Prepared for the Advisory Committee on Water Information Subcommittee on Ground Water

Results of the Montana Pilot Study for the National Ground Water Monitoring Network

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Introduction (Mike Wireman, U.S. Environmental Protection Agency)

Groundwater is the daily source of drinking water for more than 130 million Americans. Of the 83,300 million gallons per day (Mgal/d) of groundwater used in 2000, 68 percent was used for irrigation, about 23 percent was used for public supply and domestic use, 4 percent for industrial use, and the remainder for livestock, aquaculture, mining, and power generation (Hutson and others, 2004). About 35 percent of the nation's irrigation water supply is obtained from groundwater. Although overall water use in the United States (USA) has been relatively steady for more than 20 years, groundwater use has continued to increase, primarily as a percentage of public supply and irrigation. In addition to human uses, many ecosystems are dependent on groundwater discharge to streams, lakes, and wetlands.

The nation's groundwater resources are under stress and require increased interstate and national attention to assure sustainable use. State, federal, and local agencies have documented significant impacts to major and minor aquifers throughout the USA. Impacts include areas of declining water levels and contamination from chemical use and waste disposal. In addition, climate change may result in increased surface flooding which could significantly affect groundwater quality; longer and more intense drought can significantly change groundwater levels. Increased groundwater demand is expected in all sectors of the economy, including the heavy-use sectors of agriculture, drinking water, and energy production. Increased energy production from biomass will generate demand for groundwater and further degrade water quality by increased agrichemical application and residuals disposal. Proposals for geologic sequestration of carbon dioxide present the potential to acidify groundwater should carbon dioxide migrate to adjacent aquifers. Additionally, brackish and saline groundwater is likely to be increasingly developed and treated in water-deficient areas. As groundwater 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 multi-jurisdictional issues, effective management of trans-boundary aquifers and promote stakeholder involvement.

Sustainable groundwater management is currently constrained by the lack of a nationally integrated groundwater monitoring network focused on providing water-level and water-quality data for regionally and locally important aquifers. The need for a national groundwater monitoring network has been recognized by numerous water resource 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, which includes more than 70 people representing 55 different organizations, was charged with developing a framework that establishes and encourages implementation of a long-term groundwater quantity and quality monitoring network. This network is intended to provide data and information necessary for sustainable planning, management, and development of groundwater resources. The SOGW issued a report entitled, *"A National Framework for Ground Water Monitoring in the United States"* (SOGW, 2009). This report describes the steps necessary to establish, operate, and derive benefit from a National Ground Water Monitoring Network (NGWMN).

The NGWMN is envisioned as a voluntary, integrated system of data collection, management, and reporting that provides data needed to help address present and future groundwater management questions raised by Congress, federal, state and tribal agencies, and the public. The NGWMN will include selected wells from existing state, federal, and tribal groundwater 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 a sub-network that focuses on monitoring "Unstressed" parts of principle aquifers and aquifer systems, and a sub-network that "Targets" areas of concern within those aquifers (typically areas of water-level decline and contamination). Monitoring frequencies within the NGWMN will include: baseline, trend, surveillance, and special studies.

Groundwater-level monitoring has been conducted for many decades in many states. Data from these networks help agencies identify, develop, and manage groundwater supplies at the local and state level. Groundwater-quality monitoring programs have developed more recently in response to the 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 groundwater monitoring networks and 33 states have at least one active groundwater quality monitoring program. State monitoring networks are supported either by a state or through combinations of state and federal resources; the networks are operated by a variety of state agencies, some in cooperation with the United States Geological Survey (USGS). The networks address numerous state/tribal/local goals so the networks are not necessarily focused on "nationally significant and important aquifers" within a State or Reservation. As a result it is currently very difficult to obtain and use data from these groundwater monitoring programs to evaluate water availability, rates of use, and sustainability regionally or nationally. Because many aquifers support multiple jurisdictions, a focus on monitoring at the aquifer level rather than by political subdivision is critical to facilitate sustainable groundwater use.

Purpose of pilot project:

One of three key recommendations included in *"A National Framework for Ground Water Monitoring in the United States"* is to develop and conduct pilot studies to: (a) test 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.

Based on statements of interest from nine states, the SOGW selected five pilot projects: Illinois-Indiana, Texas, New Jersey, Montana, and Minnesota. These five pilots vary in scale from an intra-state monitoring network covering only a part of a single state, to an inter-state network where two states share an aquifer. Information obtained from the pilot projects helps SOGW to better understand the current status, range of coverage, and level of coordination of groundwater monitoring networks in the USA, and will serve as a foundation for estimating the resources needed for full-scale NGWMN implementation. The five pilot projects are completely voluntary efforts and have been conducted cooperatively by state monitoring network managers, the SOGW, and USGS staff. The pilot projects began in early 2010 and will be completed by March 2011. Each pilot project addresses the following objectives:

- Evaluate the feasibility of designing network segments within one or more principal, major or other important aquifers using conceptual groundwater flow models as the primary network design element.
- Determine methods to establish “Unstressed and “Targeted” sub-networks within the aquifer(s).
- Test the design of the NGWMN and its ability to provide water-level and water-quality data for large-scale assessments of the groundwater resource.
- Determine the feasibility and design parameters of a central, web-based, data portal that will allow the NGWMN to access and disseminate data, as well as promote data sharing among data providers and the public.
- Test and assess the effectiveness of coordination, cooperation, and collaboration mechanisms among federal, state, regional and local, and tribal data collectors, providers, and managers.
- Investigate methods to ensure that data collected by the data providers and, therefore, the NGWMN as a whole are comparable. Data elements including site characteristics, well construction and details, frequency of water-level measurements, water-quality analytes, water-level measurement procedures, water-quality sampling procedures, and written standard operating procedures will be evaluated.
- Determine the timeframe and costs associated with adding, upgrading, or developing a state, tribal, or local well network and data management system to be compatible with and meet the NGWMN standards.

Each pilot will evaluate potential monitoring points within the principal, major or other important aquifers included in their statement of interest for potential inclusion in the NGWMN. Additionally, the pilot will define subsets of proposed monitoring sites as “Targeted” or “Unstressed” based on the pilot’s interpretation of the Framework Document. Each pilot will identify its costs for potential participation in a NGWMN on a total and per well basis 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 data gaps. Each pilot will interface with the NGWMN data portal that is under development by the USGS.

Description of study area:

Montana's Statement of Interest (SOI) proposed that the Montana Bureau of Mines and Geology (MBMG) evaluate sites within its statewide groundwater monitoring network for potential inclusion in a NGWMN. Figure 1 shows the distribution of monitoring wells in the Montana statewide network (yellow points). Comparison of the locations shown on Figure 1 with mapped extents of principal and important aquifers included within HA370-I (Whitehead, 1996) shows that Montana is already collecting data from many principal and important aquifers segments including the heavily developed intermontane basin aquifers in the west, and the less intensively developed but widely used alluvial, Lower Tertiary, Upper Cretaceous, Lower Cretaceous, and Paleozoic aquifers in the east. Red points on Figure 1 mark the locations of more than 230,000 water production wells. Montana's statewide network, in part, monitors the impact of this development. The white northwest-southeast line in Figure 1 designates the approximate boundary between the western intermontane basin aquifers and regionally extensive eastern Montana bedrock aquifers.

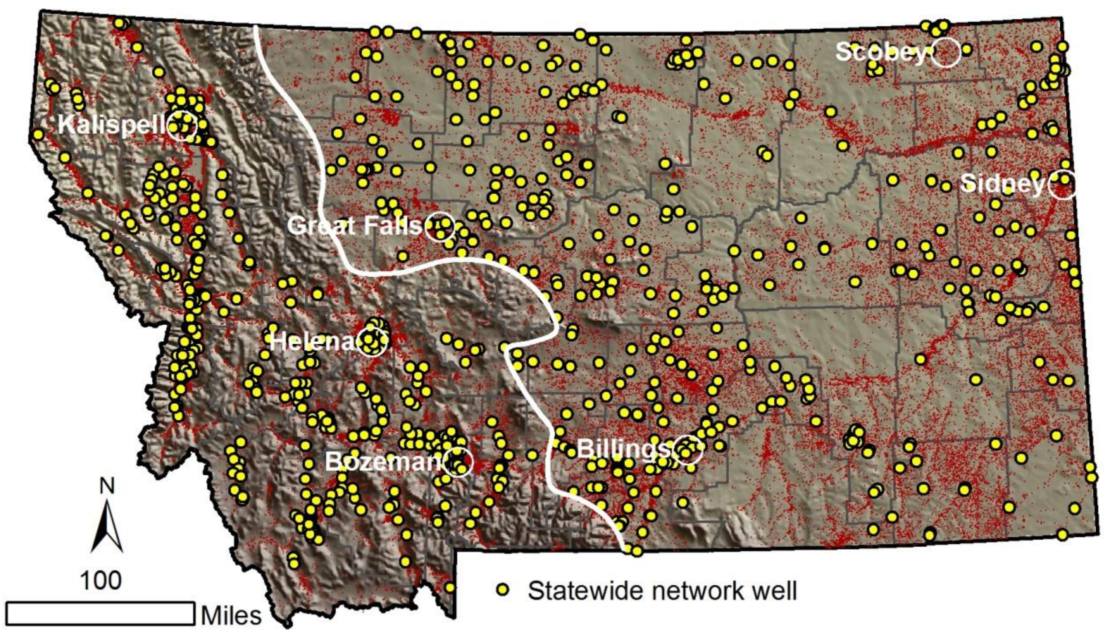

Figure 1. The distribution of monitoring points within Montana's statewide network.

Table 1 identifies the principal, major, or other important aquifers described in HA-370-I (Whitehead, 1996) that could be addressed by selecting some of Montana's statewide network sites as NGWMN sites. Important Montana aquifers not specifically described in HA370-I include extensive Upper Tertiary aggradational sand and gravel deposits in northern Montana, and Upper Cretaceous sandstone aquifers within the Judith River and Eagle Formations in north-central Montana. The "Montana comments" column in Table 1 describes how these aquifers were handled in the NGWMN-MONTANA selection process. The "Pacific Northwest volcanic rock aquifers" unit occurs only in a small area of Montana near Yellowstone National Park and is not included in the Montana statewide network.

Table 1. National/Principal aquifer codes and typical Montana equivalent aquifers.

National Aquifer/ System Name	National Aquifer Code	Montana comments	Typical Montana Aquifers (codes)*
Alluvial aquifers	N100ALLUVL	All non-glacial alluvial deposits not associated with intermontane basins. Includes Miocene/Pliocene ag-gradational sand and gravel aquifers important in northern Montana.	110ALVM, 110SNGR, 110TRRC, 111ALVM, 111SNGR, 111TRRC, 121FLXV and equivalents.
Sand and gravel aquifers (glacial regions)	N100GLCIAL	Includes sand and gravel related to glaciations in eastern Montana.	112SNGR, 112OTSH, 112TRRC, 112DRFT, 112GFLK, 112YTR3
Northern Rocky Mountains Intermontane Basins aquifer systems	S100NRMTIB	Includes Quaternary and Upper Tertiary basin-fill deposits and surrounding fractured rock aquifers associated with individual-basin flow systems. Includes glacial deposits in the Flathead, Mission, and Missoula valleys.	Codes ranging from 110, 111, 112 (ALVM, SNGR, etc), 120 (SDMS, SNGR, etc) to many differing bedrock codes for formations as old as Precambrian 400BELT.
Pacific Northwest volcanic rock aquifers	N100PCFNWV	Minor area in Montana near West Yellowstone.	No Montana codes included in network.
Lower Tertiary aquifers	N300LTRTRY	The areas mapped in HA370-I generally correspond with Lower Tertiary aquifers important in Montana.	125FRUN, 125TGRV, 125LDLW, 125TLCK, 125LEBO, and codes specific to named coals.
Upper Cretaceous aquifers	N300UPCTCS	Includes important Upper Cretaceous sandstone aquifers in north-central Montana from areas outside those mapped in HA370-I. Most Upper Cretaceous aquifers within the mapped area are too far below land surface to be economically viable.	211CLRD, 211EGLE, 211VRGL, 211FXHL, 211HLCK, 211FHHC, 211LNCE, 211COGT, 211JDRV, 211TMDC
Lower Cretaceous aquifers	N300LCRTCS	Area mapped in HA370-I generally corresponds with Lower Cretaceous aquifers important in Montana.	217KOTN, 217FCCK, 217SCCK, 217TCCK, 221MRSN, 221SWFT
Paleozoic aquifers	N500PLOZOC	Area mapped in HA370-I generally corresponds with Paleozoic aquifers important in Montana.	330MDSN, 341 JFRS

*Montana Codes listed here are described in Appendix A.

Montana hydrogeology:

Montana straddles boundaries between the northern Great Plains, Northern Rocky Mountains, and Middle Rocky Mountains physiographic regions. These boundaries result from tectonic and stratigraphic relationships in the earth's crust and create Montana's complex geology as illustrated in Figure 2 (Vuke and others, 2007a). Many publications describe Montana's geology in detail but a brief overview covering major physiographic, Precambrian provinces, major tectonic features, major faults, and other elements is available for download or purchase as a hard copy from the MBMG publications catalog (Vuke and others 2007b).

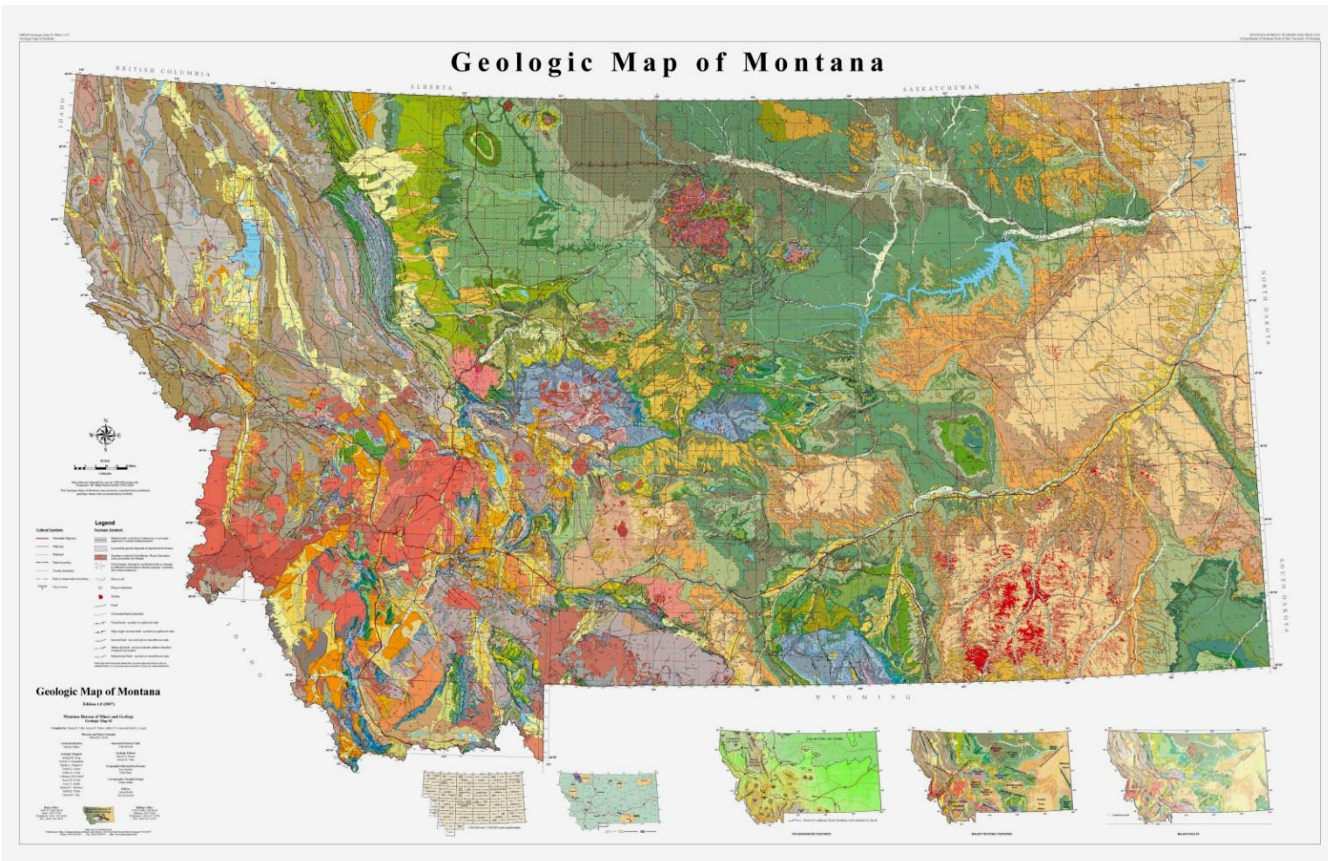

Figure 2. Geologic map of Montana (Vuke and others 2007a)

Montana's complex geology of intermontane basins in the west connected by thin alluvial deposits along river valleys (yellow and orange colored areas in the west half of Figure 2), and regionally extensive bedrock sandstone and carbonate rock aquifers in the east (expansive tan and brown colored areas in the east half of Figure 2) create generally different hydrogeologic conditions in western and eastern Montana.

- **Western Montana:** Western Montana monitoring wells are distributed within the intermontane basin aquifers west of the northwest-southeast line on Figure 1. The intermontane basins contain up to several thousand feet of sediment that, along with the surrounding bedrock valley margins, provide media for groundwater recharge, storage, and discharge (LaFave, 2000, 2006) (Kendy and Tresch, 1996). Groundwater flow is generally from a basin's margin to its center where discharge is often to surface water. Bedrock constrictions, often near where surface streams leave the basin, force upward groundwater flow which then becomes surface flow. The individual basins are hydrologically connected by surface streams within the Upper Missouri River and Columbia River basins.

- **Eastern Montana:** Eastern Montana aquifers occur in alluvial deposits along rivers and streams and in extensive Lower Tertiary to Paleozoic bedrock formations east of the northwest-southeast line in Figure 1 (Noble and others, 1982) (Whitehead, 1996). These aquifers are in outcrop or relatively close to land surface near structural highs, but are sometimes more than 1,000 ft below land surface in structural basins. Groundwater flow in the upper several hundred feet of these formations is generally from topographic upland to nearby entrenched drainages (Smith, 1998). At depth, regional flow systems transport water from topographic and structural highs to discharge areas along major streams (Smith, 1998).

Montana's statewide network (scope)

Montana's network design is based primarily on aquifer extents and level of development as measured by the number of production wells. Therefore, statewide monitoring spatially represents Montana's geology and those areas where groundwater is heavily utilized. Monitoring locations may also be keyed to local interests and a need for "Targeted" monitoring. An example of a "Targeted" segment within Montana's network is a cluster of monitoring points north of Scobey, Montana as shown on Figure 1. Coal mining in Saskatchewan, immediately north of the United States-Canada border, presents potential trans-boundary groundwater quantity and quality issues to Montana. Other "Targeted" areas are where monitoring points fall within Controlled Ground Water areas (CGWA) established by the Montana Department of Natural Resources and Conservation.

The Montana statewide monitoring network's primary goal is to build long-term time-series water-level and water-quality data sets designed to address questions such as:

- How are water supplies being impacted by climate variability/change?
- How are water supplies (sw+gw) being impacted by groundwater development?
- How does variability in oceanic conditions as indicated by the El Nino-Southern Oscillation Index and the Pacific Decadal Oscillation change groundwater storage?
- How do current irrigation practices and changes such as conversion from flood irrigation to sprinkler irrigation impact groundwater storage?
- Are there long-term water-quality changes occurring in Montana's major aquifers?
- Are land use changes causing nutrient concentrations to change in Montana's major aquifers?

The long-term time-series data in themselves delineate how the measured parameters are changing with time. The network's utility depends on what questions are eventually asked and the comparability/correlation of network data with ancillary time-series data sets such as streamflow or precipitation.

Most of Montana's statewide network is generally considered to be "Unstressed" and not "Targeted". Some exceptions include:

- A few monitoring sites dedicated to observing the long-term impact of cropping practices at a saline seep research site.
- Wells in northeast Montana north of Scobey (Figure 1) to monitor potential impacts of a coal fired power plant in Canada.
- Wells near current and reclaimed coal mining in the Powder River Basin to keep core monitoring active and observe long-term mining impacts.
- Wells located within Controlled Groundwater Areas.
- Wells near other areas of active or potentially active groundwater development; these wells have been added to the network at the request of regulatory agencies.

Water-level records from Montana network wells may demonstrate various levels of stress from nearby pumpage, in-well pumpage, irrigation practices, surface/groundwater interactions, etc. Measurements are annotated if they do not represent static conditions and flagged with remarks such as "recently pumped" Etc. at the time of collection.

Historic and current monitoring:

The Ground Water Assessment Program (GWAP) at the MBMG, together with its cooperators, manages Montana's statewide groundwater-level and groundwater-quality network of about 950 sites. Although there are numerous groundwater monitoring "networks" in Montana, many of these networks focus on environmental damage issues such as those addressed by Superfund sites in the Upper Clark Fork River Basin. These networks may collect some long-term data but the purposes are often focused on specific water-quantity and water-quality issues; sites within these networks address limited areas from a principal aquifer point of view. MBMG's statewide long-term monitoring network is designed to collect data at "aquifer-wide" scales.

Montana's statewide network is authorized in statute and, although directly managed by MBMG, is a strongly coordinated effort. 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 groundwater monitoring sites selected by MBMG. Federal agencies with water-related interests and industrial, agricultural, county, and developmental organizations are ad hoc steering committee members.

Beyond the coordination activities of the Ground Water Assessment Steering Committee, the MBMG operates some intermontane valley segments of the statewide network through memoranda of understanding with county-based local water quality protection districts. The local districts have developed dedicated monitoring networks from which they collect time-series groundwater-level and water-quality data. The MBMG contracts with these districts to reimburse quarterly data-collection costs from wells that are also statewide monitoring network sites. Each district may collect measurements more frequently than required by the statewide network and if so, forwards those data to

MBMG for distribution through the Montana Ground Water Information Center (GWIC) database's web interface.

MBMG employees and cooperators travel to network wells each calendar quarter to measure water levels, service about 100 water-level recorders, and collect water-quality samples. Figure 3 shows the distribution of dedicated, low-use, and production wells within the statewide network.

About 50 percent of the statewide network sites are dedicated monitoring wells, unused production wells, or very low-use production wells. Examples of very low-use wells are those that serve remote one-room schools in eastern Montana or highway department maintenance shops. The remainder is mostly wells that produce water for stock and domestic purposes. There are very few public water supply wells in Montana's statewide network because access to these wells is generally difficult. For example, entering a public water supply well to gather periodic water-level measurements presents potential contamination threats that operators find uncomfortable.

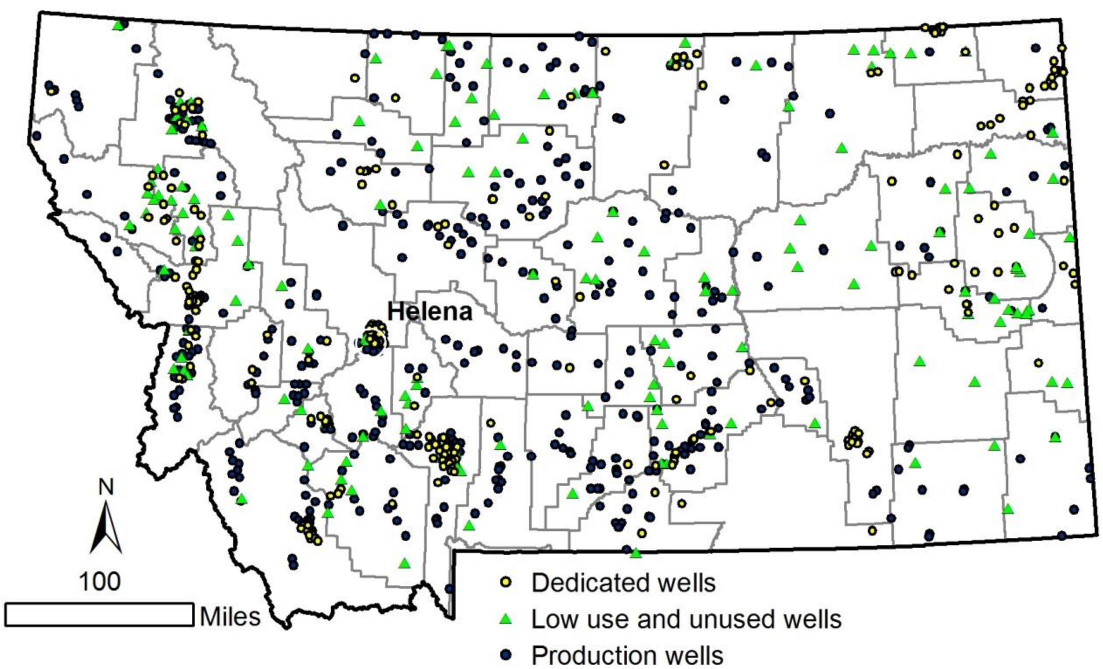

Figure 3. The distribution of dedicated, unused, and low-use wells in the Montana statewide network.

Monitoring program staff and cooperators visit each network well at least quarterly to measure groundwater levels and service water-level recorders. MBMG staff collects inorganic, trace-metal, and nutrient water-quality samples from about 70-90 sites annually, concentrating on groups of wells not sampled during the previous 10-12 years. Water-level data are entered into the GWIC database remotely or in Butte via web-based tools and appear in the database for public access usually within one week of measurement or instrumental download. Water-quality results appear on the database when released by the laboratory.

Figure 4 shows the spatial distribution of water-level measurement frequencies within the Montana network. Table 2 shows that 54 percent of network wells have between 11 and 20 years of record. The median number of measurements for all instrumented and non-instrumented wells is 4.3 per year, but the measurement frequency varies annually from about 4 per year to hourly. The frequency of measurement across a well's period of record may also vary, depending on installation of recorders, cooperative agreements, or other factors.

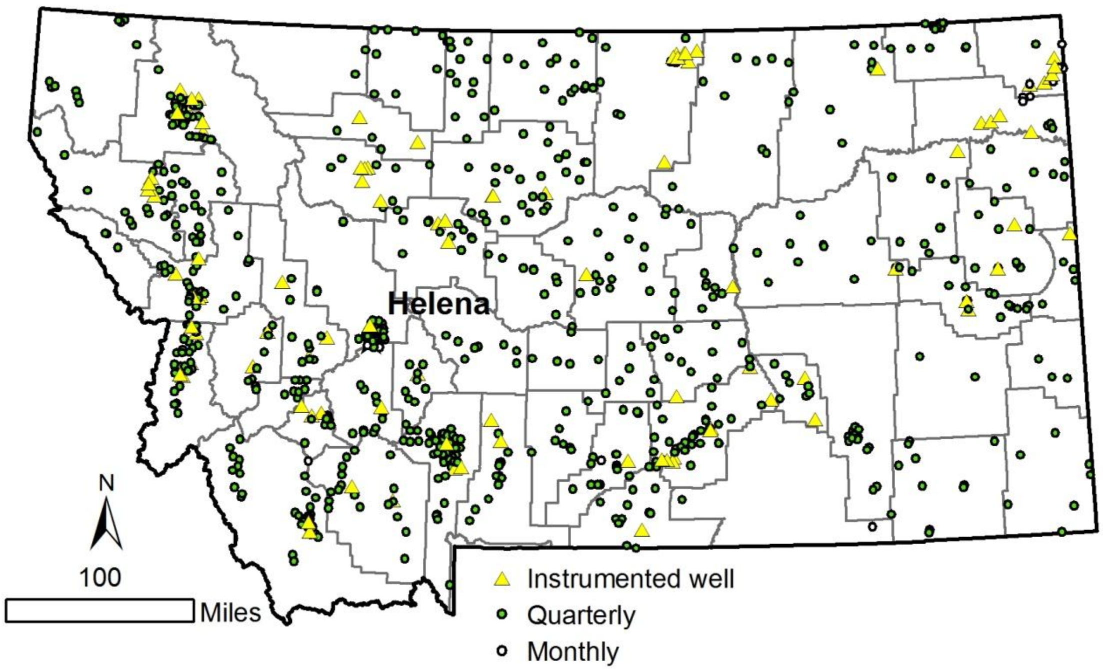

Figure 4. Measurement frequencies in the Montana statewide network.

Table 2. Periods of record and measurement frequencies for Montana statewide network wells.

Period of record			Frequency of measurement		
Period (Years)	**Wells**	**Percent**	**Measurements/Year**	**Wells**	**Percent**
0-5	70	7.3	0-1	5	0.5
6-10	119	12.4	2-3	146	15.5
11-15	245	25.6	3-4	276	29.3
16-20	274	28.7	5-12	369	39.2
21-25	69	7.2	12-24	15	1.6
>25	179	18.7	>24	161	13.9
Totals	956	100.0		942*	100.0

*Fourteen wells have less than one year of record.

Other groundwater monitoring programs within Montana that are not a part of the Montana statewide network, but are focused on non-regulatory goals include:

- (State) Montana Department of Agriculture: the department samples groundwater and surface water across the state to determine the presence of pesticides and fertilizers. The department has a permanent network of 44 monitoring wells from which it periodically collects samples for pesticide and fertilizer screenings.
- (State) MBMG: the Bureau monitors groundwater levels and collects periodic water-quality samples from a network of 231 wells within the Powder River Basin. The data are used to observe impacts of coal mining and coal bed methane development but is not regulatory. About 15 of these wells also serve as Montana statewide network wells. Information collected is available through GWIC.
- (State) MBMG: the Bureau monitors groundwater levels and collects periodic water-quality samples from a network of about 95 wells in the Anaconda-Opportunity, Montana, area. Information collected is available through GWIC.
- (State) MBMG: the Bureau monitors 17 wells in the closed groundwater area surrounding Yellowstone National Park for long-term water levels. Information collected is available through GWIC.
- (State) MBMG: the Bureau monitors 144 wells in Sheridan and Roosevelt counties to evaluate performance of a heavily developed ancestral Missouri River valley aquifer. Twenty-two of these wells are statewide monitoring wells.
- (Federal) The U.S. Geological Survey maintains 144 active monitoring points within Montana Seventy-six sites are part of the Survey's Smith River SW/GW project which began in 2006 and is scheduled to end in 2012. Twelve periodic sites are a single township in Lincoln County. Fourteen periodic sites are in a single quarter section within Missoula County. The remaining 42 sites are scattered across 13 counties. Five of the USGS sites are part of the climate monitoring network.
- (Federal) On September 30, 2010 the USGS Montana Water Science Center decided to no longer fund their side of the Cooperative Water Program with the MBMG. The 19 wells operated under that agreement reverted to MBMG for continued service although as of December 27, 2010, the wells were still listed as active on the USGS Groundwater Watch website.

Aquifers included:

The Montana SOI proposed that 934 statewide network wells completed in seven of Montana's eight principal, major, or other important aquifers be reviewed to potentially become NGWMN-MONTANA sites. The amount of work needed to fully review the Montana network by December 31, 2010 was greater than anticipated and the selection process could not be completed at the level of effort sustainable during a voluntary project. MBMG will continue to select NGWMN candidate wells during the spring of 2011 to meet the full-coverage goal of NGWMN-MONTANA.

MBMG staff selected 271 monitored wells as potential NGWMN sites. Two aquifers, the Paleozoic (N500PLOZOC – 12 candidates and 9 selected) and Lower Tertiary (N300LTRTRY – 98 candidates and 70 selected), were completely covered. Staff partially completed selection of wells in the Northern Rocky Mountains Intermontane Basins System (S100NRMTIB – 423 candidates and 139 selected) with complete reviews of the Big Hole, Bitterroot, Beaverhead-Blacktail Creek, Drummond, Helena, Gallatin, Summit, and Deer Lodge-Anaconda valleys. Unfinished work in the S100NRMTIB includes the Missoula, Mission, and Flathead valleys. Some wells in other major aquifers were selected, but work in the Alluvial (N100ALLUVL – 143 candidates and 30 selected), Glacial (N100GLCIAL – 64 candidates and 13 selected), Upper Cretaceous (N300UPCTCS – 162 candidates and 6 selected), and Lower Cretaceous (N300LCRTCS – 32 candidates and 4 selected) aquifers is incomplete. The mechanism to select NGWMN-MONTANA sites from the Montana statewide network and publish registry updates to the NGWMN portal is in place. The locations of currently selected NGWMN wells are shown on Figure 5. Yellow areas on Figure 5 show areas of intermontane basin-fill in the west, and alluvial deposits along streams in eastern Montana.

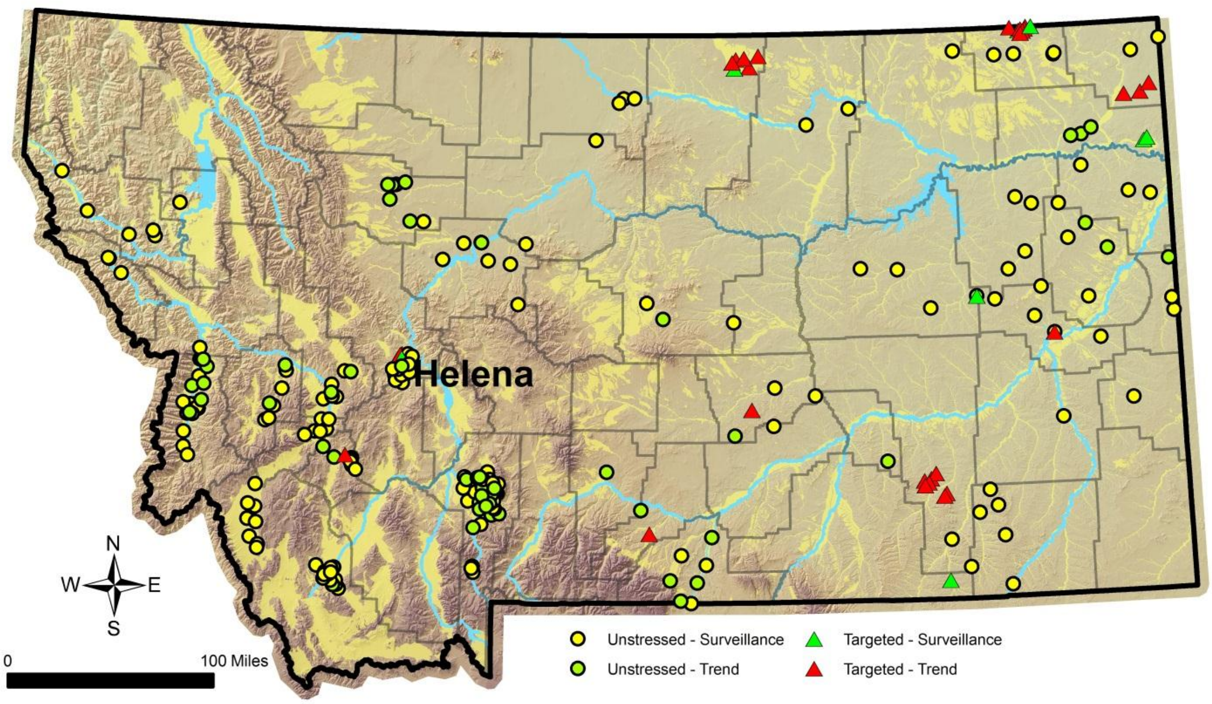

Figure 5. NGWMN well locations in principal, major and important aquifers.

Collaboration and Cooperation

The Montana statewide monitoring network, although managed and operated by MBMG through its Ground Water Assessment Program, has a strong collaborative component. Statutory management/oversight by the Ground Water Assessment Steering Committee has created an environment where many groups are aware of the network and can influence its operation. Generally, participation comes in the form of willingness to ship data to MBMG for distribution through GWIC. Agencies that actively collaborate/cooperate in the statewide network are:

- The Gallatin Valley Water Quality District provides monthly/quarterly water-level data from 47 statewide network wells in the Gallatin Valley and monthly data from the remainder of their network wells.
- The Lewis and Clark County Water Quality Protection District provides monthly/quarterly water-level data on 45 statewide network wells in the Helena Valley and monthly data from the remainder of their network wells.

- The Missoula Valley Water Quality District provides quarterly water-level data on 19 statewide network wells in the Missoula Valley and quarterly data from the remainder of their network wells.
- The Confederated Salish and Kootenai Tribes provides an annual update of quarterly water-level measurements from 28 wells on the Flathead Reservation.
- The Gros Ventre and the Assiniboine Tribes allows operation of a water-level recorder on the Fort Belknap Reservation.
- Assiniboine and Sioux Tribes allows operation of two water-level recorders on the Fort Peck Reservation.
- Montana Department of Natural Resources and Conservation forwards project-specific data from non-network wells to MBMG for distribution through GWIC. The department occasionally requests that new targeted monitoring points be added to the network.

MBMG contacted the Montana departments of Agriculture, Environmental Quality, and Natural Resources and Conservation to determine whether wells under their control but monitored by MBMG could be tagged as NGWMN wells. These agencies responded that MBMG should be Montana's lead in participating in the NGWMN and that their wells included in the statewide network could be included in the NGWMN. The Gallatin, Lewis and Clark, and Missoula county water quality districts and the Salish and Kootenai tribes have also agreed to allow data collected from their network wells to be used within the NGWMN.

Pilot study:

Because Montana's statewide network is operated by MBMG and the SOI stated that all candidate wells would come from sites already established in the statewide network; the pilot project required continued, but little new, collaboration with partner agencies. Except for the USGS Water Science Center, MBMG continues to partner with the agencies and tribes listed in the SOI. Beginning October 1, 2010, the USGS Montana Water Science Center decided to use their limited Cooperative Water Program funds for other purposes and cooperative agreements between MBMG and USGS to collect long-term water-level data expired. The sites previously monitored by the USGS for MBMG will continue to be monitored by MBMG.

Outreach presentations about the NGWMN that took place during the pilot were to:

- The National Groundwater Association Groundwater Summit in Denver, Colorado, on April 13, 2010.
- The Montana Section of the American Water Resources Association, in Helena, Montana, on October 14, 2010.

Future opportunities:

As Montana's statewide network evolves and assuming full implementation of a NGWMN, there will be opportunities to designate additional NGWMN-MONTANA wells. As other Montana agencies agree to, or ask, to have wells added to the Montana statewide network; or other MBMG programs construct wells and then move on to new project areas, new sites will become available. New wells added to the statewide network will be assigned national aquifer codes to facilitate inclusion into the NGWMN.

Although the current Framework Document would not restrict other Montana agencies from directly participating in a NGWMN, it seems appropriate that where there is a statewide monitoring network such as in Montana, the agency managing that network be the lead cooperative agency. Other agency's sites to be added to a NGWMN would be monitored cooperatively as part of the statewide network and if appropriate, added as a NGWMN-MONTANA site. The lead agency's data-gathering and data-management systems would then be used to provide consistently collected and managed data.

From the viewpoint of the NGWMN, there is likely an upper practical limit to the number of cooperative agreements that can effectively be maintained, because each agreement would require reconciling the cooperator's practices with NGWMN data-gathering and data-management procedures. An advantage of using a statewide network as an "accumulation point" for potential NGWMN wells is that data-collection and management become the cooperating agency's responsibility. The federal NGWMN operator need only deal with one set of data-gathering and data-management procedures.

National Ground Water Monitoring Network (NGWMN) Site Selection

Even though Montana data are already available nationally through the GWIC websites, several goals drove Montana's participation in the NGWMN pilot, and would drive its participation in a fully implemented NGWMN.

1. That Montana water-level and water-quality data be consistent with other states/sources and linked to principal, major or other important aquifers that cross state boundaries.
2. That Montana would be a full partner in the NGWMN and would collect a substantial part of Montana data used in NGWMN-MONTANA.
3. That participation in a NGWMN would require minimal operational change in the Montana statewide network. Montana would continue to maintain its network while giving NGWMN access to relevant data.
4. Participation in the pilot project would be impetus for a thorough review of sites within the Montana statewide network.

Montana's statewide monitoring network is part of the Montana Ground Water Assessment Program and data from the network are stored and managed within the GWIC database. Data in GWIC are accessible via the Internet; an initial question for MBMG was how to manage the metadata generated by the NGWMN site-selection process? One way would have been to retrieve data required for the NGWMN selection process from GWIC and define national aquifer, water-level and water-quality baseline periods, "Unstressed" or "Targeted" flags, etc. within a spreadsheet environment. A drawback to a spreadsheet based system would be that management of location, construction, lithologic, and other data would be difficult. These data would have to be included in the spreadsheet system but corrections resulting from the review process also would need to be made in GWIC. Additionally, looking at Montana's goals to eventually participate in a fully implemented NGWMN, working within the GWIC environment would prepare for future participation. Steps to update GWIC for NGWMN affiliation included:

- Adding a data structure to GWIC so that national aquifer codes could be linked to other well attributes through the GWIC site ID field. The new table allows linkage of any site within GWIC to a national aquifer code.
- Uploading the GWIC site ID/national aquifer code information from the SOI's Appendix D to the new table.
- Creating the project code "NGWMN-MONTANA" within GWIC's project definition table.
- Creating a NGWMN metadata table in GWIC to store status flags about NGWMN-MONTANA project sites.

These actions gave MBMG the ability to retrieve statewide monitoring network well data from GWIC using national aquifer codes, include the national aquifer codes with other monitoring network retrievals, and make NGWMN-MONTANA sites available on current GWIC websites. The metadata table allowed MBMG to generate registry templates within GWIC, prepare GWIC for web feature services, and to respond to NGWMN Ground Water Data Portal (GWDP) queries. Table 3 shows fields included in GWIC's NGWMN metadata table and outlines the logic to populate the registry template.

Table 3. Fields contained in the NGWMN metadata table.

Field name	Description	Registry template/notes
General Section		
gwicid	Unique 6-digit identifier for all wells in GWIC database.	Identifies wells in GWIC to data portal. Linkage of metadata to monitoring network sites.
ngwmn_tier	Tier one, two, or three NGWMN status.	Tier 1 – Complete water level and construction data. Tier 2 – Construction data are missing, but good water- level record. Lithologic record present. Tier 3 – good water level record, but little or no construction or lithologic data.
swl_synoptic_site	Water level monitoring point that is a NGWMN measurement site.	Designates the site as being in the SWL Sub-network. A "YES" flag here states that the site has been added at the "SURVEILLANCE" level.
qw_synoptic_site	Water quality monitoring point that is a NGWMN measurement site.	Designates the site as being in the QW Sub-network. A "YES" flag here states that the site has been added at the "SURVEILLANCE" level.
Static Water Level Section		
swl_targeted	Water level monitoring point that produces water-level data to monitor specific conditions.	A "YES" flag indicates that there is an identified influence on water levels from factors identified in framework document sub section 1.4.3.2.
swl_targeted_start	Date/time targeted static water level period begins	
swl_targeted_stop	Date/time targeted static water level period ends.	
swl_targeted_reason	Text describing reason/ purpose for targeted SWL monitoring.	

Field name	Description	Registry template/notes
swl_baseline	Water level monitoring point that has a NGWMN baseline period.	A “YES” flag indicates that the SWL record is at least 5-yrs and there are >= 20 measurements. A “NO” flag indicates that the baseline record is being built.
swl_baseline_start	Date/time baseline static water level period begins	
swl_baseline_stop	Date/time baseline static water level period ends.	
swl_trend	Water level monitoring point that is being monitored at a frequency to develop a NGWMN trend record.	A “YES” flag indicates that the site is being monitored at a frequency to build a NGWMN “TREND” record.
swl_trend_start	Date/time trend static water level period begins.	
swl_trend_stop	Date/time trend static water level period ends.	
	Water-quality Section	
qw_targeted	WQ monitoring point that produces water-quality data to monitor specific conditions.	A “YES” flag indicates that there is an identified influence on water quality from factors identified in framework document sub section 1.4.3.2.
qw_targeted_start	Date/time targeted WQ monitoring period begins.	
qwl_targeted_stop	Date/time targeted WQ monitoring period ends.	
qw_targeted_reason	Text describing reason/ purpose for WQ targeted monitoring.	
qw_baseline	WQ monitoring point that is being monitored to develop a NGWMN baseline period record	Set to “YES” if there are three or more full inorganic water-quality analyses from site.
qw_baseline_start	Date/time baseline WQ period begins	Date of earliest complete analysis.
qw_baseline_stop	Date/time baseline WQ period ends.	Date of third complete analysis.
qw_trend	WQ monitoring point that is being sampled to develop a NGWMN WQ trend record.	A “YES” flag indicates that the site is being sampled at a frequency to build a NGWMN “TREND” record.
qw_trend_start	Date/time trend WQ period begins	
swl_trend_stop	Date/time trend WQ period ends.	

To select NGWMN sites, MBMG created GIS coverages depicting the spatial distribution of potential monitoring sites within each national aquifer. The coverages allowed MBMG staff to see where potentially duplicative sites from a NGWMN viewpoint might exist. For example, if two or more nearby wells had similar periods of record and the hydrographs had similar signatures, the location with the better construction and lithologic information could be picked. For each site suggested for the NGWMN, MBMG:

1. Verified that the well was completed in one of Montana's segments of national, major, or important aquifers.
2. Considered the well's position in the flow system: up-gradient, mid-gradient, down-gradient: shallow, middle, or deep.
3. Determined if well construction information/details were available. If well construction data were missing, could they be found? Are lithologic descriptions available for the borehole? Are perforations records available?
4. Determined the ownership - private versus public.
5. Determined the likely long-term accessibility – is there any reason to believe that monitoring will not continue. In principle, statewide monitoring network wells should, by definition, be available long term, but if there would be a choice between a dedicated publicly owned well and a privately owned well that would provide much the same information, the publicly owned site would be selected.
6. Classified the well as "dedicated" or "non-dedicated" for monitoring. If the well is "non-dedicated" and/or used for water production, how disruptive can non-static water levels be?
7. Examined the quality of hydrograph: the period of record, frequency and consistency of measurement, and potential impact nearby well use or pumpage.
8. Determined the existence of static water-level baseline period (> five years and at least twenty measurements) and water-quality baseline period (at least three inorganic analyses containing common constituents and trace metals).
9. Used factors listed in Chapter 1 of the Framework Document to determine if the site should be designated as "Targeted" or "Unstressed".

If MBMG selected a well for NGWMN-MONTANA, the next step was to flag it as "Surveillance" or "Trend" to determine proposed measurement frequencies.

1. All sites added to the NGWMN-MONTANA project met the criteria for the "Surveillance" (or minimal frequency of measurement) level.
2. Depending on the site's purpose and/or the presence of a baseline period, the site may be further flagged as a "Trend" site. Logic in the registry-template retrieval resolves the flagging to: "Surveillance" if "Trend" is "NO" or if "Yes" to "Trend". Wells with installed water-level recording instruments were by default flagged as "Trend" sites. A few newly constructed dedicated monitoring wells, installed for the purpose of monitoring water-level trends were defined as "Trend" sites, despite their lack of a baseline record.

Following site review and selection, MBMG added the NGWMN metadata into GWIC (Table 3, above), and also added a NGWMN-MONTANA project code to GWIC's project table. The addition of the project code allowed the GWIC website to include the site on a "NGWMN-MONTANA" page and make associated water level, water quality, well construction, lithologic, and other GWIC data viewable as part of the NGWMN-MONTANA project. Although they were not publicly available through the GWIC website, registry-template updates could be generated and sent to the GWDP.

Water Quality network well selection:

The Framework Document recognizes that in many states water-quality network sites will not be the same as those included the water-level network. In Montana's case, where statewide network wells are primarily selected based on their position within the flow system and the primary water-quality analytes are common ions, trace metals, and selected nutrients; most network sites serve both networks. Exceptions occur where a monitored well is not accessible either for sampling or for measurement; in those cases a site will be designated as being in one or the other of the networks. Because it was not appropriate to list almost all of the sites twice; once in a descriptive table for water levels, and again in a water-quality table, the table structure describing NGWMN-selected sites as defined in the pilot report outline were combined and placed in Appendix B.

"Unstressed" and "Targeted" subnetworks:

In Chapter 1, section 1.4.3, the Framework Document defined two logical sub-networks within the NGWMN. Wells/springs designated as NGWMN sites would be flagged as:

1. "Unstressed" (background) for monitoring points located within unstressed portions of aquifers.
2. "Targeted" for monitoring points located in areas of focused interest, such as an area of current or emerging ground-water development or land-use change.

There has been considerable discussion within the SOGW about the "Unstressed" and "Targeted" designations because the terms have meanings beyond those intended by the SOGW. Thus there are differences in how the pilot projects and by extension the rest of the nation are able to use these terms. The Montana pilot project 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 in section 1.4.3.2 reserved the "Targeted" flag for aquifers (or segments of aquifers) that:

1. Are known to be heavily influenced by pumpage,
2. Have experienced substantial recharge-altering land-use changes,
3. Are located in areas of managed groundwater resources (e.g., artificial recharge or enhanced storage and recovery, or controlled withdrawals)
4. Known to have degraded water quality from human activities, or
5. Are in an area expected to soon be developed.

As Montana has pointed out on several occasions, many of its western intermontane basins would be considered "Targeted" based on item two from "section 1.4.3.2", but not necessarily under the definition of "Targeted" in section 1.4.3. Surface water has been distributed across the landscape in these basins for as long as 100 years via a network of canals, ditches, and irrigated fields causing changes in the native groundwater system; there are aquifers present today that did not exist prior to irrigation development. However, even though most of Montana's intermontane basins have undergone "recharge-altering land-use changes", for the purposes of the Montana pilot project, wells in these basins will not be flagged as "Targeted" unless one of the other factors outlined in Framework Document sections 1.4.3 or 1.4.3.2 applies. Additionally, sites within the NGWMN-MONTANA project may be designated as "Targeted" if monitoring has a specific purpose other than tracking of "natural" water-level or water-quality change (e.g. future heavy development).

NGWMN-MONTANA sites:

At the time of this report, MBMG has selected 271 points for inclusion in the NGWMN-MONTANA pilot. Seven of the eight principal, important or major aquifers within Montana are included. The exception is the "Pacific Northwest volcanic rock aquifers" which cover a very small area near West Yellowstone, Montana.

Alluvial aquifers (N100ALLUVL)

The N100ALLUVL principal aquifer includes sand and gravel deposits in western Montana not related to the Northern Rocky Mountains Intermontane Basins aquifer system and alluvial deposits in eastern Montana not related to glaciation. NGWMN-MONTANA well selection for this aquifer is incomplete with 30 wells selected from 143 candidates. Table B-1 in Appendix B lists the wells selected for NGWMN-MONTANA and maps of sites by water-level and water-quality sub-networks are shown on Figures 6 and 7. Yellow areas on the figures show areas of intermontane basin-fill in the west, and alluvial deposits along streams in eastern Montana.

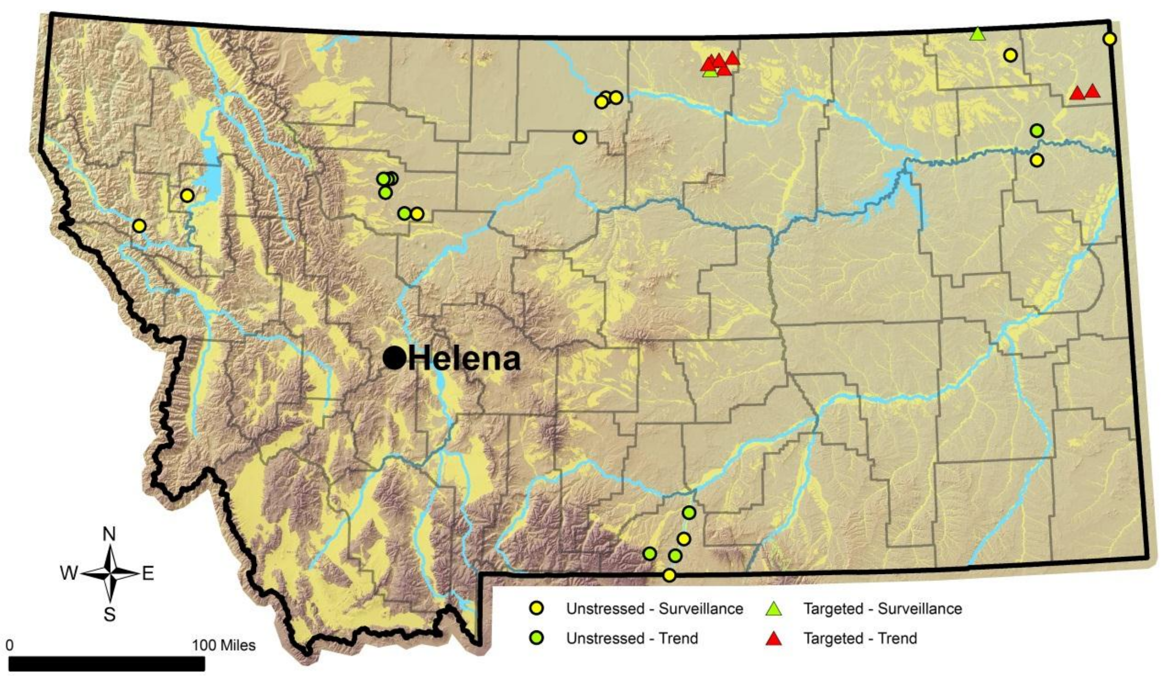

Figure 6. Map of currently selected NGWMN water-level wells in Alluvial aquifers (N100ALLUVL).

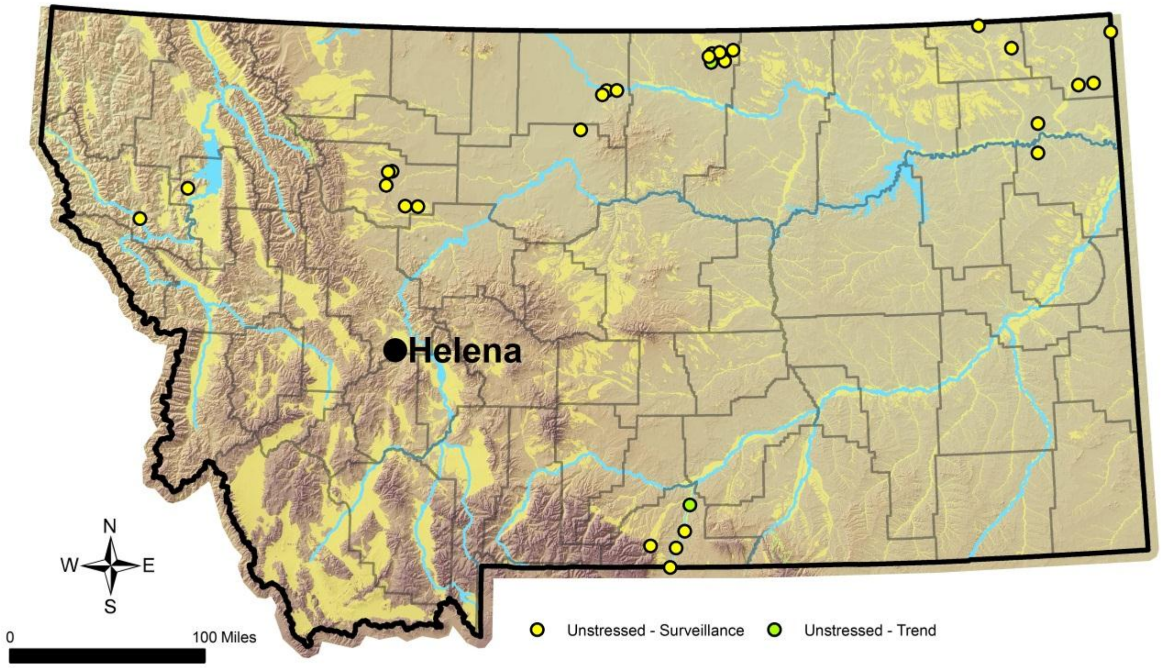

Figure 7. Map of currently selected NGWMN water-quality wells in Alluvial aquifers (N100ALLUVL).

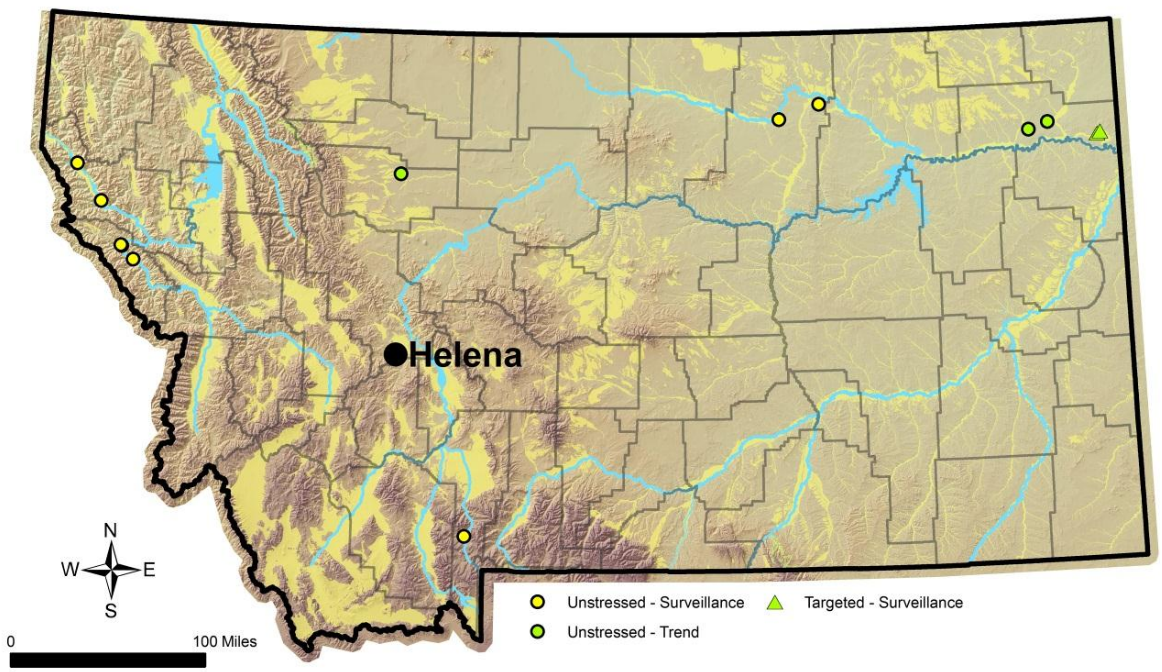

Figure 8. Map of currently selected NGWMN water-level wells in Glacial aquifers (N100GLCIAL).

Glacial aquifers (N100GLCIAL)

The N100GLCIAL principal aquifer includes glacial till, drift and outwash deposits of sand and gravel deposits in northern and northeastern Montana. It also includes glacial lakebed and outwash deposits in western Montana not within an intermontane basin. NGWMN-MONTANA well selection for this aquifer is incomplete with 13 wells selected from 64 candidates. Table B-2 in Appendix B lists the wells selected for NGWMN-MONTANA and maps of sites by water-level and water-quality sub-networks are shown on Figures 8 (above) and 9 (below). Yellow areas on the figures show areas of intermontane basin-fill in the west, and alluvial deposits along streams in eastern Montana.

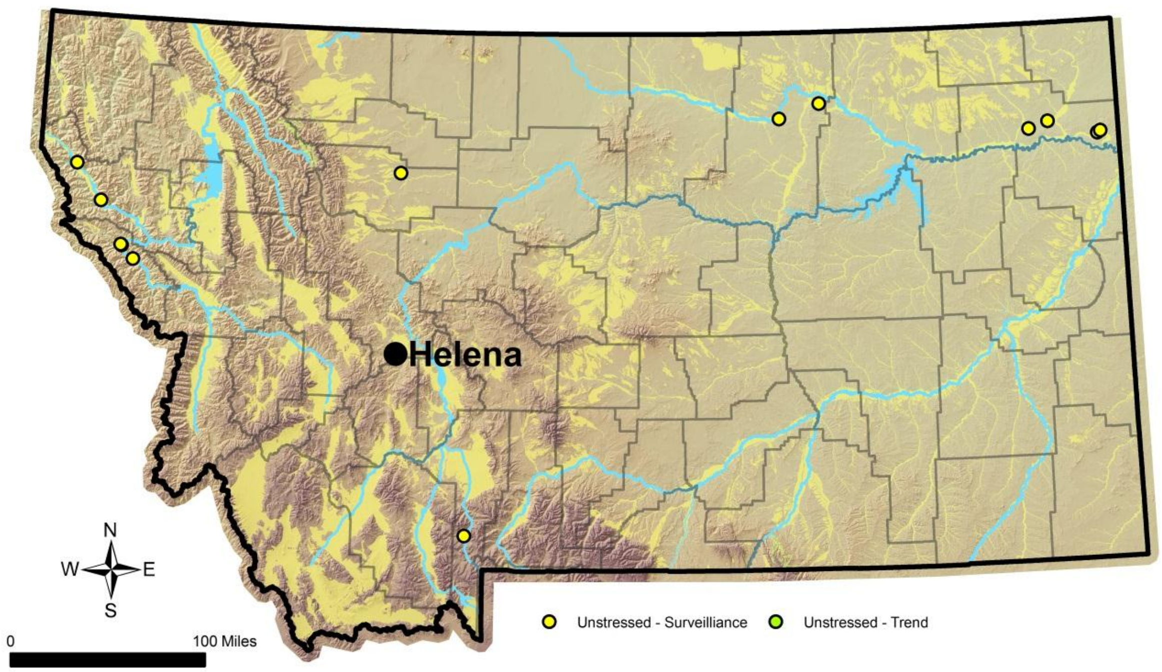

Figure 9. Map of currently selected NGWMN water-quality wells in Glacial aquifers (N100GLCIAL).

Northern Rocky Mountains Intermontane Basin aquifer system (S100NRMTIB)

The S100NRMTIB principal aquifer system includes valley-fill materials ranging in age from Holocene to Eocene. Glacial outwash and other deposits of Pleistocene age are included as are bedrock basin margins. Basin margin formations may be as old as Precambrian. NGWMN-MONTANA well selection for this aquifer is incomplete with 139 wells selected from 423 candidates. Table B-3 in Appendix B lists the wells selected for NGWMN-MONTANA and maps of sites by water-level and water-quality sub-networks are shown on Figures 10 and 11. Yellow areas on the figures show areas of intermontane basin-fill in the west, and alluvial deposits along streams in eastern Montana.

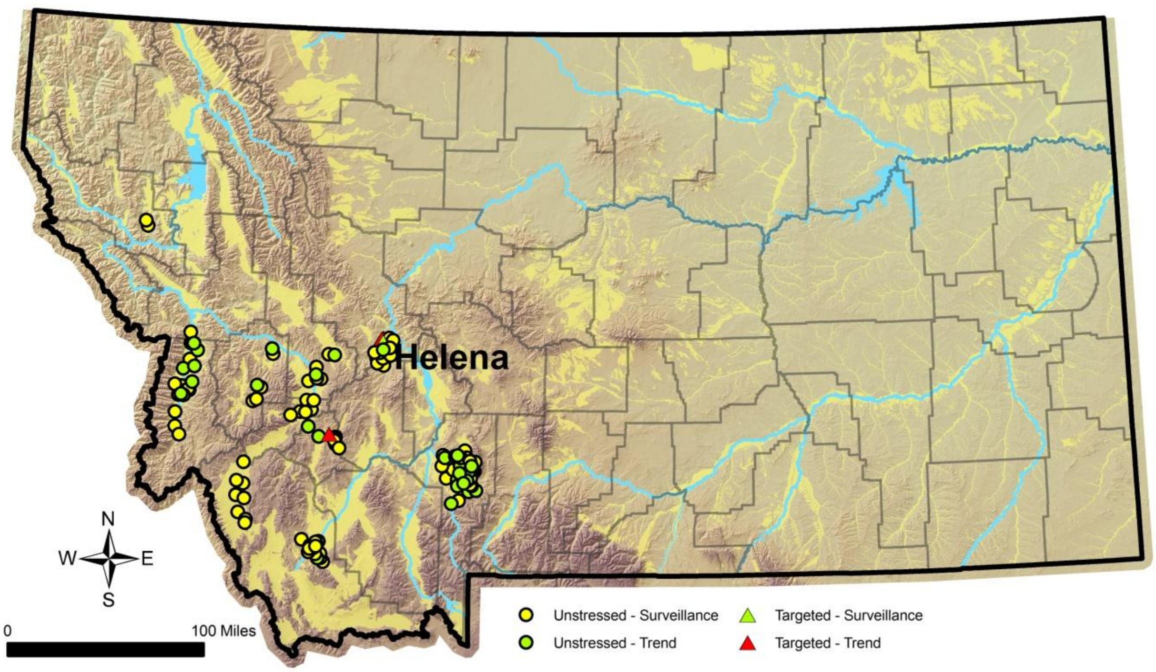

Figure 10. Map of currently selected NGWMN water-level wells in the Northern Rocky Mountains Intermontane Basin aquifer system (S100NRMTIB).

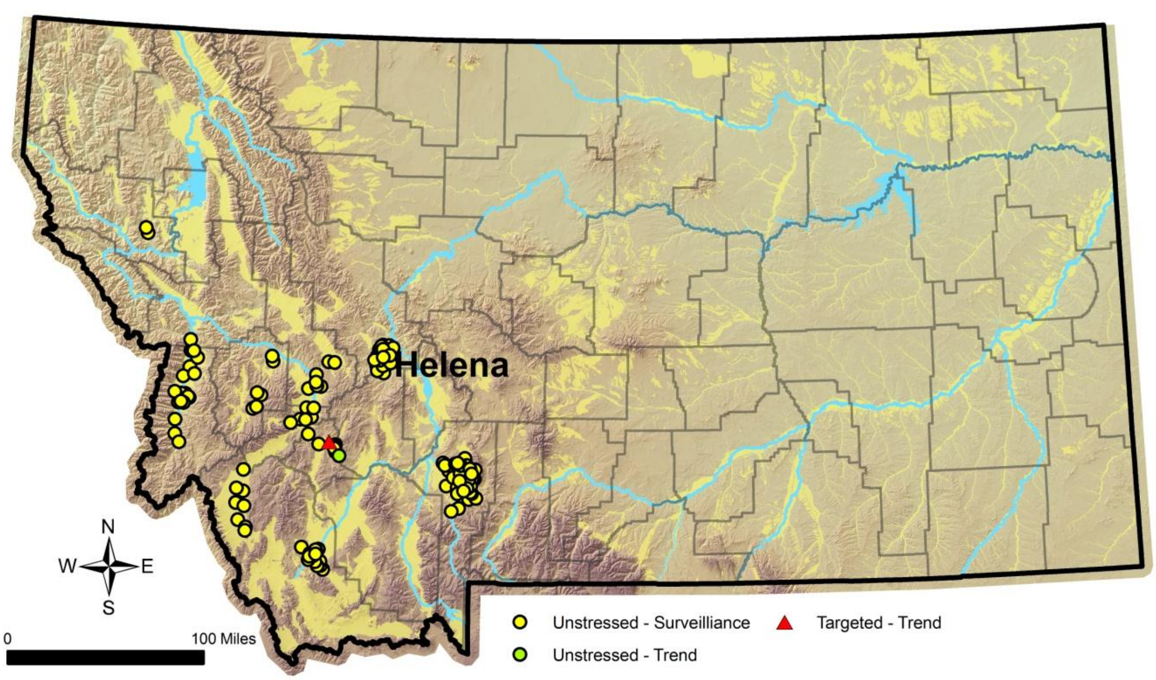

Figure 11. Map of currently selected NGWMN water-quality wells in the Northern Rocky Mountains Intermontane Basin aquifer system (S100NRMTIB).

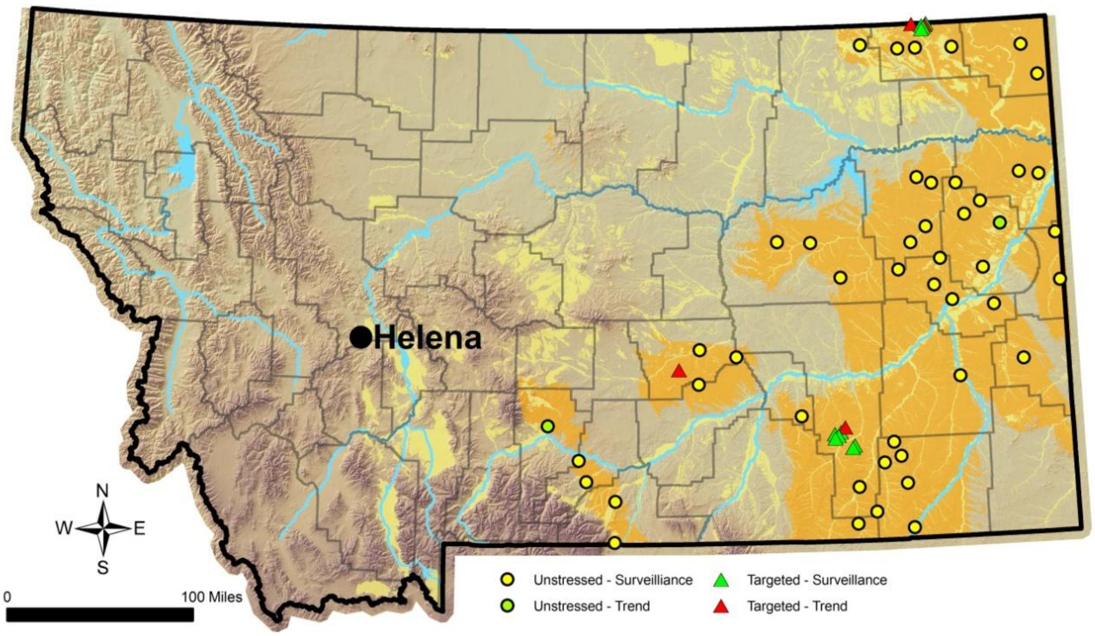

Figure 12. Map of currently selected NGWMN water-level wells in Lower Tertiary aquifers (N300LTRTRY).

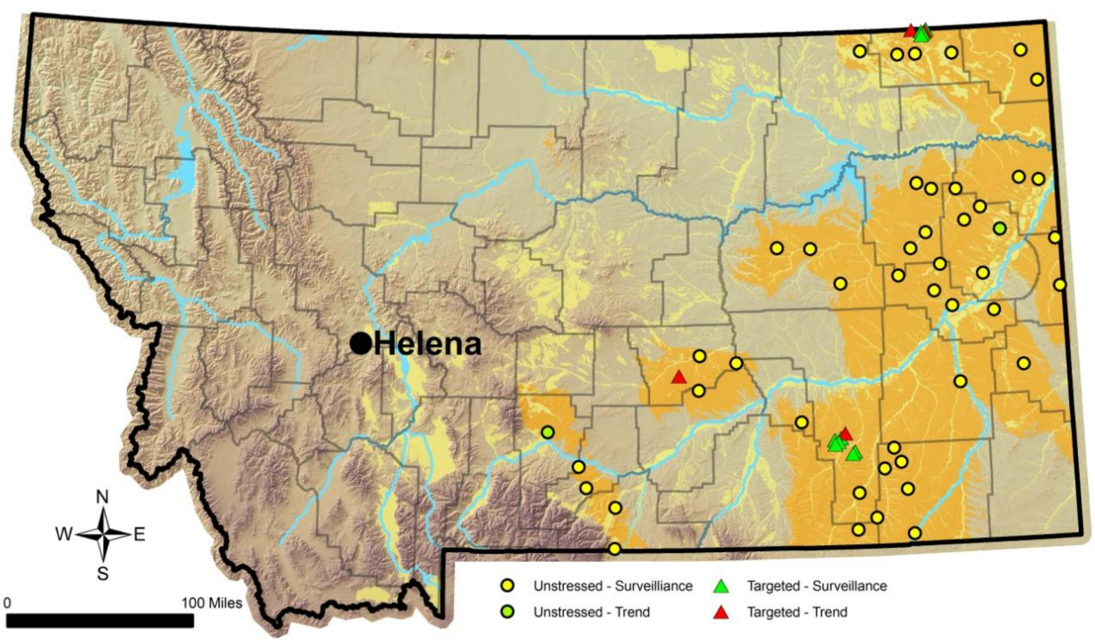

Figure 13. Map of currently selected NGWMN water-quality wells in Lower Tertiary aquifers (N300LTRTRY).

Lower Tertiary aquifers (N300LTRTRY)

The N300LTRTRY principal aquifer includes the members of the Paleocene Fort Union Formation in eastern Montana, generally shown by the orange areas on Figures 12 and 13. NGWMN-MONTANA well selection for this aquifer is complete with 70 wells selected from 98 candidates. Table

B-4 in Appendix B lists the wells selected for NGWMN-MONTANA and maps of sites by water-level and water-quality sub-networks are shown on Figures 12 and 13 (above). There are areas of "Targeted" monitoring in the N300LTRTRY primarily related to coal mining.

Upper Cretaceous aquifers (N300UPCTCS), Lower Cretaceous (N300LCRTCS) and Paleozoic (N500PLOZOC) aquifers.

The N300UPCTCS, N300LCRTS and N500PLOZOC principal aquifers includes the Fox Hills, Hell Creek, Judith River, Eagle-Virgelle, Kootenai, and Madison Formations. Aquifers materials in all the formations except for the Madison are sandstone. The Madison Formation is limestone with local to regional areas of well-developed karst. The Fox Hills and Hell Creek formations generally underlie the Fort Union Formation as shown on Figures 12 and 13. The Judith River and Eagle-Virgelle formations outcrop locally in central and northern Montana, and also underlie the eastern third of the state. The Kootenai Formation is commonly used in central Montana, but is at too great of depth to economically be an aquifer farther east. The Madison Formation is a heavily used aquifer in central Montana, near and east of Great Falls, Montana. NGWMN-MONTANA well selection for the N300UPCTCS and the N300LCRTS aquifers is incomplete with only 10 wells selected from 194 candidates. The number of remaining candidate wells in these aquifers shows their importance to Montana. Tables B-5 and B-6 in Appendix B list the wells selected for NGWMN-MONTANA. Well selection in the N500PLOZOC aquifer is complete with 9 wells selected from 12 candidates; the wells are listed in Table B-7 in Appendix B. Maps showing currently selected sites for these aquifers in the water-level and water-quality sub-networks are shown on Figures 14 and 15.

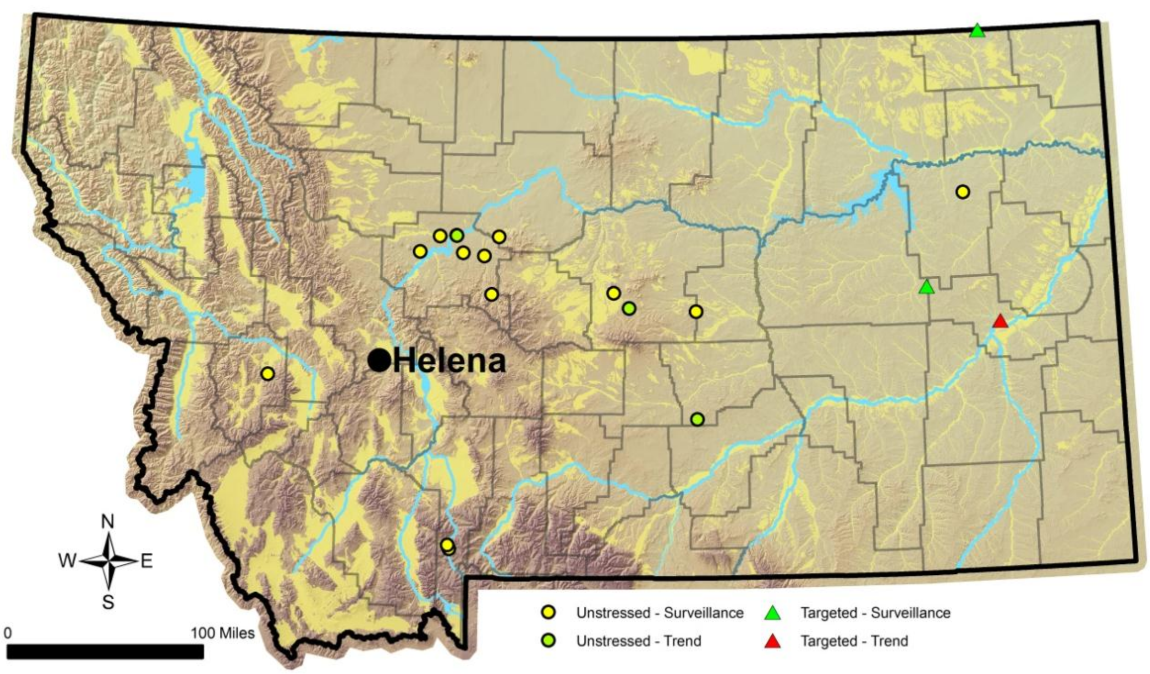

Figure 14. Map of currently selected NGWMN water-level wells in Upper Cretaceous aquifers (N300UPCTCS), Lower Cretaceous aquifers (N300LCRTCS), and Paleozoic aquifers (N500PLOZOC).

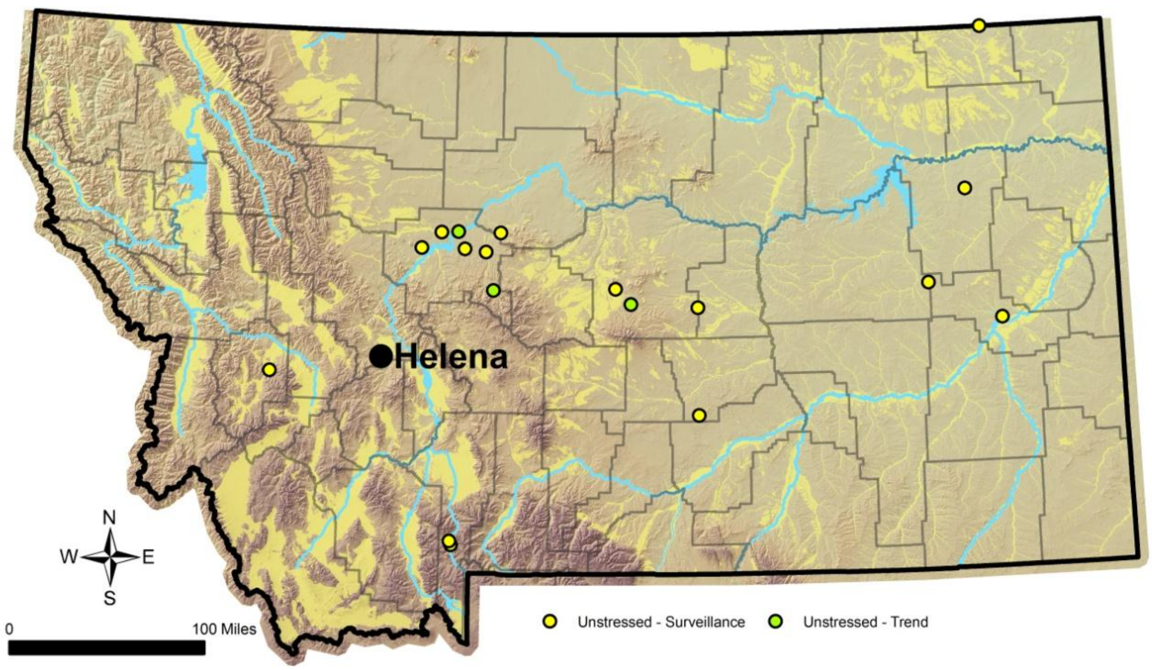

Figure 15. Map of currently selected NGWMN water-quality wells in Upper Cretaceous aquifers (N300UPCTCS), Lower Cretaceous aquifers (N300LCRTCS), and Paleozoic aquifers (N500PLOZOC).

Gap analysis:

Each pilot project is asked to estimate the number of wells required to meet the NGWMN goal of monitoring the nation's aquifers in enough detail to answer the questions posed in the Framework Document. The difference between the number of wells available within an aquifer and the wells required is a "Spatial Gap". An "Operational Gap" occurs when monitoring or sampling frequencies maintained by the cooperator are less than frequencies suggested in the Framework Document. The "Gap" analyses provided by the pilots will be used by the SOGW to estimate the costs of full NGWMN implementation.

Spatial Gaps by National Aquifer

Montana's goal for its monitoring network is to collect water-level and water-quality data from its aquifers based on the aquifer's hydrogeology. This state-level goal is modified by the financial resources available, the distribution of wells and groundwater use, and the perceived need for monitoring at various locations. For example, intermontane basin flow systems are reasonably well covered by Montana where there are relatively high populations, many wells, and high groundwater use. In less densely populated basins, Montana has established a minimal number of monitoring points that do not fully cover the groundwater flow system. The regional aquifers of eastern Montana are generally only monitored in areas of outcrop where they are most heavily used, where monitoring sites are available, and where the aquifers are relatively near land surface.

Even though the site selection process is not complete for all NGWMN aquifers, experience gained by selecting almost 300 NGWMN-MONTANA sites shows that with the exception of closely spaced wells that provide duplicative records, a few wells that are not providing good records, and occasional sites that have poor access; most Montana network wells qualify for the NGWMN-MONTANA. Because current locations in Montana’s network do not fully cover the spatial extent of NGWMN’s principal, important, or major aquifers, the current geographic distribution of wells in the Montana network can be a base from which to estimate spatial gaps in a fully implemented NGWMN-MONTANA.

Table 4 outlines the number of new sites needed to augment the spatial distribution of Montana statewide network monitoring wells to provide reasonable NGWMN spatial coverage. Estimates for the N300LTRTRY and N500PLOZOC aquifers are based on the distribution of NGWMN-MONTANA selected sites. Estimates for the other aquifers are based on the distribution of Montana network wells. For spatial gaps based on Montana candidates, the number of new NGWMN sites needed is likely minimally represented in Table 4 because there will be some statewide network wells not selected for NGWMN-MONTANA. If a well is not selected because from the NGWMN point of view it is duplicative, not selecting that well will not create a new spatial gap. Not selecting a well because of other factors will potentially add a spatial gap. The spatial gap analysis considers only the geographic distribution of monitoring sites and does not include the potential replacement of stock, domestic, or other production wells in the Montana network with dedicated non-production monitoring sites.

Table 4. Spatial gaps in NGWMN monitoring site distribution by national aquifer.

Aquifer	Total Montana statewide network candidates	Total NGWMN selected to date	NGWMN Selection complete	Spatial gap analysis based on:	New NGWMN wells	Average target depth (Ft)	Total footage to be constructed (Ft)
N100ALLUVL	143	30	No	Candidates	61	54	3,294
N100GLCIAL	64	13	No	Candidates	10	118	1,180
S100NRMTIB	423	139	No	Candidates	115	152	17,480
N300LTRTRY	98	70	Yes	NGWMN	20	172	3,440
N300UPCTCS	162	6	No	Candidates	27	355	9,585
N300LCRTCS	32	4	No	Candidates	5	509	2,545
N500PLOZOC	12	9	Yes	NGWMN	7	369	2,583
Totals	934	271	--	--	245	--	40,107

Table 4 indicates that about 40,100 feet of additional monitoring well construction would be required to fill out the Montana network to meet NGWMN goals. Most of the construction would be required to cover groundwater flow systems within the heavily populated intermontane basins of western Montana, where most groundwater development has, and will continue to occur. Additional wells would increase operation costs for the NGWMN-MONTANA network by the number of wells constructed multiplied by the number of measurements and by the cost per measurement.

Operational gaps

The Framework Document (SOGW, 2009) uses “Baseline”, “Surveillance”, and “Trend” flags to describe the measurement frequencies necessary to define a reasonable water-level record. Frequent measurements at monitoring points during baseline periods help define an aquifer’s hydrogeologic response. Once a baseline record exists, network operators can then determine measurement frequencies to meet monitoring goals or to adequately capture the water-level record. The Framework Document says that NGWMN partners will determine measurement and sampling frequencies for NGWMN sites.

In order to adequately capture water-level change in a variety of hydrogeologic conditions, suggested frequencies are presented in Table 4.5.2; the frequencies vary from hourly to annually, depending on how rapidly water levels change and the desired capture resolution (SOGW, 2009, page 45).

Table 5 lists measurement frequencies in the Montana statewide network for sites that have annual water-level changes of more-than, and less than 2-feet. The Montana pilot project defined the 2-foot annual fluctuation as a threshold above which quarterly measurements would likely not adequately describe annual water-level change. Sites with less than 2-feet of annual change would likely have hydrographs with little annual fluctuation. The chart is based on retrievals from the Montana statewide network for the January 1, 2009 to January 1, 2010 period. Table 5 includes about 70 sites that do not have baseline periods of at least 5-years and 20 measurements.

Table 5. Water-level network "Operations Gap" analysis.

NGWMN-MONTANA hydrograph classification	Montana network measurement frequency	Montana network sites	Anticipated NGWMN sites (70% of network sites)	NGWMN – MONTANA frequency	Additional NGWMN measurements required based on the anticipated number of NGWMN sites and a monthly frequency[1]
Annual > 2 feet	Monthly	9	6	Monthly	None
Annual > 2 feet	Quarterly	433	303	Monthly	2,424
Annual > 2 feet	Recorder: Daily to hourly	63	44	Daily/monthly	None
Annual <= 2 feet	Monthly	17	12	Monthly/quarterly	None
Annual <= 2 feet	Quarterly	345	241	Quarterly	None
Annual <= 2 feet	Recorder: Daily to hourly	36	25	Monthly/quarterly	None

[1] Values are calculated as ((Anticipated NGWMN sites * 12 months) – (Anticipated NGWMN sites *4 months)).

The additional measurements shown in the right-most column in Table 5 are based on the anticipated number of NGWMN-MONTANA sites. Completed evaluations of the N300LTRTRY, N500PLOZOC, and individual valleys in the S100NRMTIB, show that about 70 percent of Montana statewide network candidate wells are being selected for NGWMN. Based on the selection rate and the number of sites that do not have baseline records or frequent enough measurements to describe annual cycles of at least 2-feet, the water-level "Operations Gap" is about 2,400 periodic (site-visit) measurements annually.

The Framework Document (SOGW, 2009) says that baseline water-quality data should be collected at NGWMN sites for periods of up to 5 years before decisions are made regarding long-term sampling frequencies. The SOGW also defined lists of "Standard" and "Extended" analytes (SOGW, 2009, Table 4.6.1 on page 46) generally consisting of common field chemistry parameters (conductivity, pH, etc.) and common inorganic ions. In Table 4.5.1, SOGW suggests that baseline data be collected "quarterly to twice per year" from sites in all hydrologic regimes. After baseline sampling is completed, suggested collection frequencies drop off to "annual to every 5 years" for the "Standard" list and "every 5 years" for the "Extended" list.

For NGWMN purposes, Montana has defined monitoring sites that have three complete inorganic analyses (for common ions) as having a baseline water-quality record. Using the current Montana statewide network as the candidate set for water-quality sites, 89 sites have no analyses or cannot be sampled, 701 sites have 1 to 2 analyses, and 91 sites have baseline records of at least 3 analyses. Because the baseline period is defined by the time it takes attain three analyses, Montana network baseline periods vary from 0 to 41 years. The average and median periods are 18 and 16 years respectively.

The SOGW suggests that NGWMN sites be sampled more often than those in the Montana statewide network, particularly during the baseline period. Even after a baseline record is available, the Framework Document suggests more frequent sampling than occurs in Montana network; although the “1- to every 5-year” frequency is more like Montana’s 7 to 10 year frequency. Montana’s analyte lists include common field chemistry parameters (SOGW Standard list) and common inorganic ions (SOGW Extended list). When a Montana statewide network well is sampled, data for most analytes listed on the SOGW Standard and Extended lists are gathered. A water-quality report showing analytes typically reported for samples from Montana statewide network wells is in Appendix C.

Table 6 contains information about how sampling frequency and analytes for Montana statewide monitoring network water-quality sites compare with suggested sampling frequencies on Table 4.5.1 in the Framework Document (SOGW, 2009, page 43).

Table 6. Water-quality network baseline attainment: “Operations Gap” analysis.

NGWMN classification[2]	Montana sampling frequency	NGWMN standard sampling frequency[1]	NGWMN extended sampling frequency[1]	Montana candidate sites	Additional samples[1] based on 70% selection rate and NGWMN frequency
No baseline - no samples	Every 7-10 years	Quarterly to bi-annually	Quarterly to bi-annually	89	187**
No baseline – 1 sample	Every 7-10 years	Quarterly to bi-annually	Quarterly to bi-annually	369	517**
No baseline – 2 samples	Every 7-10 years	Quarterly to bi-annually	Quarterly to bi-annually	332	232**
Baseline	Every 7-10 years	1 to 5 years depending on medium, well depth, and aquifer characteristics	Every 5 years	91	--
Totals	--			881	936

[1] For analytes listed in Tables 4.5.1 and 4.6.1, SOGW, 2009 pages 43 and 46. [2] No baseline is fewer than 3 samples. **The number of samples necessary to complete baseline records throughout the network in the first 2-years of a fully implemented NGWMN ((Candidate sites *0.7)*(The number of samples to reach baseline)).

Table 6 shows that in the first two 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 on 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 collects samples from 70-90 statewide network sites each year; the long-term “Operations Gap” would be about 60-80 samples annually.

Sampling is time-intensive, often requiring hours to purge wells, and is generally not compatible with routine water-level monitoring runs. The Ground Water Assessment Program would need additional field staff and equipment to collect this number of additional samples and fund the laboratory services necessary to produce the analytical results.

Field Practices

MBMG and its cooperators use a variety of standard field equipment such as steel tapes, electric water-level sounders, pressure gages for artesian flowing wells, and field water-quality instruments to collect data at statewide monitoring network sites. Standard Operating Procedures guiding field activity are included in Montana’s Statement of Interest (Patton, 2009, Appendix E).

Groundwater level monitoring field practices:

During the pilot project, MBMG staff compared its standard operating procedures for water-level monitoring to the Framework Document (SOGW 2009, Appendix 5). Table 7 summarizes the comparison and the complete analysis is in Appendix D.

Table 7. Comparison of Montana statewide network water-level collection practices to Framework Document.

Item	Compliant?	Issues
Section 5.2.1.1 - Training		
Training	Yes	None
Site verification	Yes	None
Equipment decontamination	Yes	None
Site condition notations	Partial	Minor issue – weather conditions are not monitored.
Site Access	Yes	None
Established measurement point	Yes	None
Section 5.2.1.2 - Pre-collection site review and preparation		
All equipment necessary gathered and packed.	Yes	None
Field form showing information to be gathered	Partial	Minor issue – Field form does not explicitly require recording of duplicate measurements.
Section 5.2.1.3 - Minimum data elements		

Item	Compliant?	Issues
Minimum data elements	Yes	None
Section 5.2.1.4 - Onsite preparation		
Onsite preparation	Partial	Minor issue – Weather conditions not explicitly noted.
Section 5.2.1.5 - Water Level Measurements		
All measurements recorded	Yes	None
Manual measurements	Yes	None
Automated measurements	Partial	Minor issue – Instrumentation type (data logger, analog recorder, etc.) is noted in database, but serial number, model, etc. are retained in field notebooks. Field forms with instrumental calibration notes are not posted in field.
Section 5.2.2 - Minimum data standards		
Manual water-level measurements	Partial	Minor issue – measurement tolerances slightly different than NGWMN. Steel tape and chalk: +/- 0.01 for SWL <= 300 ft, +/- 0.1 ft for SWL > 300 ft. Electric well sounder: +/- 0.05 for SWL <= 300 ft, +/- 0.1 ft for SWL > 300 ft
Automated water-level measurements	Partial	Minor issue – slightly different methods and frequencies of reconciling instrumental measurements to discrete 'hand' measurements.
Section 5.2.3 - Data handling and management		
Electronic entry of data	Yes	None
Verification and editing of unit values	Yes	None
Verification and analysis of field-measurement data	Partial	Minor issue – slightly different ways of handling items listed in this section. Existing Montana network procedures can meet NGWMN expectations.

MBMG field practices for water-level data collection match closely with elements listed in Appendix 5 of the Framework Document. Most differences were related recording weather conditions at the time water-level measurements were made. Although the standard operating procedure requires that field staff collect duplicate measurements to insure that water levels are static and that measurement errors are reduced, the Ground Water Assessment Program water-level field form does not provide locations to record the duplicate measurements. Improvements to how and where metadata regarding water-level recorder instrumentation are stored could be easily added to the MBMG data base. The largest difference between MBMG field procedures and the Framework Document was about acceptable tolerances for manual steel and electric well sounder measurements. MBMG tolerances are larger than the Framework Document's for water-level measurements of more than 300-feet below land surface.

Groundwater quality monitoring field practices:

During the pilot project, MBMG compared its standard operating procedures for water-quality sampling to the Framework Document field practices (SOGW 2009, Appendix 5). Table 8 summarizes the comparison and the complete analysis is in Appendix D.

Table 8. Comparison of Montana statewide network water-quality sampling practices to Framework Document.

Item	Compliant?	Issues
Section 5.3.1 – Minimum field standards		
Pre-Collection Site Review and Preparation	Yes	None
Minimum data elements	Partial	Minor issue – weather conditions not monitored.
Onsite Preparation	Partial	Minor issue – weather conditions not monitored.
Sample collection	Partial	Moderate issue – tolerances on GWAA field parameters are slightly larger than those specified for NGWMN.
Sampling preservation, handling, and transport	Yes	None
Section 5.3.2 – Automated water-quality measurements		
Automated measurements	Yes	None
Data recording	Yes	None.

The comparison between MBMG standard operating procedures and field procedures included in the framework document showed that there were no issues with most elements. Minor issues included Montana's non-recording of weather conditions during sampling. There were more important differences in specific criteria for judging when a well's produced water was chemically stable so that samples might be bottled. See sub-section 5.3.1.5, Sample collection in Appendix D.

Gap analysis:

Differences in field practices are minor and NGWM and Montana statewide monitoring network practices will need only minimal reconciliation. The greatest difference is in the required accuracy of water-level measurements dependent on the depth of the measurement, and 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.

Data Management System

MBMG has an agency-wide comprehensive data management system that houses all of its groundwater, much of its groundwater project, and its borehole lithologic data. The database occupies a central position within MBMG accepting new data and data corrections from agency staff, and providing real-time access to agency data through public websites.

Description of pilot study system(s):

All data collected from NGWMN sites within Montana will be stored in the Montana Ground Water Information Center (GWIC) database at the Montana Bureau of Mines and Geology. GWIC is a relational database running in a mirrored Microsoft SQL Server 2008 environment that uses a unique 6-digit site-identification number to link about 140 tables that store, among many other data types, ‘sites’, ‘borehole’, ‘casing’, ‘openings’, ‘field visit’, ‘measuring point’, ‘static-water level’, ‘water-quality’, and ‘ownership’ data for about 250,000 paper documents; mostly water well logs.

Figure 16 schematically illustrates how GWIC fits within MBMG’s overall data system. In addition to GWIC (in the large tan box), other databases include: ‘‘Earthquakes’, ‘Coal Resources’, ‘Mines and Minerals’, ‘Weather’, and ‘Water-level Telemetry’ (dark blue icons).

Inside GWIC, ‘Validations’, ‘Definitions’, and ‘Audits’ tables are important controls on all GWIC data including those related to the well or ‘Borehole’ (the light green area). Dark green icons inside the ‘Borehole’ area illustrate some major logical data groups tied to the borehole by the unique 6-digit GWIC site identification number.

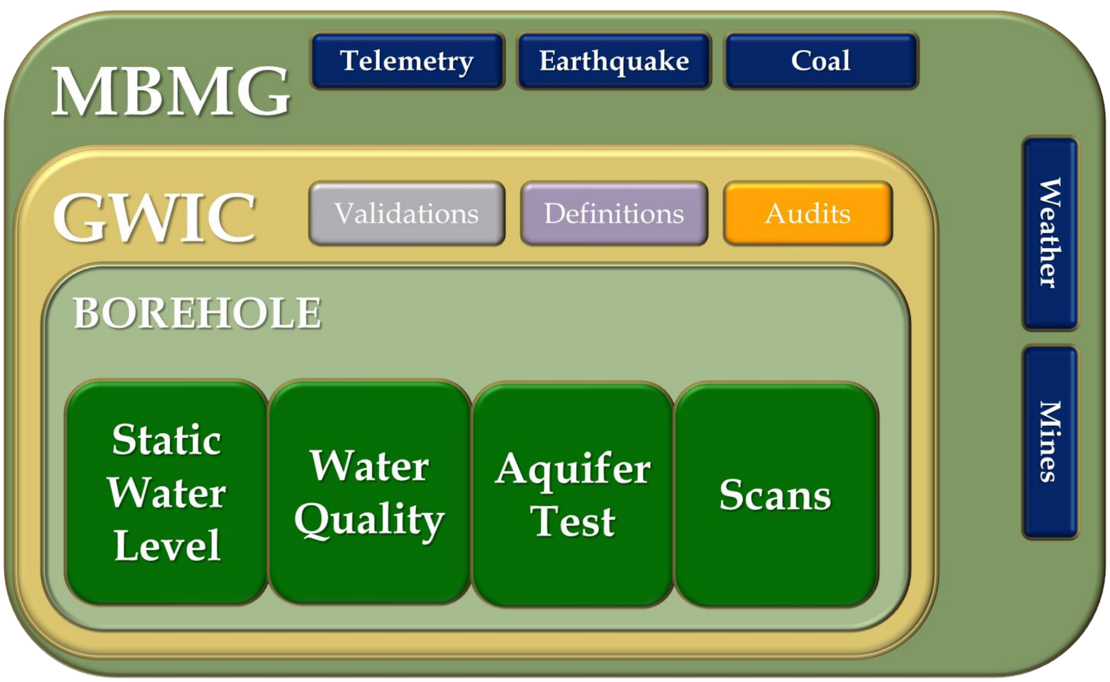

Figure 16. Montana Ground Water Information Center data relationships.

MBMG and public GWIC access is through a website at *http://mbmggwic.mtech.edu*. Website users must first create a user profile but then may use many pre-defined database queries to select, retrieve, and download well-construction, lithologic-description, water-quality, and water-level data from individual sites, or for sites within areas as large as drainage basins. GWIC currently contains more than 7.0 million water levels from about 13,600 wells. GWIC also supports specialized in-house database access for MBMG staff through standard Microsoft Office products (Excel, Access) using ODBC connections and through Microsoft's SQL Server Management Studio for custom queries. The web applications running GWIC consist of more than 1,000 scripts/pages containing about 255,000 lines of HTML/ASP code. GWIC is actively and heavily used by many customer constituencies. In 2010, customers created almost 40,300 user sessions and made almost 490,000 database queries.

Comparison to Framework Document:

GWIC data structures contain most of the NGWMN data elements outlined in the Framework Document (SOGW, 2009, Appendix 6) as shown in an annotated comparison between GWIC and NGWMN data structures included in Montana's Statement of Interest (Patton, 2009, Appendix C). During the pilot project, MBMG and USGS staff at the Center to Integrate Data Analysis (CIDA) created a mediation table based on the original comparison. The mediation table maps GWIC data elements to GWDP data elements and is included in Appendix E.

Gap analysis:

The primary gap in data management systems relative to Montana's participation in the NGWMN was the need to create structures within 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 GWDP.

The data management gaps for well-construction and water-level data were addressed during Montana's pilot project. Creation of a web feature service to transmit water-quality to the GWDP was not accomplished during the pilot project. Lack of a water-quality web feature service is a data management gap.

If GWDP portal requirements change as the NGWMN develops, some of the data management gaps may need to be addressed either by additional GWIC-to-GWDP mapping or by revisiting the classification of wells included in the NGWMN-MONTANA network.

NGWMN metadata table

The metadata table allowed pilot MBMG to generate registry templates within GWIC so that GWIC would be compatible with the web feature services needed to connect to the NGWMN Ground Water Data Portal (GWDP). Table 3 (page 15) shows the NGWMN metadata table and outlines the logic necessary to populate the registry template.

NGWMN web services – Groundwater Data Portal

For the purposes of GWDP access, GWIC staff created five Web Feature Services (WFS) for the purpose of delivering web services to the GWDP. All of the services match formats requested by CIDA staff. The five services are:

- **vwNationalNetworkSitesService:** This service displays currently available NGWMN-flagged sites in GWIC. The Sites Service is not currently active because the data available are being manually retrieved and transmitted to the GWDP via spreadsheet. The pilot project developed the service to automate later delivery of the 'registry template'. Fields delivered via this service are shown in Appendix F.
- **vwNationalNetworkLithology:** This service provides the GWDP with lithologic details for NGWMN sites in the GWIC database. It is designed to supply information for the "Well Log" tab. Fields delivered via this service are shown in Appendix F.
- **vwNationalNetworkCasing:** This service provides the GWDP with casing details for NGWMN sites in the GWIC database. The data from this service will be combined with the lithology and completion services to populate the "Well Log" tab. Fields delivered via this service are shown in Appendix F.
- **vwNationalNetworkCompletion:** This service provides the GWDP with completion or open interval details for NGWMN sites in the GWIC database. The data from this service will be combined with the lithology and casing services to populate the "Well Log" tab. Fields delivered via this service are shown in Appendix F.
- **vwNationalNetworkWaterLevels:** This service provides the GWDP with water level measurement details for NGWMN sites in the GWIC database. The data will be used to create hydrographs. Fields delivered via this service are shown in Appendix F.

Registry template:

At the request of CIDA and using the GWIC-NGWMN metadata table, the Montana pilot project developed retrievals and provided registry templates so that NGWMN-MONTANA sites could be displayed on the GWDP. During the pilot project Montana presented 271 sites to the portal.

Summary of Gap Analyses

The evaluations of gaps between current spatial extents and operations in the Montana statewide monitoring network and the NGWMN are summarized below.

- Spatial by national aquifer:
  - Reasonable coverage of Montana segments of principal, important or major aquifers would require an additional 245 wells and about 40,100 feet of new construction.
- Operational – field measurement/sampling frequencies:
  - An additional 2,400 periodic measurements annually in about 300 wells are necessary to adequately capture annual groundwater cycles. The gap represents an increase of measurement frequency from quarterly to monthly.

- If 245 sites were constructed to improve spatial coverage in the NGWMN-MONTANA network, an additional 2,940 measurements annually would be needed to collect baseline water-level records.
    - The number of additional periodic measurements could be reduced to about 1,620 by installing 100 water-level loggers on wells that need increased measurement frequencies.
    - About 940 samples would be needed in a 2-year period to create full baseline water-quality records for about 620 potential NGWMN sites. Seventy to ninety additional samples annually would be necessary to bring the sample frequency rate in NGWMN and Montana statewide network wells to about once every 5 years.
    - If 245 sites were constructed to improve spatial coverage in the NGWMN-MONTANA network, an additional 745 samples annually would be needed to collect baseline water-quality. After baseline data were collected, about 50 samples annually would be required to re-sample these wells every 5 years.
- Field practices:
    - No substantial gaps exist between Montana statewide network and NGWMN field practices exist. Minor gaps can be easily reconciled under existing operating conditions.
- Data management:
    - Few gaps exist between Montana statewide network data management practices and NGWMN practices as represented by the current GWDP. Except for water-quality data, most issues related to preparing GWIC to transmit data to the portal were resolved during the pilot project. If SOGW modifies how NGWMN sites are classified (Surveillance, Trend, Targeted, Unstressed, Etc.) some areas in GWIC may need to be restructured to accommodate the changes.

Proposed Changes to the Framework Document

The Framework Document provides much guidance towards the creation of a NGWMN. Issues remain regarding the classification of monitoring sites relative to “Unstressed” and “Targeted” and these terms have been extensively discussed by the SOGW and the pilot project states. “Unstressed” and “Targeted” offer implications about aquifer conditions that NGWMN cooperators and the SOGW may not wish to convey. Although the MBMG, as operator of the Montana statewide network, does not have a strong opinion regarding usage of these terms, MBMG suggests that the SOGW develop a more judicious set of labels describing a monitoring site’s purpose.

There are 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 defined inconsistently:

1) Within Chapter 1, sub-section 1.4.4.1 – the word “*trend*” is used as a statistical term, and also as a “type” of monitoring making the meaning of “trend” unclear.
2) Within Chapter 1, sub-section 1.4.4.2 – *Surveillance Monitoring* is defined as a method to “…assess long-term natural ***trends***…” – surveillance is also defined as “…periodic aquifer *mass measurements*, or *synoptic measurements*. The first definition confuses the reader regarding the document’s meanings of “Surveillance” and “Trend”. The second definition implies that “Surveillance” (synoptic) measurements are not “Trend” related.

3) Within Chapter 1, sub-section 1.4.4.3 – "*Trend* monitoring is similar to *Surveillance* monitoring…", but conducted more frequently at fewer sites. *Trend* is also co-related to site types: 'core' or 'backbone'. Here, "Trend", a statistical term, is used to imply that "Trend" sites are monitored more frequently than are "Surveillance" sites.
4) In Chapter 4, tables 4.5.1 and 4.5.2 there are suggested frequencies for *Surveillance* and *Baseline* monitoring, but there is no reference to measurement frequencies for *Trend*.
5) In Chapter 7, sub-section 7.1, where the Framework Document revisits NGWMN definitions, there is no mention of *Surveillance*.
6) There is no definition of measurement frequencies for "Trend" sites anywhere in the Framework Document.

The "Surveillance" versus "Trend" site designations, in addition to defining sites with less than 5-years of record as "Baseline" complicates the NGWM structure. Considering that surveillance, reconnaissance, and trend are defined as:

- **Surveillance** –watching closely over someone or something. (Mirriam-Webster on-line dictionary),
- **Reconnaissance** – a general (exploratory?) survey of certain features of a region. (Glossary of Geology, Fifth Edition), and
- **Trend** – the general movement through a sufficiently long period of time of some statistical progressive change. (Glossary of Geology, Fifth Edition)

SOGW should consider a simpler monitoring site classification such as:

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" data set 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.

In this structure "Baseline" would not be a site type, but would be retained in the NGWMN database as a "Yes-No" field. NGWMN data structures would contain whether a site's baseline records were complete and the beginning and ending dates of the period used for the NGWMN baseline.

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 un-attainable 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.

Benefits of the NGWMN

Even though Montana data are already available nationally through the GWIC website, several goals drove Montana's participation in the NGWMN pilot and would drive its participation in a fully implemented NGWMN.

- That Montana groundwater-level and groundwater-quality data be consistent with data from other states/sources and linked to principal, major, or other important aquifers that cross state boundaries.
- That Montana would be a partner in the NGWMN and would collect a substantial part of Montana data used by the NGWMN. Federal funding to support that partnership would be available.
- That participation in a NGWMN would require minimal operational change in the Montana statewide network. Montana would continue to maintain its network, and the NGWMN would have access to and retrieve Montana data.
- Participation in the pilot project would be impetus for a thorough review of sites within the Montana statewide network.
- The pilot project would invoke a current review of Montana's standard operating procedures.
- The pilot project would invoke an in-depth review of Montana's current statewide network - are we measuring the right wells, too many wells, etc?
- Pilot project review might identify data gaps in Montana's long-term monitoring well network.

Cost Estimates

The number of staff hours needed to collect Montana statewide network groundwater-level and water-quality data varies widely, mostly because of the long distances between monitoring points. Staff spends much field time, up to 3 or more hours just travelling from site to site, between well measurements. Instead of calculating the hours expended per measurement, MBMG used the Montana Ground Water Assessment Program's annual monitoring budget of about $243,000 (Table 9) and the number of periodic hand measurements annually to calculate an average cost per measurement. During fiscal year 2010, estimated costs to collect periodic measurements were about $49 per water-level measurement and $330 per water-quality sample (includes analytical charges) (Table 10).

Table 9. Montana statewide monitoring network operation costs for fiscal year 2010.

	Montana Statewide Monitoring
	(July 1, 2009 through June 30, 2010)
Total Personnel	$152,667
Cooperative/contracts	$18,202
Drilling*	$5,000
Laboratory charges*	$15,000

Supplies	$3,838
Miscellaneous	$1,535
Mileage	$29,768
Per Diem	$11,394
Equipment/instruments*	$5,311
Total Operations	$90,048
Total Monitoring Program	$242,715

*Did not include FY 2010 one-time-only drilling costs of $93,257; Laboratory charges of $16,200; and equipment costs of $22,604.

Table 10. Cost per static water-level measurement: Montana statewide monitoring network

Montana Statewide Monitoring	
(July 1, 2009 through June 30, 2010)	
Cost per periodic measurement*	$ 49
Cost per water-quality Sample**	$330

*Based on program expenses of $222,715 after drilling charges of $5,000 and laboratory charges of $15,000 deducted, and on 4,517 periodic measurements made during the year.

**Estimated cost based on: (Analytical laboratory charges) + (Hand-measurement cost) + ($80 in wages/benefits to cover staff time at site).

Cost to participate in the Pilot Study:

Montana's cost to participate in the NGWM pilot project was $31,659 which includes salary, wages, and benefits for the pilot project leader and the database administrator. MBMG obligated about 430 personnel hours to the pilot. Operations costs were minor and consisted of $969 to travel to the National Ground Water Association Groundwater Summit in April 2010 and present an update on the Montana pilot project. Costs included benefits of 46 percent on salaries and wages and Montana Tech's negotiated federal indirect cost rate of 43.2 percent.

Cost to operate and manage NGWMN wells:

Costs to gather periodic water-level measurements from the Montana statewide network are shown in Table 11 and include staff time to gather the measurement, travel to the sites, and enter new water-level data into the GWIC database. The Montana statewide network "Cost per periodic measurement" value from Table 10, multiplied by the number of selected or anticipated NGWMN sites and the number of periodic measurements provides the estimated NGWMN cost. The costs in Table 11 are based on current Montana statewide network measurement frequencies of four periodic measurements for water levels, and one water-quality sample every 10 years. The cost for operating NGWMN-MONTANA is currently estimated to be about $150,200 but the cost will be refined once all NGWMN-MONTANA sites are selected.

Table 11. Cost estimates for monitoring NGWMN wells within the Montana network.

Aquifer	Total Montana statewide network candidates	Total NGWMN selected to date	NGWMN Selection complete	Estimated NGWMN wells	Estimated water-level Operations cost[1]	Estimated water-quality operations cost[2]
N100ALLUVL	143	30	No	100	$19,620	$3,303
N100GLCIAL	64	13	No	45	8,781	$1,478
S100NRMTIB	423	139	No	296	$58,036	$9,771
N300LTRTRY	98	70	Yes	70	$13,720	$2,310
N300UPCTCS	162	6	No	113	$22,226	$3,742
N300LCRTCS	32	4	No	22	$4,390	$739
N500PLOZOC	12	9	Yes	9	$1,764	$297
Totals	934	271	--	656	$128,537	$21,641

[1] ((Candidate wells) * (0.7) *(Number of periodic measurements)*(Cost of measurement)) for aquifers with incomplete NGWMN site selection. Otherwise, ((Total number of NGWMN selected wells) *(Number of periodic measurements)*(Cost of measurement)). [2](((Candidate wells) * (0.7) / (Current sampling frequency))*(cost of sampling)) for aquifers with incomplete NGWMN site selection. Otherwise, (((Total number of NGWMN selected wells) / (sampling frequency))*(Cost of sampling).

The estimated costs of $150,178 (Table 11) to monitor NGWMN-MONTANA wells would ordinarily be shared between Montana and the federal government based on the balance of state and federal interests in the data. For example if the federal interest was agreed to be 75 percent, federal payments of about $112,600 annually would support its share of NGWMN-MONTANA. The federal share would provide new funds to the Montana statewide network to support new monitoring-well construction, additional water-quality samples, and additional field staff to gather periodic measurements for NGWMN-MONTANA.

Cost to implement the changes identified in the gap analysis:

The “Spatial” gap analyses shows that additional sites are needed to meet Framework Document goals to monitor groundwater within Montana’s segments of the principal, important, or major aquifers. The “Operations” gap analysis showed that more frequent water-level measurements (or additional instrumentation) are necessary for Montana to meet suggested Framework Document measurement frequencies. The “Operations” gap between the Montana network and the NGWMN for water-quality sampling is large, partly due to ambitious Framework Document goals and partly because Montana has emphasized water-level measurements over water quality.

Table 12 contains costs (in 2010 dollars) to close “Spatial” and “Operations” gaps between the current Montana statewide network and the NGWMN. Total costs to close “Spatial” gaps are about $1.6 million; closing the “Spatial” gap also creates a new “Operations” gap for the added wells. It would cost about $160,000 annually to service the 245 proposed wells at the suggested measurement/sampling frequencies. Another $243,000 would be necessary to generate baseline water-quality records within a 3-year time frame.

Even if the “Spatial” gap is not addressed by new construction, an “Operations” gap based in the current well distribution and caused by differing sample frequencies and lack of baseline water-quality records still exists. Increasing the water-level measurement frequency in wells with water levels that move more than two feet annually each year to monthly and increasing the water-quality sample frequency from once every 10 years to once every 5 years would require about $147,300 annually. An additional $310,000 would provide missing baseline water-quality records for NGWMN-MONTANA wells during a two year period. A capital expenditure of about $140,000 for data-logger instrumentation would provide additional "Trend" site records and offset some of the cost to obtain "Surveillance" records.

Table 12. Incremental Cost to States to Participate in a National Ground Water Monitoring Network

NGWMN Pilot Program Element	Incremental changes needed to meet network guidelines	Estimated Capital Costs	Estimated O&M costs
Spatial Gaps:	Construction of 245 new NGWMN sites to augment the network's spatial monitoring coverage will require about 40,100 feet of drilling. Based on awarded drilling contracts in 2010, per foot charges would be about $40.	**$1,604,000** for 6-inch diameter steel cased wells with completions varying from stainless steel continuous screen to down-hole perforations. New monitoring well installations would be expected to last 30-40 years. Total Capital = $**1,604,000**	**$144,060** annually to provide monthly measurements for new wells at **$49** per measurement. **$242,550** during a 3-year period to provide baseline water-quality data at **$330** per sample collected and processed. **$16,170** annually to sample new wells at a once every 5-year frequency at **$330** per sample collected and processed. Total O&M = **$402,780**
Field Practice Gaps:	Incremental changes in Field Practices are negligible.	$0	$0
Data Management Gaps:	Data Management changes are negligible at the completion of the pilot project and assuming stability in the Framework Document data management requirements. Should NGWMN well classifications change, relatively minor changes in database structures will be necessary.	(a) MBMG spent about **$3,400** in one-time costs during the pilot project to prepare GWIC for NGWMN. (b) If NGWMN data management standards change, an additional **$3,000 - $5,000** in one-time costs might be necessary	Operation and Management costs to implement data management changes are currently negligible.
Operations Gaps:	Increasing water-level monitoring frequency in about 300 wells to monthly would require 2,400 additional measurements annually. Sampling to create water-quality baseline records:	--	**$117,600** to provide adequate measurement frequencies at NGWMN sites at **$49** per visit. **$310,200** over 2 years to provide baseline water-quality

NGWMN Pilot Program Element	Incremental changes needed to meet network guidelines	Estimated Capital Costs	Estimated O&M costs
	940 samples in 2 years. Improving sampling frequency to once every 5 years would require 90 additional samples annually.		records in NGWMN wells. **$29,700** annually for additional water-quality samples and analyses in NGWMN wells. Total O&M = **$457,500**
Analyte Gaps:	Montana network analytes match closely with NGWMN analytes as long as the Framework Document emphasizes standard field chemistry measurements, common anions, and trace metals.	One time capital costs to incorporate additional analytes are negligible under the current Framework Document.	Operations and Management costs to implement additional analytes are negligible under the current Framework Document.
Other investments:	Purchase and installation of 100 water-level loggers. Installation of the loggers would reduce the number of new periodic measurements from 2,400 to 1,620.	**$140,000** for purchase of 100 additional water-level logger systems at $1,400 per system to upgrade “Surveillance” sites to “Trend” sites. Logger system life would be expected to be 6-8 years.	Annual costs to service the recorder sites are covered in monthly visit costs above. Sites with loggers would only be visited quarterly. Installing loggers would decrease new periodic measurement costs from $117,600 to **$79,380** annually. Replacement costs for 10-year depreciation would be **$14,000.**

Concluding Thoughts

The analysis behind the incremental costs (Table 12) assumes that all Montana statewide network wells would be measured quarterly or monthly to meet the Framework Document’s goal of providing “Surveillance” records of water-level change in the Montana segments of the nations principal, important, or major aquifers. A large part of the “Operations” gap is related to the resources necessary to improve water-level measurement frequencies and to collect baseline and periodic water-quality data. A modest investment of about $140,000 for water-level data-logger instruments would reduce increases in travel to provide adequate “Surveillance” measurements by converting some “Surveillance” sites to “Trend” sites. The number of site visits to service the instruments at the “Trend” sites would be less than those needed to gather adequate “Surveillance” records.

An option for the SOGW might be to concentrate on normalizing field practices and data management attributes offered by potential cooperative networks, and pay less attention to the frequencies of measurement (“Surveillance”, “Trend”) and reconciliation of water-quality analyte lists. If field practices are consistent, the resulting data even though not containing all the parameters listed in the Framework Document are likely to be comparable. If data management practices are compatible, the information can be displayed by the GWDP. Accepting what compatible, comparable, and deliverable data a cooperator might have without initially evaluating and pushing for spatial completeness or certain measurement frequencies, fits the "*walk before you run*" caution heard often during SOGW meetings. Set up the data management linkages, make sure that the data you do get are comparable, and challenge the "Spatial" and "Operations" gaps later as resources become available.

Considering the modified 'STATEMAP' funding model included in the Framework Document invokes the question of state and federal interests. For example, considering a cooperative agreement between Montana and the federal government to provide $1.6 million reduce the "Spatial" gap in the NGWMN-MONTANA network, Montana could only provide a 15 percent in-kind services match based on its entire current monitoring program budget. However, a federal cost share of about $100,000 to operate NGWMN-MONTANA wells at current measurement frequencies is matcheable by Montana's state-funded network operations; the federal share would become new dollars that Montana could use to improve its network incrementally, filling in "Spatial" gaps and lessening "Operations" gaps towards meeting state and NGWMN standards.

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Appendices

Appendix A – Typical aquifer codes included in the Montana NGWMN.

Code	Description
110ALVM	ALLUVIUM (QUATERNARY)
110TRRC	TERRACE DEPOSITS (QUATERNARY)
111ALVM	ALLUVIUM (HOLOCENE)
111SNGR	SAND AND GRAVEL (HOLOCENE)
111TRRC	TERRACE DEPOSITS (HOLOCENE)
121FLXV	FLAXVILLE GRAVELS (PLIOCENE-MIOCENE)
112DRFT	GLACIAL DRIFT
112GFLK	GLACIAL GREAT FALLS LAKE SEDIMENTS
112SNGR	SAND AND GRAVEL (PLEISTOCENE)
112DRFT	GLACIAL DRIFT
112TRRC	TERRACE DEPOSITS (PLEISTOCENE)
112YRT2	YELLOWSTONE RIVER TERRACE-2
112YRT3	YELLOWSTONE RIVER TERRACE-3
112YRT4	YELLOWSTONE RIVER TERRACE-4
120SDMS	SEDIMENTS (TERTIARY)
120SNGR	SAND AND GRAVEL (TERTIARY)
125FRUN	FORT UNION FORMATION
125TGRV	TONGUE RIVER MEMBER (OF FT UNION FM.)
125TLCK	TULLOCK MEMBER (OF FT UNION FM.)
125LDLW	LUDLOW MEMBER (OF FT UNION FM.)
125LEBO	LEBO SHALE MEMBER (OF FT UNION FM.)
211CLRD	COLORADO SHALE OR FM. (OF COLORADO GROUP)
211EGLE	EAGLE SANDSTONE
211VRGL	VIRGELLE SANDSTONE MEMBER (OF EAGLE SANDSTONE)
211FXHL	FOX HILLS FORMATION OR SANDSTONE
211HLCK	HELL CREEK FORMATION
211FHHC	FOX HILLS-HELL CREEK AQUIFER
211LNCE	LANCE FORMATION
211COGT	COLGATE SANDSTONE MEMBER (OF FOX HILLS FM.)
211JDRV	JUDITH RIVER FORMATION (OF MONTANA GROUP)
211TMDC	TWO MEDICINE FORMATION (OF MONTANA GROUP)
217KOTN	KOOTENAI FORMATION
217FCCK	FIRST CAT CREEK SANDSTONE (BASE OF COLORADO GP)
217SCCK	SECOND CAT CREEK SANDSTONE (OF KOOTENAI FM)
217TCCK	THIRD CAT CREEK SANDSTONE (BASAL KOOTENAI FM)
221MRSN	MORRISON FORMATION
221SWFT	SWIFT FORMATION (OF ELLIS GROUP)
330MDSN	MADISON GROUP OR LIMESTONE
341JFRS	JEFFERSON LIMESTONE

Code	Description
400BELT	BELT SUPERGROUP

Appendix B – Tables of wells and springs selected for the Montana NGWMN.

Note: for all tables in Appendix B, "Surv." means "Surveillance". "Recorder" generally means hourly.

B-1. Wells included in the alluvial aquifers (N100ALLUVL) network.

GWIC Id	SWL	SWL S or T[1]	SWL baseline	SWL frequency	Period (Years)	DWE[2]	SWL Targeted	WQ	WQ S or T[1]	WQ baseline	WQ Targeted
3501	Yes	Surv.	Yes	Quarterly	63	167	No	Yes	Surv.	No	No
3539	Yes	Trend	Yes	Recorder	10	95	No	Yes	Surv.	No	No
3766	Yes	Trend	Yes	Recorder	25	201	Yes	Yes	Surv.	No	No
3769	Yes	Trend	Yes	Recorder	25	230	Yes	Yes	Surv.	No	No
3977	Yes	Trend	Yes	Recorder	25	60	Yes	Yes	Surv.	No	No
3988	Yes	Trend	Yes	Recorder	25	45	Yes	Yes	Surv.	No	No
4030	Yes	Surv.	Yes	Quarterly	23	48	No	Yes	Surv.	No	No
4261	Yes	Surv.	Yes	Quarterly	22	59	Yes	Yes	Surv.	Yes	No
6184	Yes	Surv.	Yes	Quarterly	29	5.5	No	Yes	Surv.	Yes	No
6276	Yes	Surv.	Yes	Quarterly	25	40	No	Yes	Surv.	No	No
43335	Yes	Surv.	Yes	Quarterly	15	111	No	Yes	Surv.	No	No
43571	Yes	Surv.	Yes	Quarterly	10	166	No	Yes	Surv.	No	No
75108	Yes	Surv.	Yes	Quarterly	15	30	No	Yes	Surv.	No	No
76659	Yes	Trend	Yes	Recorder	19	50	No	Yes	Surv.	No	No
78294	Yes	Trend	Yes	Recorder	22	19.5	No	Yes	Surv.	No	No
78887	Yes	Trend	Yes	Recorder	23	12.4	No	Yes	Surv.	Yes	No
78891	Yes	Trend	Yes	Recorder	23	48.7	No	Yes	Surv.	Yes	No
78983	Yes	Trend	Yes	Recorder	24	53	No	No	--	No	No
105523	Yes	Trend	Yes	Recorder	8	46	No	Yes	Surv.	No	No
120894	Yes	Surv.	Yes	Quarterly	20	29.2	Yes	Yes	Trend	Yes	No
122340	Yes	Trend	Yes	Quarterly	19	12.6	No	Yes	Trend	No	No
126439	Yes	Surv.	Yes	Quarterly	8	47	No	Yes	Surv.	No	No
133034	Yes	Trend	Yes	Recorder	25	44	Yes	Yes	Surv.	No	No
133035	Yes	Trend	Yes	Recorder	25	37	Yes	Yes	Surv.	No	No
140367	Yes	Trend	Yes	Recorder	24	--	Yes	Yes	Surv.	No	No
140484	Yes	Surv.	Yes	Quarterly	63	--	No	Yes	Surv.	No	No
143947	Yes	Surv.	Yes	Quarterly	16	26	No	Yes	Surv.	No	No
146238	Yes	Surv.	No	Quarterly	2	77	No	Yes	Surv.	No	No
171415	Yes	Surv.	Yes	Quarterly	6	57.3	No	Yes	Surv.	No	No
173039	Yes	Trend	Yes	Recorder	8	60	No	Yes	Surv.	No	No

[1]Surveillance or Trend site. [2]DWE is Depth Water Enters

B-2. Wells and springs included in the glacial aquifers (N100GLCIAL) network.

GWIC Id	SWL	SWL S or T[1]	SWL baseline	SWL frequency	Period (Years)	DWE[2]	SWL Targeted	WQ	WQ S or T[1]	WQ baseline	WQ Targeted
3480	Yes	Surv.	Yes	Quarterly	10	170	Yes	Yes	Surv.	No	No
3533	Yes	Trend	Yes	Recorder	25	4	No	Yes	Surv.	No	No
3541	Yes	Trend	Yes	Recorder	10	57	No	Yes	Surv.	No	No
41865	Yes	Surv.	No	Quarterly	2	60	No	Yes	Surv.	No	No
42702	Yes	Surv.	No	Quarterly	74		No	Yes	Surv.	No	No
73165	Yes	Surv.	Yes	Quarterly	17	318	No	Yes	Surv.	No	No
73642	Yes	Surv.	Yes	Quarterly	17	192	No	Yes	Surv.	No	No
78841	Yes	Trend	Yes	Quarterly	16	65	No	Yes	Surv.	No	No
127172	Yes	Surv.	Yes	Quarterly	15	281	No	Yes	Surv.	No	No
133571	Yes	Surv.	No	Quarterly	4	30	No	Yes	Surv.	No	No
149183	Yes	Surv.	Yes	Quarterly	15	308	No	Yes	Surv.	No	No
159523	Yes	Surv.	Yes	Quarterly	10	58	No	Yes	Surv.	No	No
239610	Yes	Surv.	No	Quarterly	3		Yes	Yes	Surv.	No	No

[1]Surveillance or Trend site. [2]DWE is Depth Water Enters

B-3. Wells and springs included in the Northern Rocky Mountains Intermontane Basin (S100NRMTIB) network.

GWIC Id	SWL	SWL S or T[1]	SWL baseline	SWL frequency	Period (Years)	DWE[2]	SWL Targeted	WQ	WQ S or T[1]	WQ baseline	WQ Targeted
4716	Yes	Surv.	Yes	Monthly	22	108	No	Yes	Surv.	Yes	No
4719	Yes	Surv.	Yes	Monthly	22	65	No	Yes	Surv.	Yes	No
5376	Yes	Surv.	Yes	Quarterly	25	--	No	Yes	Surv.	Yes	No
5410	Yes	Surv.	Yes	Quarterly	25	58	No	Yes	Surv.	No	No
5418	Yes	Surv.	Yes	Quarterly	31	209	No	Yes	Surv.	No	No
6104	Yes	Surv.	Yes	Quarterly	25	11	No	Yes	Surv.	No	No
9010	Yes	Surv.	Yes	Quarterly	28	32	No	Yes	Surv.	Yes	No
9858	Yes	Surv.	Yes	Quarterly	19	60	No	Yes	Surv.	No	No
49336	Yes	Surv.	Yes	Quarterly	18	75	No	Yes	Surv.	Yes	No
50275	Yes	Surv.	Yes	Quarterly	42	--	No	Yes	Surv.	No	No
50808	Yes	Surv.	Yes	Quarterly	17	116	No	Yes	Surv.	No	No
51325	Yes	Trend	Yes	Recorder	18	70	No	Yes	Surv.	No	No
51731	Yes	Surv.	Yes	Quarterly	25	109	No	Yes	Surv.	No	No
51775	Yes	Surv.	Yes	Quarterly	9	94	No	Yes	Surv.	No	No

GWIC Id	SWL	SWL S or T[1]	SWL baseline	SWL frequency	Period (Years)	DWE[2]	SWL Targeted	WQ	WQ S or T[1]	WQ baseline	WQ Targeted
53637	Yes	Surv.	Yes	Quarterly	17	80	No	Yes	Surv.	Yes	No
53982	Yes	Surv.	Yes	Quarterly	9	22	No	Yes	Surv.	No	No
55463	Yes	Surv.	Yes	Quarterly	19	74	No	Yes	Surv.	No	No
55965	Yes	Surv.	Yes	Quarterly	17	42	No	Yes	Surv.	Yes	No
56528	Yes	Trend	Yes	Quarterly	38	40	No	Yes	Surv.	Yes	No
57128	Yes	Surv.	Yes	Quarterly	27	23	No	Yes	Surv.	Yes	No
57391	Yes	Surv.	Yes	Quarterly	25	22	No	Yes	Surv.	No	No
58737	Yes	Surv.	Yes	Quarterly	17	207	No	Yes	Surv.	No	No
58923	Yes	Surv.	Yes	Monthly	17	84	No	Yes	Surv.	No	No
60137	Yes	Surv.	Yes	Quarterly	19	310	No	Yes	Surv.	No	No
62006	Yes	Surv.	Yes	Monthly	17	60	No	Yes	Surv.	No	No
62261	Yes	Surv.	Yes	Quarterly	17	80	No	Yes	Surv.	No	No
62369	Yes	Trend	Yes	Monthly	34	80	Yes	Yes	Surv.	Yes	No
62523	Yes	Trend	Yes	Quarterly	20	30	Yes	Yes	Surv.	Yes	No
63339	Yes	Surv.	Yes	Quarterly	17	70	No	Yes	Surv.	No	No
63811	Yes	Surv.	Yes	Quarterly	13	237	No	Yes	Surv.	No	No
64077	Yes	Surv.	Yes	Quarterly	12	67	No	Yes	Surv.	No	No
64649	Yes	Surv.	No	Quarterly	15	70	Yes	Yes	Surv.	No	No
64737	Yes	Trend	Yes	Monthly	20	142	Yes	Yes	Surv.	No	No
65432	Yes	Trend	Yes	Recorder	15	110	Yes	Yes	Surv.	No	No
84910	Yes	Surv.	Yes	Quarterly	13	163	No	Yes	Surv.	No	No
91244	Yes	Surv.	Yes	Quarterly	18	45	No	Yes	Surv.	No	No
91931	Yes	Surv.	Yes	Quarterly	15	200	No	Yes	Surv.	No	No
92804	Yes	Surv.	Yes	Quarterly	13	82	No	Yes	Surv.	No	No
96132	Yes	Trend	Yes	Recorder	59	70	No	Yes	Surv.	No	No
96826	Yes	Trend	Yes	Recorder	19	142	No	Yes	Surv.	No	No
99215	Yes	Surv.	Yes	Quarterly	19	50	No	Yes	Surv.	No	No
108215	Yes	Surv.	Yes	Quarterly	28	180	No	Yes	Surv.	Yes	No
108595	Yes	Surv.	Yes	Quarterly	28	31	No	Yes	Surv.	Yes	No
108610	Yes	Surv.	Yes	Quarterly	28	30	No	Yes	Surv.	No	No
109717	Yes	Surv.	Yes	Quarterly	19	41	No	Yes	Surv.	No	No
120721	Yes	Surv.	Yes	Quarterly	8	31	No	Yes	Surv.	No	No
123858	Yes	Surv.	Yes	Quarterly	18	110	No	Yes	Surv.	Yes	No
125628	Yes	Surv.	Yes	Quarterly	16	124	Yes	Yes	Surv.	No	No

GWIC Id	SWL	SWL S or T[1]	SWL baseline	SWL frequency	Period (Years)	DWE[2]	SWL Targeted	WQ	WQ S or T[1]	WQ baseline	WQ Targeted
126354	Yes	Surv.	Yes	Quarterly	15	55	No	Yes	Surv.	No	No
126664	Yes	Surv.	Yes	Quarterly	19	141.8	No	Yes	Surv.	No	No
126669	Yes	Surv.	Yes	Quarterly	19	45.5	No	Yes	Surv.	No	No
126793	Yes	Surv.	Yes	Quarterly	17	90	No	Yes	Surv.	No	No
128682	Yes	Surv.	Yes	Quarterly	50	--	No	Yes	Surv.	No	No
128684	Yes	Surv.	Yes	Quarterly	25	--	No	Yes	Surv.	--	No
128741	Yes	Surv.	Yes	Quarterly	21	30	No	Yes	Surv.	No	No
129084	Yes	Surv.	Yes	Quarterly	28	140	No	Yes	Surv.	No	No
129151	Yes	Surv.	Yes	Quarterly	28	--	No	Yes	Surv.	No	No
129343	Yes	Surv.	Yes	Quarterly	10	140	No	Yes	Surv.	No	No
131122	Yes	Surv.	Yes	Quarterly	18	130	No	Yes	Surv.	No	No
131579	Yes	Trend	Yes	Recorder	17	--	No	Yes	Surv.	No	No
133162	Yes	Surv.	Yes	Quarterly	57	300	No	Yes	Surv.	Yes	No
133165	Yes	Surv.	Yes	Quarterly	18	15	No	Yes	Surv.	Yes	No
133167	Yes	Surv.	Yes	Quarterly	18	42	No	Yes	Surv.	Yes	No
133172	Yes	Surv.	Yes	Quarterly	18	15	No	Yes	Surv.	No	No
133174	Yes	Surv.	Yes	Quarterly	57	--	No	Yes	Surv.	No	No
133176	Yes	Surv.	Yes	Quarterly	57	15	No	Yes	Surv.	Yes	No
133332	Yes	Surv.	Yes	Quarterly	17	86	No	Yes	Surv.	No	No
133371	Yes	Trend	Yes	Recorder	18	211	No	Yes	Surv.	No	No
133375	Yes	Surv.	Yes	Quarterly	17	269.6	No	Yes	Surv.	No	No
133382	Yes	Surv.	Yes	Quarterly	17	190	No	Yes	Surv.	No	No
133384	Yes	Surv.	Yes	Quarterly	17	315.5	No	Yes	Surv.	No	No
133387	Yes	Surv.	Yes	Quarterly	18	96	No	Yes	Surv.	No	No
133390	Yes	Surv.	Yes	Quarterly	18	17.9	No	Yes	Surv.	No	No
133392	Yes	Surv.	Yes	Quarterly	17	475	No	Yes	Surv.	No	No
133397	Yes	Surv.	Yes	Quarterly	18	43.5	No	Yes	Surv.	No	No
133399	Yes	Surv.	Yes	Quarterly	17	65	No	Yes	Surv.	No	No
133886	Yes	Surv.	Yes	Quarterly	27	--	No	Yes	Surv.	No	No
134562	Yes	Surv.	Yes	Quarterly	17	60	No	Yes	Surv.	Yes	No
135680	Yes	Surv.	Yes	Quarterly	59	--	No	Yes	Surv.	No	No
135689	Yes	Surv.	Yes	Quarterly	18	--	No	Yes	Surv.	No	No
135720	Yes	Surv.	Yes	Quarterly	18	--	No	Yes	Surv.	No	No
135722	Yes	Surv.	Yes	Quarterly	18	--	No	No	NULL	No	No

GWIC Id	SWL	SWL S or T[1]	SWL baseline	SWL frequency	Period (Years)	DWE[2]	SWL Targeted	WQ	WQ S or T[1]	WQ baseline	WQ Targeted
135735	Yes	Trend	Yes	Recorder	59	10	No	Yes	Surv.	No	No
135737	Yes	Surv.	Yes	Quarterly	17	--	No	Yes	Surv.	No	No
136486	Yes	Trend	Yes	Recorder	51	--	No	Yes	Surv.	No	No
136964	Yes	Trend	Yes	Recorder	40	30	No	Yes	Surv.	No	No
136969	Yes	Trend	Yes	Quarterly	53	--	No	Yes	Surv.	No	No
136970	Yes	Trend	Yes	Quarterly	54	--	No	Yes	Surv.	No	No
139851	Yes	Surv.	Yes	Quarterly	11	139	No	Yes	Surv.	No	No
139989	Yes	Surv.	Yes	Quarterly	22	169	No	Yes	Surv.	No	No
140366	Yes	Surv.	Yes	Quarterly	16	55	No	Yes	Surv.	No	No
140486	Yes	Surv.	Yes	Quarterly	16	80	No	Yes	Surv.	No	No
145392	Yes	Surv.	Yes	Quarterly	17	--	No	Yes	Surv.	No	No
145960	Yes	Surv.	Yes	Quarterly	10	80	No	Yes	Trend	Yes	No
148259	Yes	Surv.	Yes	Quarterly	15	300	No	Yes	Surv.	No	No
148531	Yes	Surv.	Yes	Quarterly	21	60	No	No	--	No	No
149511	Yes	Surv.	Yes	Quarterly	15	274.9	No	Yes	Surv.	No	No
149512	Yes	Surv.	Yes	Quarterly	15	275	No	Yes	Surv.	No	No
153311	Yes	Surv.	Yes	Quarterly	15	198	No	Yes	Surv.	No	No
154007	Yes	Surv.	Yes	Quarterly	13	150	No	Yes	Surv.	No	No
154583	Yes	Trend	Yes	Quarterly	15	127	No	Yes	Surv.	No	No
154584	Yes	Trend	Yes	Recorder	15	40	No	Yes	Surv.	No	No
154593	Yes	Surv.	Yes	Quarterly	14	138	No	Yes	Surv.	No	No
154595	Yes	Trend	Yes	Recorder	14	115	No	Yes	Surv.	No	No
163226	Yes	Trend	Yes	Recorder	13	130	No	Yes	Surv.	No	No
165827	Yes	Surv.	Yes	Quarterly	11	27	No	Yes	Surv.	No	No
168180	Yes	Trend	Yes	Recorder	12	--	No	Yes	Surv.	No	No
170202	Yes	Surv.	Yes	Quarterly	10	180	No	Yes	Surv.	No	No
174343	Yes	Trend	Yes	Recorder	49	--	No	Yes	Surv.	No	No
183082	Yes	Surv.	Yes	Quarterly	10	138.5	No	Yes	Surv.	No	No
191526	Yes	Surv.	Yes	Quarterly	9	36	No	Yes	Surv.	No	No
191532	Yes	Trend	Yes	Recorder	9	90	Yes	Yes	Surv.	Yes	No
191537	Yes	Surv.	Yes	Quarterly	9	33	Yes	Yes	Surv.	Yes	No
191539	Yes	Surv.	Yes	Quarterly	9	9	No	Yes	Surv.	No	No
191554	Yes	Surv.	Yes	Quarterly	9	51	No	Yes	Surv.	No	No
207831	Yes	Trend	Yes	Recorder	7	--	No	No	--	No	No

GWIC Id	SWL	SWL S or T[1]	SWL baseline	SWL frequency	Period (Years)	DWE[2]	SWL Targeted	WQ	WQ S or T[1]	WQ baseline	WQ Targeted
216675	Yes	Trend	No	Quarterly	3	8	No	Yes	Surv.	No	No
219909	Yes	Trend	Yes	Recorder	5	75	No	Yes	Surv.	No	No
219913	Yes	Trend	Yes	Recorder	5	14	No	Yes	Surv.	No	No
226761	Yes	Surv.	No	Quarterly	4	73	No	Yes	Surv.	No	No
226763	Yes	Trend	No	Quarterly	4	55	No	Yes	Surv.	No	No
226764	Yes	Trend	No	Quarterly	4	18	No	Yes	Surv.	No	No
226766	Yes	Trend	No	Quarterly	4	29	No	Yes	Surv.	No	No
226768	Yes	Trend	No	Quarterly	4	68	No	Yes	Surv.	No	No
226769	Yes	Trend	No	Quarterly	4	35	No	Yes	Surv.	No	No
226772	Yes	Trend	No	Quarterly	4	46	No	Yes	Surv.	No	No
234907	Yes	Trend	No	Quarterly	3	16	No	Yes	Surv.	Yes	No
234909	Yes	Trend	No	Quarterly	3	66.5	No	Yes	Surv.	No	No
235474	Yes	Trend	No	Quarterly	3	62	No	Yes	Surv.	No	No
235475	Yes	Trend	No	Quarterly	3	58	No	Yes	Surv.	Yes	No
235511	Yes	Trend	No	Quarterly	3	26	No	Yes	Surv.	No	No
235512	Yes	Trend	No	Quarterly	3	47	No	Yes	Surv.	Yes	No
248640	Yes	Surv.	No	Quarterly	15	49	No	Yes	Surv.	No	No
257423	Yes	Trend	No	Recorder	0	155	No	Yes	Surv.	No	No
257424	Yes	Trend	No	Recorder	0	185	No	Yes	Surv.	No	No
257425	Yes	Trend	No	Recorder	0	259	No	Yes	Surv.	No	No
257455	Yes	Trend	No	Recorder	0	190.25	No	Yes	Surv.	No	No
892116	Yes	Trend	Yes	Recorder	17	138	Yes	Yes	Trend	Yes	Yes
892195	Yes	Trend	Yes	Quarterly	32	20	No	Yes	Surv.	No	No

[1]Surveillance or Trend site. [2]DWE is Depth Water Enters

B-4. Wells and springs included in the Lower Tertiary aquifers (N300LTRTY) network.

GWIC Id	SWL	SWL S or T[1]	SWL baseline	SWL frequency	Period (Years)	DWE[2]	SWL Targeted	WQ	WQ S or T[1]	WQ baseline	WQ Targeted
206	Yes	Trend	Yes	Quarterly	35	212	Yes	Yes	Surv.	Yes	Yes
210	Yes	Trend	Yes	Quarterly	35	121	Yes	Yes	Surv.	Yes	Yes
337	Yes	Trend	Yes	Quarterly	36	235	Yes	Yes	Surv.	Yes	Yes
339	Yes	Trend	Yes	Quarterly	36	197	Yes	Yes	Surv.	Yes	Yes
1103	Yes	Trend	Yes	Quarterly	37	33.5	Yes	Yes	Trend	Yes	Yes
1115	Yes	Trend	Yes	Quarterly	37	16.5	Yes	Yes	Trend	Yes	Yes
1575	Yes	Trend	Yes	Quarterly	29	142	Yes	Yes	Trend	Yes	Yes

GWIC Id	SWL	SWL S or T[1]	SWL baseline	SWL frequency	Period (Years)	DWE[2]	SWL Targeted	WQ	WQ S or T[1]	WQ baseline	WQ Targeted
1845	Yes	Surv.	Yes	Quarterly	31	243	No	Yes	Surv.	Yes	No
3001	Yes	Surv.	Yes	Quarterly	30	91	No	Yes	Surv.	No	No
3772	Yes	Trend	Yes	Monthly	25	303	Yes	Yes	Surv.	No	No
4211	Yes	Trend	Yes	Quarterly	26	78	Yes	Yes	Trend	Yes	Yes
4227	Yes	Trend	Yes	Quarterly	31	63	Yes	Yes	Surv.	--	Yes
4248	Yes	Trend	Yes	Quarterly	26	185	Yes	Yes	Surv.	Yes	Yes
4267	Yes	Trend	Yes	Quarterly	31	128	Yes	Yes	Trend	Yes	Yes
4290	Yes	Trend	Yes	Quarterly	26	179	Yes	Yes	Surv.	Yes	Yes
4297	Yes	Trend	Yes	Quarterly	26	263	Yes	Yes	Surv.	Yes	Yes
8107	Yes	Surv.	Yes	Monthly	36	209	Yes	Yes	Surv.	Yes	No
8863	Yes	Surv.	Yes	Quarterly	31	--	No	Yes	Surv.	No	No
18368	Yes	Surv.	Yes	Quarterly	14	60	No	Yes	Surv.	No	No
27457	Yes	Surv.	Yes	Quarterly	16	165	No	Yes	Surv.	No	No
31035	Yes	Surv.	Yes	Quarterly	16	70	No	Yes	Surv.	No	No
31087	Yes	Surv.	Yes	Quarterly	16	110	No	Yes	Surv.	No	No
31653	Yes	Trend	Yes	Recorder	17	--	No	Yes	Surv.	No	No
36251	Yes	Surv.	Yes	Quarterly	35	--	No	Yes	Surv.	No	No
36423	Yes	Surv.	Yes	Quarterly	16	--	No	Yes	Surv.	No	No
37259	Yes	Surv.	Yes	Quarterly	30	16	No	Yes	Surv.	No	No
47501	Yes	Surv.	Yes	Quarterly	10	--	No	Yes	Surv.	No	No
94666	Yes	Surv.	Yes	Quarterly	10	168	No	Yes	Surv.	No	No
100472	Yes	Surv.	Yes	Quarterly	10	--	No	Yes	Surv.	Yes	No
105007	Yes	Surv.	Yes	Quarterly	32	70	No	Yes	Surv.	No	No
120639	Yes	Surv.	Yes	Quarterly	17	80	No	Yes	Surv.	No	No
122303	Yes	Surv.	Yes	Quarterly	16	60	No	Yes	Surv.	No	No
123790	Yes	Trend	Yes	Quarterly	35	146.5	Yes	Yes	Surv.	Yes	Yes
123791	Yes	Trend	Yes	Quarterly	35	196.5	Yes	Yes	Surv.	Yes	Yes
129758	Yes	Trend	Yes	Quarterly	19	200	Yes	Yes	Surv.	No	Yes
132732	Yes	Trend	Yes	Quarterly	27	218	No	No	--	No	No
132734	Yes	Trend	Yes	Recorder	29	63	No	No	--	No	No
132892	Yes	Trend	Yes	Quarterly	19	265	Yes	Yes	Surv.	Yes	Yes
132904	Yes	Surv.	Yes	Quarterly	28	401.4	No	Yes	Surv.	No	No
136678	Yes	Surv.	Yes	Quarterly	30	108	No	Yes	Surv.	No	No
136679	Yes	Surv.	Yes	Quarterly	29	--	No	Yes	Surv.	No	No

GWIC Id	SWL	SWL S or T[1]	SWL baseline	SWL frequency	Period (Years)	DWE[2]	SWL Targeted	WQ	WQ S or T[1]	WQ baseline	WQ Targeted
136680	Yes	Trend	Yes	Recorder	29	--	No	Yes	Surv.	No	No
137973	Yes	Trend	Yes	Recorder	29	80	No	Yes	Trend	No	No
138001	Yes	Surv.	Yes	Quarterly	27	118	No	Yes	Surv.	No	No
138134	Yes	Surv.	Yes	Quarterly	17	103.5	No	Yes	Surv.	No	No
138227	Yes	Surv.	Yes	Quarterly	17	--	No	Yes	Surv.	No	No
138914	Yes	Trend	Yes	Quarterly	15	95	No	Yes	Trend	No	No
141828	Yes	Surv.	Yes	Quarterly	14	--	No	Yes	Surv.	No	No
143790	Yes	Surv.	Yes	Quarterly	27	136	No	Yes	Surv.	No	No
143791	Yes	Surv.	Yes	Quarterly	16	63	No	Yes	Surv.	No	No
143795	Yes	Surv.	Yes	Quarterly	28	341.5	No	Yes	Surv.	No	No
143805	Yes	Trend	Yes	Quarterly	35	36	No	Yes	Surv.	Yes	No
143948	Yes	Surv.	Yes	Quarterly	32	212	No	Yes	Surv.	No	No
149510	Yes	Trend	Yes	Quarterly	15	--	No	Yes	Surv.	No	No
152305	Yes	Surv.	Yes	Quarterly	15	52.8	No	No	--	No	No
157581	Yes	Surv.	Yes	Quarterly	15	--	No	Yes	Surv.	No	No
157879	Yes	Trend	Yes	Quarterly	14	72	Yes	Yes	Surv.	No	Yes
157883	Yes	Trend	Yes	Quarterly	14	71.5	Yes	Yes	Surv.	No	Yes
161429	Yes	Trend	Yes	Quarterly	8	110	No	Yes	Surv.	No	No
182530	Yes	Surv.	Yes	Quarterly	10	--	No	Yes	Surv.	No	No
182531	Yes	Surv.	Yes	Quarterly	10	--	No	Yes	Surv.	No	No
182533	Yes	Surv.	Yes	Quarterly	10	--	No	Yes	Surv.	No	No
182534	Yes	Surv.	Yes	Quarterly	10	--	No	Yes	Surv.	No	No
183559	Yes	Surv.	Yes	Quarterly	10	--	No	Yes	Surv.	No	No
183561	Yes	Surv.	Yes	Quarterly	10	--	No	Yes	Surv.	No	No
183564	Yes	Surv.	Yes	Quarterly	10	--	No	Yes	Surv.	No	No
183565	Yes	Surv.	Yes	Quarterly	10	--	No	Yes	Surv.	No	No
185284	Yes	Trend	Yes	Quarterly	8	140	Yes	Yes	Surv.	No	No
197444	Yes	Surv.	Yes	Quarterly	8	80	No	Yes	Surv.	No	No
705232	Yes	Trend	Yes	Recorder	14	--	No	Yes	Surv.	No	No

[1]Surveillance or Trend site. [2]DWE is Depth Water Enters

B-5 Wells and springs included in the Upper Cretaceous aquifers (N300UPCTCS) network.

GWIC Id	SWL	SWL S or T[1]	SWL baseline	SWL frequency	Period (Years)	DWE[2]	SWL Targeted	WQ	WQ S or T[1]	WQ baseline	WQ Targeted
1388	Yes	Trend	Yes	Recorder	30	362	No	Yes	Surv.	No	No

GWIC Id	SWL	SWL S or T[1]	SWL baseline	SWL frequency	Period (Years)	DWE[2]	SWL Targeted	WQ	WQ S or T[1]	WQ baseline	WQ Targeted
1846	Yes	Trend	Yes	Recorder	31	778	Yes	Yes	Surv.	Yes	No
2061	Yes	Surv.	Yes	Quarterly	30	1135	Yes	Yes	Surv.	No	No
3002	Yes	Surv.	Yes	Quarterly	26	580	No	Yes	Surv.	Yes	No
4329	Yes	Surv.	Yes	Quarterly	31	212	Yes	Yes	Surv.	Yes	No
34665	Yes	Surv.	Yes	Quarterly	14	--	No	Yes	Surv.	No	No

[1]Surveillance or Trend site. [2]DWE is Depth Water Enters

B-6 Wells and springs included in the Lower Cretaceous aquifers (N300LCRTCS) network.

GWIC Id	SWL	SWL S or T[1]	SWL baseline	SWL frequency	Period (Years)	DWE[2]	SWL Targeted	WQ	WQ S or T[1]	WQ baseline	WQ Targeted
2031	Yes	Surv.	Yes	Quarterly	30	240	No	Yes	Surv.	Yes	No
25943	Yes	Surv.	Yes	Quarterly	15	180	No	Yes	Surv.	No	No
167347	Yes	Surv.	Yes	Quarterly	9	55	No	Yes	Surv.	No	No
185464	Yes	Surv.	Yes	Quarterly	9	90	No	Yes	Surv.	No	No

[1]Surveillance or Trend site. [2]DWE is Depth Water Enters

B-7 Wells and springs included in the Paleozoic aquifers (N500PLOZOC) network.

GWIC Id	SWL	SWL S or T[1]	SWL baseline	SWL frequency	Period (Years)	DWE[2]	SWL Targeted	WQ	WQ S or T[1]	WQ baseline	WQ Targeted
2247	Yes	Surv.	Yes	Quarterly	17	185	No	Yes	Surv.	Yes	No
2315	Yes	Surv.	Yes	Quarterly	28	242	No	Yes	Surv.	No	No
2394	Yes	Surv.	Yes	Quarterly	31	518	No	Yes	Surv.	Yes	No
2526	Yes	Trend	Yes	Recorder	26	24	No	No	--	Yes	No
120525	Yes	Trend	No	Quarterly	2	26.8	No	Yes	Trend	No	No
120973	Yes	Surv.	No	Quarterly	4	1078	No	Yes	Surv.	No	No
165356	Yes	Surv.	Yes	Quarterly	10	85	No	Yes	Surv.	No	No
186362	Yes	Surv.	Yes	Quarterly	5	173	No	Yes	Trend	No	No
216851	Yes	Trend	Yes	Recorder	5	440	No	Yes	Trend	No	No

[1]Surveillance or Trend site. [2]DWE is Depth Water Enters

Appendix C – Typical Montana statewide network water-quality analysis.

(Highlighted fields correspond to SOGW Standard and Extended analyte lists.)

Ground-Water Information Center Water Quality Report | **Site Name:** MBMG MADISON VALLEY VARNEY DEEP WELL

Report Date: 1/5/2011 | **Compare to Water Quality Standards**

Location Information

Sample Id/Site Id:	2011Q0246 / 256852	Sample Date:	8/11/2010 9:23:00 AM
Location (TRS):	07S 01W 16 ADDD	Agency/Sampler:	MBMG / RICHTER, MIKE G.
Latitude/Longitude:	45° 13' 32" N 111° 43' 13" W	Field Number:	256852
Datum:	NAD83	Lab Date:	11/8/2010
Altitude:	5322.7264	Lab/Analyst:	MBMG / SM
County/State:	MADISON / MT	Sample Method/Handling:	/ 4230
Site Type:	WELL	Procedure Type:	DISSOLVED
Geology:	120SNGR	Total Depth (ft):	457
USGS 7.5' Quad:	CAMERON	SWL-MP (ft):	139.14
PWS Id:		Depth Water Enters (ft):	447
Project:	GWCP08, GWAAMON, GWCP08MON		

Major Ion Results

	mg/L	meq/L		mg/L	meq/L
Calcium (Ca)	38.200	1.906	Bicarbonate (HCO3)	200.800	3.291
Magnesium (Mg)	7.970	0.656	Carbonate (CO3)	0.000	0.000
Sodium (Na)	29.800	1.296	Chloride (Cl)	10.490	0.296
Potassium (K)	5.310	0.136	Sulfate (SO4)	19.860	0.414
Iron (Fe)	0.029	0.002	Nitrate (as N)	0.393	0.028
Manganese (Mn)	0.034	0.001	Fluoride (F)	2.050	0.108
Silica (SiO2)	38.700		Orthophosphate (as P)	<0.05	0.000
	Total Cations	4.011		**Total Anions**	4.137

Trace Element Results (µg/L)

Aluminum (Al):	<2.0	Cesium (Cs):	<0.5	Molybdenum (Mo):	3.760	Strontium (Sr):	104.000
Antimony (Sb):	1.980	Chromium (Cr):	0.423	Nickel (Ni):	<0.2	Thallium (Tl):	<0.2
Arsenic (As):	55.800	Cobalt (Co):	<0.2	Niobium (Nb):	<0.2	Thorium (Th):	<0.2
Barium (Ba):	37.000	Copper (Cu):	<0.5	Neodymium (Nd):	<0.2	Tin (Sn):	<0.2
Beryllium (Be):	<0.2	Gallium (Ga):	<0.2	Palladium (Pd):	<0.5	Titanium (Ti):	<0.2
Boron (B):	121.000	Lanthanum (La):	<0.2	Praseodymium (Pr):	<0.2	Tungsten (W):	4.830
Bromide (Br):	<50	Lead (Pb):	<0.2	Rubidium (Rb):	6.380	Uranium (U):	2.450
Cadmium (Cd):	<0.2	Lithium (Li):	173.000	Silver (Ag):	<0.2	Vanadium (V):	2.520
Cerium (Ce):	<0.2	Mercury (Hg):	NR	Selenium (Se):	0.381	Zinc (Zn):	<1.0
						Zirconiuim (Zr):	0.253

Field Chemistry and Other Analytical Results

**Total Dissolved Solids (mg/L):	251.180	Field Hardness as CaCO3 (mg/L):	NR	Ammonia (mg/L):	NR
**Sum of Diss. Constituents (mg/L):	353.170	Hardness as CaCO3:	128.190	T.P. Hydrocarbons (µg/L):	NR
Field Conductivity (µmhos):	393	Field Alkalinity as CaCO3 (mg/L):	154	PCP (µg/L):	NR
Lab Conductivity (µmhos):	337	Alkalinity as CaCO3 (mg/L):	164.85	Phosphate, TD (mg/L as P):	<0.025
Field pH:	7.85	Ryznar Stability Index:	7.452	Field Nitrate (mg/L):	0.000
Lab pH:	7.95	Sodium Adsorption Ratio:	1.153	Field Dissolved O2 (mg/L):	6.960
Water Temp (°C):	11.7	Langlier Saturation Index:	0.249	Field Chloride (mg/L):	NR
Air Temp (°C):	NR	Nitrite (mg/L as N):	<0.05	Field Redox (mV):	45
Nitrate + Nitrite (mg/L as N)	NR	Hydroxide (mg/L as OH):	NR	Lab, Diss. Organic Carbon (mg/L):	NR
Total Kjeldahl Nitrogen (mg/L as N)	NR	Lab, Diss. Inorganic Carbon (mg/L):	NR	Lab, Total Organic Carbon (mg/L):	NR
Total Nitrogen (mg/L as N)	NR				

Notes

Sample Condition:

Field Remarks:

Lab Remarks:

Explanation: **mg/L** = milligrams per Liter; **µg/L** = micrograms per Liter; **ft** = feet; **NR** = No Reading in GWIC

Qualifiers: **A** = Hydride atomic absorption; **E** = Estimated due to interference; **H** = Exceeded holding time; **K** = Na+K combined; **N** = Spiked sample recovery not within control limits; **P** = Preserved sample; **S** = Method of standard additions; ***** = Duplicate analysis not within control limits; ****** = Sum of Dissolved Constituents is the sum of major cations (Na, Ca, K, Mg, Mn, Fe) and anions (HCO3, CO3, SO4, Cl, SiO2, NO3, F) in mg/L. Total Dissolved Solids is reported as equivalent weight of evaporation residue.

Appendix D – Comparison of NGWMN field standards to MBMG field standards.

Item	NGWMN	GWAA	Compliant	Item(s) different	Compliance - changes
Field practices for groundwater levels					
Section 5.2.1.1 Training					
Training	Operator training is necessary	Operator training is necessary	Yes		
Site verification	Numerous methods, mostly through previous site visits	Numerous methods including site note containing directions to the site, photographs of the site, wells tagged with unique identification number, previous site visits.	Yes		
Equipment decontamination	Equipment must be decontaminated between site visits	Equipment must be decontaminated between site visits	Yes		
Site condition notations	Date and time, weather, measuring point condition, damage, other factors	Date and time are part of the measurement. Measuring point conditions monitored - repaired/redefined as necessary.	Partial	Weather conditions not monitored.	No plans to modify
Site Access	Gates, enclosures, etc.	Site notes describe access to the site including gates, locks, building access etc. Contact information for land owner contained in ownership records.	Yes		
Established measurement point	NGWMN requires a designated measuring point.	Designated measuring point including altitude above mean sea level, date established and textual description required	Yes		
Section 5.2.1.2 Pre-collection site review and preparation					
All equipment necessary for a successful trip gathered and packed. Prior knowledge of distance to water.	Equipment gathered, supplies collected, tools on hand, maps, site forms, steel tape, electric water-level measurement tapes, disinfectant, protective gloves	Equipment gathered, supplies collected, tools on hand, maps, site forms, steel tape, electric water-level measurement tapes, disinfectant, protective gloves. Downloaded route list including most recent previous distance to water.	Yes		

Item	NGWMN	GWAA	Compliant	Item(s) different	Compliance - changes
Field form showing information to be gathered	Figure 5.2.1.2 - basic information to be collected with a water-level measurement	Route list contains multiple sites per page. Corresponding field data recording sheet contains places for date time, steel tape hold-cut dtw/mp, electric tape dtw/mp, remarks field for noting water-level status, recovering, recently pumped, etc.	Partial	Field form from route listing does not explicitly require recording of duplicate measurements.	Should modify field form to include all fields currently in GWIC data entry screens; Non static, Dry
Section 5.2.1.3 Minimum data elements					
Minimum data elements	Minimum elements are required. Field personnel should note which minimum elements might have changed and gather information as necessary to insure that all attribute fields are current.	Missing minimum elements and elements needing modification are noted on field measurement form. Most wells in Montana network have been visited numerous times and elements are generally known.	Yes		
Section 5.2.1.4 Onsite preparation					
Onsite preparation	Verification, equipment decontamination, site condition notations, site access, establish measuring point.	Field staff verifies the site by knowledge from previous visits. Otherwise maps, photographs, gps coordinates, and observation of a physical tag on the well head are used to verify the location. Equipment is decontaminated between measurements. Date-time, measuring point condition/change, other factors are noted at time measurements gathered. Site access is documented in site notes field reproduced on route listings. Measuring points are established at time site added to monitoring network; changes in measuring points tracked by date changes observed.	Partial	Weather conditions not explicitly noted.	No plans to modify
Section 5.2.1.5 Water Level Measurements					

Item	NGWMN	GWAA	Compliant	Item(s) different	Compliance - changes
All measurements recorded	Measurements recorded on paper or electronically at time of collection. Measurements recorded on paper entered to databases. Paper records filed - not returned to field. Electronic records stored in way that preserves original measurements. Paper records entered	Discrete measurements recorded on field sheets are entered to data base by observer upon return from field or remotely through an employee database portal. Field record sheets are archived and scanned into database's document manager component. Currently, measurements are not generally recorded electronically in the field.	Yes		
Sub-section 5.2.1.5.1 Manual measurements	Measurements should be gathered by repeatable and accurate methods.	Measurements are gathered using repeatable and accurate methods. SOPs exist to guide field staff in gathering water-level measurements in non-flowing and flowing wells. Repeated measurements are to be used to determine if measured value represents a static water level. Method of measurement is recorded with each data value.	Yes		See field form note above
Sub-section 5.2.1.5.2 Automated measurements	Instrumental gathered near-continuous measurements with little human intervention. Correct selection of instruments to cover the entire range of expected water-level movement at the required accuracy. Instruments must be calibrated to discrete hand measurements.	Instruments are calibrated to hand measurements each time downloaded or serviced. Instrumental record treated like logical "charts" from analog recorders. Final measurement of period becomes initial measurement for next period. Instrumental values are reconciled to hand measurements	Partial	Although instrumentation type (F-type, A-Type, Levelogger) is noted in database, serial number, model etc. is retained in field notebooks. Field forms with instrumental calibration notes are not posted in field.	Would modify GWIC structure to handle make, model, serial number etc. of instru-ments installed at sites. Most sites in network do not have places where field forms can be preserved - no plans to put field calibration

Item	NGWMN	GWAA	Compliant	Item(s) different	Compliance - changes
					forms in field.
Section 5.2.2 Minimum data standards					
Sub-section 5.2.2.1 Manual water-level measurements	Measurements made repeatedly to ensure +/- 0.02 ft between measurements. At least three repeated measurements for electric tapes.	Steel tape and chalk: +/- 0.01 for SWL <= 300 ft, +/- 0.1 ft for SWL > 300 ft. Electric well sounder: +/- 0.05 for SWL <= 300 ft, +/- 0.1 ft for SWL > 300 ft	Partial	GWAA: repeated measurements until required repeatability obtained (or not). Also use repeated measurements to determine if water-level is static (i.e. not recovering etc.). Field staff discretion whether to retain measure-ment and flag appropriately.	No plans to modify Montana practices. Repeatability goals very similar to NGWMN.
Sub-section 5.2.2.2 Automated water-level measurements	Automated measurements to within 0.02 ft. Site visits often enough to insure that instruments are working properly and results not compromised by excessive drift or water-level change.	Instrumental record reconciled to discrete hand measurements at the beginning and end of instrumental periods. Reconciliation to within 0.05 ft desired but not always obtained. Comparison of multiple instrumental periods to sets of discrete measurements may be required to resolve issues. Instrument sites visited during routine SWL route runs approximately every 90 days. Three telemetry sites are online - Three more next year	Partial	Frequency of visit on the order of 12-weeks, not 6-8 weeks. Instruments re-calibrated to hand measurements each download. All water-level measurements stored in same table - method flag differentiates discrete measurements from instrumental record.	No plans to modify schedule without funding to support more field staff.
Section 5.2.3 Data handling and management					
Sub-section 5.2.3.1 Electronic entry of data	Field data including date, time, distance to water, measuring point elevation entered into an electronic database.	Field data including date, time, distance to water, measuring point elevation entered into an electronic database.	Yes		

Item	NGWMN	GWAA	Compliant	Item(s) different	Compliance - changes
Sub-section 5.2.3.2 Verification and editing of unit values	Unit values should be checked against field measurements before being used in further analysis. A unit value can also refer to the relating the initial measurement of a water-level recorder to a discrete physical measurement. The logger may record data at hourly frequencies and the individual measurements may be used to calculate values such as daily averages for reporting purposes.	Unit values as bases for development of rating curves and other analytical tools used in surface water hydrography have not been a part of the Montana network. Water-level measurements generated by water-level recorders are tied to discrete physical measurements at either end of a recording period.	Yes		
Sub-section 5.2.3.3 Verification and analysis of field-measurement data	Field measurement data: discrete water-level measurements, well construction data, miscellaneous field notes. Check for arithmetic and logical errors. Calculated values management. Measuring point elevation management. Retain original paper records	Field measurements in the context of the operating monitoring network include: date-time, distance to water from MP, MP changes, method of SWL measurement, whether SWL is static, whether the measurement is DRY, and general remarks about the measurement. Generally do not include well construction information which is generated independently. Original paper records are kept in office and archived/scanned to database for reference.	Partial	Raw data input to SWL tables is: date-time, DTW from the MP, temperature (from data loggers), agency, method, non-static flag, dry flag, and remarks. Calculations of SWL ground and SWL elevation are done in the database at time of retrieval	No plans to change GWIC data structure. Existing procedures can meet expectations of NGWMN
Section 5.2.4 Measurement frequency (incorporated into main body of Framework Document.					
Field practices for groundwater quality					
Section 5.3.1 Minimum Field Standards					

Item	NGWMN	GWAA	Compliant	Item(s) different	Compliance - changes
Sub-section 5.3.1.2 Pre-Collection Site Review and Preparation	Corrections and updates to site information should be made prior to sampling. Preparation for sampling includes the gathering of equipment and supplies such as, pumps, bailers, probes, analysis kits, meters, and coolers and all supplies such as batteries, bottles, preservatives, cooling media, forms, labels, filter media, tape, and gloves. Equipment and meters should be decontaminated and calibrated.	Online tools define wells within routes that need to be sampled. Field staff plan their trips accordingly to collect water from sites to be sampled by taking all pumps, meters, bottles, ice chests etc. along necessary to collect and preserve water samples. Because sites are well known to the staff and the sites have all been visited many times, site correction and update are usually results of the trips because changed field conditions are not known while in the office.	Yes		
Sub-Section 5.3.1.3 Minimum Data Elements	There are inherent data elements that must be known at each sampling site. Site identifiers, location (latitude, longitude, etc.) ownership, well construction details, measuring point attributes, distance to water, site notes, etc. Date and time of sampling, weather conditions, the sampler's identity/affiliation, purge method/volume, sample appearance, preservation and handling, analyses and methods requested, and transfer date to laboratory.	Most site identifiers, the location, ownership, well construction details, measuring point attributes are known to the samplers because the sites are included in the network and are repeatedly visited. GWAA staff are always vigilant for locational and other errors but once these parameters are set and confirmed, must confirm that the ID number they place on the bottles and sample documentation match that of the location. Correlative sample documentation elements are routinely collected by field staff while sampling including pumping rates, water levels and field measured parameters such as pH, Conductivity, temperature. Etc. Weather conditions are generally not observed for groundwater sample	Partial	Weather conditions not observed.	No plans to modify

Item	NGWMN	GWAA	Compliant	Item(s) different	Compliance - changes
		collection.			
Sub-Section 5.3.1.4 Onsite Preparation	Site verification, cleaning the sampling point, equipment decontamination, initial static water level, volume to be purged, pump installation, sample point condition, date and time, weather conditions, other conditions as necessary.	Sites are verified by methods utilized in 5.2.1.1. An initial static water level is collected and well construction data are used to calculate the well volume. Most GWAA samples are collected using dedicated sample tubing connected to a Y-adapter at the well head or spigot which splits the discharge between waste and an instrument chamber. At the instrument chamber, flow is split between sampling ports and the chamber. Probes in the instrument chamber monitor field chemistry (pH, Conductivity, etc.) during purging. The sampler monitors the discharge rate and total system discharge during purging. Spigot threads and the Y-adapter connections are cleaned with DI water at during assembly.	Partial	Weather conditions not observed.	No plans to modify

Item	NGWMN	GWAA	Compliant	Item(s) different	Compliance - changes
Sub-Section 5.3.1.5 Sample collection	Purging efficacy check; purging of at least three casing volumes of fluid is necessary. Sampler preparation, sample container preparation, filling method. Monitoring of drawdown during purging. During purging, the sampler should monitor the temperature, conductivity, and pH to assess the adequacy of the purging operation and record the results at least once for each casing volume of fluid purged. The difference between the last two field measurements of temperature, conductivity, and pH should fall within the following allowances: Temperature ± 0.2°C, Conductivity ± 3%, pH ± 0.1 pH units. Samples should be placed in new or prepared bottles under laminar flow conditions. Thus, the pumping rate for sample collection should be low enough to prevent turbulent flow or aeration of the sample.	Before bottling, at least one well volume should be pumped from the well and the purging parameters (temperature, pH, redox, dissolved oxygen and specific conductance) should stabilize. The field parameters should be recorded at regular intervals during purging, dependent on the total time necessary to purge the well. If the purging parameters are not stable after three well volumes have been removed, note the instability and go ahead and bottle the sample. Temperature is considered stable when three consecutive readings are within 0.5 degrees. The pH is considered stable if three consecutive readings are within 0.1 units. The specific conductance is considered stable if three consecutive readings are within +/- 5 percent. Polyethylene or glass sample bottles with screw-on caps should be used. Rinse sample bottles and caps 3 times with sample water and fill slowly.	Partial	Tolerances on GWAA field parameters are slightly larger than those specified for NGWMN. Conversely, GWAA requires more measurements to determine stability. Wells may be sampled after parameters are stable and one well volume purged. Wells may be sampled after three well volumes, even if parameters do not meet stability criteria.	Sampling procedures are substantially the same as NGWMN proposed. No plans to change GWAA procedures.

Item	NGWMN	GWAA	Compliant	Item(s) different	Compliance - changes
Sub-Section 5.3.1.6 Sampling Preservation, Handling, and Transport	Necessary preservation to prevent sample degradation depending on the analyses to be conducted. Samples for analysis of cations/ metals must be preserved to pH <2 using nitric acid and may be, but need not be, chilled. Observance of holding time restrictions dependent on analytical procedure. Samples transportation in appropriate clean coolers/ designed to keep the contents at a constant or even temperature, prevent the spillage of samples, and prevent damage to sample containers.	For the samples that require preservative (metals, trace metals, nitrate-nitrite), leave enough head space to accommodate the preservative, add the preservative, tightly cap, and gently shake to disperse the preservative. The laboratory will provide premeasured ampules of acid (nitric for metals samples or sulfuric for nitrate-nitrite samples). With either preservative the sample's resulting pH should be < 2. Samples should be immediately transferred to coolers packed with ice and the sample temperature maintained as close to 4 degrees C as possible.	Yes		
Section 5.3.2 Automated Water-Quality Measurements					
Section 5.3.2 Automated Water-Quality Measurements	Purging requirements make routine automatic water-quality measurements atypical.	Automatic water-quality sampling is not part of GWAA activities.	Yes		
Section 5.3.3 Data Handling and management					
Sub-Section 5.3.3.1 Data Recording	Methods to record field data range from pen and paper to direct data entry into a database. A critical factor is having a structured method of data recording so that critical elements are not left out.	Information documented on the Water-Quality Data Sheet, field data sheet, or field log book should include what type of sample was collected, who collected sample, when the sample was collected, the location of the sampling point, why or for what program the	Yes		

Item	NGWMN	GWAA	Compliant	Item(s) different	Compliance - changes
	Simple recording of data elements into a field notebook without structured forms listing the elements is more likely to result in errors of omission. Recording field data electronically is preferable because electronic structured data entry forms can reduce errors of omission and eliminate hand transcription/ re-entry of the data.	sample was collected, condition of the sample, and the stabilization criteria and the purging method. Additionally, the total number of bottles, the filter and preservation status, and the desired analyses must be documented.			

Appendix E – GWDP and Montana GWIC data mediation table.

Note: dbo in the Source file column means that the source is the Ground Water Information Canter (GWIC) data structures and made available through a web service.

SOGW Data Element	Source File / Schema@Database	GWDP or GWIC Table Name	GWDP or GWIC Column Name	GWDP Join Condition	GWDP Comments
1.0 POINT OF CONTACT					
1.1 Source of data	Pilot Well Registry Spreadsheet	Uploaded into gw_data_portal.well_registry@widw.er.usgs.gov	data_provider	--	--
1.1.1 Organization Name	Pilot Well Registry Spreadsheet	Uploaded into gw_data_portal.well_registry@widw.er.usgs.gov	agency_cd	--	--
1.1.2 Mailing Address	--	--	--	--	--
1.1.2.1 City, Town, Village Name	--	--	--	--	--
1.1.2.2 State Name	--	--	--	--	--
1.1.2.3 Mailing Address ZIP Code/Postal Code	--	--	--	--	--
1.1.3 Telephone number	--	--	--	--	--
1.1.4 Electronic Mail Address	--	--	--	--	--
2.0 SITE IDENTIFICATION/DESCRIPTION					
2.1 Site Identifier	Pilot Well Registry Spreadsheet	Uploaded into gw_data_portal.well_registry@widw.er.usgs.gov	site_no	--	--
3.0 GEOLOGIC/HYDROLOGIC DESCRIPTION					
3.1 Hydrologic basin	--	--	--	--	--
3.2 Geologic unit(s) containing aquifer (Aquifer lithology; the lithology of the primary contributing unit(s))	dbo	lithology	lith_from, lith_to, description	litholoy.gwicid = well_registry.site_no	--
3.3 Aquifer tapped (Principal Aquifer or other significantly used aquifer; primary unit(s)contributing water to the well)	Pilot Well Registry Spreadsheet	Uploaded into gw_data_portal.well_registry@widw.er.usgs.gov	nat_aqfr_cd	well_registry.nat_aqfr_cd = nat_aqfr.nat_aqfr_cd	may also want to look at aqfr_cd and name in sites_gw_mvw_all
--	gw_data_portal@widw.er.usgs.gov	nat_aqfr	nat_aqfr_desc	also in sites_gw_all_mvw	--
3.4 Local aquifer name (if applicable)	Pilot Well Registry Spreadsheet	Uploaded into gw_data_portal.well_registry@widw.er.usgs.gov	local_aquifer_name	--	--

SOGW Data Element	Source File / Schema@Database	GWDP or GWIC Table Name	GWDP or GWIC Column Name	GWDP Join Condition	GWDP Comments
3.5 Aquifer type	--	--	--	--	--
3.6 Aquifer conditions: (1) confined or (2) unconfined or leaky confined	--	--	--	--	--
4.0 WELL LOCATION					
4.1 Horizontal Location					
4.1.1 Latitude	Pilot Well Registry Spreadsheet	Uploaded into gw_data_portal.well_registry@widw.er.usgs.gov	dec_lat_va	--	--
4.1.2 Longitude	Pilot Well Registry Spreadsheet	Uploaded into gw_data_portal.well_registry@widw.er.usgs.gov	dec_log_va	--	--
4.1.3 Horizontal Reference Datum	Pilot Well Registry Spreadsheet	Uploaded into gw_data_portal.well_registry@widw.er.usgs.gov	horz_datum	--	--
4.1.4 Location Horizontal Accuracy	dbo	sites	latacc, lonacc	--	--
4.1.5 Location Collection Method	dbo	sites	geomethod	--	--
4.2 Vertical Location					
4.2.1 Altitude of Land Surface at Wellhead	--	--	--	--	--
4.2.2 Altitude measurement method	dbo	sites	method_altitude	--	--
4.2.3 Altitude (Land surface elevation)	Pilot Well Registry Spreadsheet	Uploaded into gw_data_portal.well_registry@widw.er.usgs.gov	alt_va	--	--
4.2.4 Altitude accuracy	--	--	--	--	--
4.2.5 Vertical Reference Datum	Pilot Well Registry Spreadsheet	Uploaded into gw_data_portal.well_registry@widw.er.usgs.gov	alt_datum_cd	--	--
4.3 Well Address					
4.3.1 Owner data	dbo	owner	owner	owner.gwicid = well_registry.site_no	--
4.3.2 Mailing Address	dbo	owner	address	--	--
4.3.3 City or Town	dbo	owner	city	--	--
4.3.4 State name	dbo	owner	state	--	--
4.3.5 Tribal Reservation/Country	--	--	--	--	--
4.3.6 Mailing Address ZIP Code/Postal Code	dbo	owner	postalcode	--	--

SOGW Data Element	Source File / Schema@Database	GWDP or GWIC Table Name	GWDP or GWIC Column Name	GWDP Join Condition	GWDP Comments
4.3.7 Time Zone	--	--	--	--	--
4.3.8 Daylight Savings Zone flag	--	--	--	--	--
5.0 WELL CHARACTERISTICS					
5.1 Local/State Identifier	dbo	sites	gwicid	--	--
5.2 Depth of well	dbo	boreholes	total_depth	boreholes.gwicid = well_registry.site_no	--
5.3 Source of Data	Pilot Well Registry Spreadsheet	Uploaded into gw_data_portal.well_registry@widw.er.usgs.gov	data_provider	--	--
5.6 Casing depth of well	dbo	casing	case_from, case_to	casing.gwicid = well_registry.site_no	--
5.7 Top of screened or open hole (rtd) (Depth to top of each open interval)	dbo	completion	comp_from, comp_to	completion.gwicid = well_registry.site_no	--
5.8 Bottom of screened or open hole (rtd) (Depth to bottom of each open interval)	dbo	completion	comp_from, comp_to	completion.gwicid = well_registry.site_no	--
5.9 Casing material(s), if there is a casing	dbo	casing	material	casing.gwicid = well_registry.site_no	--
5.10 Screen material type(s) at each open interval(s), if the well has well screen(s)	--	--	--	--	--
5.11 Well type	Pilot Well Registry Spreadsheet	Uploaded into gw_data_portal.well_registry@widw.er.usgs.gov	qw_us_flag, wl_us_flag	--	--
5.12 Well Purpose	Pilot Well Registry Spreadsheet	Uploaded into gw_data_portal.well_registry@widw.er.usgs.gov	qw_well_type, wl_well_type	--	--
5.13 Well Log or Completion Report Available	--	--	--	--	--
5.2 Measurement Location					
5.2.1 Description of Measurement/Sampling/Reference Point	dbo	mp_table	mp_description	mp_table.gwicid = well_registry.site_no	--
5.2.2 Measurement/Sampling point height	dbo	mp_table	mp_altitude	mp_table.gwicid = well_registr	--

SOGW Data Element	Source File / Schema@Database	GWDP or GWIC Table Name	GWDP or GWIC Column Name	GWDP Join Condition	GWDP Comments
(Measuring point elevation relative to datum (rtd))				y.site_no	
5.2.3 Measuring/Sampling Point Accuracy of Measurement	--	--	--	--	--
6.0 MEASUREMENT/SAMPLING EVENT					
6.1 Purpose					
6.1.1 Monitoring Purpose	--	--	--	--	--
6.2 Date and Time					
6.2.1 Time zone code	--	--	--	--	--
6.2.2 Measurement/Sampling date/time	--	--	--	--	--
6.2.3 Level Measurement date and time (Data for water level measurement collected and reported for each measurement event)	--	--	--	--	--
6.2.3.1 Water-level measurement date	dbo	swl_table	date_measured	swl_table.gwicid = well_registry.site_no	--
6.2.3.2 Water-level measurement time	dbo	swl_table	date_measured	swl_table.gwicid = well_registry.site_no	--
6.3 Measurement/Sampling Site Use					
6.3.1 Site use at time of measurement/sampling event	dbo	sites	site_type	--	--
6.4 Level Elevation Measurement					
6.4.1 Water Level	--	--	--	--	--
6.4.2 Measurement method	dbo	swl_table	method	swl_table.gwicid = well_registry.site_no	--
6.4.3 Water level accuracy	--	--	--	--	--
6.4.4 Water-level status	--	--	--	--	--
6.5 Sampling Point Elevation Measurement					

SOGW Data Element	Source File / Schema@Database	GWDP or GWIC Table Name	GWDP or GWIC Column Name	GWDP Join Condition	GWDP Comments
6.5.1 Sampling Point Elevation	Pilot Well Registry Spreadsheet	Uploaded into gw_data_portal.well_registry@widw.er.usgs.gov	alt_va	if the level is referenced to a vertical datum, the datum is in gwsi_levels.sl_datum_cd	
6.5.2 Sampling Point Elevation Measurement method	--	--	--	--	--
6.5.3 Sampling Point Elevation accuracy	--	--	--	--	--

Appendix F – Fields provided by MBMG GWIC web services.

vwNationalNetworkSitesService

The vwNationalNetworkSitesService exports fields from a data view of the same name and delivers the following fields:

- Organization,
- SiteId,
- SiteName,
- Latitude,
- Longitude,
- HorizontalDatum,
- Altitude,
- AltitudeDatum,
- NationalAquiferCode,
- LocalAquiferName,
- WaterQualitySubnetwork,
- WQBaselineAchieved,
- QWUnstressed,
- WQWellType,
- WQSystemName,
- WaterLevelSubnetwork,
- WLBaselineAchieved,
- WLUnstressed,
- Wl_well_type,
- WLSystemName

These are the same fields as are being currently delivered to GWDP manually by periodic retrievals from GWIC and transmittal via spreadsheet.

vwNationalNetworkLithology

The vwNationalNetworkLithology service uses a data view of the same name and exports the following fields:

- gwicid
- lith_from
- lith_to
- description
- data_source
- total_depth
- well_log_available

These fields are intended to provide lithologic data to the GWDP.

vwNationalNetworkCasing

The vwNationalNetworkCasing service uses a data view of the same name and exports the following fields:

- gwicid
- case_from
- case_to
- material
- diameter
- wall_thickness
- data_source

These fields are intended to provide borehole casing information to the GWDP.

vwNationalNetworkCompletion

The vwNationalNetworkCompletion service uses a data view of the same name and exports the following fields:

- gwicid
- comp_from
- comp_to
- description
- diameter
- data_source

These fields are intended to provide borehole openings information to the GWDP.

vwNationalNetworkWaterLevels

The vwNationalNetworkWaterLevels service uses a data view of the same name and exports the following fields:

- gwicid
- date_measured
- time_zone
- swl_ground
- method
- status
- data_source

These fields are intended to provide water-level data to the GWDP.