report, the Texas Water Development Board defines its synoptic-type measuring events (an annual water-level observation program) historically conducted during the same 1 of 4 months—November through February—as surveillance monitoring. Wells with automatic water-level recorders are classified as trend wells.

Unstressed and targeted wells were classified as shown below for water-level monitoring wells. As discussed later, the Texas Pilot Study did not think the terms were appropriate. As stated in the Texas Pilot Report (Hopkins and others, 2011), wells were classified as unstressed if their water-level histories

1. showed little change, or little change throughout time despite a secondary overprint of seasonal fluctuations of whatever magnitude,
2. had originally shown declines from shallower depths and had subsequently recovered to the same level (or recovered sufficiently such that there is 2 ft per year decline or less between original and most recent measurement), or
3. had originally been measured at deeper depths but have recovered or are currently in recovery.

Table 5. Summary of Texas water-level wells for the National Ground-Water Monitoring Network by principal aquifer, local aquifer, well type, and well status.

Principal aquifer	Texas aquifer	Well type	Targeted count	Unstressed count	Total
Coastal lowlands aquifer system	Gulf Coast Aquifer	Trend	3	2	5
		Surveillance	31	52	83
Texas Coastal uplands aquifer system	Carrizo-Wilcox Aquifer	Trend	3	5	8
		Surveillance	67	34	101
Seymour aquifer	Seymour Aquifer	Trend	0	2	2
		Surveillance	4	14	18
Pecos River Basin alluvial aquifer	Pecos Valley Aquifer	Trend	2	0	2
		Surveillance	6	11	17
Rio Grande aquifer system	Hueco-Mesilla Bolsons Aquifer	Trend	1	0	1
		Surveillance	10	8	18
Edwards-Trinity aquifer system	Trinity Aquifer; Edwards (Balcones Fault Zone) Aquifer; Edwards-Trinity Plateau Aquifer	Trend	19	20	39
		Surveillance	51	80	131
Subtotal trend			28	29	57
Subtotal surveillance			169	199	368
TOTAL			197	228	425

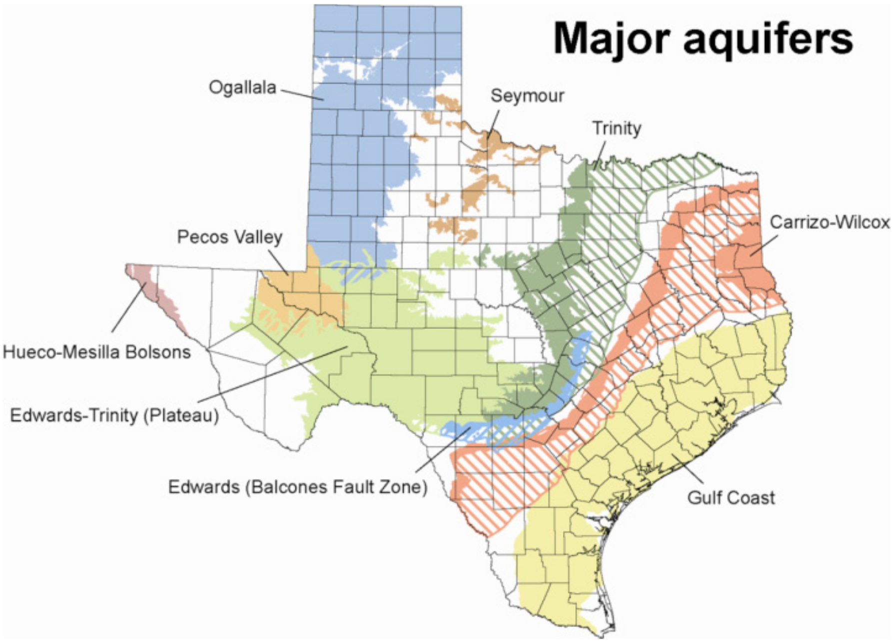

Figure 8. Locations of the principal aquifers in Texas.

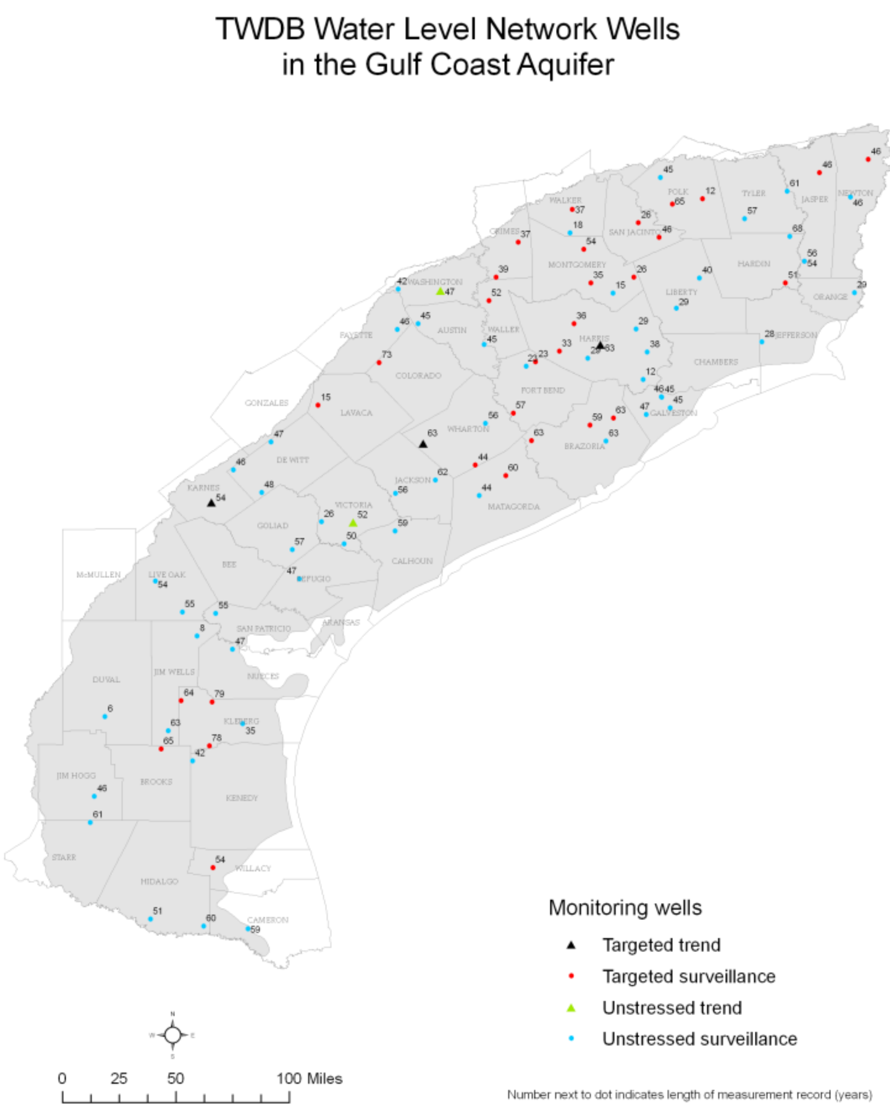

Figure 9. Locations of the ground-water-level monitoring network wells in the Gulf Coast aquifer of Texas.

Wells were considered as targeted if hydrographs indicated

1. that an overall decline from first to most recent measurement of greater than 20 ft had occurred, with or without an overprint of fluctuating water levels,
2. an overall decline of greater than 2 ft per year, or
3. an overall decline of 40 ft with recovery in progress but level not yet to within 20 ft of original measurement.

Gaps Identified in Each Pilot Study

After a thorough evaluation of the monitoring program in their selected principal or major aquifers, each pilot study was asked to provide a “gap analysis” by defining the changes that would be necessary to their existing program in order to meet all of the requirements of the Framework Document. These suggestions can be summarized in the following categories:

- Spatial Gaps: Additional monitoring points identified to provide an adequate areal distribution of wells or springs. In some cases this may be a three-dimensional gap – the need for monitoring points at different depths in an aquifer.
- Temporal Gaps: An increase in the frequency of water-level measurement in order to meet the requirements of the Framework Document.
- Field Practice Gaps: Changes in water-level measurement techniques or documentation in order to meet the requirements of the Framework Document.
- Data-Management Gaps: Missing data elements required by the Framework Document or other data-handling issues.

Illinois-Indiana

The Water-Level Network Gaps identified in the Illinois-Indiana Pilot Report (Wehrmann and others, 2011) are as follows:

1. Spatial Gaps – An addition of 12 wells is identified.
2. Temporal Gaps – Upgrading of network with data loggers or telemetry.
3. Field Practices Gaps – None identified.
4. Data-Management Gaps –
    - Data gaps exist in completing the minimum data elements for some wells.
    - Several wells need accurate elevations.

Minnesota

The Water-Level Network Gaps identified in the Minnesota Pilot Report (MacDonald and Kroening, 2011) are as follows:

1. Spatial Gaps – An additional 98 wells are needed to meet the NGWMN needs.
    - Upper Ordovician aquifer – 28 new wells, 30 total wells
    - Prairie du Chien/Jordan aquifer – 31 new wells, 60 total wells
    - Tunnel City/Wonewoc aquifer – 19 new wells, 30 total wells
    - Mt. Simon aquifer – 20 new wells, 30 total wells
2. Temporal Gaps – None identified.
3. Field Practices Gaps – Eight specific DNR field practices do not match those in the Framework Document. Most of the differences in field practices were minor, such as not collecting weather conditions at every site visit or needing to modify the field forms to collect all of the recommended data.
4. Data-Management Gaps – The DNR’s data-management system does not capture 48 of the 63 elements recommended in the Framework Document. The data are available for many of these data elements, but they are not stored in the database.

Montana

The Water-Level Network Gaps identified in the Montana Pilot Report (Patton and Buckley, 2011) are as follows:

1. Spatial Gaps – An additional 245 wells are needed.
2. Temporal Gaps – About 2,400 periodic (site-visits) measurements would be needed to meet the Framework Document’s water-level frequency requirements. The additional visits would increase monitoring frequency on wells with more than 2 ft of annual fluctuation from quarterly to monthly.
3. Field Practices Gaps – Differences in field practices between Montana Bureau of Mines and Geology and the Framework Document are minimal.
4. Data-Management Gaps – The primary gap in data-management systems relative to Montana’s participation in the NGWMN was the need to create structures within Montana’s Ground Water Information Center (GWIC) to link national aquifer codes to individual GWIC sites and to handle metadata required by the NGWMN necessary to flag NGWMN sites as needed for the NGWMN data portal. Additionally, Web-feature services needed to be created to allow retrieval

of water-level and well-construction data from GWIC. Montana closed most of the data-management-system gaps during its participation in the pilot study.

New Jersey

The Water-Level Network Gaps identified in the New Jersey Pilot Report (Domber and others, 2011) are as follows:

1. Spatial Gaps – Addition of two wells in the Early Mesozoic basins aquifer and 1 well in the New York and New England carbonate-rock aquifer.
2. Temporal Gap – The New Jersey Surveillance Network wells are measured once every 5 years. To meet the requirements of the Framework Document that surveillance wells be measured at least once annually would require that 844 wells be measured every year instead of every 5 years, which obviously would increase cost.
3. Field Practices Gaps –
    - Measuring tapes are currently not decontaminated between wells. Steel tapes are wiped off, but not with a disinfectant.
    - New Jersey currently does not have a protocol to calibrate steel or electric tapes.
    - Different criteria are used when comparing manual to automatic data recorder measurements. New Jersey uses 0.03 ft (0.05 to 0.1 ft for wells deeper than 100 ft), and the Framework Document requires 0.01 ft.
    - The required accuracy of continuous measurements of 0.02 ft may be sufficient for most wells, but wells with deeper water levels often require an instrument with a larger measurement range that results in less accuracy.
4. Data-Management Gaps – The gaps are minimal. Weather conditions at time of data collection are not collected.

Texas

The Water-Level Network Gaps identified in the Texas Pilot Report (Hopkins and others, 2011) are as follows:

1. Spatial Gaps – Addition of wells in the Seymour, Pecos Valley, and Hueco-Mesilla Bolsons aquifers to bring the minimum number of wells per aquifer up to 30.
2. Temporal Gaps – To meet the requirements of the Framework Document would require 2,200 more site visits.
3. Field Practices Gaps – Gaps exist but are minimal.
4. Data-Management Gaps – Monitoring site attributes, specifically screened interval and completion data, are lacking.

USGS New Jersey Water Science Center

Observation wells near Sandy Hook, New Jersey.

Water-Quality Monitoring Network

Network Designs

Illinois-Indiana

The Illinois-Indiana Water-Quality Monitoring Network consists of 14 wells (table 6). The network includes a total of 0 targeted wells and 14 unstressed wells (fig. 10). The water-quality monitoring wells in Illinois are all public supply wells that are part of the Illinois Environmental Protection Agency Community Water Supply Ambient Network. The method of classifying trend and surveillance wells was not defined.

Unstressed and targeted wells were classified by water quality. For the purpose of this study, the Illinois-Indiana Pilot Report (Wehrmann and others, 2011) specified "targeted" as water-quality wells showing an impact from anthropogenic activities on water quality. The presence of synthetic compounds in ground water would cause a well to be classified in the targeted water-quality subnetwork. However, no wells in the Illinois-Indiana Water-Quality Monitoring Network were identified as targeted.

Minnesota

The Minnesota Water-Quality Monitoring Network consists of 37 wells (table 7). The network includes a total of 26 targeted wells and 11 unstressed wells. The locations of the National Ground-Water Monitoring Network water-quality monitoring wells for the targeted water-quality subnetwork are shown in figure 11.

All wells in the Minnesota Water-Quality Monitoring Network were identified as trend wells. A definition of surveillance wells was not provided.

Unstressed and targeted wells were classified by using the nitrate and chloride concentrations of the water samples. Wells with nitrate concentrations less than 1 milligram per liter (mg/L) or chloride concentrations less than 35 mg/L were classified as unstressed, and wells containing concentrations greater than these were classified as targeted.

Table 6. Summary of Illinois and Indiana water-quality wells for the National Ground-Water Monitoring Network by principal aquifer, local aquifer, well type, and well status.

Principal aquifer	Illinois-Indiana aquifer	Well type	Targeted count	Unstressed count	Total
Sand and gravel aquifers	Mahomet-Teays	Trend	0	0	0
		Surveillance	0	13	13
	Glasford and Mason	Trend	0	0	0
		Surveillance	0	1	1
Subtotal trend			0	0	0
Subtotal surveillance			0	14	14
TOTAL			0	14	14

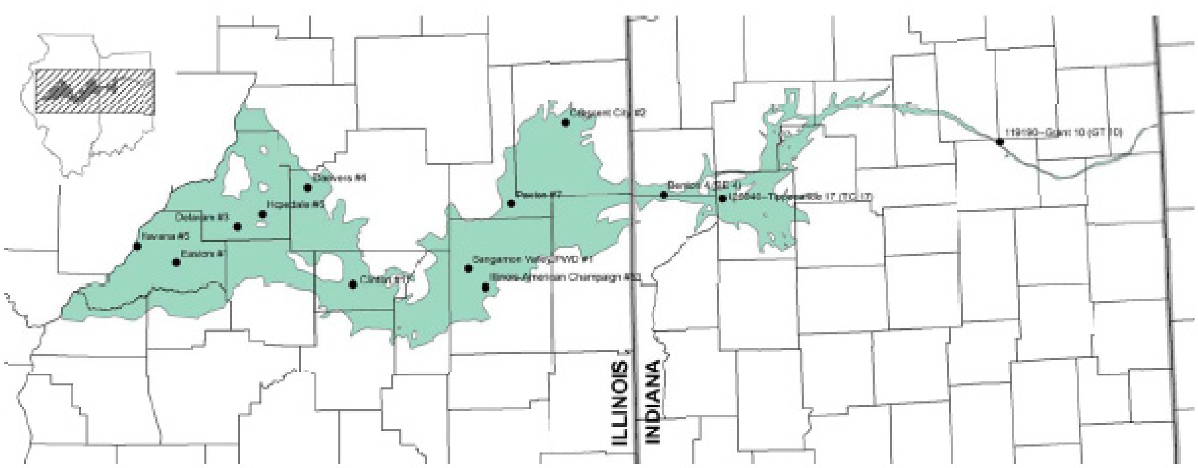

Figure 10. Locations of the ground-water-quality monitoring network wells in the Mahomet-Teays aquifer in Illinois and Indiana.

Table 7. Summary of Minnesota water-quality wells for the National Ground-Water Monitoring Network by principal aquifer, local aquifer, well type, and well status.

Principal aquifer	Minnosota aquifer	Well type	Targeted count	Unstressed count	Total
Cambrian-Ordovician aquifer system	Upper Ordovician aquifer	Trend	3	5	8
		Surveillance			
	Prairie du Chien/Jordan aquifer	Trend	22	5	27
		Surveillance			
	Tunnel City/Wonewoc aquifer	Trend	1	1	2
		Surveillance			
	Mount Simon aquifer	Trend	0	0	0
		Surveillance			
Subtotal trend			26	11	37
Subtotal surveillance					
TOTAL			26	11	37

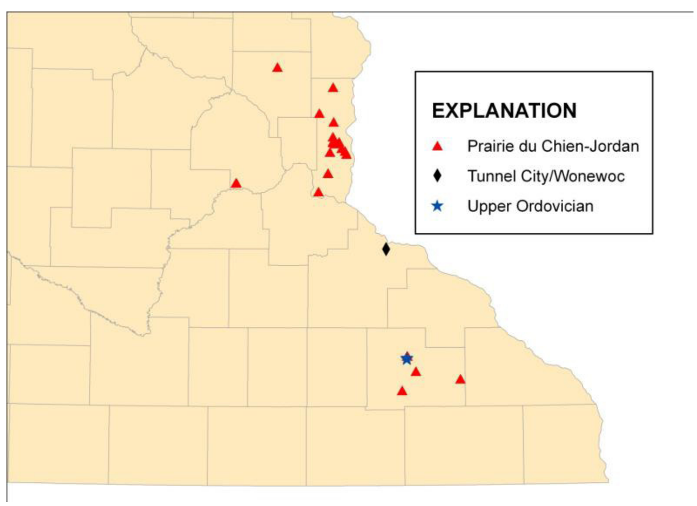

Figure 11. Locations of the Minnesota National Ground-Water Monitoring Network water-quality monitoring wells for the targeted water-quality subnetwork.

Montana

The Montana Water-Quality Monitoring Network of the NGWMN consists of 261 wells (table 8; fig. 12). The network includes a total of 20 targeted wells and 241 unstressed wells. The method of classifying trend and surveillance wells for the water-quality network was not defined.

The Montana Pilot Study attempted to follow the definitions of “targeted” and “unstressed” as used in the Framework Document in conjunction with guidance offered by the SOGW during the project period. That guidance suggested that the pilot project define targeted from a water-level or water-quality perspective, and then further define unstressed as not being targeted.

The Framework Document (section 1.4.3.2) reserved the targeted flag for aquifers (or segments of aquifers) that

1. Are known to be heavily influenced by pumping,
2. Have experienced substantial recharge-altering land-use changes,
3. Are located in areas of managed ground-water resources (for example, artificial recharge or enhanced storage and recovery, or controlled withdrawals)
4. Are known to have degraded water quality as a result of human activities, or
5. Are in an area expected to soon be developed.

Table 8. Summary of Montana water-quality wells for the National Ground-Water Monitoring Network by principal aquifer, local aquifer, well type, and well status.

Principal aquifer	Montana aquifer	Well type	Targeted count	Unstressed count	Total
Alluvial aquifers	Many specific local geologic codes describing Quaternary sediments. Excludes glacial aquifers but does include sediments of Miocene/Pliocene age in northern Montana.	Trend	0	2	2
		Surveillance	0	27	27
Glacial aquifers	Many specific local geologic codes describing glacial aquifers.	Trend	0	0	0
		Surveillance	0	13	13
Northern Rocky Mountains Intermontane basin aquifer system	Many specific local geologic formation and materials codes that describe the basin-fill materials in and surrounding bedrock of intermontane basins.	Trend	1	1	2
		Surveillance	0	134	134
Lower Tertiary aquifers	Many specific local geologic formation and materials codes describing the Fort Union Formation.	Trend	5	2	7
		Surveillance	14	44	58
Upper Cretaceous and Lower Cretaceous aquifers	Many specific local geologic formation and materials codes for regional aquifers in rocks of Cretaceous age (Fox Hills-Hell Creek, Judith River, Eagle, Kootenai Formation aquifers).	Trend	0	0	0
		Surveillance	0	10	10
Paleozoic aquifers	Almost entirely corresponds to the Mississippian Madison Group.	Trend	0	3	3
		Surveillance	0	5	5
Subtotal trend			6	8	14
Subtotal surveillance			14	233	247
TOTAL			20	241	261

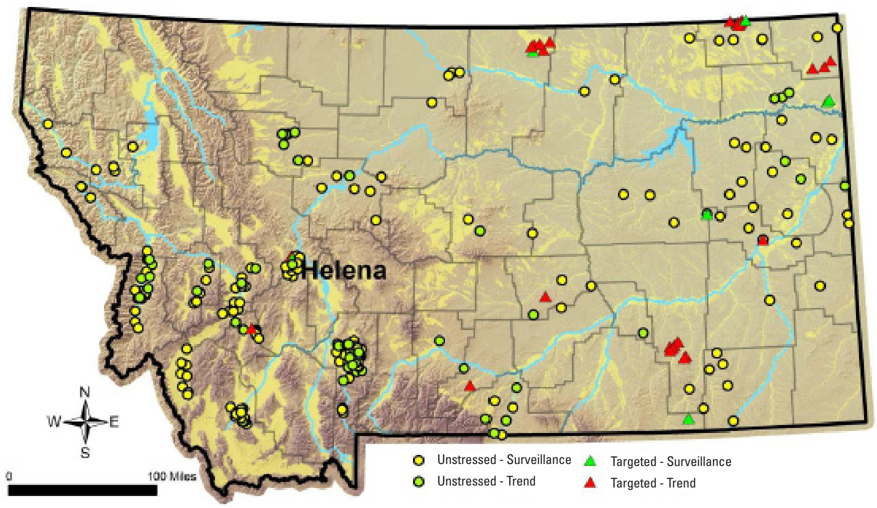

Figure 12. Locations of the ground-water-quality monitoring network wells in Montana.

However, even though most of Montana's intermontane basins have undergone "recharge-altering land-use changes" (because of surface-water irrigation), for the purposes of the Montana pilot project, wells in these 19 basins were not flagged as targeted unless one of the other factors outlined in the Framework Document applied.

New Jersey

New Jersey has two ground-water-quality networks that are included in the NGWMN; an ambient shallow ground-water-quality network and a chloride ground-water-quality network (primarily in the confined aquifers of the New Jersey Coastal Plain).

The New Jersey Ambient Ground-Water-Quality Monitoring Network provides information about land-use-related nonpoint-source contaminant effects on shallow nonconfined ground-water quality. The New Jersey Ambient Water-Quality Monitoring Network consists of 145 wells (table 9). The network includes a total of 116 targeted wells and 29 unstressed wells (fig. 13). Approximately one-fifth of the wells are sampled every year, thus every well is sampled every 5 years. Because of this sampling frequency, all wells are considered to be classified as surveillance wells in the Ambient Ground-Water-Quality Monitoring Network.

The method to classify wells as either unstressed or targeted in the New Jersey Ambient Water-Quality Monitoring Network is based on the land-use classification used in the selection of the wells for the network because all wells in the network are shallow wells. The wells associated with urban and agricultural land uses are designated as targeted. The wells identified as undeveloped or unimpacted are designated as unstressed because they were installed to determine background or unimpacted water quality.

The chloride monitoring network has 87 wells as outlined in table 10. Data are collected from coastal areas and areas with salty ground water to delineate areas of saltwater intrusion (fig. 13). The chloride network covers nine confined aquifers in the Coastal Plain and parts of the unconfined Kirkwood-Cohansey aquifer. Wells are sampled every 5 to 10 years and, therefore, are classified as surveillance wells.

The method used to classify wells as either unstressed or targeted in the New Jersey Chloride Monitoring Network is based on the most recent chloride value. Wells where the recent chloride value is greater than 125 mg/L are designated as targeted in the chloride monitoring network.

USGS New Jersey Water Science Center

Observation well in Atlantic County, New Jersey.

Table 9. Summary of New Jersey water-quality wells for the National Ground-Water Monitoring Network by principal aquifer, local aquifer, well type, and well status.

Principal aquifer	New Jersey aquifer	Well type	Targeted count	Unstressed count	Total
Sand and gravel aquifers	same	Surveillance	26	9	35
Early Mesozoic basin aquifers	same	Surveillance	21	1	22
Piedmont and Blue Ridge crystalline-rock aquifers and Piedmont and Blue Ridge carbonate-rock aquifers	same	Surveillance	5	0	5
Valley and Ridge aquifers, Valley and Ridge Carbonate Rock aquifers, and New York and New England carbonate-rock aquifers	same	Surveillance	1	1	2
Northern Atlantic Coastal Plain aquifer system	Kirkwood-Cohansey aquifer system	Surveillance	24	16	50
	Other aquifers	Surveillance	29	2	31
TOTAL			116	29	145

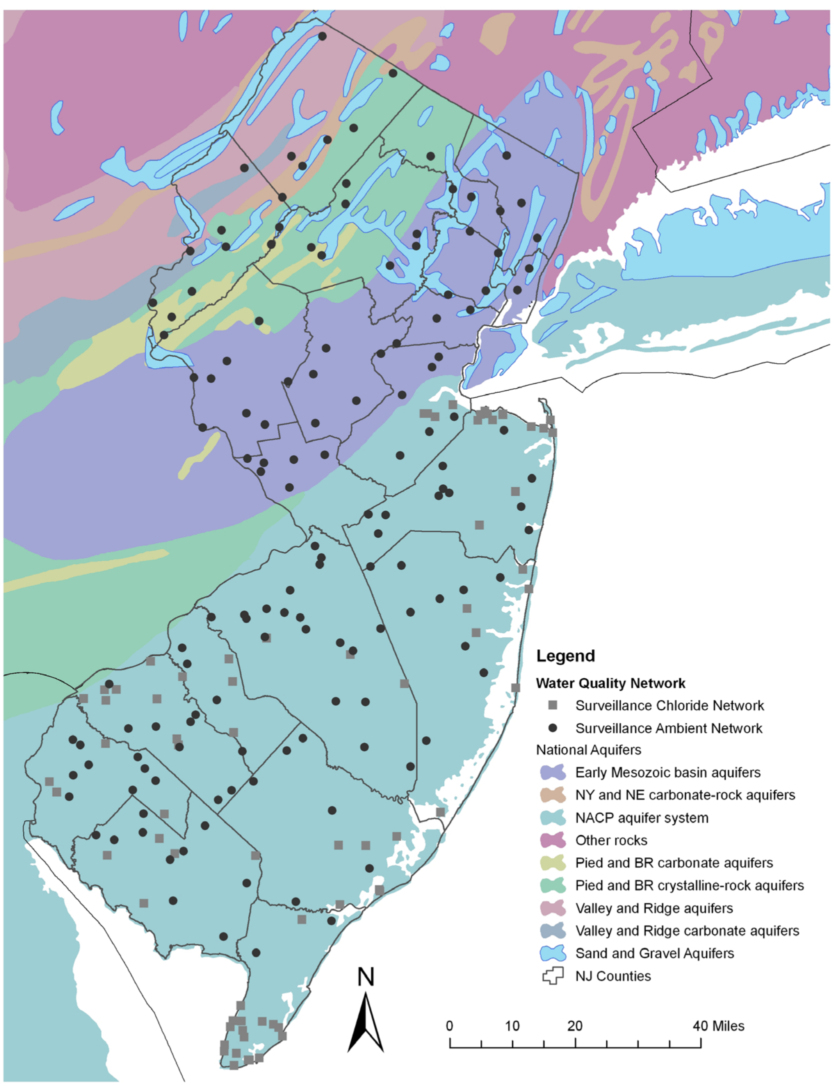

Figure 13. Locations of the ground-water quality monitoring network wells and the principal aquifers in New Jersey.

Table 10. Summary of New Jersey chloride ground-water-quality wells for the National Ground-water Monitoring Network by principal aquifer, local aquifer, well type, and well status.

[WBZ, water-bearing zone]

Principal aquifer	New Jersey aquifer	Well type	Targeted count	Unstressed count	Total
Northern Atlantic Coastal Plain aquifer system	Kirkwood-Cohansey aquifer system - unconfined	Surveillance	0	3	3
	Kirkwood-Cohansey aquifer system - confined	Surveillance	2	12	14
	Atlantic City 800-foot sand aquifer (with Rio Grande WBZ)	Surveillance	1	7	8
	Piney Point aquifer	Surveillance	3	4	7
	Vincentown aquifer	Surveillance	0	0	0
	Wenonah-Mount Laurel aquifer	Surveillance	0	4	4
	Englishtown aquifer	Surveillance	1	4	5
	Upper Potomac-Raritan-Magothy aquifer system	Surveillance	9	12	21
	Middle Potomac-Raritan-Magothy aquifer system (with undifferentiated Potomac-Raritan-Magothy)	Surveillance	9	7	16
	Lower Potomac-Raritan-Magothy aquifer system	Surveillance	5	4	9
TOTAL			30	57	87

Bill Dye, Illinois State Geological Survey

The Illinois State Geological Survey drill rig drilling a borehole for one of the observation wells that is included in the Illinois network for the NGWMN pilot project.

Texas

The Texas Water-Quality Monitoring Network consists of 851 wells (table 11). Figure 14 shows the well locations for the Gulf Coast aquifer. These wells were not classified as targeted or unstressed wells because of reasons that will be discussed later in this report.

All water-quality wells were classified as surveillance wells. A definition of trend wells for water quality was not provided.

Gaps Identified in Each Pilot Study

As with the water-level monitoring program, each pilot study was asked to provide a "gap analysis" by defining the changes that would be necessary to their existing program in order to meet all of the requirements of the Framework Document. These suggestions can be summarized in the follow categories:

- Spatial Gaps: Additional sampling points identified to provide an adequate areal distribution of wells or springs. In some cases this may be a three-dimensional gap – the need for sampling at different depths in an aquifer.
- Temporal Gaps: An increase in the frequency of sampling in order to meet the requirements of the Framework Document.
- Field Practice Gaps: Changes in sampling techniques or documentation in order to meet the requirements of the Framework Document.
- Data-Management Gaps: Missing data elements required by the Framework Document or other data-handling issues.

Illinois-Indiana

The Water-Quality Network Gaps identified in the Illinois-Indiana Pilot Report (Wehrmann and others, 2011) are as follows:

1. Spatial Gaps – A greater density of sampling points, especially in Indiana, is needed.
2. Temporal Gaps – The list of analytes for the Indiana and Illinois wells appears to cover the minimum desired set of constituents at an adequate sampling frequency (that is, annual).
3. Field Practices Gaps – The field and laboratory practices of the USGS-IN, InDNR, and IEPA compare favorably with the Framework Document (Subcommittee on Ground Water, 2009). No major differences were identified.
4. Data-Management Gaps – Principal data-management needs relate to NGWMN portal access to water-level, water-quality, and associated geologic and well-construction data originating from Illinois agencies. The ISWS is willing to host the data for the NGWMN portal. Procedures are needed to create a routine for IEPA to send new data to the ISWS and for ISWS to provide that data to NGWMN portal users.

Table 11. Summary of Texas water-quality wells for the National Ground-Water Monitoring Network by principal aquifer, local aquifer, well type, and well status.

Principal aquifer	Texas aquifer	Well type	Total
Coastal lowlands aquifer system	Gulf Coast aquifer	Surveillance	230
Texas Coastal uplands aquifer system	Carrizo-Wilcox aquifer	Surveillance	205
Seymour aquifer	Seymour aquifer	Surveillance	45
Pecos River Basin alluvial aquifer	Pecos Valley aquifer	Surveillance	30
Rio Grande aquifer system	Hueco-Mesilla Bolsons aquifer	Surveillance	35
Edwards-Trinity aquifer system	Trinity aquifer Edwards (Balcones Fault Zone) aquifer Edwards-Trinity Plateau aquifer	Surveillance	306
TOTAL			851

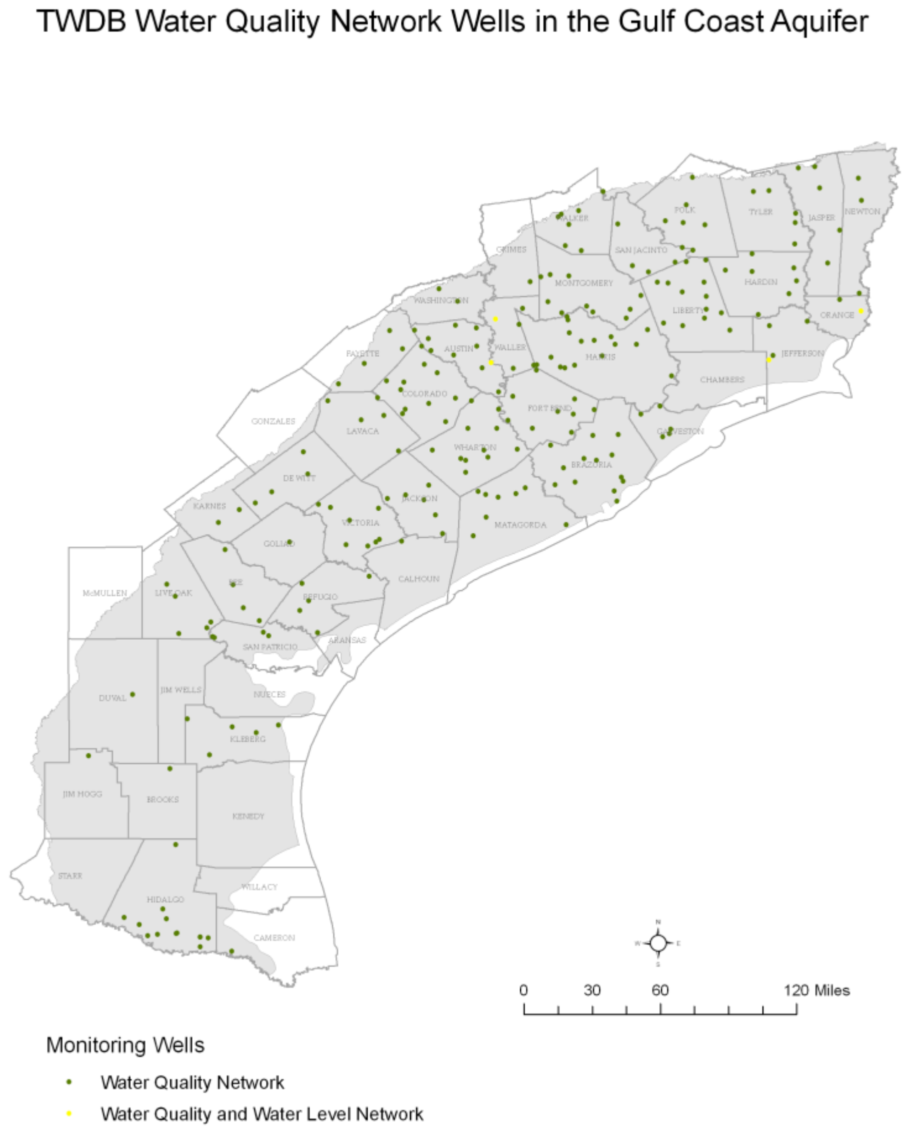

Figure 14. Locations of the ground-water-quality monitoring network wells for the Gulf Coast aquifer in Texas.

Minnesota

The Water-Quality Network Gaps identified in the Minnesota Pilot Report (MacDonald and Kroening, 2011) are as follows:

1. Spatial Gaps – The Water Quality Trend Network is disproportionately focused on the Minneapolis-St. Paul metropolitan area and does not describe water-quality conditions throughout the entire Cambrian-Ordovician system in Minnesota. A Surveillance Monitoring Network of about 130 wells is proposed to fill the identified spatial gaps in the Water-Quality Trend Network.
2. Temporal Gaps – The Water-Quality Trend Network lacks sufficient data to quantify ground-water-quality trends. Thirty-one of the 37 wells have water-quality records extending at least 5 years, but only one of these wells has a record extending at least 10 years.
3. Field Practices Gaps – There are slight differences between the MPCA's field methods and those listed in the Framework Document.
4. Data-Management Gaps – Approximately 40 data elements listed in the Framework Document for the NGWMN are not currently stored in the MPCA's data-management system. These data elements will need to be added to the database to fully implement the NGWMN.

Montana

The Water-Quality Network Gaps identified in the Montana Pilot Report (Patton and Buckley, 2011) are as follows:

1. Spatial Gaps – An additional 245 wells are needed. The same wells are identified in the Water-Level Gap Analysis.
2. Temporal Gaps – In the first 2 years of implementation of a NGWMN, Montana would need to collect about 940 water-quality samples (standard and extended list analytes) to complete baseline records for NGWMN-Montana sites. Completion of baseline records for NGWMN-Montana sites would be a short-term "operations gap." Once baseline records are attained, ongoing sampling of about 750 NGWMN-Montana sites at a once-every-5-year frequency would require about 150 samples annually. The Montana Ground-Water Assessment Program currently (as of 2010) collects samples from 70 to 90 statewide network sites each year; the long-term operations gap would be about 60–80 samples annually.
3. Field Practices Gaps – Differences in field practices are minor, and NGWMN and Montana statewide monitoring network practices will need only minimal reconciliation. The greatest difference is how well-purging details are specified to indicate stable water chemistry. Both sets of well-purging instructions use field parameters to determine when water chemistry is stable prior to bottling samples. If necessary, the field methods can be easily and inexpensively reconciled.
4. Data-Management Gaps – Creation of a Web-feature service to transmit water-quality data to the GWDP was not accomplished during the pilot project. Lack of this water-quality Web-feature service is the primary data-management gap.

New Jersey

The Water-Quality Network Gaps identified in the New Jersey Pilot Report (Domber and others, 2011) are as follows:

1. Spatial Gaps – No wells are located in the New York and New England carbonate-rock aquifer, and the Piedmont and Blue Ridge crystalline-rock aquifer is underrepresented in its northern reaches for the Ambient Network. The exact number of monitoring wells that would be needed to address this issue has not been determined. It is believed, however, that this data gap could be bridged with the addition of three to four wells in each aquifer. An additional seven wells are suggested for the chloride network.
2. A gap was identified in monitoring bedrock or deep aquifer water quality. One deep well installed next to each of the 145 shallow ambient network wells was proposed.
3. Temporal Gaps – The largest data gap regarding ground-water quality between the New Jersey Ambient Ground-Water-Quality Monitoring Network (AGWQMN) and the Framework Document is the frequency of sampling. The SOGW Framework Document states that each monitoring well should have a baseline of data more than 5 consecutive years, with a sampling frequency of quarterly to twice per year. To date (2011), no individual AGWQMN well has 5 consecutive years of data. The chloride network also does not meet the annual monitoring frequency because the chloride wells are sampled approximately every 5 to 10 years.
4. Field Practices Gaps – No gaps exist.
5. Data-Management Gaps – No gaps exist.

Texas

The Water-Quality Network Gaps identified in the Texas Pilot Report (Hopkins and others, 2011) are as follows:

1. Spatial Gaps – The Texas Water Development Board is in the process of including Texas Commission on Environmental Quality (TCEQ) information in the water-quality database. Coverage gaps will be identified after this major effort.
2. Temporal Gaps – Gaps in the frequency of sampling exist to some degree, but are not estimated at the time of this report.
3. Field Practices Gaps – Field practice standard gaps exist and are minimal, involving only lack of decontamination of steel measuring tapes and collection of measurement time and land use at the measuring or sampling sites.
4. Data-Management Gaps – Data-management gaps mainly involve the database's lack of fields in all seven categories described in appendix 6 of the Framework Document (most crucially, the unique identifier for any well chosen as a NGWMN well) and development of Web services to facilitate data transfer to the portal.

Overview of the Pilot Networks

The networks designed by each pilot study cannot be compared directly because they were designed for different areas. Some pilots covered the principal aquifers in the entire State while other pilots covered specific aquifer systems. Thus, the coverage (both size of the area and the number of principal aquifers) of the network design must be considered when comparing the number of wells in each pilot network.

Table 12. Summary of water-level and water-quality monitoring wells for the pilot studies.

[NGWMN, National Ground-Water Monitoring Network; m^2, square mile]

State	Area to be monitored	Total monitoring wells in area	Proposed wells for NGWMN water-level monitoring	Additional number of water-level wells needed as proposed in gap analysis	Proposed wells for NGWMN water-quality monitoring	Additional number of water-quality wells needed as proposed in gap analysis
Illinois-Indiana	Mahomet-Teays aquifer–4,654 mi^2		28	12	14 (more wells available through Illinois Department of Agriculture water-quality network)	To be determined
Minnesota	Cambrian-Ordovician aquifer system in the Twin Cities Metro Area – 15,000 mi^2	157	52	98	37	93 (130–37)
Montana	Entire State – 147,042 mi^2	934	271	245	261 (overlap with levels monitoring)	245
New Jersey	Entire State – 8,721 mi^2	19,000	982	3	145 (may be overlap with levels monitoring)	Approximately 6 to 8
Texas	Entire State (except Ogallala aquifer) – 235,180 mi^2 (= 268,580 mi^2 – 33,400 mi^2)	2,250	425	Approximately 32	851 (may be overlap with levels monitoring)	To be determined

Table 12 provides a summary of the area covered and the number of wells proposed for the NGWMN in each pilot study. Also included for comparison is the total number of monitoring wells available in the entire area from which the NGWMN wells were selected and the number of additional wells the pilot studies proposed as needed to meet the objectives of the National Ground-water Monitoring Network.

Cost of Network

The NGWMN design includes surveillance sites ("synoptic" sites for water-level or water-quality monitoring) and trend sites (fewer sites but with more frequent measurements, such as a continuous water-level recorder) within "unstressed" and "targeted" subnetworks. The SOGW provided no specific guidance on a minimum or maximum number of wells or springs for any proposed subnetwork. Pilots selected wells from among their existing networks and identified spatial and temporal gaps using their interpretation of the goals of the NGWMN as provided in the Framework Document. No limits, financial or otherwise, were placed on the pilot studies for this exercise. The network design selected by each pilot study drives any cost estimates for full implementation of the NGWMN. Actual implementation may be more or, in fact, less that those cited in this report, depending on the final network design.

Summary of Incremental Costs for State Participation in NGWMN

The NGWMN design included surveillance (routine frequent samples) and trend (long-term sampling) monitoring approaches for measuring water levels and water quality. States were asked to report costs for their existing ground-water monitoring program and the incremental costs of the NGWMN participation. These costs occurred in the following monitoring categories: initial organization/participation, well network installation and maintenance, field practices, data management, and monitoring program implementation. These costs also include one-time and capital costs and operation and maintenance costs. Table 13 provides detailed costs, which are summarized below. Because the number of wells significantly affects the incremental costs, some costs vary widely from State to State, ranging from no additional wells to 245 new wells proposed.

Table 13. Incremental State pilot project costs to participate in the National Ground-Water Monitoring Network and address all gaps.

	Illinois-Indiana	Minnesota	Montana	New Jersey	Texas	Total	Average
One-Time and Capital Costs							
State Initial Participation	$32,500	27,000	31,659	38,000	36,275	165,434	$33,087
Monitoring Network	200,600	3,525,000	1,604,000	1,515,900	131,950	6,977,450	1,395,490
Field Practices	0	17,500	0	0	0	17,500	3,500
Data Management	13,100	17,500	8,400	0	21,800	60,800	12,160
Monitoring Program	0	15,000	552,750	121,000	0	688,750	137,750
TOTAL ONE-TIME AND CAPITAL COSTS	$246,200	$3,602,000	$2,196,809	$1,674,900	$190,025	$7,909,934	$1,581,987
Operation and Maintenance Costs							
Monitoring Network	$33,715	13,500	160,230	546,000	0	753,445	150,689
Field Practices	0	0	0	32,900	100	33,000	6,600
Data Management	34,000	0	0	0	0	34,000	6,800
Monitoring Program	0	123,100	147,300	4,702,100	78,250	5,050,750	1,010,150
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS	$67,715	$136,600	$307,530	$5,281,000	$78,350	$5,871,195	$1,174,239

State Participation – One-Time Costs

State monitoring program costs to participate in the proposed NGWMN were fairly consistent from State to State. These costs are primarily for staff time to become familiar with the NGWMN Framework, consult internally and with the Subcommittee on Ground Water, analyze their monitoring networks relative to the framework, identify wells for the State's portion of a proposed NGWMN, evaluate field practices and data management to determine their consistency with the framework, and write a report identifying their proposed portion of a national network, any monitoring program gaps, and the associated costs to be equivalent to the proposed framework, as well as propose potential changes to the framework. The costs ranged from $27,000 (Minnesota) to $38,000 (New Jersey) and averaged $33,087.

State Incremental Framework Costs

States evaluated their monitoring programs and networks to determine what the costs would be to meet the specifications of the NGWMN framework in four principal areas: (1) Monitoring Well Network, (2) Field Practices, (3) Data Management, and (4) Monitoring Program. Each area may have incremental framework (gap) costs that are one-time (start-up or front-end) expenses, capital expenditures and annual operation and maintenance outlays.

Monitoring Well Network: The monitoring well installation and instrumentation incremental costs across the five State pilot projects averaged $1,395,490 (total $6,977,450), which was mainly to install monitoring wells in areas not adequately represented by the current States' networks. Notably, three State pilot projects focused on the entire State's networks and two focused on an individual aquifer or a metropolitan area. For the three States that examined the networks for the entire geographic State area, the average well installation and instrumentation incremental costs were $1,083,950.

The average incremental operation and maintenance costs for the added wells for water-level measurements are $77,388 (two States) and for water-quality monitoring are $292,293 (four States).

Field Practices: Minnesota identified one-time costs for proposed field practice standards of $17,500. Relative to field practices operation and maintenance costs, Texas proposed $100 per year for cleaning measuring tapes, and New Jersey identified $32,900 for modified water-level measurements and well-sampling preparation.

Data Management: One-time proposed data-management costs include modifying data standards, automating data collection, and establishing Web portal reporting, averaging $12,160 (total $60,800) for the five State pilot projects.

Monitoring Program: For one-time costs of baseline data collection, New Jersey proposed collecting baseline well data for $121,000, Montana proposed water levels and water quality for $552,550, and Minnesota proposed monitoring equipment for $15,000. States will need to increase monitoring of levels and (or) quality at a greater frequency. Incremental operation and maintenance costs for more frequent monitoring for the five State pilot projects averaged $1,010,150 (total $5,050,750). New Jersey proposed a large number of additional wells for its portion of the network. The average cost for proposed increasing monitoring frequency across the four other State pilots is $87,163.

Cross-State Program Costs: Combined, the one-time and capital costs for the five State pilot projects are $7,909,934 and $4,061,734 for the three States that include their entire State area or an average of $1,353,911 across the three States. The incremental operation and maintenance costs for the five State pilots are $5,871,195, an average of $1,174,239 for the five States, and $5,666,880 or an average of $1,888,960 for the three States reporting on entire State networks.

Cost of Using Existing Wells Only

If the NGWMN relied only on existing wells, the incremental costs of well installation and maintenance and associated monitoring, including one-time baseline monitoring for new wells, would not be considered. In this case, the incremental cost of the NGWMN would be significantly different (table 14). The capital and one-time costs would include primarily some limited well logging and instrumentation, modifying field practices and data standards and automated data collection totaling $865,384, an average of $173,077 for the five State pilot projects. Incremental annual operation and maintenance costs would include changes in field practices for water levels and water-quality measurements, data transmission to a national portal, and increasing frequency of monitoring totaling $1,868,720, an average of $373,756 for the five State pilot projects. In taking this approach, however, the objective of coverage in spatially underrepresented aquifers would not be addressed.

Table 14. Incremental State pilot project costs to participate in the National Ground-Water Monitoring Network for existing wells and other gaps.

[--, not reported and assumed to be $0]

One-Time and Capital Costs							
	Illinois-Indiana	**Minnesota**	**Montana**	**New Jersey**	**Texas**	**Total**	**Average**
State Initial Participation	$32,500	27,000	31,659	38,000	36,275	165,434	$33,087
Monitoring Network	66,000	--	--	--	131,950	197,950	39,590
Field Practices	--	17,500	--	--	--	17,500	3,500
Data Management	13,100	--	3,400	121,000	21,800	159,300	31,860
Monitoring Program	--	15,000	310,200	--	--	325,200	65,040
TOTAL ONE-TIME AND CAPITAL COSTS	$111,600	$59,500	$345,259	$159,000	$190,025	$865,384	$173,077
Operation and Maintenance Costs							
Monitoring Network	--	13,500	160,230	--	--	173,730	34,746
Field Practices	--	--	--	32,900	100	33,000	6,600
Data Management	--	--	--	--	--	0	0
Monitoring Program	--	123,100	147,300	1,313,400	78,250	1,662,050	332,410
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS	$0	$136,600	$307,530	$1,346,300	$78,350	$1,868,780	$373,756

Suggested Changes to Plan Based on the Experience of the Pilot Studies

The Framework Document was developed through an extended, consensus-driven collaborative process by experienced hydrogeologists and water-resource managers. It was acknowledged throughout the process, however, that the concepts for the NGWMN were not applied "on the ground" prior to completion. Thus one of the objectives of the pilot process was to identify possible changes to the Framework Document—requirements that are impractical, expensive, or present other barriers to participation. Pilots were encouraged to provide feedback to the SOGW on any suggested changes to the Framework Document. Recommendations are grouped by network design, classification of wells, and required data elements.

Network Design

The Illinois-Indiana Pilot Study noted "One area that might need additional clarification relates to monitoring/sampling frequency."

The Minnesota Pilot Study recommended the following for the design of the network:

1. Additional guidance is needed to assist the States in determining the number of wells required for a National assessment of ground-water conditions.
2. It is recommended to increase the water-level measurement frequency in the Framework Document.
3. It is recommended to decrease the water-quality sampling frequency in some settings.

The Montana Pilot Study had a comment on sampling frequencies for standard and extended analyte lists. The report stated: "The analyte groups as listed in the Framework Document are adequate to describe water quality for the NGWMN's purposes. However, the suggested sampling frequencies are almost unattainable from cost and time viewpoints. For example, even collecting Standard List parameters 'during every visit' to create a baseline record is not feasible. Most of these parameters do not vary that quickly and the length of time necessary to purge the well and get the data every time a water-level measurement is collected is time consuming and expensive. SOGW should consider relaxing the suggested frequencies of sampling for NGWMN water-quality sites."

In addition, the Montana Pilot Report (Patton and Buckley, 2011, p. 41–42) offered some suggestions that SOGW might consider first focusing on reconciling field practices and data-management attributes offered by various cooperators, then work to fill spatial and measurement frequency gaps. They suggest first accepting what compatible, comparable, and deliverable data a cooperator might have without initially evaluating and pushing for spatial completeness or certain measurement frequencies, which fits the "*walk before you run*" caution heard often during SOGW meetings. Set up the data-management links, make sure that the data you do get are comparable, and challenge the "spatial" and "operations" gaps later as resources become available.

The New Jersey Pilot Study had a major set of recommendations regarding the definitions of the surveillance and trend networks and the frequency of measurements required for each. A few of their comments are as follows:

1. The frequency of measurements recommended by the Framework Document for surveillance networks is fairly short and under some conditions turns a surveillance network into a trend network.
2. The frequency of measurements suggested in table 4.5.2 of the Framework Document does not meet the purpose of the surveillance network described in section 1.4.4.2 of an "overall snapshot of ground-water conditions" and should have a monitoring frequency "much less than trend monitoring." The text and table sections of the Framework Document should be clarified and made consistent.
3. The requirement for a baseline period of 5 years for a surveillance network essentially turns the surveillance network into a trend network for 5 years and adds greatly to the cost.
4. New Jersey recommends that potable supply wells be allowed in the network assuming they follow a protocol where the well and other nearby wells are shut down and water levels are not rapidly changing.

In addition, the New Jersey Pilot Study requested that because the NGWMN is likely to be populated by existing wells, the SOGW should consider the impacts to participants if only part of an existing network is included in the NGWMN, particularly if the national network will fund an expansion of the existing local network.

Classification of Wells

It is clear from the pilot reports that the SOGW must reevaluate the guidance in the Framework Document with respect to the classification of wells. This topic dominated the discussion during the pilot process, and each of the pilot projects commented on the network design classification of "targeted" and "unstressed" subnetworks.

The Texas Pilot Study suggested the deletion of the designation of wells as targeted and unstressed. The Texas Pilot Study considered the terms to be inappropriate in the context of a database entry and should be interpreted in objective driven studies of ground-water conditions, ground-water availability, and ground-water sustainability. The reasons for this suggestion from the Texas Pilot report (Hopkins and others, 2011) are stated as follows:

"Inclusion [*of these terms*] in a monitoring database (national or local) is inappropriate for the following reasons: (1) the intended definitions could be misread and misunderstood and (or) (2) their definitions are being understood but disagreed with; this latter is especially problematic if any data users perceive that the data providers are cherry-picking facts or are attaching them to agendas. This classification was also problematic in choosing wells for the water-quality subnetwork, in part for the same reason; what amount or percentage of change would have to occur, at what thresholds, over what period, and in how many analytes to justify a straightforward description of change?"

The Illinois-Indiana Pilot Study stated: "We agree with those that argue for NOT classifying wells into unstressed or targeted categories."

The Minnesota Pilot Study stated: "Additional guidance is also needed for the States to classify wells into the targeted and unstressed subnetworks to facilitate data interpretations at the national level."

The Montana Pilot Study also noted the problems with classifying wells as targeted and unstressed. In addition, they noted some issues in the Framework Document with labeling NGWMN sites as "baseline," "surveillance," or "trend," primarily because surveillance and trend are used outside of their usual meanings and are defined inconsistently. Montana suggested that the SOGW consider a simpler monitoring site classification system using terms aligned with their more common definitions of the terms trend and surveillance.

1. **NGWMN Site** – A location at which quantity and (or) quality monitoring occurs at frequencies designed to provide generalized status and trend records for a principal or major aquifer. (A reconnaissance or general-survey site.) The site's measurement frequency shall be based on the water-level record after a baseline dataset has been collected and be often enough to capture most large-scale water-level changes.
2. **NGWMN Surveillance Site** – A location where quantity and (or) quality monitoring occurs at frequencies designed to provide detailed status and trend records for a principal or major aquifer. These sites may also be called "core" or "backbone" sites. Measurement shall be collected at a surveillance site so that high-frequency (weekly to daily) changes in the hydrograph are captured.

The New Jersey Pilot Study noted: "One of the more difficult tasks of this pilot study was the definition and classification of wells as targeted or unstressed. New Jersey Pilot Study believes that much better definitions of these conditions are needed."

This classification of wells will be revisited by the SOGW, and appropriate changes will be made to the Framework Document.

Data Elements

A comparison of New Jersey's database-management procedures with those required by the Framework Document identified some potential problems with the guidance in the Framework Document. The list below summarizes those findings.

1. Well owner name and contacts in network database should not be included because of privacy and security concerns.
2. Some long-term monitoring wells do not have complete data to meet the framework requirements. Eliminating these wells would create spatial and temporal gaps that cannot be replaced. New Jersey suggests letting legacy wells not comply completely with the Framework Document, but requiring new wells to fully comply. Alternatively, a reduced number of required elements could be specified (location and aquifer) and population of the rest of the fields could be encouraged but not required.
3. Many of the data elements required in the Framework Document are not shown on the NGWMN portal. If users are required to submit/collect these data, it should be displayed on the portal.
4. The Framework Document and NGWMN Portal should add a major aquifer code and also allow the use of local aquifer names. This would facilitate the use by local users and encourage them to link their local aquifer with the larger regional aquifer.

NGWMN Portal

A NGWMN Web-based data portal (*http://cida.usgs.gov/gw_data_portal/*) was a key element of the pilot process. A pilot data portal was developed by the USGS using state-of-the-art informatics processes to unify data provided from nine disparate data systems. Site data and measurements from NGWMN sites are unified and available through the network data portal, in many cases on the fly using Web services. This section of the report summarizes information provided by the Portal Developers (Jessica Lucido, U.S. Geological Survey, written commun., 2011) on the design and implementation of the pilot NGWMN data portal.

Design Concepts

The NGWMN Web portal aggregates and disseminates ground-water monitoring data from participating organizations to interested parties, including policy makers, scientists, and the general public. The goal of the portal is to create a single location (Web site) that is publically accessible for compiling and relaying ground-water levels, ground-water-quality data and associated metadata from distributed databases located within participating agencies through a map-based graphical user interface (Lucido and others, in review).

The Web portal is a map-based interface through which users discover the wells for which data are available and request respective data associated with those wells. Users can search across the multistate network by using several search criteria, and the resultant wells are displayed on the map. This architecture allows users to focus their search, visualize the results, and then request a download of data from those wells all through a common interface. When a user requests a dataset download, the portal sends the request to the respective organization or organizations depending on the scope of the search. With this approach, the data providers retain ownership and control over their monitoring data, reducing the challenges of collecting, aggregating, and maintaining large amounts of dynamic data that are inherent with the formation of national data repositories. By implementing a mediation framework, the need for data providers to standardize their output is minimized, providing flexibility and a lower barrier for participation.

Implementation with the Pilot Projects

Creation of a Centralized Well Registry

A well registry was created to maintain the basic well information for each of the NGWMN wells. A well registry data template was distributed to participating organizations, and a data-loading plan was created to systematically transform and load the data files provided into the well registry. The plan could be extended to additional organizations beyond the pilot phase; however, a more automated mechanism for maintaining the registry would be appropriate.

Development of Mediation Framework

A data mediation framework was implemented to dynamically compile, aggregate, and serve datasets from multiple organizations served in different formats and returned in a common standard format. Rather than manually altering the format of differing datasets or requiring data providers to synchronize their data formats to a prescribed standard, a central data mediation framework automatically transforms the data to a common format. This automation reduces the resources needed on the part of the data providers toward data formatting. Once the data exchange mechanism is in place, minimal maintenance is required.

Service Hook-Up and Data Acquisition

In addition to the technical development of the portal software, the portal implementation required participating organizations to define the way they wanted to make their data available. As previously described, the portal architecture afforded some flexibility to data providers. Three of the five pilots put either a Simple Object Access Protocol (SOAP) or a Representational State Transfer (RESTful) Web service in place to allow access to their data. Where it was not possible to set up a Web service, database exports were supplied to the USGS and served to the portal in a RESTful Web Feature Service (WFS). In addition, several of the pilot agencies had ground-water data already in one of the national water information databases, the USGS's National Water Information System (NWIS) and U.S. Environmental Protection Agency's Storage and Retrieval (STORET) repository of water monitoring data, which were accessed through existing Web services. Table 15 lists the method and status of data acquisition from each of the participating pilot States.

Table 15. Data acquisition status chart.

[Green – Acquisition complete, Blue – Data not provided or are not available (NA), Orange – Data were not requested for pilot study, but plans are to incorporate in the future. WFS, Web Feature Service; NWIS, U.S. Geological Survey National Water Information System; STORET, U.S. Environmental Protection Agency Storage and Retrieval; SOAP, Simple Object Access Protocol]

<table>
<tr><th rowspan="3"></th><th rowspan="3">Water levels</th><th colspan="6">Well log</th><th rowspan="3">Water quality</th></tr>
<tr><th rowspan="2">General</th><th colspan="2">Construction</th><th colspan="2" rowspan="2">Lithology</th></tr>
<tr><th>Casing</th><th>Screen</th></tr>
<tr><td>Illinois</td><td>Import/WFS</td><td>NA</td><td colspan="2">Import/WFS</td><td colspan="2">Import/WFS</td><td>Import/WFS</td></tr>
<tr><td>Indiana</td><td>NWIS</td><td colspan="5">NWIS</td><td>NWIS</td></tr>
<tr><td>Minnesota</td><td>WFS</td><td colspan="4">WFS</td><td>NA</td><td>STORET</td></tr>
<tr><td>Montana</td><td>WFS</td><td>NA</td><td>WFS</td><td colspan="2">WFS</td><td>WFS</td><td>NA</td></tr>
<tr><td>New Jersey</td><td>NWIS</td><td colspan="5">NWIS</td><td>NWIS</td></tr>
<tr><td>Texas</td><td>SOAP</td><td>NA</td><td>SOAP</td><td colspan="2">NA</td><td>NA</td><td>NA</td></tr>
</table>

Web Application

A Web-based data portal was created for the purpose of making the NGWMN publically available. The application allows users to view all NGWMN wells on the map and to filter the wells by agency, national aquifer designation, water-level designation, and water-quality designation (fig. 15). Future versions of the application could allow users to apply advanced filters on the basis of water-level and water-quality results or observations.

The portal incorporates several base-map layers to display the boundaries of principal aquifers, governmental units, roads, highways, water bodies, as well as the U.S. shaded elevation relief map. These layers can be turned on and off and their opacity adjusted. Specific wells of interest can be identified in the portal when a user clicks on a well or group of wells. When a well is selected, a window with tabs for well information, well log data, water-level data, and water-quality data is displayed.

Obstacles and Challenges

Throughout the process of building the NGWMN portal and the data exchange framework that supports it, several obstacles have been identified that would need to be overcome in order to fully meet the requirements of the NGWMN portal. These obstacles include challenges with data availability, data accessibility, data quality, configuration of mediation framework, service consumption, performance, IT infrastructure, and personnel of participating State agencies.

Strategy for Future Work

The ultimate goal of the NGWMN is for all 50 States to make ground-water monitoring data available through the NGWMN data portal. The general architecture of the portal can remain with an expansion of the well registry and reconfiguration of the mediator for each service that is added. Additional capacity building is required for State agencies to make their data available through Web services. Through

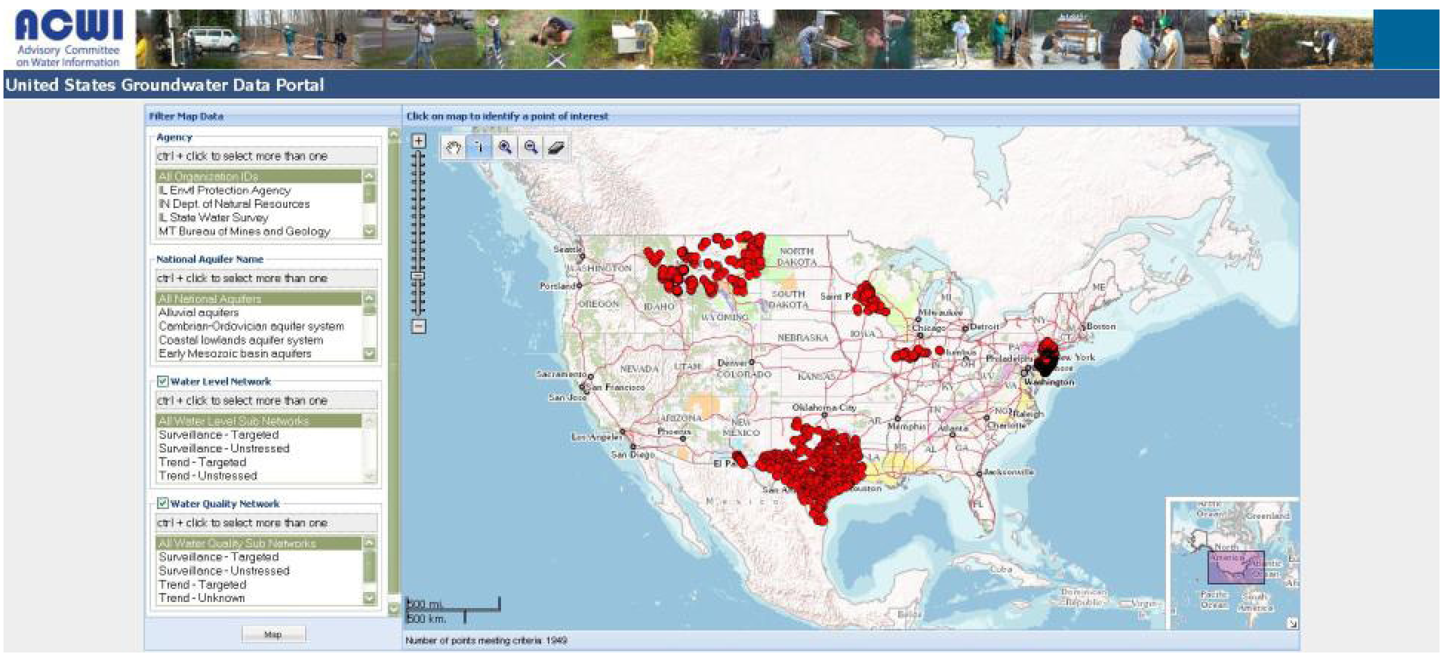

Figure 15. Screen shot of the main page of the National Ground-Water Monitoring Network portal.

lessons taken from the pilot studies, support documents on server configuration options and Web service implementations can be developed. A set of requirements for Web-service configuration may be necessary to enhance performance and scalability.

Benefits of the NGWMN Identified by the Pilot Studies

Many of the benefits of having a National Ground-Water Monitoring Network have been described and explained in the Framework Document (Subcommittee on Ground Water, 2009), particularly in the section on “Key Concepts and Recommendations” (p. 30–31). Two key benefits are the availability of a single consistent dataset for assessment of shared interstate ground-water resources and a common data portal available to everyone to access these data. Most of the pilot studies acknowledged these key benefits.

Furthermore, the pilot studies found unforeseen additional benefits in participating in the pilot process and the NGWMN. These benefits are identified in a section in each pilot summary report. Some of the more common additional benefits reported are

1. The opportunity to share data and open additional avenues of communication among States and other agencies within the State. Participation in the pilot study required the volunteer participants to discuss field and data procedures among State agencies responsible for different aspects of the ground-water resource. This nonconfrontational assessment of the entire field-collection methodology, data management, and Web-based availability of data within and between State agencies was identified as an opportunity that was beneficial. The Minnesota Pilot Report (MacDonald and Kroening, 2011, p. 26) cited the “opportunity to work more closely with State agencies with ground water responsibilities within Minnesota” and “more opportunities for collaboration between the DNR [Department of Natural Resources] and MPCA [Minnesota Pollution Control Agency] ground-water programs” as two of the key internal benefits to their participation.
2. The interaction among the participants of the different State pilot studies served to share knowledge and information about different approaches the States have taken to monitor their ground-water systems. The Illinois-Indiana Pilot Report (Wehrman and others, 2011, p. 59) stated: “Hearing about how other States operate their monitoring networks was extremely informative, and provided a gauge against we can measure how well we operate our networks.”
3. Participation in the NGWMN required a critical review of field procedures and data-management procedures, as well as the available documentation on these procedures within each pilot study. This served as impetus to update procedures and identify some missing minimum data elements. As summarized in the Texas Pilot Report (Hopkins and others, 2011, p. 58), this review will ultimately “…result in more complete and more readily available data to the public.”

A well in Ocean County, New Jersey, equipped with satellite telemetry.

Conclusions

The SOGW’s NGWMN Framework Document documented that ground-water monitoring is conducted by many Federal, Tribal, State, and local agencies for many purposes. The pilot studies documented that the incremental costs of using the existing State monitoring systems appear to have low near-term costs for incrementally integrating them to form a national monitoring network. Such an approach would not address the geospatial gaps in ground-water monitoring that may exist and were identified by the State pilots. Addressing the geospatial gaps will increase the cost of developing a consistent approach among States that would be necessary for a national network.

A test of the SOGW's comprehensive design plan for a NGWMN was needed before pursuit of network implementation. Five State- and aquifer-based volunteer pilots—Illinois-Indiana, Minnesota, Montana, New Jersey, and Texas—began in January 2010 to test the proposed network design and implementation concepts. These pilots have completed their 1-year volunteer pilot projects and have successfully demonstrated the feasibility of a collaborative national ground-water monitoring network that would provide information necessary for the planning, management, and development of ground-water supplies to meet current and future water needs.

The NGWMN Web-based data portal was a key element to the success of a NGWMN. A pilot NGWMN portal was developed using state-of-the-art informatics processes to unify data provided from nine disparate data systems. Site data and measurements from NGWMN sites were unified and available through the network data portal in many cases on the fly using Web services. The pilot portal effort found that even though States recorded data in the databases differently and used different database platforms, States typically included nearly all of the data needed for comparable reporting in their existing databases, and making adjustments in those systems was not foreseen as a major cost. Thus, the SOGW template for reporting provided a consistent approach for integrating the State data and mapping it to the portal.

The pilot projects identified some changes to the NGWMN Framework Document that would improve the clarity of the guidance in the document and ease participation by NGWMN data providers. The SOGW must address these proposed changes.

A nationwide collaboration for ground-water monitoring has been considered for decades. The NGWMN Framework Document and five successful pilot projects have illustrated that a convergence of information technology improvements, increased information needs, and interest in collaboration make this the ideal time to pursue a NGWMN. This convergence is further supported by concerns about the range of economic and environmental factors projected to be faced by the economic sectors of the United States.

USGS New Jersey Water Science Center

Hand pump at state park in New Jersey Pinelands.

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