July 11, 2007

Members of the Water Policy Interim Committee,

My name is Robert Van Deren. We have a ranch north of Dillon on the west side of the Beaverhead River.

I understand part of your materials include the Bureau of Mines and Geology report, "Hydrogeology of the Upper Beaverhead Basin near Dillon, Montana" by Uthman and Beck.

Pages 3-5 of the report discusses the situation that initiated the groundwater study. Basically, there were significant ground water developments occurring in the Upper Beaverhead along Rattlesnake and Blacktail Deer Creeks. There was a concern that the ground water pumping was shorting water from the River, because the volume of water pumped was thought to be approximately equal to the storage water lost below Barretts Diversion dam. East Bench was particularly concerned because their second priority meant they would be the first to bear any shortages.

The report only considered induced surface water infiltration or when a wells cone of depression intercepts surface water. It did not contemplate the interception of groundwater flow tributary to the stream because it was completed about 10 years before the Trout Unlimited Smith River decision. Uthman and Beck's conclusions would likely be different today because of the different legal standard.

The report looked at the cumulative impacts of ground water pumping during the time of the study, 1991 to 1996. Uthman and Beck did not analyze the cumulative impacts of the wells we looked at yesterday, because they did not exist at the time of the study.

The Montana Bureau of Mines and Geology has continued to monitor the wells from the Uthman and Beck study. Generally, the deeps wells appear to show long term declines and the shallow wells appear to be affected by the stage or level of surface water in nearby river/stream/canal. This long-term monitoring data was not available to Uthman and Beck.

As the report title states, it is the "Hydrogeology of the Upper Beaverhead Basin". The analysis area did not include the lower Beaverhead from Dillon to the Beaverhead Rock or Point of Rocks. Uthman and Beck did not analyze the cumulative impacts that groundwater pumping in the Upper Beaverhead may have below Dillon. I have included a copy of a report by Montana Tech Geology Professor Willis Weight. Weight completed an initial study on Beaverhead Basin below Dillon that was published in July 2007.

Thank you for the opportunity to provide these comments.

Rob Van Deren
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WATER POLICY INTERIM COMM.
JULY 10-11, 2007
EXHIBIT 24

Beaverhead Valley Groundwater Study
Final Report – USBR Fund 526091

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Department of Geological Engineering
Montana Tech of the University of Montana - Butte

Introduction

Within the Pick-Sloan Missouri River Basin Program is the East Bench Unit (EB Unit), which includes the East Bench Irrigation District (EBDist) and the Clark Canyon Water Supply Company (CCWSC). The EBDist supplies irrigation waters for bench lands on the east side of the valley and the CCWSC supplies water for the valley bottom (Figure 1). Waters stored in the Clark Canyon Reservoir (CCR) mostly supply the EBUnit. The Clark Canyon Reservoir has supplied water for the East Bench Canal as well as waters to the Beaverhead River to supply minimum flows for fisheries and recreation. Both the EBDist and CCWSC have contracts for storage water from the CCR with the Bureau of Reclamation. Waters to the EBDist are directed through a single diversion at Barrett's, while waters supplied to the CCWSC are supplied by many diversion points downstream of the Barrett's diversion. It is significant to note that EBDist's water rights are junior to those of the CCWSC.

Figure 1. Google Earth view of study area showing Dillon Montana, Highways 41, 91 and Interstate 15. Green areas in the photo indicate the influence of irrigation waters from the East Bench Canal, the West Side Canal, and the floodplain of the Beaverhead River. North is toward the left side.

In 2004 and 2005 a water-budget analysis was conducted by Montana State University (MSU) to account for major diversions of surface water and attempt to account for irrigation return flows occurring between Clark Canyon Reservoir (CCR) and Twin Bridges, Montana. This was done to better understand issues related to allocation and distribution. Complicating matters were the effects of a drought and subsequent drilling and exploitation of groundwater to augment the demands. In 2004 twenty-two gauging sites were established on the Beaverhead River from the CCR to Twin Bridges as a first attempt to monitor surface flow from May to October. In 2005 the number of surface sites was expanded to 34 stations. The study area was broken into six sections and the unmonitored gains or losses for each section was calculated and compared with the measured flows (Table 1).

Table 1. Summary of MSU water balance estimates and seasonal flows in acre-feet for sections of the Beaverhead River recorded at MSU and USGS gaining stations. (After: Progress Report 2005 by Sessoms and Bauder, 2005).

Section	Calculated Balance in acre-feet	Measured Flow in acre-feet	Unmonitored gain or loss to/from each section of the BH River (acre-feet)
1. Clark Canyon Dam to Beaverhead at Barrett's	90,008	102,487	12,479
2.Barrett's to Dillon USGS Station	29,925	37,318	7,393
3. Dillon USGS station to Anderson Lane	32,582	25,932	6,650
4. Anderson Lane to Point of Rocks	12,183	41,114	28,930
5. Point of Rocks to Giem Bridge	32,459	24,255	8,204
6. Giem Bridge to Twin Bridges	144,691	137,383	7,308

The most glaring section in Table 1 is Section 4 (from Anderson Lane to Point of Rocks), showing a nearly 29,000 acre-feet gain. Where did this water come from and why did the surface water accounting system fail to account for the increase? There were no groundwater studies conducted to complement the surface-water study.

Background

The principal author's interest in this groundwater study north of Dillon began in early 2003, while performing consulting work for a client who was worried about having enough water to run "the farm", while surface-water allotments seemed to be threatened by an enduring drought. In an act of desperation, ranchers and farmers drilled a number of high-capacity irrigation wells to remain in business, until surface flows in the East Bench Canal returned. The drilling and pumping of new wells was clearly an exacerbation of the problem. With no baseline data it seemed imperative that something be done to understand the groundwater system north of Dillon. Gratefully, the Beaverhead County Commissioners offered some seed money to promote the initiation of data collection, followed by the Bureau of Reclamation contributing enough to cover the basic expenses of a graduate student. All time and efforts by the principal author are "in-kind", including this report, but are offered to provide information to those persons kind enough to allow data collection from their wells and to offer a better understanding of a very important problem.

During the early 1990's a detailed groundwater field study was conducted to evaluate the impacts of irrigation wells on the groundwater system in the Beaverhead drainage area near Dillon (Uthman and Beck, 1998). The monitoring network in the study area was comprised of domestic and drilled wells within Section 2 of Table 1. As part of those studies, it was discovered that the East Bench Canal contributes recharge to the aquifers of the areas it passes over. Between July 2003 and May 2005 the flow of water in the East Bench Canal was completely shutdown. What happened to water levels in wells near the canal? What are the impacts of new wells in the area and how much groundwater that would normally flow to the Beaverhead River is being intercepted by these activities? Where did all the water come from in the Beaverhead River that arrived at Beaverhead Rock?

Acknowledgements

A network of approximately 40 wells (domestic, stock and irrigation production wells) was established by permission of kind and helpful residents within the study area (Figure 2). Gratefully the Beaverhead County Commissioners supplied some seed money to get this study started, followed by the US Bureau of Reclamation. Additionally, Bill Uthman of the DNRC was helpful in showing us where wells from the previous study were located and assisted in surveying (GPS) the positions and elevations of the new wells. Water quality equipment from the Department of Geological Engineering at Montana Tech's campus in Butte facilitated the collection and evaluation of surface water quality data and groundwater return flows from irrigation along with other recharge waters from precipitation.

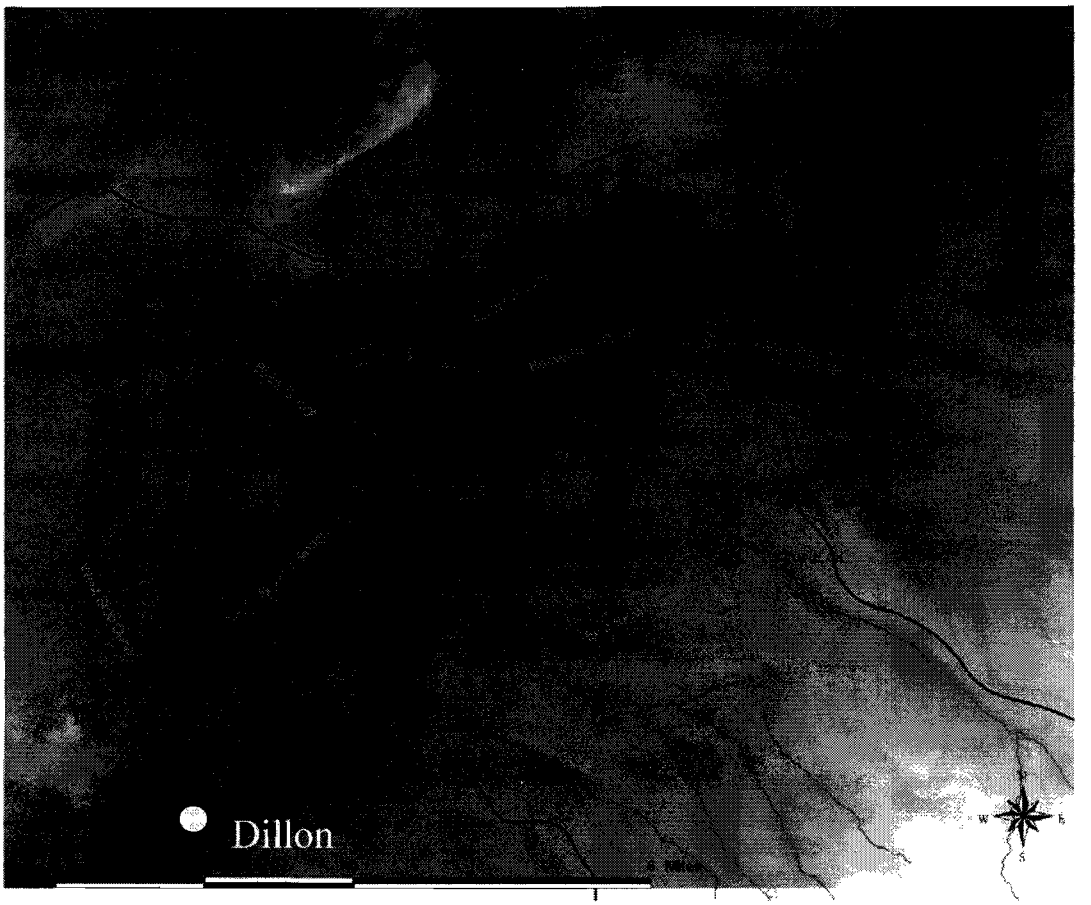

Figure 2. Network of wells (in red) used to evaluate water levels north of Dillon Montana.

Scope

The following objectives were set forth for this study:

- Reevaluate the groundwater conditions in the Dillon area (Section 2 in Table 1) by re-measuring the water levels in wells used in the 1990 – 1995 study. Compare hydrographs of wells scattered over the region to evaluate changes largely attributed to drought.

- Establish a network of groundwater wells in lands represented by Sections 3 and 4 of Table 1 to establish a baseline from which future water levels can be compared. Funding was not available to drill new wells within the study area. Water-level elevations were to be contoured to represent a potentiometric surface of groundwater conditions in the spring (April or May) and late summer (August or September) for 2005 and 2006. At least monthly levels were measured for most wells.

- Gather aquifer-testing data from constant-discharge tests or slug tests to characterize the aquifer properties within the study area (Weight and Sonderegger, 2001). No data were collected within the Beaverhead River floodplain in Sections 3 and 4 of Table 1, however aquifer properties from pumping tests in the floodplain of the Beaverhead River in Section 2 of Table 1 were published in the study by Uthman and Beck (1998) and slug test data were published by Weight and Wittman (1999).

- Collect water-quality data to evaluate the interaction of groundwater and surface water.

Geology

The geology of the area can be characterized by Quaternary alluvial deposits (orange brown) overlying Tertiary layered sediments (brown) consisting of silty materials interbedded with sand and locally cemented gravels (Figure 3). In the north-central part of the monitoring area in Figure 3 are low hills consisting of Tertiary volcanics (dark brown). (The Dallasera well in Table 2 below is completed in the Tertiary volcanics for example). Drillhole data indicate that Tertiary sediments yielding groundwater to production wells are thinner on the west side, with thicknesses less than or near 400 feet, while test holes exceeding 550 feet on the east side did not penetrate the Tertiary aquifer. It is typical that most basins in southwest Montana are asymmetrical with the east side having thicker packages (being down-dropped further) of sediment than on the west (Ruppel and Others, 1993).

Figure 3. Geology of the north Dillon area from the Dillon 1o by 2o sheet after (Ruppel and Others, 1993).

Comparison of 1995 data with 2005

Water levels were collected at several of the same wells measured by Uthman and Beck (1998) during 2005. In comparing the groundwater elevations, the effects of the seven-year drought are observed (Figure 4). Generally, there was a drop of approximately 2 to 5 feet in the potentiometric surface from 2005 data over 1995 data.

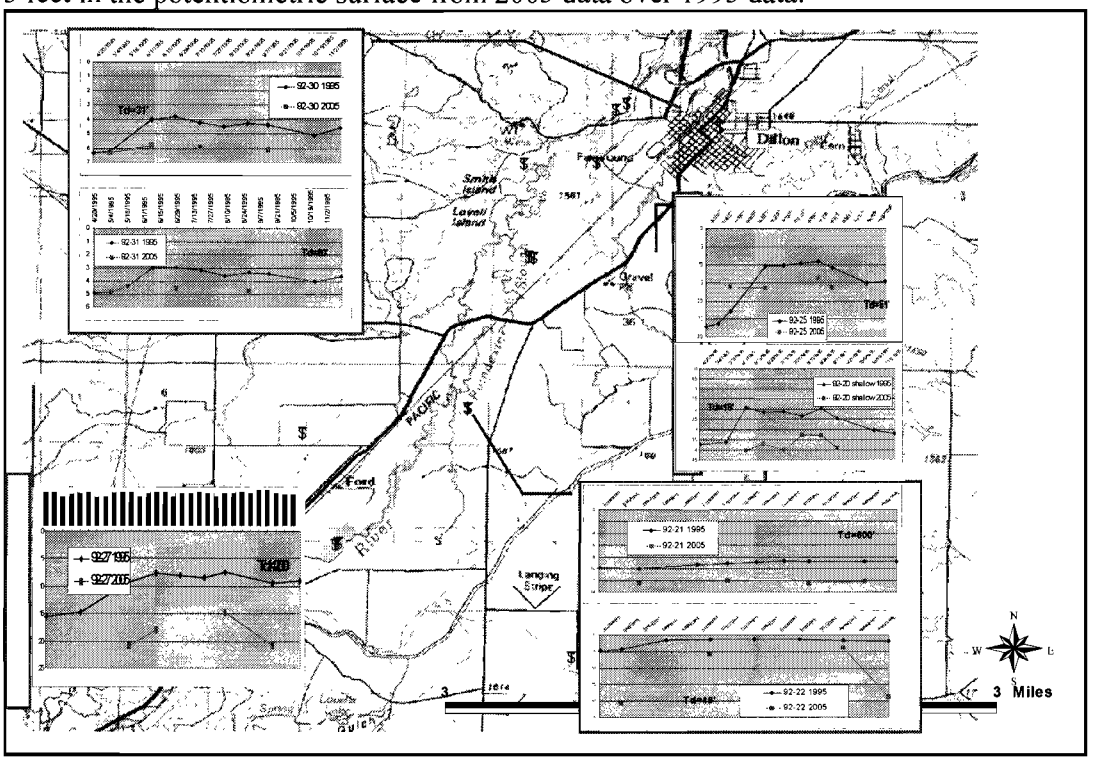

Figure 4. Comparison of water levels from 2005 (pink) with those taken in 1995 (blue). Most levels are 2 to 5 feet lower, indicating the effects of the 7-year drought.

Well Network North of Dillon

Approximately forty wells were included in a network over various parts of the region between Dillon and Point of Rocks (Figure 2). The elevations and locations of wells were determined via a GPS survey facilitated by Bill Uthman and equipment from the DNRC. The results of the surveys with locations of the wells are shown in Table 2.

Table 2 Measuring Locations of Wells North of Dillon Montana Used in Monitoring Network.

SITE DECSRIPTION	STICK-UP	Latitude	Longitude	Elevation
Dillon Equip.	-1.50	45.23069	-112.62783	5068.134
Coburn gps front	-1.20	45.24419	-112.62542	5045.416
Coburn gps back	0.20	45.24439	-112.62503	5049.766
Hilton Apts Well	-1.50	45.23461	-112.62324	5060.783
LS gravel pit	20.00	45.24446	-112.63392	5034.302
LS office well	-1.00	45.24557	-112.63551	5054.640
Contway Domestic	-1.00	45.31954	-112.63948	5123.188
Roxies Green House	-2.50	45.24753	-112.62782	5045.584

DALLASERA Obs Well	-1.00	45.35746	-112.63020	5128.453
HERMAN Domestic	-1.70	45.33553	-112.64708	5156.987
Anderson Domestic	3.00	45.32060	-112.61872	5012.899
Mangel House	-1.40	45.34886	-112.59129	5068.538
Mangel Trailer	-1.50	45.34476	-112.59365	5048.412
Erb barn	-3.40	45.32852	-112.58445	4944.541
Mallon Stcok - pit	2.80	45.31347	-112.60942	4997.509
VANDEREN BENCH	-1.40	45.34775	-112.57013	5046.756
Vanderen HOUSE	-1.50	45.34484	-112.55887	4944.021
Cody Meine Domestic	-1.10	45.31348	-112.60035	4982.954
Thrift - Domestic	-1.00	45.30658	-112.60331	5033.823
Meine house	-1.00	45.32092	-112.60084	4979.806
Erb Stock near Ander Ln.	-1.80	45.30114	-112.58176	4955.624
Stod Bros 800OBS	-0.70	45.30582	-112.52837	5046.694
STOCK1 neat S Bros	-0.70	45.30790	-112.52964	5021.267
Spud Cellar Well	-1.80			
SKONE & Conners Stock	-0.80	45.31242	-112.49940	5033.844
Stock in SWALE	-1.20	45.29365	-112.49712	5160.749
STONE CK near Hwy 41	-2.00	45.29040	-112.46496	5279.811
Stoddard Shop	-1.00	45.30545	-112.49763	5121.610
Stoddard MAIN Obs	-1.50	45.29994	-112.49232	5167.305
SETH Stoddard Domestic	-2.00	45.28498	-112.47851	5319.616
TEST near East B	-1.60	45.29023	-112.48438	5231.401
MEXI Trailer well	-1.00	45.30149	-112.47878	5160.407
HELLENBRN Domestic		45.25006	-112.57266	5065.826
KONEN Domestic	-1.40	45.25152	-112.57716	5049.358
HELLENSTOCK1350	-1.10	45.27527	-112.54689	5060.068
COTTOM OBS		45° 14' 42.66756"	112° 35' 18.14655"	5034.064
COTTOM NISSEN		45° 14' 6.45522"	112° 34' 55.59557"	5087.546
COTTOM NISSMAIN		45° 14' 8.45074"	112° 34' 55.76737"	5082.698

Data from water-level measurements were used to construct potentiometric surfaces and evaluate whether there may be more than one aquifer system (Figure 5).

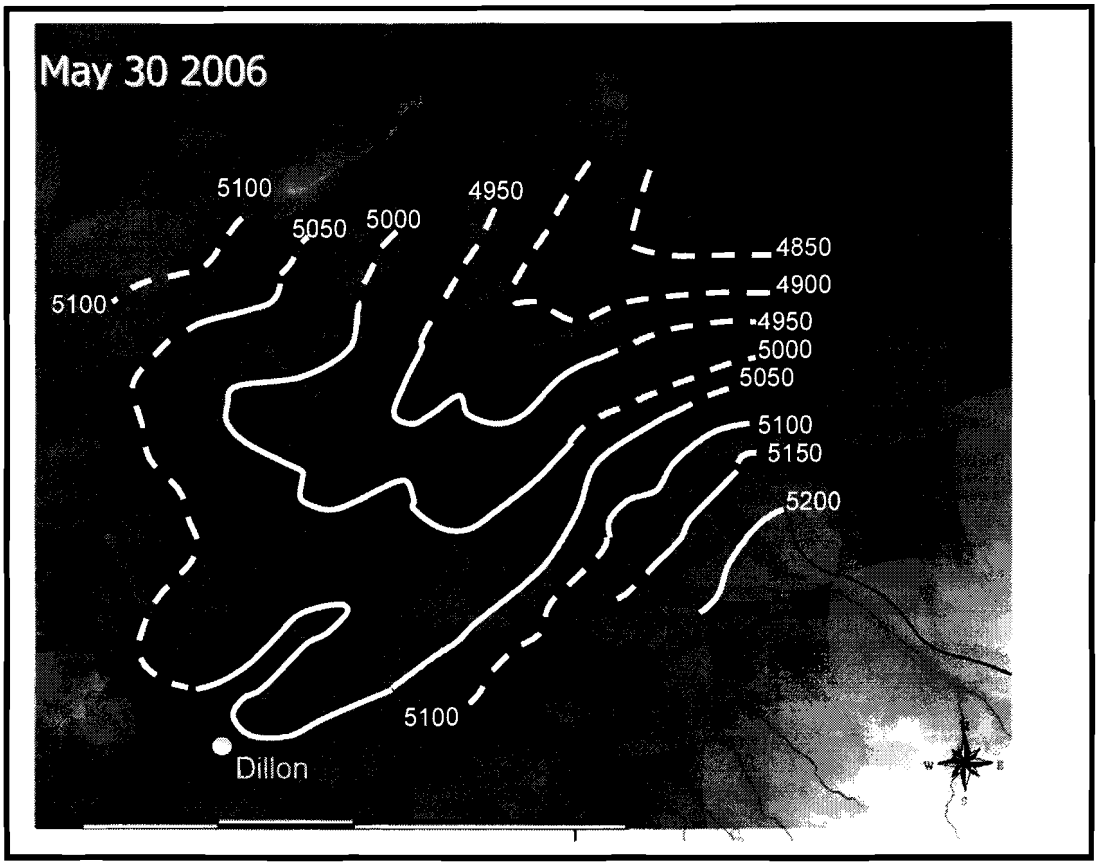

Figure 5. Potentiometric surface showing the May 30 2006 water-level data. Contours are every 50 feet.

The potentiometric surface shown in Figure 5 indicates the Beaverhead River has a higher stage elevation than the nearby groundwater levels north of Dillon resulting in significant loses of surface water to the groundwater system (groundwater flows away from the River). (Notice that this occurs where the valley widens). The Beaverhead River appears to continue to lose water until after its confluence with Stone Creek. From then on surface sloughs and groundwater flow seeps back towards the Beaverhead River resulting in a gaining river. Note also that this is where the valley narrows once again, constricting groundwater flow, resulting in the large wetlands near Beaverhead Rock (Figure 6). Given the scale of the area in Figure 5 the contour interval, 2005 data and August 2006 data are not significantly different; therefore other figures were not created for these data; however the hydrographs of individual wells are presented and compared later on.

The slope of the potentiometric surface is proportional to the transmissivity properties of the aquifer. For example, the slope of the potentiometric surface in Figure 5 is flatter within the floodplain of the Beaverhead River indicating a higher transmissivity than the slopes of the water table towards (from the south and northwest) the Beaverhead River. In addition, the recharge elevation on the East Bench side appears to be higher than that on the West Side. The West Side also appears to have a depression where the 5000-foot

elevation contour loops to the west. Most of the wells on the west side used to create the contours in Figure 5 were relatively shallow (less than 150 feet). Two wells shown further to the west near Highway 91(Herman and Contway) and up-gradient of the West Side Canal are much deeper (greater than 300 feet) and the water level elevations are approximately 50 to 80 feet lower than those of the shallower wells. A 50 to 100 foot clay layer that separates the upper aquifer from the lower zone can explain this. The behavior of hydrographs from most wells is discussed later in the next section.

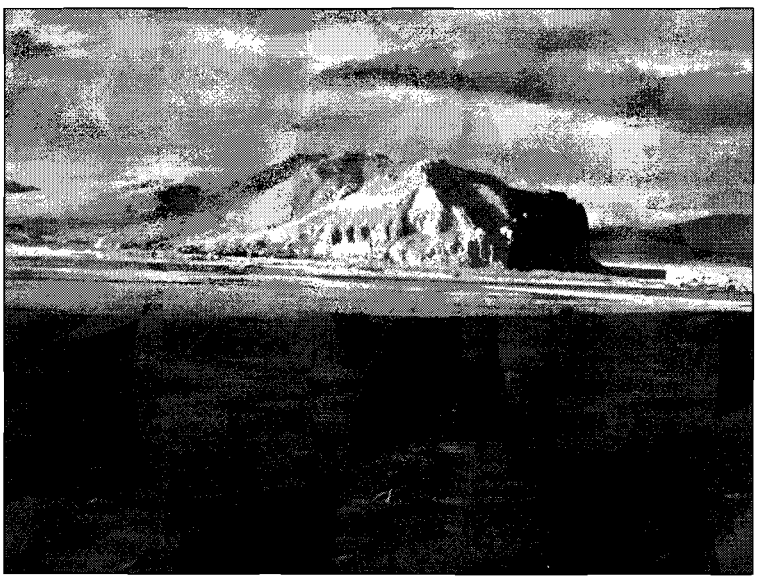

Figure 6. Photo of Beaverhead Rock, also showing large wetlands along the Beaverhead River.

Hydrograph Data

When one plots the elevation of groundwater levels over time a hydrograph is obtained. Patterns and trends are then explained by interpretation. Figure 7 shows the hydrographs of two wells located near the East Bench Canal. The hydrographs clearly indicate the impacts from having no recharge water from the Canal between July 2003 and May 2005. (The elevations of water levels in Figure 7 drop dramatically beginning in 2003). Data like these are helpful in helping understand the surface-water groundwater system.

Hydrographs were prepared to compare the behavior of wells in the Beaverhead River Floodplain, the West Side, and the East side. This is followed by discussion.

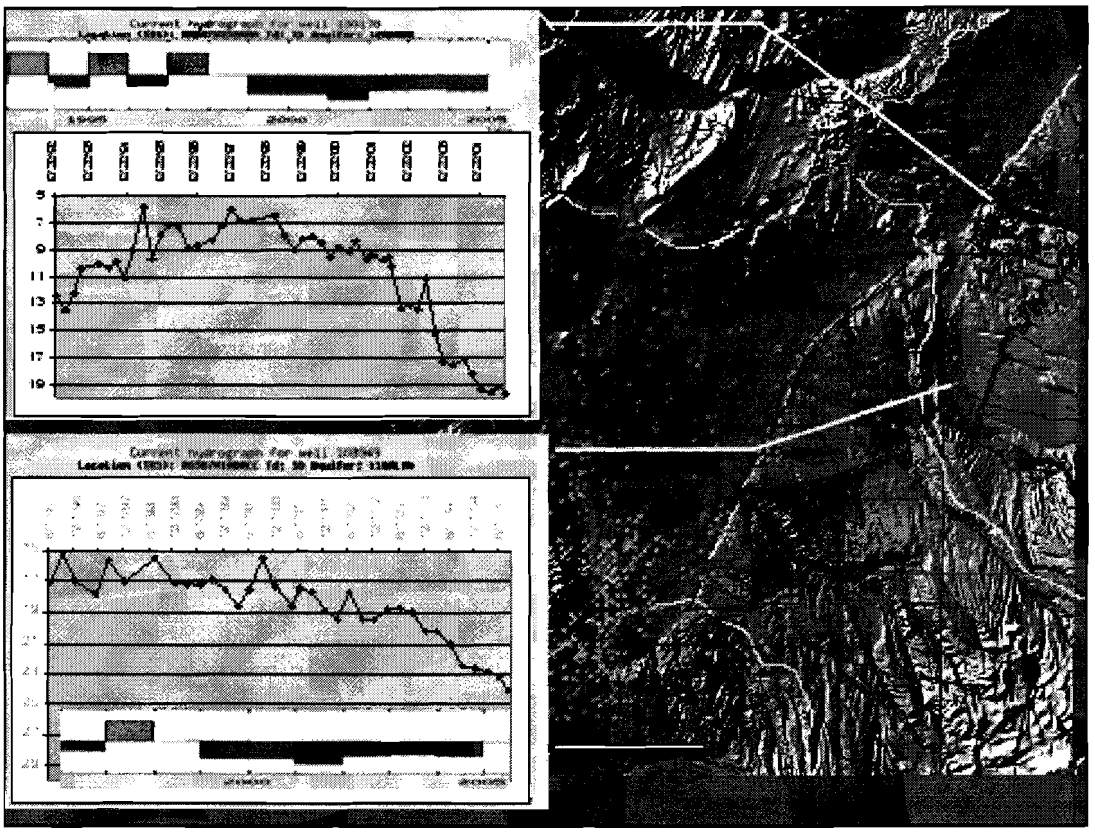

Figure 7. Hydrographs of two wells located in the Tertiary of the East Side below (down-gradient) the East bench Canal. The data span ten years from 1995 to 2005. The red columns below each graph indicate below normal precipitation and the green panels represent above normal precipitation. Note the long trend of red panels representing the drought. Data are from the Montana Bureau of Mines and Geology GWIC database.

Figure 8 shows the locations of wells north of Dillon within the Beaverhead River floodplain. There are some located on both sides of the river. The hydrographs of some of these wells are shown in Figure 9. The cyclic pattern shows the response of groundwater water elevations to river stage. Water released from the CCR in late summer corresponds to the rise in groundwater elevations. The level elevations of these wells span two years, from 2005 to 2006. The response of the groundwater elevations with river stage indicates that the groundwater surface-water system in the floodplain is well connected. Notice how all wells show the same rising and falling trends compared to surface water stage and flow presented below.

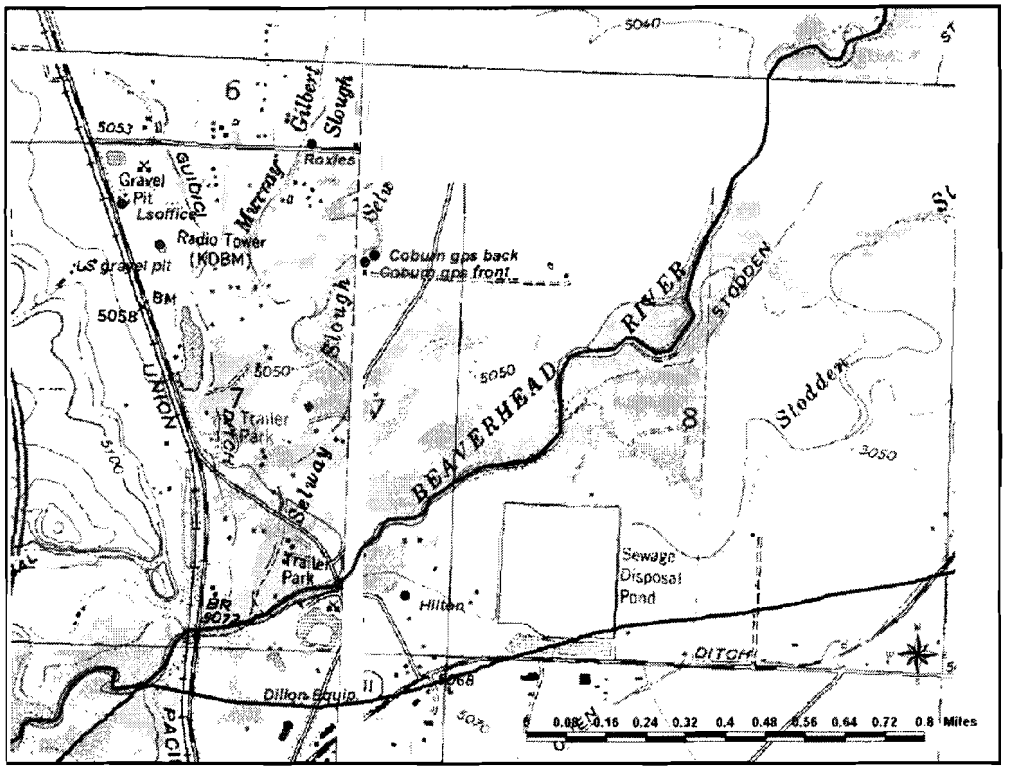

Figure 8. Location of some of the wells within the Beaverhead River Floodplain shown in red and the location information is found in Table 2.

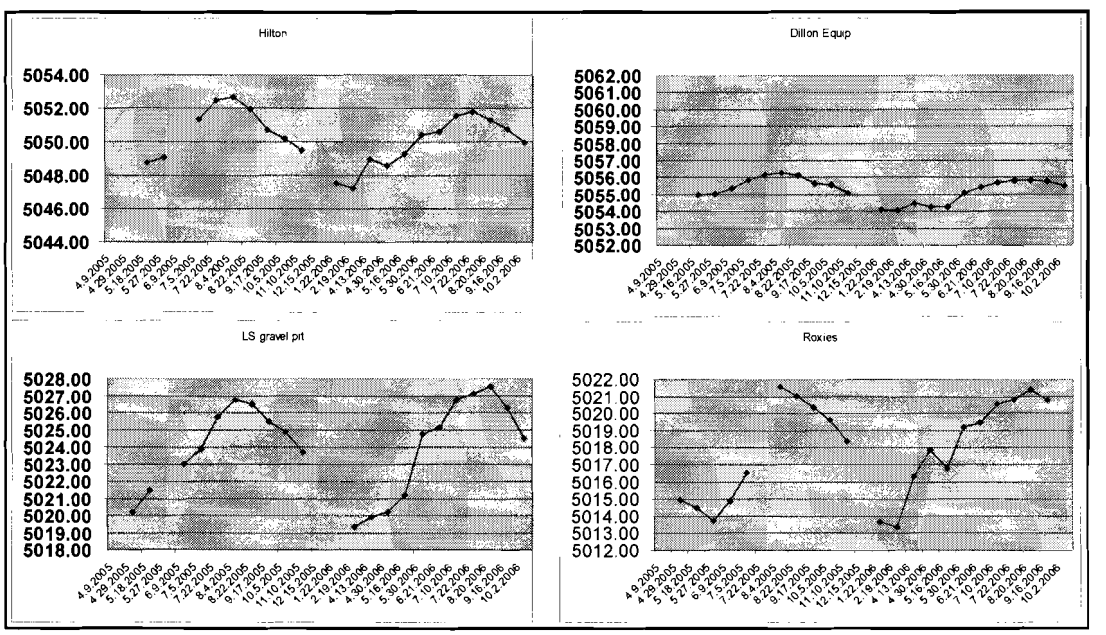

Figure 9. Hydrographs of the Hilton, Dillon Equipment, LS Gravel Pit, and Roxie's Greenhouse wells from April 9, 2005 to Oct 2, 2006. Each dot represents a level measurement. Note the peaks during late July through early August.

The flow rate in cubic feet per second (cfs) of the Beaverhead River from 2003 to 2006 is shown in Figure 10. Notice how the patterns of flow are similar in years 2003, 2004, and 2005 (drought years), where there is a peak after the July grain cutting followed by a curved decline in flow, while in 2006 (normal precipitation year) a fairly steady flux near 150 cfs was maintained clear through August. Stage levels start out lower in April before significant releases from CCR occur (Figure 11).

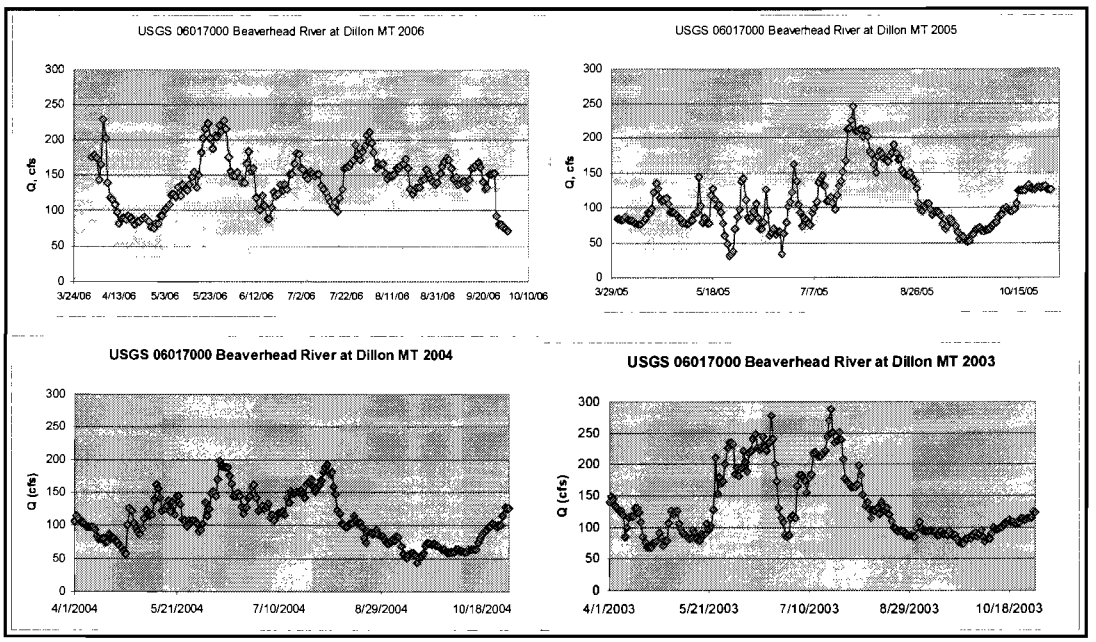

Figure 10. Flow in cfs in the Beaverhead River at the USGS gauging station in Dillon Montana for the 2003, 2004, 2005, and 2006 irrigation season (April through October).

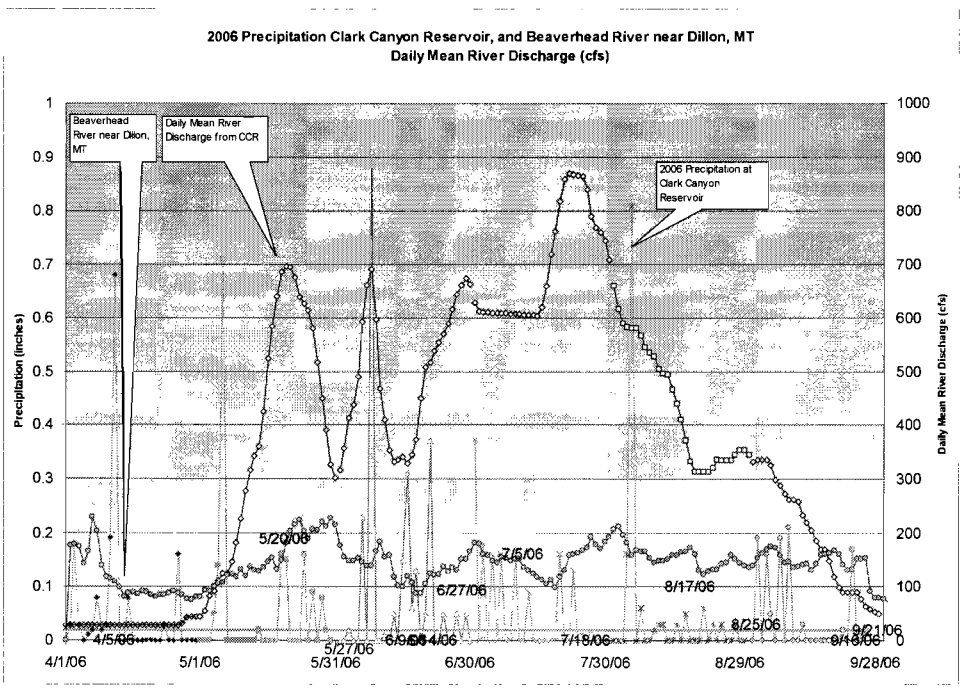

Figure 11. Graph showing precipitation (orange with left-side scale in inches), flow released from the Clark Canyon Reservoir in cfs (blue), and flow in the Beaverhead River in cfs (red) between April 1 and Oct 1, 2006. CFS scales are on the right side of the graph. Notice the similarity (mirror image) of the flow for the Beaverhead River (red) with Figure 10 for year 2006.

Figure 12 shows the locations of wells monitored on the west side of the Beaverhead River. The Vanderen House well is located within the Beaverhead River floodplain and the Erb Barn stock well is right on the edge of the floodplain, completed in the Tertiary. Two of the wells shown in Figure 12, Herman and Contway, are deep wells (greater than 300 feet deep) and have a different behavior than the shallower wells. Lithologic logs indicate a clay layer separates the shallower aquifer from the deeper zone. (The elevations of groundwater levels in the shallower wells were contoured in Figure 5 above). Hydrographs for some of the wells are shown in Figure 13.

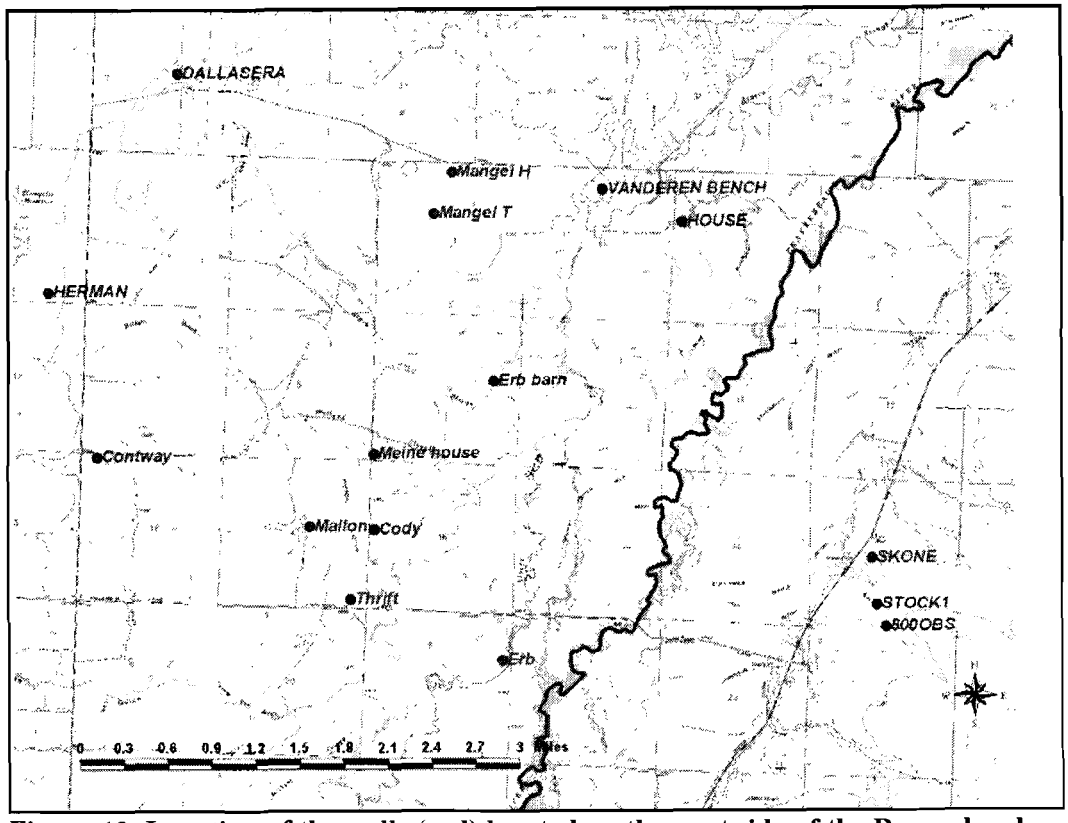

Figure 12. Location of the wells (red) located on the west side of the Beaverhead River. A few located on the east side are also shown.

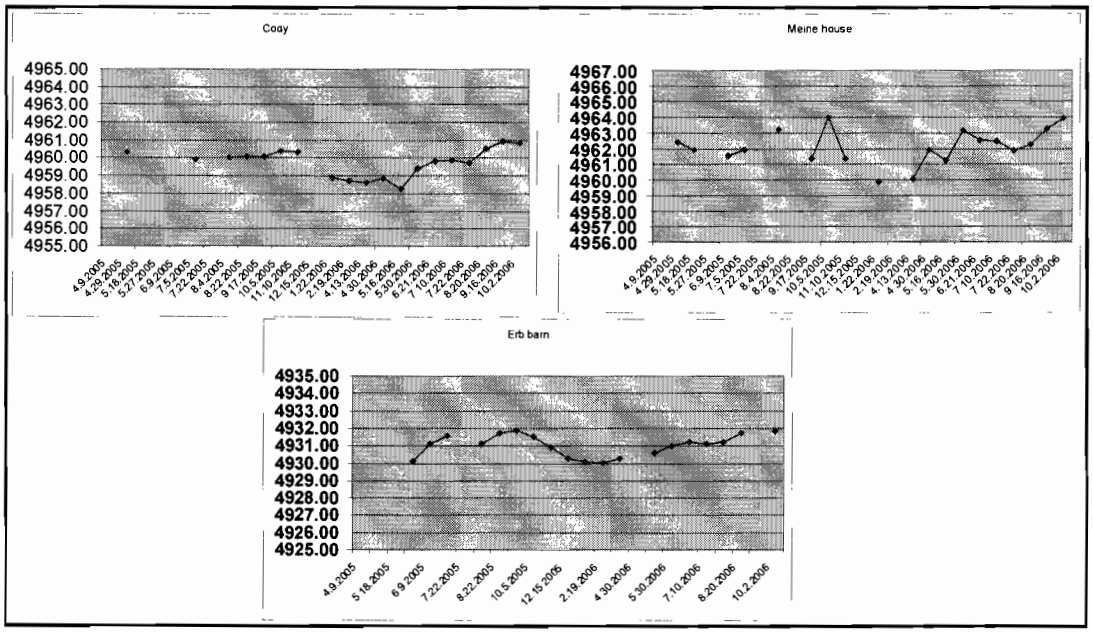

Figure 13. Hydrographs of some of the wells on the West Side of the Beaverhead River below (down-gradient) of the West Side Canal. Levels were measured between April 9 2005 and Oct 2 2006.

All of the hydrographs for wells shown in Figure 13 are located down-gradient of the West Side Canal. We believe there is an influence of groundwater levels from this Canal. Notice how groundwater levels rise in April and then decrease at the end of October when flow in the West Side Canal is shut off. These wells are completed above the clay layer that separates the aquifer below. As a comparison the hydrographs for the Herman and Contway wells from the deeper zone are shown in Figure 14.

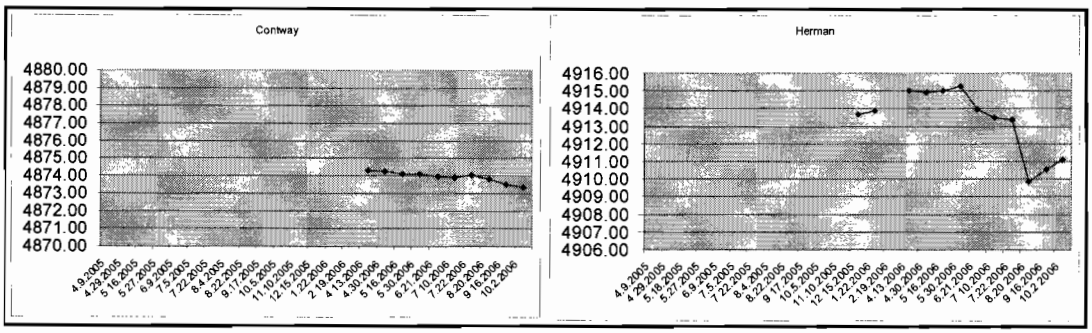

Figure 14. Hydrographs for the Contway and Herman wells completed more than 300 feet deep on the west side.

The Contway and Herman wells are located much higher on the Tertiary bench (Figure 12 above); however the elevations of the water levels are much lower than the shallower wells influenced by the West Side Canal (compare with Figure 13). These wells likely represent a more regional response of precipitation and recharge from the mountains to the west (Pioneer Range). It is also noted that there appears to be a decreasing trend. One

additional set of hydrographs from the west side is included for comparison purposes (Figure 15). These lie in a transect perpendicular to the Beaverhead River starting in the Tertiary volcanics (Dallasera well) and continue towards the edge of the Tertiary bench overlooking the Beaverhead River floodplain (Figure 16). All of these wells occur above any influence of a canal and are located down valley from the other west side wells, yet their elevations are strikingly higher in elevation than the other wells on the west side. We believe the Tertiary volcanics could be a source of recharge to the Tertiary sediments in the area. Transmissivities of wells completed in the Volcanics are very high compared to those in the Tertiary sediments.

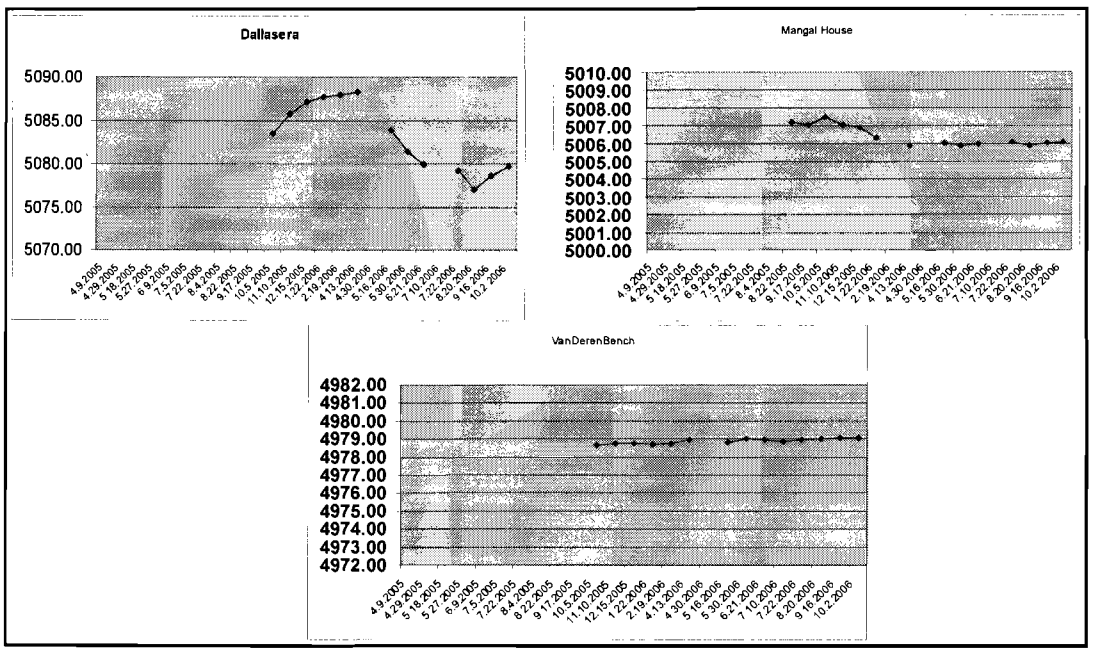

Figure 15. Hydrographs of west side wells starting in the Tertiary volcanics (Dallasera well) and continuing toward the Beaverhead River floodplain. Locations are shown in Figure 12.

Figure 16. View looking east over Albers Slough within the Beaverhead River floodplain, taken from the Vanderen Bench well.

The final presentation of hydrographs is from wells located on the East Side of the Beaverhead River up on the Tertiary bench above and below the East bench Canal (Figure 17, compare with Figure 2).

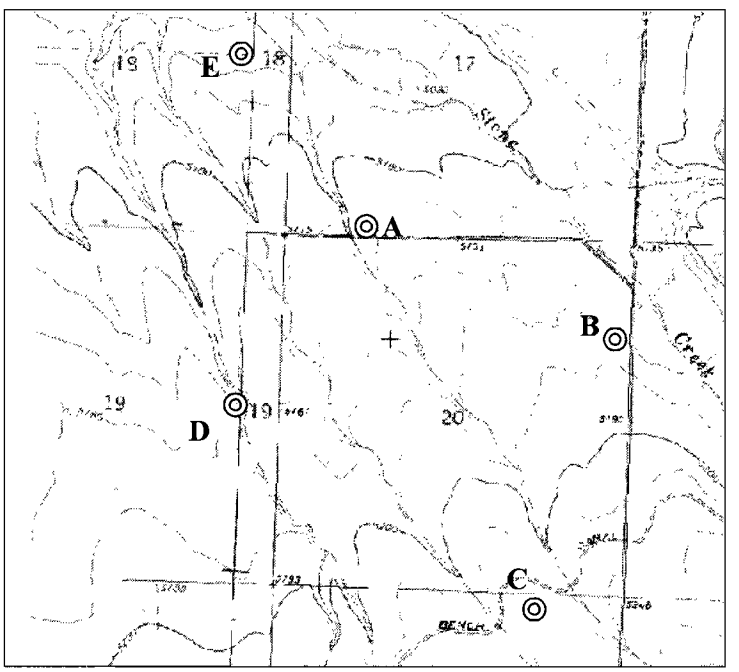

Figure 17. Wells located on the East Side of the Beaverhead River near the East Bench Canal (lower right corner above well C). Well A = Main OBS, Well B = Mexi

Trailer, C = Test near EB, D = Swale stock, and E = Stoddard Shop. The locations are in Table 2.

The first set of hydrographs is from wells located down-gradient or down slope from the East Bench Canal (Figure 18) and the second series of hydrographs is from wells up-gradient from the East bench Canal (Figure 19). Shown on most of the hydrographs is a red dot representing the elevation of the groundwater level in April 2004. It is noted that snow pack was very poor during the winter of 2005.

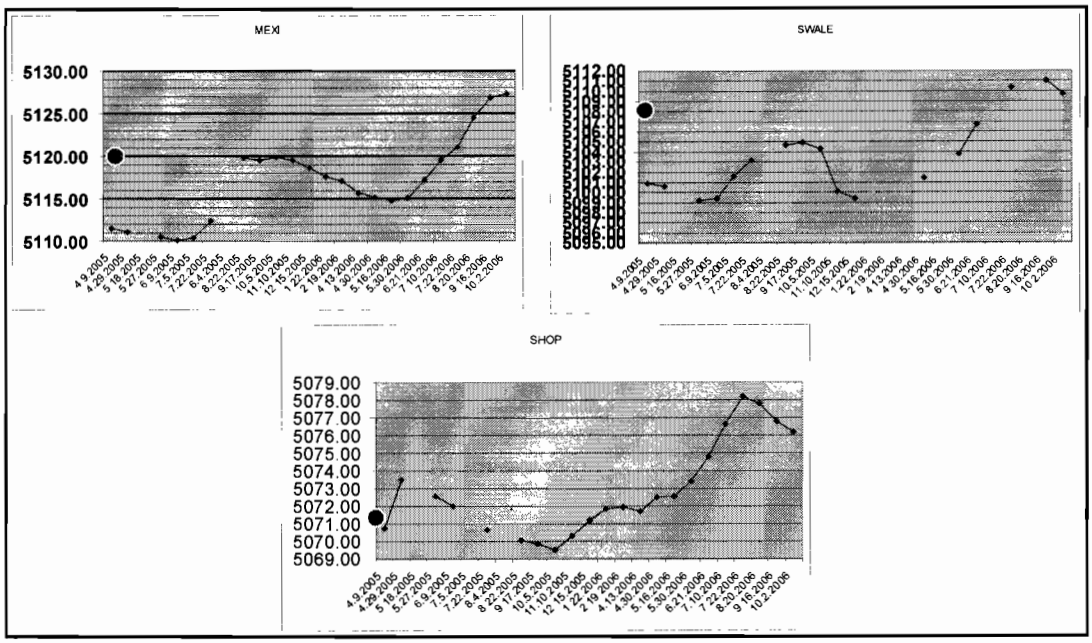

Figure 18. Hydrographs of the Mexi trailer, Swale, and Stoddard Shop well from April 9 2005 to Oct 2 2006. The red dot indicates the groundwater elevations in April 2004. The locations are shown in Figures 17 and 2.

The groundwater levels in the Stoddard Shop well are different than the other two stock wells; however all three show a similar peak in late August of 2006. The elevations of water levels starting in 2005 are from 6 to 8 feet lower than those in April 2004 (red dot) for the Mexi and Swale wells. This was probably influenced by poor precipitation recharge, effects from pumping, and drought. The Stoddard Shop well was likely used more than the other two and this affected the pattern somewhat. It is possible that the peaks represent recharge from the East Bench Canal, a decrease in pumping, or a delayed arrival of precipitation from the recharge area in the mountains. It is interesting to see groundwater elevations rise through the summer even though pumping is occurring nearby.

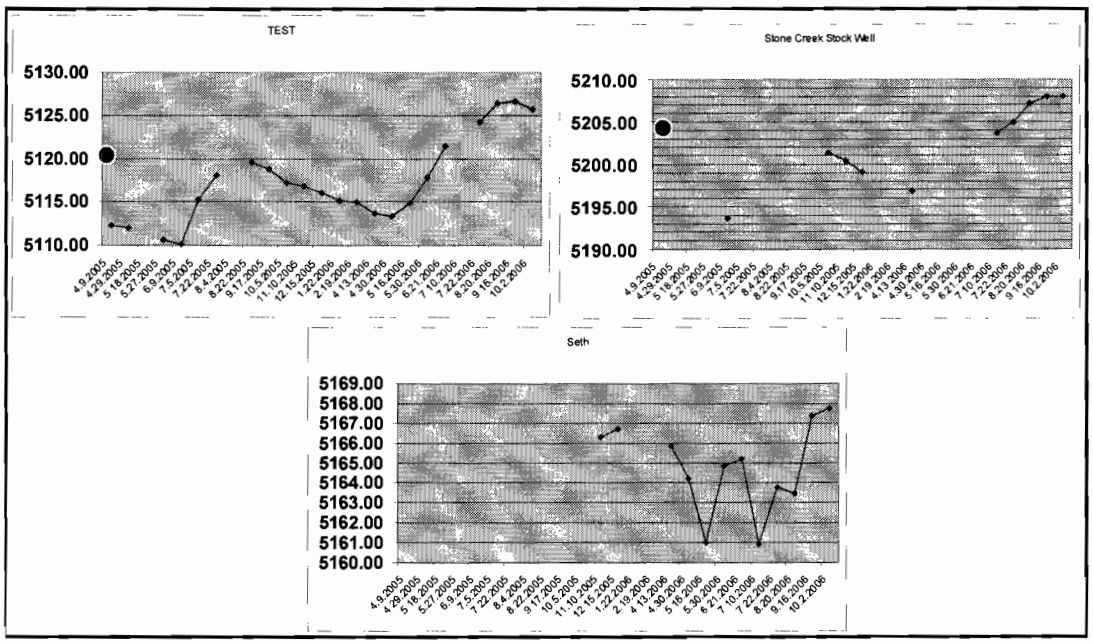

Figure 19. Hydrographs of the Test near EB well, Stone Creek Stock well, and Seth Stoddard domestic well from April 9 2005 to Oct 2 2006. The red dot indicates the groundwater elevations in April 2004. The locations are shown in Figures 17 and 2.

The patterns in Figure 19 are strikingly similar to those of Figure 18. The red dots indicate that groundwater elevations in April 2004 were approximately ten feet higher than those of April 2005 and had only recovered an additional four feet by April 2006, over a normal precipitation year. Is the effect of pumping in the area taking a toll?

Aquifer Properties

Data from three aquifer tests conducted in wells within the study area were obtained between 2004 and 2006. In addition, slug-test data from wells within floodplain of the Beaverhead south of Dillon (Section 2 of Table 1) were performed in the late 1990's (Weight and Wittman, 1999) and can be used for comparison purposes.

Two production wells with observation wells were tested within Tertiary sediments on the East Side during the summer of 2004. The first data set was collected from observation well "Main Obs" (Well "A" in Figure 17), which was within 26 feet of the production well. The test went for 72-hours and the pumping rate was 1800 gpm. A transmissivity of 6000 ft^2/day was obtained from approximately 300 feet of aquifer thickness. This is a very productive well and the cone of depression was projected to extend approximately two miles up-gradient after 180 days of pumping. The storativity was calculated to be slightly over 0.01, indicating a very leaky or slightly semi-confined aquifer.

The second well on the east side was from a 24-hour pumping test conducted at 800 gpm. The data were collected from an observation well located less than 30 feet away. The transmissivity was calculated to be 600 ft^2/day, and the storativity was calculated to be

approximately 0.008, indicating a leaky-confined aquifer. The cone of depression was projected to extend approximately one mile up gradient. The aquifer sediments from the first test are coarser-grained and closer to the mountain recharge source. Conceptually, it appears that sediments become finer-grained away from the mountain source in the down-gradient direction. The second well also had siltier materials compared to the first that would semi-confine the coarser-grained units.

Data from a third aquifer test were obtained in the summer of 2005 from a production well on the West Side. It is significant to note that six test wells were drilled over a two-mile area to find a suitable location. None looked too promising. It appears that the Tertiary sediments on the west side are generally finer-grained. A 72-hour test was conducted on a well approximately 400 feet deep at a pumping rate near 325 gpm. The transmissivity was calculated to be 300 ft^2/day and the storativity was 0.0001, indicating a confined aquifer. The data suggest that the Tertiary is thinner and less transmissive on the West Side and that a clay unit confines the deeper aquifer.

Slug-test data from wells within the floodplain of the Beaverhead River south of Dillon measured by Weight and Wittman (1999) indicate transmissivities between 8000 and 15,000 ft^2/day. This is expected in coarse-grained fluvial deposits, where groundwater movement also travels at a higher rate. It is expected that other high-production wells within the floodplain of the Beaverhead River would also exhibit similar transmissivity values. This is consistent with the flatter hydraulic gradient of the water-table surface shown in Figure 5. It also explains the apparent connectivity of groundwater with surface water in the behavior shown in the hydrographs of Figure 9.

Water Quality Data

In order to better understand the relationships of groundwater, surface water, and irrigation return flows, water quality monitoring was performed. There was no budget to collect water samples; therefore only field parameters using a WTW 3400i multi-meter probe from the Montana Tech Geological Engineering Department were collected during 2006. Field parameters included specific conductance, pH, and temperature. An attempt was made to monitor any water-quality changes over time.

When one compares measurements of pH verses specific conductance in µSiemens/cm an inverse relationship is observed (Figure 20). For every decrease in pH unit by 0.5 there is an increase of 1.5 times the value of specific conductivity. Lower pH waters come from groundwater mixing with surface waters. Precipitation and irrigation return flows are subject to increased partial pressure of carbon dioxide in the soil zone, thus reducing the pH. This appears to cause the dissolving of more minerals in the process, thus increasing the specific conductivity. Technically speaking for every decrease in pH unit by 0.5 the partial pressure of carbon dioxide in the atmosphere must rise from $10^{-3.5}$ to $10^{-2.77}$. Since the partial pressure in soils run between $10^{-1.5}$ and $10^{-2.5}$, this explains the reason that the decrease in pH in groundwaters could occur. There appears to be a slight shift or increase of specific conductivity from the May to July measurements in Figure 20, without significant changes in pH. A plot of the pH and specific conductance values by location is shown in Figures 21 and 22 respectively.

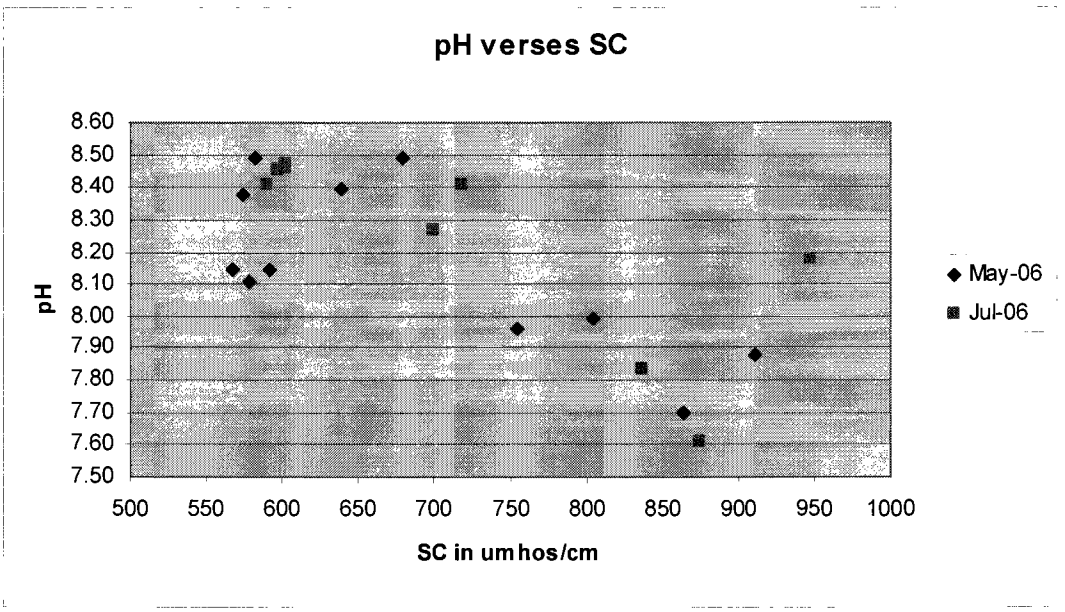

Figure 20. Plot of pH (y axis) verses Specific conductivity in µmhos/cm or µSeimens/cm (x axis) for May and late July 2006.

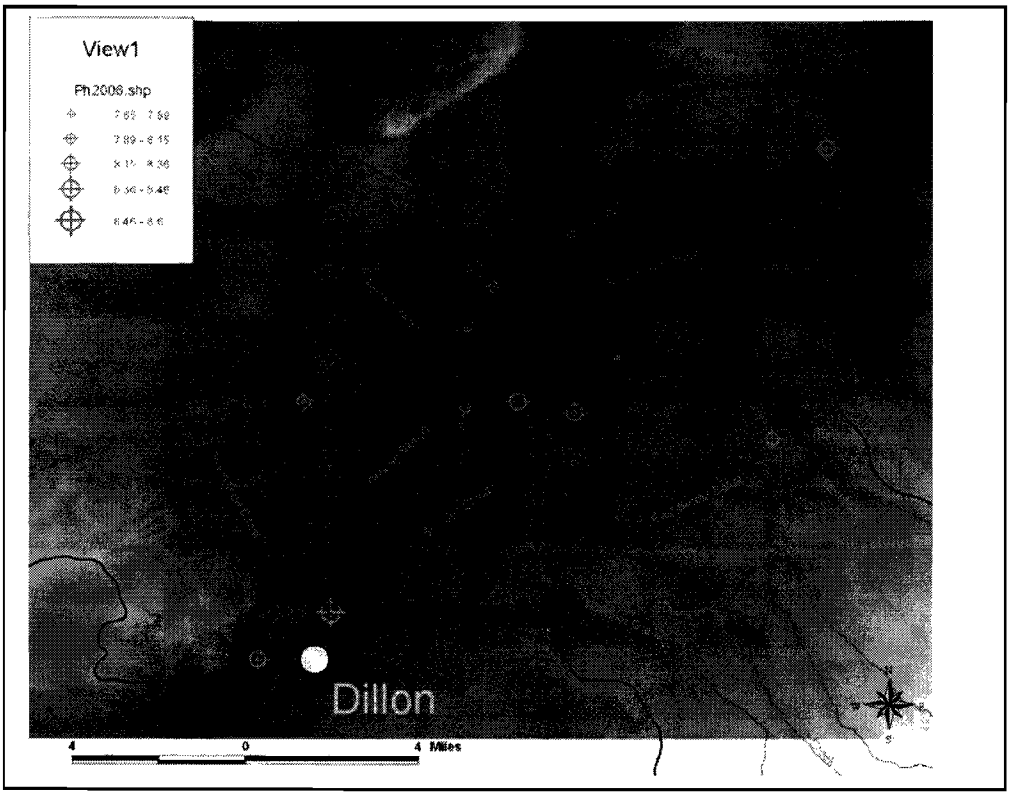

Figure 21. Plot of pH measurements taken at various surface-water site locations north of Dillon Montana.

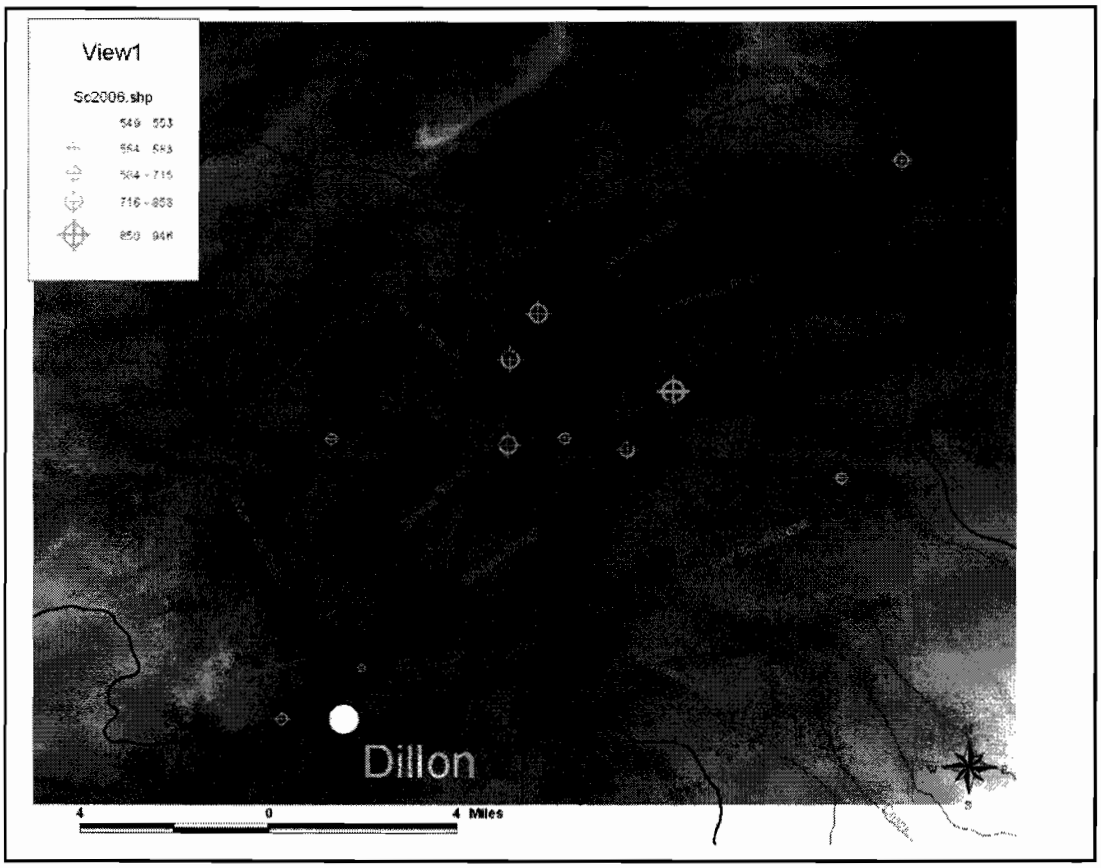

Figure 22. Plot of Specific Conductivity measurements taken at various surface-water site locations north of Dillon Montana.

Conclusions and Recommendations

A large unmonitored gain of surface water was unaccounted at the Point of Rocks gauging site compared to the Dillon USGS gauging station in 2005 (Sessoms and Bauder, 2005). This could not be resolved without evaluating the groundwater system in concert with the surface-water system, as they are really a single system. Surface waters from the Beaverhead River, its sloughs and canal systems lose water to the groundwater system, within the floodplain and on the Tertiary benches. It addition precipitation recharge enters the system from the mountains on both sides of the valley. The quantity of precipitation recharge is unknown, but may be significant. Since the valley is constricted near Beaverhead Rock, groundwater discharges upward to the Beaverhead River, where all sources emerge, thus accounting for the large increase.

Recommendations for further study would require a significant increase in budget, but would aid in better understanding the watershed system. Specific recommendations include:

- Provide funding for a principle investigator and graduate student to expand the groundwater monitoring network
- Provide for the development of a numerical model to simulate the system as a management tool, so that "what if" scenarios could be implemented

- Investigate the contribution of recharge from precipitation
- Provide funding for drilling additional monitoring wells north of Dillon.
- Fund groundwater surface-water temperature studies to evaluate the flux both toward and away from the Beaverhead River, to better define this relationship.

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