OVERVIEW OF THE HYDROGEOLOGY OF THE GALLATIN VALLEY

Prepared For

2007 Montana Legislature Water Policy Interim Committee

By

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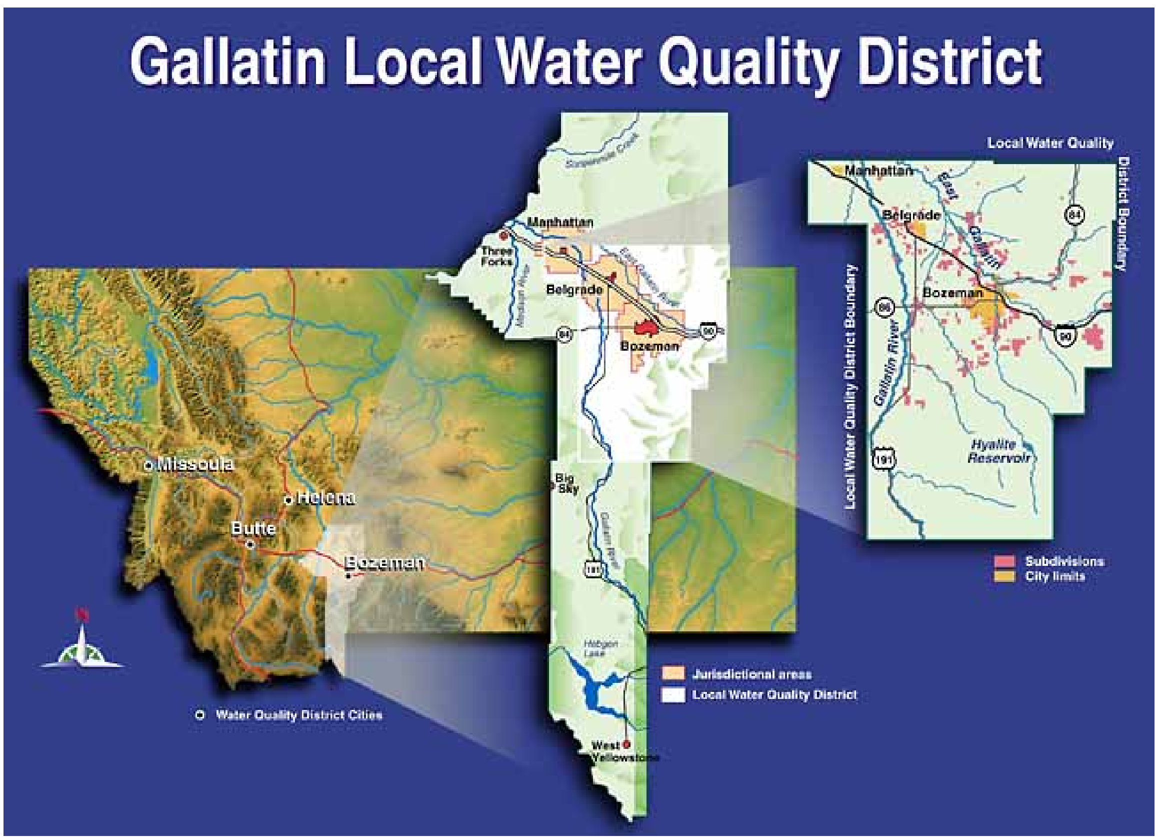

I. GEOLOGIC STRUCTURE OF THE GALLATIN VALLEY

- ✓ The Gallatin Valley forms the eastern half of a much larger bedrock structural basin called the Three Forks Basin, with the Tobacco Root Mountains forming part of the western boundary of the basin.

- ✓ The Gallatin Valley is bounded on the north, east, southeast and southwest by exposed bedrock mountain ranges. The western boundary is the Madison Plateau (see Figure 1).

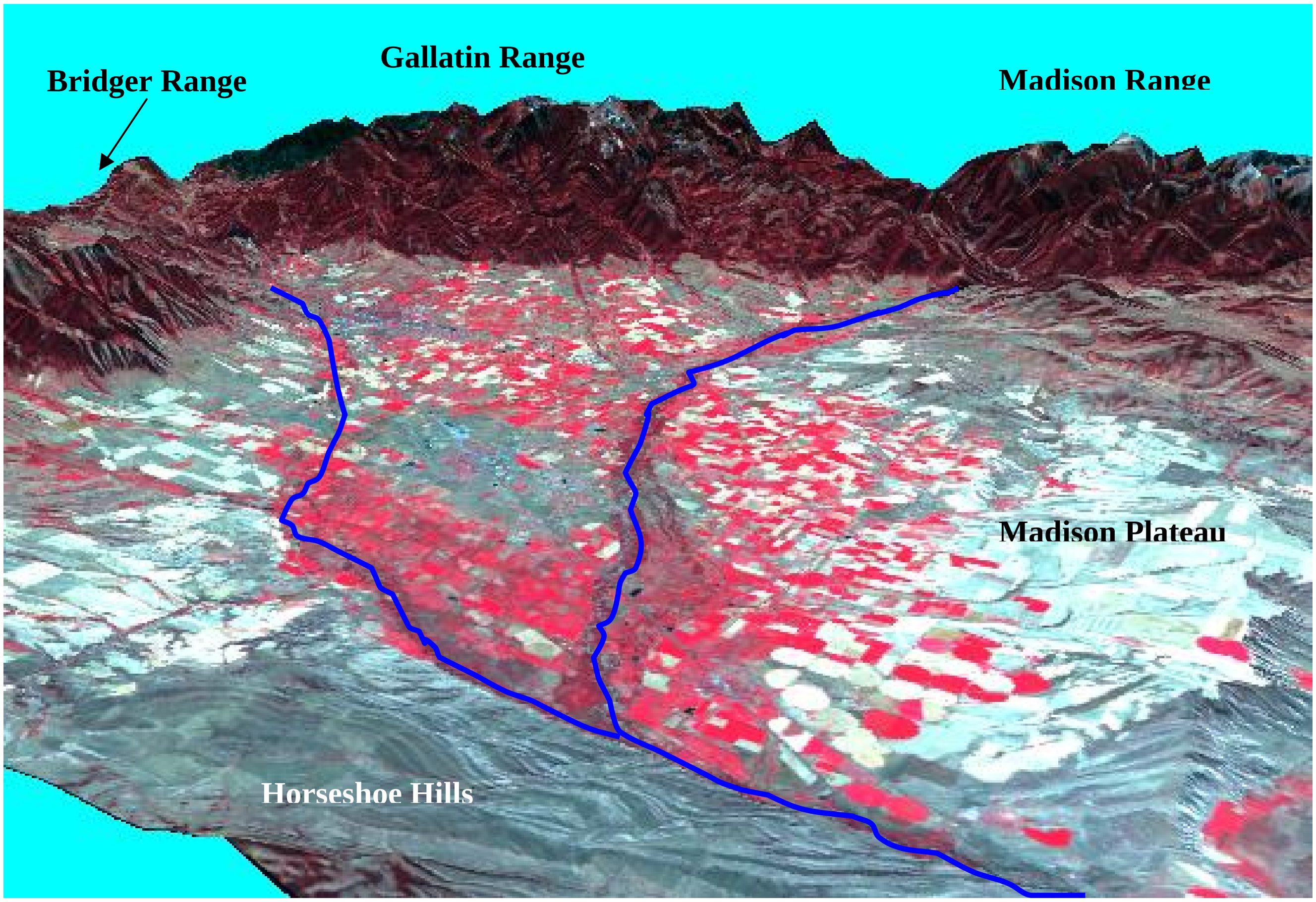

Figure 1. Oblique aerial view of the Gallatin Valley looking southeast. Base map is a digital mosaic of color infrared aerial imagery. The Gallatin Valley is bounded on the north, east, southeast, and southwest by uplifted mountains with exposed bedrock. The western boundary is the Madison Plateau, which is a broad area of higher elevation underlain by tilted Tertiary age sediments.

- ✓ Based primarily on detailed measurements of variations in the Earth's gravity around the valley, it is thought that the valley-fill sediments (gravel, sand, silt and clay) are up to 6000 feet thick in some places.

- ✓ However, the valley is not like a giant bowl filled with 6000 feet of sediment. Like the exposed bedrock in the surrounding mountains, bedrock under the valley is probably highly folded and faulted, with some very deep holes, and some areas where bedrock is close to the surface (see Figure 2).

Figure 2. A study of variations in the earth's gravity around the Gallatin Valley suggests deep holes along the base of the Gallatin Range, and east of Belgrade near the Bridger Range.

- ✓ Bedrock appears to be close to the surface in a line extended from the bedrock outcrops just southwest of Four Corners, through the area of Bozeman Hot Springs, under the MSU campus, and towards the Bozeman pass area. Excavations on the MSU campus have documented bedrock about 25 feet below ground surface.

- ✓ North of Belgrade a major fault crosses the valley following a line extending from Willow Creek, through the Central Park area, and through the Bridger Range as Ross Pass. North of this fault system bedrock is closer to the surface, while to the south in the Belgrade area, bedrock appears to be very deep.

- ✓ Almost all of the sediments filling the valley and resting on the bedrock floor are Tertiary age (2.5my-65my) sediments consisting of semi-consolidated (rocklike) clay, silt, sand, and fine gravels.

- ✓ With the exception of the Belgrade area, a thin layer of younger Quaternary age (2.5my-recent) gravel, sand, and has been deposited on top of the Tertiary age valley fill sediments.

- ✓ In the Belgrade area the younger Quaternary age sand and gravel deposits are over 400 feet thick.

II. AQUIFERS AND AQUIFER GEOMETRY IN THE GALLATIN VALLEY

- ✓ All of the ground water developed in the Gallatin Valley comes from three types of sedimentary aquifer materials (see figure 3).

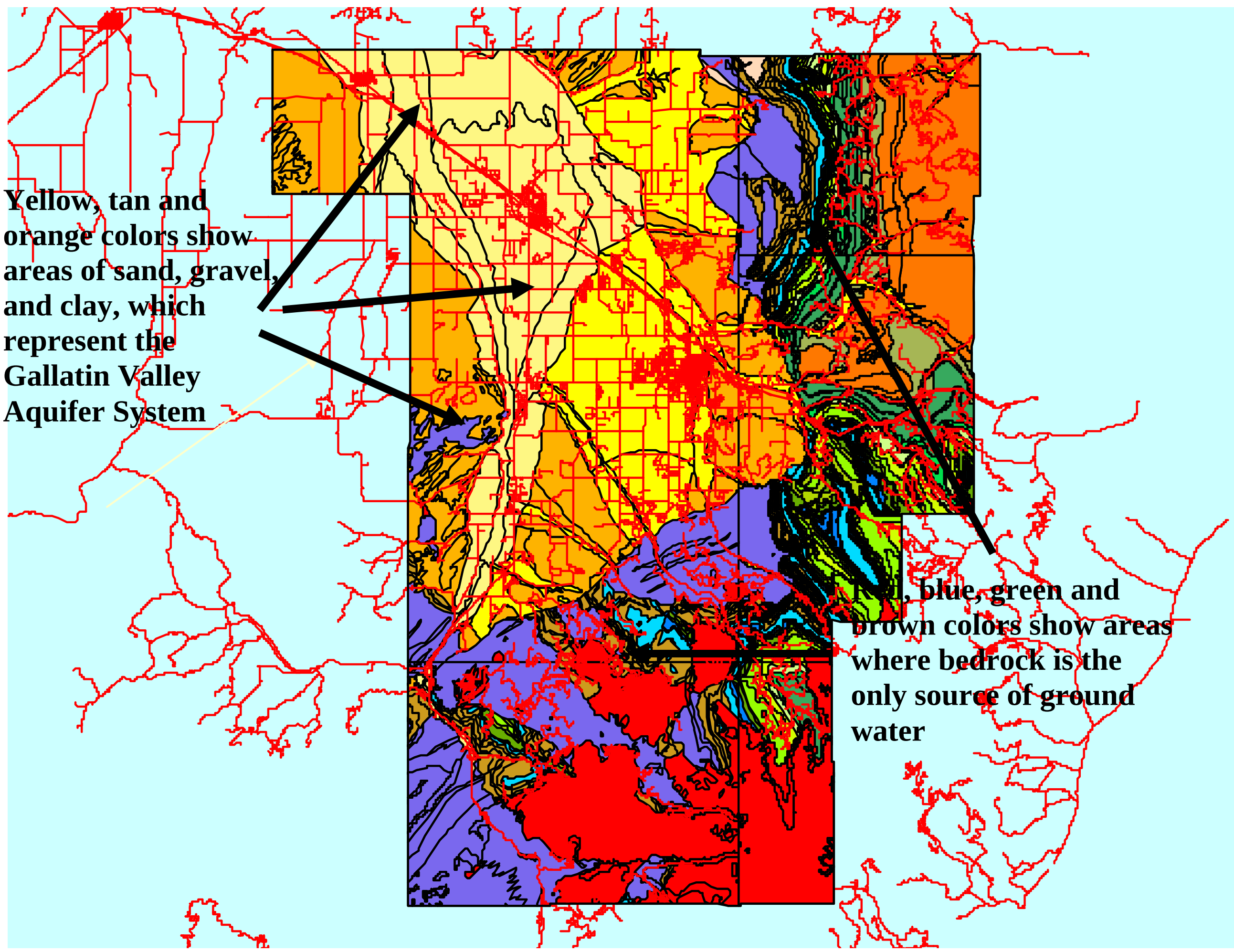

Figure 3. Generalized hydrogeologic map of the Gallatin Local Water Quality District showing the four primary types of aquifers in the Gallatin Valley. Coarse-grained deposits of the West Gallatin River (pale yellow), finer grained small stream deposits (bright yellow), and mostly fine grained Tertiary age deposits (orange) cover the surface of the Gallatin Valley. Various type of bedrock surrounds the valley.

- ✓ The most productive aquifer materials in the valley are coarse-grained sediments deposited by the West Gallatin River, referred to as West Gallatin Alluvium. These aquifer materials consist mainly of sand, gravel, and cobbles.

- ✓ The West Gallatin Alluvium covers the valley floor from the mouth of Gallatin Canyon to Manhattan, as shown on Figure 3.

- ✓ The West Gallatin Alluvium is generally less than 100 feet thick between the mouth of Gallatin Canyon and the Four Corners area, but it is over 400 feet thick to the north, under the area of Belgrade.

- ✓ North of Belgrade the West Gallatin Alluvium thins out across the Central Park Fault, and contains less cobbles and more silt and sand.

III. GROUND WATER FLOW IN THE GALLATIN VALLEY

Like the geology, very little is known about deep ground water flow in the valley. The following statements focus on what is know about ground water flow in the upper several hundred feet of the aquifer materials covering the valley floor:

- ✓ Ground water generally flows from southeast to northwest across the Gallatin Valley following the slope of the land surface, with the exception of ground water near the West Gallatin River (see Figure 4).

- ✓ The primary sources of recharge to the Gallatin Valley aquifer system is surface water flow into the valley via the West Gallatin River, tributary streams flowing out of the Gallatin Range, and tributary streams flowing off the Bridger Range.

- ✓ This source, timing and location of surface water recharge to valley aquifers is heavily modified by irrigation practices that redistribute surface waters. Much of this redistribution is associated with the West Gallatin River, with water distributed across the southeastern portion of the valley and along the east and west sides of the West Gallatin River valley. This irrigation water provides secondary, artificial recharge of surface water into the aquifer system.

- ✓ Recharge to the aquifer system from direct precipitation is less significant, and probably only occurs during significant rain events, and when valley snow cover melts off in the springtime.

- ✓ In the north/northwestern area of the Gallatin Valley there is a large ground water discharge area (see Figure 4). This is the lowest area in the valley, the aquifer materials appear to become thinner and finer grained, and there is bedrock along the north side (Horseshoe Hills) and across the Gallatin River at Logan (see Figure 5).

- ✓ Almost all of the ground water flowing through the valley discharges back into the lower West Gallatin, lower East Gallatin River, and the Main Gallatin River before Logan.

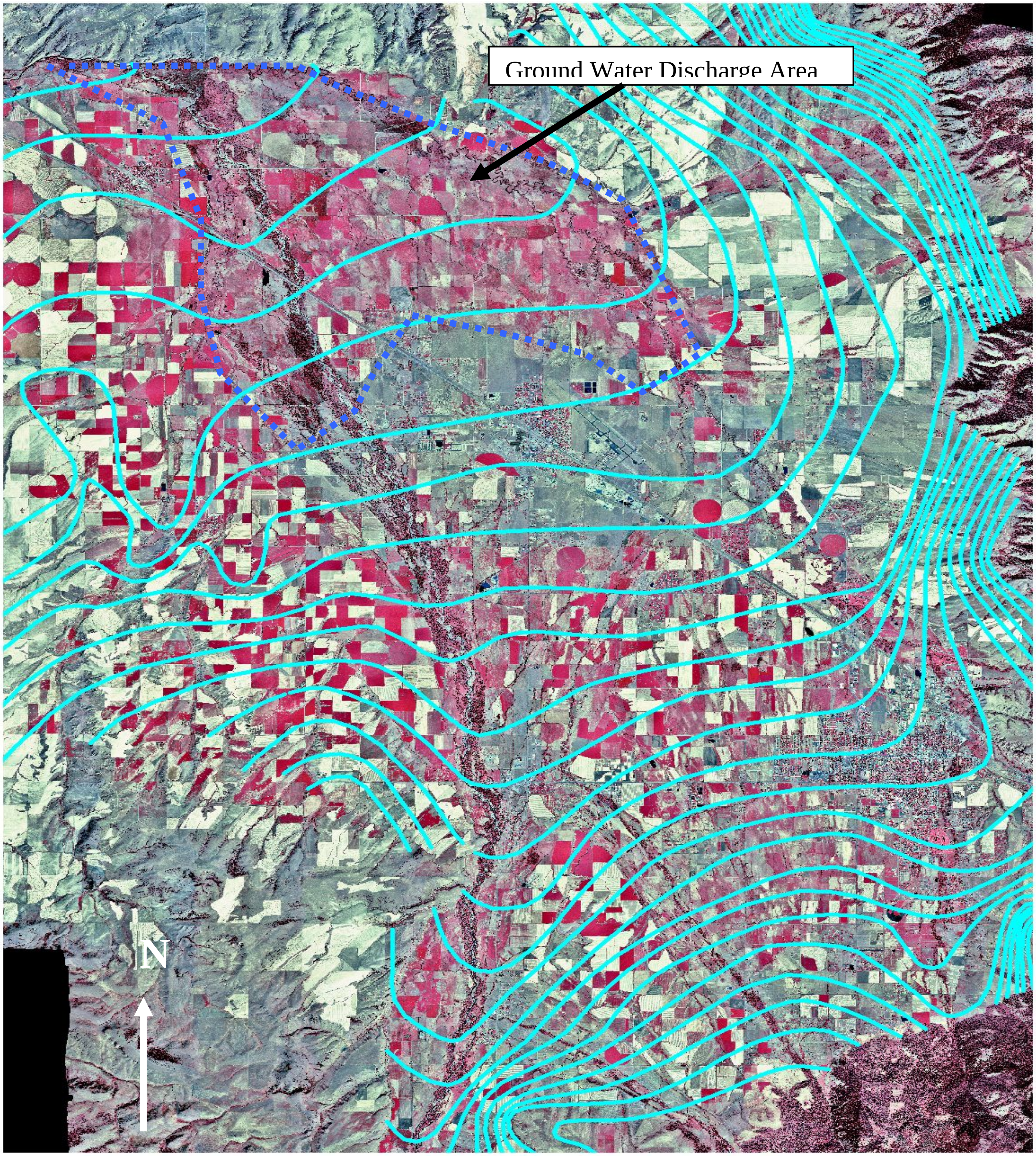

Figure 4. Elevation contour lines as mapped by the USGS (Slagle 1995) are overlain on a color infrared aerial photo mosaic of the Gallatin Valley taken in September 2001. Areas shown in bright red were being actively irrigated. Areas that appear as mottled darker red to purple are generally sub-irrigated or flood irrigated areas. A large ground water discharge area is visible in the northwestern portion of the Gallatin Valley.

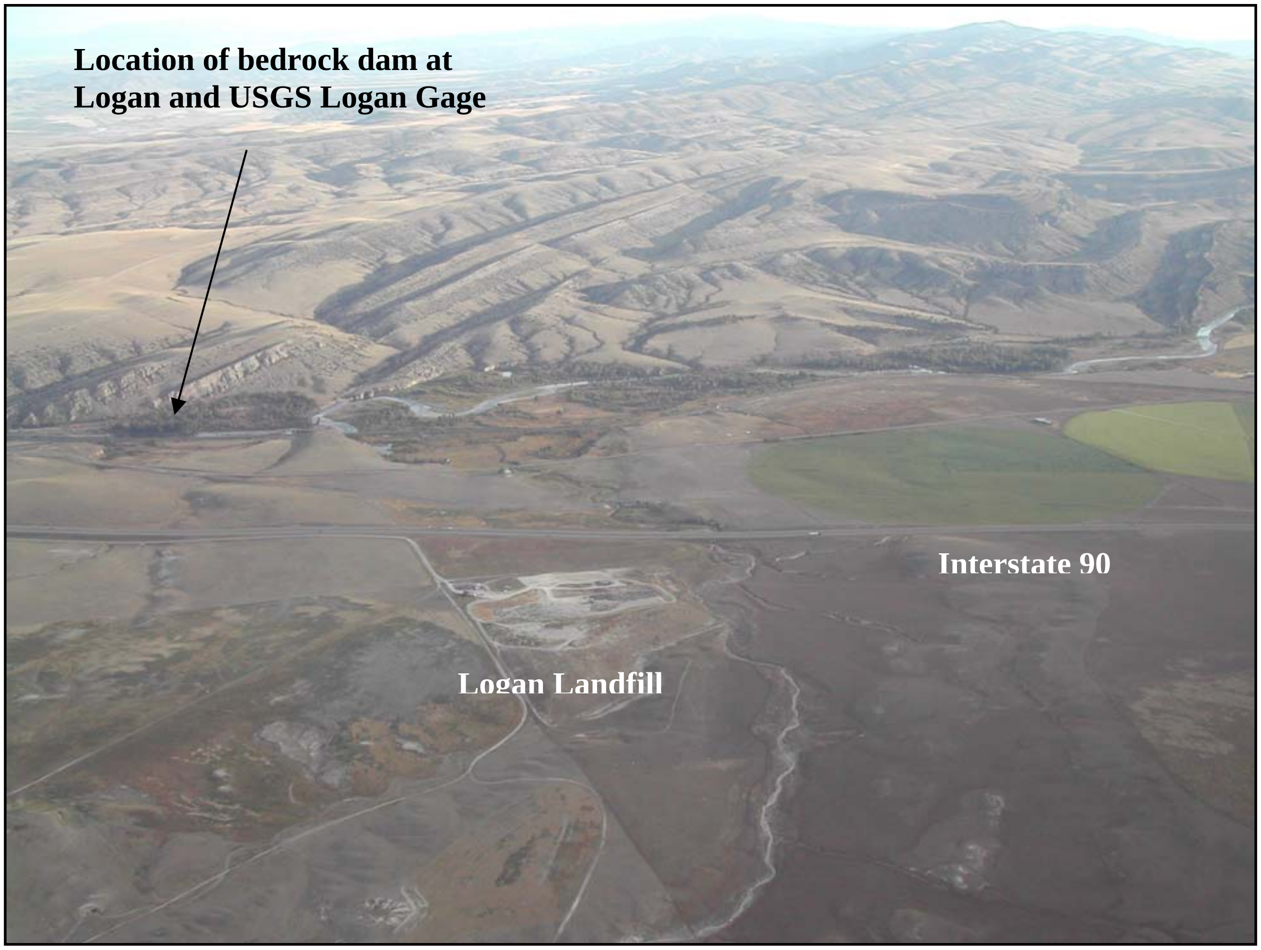

Figure 5. Oblique aerial view looking north where the Gallatin River crosses uplifted bedrock of the Horseshoe Hills. The bedrock acts as a dam, controlling the base level of the Gallatin River. Photo courtesy of Alan English, 2004.

IV. SURFACE WATER FLOW IN THE GALLATIN VALLEY

- ✓ The West Gallatin River is the primary source of surface water flow into the Gallatin Valley. Flow of the river into the valley has been measured by the USGS at the Gateway Gage since 1890. The Gateway Gage is located just upstream of the mouth of Gallatin Canyon.

- ✓ Based on long-term flow records for the Gateway Gage, the average flow surface water into the valley from the West Gallatin River is 584,000 acre-feet/year (see Figure 6).

- ✓ The flow of the West Gallatin River varies dramatically from year to year, ranging from a record low of 295,525 acre-feet/year in 1937 to a record high of 856,973 acre-feet/year in 1976. The difference in the highest and lowest flows is over 500,000 acre-feet/year.

- ✓ The significant variations in flow of the West Gallatin River and other rivers and streams is an important consideration for long-term use and management of the water resrouces.

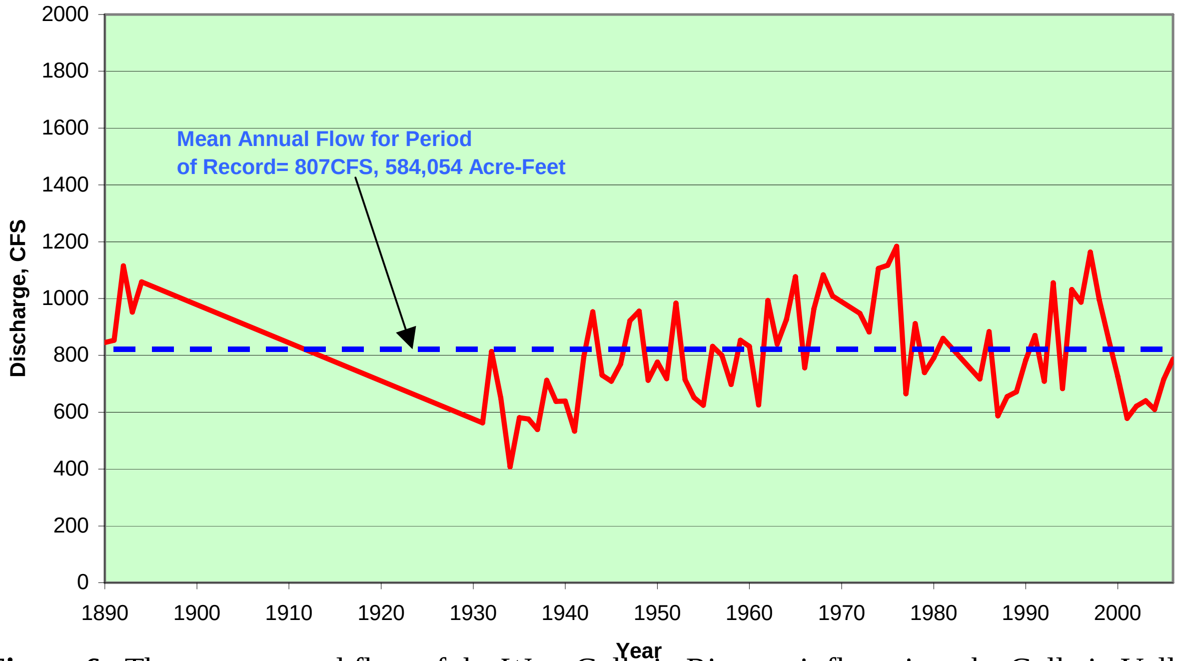

Figure 6. The mean annual flow of the West Gallatin River as it flows into the Gallatin Valley is 584,054 acre-feet/year. This flow is highly variable from year-to-year, which is an important consideration for use and management of the resource. Data from USGS Gateway Gage Station.

- ✓ Surface water flow into the Gallatin Valley from tributary streams flowing in from the Bridger, Gallatin, and Madison ranges contribute another 198,000 t0 234,000 acre-feet/year of water to the valley (Hackett, USGS 1960).

- ✓ The hydrograph of daily flow of the West Gallatin River at the Gateway Gage shows a typical curve for a stream dominated by melting of snowpack, but average daily flows vary dramatically from minimum and maximum daily flows (see Figure 7).

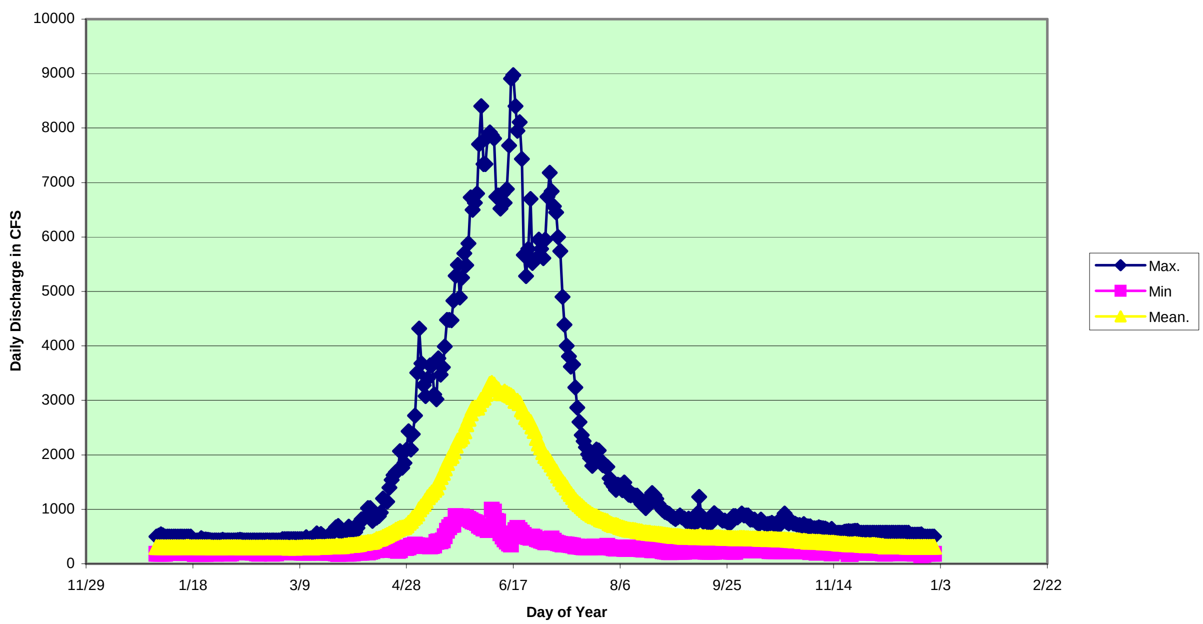

Figure 7. Record minimum and maximum daily flow of the West Gallatin varies from the mean daily average flow (yellow). Date from USGS Gateway Gage.

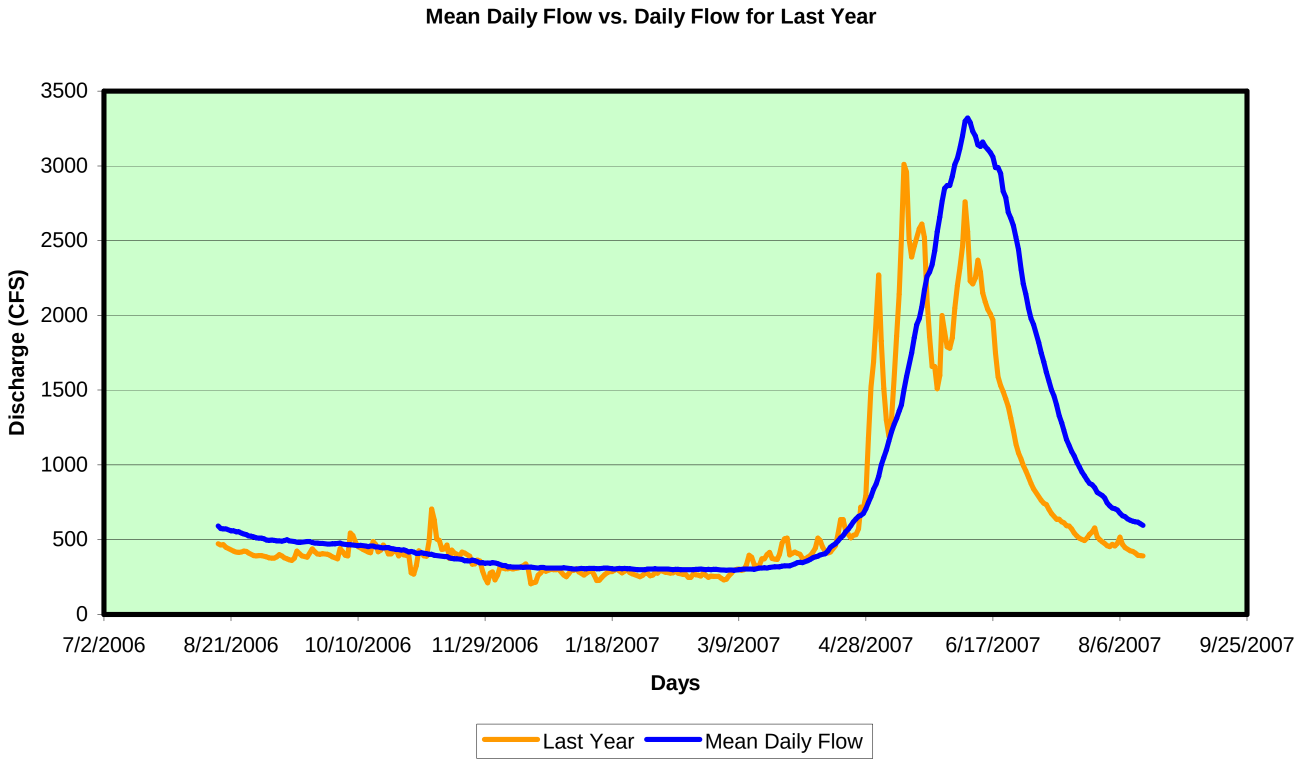

Figure 8. A comparison of the mean daily flow at the Gateway Gage and the daily flow for the last year (8-16-06 to 8-15-07) shows the unusually early snow melt peak experienced this year, and the current below normal flow in the West Gallatin River.

- ✓ This years flow in the West Gallatin at the Gateway Gage was unusual, with an early melt off of the snowpack. A comparison of flow for the last year with the long-term mean daily flows shows the hydrography is shifted about two weeks ahead of normal, and the current low flow is lower than normal. Data from USGS Gateway Gage.

- ✓ All of the surface water flowing out of the Gallatin Valley exits across the bedrock dam at Logan. The USGS has maintained a gage at Logan since 1893. This gage is effectively measuring the combined output of both ground water and surface water from the Gallatin Valley.

- ✓ Mean Annual flow of surface water out of the Gallatin Valley at Logan is about 773,000 acre-feet/year. Based on the Hackett study (USGS 1960) about 30% of the flow is attributable to surfacing ground water.

- ✓ Like flow at the Gateway Gage, the annual flow at Logan varies dramatically from year to year.

- ✓ A unique feature of the flow at Logan is that the annual hydrograph is modified from a standard snowmelt dominated peak. Flow at Logan reaches a minimum in early August, and then gradually increases through mid-November. This late season increase is probably due to a combination of ground water return flow and the end of the surface water diversions for the year (see Figure 8).

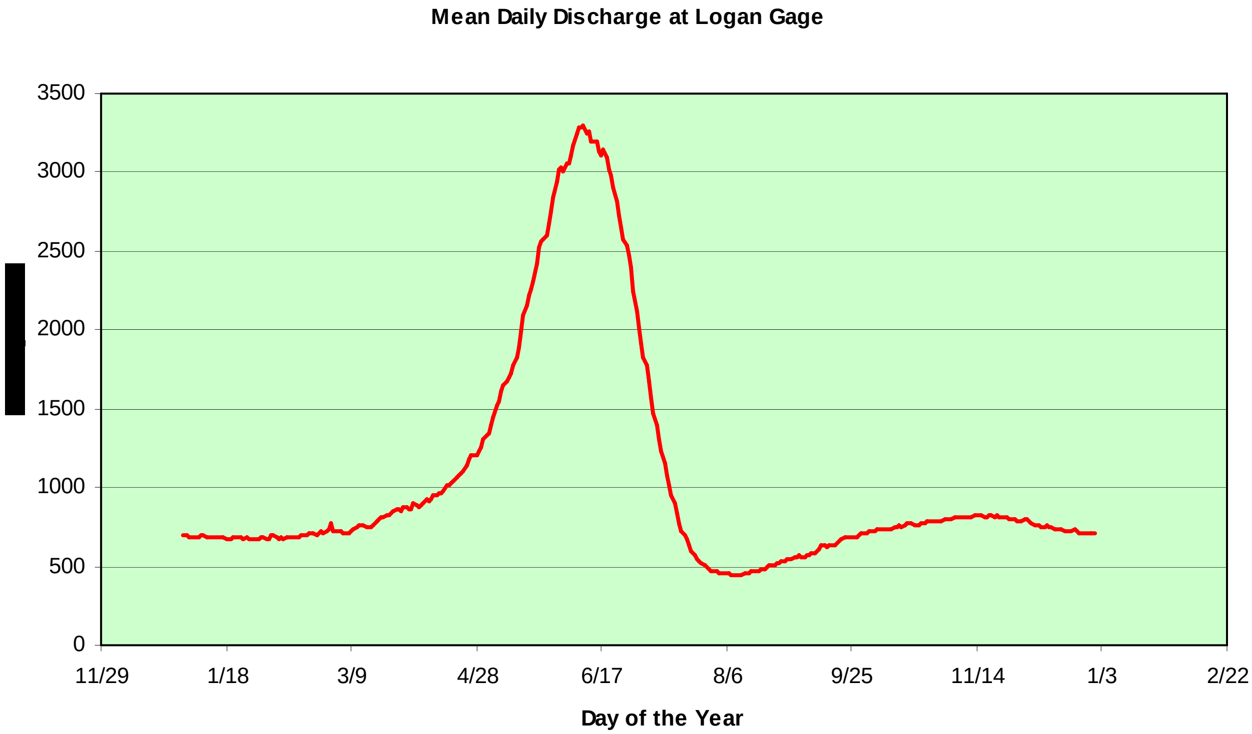

Figure 8. A plot of the average daily flow at the Logan Gage for the period of record from 1893 to 2006 shows that the flow is influenced by the spring snowpack melt, and by late season ground water discharge. Data from USGS Logan Gage Station.

V. APPROXIMATE WATER BUDGET FOR THE GALLATIN VALLEY

- ✓ An estimate of the annual amount of water that moves into and out of the Gallatin Valley was made using existing information available in 2001 (see Figure 9).

- ✓ Water flow into the valley comes from the West Gallatin River, tributary streams, ground water flow, and direct precipitation.

- ✓ With few exceptions, almost all of the water that leaves the valley exits as surface water flow at Logan, enters the atmosphere by evaporation, or is evapotranspired by native plants and crops.

- ✓ The budget assumes that in the long-term ground water levels remain fairly constant and ground water recharge and discharge are in balance.

- ✓ Based on the estimates used, the overall water balance appears reasonable, with an error of about 1.5%. While the numbers used to develop the water budget have errors, and need updating, the budget still shows what the general magnitude of the different sources of water into and out of the Gallatin Valley are, and what the primary consumptive uses of water are.

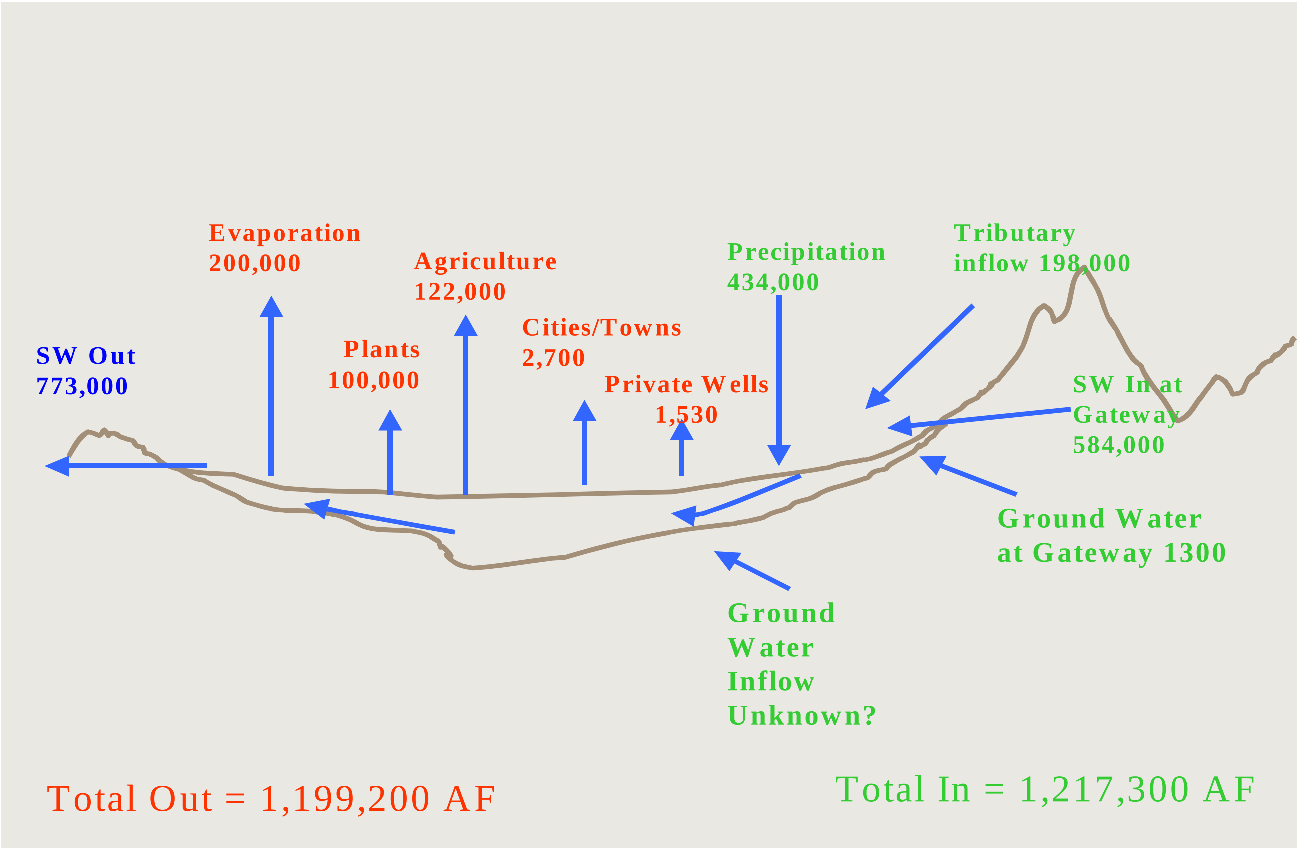

Figure 9. An approximate water budget for the Gallatin Valley showing sources and relative amounts of water that come into, and leave the valley. The data was compiled from a number of sources by the Gallatin Local Water Quality District.

- ✓ There is no dought that the consumptive use of water by cities, towns, small public water supplies, and private (exempt) wells has increased significantly during the last 10- years.

- ✓ Figure 10 shows the rate of drilling of wells in Gallatin County by year. The data shows that for the last 10 years more than 500 wells per year are being drilled. Data for 2007 is incomplete.

- ✓ There are currently 14,517 wells on record for Gallatin County. Using the same numbers used in the water budget (figure 9), the consumptive use of water for private wells is estimated to be 2,439 acre-feet/year

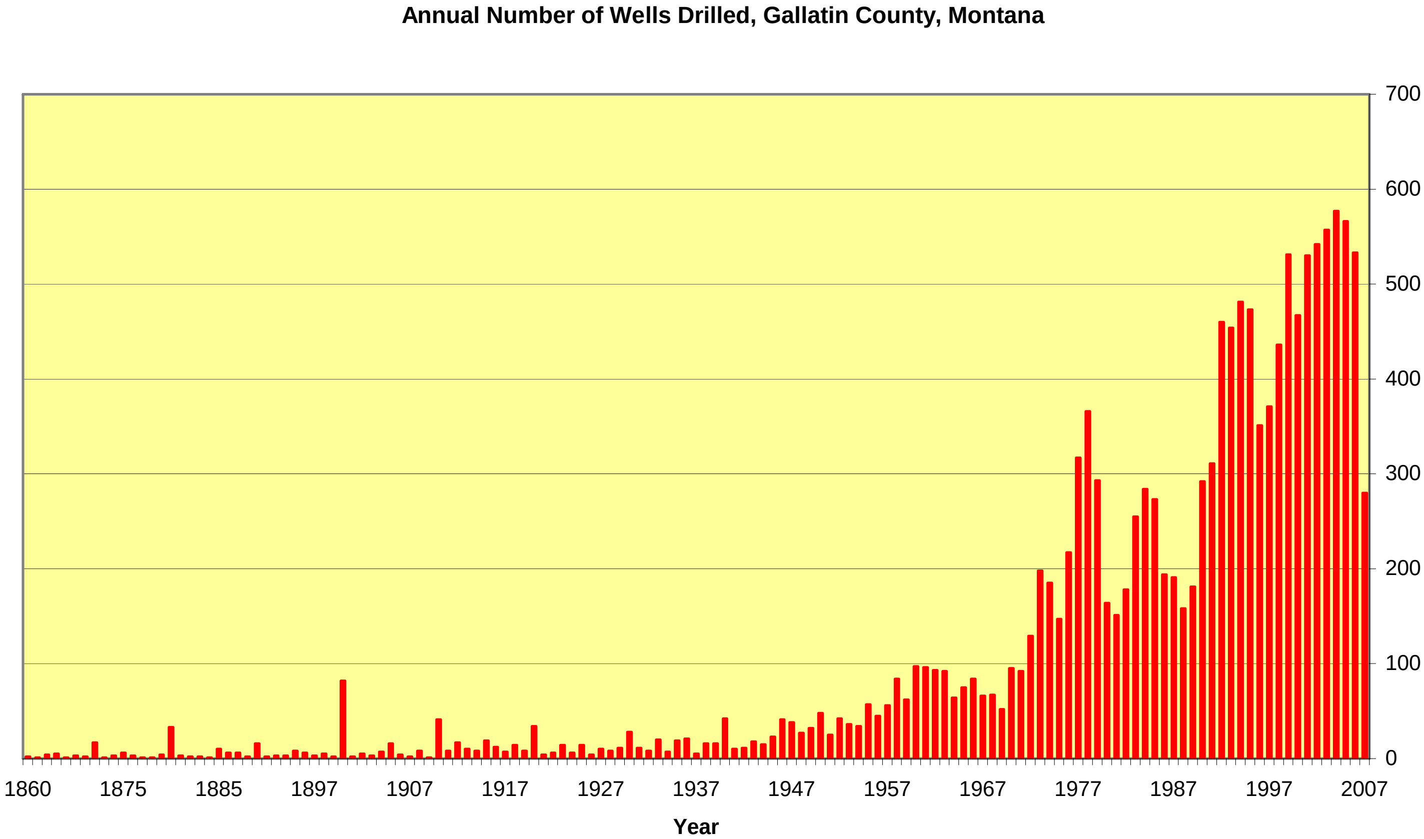

Figure 10. Wells drilled in Gallatin County per year are plotted to show the dramatic increase in well drilling in Gallatin County since the late 1980s. The earlier growth spike in the area in the 1970s also appears. Currently wells are being drilled at a rate of more than 500 per year. Date from MBMG Ground Water Information Center.