

Information Pamphlet 9

TRACKING MONTANA'S GROUNDWATER

John I. LaFave

Senior Research Hydrogeologist
Montana Bureau of Mines and Geology



Ground Water Assessment Program statewide monitoring network wells.

INTRODUCTION

Groundwater, often called the “hidden resource,” is one of Montana’s most valuable natural assets. In most rural areas, groundwater supplies all the domestic, stock, and ranch needs—and in some of Montana’s more “urban” areas, such as Missoula, Kalispell, and Sidney, it is the public water supply source. Groundwater also plays a crucial role in sustaining stream flow; about half of the total annual flow in typical Montana streams is derived from groundwater.

The drought of the late 1980s highlighted not only how important groundwater is for Montanans, but also how much we don’t know about this resource (think; “You don’t miss the water until the well runs dry”). A task force authorized by the 1989 Legislature found, among other things, that: (1) there is insufficient information about the State’s groundwater, and (2) groundwater information deficiencies are hampering efforts to properly manage, protect, and develop groundwater.

In response, the 1991 Legislature passed the Ground Water Assessment Act, which established three programs at the Montana Bureau of Mines and Geology (MBMG) that focused on addressing Montana’s groundwater information needs:

1. The Groundwater Monitoring Program, to provide long-term records of water quality and water levels for the State’s major aquifers;
2. The Groundwater Characterization Program, to map the distribution of and document the water quality and water-yielding properties of individual aquifers across the State;
3. The Ground Water Information Center (GWIC), to make groundwater information readily accessible.

Assessment Act implementation is overseen by a steering committee that consists of representatives from water agencies in State and Federal government, representatives from local governments, and representatives from water-user groups. The committee also provides a forum through which units of State, Federal, and local government can coordinate groundwater research.

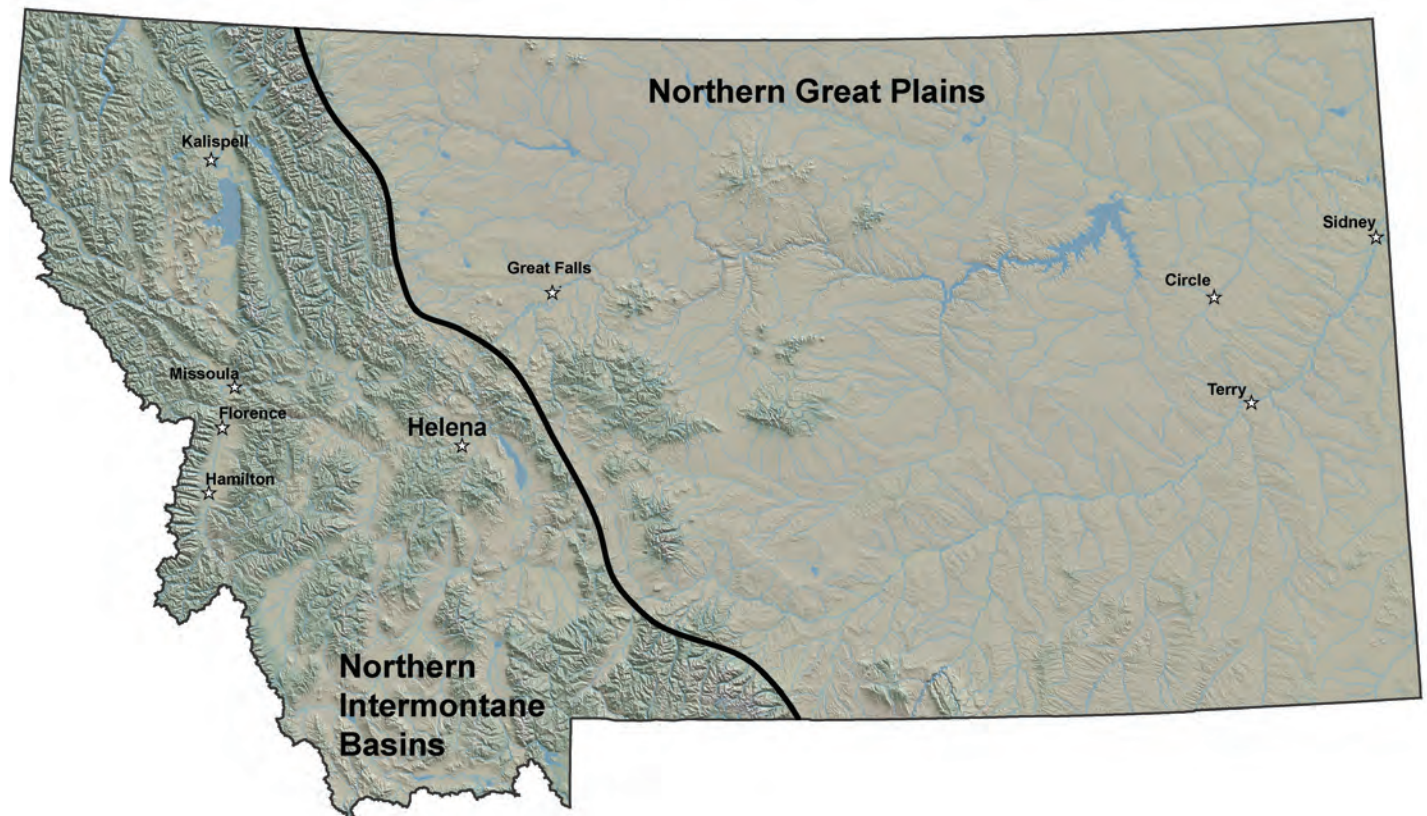


Figure 1. Montana is divided into two different physiographic regions, the Northern Great Plains and the Northern Rocky Mountains.

MONTANA GROUNDWATER AND WELLS

Montana's groundwater is stored within aquifers closely tied to the geology of Montana's two prominent physiographic regions: (1) the intermontane basins of the northern Rocky Mountains and (2) the northern Great Plains (figure 1).

Each physiographic province represents broad differences in geology and geologic history, which in turn creates different hydrogeologic settings. Generally speaking, the geologic units range from unconsolidated sand and gravel deposits to consolidated sedimentary, metamorphic, igneous, and volcanic rocks.

Within the intermontane basins, groundwater generally occurs in: (1) shallow water-table aquifers in sand and gravel and (2) deep confined to semi-confined aquifers in basin-fill. Both aquifer types contain large amounts of groundwater and are highly produc-

tive and utilized.

In the northern Great Plains, aquifers are not as productive, but nevertheless groundwater is highly utilized. Layers of sedimentary sandstone and limestone form the most important aquifers. More localized but also important are alluvial aquifers within major stream valleys.

About 200,000 wells withdraw water for domestic, stock, industrial/commercial, irrigation, and public water supply uses. Most wells (93%) provide domestic or stock water; irrigation, public water supply, and industrial wells account for the other 7 percent. Montana's water wells provide about 285 million gallons of groundwater per day (USGS). Domestic and stock-water use is volumetrically the smallest, accounting for about 12 percent of withdrawals. Irrigation, public water supply, and industrial wells account for 88 percent of annual withdrawals (figure 2).

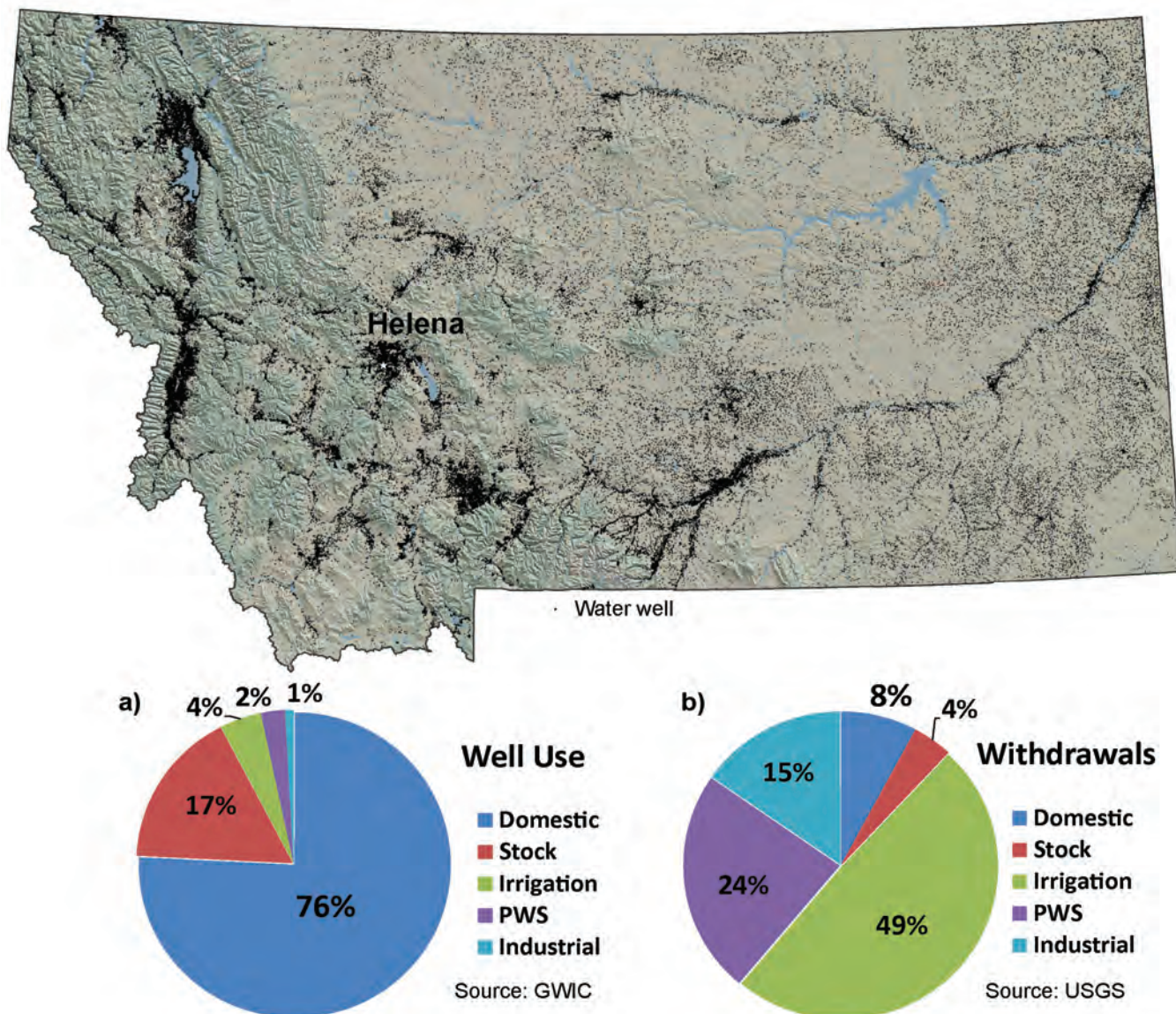


Figure 2. There are about 200,000 wells (black dots in figure) that provide water for a variety of different uses. (a) Most of the wells are for domestic and stock use. (b) Most of the withdrawals are for irrigation and public water supply.

THE MONITORING PROGRAM

When you consider our more than 200,000 wells producing 285 million gallons per day, some basic questions arise: Are groundwater resources being stressed? Are we running out of groundwater? Where are aquifers most available for future supply?

These are questions that the Ground Water Assessment Program helps address. The statewide monitoring network has been collecting systematic groundwater-level data from the State's major aquifers since 1993; some of these wells have been consistently monitored since the 1950s. Currently, the network consists of more than 900 wells from less than 10 feet to more than 3,600 feet deep that provide data for unconfined alluvial, deep basin-fill, and deep confined bedrock aquifers (shown in cover figure). Some network wells are dedicated specifically to measuring groundwater levels but many are low-use water supply or unused wells.

MBMG staff are responsible for most of the water-level measurements; however, cooperative agreements with Local Water Quality Districts in Missoula, Lewis and Clark, and Gallatin Counties as well as the Confederated Salish and Kootenai tribes augment the network.

Groundwater-level change records the balance among recharge to, storage in, and discharge from an aquifer. When water levels rise, more water is entering the aquifer (recharge) than exiting (discharge). Similarly, when water levels fall, more water is leaving the aquifer than is being replenished. Persistent long-term water-level decline suggests groundwater storage depletion.

Water levels in many Montana aquifers follow a natural seasonal cyclic pattern, typically rising during the spring and early summer in response to snow-melt, precipitation, and run-off. Water levels decline during summer and fall months because of less recharge and high evapotranspiration. The magnitude of groundwater-level fluctuations varies seasonally and from year to year in response to varying climatic conditions, illustrating that Montana's groundwater systems dynamically adjust to short- and long-term climate variability. Other factors that affect water levels include groundwater withdrawals and land use. The following examples show how data from the statewide network document the effects of climatic variability, groundwater development, and land use in several Montana aquifers.

CLIMATIC VARIABILITY: THE MADISON LIMESTONE

The Madison Limestone is a bedrock aquifer that underlies most of central and eastern Montana. Where it is close to or exposed at the surface, it is a productive and important source of municipal, domestic, industrial, and stock water; it also is the source for many large springs, including Giant Springs at Great Falls. Data from GWIC show that in Cascade County more than 900 wells, roughly 75 percent of all Madison wells statewide, use the Madison aquifer. Most of these wells are located in a 700-square-mile area between the Little Belt Mountains and the Missouri River near Great Falls (figure 3).

In Cascade County, between about 1995 and 2006, the number of wells completed in the Madison aquifer nearly doubled, from about 400 to 800 (figure 4). During this same time, water levels in Madison aquifer observation wells near Great Falls dropped about 30 feet (figure 4). Based on these facts, it appeared water was being removed from the aquifer faster than it could be replenished, and many water users began to question the aquifer's sustainability.

However, since 2006, even though new wells continued to be drilled into the Madison aquifer, water levels have climbed to altitudes higher than those measured in 1995. Although there may be a development impact, the data suggest that groundwater withdrawals are not currently driving water-level changes. Rather climate, or more specifically precipitation, appears to be the primary water-level control. Comparing water-level trends to departures from average annual precipitation shows that the period when water levels declined between 1995 and 2005 coincided with below-average precipitation (figure 4). Recovery occurred between 2006 and 2013 when the climate was relatively wet.

This example highlights the importance of long-term water-level data with regard to developing a comprehensive understanding of groundwater storage change. The Madison aquifer system is dynamic and is strongly impacted by short- and long-term climate variability.

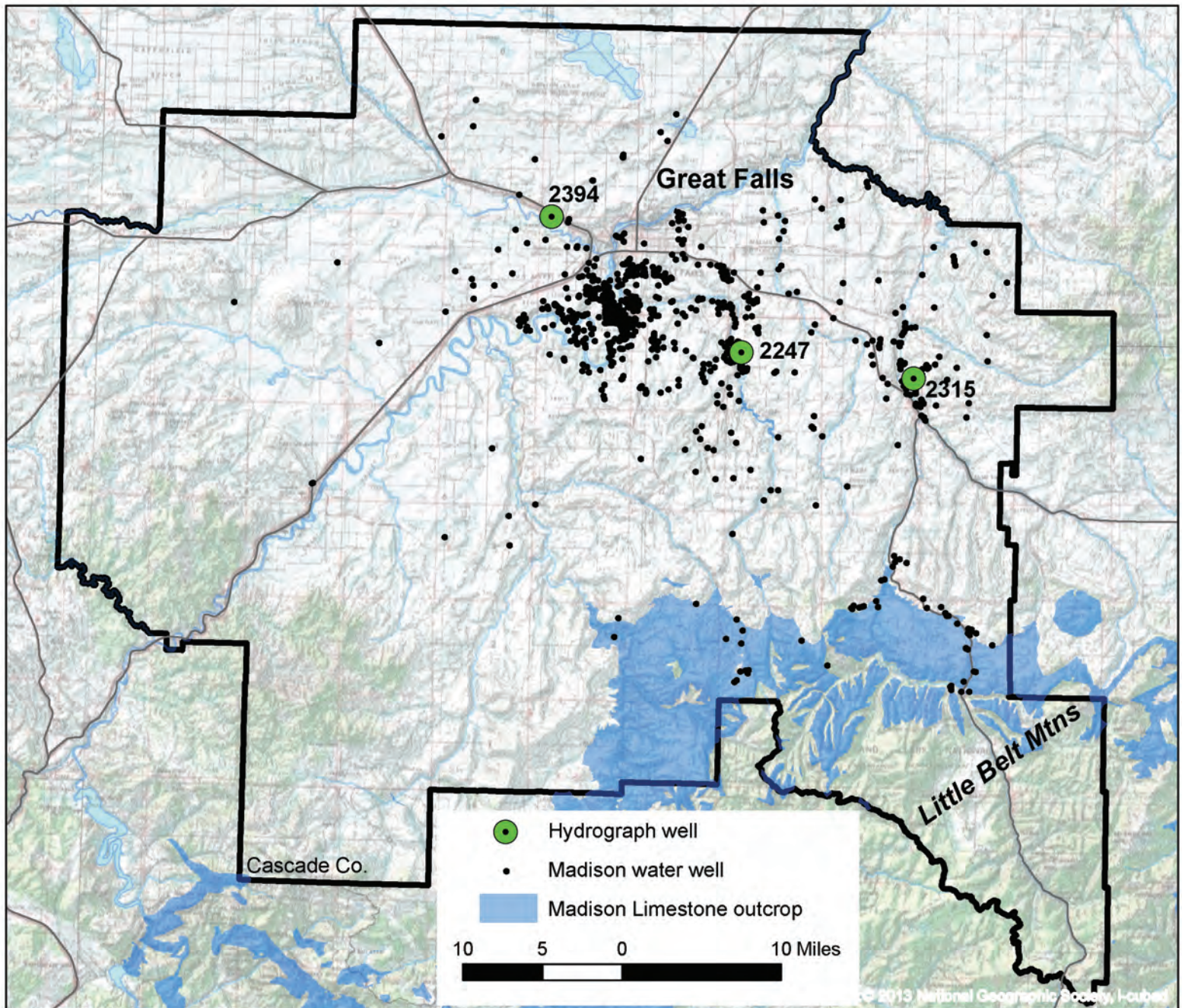


Figure 3. More than 900 wells (black dots) obtain water from the Madison Limestone near Great Falls. The Madison Limestone is exposed at the surface in the Little Belt Mountains (blue area on map), but is more than 400 feet below the surface at Great Falls.

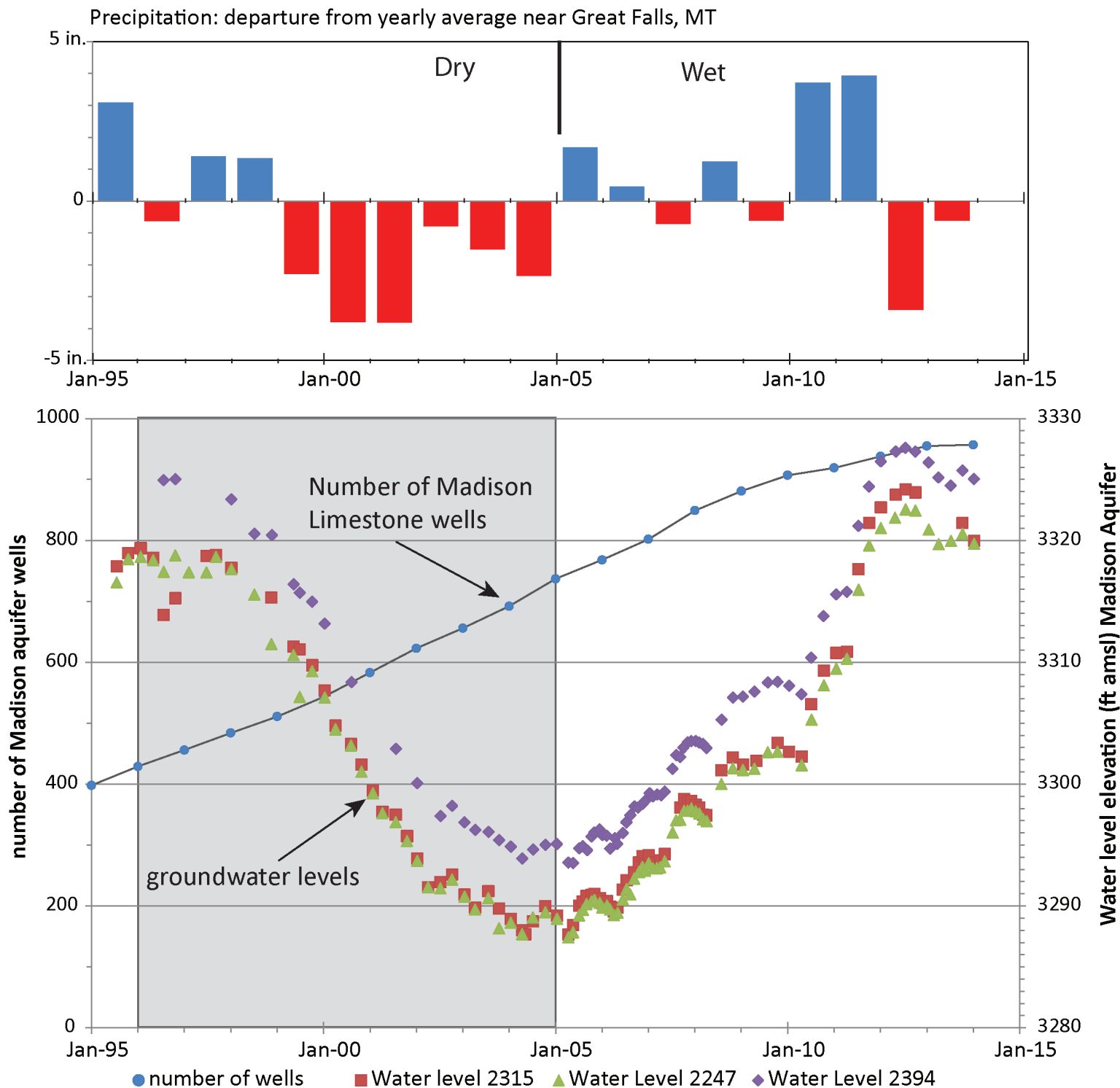


Figure 4. Between 1995 and 2005, the number of wells drilled into the Madison Limestone around Great Falls nearly doubled. During the same time period, water levels in the aquifer dropped 30 feet. However, this was also a very dry period, as indicated by the departure from average precipitation plot above. Water levels recovered following several “wet” years even though wells continued to be drilled into the aquifer. Location of the hydrograph wells is shown in figure 3.

GROUNDWATER DEVELOPMENT: THE FOX HILLS–HELL CREEK

Where groundwater production exceeds recharge, groundwater levels will decline. Where aquifers are undergoing development, a water-level record that encompasses the transitional period between the natural and the developed state of the aquifer can provide an invaluable understanding of developing problems and appropriate responses. A prime example is the history of groundwater development in the Fox Hills–Hell Creek (FHHC) aquifer in eastern Montana.

Groundwater from the FHHC is used primarily for domestic purposes and stock watering. However, the cities of Baker, Circle, Lambert, and Richey rely on it for municipal water supply. In the lower Yellowstone River area there are about 1,500 wells completed in the aquifer (figure 5). The widespread use of the aquifer has resulted in persistent water-level declines, especially in the Yellowstone River Valley. The hydrograph from an observation well (figure 5, well 1846) near Terry shows declining water levels there—about 25 feet during the past 33 years. The long-term declines occur when more water is removed from the aquifer than is recharged. At some point these declines can create undesirable effects such as increased lift costs, decreased yields, and flowing wells

ceasing to flow.

Over-pumping the FHHC resulted in Montana's first controlled groundwater area. In the early 1960s at the South Pine oil field near Baker, the FHHC was pumped at about 450 gallons per minute to support secondary oil recovery. The withdrawals caused water-level declines that affected surrounding stock and domestic wells. In response to landowner complaints, the South Pine Controlled Groundwater Area was created in 1967 to limit FHHC pumping and slow the rate of water-level decline. Between 1975 and 1977 the industrial water supply wells were phased out of production, and water levels in the aquifer began to recover.

The long-term hydrograph from an observation well (figure 5, well 136642) located within the controlled groundwater area shows that between 1962 and 1967 pumping caused the water level to drop more than 130 feet. After the controlled groundwater area was established and industrial pumping reduced, the rate of water-level decline slowed considerably—dropping about 20 feet after 1967. When pumping ceased, the water level rose about 110 feet, but stabilized about 40 feet below the 1962 level. The failure to fully recover may likely be related to the same over-drafts that are creating the declines observed near Terry.

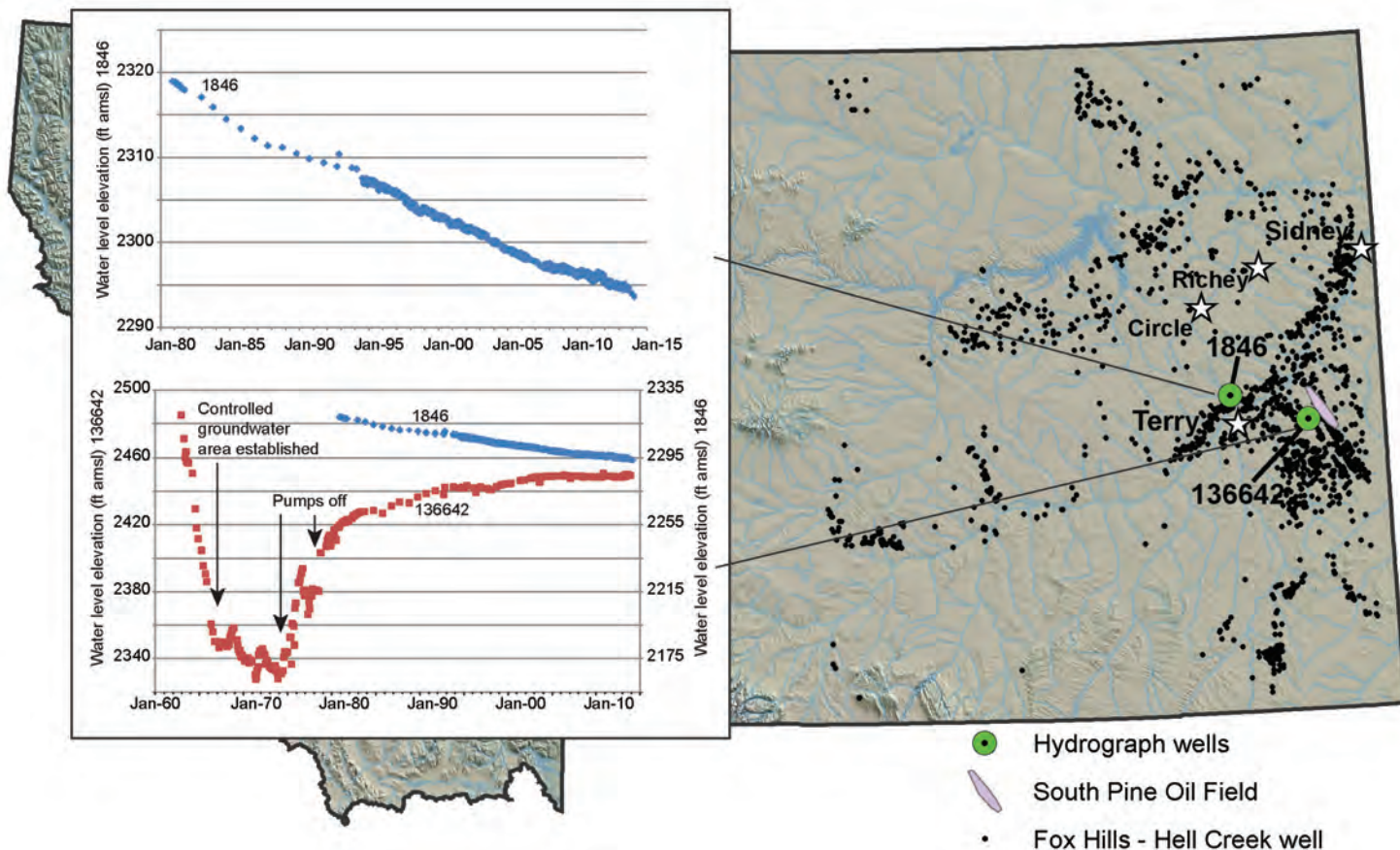


Figure 5. Water levels in the Fox Hills–Hell Creek aquifer near Terry are declining at a rate of about 1 foot per year. Near the South Pine field, water levels have recovered since industrial pumping ceased; however, they are still 40 ft lower than 1960s levels.

LAND USE: INCIDENTAL RECHARGE, BITTERROOT VALLEY

Montana's river valleys and alluvial terraces are laced with more than 7,000 miles of irrigation canals. These canals are mostly unlined, and carry about 10.5 million acre-feet of surface water each year to irrigate about 2 million acres. In these valleys, losses from the canals and seepage from irrigated fields constitute a significant fraction of aquifer recharge. Groundwater levels in such areas typically start rising during April and May when irrigation begins, remain elevated from midsummer to the end of the irrigation season, and then decline to an annual minimum just before the next growing season. This response is observed throughout the irrigated valleys in Montana.

Hydrographs from two Bitterroot Valley wells completed in the same aquifer, one in an irrigated area the other not, highlight the significance of irrigation recharge. Figure 6 shows that groundwater levels in the irrigated area near Hamilton rise quickly at the onset of irrigation, remain elevated throughout the irrigation season, and then decline in the late summer or fall when irrigation ceases. A well near Florence that is distant from irrigation shows a much different water-level response synchronized with Bitterroot River flow; water levels peak near when stream flow peaks and then gradually fall back to a base level. On average, water-level fluctuation in the Florence well is about 2 feet, whereas the average water-level fluctuation in the Hamilton well is nearly 10 feet. Recharge from irrigation water accounts for the difference.

Changes in irrigation practices, such as the conversion of flood to sprinkler irrigation or lining irrigation canals, can reduce recharge to aquifers and result in water-level declines. Urban development and subdivisions that result in an increase in paved areas and storm-water controls can also reduce aquifer recharge.

WHY MONITOR GROUNDWATER LEVELS?

Long-term water-level measurements provide a fundamental indicator of an aquifer's status. The examples presented above highlight the importance of long-term systematic data collection necessary to: 1) develop a comprehensive understanding of how aquifers respond to different stresses and 2) develop meaningful evaluations of the groundwater supply. The Ground Water Assessment Program at the Montana Bureau of Mines and Geology provides reliable baseline groundwater data against which future changes can be measured, and makes those data readily available. Through these efforts, Montana will be better positioned in coming decades to make wise use of its groundwater resources.

To see what groundwater levels are doing in your area, check out the Ground Water Information Center website: <http://mbmggwic.mtech.edu/>. There you can find updated hydrographs, technical reports, maps, and well logs.

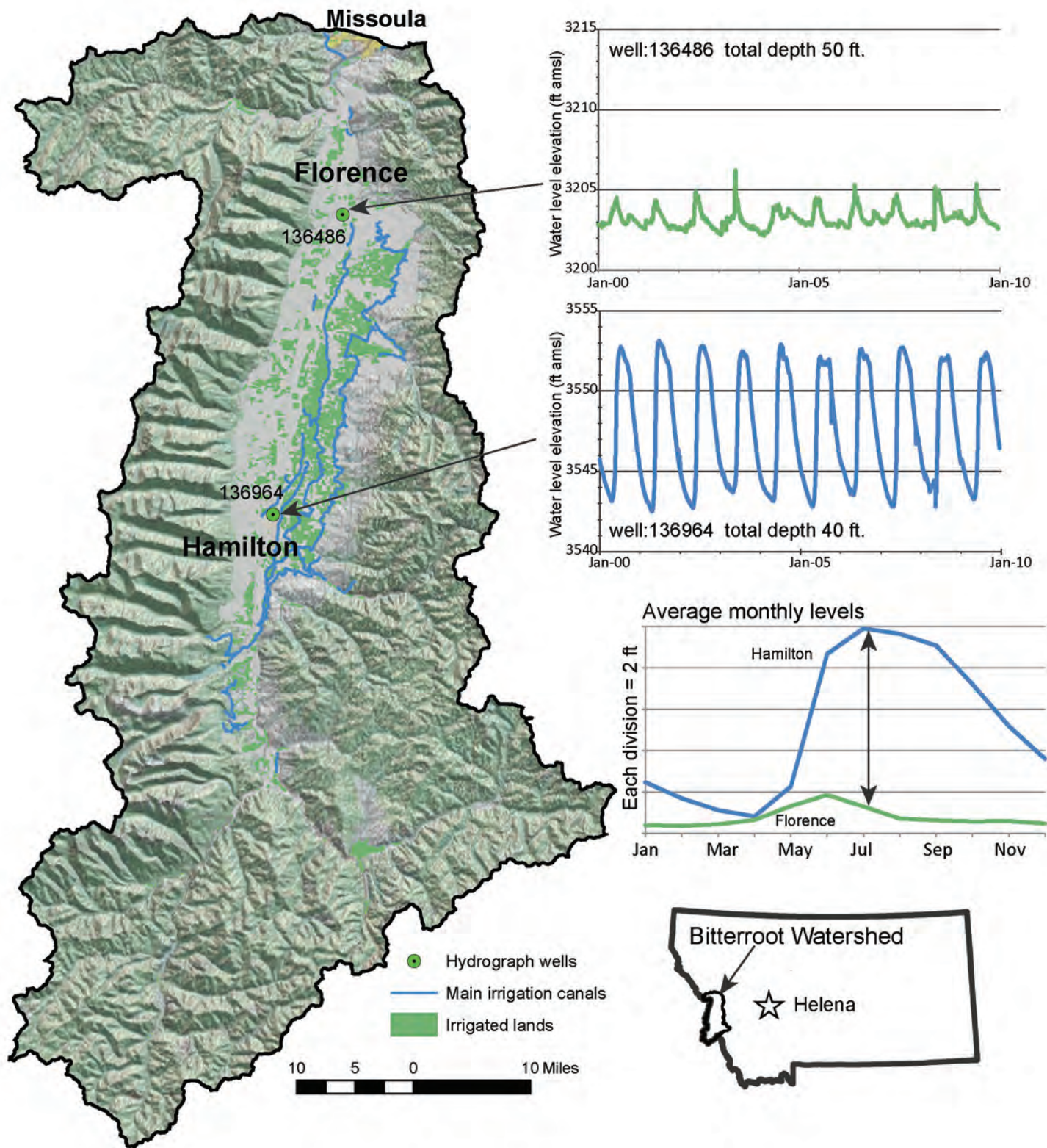


Figure 6. Hydrographs for two wells completed in the same aquifer near the Bitterroot River show very different responses. The well near Hamilton is downgradient from several irrigation canals and irrigated fields; the well near Florence is not located near irrigation. The average monthly water levels show the difference in seasonal response and highlight the importance of irrigation water as a source of recharge to the shallow aquifers.

