Ground Water Conditions at the Horse Creek Temporary Controlled Ground Water Area

Montana Department of Natural Resources and Conservation

April 2009

Executive Summary

The Horse Creek Temporary Controlled Ground Water Area (CGWA) was designated in response to concerns by the Horse Creek Water Users (HCWU) that ground-water development in a 65-lot subdivision within the area would affect flows to springs and Horse Creek that are relied on for stock watering. HCWU identified two sources of recharge; a relatively shallow aquifer in the Tongue River Member of the Fort Union Formation and a deeper aquifer in the Tullock Member of the Fort Union Formation from which water discharges to the surface along steeply dipping faults. The primary concern expressed by HCWU is that ground-water development from the deeper aquifer will obtain water from the same fracture system that supplies springs. HCWU allege criteria under §85-2-506 MCA that ground-water withdrawals exceed recharge, excessive withdrawals are likely to occur, there are significant disputes by appropriators, ground-water levels are declining and water quality is not suited for a specific beneficial use.

HCWU and the Montana Department of Natural Resources and Conservation (DNRC) collected water flow and chemistry data over four-plus years to address the concerns expressed in the petition for the CGWA. The purpose of this report is to present information collected during the study period as well as other pertinent data. Geologic maps published by the Montana Bureau of Mines and Geology (MBMG) are relied on for understanding the geology in the CGWA and a larger study area. Ground-water level data are used to evaluate whether water levels are declining. Water chemistry is used to evaluate the sources of water discharging from springs and flow into Horse Creek. Finally, water budgets for dry and wet years are evaluated for the purpose of estimating recharge and comparing withdrawals to recharge. The rates of withdrawals and consumption from wells used in the water budget evaluation are estimated from published studies of household use, the size of lawn and garden area that is irrigated at existing developed lots in the subdivision, and calculations of irrigation water demands.

Spring discharge rates and ground-water levels fluctuated seasonally, but remained relatively constant from year to year during the period of the study. Spring discharge rates, in particular, experienced sharp peaks in response to large precipitation or snow melt events. Water that infiltrates ground water during these periodic events drains rapidly to springs, generally within months. Therefore, flows to springs and Horse Creek are heavily dependent on infiltration of recent precipitation and rapidly recede to relatively low discharge rates.

Chemical analyses of water samples support the HCWU hypothesis regarding shallow and deep sources of flow to springs and Horse Creek. Water chemistry data indicate that approximately one quarter of flow to Horse Creek discharges from faults with the remainder coming from shallow ground water that discharges from the Tongue River Member. Total recharge during a dry year is estimated to be approximately 0.6 inches which is 5 percent of precipitation during that year. Recharge during a wet year is estimated to be approximately 1.9 inches or 9 percent of precipitation. Current net withdrawal within the study area, taking into account return flows from wastewater systems, is estimated to be 7.5 acre-feet (AF) which is 1.3 percent of recharge over the study area of 7,700 acres during a normal year. Net withdrawal within the study area at full build-out of Crow Chief Meadows Subdivision is estimated to be 20.5 AF which is 4 percent of projected recharge from precipitation over the study area during a normal year.

HCWU focus their concerns and analyses on the Horse Creek drainage where current and prospective future development is concentrated. If the effects are localized as HCWU argue, net withdrawals from full development within the Horse Creek Drainage would be 18.0 AF which is 20 percent of recharge from precipitation during a normal year. This is a conservative analysis, however, because drawdown caused by wells completed in faults that also supply springs most likely will propagate along those faults beyond the Horse Creek drainage. The impacts will be distributed to springs outside the drainage and to other streams including Rosebud Creek and the Stillwater River.

Proposed ground-water withdrawals at the prevailing rates could reduce or eliminate discharge along faults and noticeably reduce flows to springs and Horse Creek during dry years. Watering of larger lawns than current practices would exacerbate those effects proportional to the increased acreage. Beyond the subdivision, the majority of undeveloped land within the CGWA and the study area is owned by HCWU members and, therefore there appears to be a small potential for development outside Crow Chief Meadows Subdivision.

Introduction

A petition requesting establishment of the Horse Creek Temporary Controlled Ground Water Area (CGWA) was filed with the Montana Department of Natural Resources and Conservation (DNRC) on September 19, 2001 by the Horse Creek Water Users (HCWU) (Figure 1). The petition alleged that: a) ground water withdrawals are in excess of recharge; b) excessive withdrawals are likely to occur in the future due to consistent increases in withdrawals within the area; c) significant disputes regarding priority rights and amounts of water used by appropriators; d) ground water levels or pressures in the area are declining; and e) water quality within the area is not suited for specific beneficial uses. A hearing was held on October 9, 2003 and DNRC designated the CGWA on February 12, 2004 for the purpose of *"gathering information on aquifer properties, aquifer recharge, and aquifer withdrawals to assist in determining if a permanent controlled groundwater area is warranted"*. The First Judicial District determined in November 2008 that the CGWA has expired; however, DNRC continued compiling the information presented in this report.

The specific objectives of this report are to:

- describe the hydrogeology of the aquifer system in the control area
- describe and evaluate ground-water level changes
- estimate a budget of aquifer recharge and withdrawals

Methodology

HCWU monitored spring and stream flows, ground-water levels, and field water chemistry including specific conductance, pH, and temperature monthly beginning in 2004. In addition, HCWU collected water samples for laboratory analysis at approximately 30 sites with up to five repeat samples on different dates. DNRC monitored spring flows and ground-water levels within Crow Chief Meadows Subdivision, and monitoring stream flows in Grove Creek and Horse Creek. DNRC surveyed locations and elevations of monitoring sites using a survey-grade GPS system.

Published geologic maps by Lopez (2000 and 2001) are the basis for describing potential areas of aquifer recharge and the overall hydrogeology of the aquifer system. Water chemistry and measurements of spring flow and water levels are used to evaluate the source of water discharging from springs and wells. Estimates of recharge and ground-water withdrawals over an expanded study area are evaluated to determine whether ground-water withdrawals are in excess of recharge. The rate of recharge is evaluated using a water-budget analysis for the Horse Creek drainage. For the water-budget analysis, uses of water collected from naturally flowing springs or streams, or consumed via evapotranspiration (ET) by phreatophyte vegetation are not considered to be ground-water withdrawals. In the past, these water uses and discharges have not been part of the calculations of ground-water withdrawals under §85-2-506 MCA, and do not appear to fall within the meaning of "ground-water withdrawals."

Withdrawal from wells is defined for this study as the net consumption of water determined by subtracting amounts of water returned to the aquifer. Net consumption of water used indoors includes a small amount of evaporation resulting from cooking and showering, but is primarily a result of evaporation or ET during wastewater treatment. In the CGWA, wastewater is treated by septic systems and consumption results from plant uptake from drainfields. The total rate of consumption of water used indoors is assumed for this study to be 5 percent. This rate of consumption is between an estimate by Kimsey and Flood (1987) of 2 percent for households served by municipal wastewater treatment plants and an estimate of 12 percent by Vanslyke and Simpson (1974) and 15.6 percent by Paul, et al (2007) for households with individual septic systems. The 5 percent value used for this study is selected at the low end of the observed range because the studies indicating higher consumptive use rates, in particular the Paul, Poeter and Laws study, do not consider consumptive use by lawn irrigation. Using the higher rate for indoor uses would overestimate consumptive use when drainfields are under lawn areas and consumptive use from lawn watering is calculated separately as is done in this study.

Annual and monthly net consumptive use via lawn and garden irrigation is estimated using the Irrigation Water Requirements (IWR) computer program developed and distributed by the Natural Resource Conservation Service. IWR uses the U.S. Soil Conservation Service (SCS) Blaney Criddle method to estimate monthly ET, effective precipitation, and net irrigation requirements for different crops using site-specific weather station data from 1971 to 2000. Data for turf grass and pasture grass are used to estimate net consumption for lawn and garden irrigation and data for alfalfa are used to estimate net consumption by phreatophyte vegetation.

Measured ground-water levels and spring flows are graphed and compared to precipitation at the National Weather Service station at Fishtail to evaluate whether ground-water levels are declining and, if so, whether declines can be explained by ground-water withdrawals or climate.

Geography and Climate

The CGWA encompasses approximately 4,600 acres or 7.2 square miles southwest of Absarokee in Stillwater County (Figure 1). There are approximately 22 established residences within the original CGWA area with 18 in the Crow Chief Meadows Subdivision (see Appendix A for list of wells). There are an additional 5 residences in the 7,700-acre study area defined in this report. Elevations in the study area range from approximately 4,050 feet along the alluvium of Rosebud Creek and the Stillwater River to 4,725 feet in the west half of the study area. Crow Chief Meadows is the only established subdivision and is platted for 65 lots. Approximately 72 percent of the remainder of the study area is owned HCWU members or the State of Montana. The average irrigated size of lawn and garden within Crow Chief Meadows is approximately 0.2 acres. Vegetation on undeveloped land within and outside the subdivision is grass rangeland with wetland grasses and shrubs, and cottonwoods along intermittent streams.

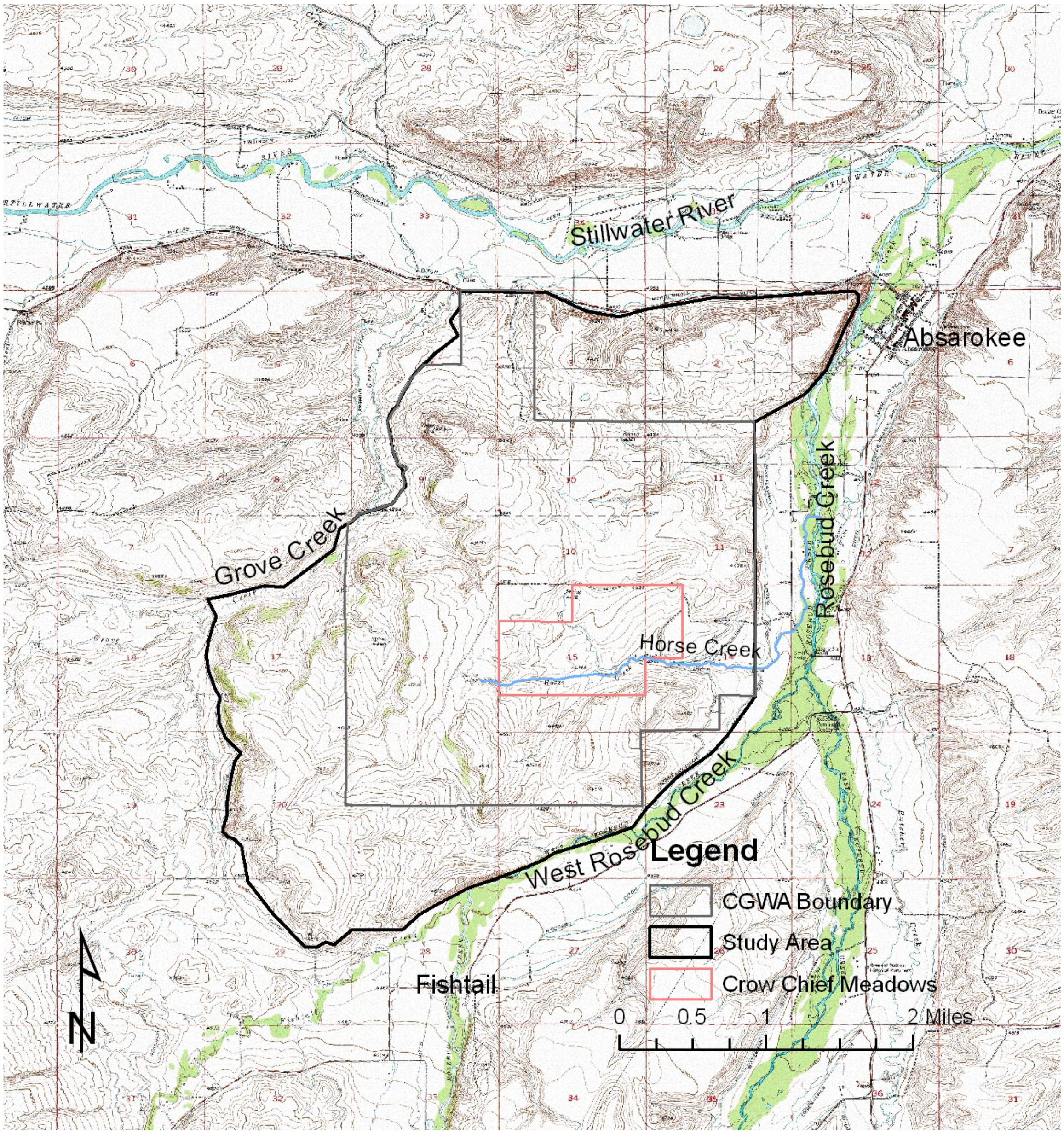


Figure 1. Location map of CGWA boundary and study area.

Annual precipitation at the weather station at Fishtail averaged 18.09 inches between 1952 and 2007. Precipitation is greatest in the spring and early fall and varies considerably from year to year (Figure 2). Potential ET exceeds precipitation during much of the growing season, generally precluding recharge during those months except during periods of intense rain. In addition, frozen ground limits the amount of water that infiltrates to the water table during the winter. Therefore, most recharge from direct infiltration occurs in the months of April and May after the ground has thawed and snowmelt and spring rains occur, and to a lesser extent during September and October after ET is reduced and autumn rains occur.

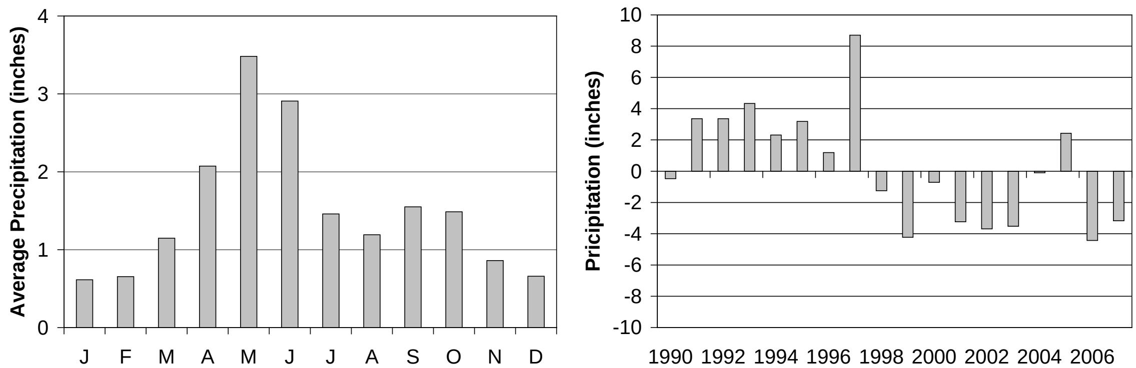


Figure 2. Average monthly precipitation and deviations from average annual precipitation (based on data from Fishtail for 1952-2007).

Hydrogeology

The main geologic structure in the vicinity of the study area is the Reed Point Syncline, the axis of which trends northwest and passes just to the east (Figure 3). Rocks of Tertiary through Paleozoic age are upturned and outcrop southwest of the CGWA forming a regional recharge area. Ground water generally flows northeast from the regional recharge area through multiple confined aquifers beneath the CGWA. Steep-dipping normal faults traverse the area, offsetting the rock units and providing avenues for water to preferentially flow from recharge areas across formations to the surface and discharge as springs. Some of the same formations that outcrop southwest of the study area are folded back to the surface on the east limb of the Reed Point Syncline and outcrop or subcrop beneath the Stillwater River; delineating the eastern extent of the discharge area for the bedrock aquifers in the vicinity of the study area. Northeast-trending normal faults southwest of the study area create preferential pathways for recharge water to flow across formations and from higher elevation recharge areas to the study area.

Surficial sediments and gently dipping rocks of the Tongue River, Lebo, and Tullock members of the Fort Union Formation outcrop within the study area (Figure 3). The Tongue River and Tullock members are predominantly sandstone and generally considered aquifers. The Lebo Member is predominantly shale and generally is considered an aquitard, but contains sandstone lenses and fractures that may supply water to wells. Many of the wells in the Crow Chief Meadows Subdivision flow at the surface and others have water levels near the surface indicating that the aquifer they intercept is confined and that there is a potential for upward flow. Existing wells in the subdivision are completed within either the Lebo or Tullock members. Regardless of which member they are completed in, many of the wells probably are supplied by faults that cross formation and member boundaries.

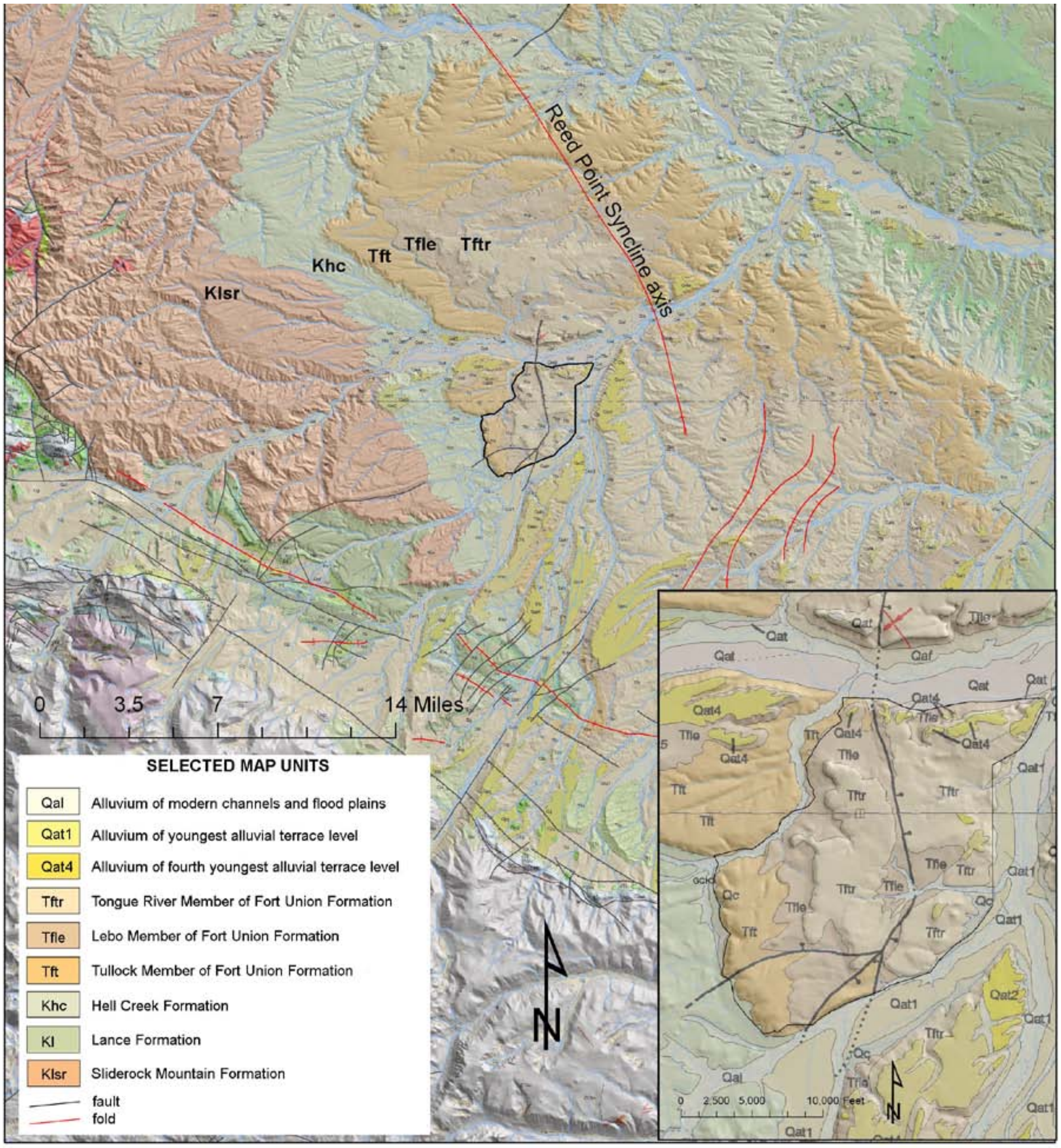


Figure 3. Geologic map of Horse Creek vicinity (modified from Lopez, 2001).

The predominant geochemical processes determining water quality in the study area are dissolution of silica, sulfate, and carbonate minerals in recharge areas, subsequent exchange of calcium and magnesium for sodium on clay minerals in shale units, and mixing. The concentration of sodium relative to calcium and magnesium is expected to increase with length of ground-water flow path and depth. Based on this geochemical conceptual model, chemical analysis of water from springs, wells, and surface water (Figure 4) indicate there are two general sources of water to springs, primarily based on the concentrations of sodium relative to calcium and magnesium (Figures 5, 6, and 7). Springs with low relative sodium concentrations generally receive water that infiltrates on nearby benches and issues from outcrops of the Tongue River Member of the Fort Union Formation. Water from other springs that have relatively higher sodium concentrations approaching that of wells probably are mixtures of local recharge and recharge that flows upward along faults from the Tullock Member or possibly deeper aquifers. Water from springs discharge to ephemeral drainages or infiltrate into colluvium or alluvium along those drainages where water users collect it for stock watering (see photographs in Appendix D). Spring collection systems do not increase the flow from the bedrock aquifers and, as stated previously, are not considered withdrawals in this report. The chemistries of Horse and Grove creeks are influenced by contributions from different sources of ground water with different chemistries.

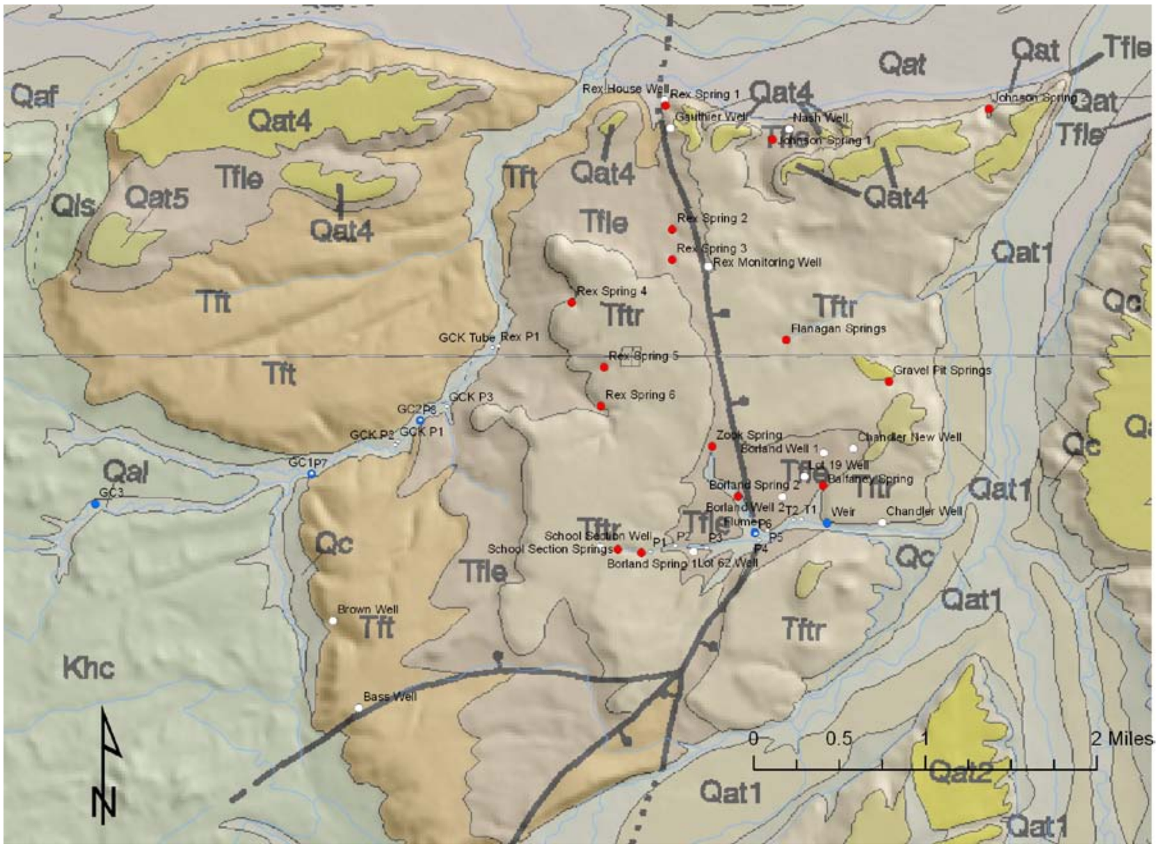


Figure 4. Location map of wells and springs sampled.

The primary concern of HCWU is that ground-water development from wells in Crow Chief Meadows Subdivision will adversely affect flows from springs and Horse Creek by reducing discharge from faults intersected by wells. In general, withdrawal of water from an aquifer ultimately must be balanced by either increased recharge or decreased discharge (Theis, 1938) if ground-water levels are to remain stable. The increase in recharge or decrease in discharge is referred to as capture (Lohman, 1972). Bredehoeft (1982) and others argue that recharge is generally independent of ground-water withdrawals and, therefore capture generally occurs through reduced discharge.

Average recharge equals average discharge before pumping from an aquifer begins. This is considered a dynamic water balance because recharge can be greater or less than discharge over short time intervals because of variable precipitation. Short-term imbalance between recharge and discharge is most evident during periods of seasonal recharge when recharge exceeds discharge, resulting in increased ground-water levels.

The resulting increase in ground-water storage is redistributed throughout the aquifer resulting in increased discharge and a long-term balance. Discharge is captured and begins to decline as water is withdrawn from wells, as discussed previously, and recharge equals discharge plus net withdrawals. Discharge may stop entirely if withdrawals exceed the pre-pumping discharge rate or the recharge rate (which again is equivalent to the pre-pumping discharge rate).

According to Theis (1940) and Bredehoeft (1982), whether or not the natural discharge can be decreased and a stable hydraulic system reestablished depends on the conditions of flow in the aquifer. Water-level drawdown caused by pumping creates a cone of depression that propagates generally in all directions and initiates capture when water levels are affected at points of discharge such as springs, streams, or areas where phreatophyte vegetation uses ground water directly. Therefore, the location where capture occurs depends on the factors that control propagation of the cone of depression: the location of withdrawals, the connectivity and properties of the aquifer (e.g. fracturing and faulting), and the distance to and conditions at aquifer boundaries (Theis, 1940).

Opinions of experts hired by HCWU and Crow Chief Meadows Subdivision differ on whether effects of pumping ground water within the Subdivision will be localized or will expand throughout the aquifer. HCWU argue that faults are conduits supplying water to springs; however, they also argue that faults are barriers that prevent effects of pumping from propagating outside the Horse Creek drainage (Weight, 2009). The physical and geochemical evidence that mapped faults supply water to some springs and wells is described above. Further, there is evidence from aquifer testing that there are barriers to ground-water flow within the aquifer (see Appendix E for aquifer testing summary). The nature of the response during a 47-hour duration aquifer test indicates that the fracture system is discontinuous at the location of the test wells. However, this response also suggests that the fracture system at the location of the test well may not be connected to the system of more continuous mapped faults that supply springs and some wells. Drawdown from wells that intercept the more continuous faults that have been correlated to springs are likely to propagate outside the Subdivision and Horse Creek drainage along those faults.

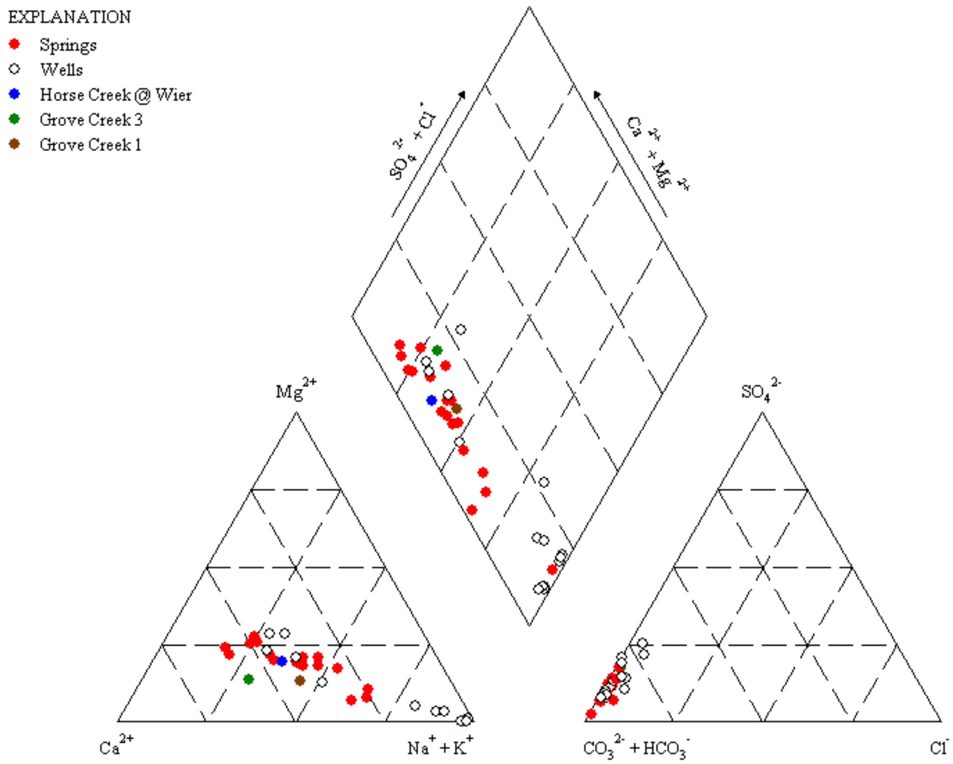


Figure 5. Piper plot of average water composition for waters in the Horse Creek CGWA.

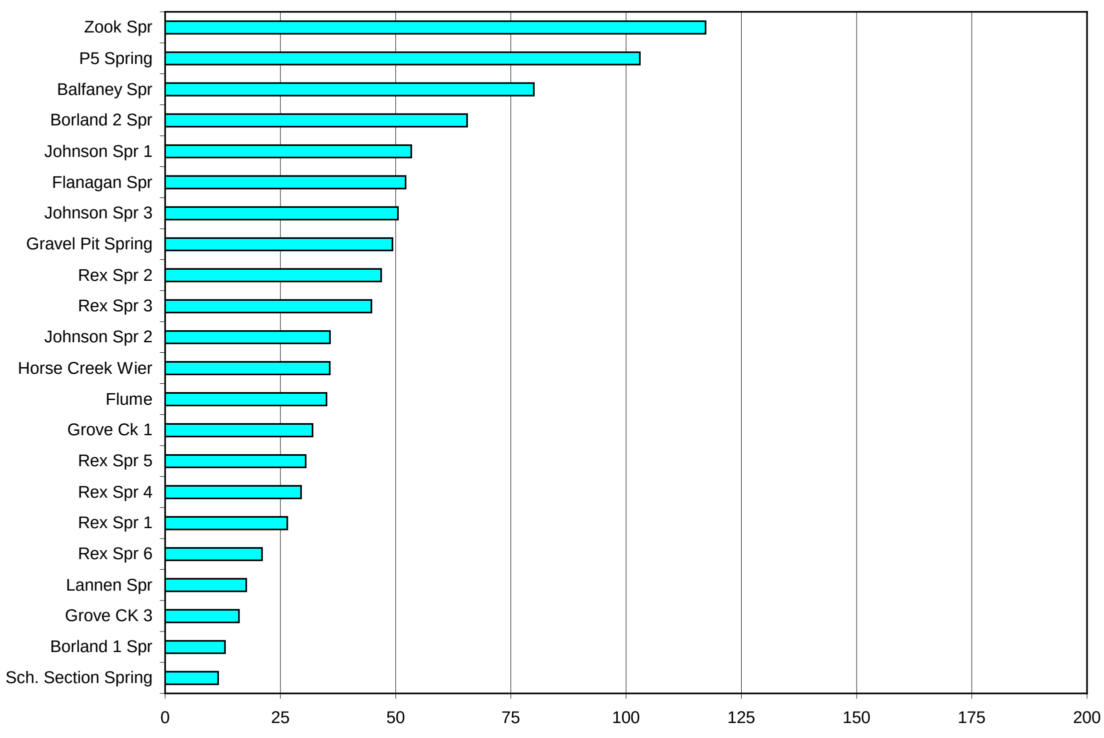


Figure 6. Average sodium concentrations in springs.

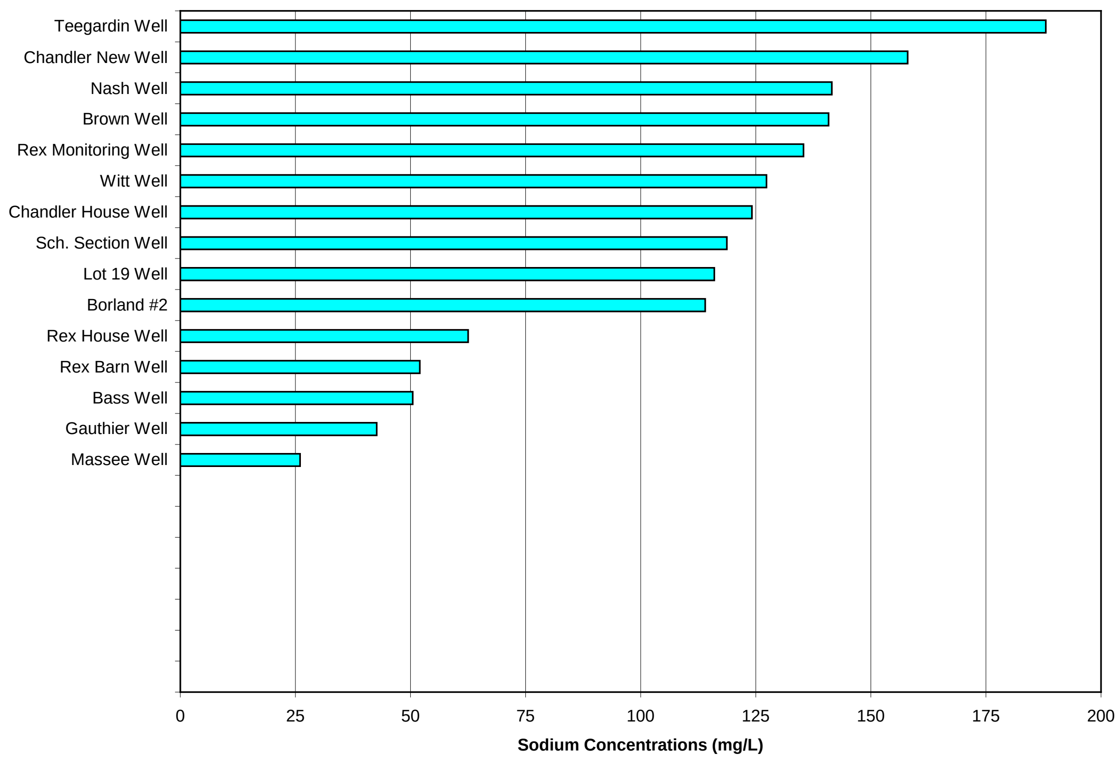


Figure 7. Average sodium concentrations in wells.

Ground-Water Hydrographs

HCWU measured static water levels monthly in nine wells and every two hours in two wells using pressure transducers and electronic dataloggers. DNRC monitored water level in two additional wells using pressure transducers and dataloggers. Data from these wells are plotted with three-month average precipitation in Figure 8.

Ground-water levels in the study area fluctuate from 10 to 20 feet in correlation with the pattern of precipitation, but show little or no long-term trend during the period of study. The seasonal rise in ground-water levels is a result of infiltration of precipitation during snow melt and rainfall events in the spring. Stream losses from Grove Creek may also contribute recharge; however, the seasonal patterns of ground-water level fluctuations do not appear to correlate with stream hydrographs of Grove Creek. That is not to say that regional recharge from Grove Creek or other sources is not significant. The seasonal effect of regional recharge on ground-water levels probably is dampened because of distance and likely follows a multi-year pattern related to climate-scale drought cycles that is not evident during the period of study.

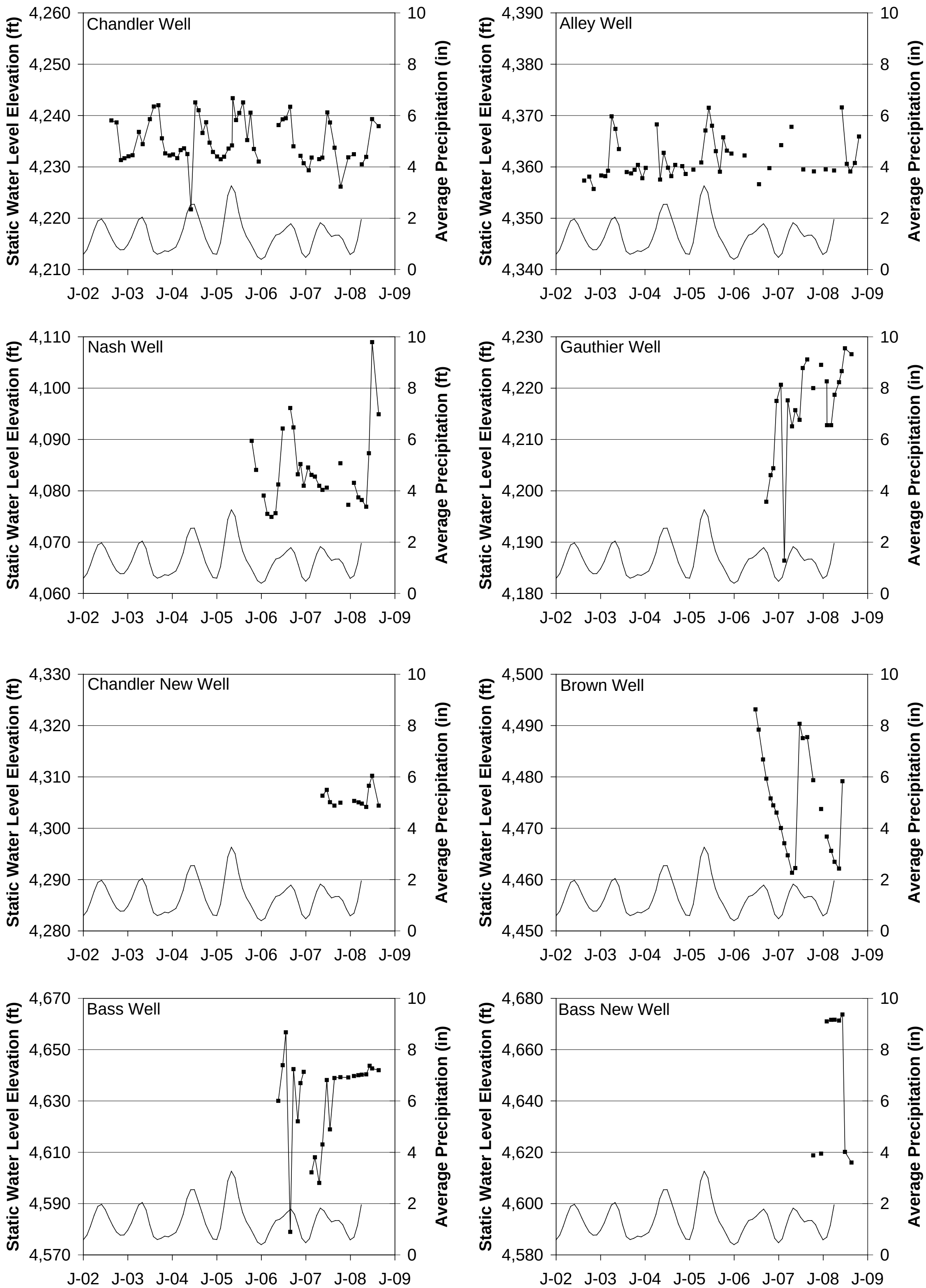


Figure 8. Water levels in wells in Horse Creek CGWA (lines and symbols) with 3-month moving average precipitation at Fishtail (solid lines).

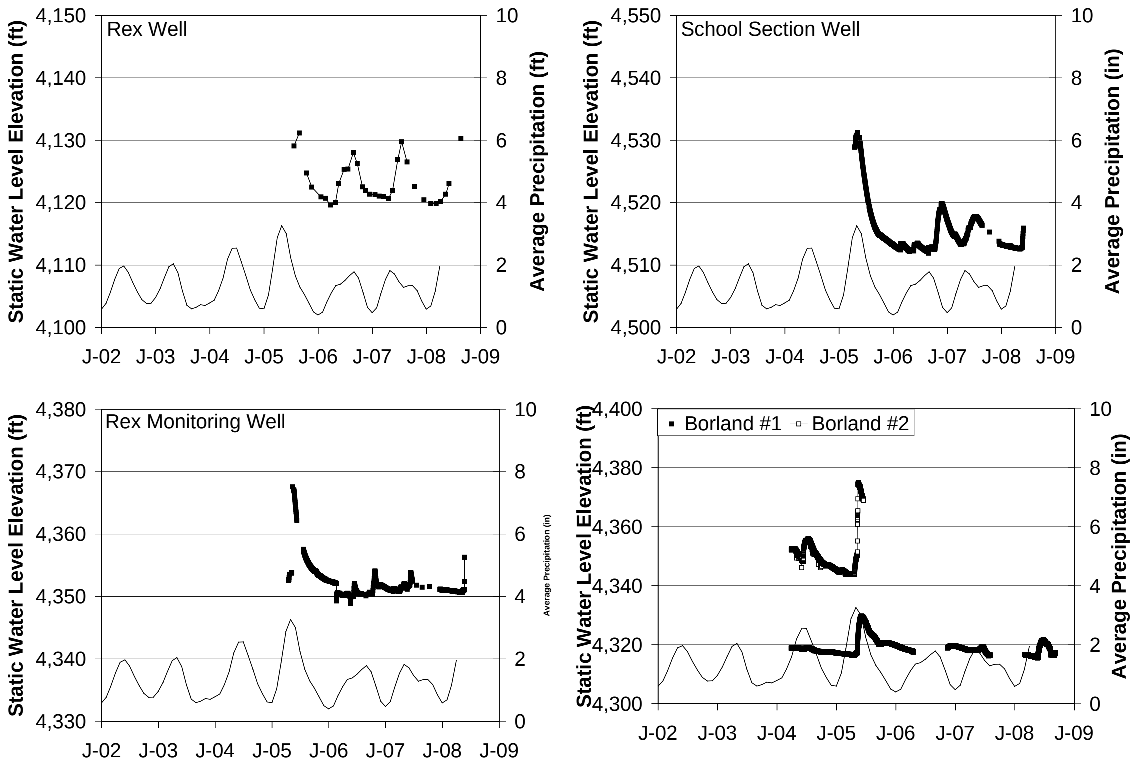


Figure 8 (continued). Water levels in wells in Horse Creek CGWA (lines and symbols) with 3-month moving average precipitation at Fishtail (solid lines).

Spring and Surface-Water Hydrographs

HCWU measured flows from 13 springs in addition to flows in Horse and Grove creeks. DNRC measured flows in two springs within Crow Chief Meadows as well as flows in Horse Creek and Grove Creek. Flow data for springs and streams are plotted in figures 9 and 10, respectively.

Spring and surface water flows are affected more dramatically by rain or snow-melt events (e.g. May 2005 rain event) than ground-water levels are, with strong peaks during events that occur during spring and occasionally early fall and relatively low base flows during other times. Horse Creek generally flows less than 50 gallons per minute (gpm) except during these brief events and only flowed between Borland #1 Spring and the DNRC flume following one event in May, 2005 and during the early summer of 2008. During other times, flows from the School Section Spring and Borland #1 spring infiltrated colluvium near their sources and reemerged as surface water near the flume.

Flows in Grove Creek are influenced strongly by return flows from irrigation water diverted from the West Rosebud Creek. The stage elevation of Grove Creek is higher than the water level elevation in nearby piezometers at GC1 and GC2 and indicate there is a potential for leakage and recharge to underlying alluvium and Tullock Member rocks. Again, the hydrograph for Grove Creek does not match the hydrographs for springs or wells and, therefore leakage from Grove Creek is not the primary source of recharge affecting spring flows or ground-water levels.

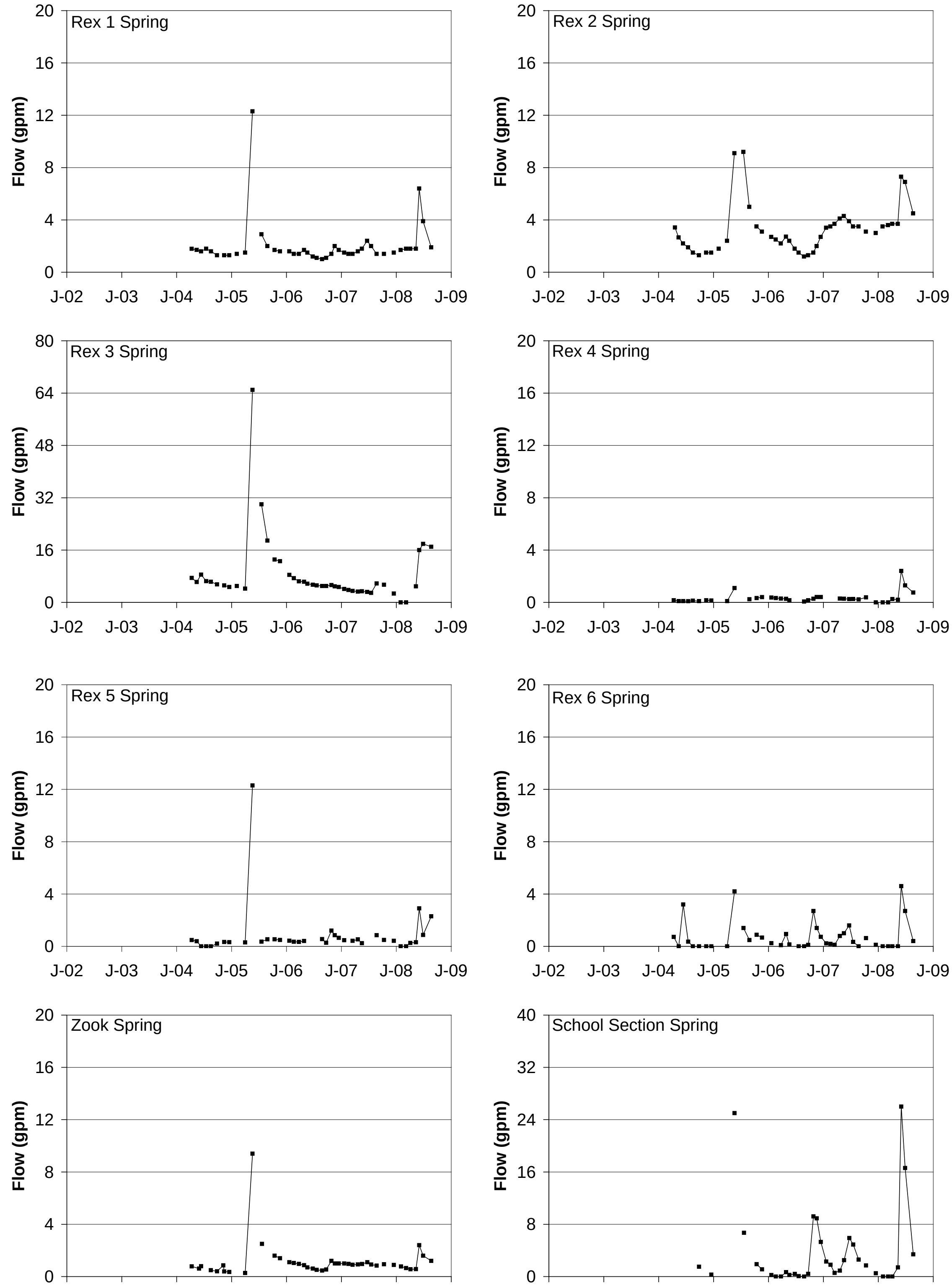


Figure 9. Flows from springs in Horse Creek CGWA.

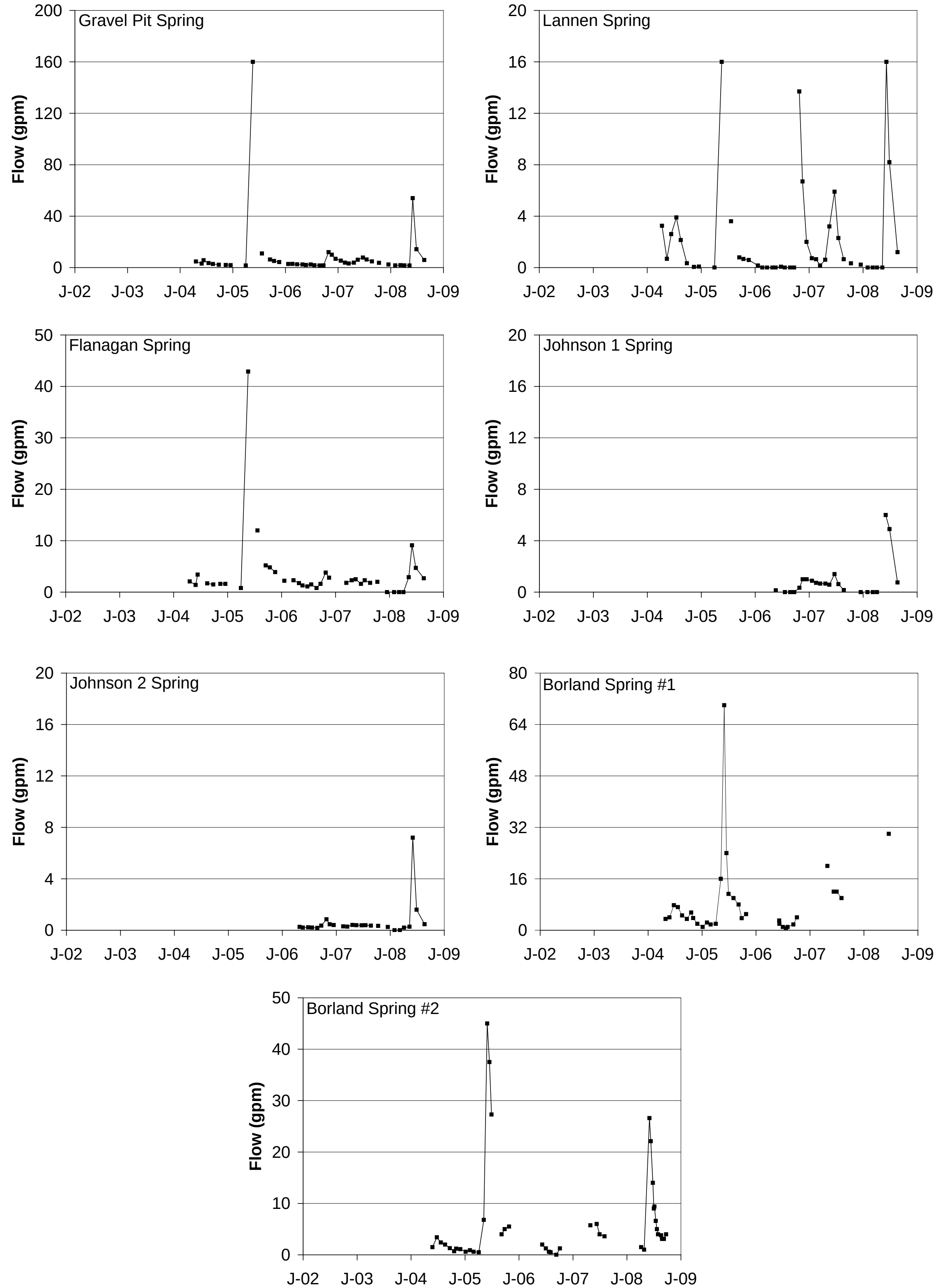


Figure 9 (continued). Flows from springs in Horse Creek CGWA.

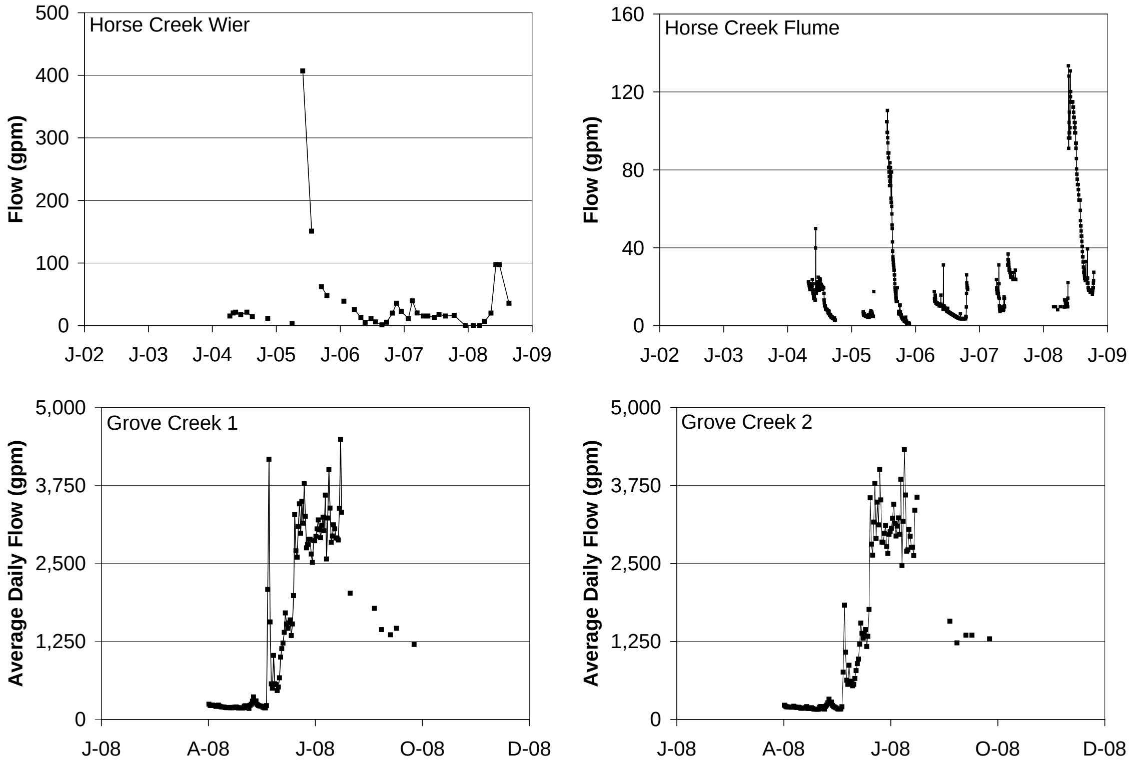


Figure 10. Flows of streams in study area.

Water Budget

The purpose of the water budget calculation is to estimate recharge for comparison with net withdrawals by wells. Data for the Horse Creek drainage basin for the 2005 and 2007 water years are used as a basis for water budget calculations that are applied to the study area as a whole. The 2007 water year was selected because it was a dry year and spring and Horse Creek flows were similar at the start and end of that period, indicating that changes in ground-water storage were negligible. If anything, flows were higher at the end of the period indicating higher ground-water levels and a net accumulation of storage. The estimates of recharge in this analysis are conservative in that case. The 2005 water year was selected because it was the only above average year during the study period.

In general, a water budget is expressed by the relationship:

Recharge – Discharge = Change in Storage

For the 2007 water year, change in storage is zero and the relationship becomes Recharge = Discharge. Water levels at the end of the 2005 water year were higher than at the start; however, the change in storage is not considered in this analysis because it is difficult to evaluate, and its exclusion provides a conservative evaluation.

Elements of the water budget include recharge through infiltration within the Horse Creek drainage, ground-water inflow along faults into the drainage basin, discharge to Horse Creek, discharge via ET by phreatophyte vegetation, and withdrawal from wells. Flow records for the Chandler Weir are used to estimate Horse Creek flows. Infrared aerial photography is used to estimate the area covered by phreatophytes and IWR is used to estimate ET. Standard guidelines for household water use and IWR estimates of irrigation demand are used to estimate net withdrawal from wells. Total recharge is set equal to total discharge and the relative contribution of recharge from infiltration and ground-water inflow is evaluated from mixing proportions using water chemistry.

Ground-Water Discharge

Annual flow in Horse Creek at the Chandler Weir is estimated by multiplying measured flow rates by time intervals that they represent. For example, the flow rate of 39 gpm for December 2006 is multiplied by 37 days from the start of the year to the mid point to the February measurement (with appropriate unit conversions). This sums to 31.08 acre-feet (AF) for the 2007 water year and 156 AF for the 2005 water year. Precipitation at Fishtail during the 2007 water year was 14.02 inches, which is 43rd among 55 years on record. Precipitation during 2005 was 21.02 inches which ranked 17th.

Approximately 16.8 acres of phreatophyte vegetation are delineated using infrared aerial photography taken in 2005 in conjunction with ArcView software (ESRI, 2008). Vegetation consists of grasses, sedges, and occasional willows and cottonwoods. Water consumption of 16.63 inches for alfalfa in a dry year obtained from the IWR program (Appendix F) yields an estimate of discharge via ET by phreatophytes equal to 23.3 AF for 2007. Normal-year water consumption of 15.41 inches obtained from IWR yields an estimate of 21.6 AF for 2005. These ET estimates probably are lower than actual because consumption by existing vegetation probably is greater than for alfalfa. For example, methodology used in Wyoming indicates ET by wetland sedge grass to be in excess of 32 inches (U.S. Forest Service, 2001). The consequence of underestimating ET by phreatophytes is that recharge is underestimated in the water budget calculated below.

Relative Contribution of Recharge Sources

The Borland #1 or School Section spring and the Zook spring represent geochemical end-members among spring sampling sites within the Horse Creek drainage (Figure 11). The first two are derived from local recharge and the Zook spring is fed by faults from underlying aquifers. A mixing ratio of the Borland #1 spring water to Zook spring water of 3.34:1, as determined by sodium concentration, yields a close match for all major ions at their confluence at the Horse Creek flume and the Horse Creek weir (Table 1). This ratio is used to evaluate the relative contributions of the two source types.

Withdrawals from Wells

Estimates of withdrawals from existing wells within the Horse Creek drainage (18), within the study area (27), and within the study area at full build-out of Crow Chief Meadows Subdivision (74) are summarized in Table 2. Consumptive use for lawn and garden irrigation is estimated assuming 0.2 acre of lawn and garden per house and a net irrigation requirement of 16.06 inches (17.76 inches for a dry year) obtained using IWR (Appendix F). Net irrigation requirement of 14.16 inches (15.66 inches for a dry year) for pasture grass obtained from IWR was adjusted upward by 8 percent to approximate turf grass and by 5 percent to account for spray loss. The 8-percent adjustment for turf grass is based on the net irrigation requirement for turf grass relative to pasture grass for the weather station at the Billings Wastewater Treatment Plant, the nearest station with data for both grasses. Average daily diversion for in-house use is estimated to be 160 gallons per day (gpd) per household with net water consumption assumed to be 5 percent of the amount diverted based on published studies (Kimsey, D.W. and P.K. Flood, 1987; Paul, W., Poeter, E., and R Laows, 2007; Vanslyke, G. and H. Simpson, 1974). Figure 12 shows estimated consumptive use by month for current uses and full build-out of Crow Chief Meadows Subdivision.

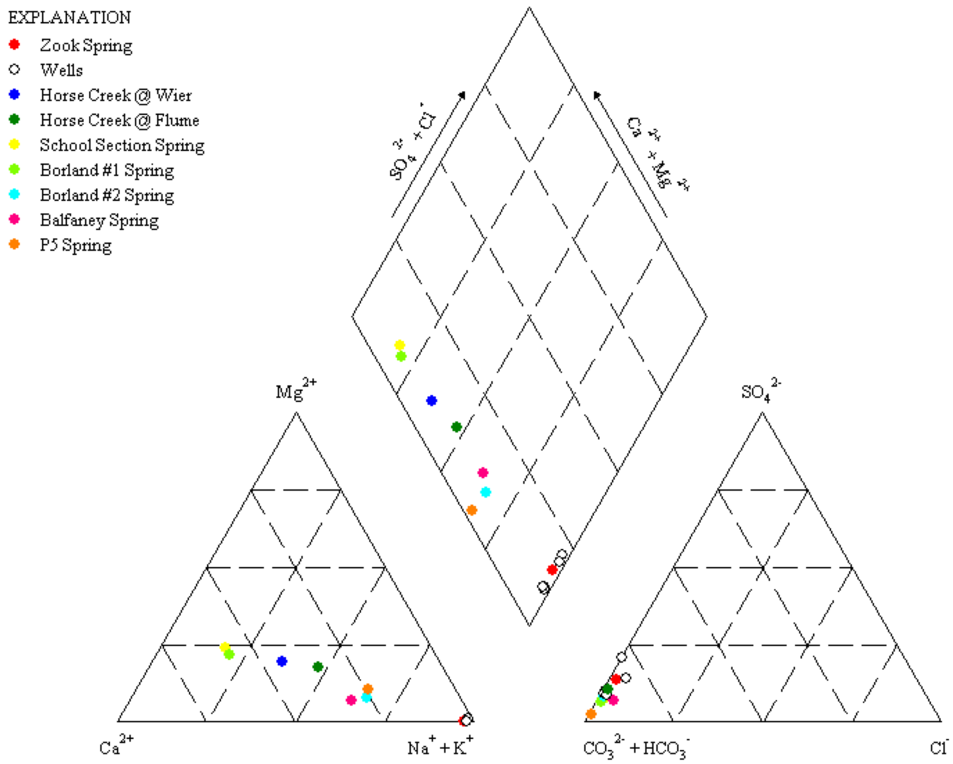


Figure 11. Trilinear diagram of major dissolved ionic constituents

Table 1. Major ion concentrations of Borland #1 spring, Zook spring, and a calculated mixture of the two (3.34:1 ratio) compared to average major ion concentrations at the Horse Creek flume and the Horse Creek weir

	Borland1 Spring	Zook Spring	77% Borland1 + 23% Zook	Horse Creek Flume	Horse Creek Weir
Ca	33.5	2.63	26	24	39
Mg	7.5	0	6	7	10
Na	13	117.25	37	37	36
K	1.2	0	1	1	1
HCO_3	166	267.38	189	189	235
Cl	1.35	3.63	2	2	2
SO_4	9.1	33	15	17	17

Table 2. Estimates of ground-water withdrawals within (1) Horse Creek drainage, (2) study area and (3) study area at full build-out (dry year estimates in parentheses).

Use	**Diverted**	**Consumed**	**Withdrawal**	
			Average gpm	**Acre-Feet**
1- Domestic	18 @160 gpd	18 @8 gpd	0.10	0.16
1- Lawn and garden	18 @239 gpd	18 @239 gpd	3.0 (3.3)	4.8 (5.3)
Subtotal			**3.1 (3.4)**	**5.0 (5.5)**
2- Domestic	27 @160 gpd	27 @8 gpd	0.15	0.24
2- Lawn and garden	27 @239 gpd	27 @239 gpd	4.5 (5.0)	7.2 (8.0)
Subtotal			**4.6 (5.1)**	**7.5 (8.2)**
3- Domestic	74 @160 gpd	74 @8 gpd	0.41	0.66
3- Lawn &	74 @239 gpd	74 @239 gpd	12.3 (13.6)	19.8 (21.9)
Total			**12.7 (14.0)**	**20.5 (22.6)**

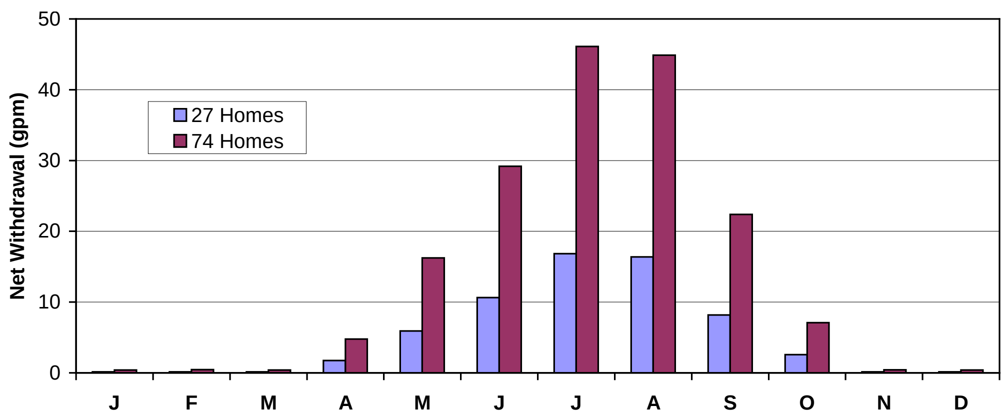


Figure 12. Net withdrawals by month for current uses and at full build-out of Crow Chief Meadows Subdivision.

<u>Water Budget Calculation</u>

The water budgets of inflows and outflows in the Horse Creek drainage for the 2005 and 2007 water years are defined by the following equation.

Infiltration + Ground-Water Inflow = Horse Creek outflow + Phreatophyte ET + Net Withdrawal

The net change in ground-water storage is assumed to be zero in the following calculations as discussed previously.

2007 water year: 2007 was drier than average. Total precipitation was 14.09 inches ranking 43rd of 55 years on record at Fishtail (exceeded by 77.8%). For these calculations, all withdrawals from 18 existing wells are assumed to result in reduced discharge to springs within the Horse Creek drainage and Horse Creek. Net withdrawal equals 5.5 AF with diversion equal to 8.6 AF and return flows from wastewater equal to 3.1 AF.

Horse Creek outflow = 31.1 AF (based on Horse Creek weir data)
Net Withdrawal = 5.5 AF (Table 2 – dry year)

Phreatophyte ET = 23.3 AF (estimated from IR aerial photography and IWR)

Infiltration + Ground-Water Inflow = 31.1 AF + 5.5 AF + 23.3 AF = **59.9 AF**
Infiltration = 0.77 * 59.9 AF = **46.1 AF** (based on water chemistry)
Ground-Water Inflow = 0.23 * 59.9 AF = **13.8 AF** (based on water chemistry)

Recharge estimated to be 59.9 AF during the 2007 water year over 1,168 acres of the Horse Creek drainage above the Horse Creek weir yields an annual recharge of 0.61 inches which is 4.4 percent of 14.02 inches of precipitation for the 2007 water year.

2005 water year: 2005 was the only wetter than average year at Fishtail since 1997. Total precipitation was 21.02 inches ranking it 17th of 55 years on record at Fishtail (exceeded by 29.7%). Withdrawal equals 5.0 AF with diversion equal to 8.1 AF and return flows from wastewater equal to 3.1 AF.

Horse Creek outflow = 156 AF (based on Horse Creek weir flow data)
Net Withdrawal = 5.0 AF (Table 2 – normal year)
Phreatophyte ET = 21.6 AF (estimated from IR aerial photography and IWR)

Infiltration + Ground-Water Inflow = 156 AF + 5.0 AF + 21.6 AF **= 182.6 AF**
Infiltration = 0.77 * 182.6 = **140.6 AF**
Ground-Water Inflow = 0.23 * 182.6 = **42 AF**

Recharge estimated to be 182.6 AF during the 2005 water year over 1,168 acres of the Horse Creek drainage above the Horse Creek weir yields an annual recharge of 1.9 inches which is 9 percent of 21.02 inches of precipitation for the 2005 water year. One quarter of precipitation for the year came in one storm on May 11th and 12th that resulted in significant runoff and discharge of ground water with short residence time. The estimate of Horse Creek flow does not include surface runoff from the May storm; however, it does include the effect of discharge of ground water with short residence time. Taking the peak measurement of 407 gpm on June 2nd out of the calculation reduces Horse Creek outflow to 73 AF and calculated recharge to 99.6 AF which is 5 percent of precipitation. It should be noted that flow at the end of the water year was 62 gpm compared to 11.6 gpm near the beginning of the water year, indicating that some recharge during the water year remained in ground-water storage and the estimate of recharge during 2005 therefore is conservative.

Comparing Withdrawals to Recharge

Existing net withdrawals for 27 wells of 7.5 AF is 1.3 percent of net recharge of 580 AF over 7,700 acres, assuming recharge equal to five percent of normal year precipitation. Withdrawal of 20.5 AF in the study area at full build-out of Crow Chief Meadows Subdivision is 3.5 percent of net recharge of 580 AF over 7,700 acres, again assuming recharge equal to five percent of normal year precipitation. Ultimately, net withdrawals within the study area will be offset by reduced ground-water discharge. Ground-water discharge from springs that receive water from the Tullock Member along faults, such as Zook Spring, could be eliminated during dry years, assuming the subdivision is fully built out and that the effects of withdrawals are concentrated within the Horse Creek drainage. Springs that do not receive water along faults are not expected to be affected or at least will be affected much less. Elimination of ground-water inflow would reduce phreatophyte ET and flows in Horse Creek. For example, flows to Horse Creek and ET could be reduced by 7.9 AF and 5.9AF respectively (according to their estimated current proportions) if 13.8 AF of ground-water inflow during a dry year such as 2007 is eliminated. Under those conditions, Horse Creek flows would be reduced from 31.1 AF (19 gpm) to 23.2 AF (14 gpm) or approximately 25%. This estimate is conservative because drawdown caused by pumping can propagate along faults and capture discharge from springs or surface waters outside the Horses Creek drainage. Of course, flows to springs in other parts of the study area or surface waters at study area boundaries will be reduced when drawdown propagates away from Crow Chief Meadows.

Discussion

The primary concern expressed in the petition for the CGWA is that ground-water development from wells will adversely affect flows from springs and Horse Creek that are relied on for stock watering. The springs of concern have two general sources; one relatively shallow from the Tongue River Member and one deeper that is associated with steep dipping faults that cross the area and allow water to flow to the surface from deeper aquifers. The basic premise of the argument by HCWU is that wells will draw water from the deeper source that feeds springs through faults.

Basic hydrologic principles hold that increased withdrawal of ground water ultimately will be offset by decreased discharge to the surface or, less often, increased recharge from the surface. This capture process occurs as drawdown caused by ground-water pumping reduces the head or pressure that is driving discharge or controls the rate of recharge. Ground water discharges to springs, phreatophyte vegetation, and surface waters including Horse Creek, the Stillwater River and Rosebud Creek. Capture may affect any of those discharges depending on how drawdown propagates.

Data collected by HCWU and DNRC show that ground-water levels and flows to springs in the study area fluctuate seasonally as a result of varying recharge, but generally are not declining year-over-year. In particular, there is no evidence that the current relatively limited withdrawals are causing ground-water level declines. A water budget calculation for the Horse Creek drainage indicates that total recharge is 4.4 percent of precipitation during a relatively dry year and 9 percent during a relatively wet year. Approximately three quarters of that recharge is from shallow sources, with the remainder from seepage along faults. The period of record for the study is not adequate to evaluate the contribution of recharge from regional sources; however, local recharge to the Tongue River Member of the Fort Union Formation and slightly more distant infiltration at the outcrop of the Tullock Member can explain the shallow and deeper sources of recharge, respectively. Recharge observed during the study period discussed in this report was retained as ground-water storage for short time periods and quickly drained to springs and streams.

Assuming no contribution from regional recharge, existing net withdrawals are estimated to be 1.3 and 6.2 percent of average annual recharge in the study area and the Horse Creek Drainage respectively. Further, net withdrawals in the study area and Horse Creek Drainage at full build-out of Crow Chief Meadows Subdivision are estimated to be 4 and 20 percent of average annual recharge. Under worst case assumptions, springs in the Horse Creek drainage could dry up and average annual flows in Horse Creek could be reduced by 25 percent during dry years upon full build-out. However, the effects of withdrawals will be distributed outside the Horse Creek drainage as drawdown propagates along faults.

References

Bredehoeft, J. D., S.S. Papadopulos, and H.H. Cooper, Jr., 1982. Groundwater: the water-budget myth, Scientific Basis of Water Management, National Academy of Sciences Studies in Geophysics, p. 51-57.

Bredehoeft, J. D., 2002. The water budget myth revisited: why hydrogeologists model, Ground Water, V. 40, No. 4, p 340-345.

Edwards, D.C. and T.B. McKee, 1997. Characteristics of 20th century drought in the United States at multiple time scales. Climo Report 97-2, Dept. of Atmos. Sci., Colorado State University, Fort Collins, CO, May, 155 pp.

Kimsey, D.W. and P.K. Flood, 1987. Domestic consumptive use, technical memorandum to the Chief Engineer of the State of Colorado, 16 p.

Lopez, D.A., 2000, Geologic map of the Big Timber 30' x 60' quadrangle, south-central Montana, Montana Bureau of Mines and Geology: Open-File Report 405, 1 sheet(s), 1:100,000.

Lopez, D.A., 2001, Preliminary geologic map of the Red Lodge 30' x 60' quadrangle, south-central Montana, Montana Bureau of Mines and Geology: Open-File Report 423

Paul, W., Poeter, E., and R Laows, 2007. Consumptive loss from and individual sewage disposal system in a semi-arid mountain environment. Colorado Water, Newsletter of the Water Center of Colorado State University, August/September 2007, Volume 24, Issue 4.

Theis, C.V., 1938. The significance and nature of the cone of depression in ground-water bodies, Economic Geology, pp. 889-902.

Theis, C.V., 1940. The source of water derived from wells: essential factors controlling the response of an aquifer to development, Civil Engineering, V. 10, p. 277-280.

U.S. Forest Service, 2001. Technical Report R2-RR-2001-01. Ecological Types of the Upper Gunnison Basin: Series 17 - Water Sedge.

Vanslyke, G. and H. Simpson, 1974. Consumptive use of water by homes utilizing leach fields for sewage disposal, technical memorandum by the Colorado Division of Water Resources, 5 p.

Appendix A: Wells

GWIC	NAME	Lot #	WR#	TRS	Latitude	Longitude	TD	SWL	YIELD	Date
185284	Alley	CCM L3	43C 116774 00	04S 18E 15 ABAD	45.4914	-109.4857	300	50	11	11/16/2000
185283	Alley	CCM L3		04S 18E 15 AAB	45.4924	-109.4838	300	125	1.5	11/13/2000
236299	Baird	CCM L2		04S 18E 15 ABA	45.4925	-109.4868	270	75	12	3/5/2007
216365	Balfany	CCM L24	43C 30012436	04S 18E 14 BDB	45.4888	-109.4739	250	84	5	11/18/2004
170594	Borland	CCM L36		04S 18E 15 ADBB	45.4887	-109.4831	160	2.2	75	1/23/1997
236748	Borland	CCM L64		04S 18E 15 DBB	45.4843	-109.4880	101.5	24.2	43	6/29/2007
234528	Bretherick	CCM L37	43C 30022934	4S 18E 15 BD	45.4880	-109.4932	170	44	8	9/19/2006
239004	Busemann	CCM L43		04S 18E 15 AC	45.4880	-109.4881	150	8	50	9/19/2007
236303	Chandler			04S 18E 14 BAB	45.4924	-109.4739	130	69	35	5/16/2007
101301	Chandler			04S 18E 14 CAAA	45.4860	-109.4706	170	18	2	11/13/1979
	CCM		43C 179909 00	04S 18E 15 DAA						
243787	Davis	CCM L33		04S 18E 15 A	45.4898	-109.4855	155	5	20	4/25/2008
195663	Duffy	CCM L16		04S 18E 14 BBA	45.4920	-109.4755	120	63	30	4/23/2002
198090	Erikson	CCM L15		04S 18E 14 BBB	45.4922	-109.4768	160	70	25	8/5/2002
101264	Flanagan			04S 18E 10 AA	45.5060	-109.4825		35	15	7/1/1943
207401	Flanagan			04S 18E 10 DDB	45.4960	-109.4838	230	44		9/30/2003
202657	Flynn	CCM L29	43C 30007399	04S 18E 15 DDB	45.4875	-109.4838	125	14.5	60	10/10/2002
202653	Hamilton		43C 30006311	04S 18E 15 ADB	45.4872	-109.4832	104	28.5	30	10/10/2002
170593	Harvkey	CCM L39		04S 18E 15 ACA	45.4889	-109.4868	100		34	11/23/1997
101260	Herigstad			04S 18E 3 BB	45.5204	-109.4979	130	55		10/7/1977
215398	HCWU			04S 18E 16 DA	45.4844	-109.5035	200		3.5	11/9/2004
236298	Kynast	CCM L53	43C 30026229	04S 18E 15 BDA	45.4889	-109.4919	110	29	30	3/7/2007
245643	Lindermuth	CCM L62		04S 18E 15 CAC	45.4834	-109.4945	103	32	30	7/14/2008
192456	Lofstedt	CCM L13,14	43C 30001933	04S 18E 14 BBA	45.4927	-109.4760	132	93.33	21	9/6/2001
235627	Poliseno	CCM L56		04S 18E 15 BCA	45.4880	-109.4962	103	29.5	21	4/30/2007
234528	Poliseno	CCM L54		04S 18E 15 BD	45.4880	-109.4932	170	44	8	9/19/2006
224961	Poliseno	CCM L57	43C 30016588	04S 18E 15 CAC	45.4944	-109.7458	220	31	4	10/17/2005
202653	Skorka	CCM L30		04S 18E 15 ADB	45.4872	-109.4832	104	28.5	30	10/10/2002
192455	Stebbins	CCM L12		04S 18E 14 BBB	45.4910	-109.4778	110	35.91	50	11/6/2001
246156	Waite	CCM L19		04S 18E 14 BBB	45.4924	-109.4791	124	23.85	60	7/15/2008
179441	Walsh	CCM L1A	43C 30003503	04S 18E 15 ABA	45.4918	-109.4876	130	42	30	11/22/1999
192450	Wassman	CCM L11	43C 30028074	04S 18E 14 BBB	45.4912	-109.4788	130	41	25	12/6/2001

Appendix B: Other Water Rights

Water Right #	Owner	Type	Diversion	Location	Priority
43C 197359 00	Flanagan, Joe G. & John J.	Groundwater	Livestock direct from source	4S 18E 2 CCD	1/1/1900
43C 197360 00	Flanagan, Joe G. & John J.	Groundwater	Livestock direct from source	4S 18E 10 ADD	1/1/1900
43C 197368 00	Flanagan, Joe G. & John J.	Groundwater	Livestock direct from source	4S 18E 3 DBA	1/1/1900
43C 197369 00	Flanagan, Joe G. & John J.	Groundwater	Livestock direct from source	4S 18E 11 ABC	1/1/1900
43C 200074 00	Flanagan, Joe G. & John J.	Groundwater	Livestock direct from source	4S 18E 11 AAC	1/1/1900
43C 200075 00	Flanagan, Joe G. & John J.	Groundwater	Livestock direct from source	4S 18E 13 BBD	1/1/1900
43C 200076 00	Flanagan, Joe G. & John J.	Groundwater	Livestock direct from source	4S 18E 10 AAB	1/1/1900
43C 15048 00	Rex, Polly T.	Groundwater	Livestock direct from source	4S 18E 9 DDA	4/7/1919
43C 15049 00	Rex, Polly T.	Groundwater	Livestock direct from source	4S 18E 9 DAB	4/7/1919
43C 15050 00	Rex, Polly T.	Groundwater	Livestock direct from source	4S 18E 9 ABC	6/5/1919
43C 15700 00	Rex, Polly T.	Surface Water	Headgate	4S 18E 3 BC	7/1/1897
43C 15701 00	Rex, Polly T.	Groundwater	Livestock direct from source	4S 18E 3 CCD	8/8/1917
43C 15702 00	Rex, Polly T.	Groundwater	Livestock direct from source	4S 18E 3 CDD	8/11/1917
43C 208831 00	Eggers, Jacob P.	Surface Water	Headgate	4S 18E 22 DAD	5/11/1918
43C 105904 00	Gauthier, Marta & Rodney J.	Surface Water	Developed spring	4S 18E 3 CAB	10/1/1998
43C 130367 00	Campbell, Wallace L. & Wendelin L.	Groundwater	Livestock direct from source	4S 18E 14 DDC	4/30/1893
43C 130368 00	Campbell, Wallace L. & Wendelin L.	Groundwater	Livestock direct from source	4S 18E 14 DDC	4/30/1893
43C 130370 00	Crow Chief Meadows, Inc	Groundwater	Livestock direct from source	4S 18E 14 BCB	4/30/1893
43C 109824 00	Baulmer, Jill I.	Groundwater	Developed spring	4S 18E 15 BAA	11/16/1999
43C 130371 00	Crow Chief Meadows, Inc	Groundwater	Livestock direct from source	4S 18E 14 DBA	4/30/1893
43C 130374 00	Crow Chief Meadows, Inc	Groundwater	Livestock direct from source	4S 18E 14 BDA	4/30/1893
43C 130375 00	Crow Chief Meadows, Inc	Groundwater	Livestock direct from source	4S 18E 14 CBC	4/30/1893
43C 179910 00	Crow Chief Meadows, Inc	Groundwater	Livestock direct from source	4S 18E 14 DAB	4/30/1893
43C 181271 00	Crow Chief Meadows, Inc	Groundwater	Livestock direct from source	4S 18E 14	4/30/1893
43C 130372 00	Crow Chief Meadows, Inc	Groundwater	Livestock direct from source	4S 18E 14 ACC	4/30/1893
43C 130355 00	Crow Chief Meadows, Inc	Groundwater	Livestock direct from source	4S 18E 14 DAA	4/30/1893
43C 130376 00	Crow Chief Meadows, Inc	Groundwater	Livestock direct from source	4S 18E 14 DAA	4/30/1963
43C 179781 00	Crow Chief Meadows, Inc	Groundwater	Livestock direct from source	4S 18E 14 DAB	5/11/1918
43C 29846 00	Board of Land Commissioners	Groundwater	Livestock direct from source	4S 18E 16 DAD	2/15/1910
43C 298852 00	Board of Land Commissioners	Groundwater	Livestock direct from source	4S 18E 16 BDC	2/15/1910
43C 17334 00	Bass, Carol Anne Trust	Groundwater	Livestock direct from source	4S 18E 20 AAA	5/1/1973
43C 17336 00	Bass, Carol Anne Trust	Groundwater	Livestock direct from source	4S 18E 20 CAC	12/31/1913

Water Right #	Owner	Type	Diversion	Location	Priority
43C 111946 00	Daniel, Arthur D. & Bonita L.	Groundwater	Livestock direct from source	4S 18E 21AAC	12/3/1914
43C 111948 00	Daniel, Arthur D. & Bonita L.	Groundwater	Livestock direct from source	4S 18E 21CBD	3/19/1971
43C 111947 00	Daniel, Arthur D. & Bonita L.	Groundwater	Livestock direct from source	4S 18E 21 BCB	3/19/1971

Appendix C: Average Major-Ion Chemistry

Sample Site	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	TDS
School Section Spring	31.67	7.82	11.50	0.00	0.00	148.83	1.62	9.33	157.33
Borland 1 Spring	33.5	7.5	13	1.15	0	166	1.35	9.1	174
Grove Creek 3	27	3.9	16	0.9	0	126	1.5	21	168
Lannen Spring	30.80	9.40	17.60	0.00	0.00	171.20	1.25	9.60	171.40
Rex Spring 6	36.50	12.50	21.00	1.00	0.00	192.50	1.50	24.50	206.00
Massee Well	35.00	14.00	26.00	1.00	0.00	229.00	3.00	25.00	223.00
Rex Spring 1	43.50	14.00	26.50	1.00	0.00	242.00	2.50	14.50	234.00
Rex Spring 4	34.50	9.00	29.50	0.00	0.00	178.50	1.00	30.50	207.50
Rex Spring 5	39.00	11.00	30.50	1.00	0.00	207.00	1.00	22.50	224.00
Grove Creek 1	27	5	32	1.6	0	172	1.8	21	220
Horse Creek Weir	38.57	10.14	35.71	1.36	0.00	235.43	2.29	16.57	235.43
Johnson Spring 2	28.25	9.25	35.75	0.00	0.00	191.75	1.00	24.25	208.75
Horse Creek Flume	24.00	7.30	37.00	1.00	0.00	189.00	1.80	17.00	226.00
Gauthier Well	26.67	5.67	42.67	1.00	0.00	195.67	3.00	13.33	201.33
Rex Spring 3	28.63	9.00	44.75	0.00	0.00	218.38	1.38	23.50	228.17
Rex Spring 2	40.13	11.88	46.88	0.00	0.00	267.00	4.00	26.75	273.50
Gravel Pit Spring	31.67	12.00	49.33	2.67	0.00	253.67	2.67	21.67	250.50
Bass Well	52.50	23.50	50.50	1.83	0.00	290.83	9.33	80.17	376.00
Johnson Spring 3	44.00	12.50	50.50	1.38	0.00	284.50	2.00	22.00	284.50
Rex Barn Well	70.00	21.00	52.00	2.00	0.00	403.00	5.00	40.00	409.00
Flanagan Spring	25.67	8.83	52.17	1.58	0.00	233.50	1.83	18.50	235.80
Johnson Spring 1	42.40	12.00	53.40	1.40	0.00	284.00	2.80	24.00	289.80
Rex House Well	55.00	17.50	62.50	2.00	0.00	344.50	3.50	41.50	367.00
Borland 2 Spring	22.5	4.05	65.5	1	0	238.5	2.5	16.5	271
Balfaney Spring	35	4.5	80	1.6	0	307	9.9	18	314
P5 Spring	34	8.8	103	2.8	0	407	1.5	7.3	454
Borland #2 Well	2.00	0.00	114.00	0.00	12.00	224.00	1.00	22.00	261.00
Lot 19 Well	1.95	0	116	0.5	7	271.5	1.65	22.5	281
Zook Spring	2.63	0.00	117.25	0.00	0.00	267.38	3.63	33.00	298.63
School Section Well	2.29	0.00	118.71	0.00	8.14	229.29	0.00	50.29	309.83
Chandler House	1.50	0.50	124.17	0.50	17.17	251.33	3.83	21.00	304.60
Witt Well	2.17	0.00	127.33	0.00	13.67	241.33	9.67	36.00	307.20
Rex Monitoring Well	4.00	0.00	135.38	2.00	16.25	283.38	2.00	20.13	431.00
Brown Well	2.60	0.00	140.80	0.00	8.80	268.40	2.40	52.80	352.60
Nash Well	12.75	2.50	141.50	0.75	6.00	340.00	14.25	33.50	377.67
Chandler New	10.00	3.00	158.00	3.00	19.00	280.00	7.00	44.00	446.00
Teegardin Well	28.00	6.00	188.00	0.00	0.00	466.00	23.00	108.00	572.00

Appendix D: Photographs

Horse Creek with flume and recorder enclosure: April 30, 2004.

Horse Creek with flume and recorder enclosure: August 8, 2008.

Horse Creek at Horse Creek Weir: April 30, 2004.

Looking southwest across Crow Chief Meadows Subdivision: April 8, 2008

Vegetation along Horse Creek in Crow Chief Meadows Subdivision: August 8, 2008

Grove Creek above culvert under Grove Creek Road: March 24, 2008

Borland 1 Spring: April 30, 2004

Horse Creek Source downstream from Borland 1 Spring: April 30, 2004

Borland 2 Spring: April 8, 2008

Zook Spring Box: April 30, 2004

Balfany Spring: September 30, 2008

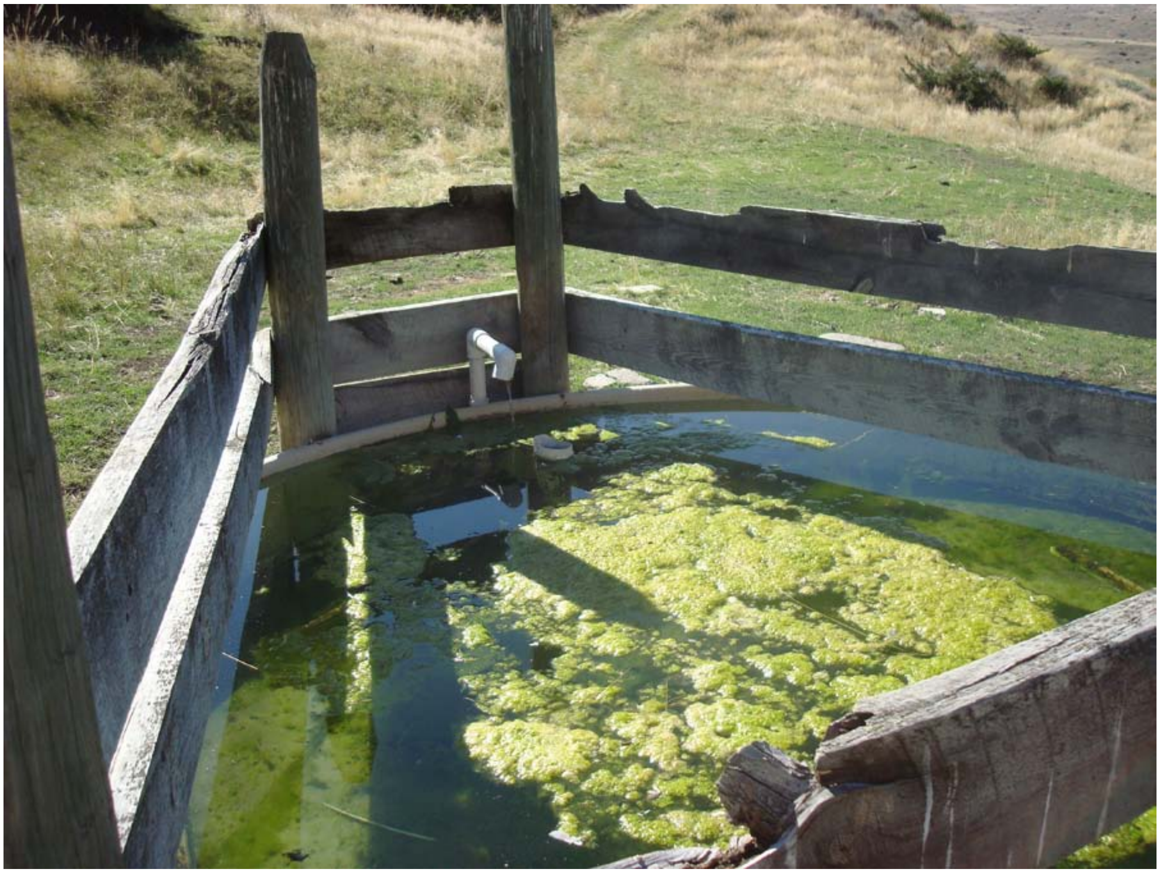
Gravel Pit Spring: September 30, 2008

Flanagan Spring: September 30, 2008

Rex Spring 6: September 30, 2008

Rex Spring 5 watering trough: September 30, 2008

Rex Spring 5 Source: September 30, 2008



Rex Spring 4 watering trough: September 30, 2008

Rex Spring 4 Source: September 30, 2008

Rex Spring 3 Source: September 30, 2008

Rex Spring 2: September 30, 2008

Rex Spring 1: September 30, 2008

Johnson Spring 2: September 30, 2008


P5 Spring: August 8, 2008

Appendix E: Aquifer Test Analysis

Aquifer Testing

A constant discharge aquifer test was conducted by DNRC on a well drilled on lot 19 of Crow Chief Meadows Subdivision. The test ran from 11:00 on 8/6/08 until 10:00 on 8/8/08 for a total pumping time of 47 hours. The pumping rate during the test was held constant between 58 and 59 gpm, averaging 58.5 gpm. Water levels were monitored in the pumping well using an electronic water-level probe and in wells in lots 8 and 62 using pressure transducers and dataloggers. A pressure transducer was installed in the pumping well, but apparently hung up above the water level and did not record any useful data. For that reason, drawdown analysis for the pumping well is based on measurements taken using an electronic probe and no recovery data were collected. Water-level trends were observed from pre-test monitoring and were corrected before analysis.

The water level in the lot 19 pumping well drew down approximately 24 feet during the test (Figure E1). Drawdown in the pumping well followed a straight line on a semi-log plot for approximately the first eight hours of the test indicating radial flow. After eight hours, drawdown deviated from the straight line, indicating the fracture system supplying the well is discontinuous or there is an impermeable boundary resulting from a change in lithology or faulting. Analysis using the Cooper-Jacob straight-line method yields a transmissivity estimate of approximately 1,000 ft^2/day (Figure E2). Because the aquifer is discontinuous, transmissivity values calculated for early time data are not representative of the aquifer outside the area nearby the test wells.

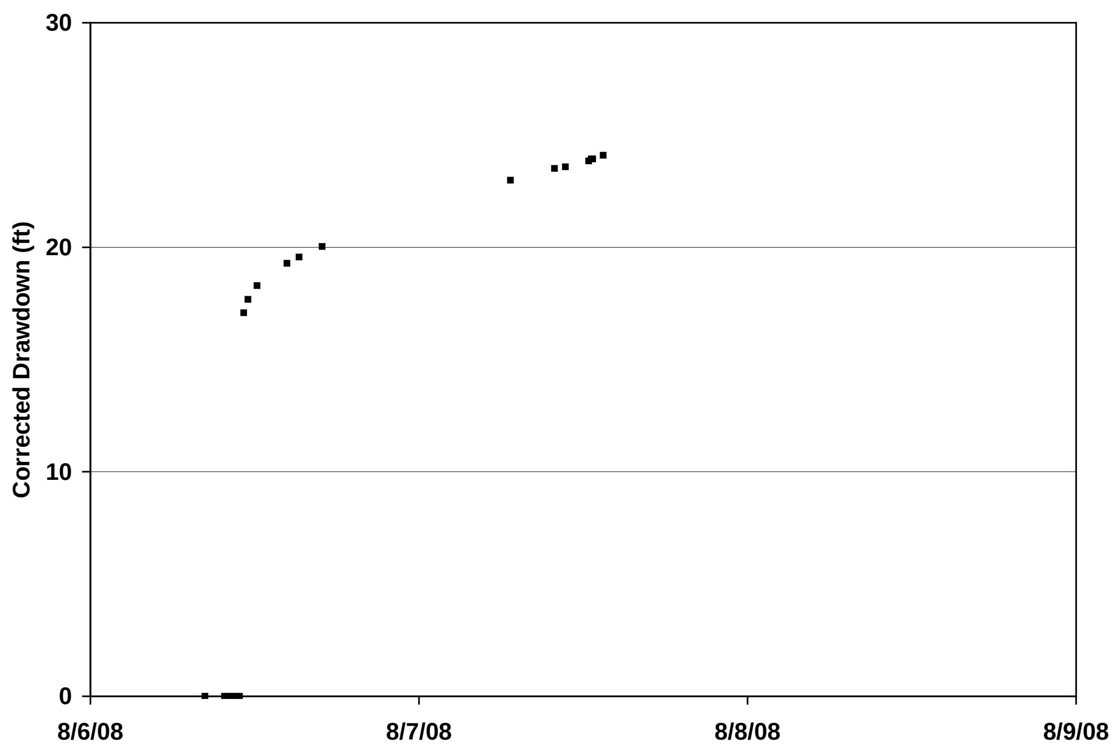


Figure E1. Drawdown during 47-hour constant-discharge test for lot 19 pumping well.

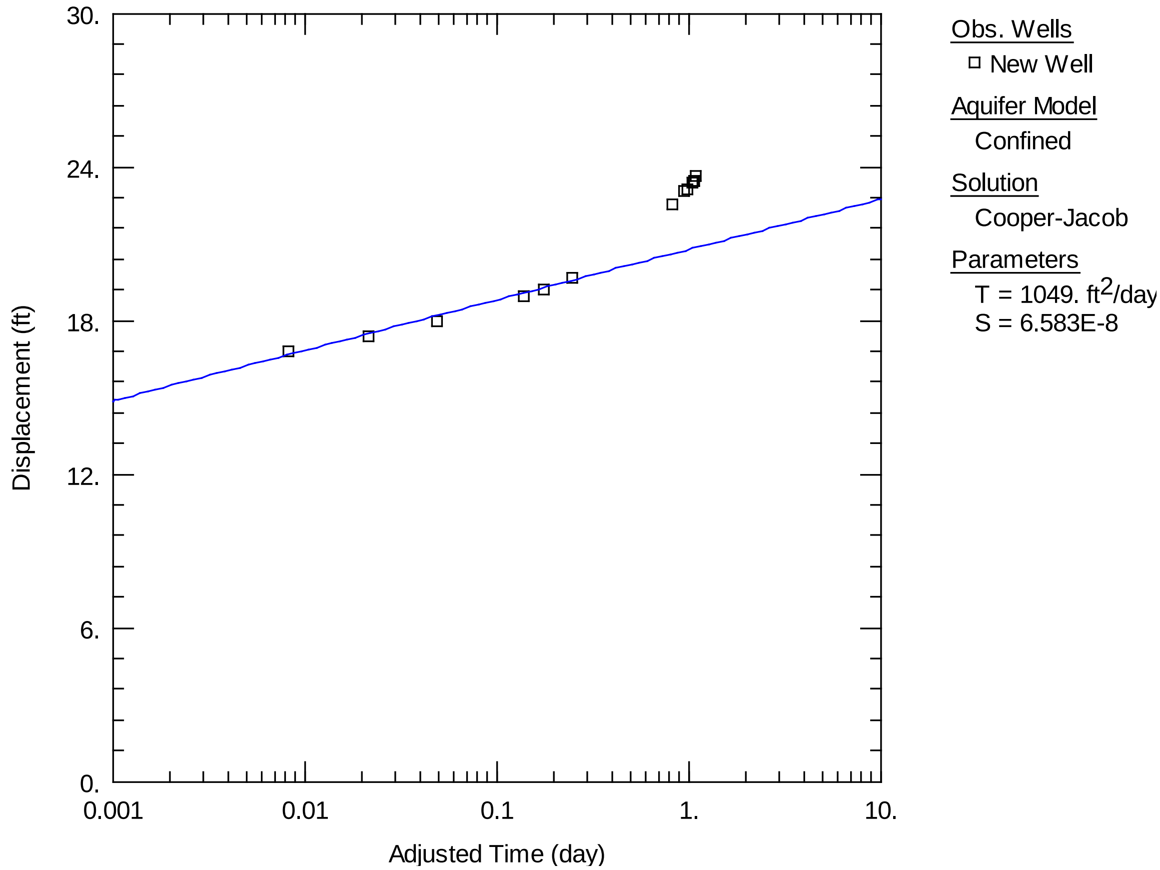


Figure E2. Cooper-Jacob straight line fit to drawdown data from lot 19 pumping well.

Approximately 1.5 feet of drawdown (corrected for pre-test trend) were observed in a well in lot 8, located 940 feet from the lot-19 pumping well (Figure E3). Drawdown in the lot-8 observation well followed the Theis model for radial flow in a homogeneous aquifer early in the test (Figure E4), but later deviates above the Theis curve indicating a discontinuous fracture system or no-flow boundary. The water level in the lot 8 observation well recovered slowly after the aquifer test, eventually returning to the pre-test trend line after approximately nine days of recovery (Figure E5), also indicating the fracture system supplying the well is discontinuous. Drawdown data for the first 5 ½ hours were matched to the Theis type curve to obtain estimates of transmissivity equal to 1,600 ft^2/day and storativity equal to 0.0014 (Figure E4). Again, transmissivity estimated using the Theis model is not representative of the aquifer outside the area nearby the test wells because of the boundary effects observed late in the test.

The water level in a well in lot 62 located 4,120 feet from the lot-19 pumping well showed no effect during the test that can be separated from background fluctuations. In addition, no changes were detected in flows of Borland Spring #2 or at the Horse Creek Flume.

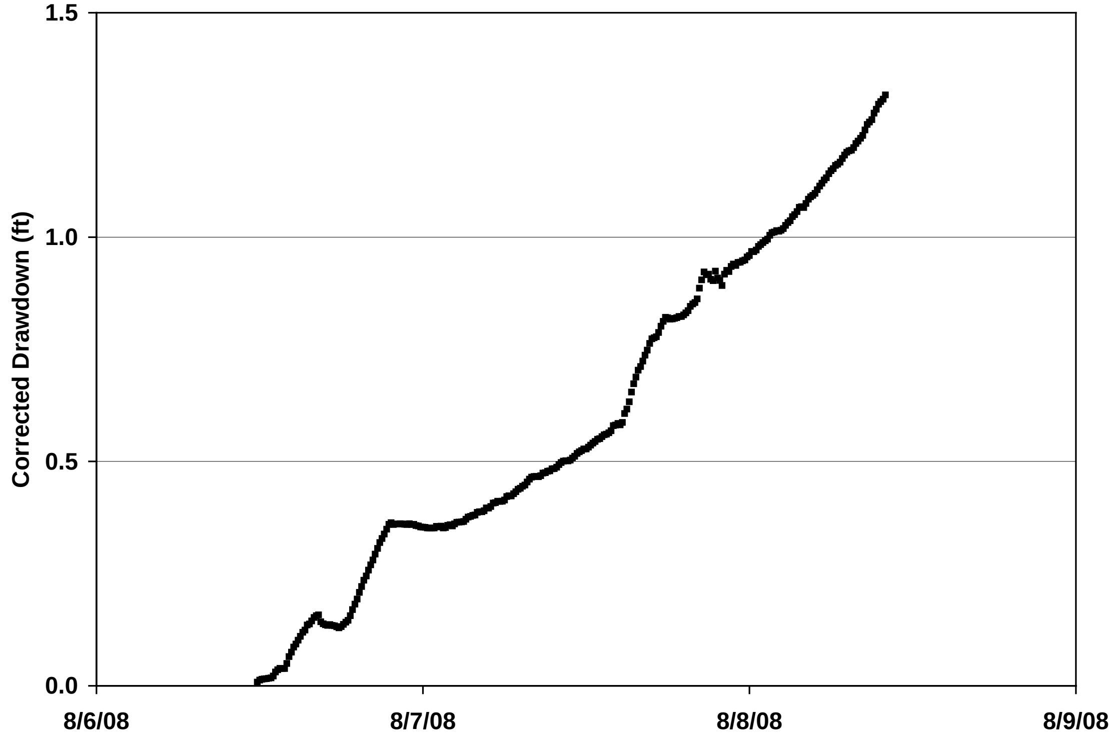


Figure E3. Drawdown in Lot 8 observation well during 47-hour constant-discharge test of Lot 19 pumping well.

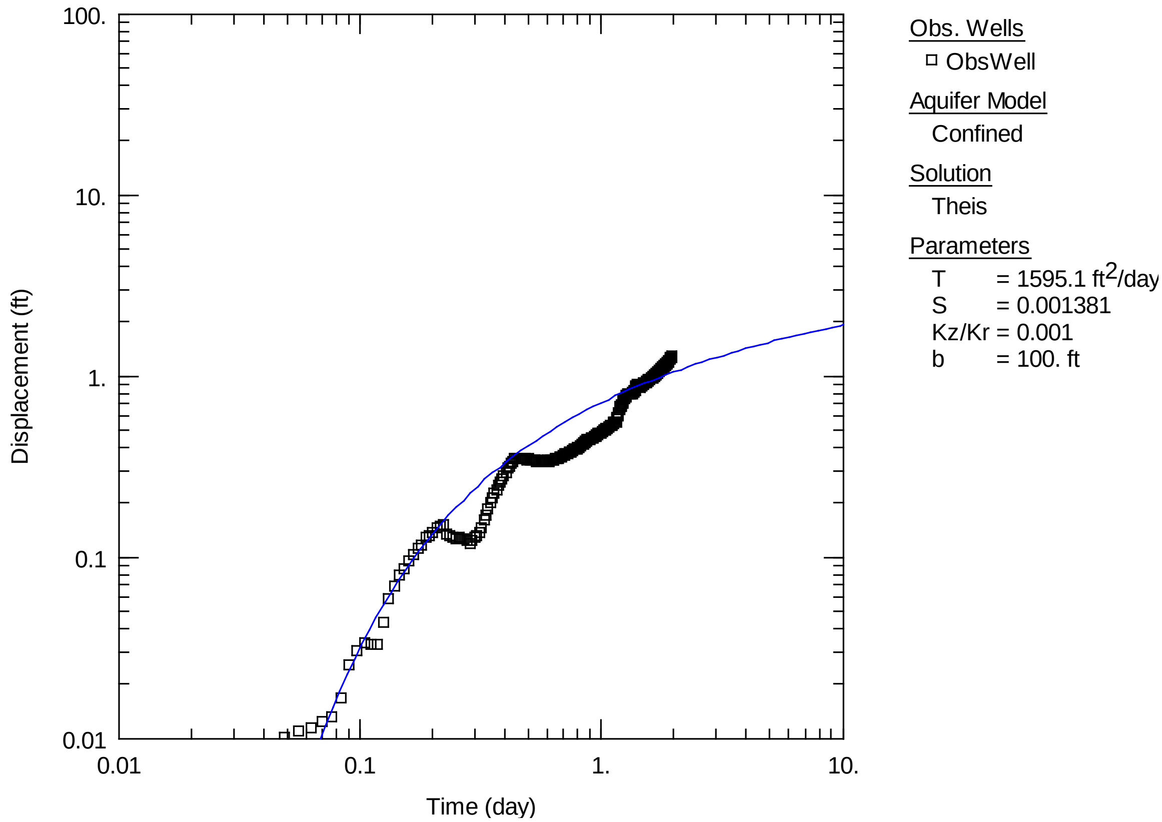


Figure E4. Theis type curve fit to drawdown data from Lot 8 observation well.

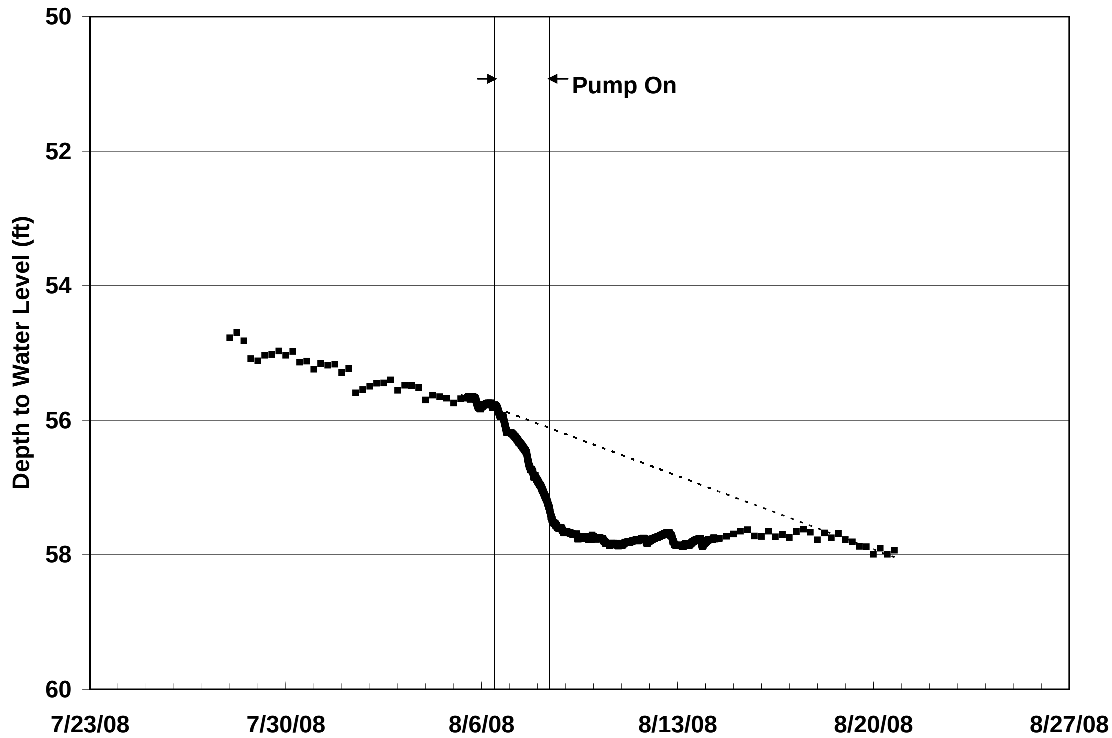


Figure E5. Depth to water in lot 8 observation well before, during and after test of lot 19 pumping well.

Appendix F: Irrigation Water Requirement Reports

Irrigation Water Requirements
Crop Data Summary

Job: **Subirrigation Alfalfa**
Location: **Horse Creek**
By: **Russell Levens**
Weather Station: **NYE 2**
Latitude: **4526** Longitude: **10948**
Computation Method: **Blaney Criddle (TR21)**
Crop Curve: **Blaney Criddle Perennial Crop**
Begin Growth: **5/10** End Growth: **9/22**

Crop: **Alfalfa Hay**
County: **Stillwater, MT**
Date: **10/29/08**
Sta No: **MT6190**
Elevation: **4810** feet above sea level

Net irrigation application: **1** inches
Estimated carryover moisture used at season:
Begin: **1** inches End: **1** inches

Month	Total Monthly ET (3) inches	Dry Year 80% Chance (1)		Normal Year 50% Chance (1)		Average Daily ETc inches	Peak Daily ETPk inches
		Effective Precipitation inches	Net Irrigation Reqirements inches (2)	Effective Precipitation inches	Net Irrigation Reqirements inches (2)		
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.00	0.00	0.00	0.00	0.00	0.00	
May	2.23	0.82	0.42	1.05	0.19	0.10	
June	5.41	1.41	4.00	1.81	3.60	0.18	0.21
July	6.76	0.97	5.78	1.24	5.51	0.22	0.27
August	6.02	0.67	5.35	0.85	5.17	0.19	0.24
September	2.54	0.47	1.08	0.60	0.95	0.12	
October	0.00	0.00	0.00	0.00	0.00	0.00	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**22.97**	**4.34**	**16.63**	**5.56**	**15.41**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

(3) ET Evapotranspiration) is adjusted upwards 10% per 1000 meters above sea level.

Date: 11/13/2008

Irrigation Water Requirements
Crop Data Summary

Job: **Horse Creek Final**
Location: **Stillwater County**
By: **Russell Levens**
Weather Station: **NYE 2**
Latitude: **4526** Longitude: **10948**
Computation Method: **Blaney Criddle (TR21)**
Crop Curve: **Blaney Criddle Perennial Crop**
Begin Growth: **4/20** End Growth: **10/20**

Crop: **Pasture (grass)**
County: **Stillwater, MT**
Date: **10/08/08**
Sta No: **MT6190**
Elevation: **4810** feet above sea level

Net irrigation application: **1** inches
Estimated carryover moisture used at season:
Begin: **1** inches End: **1** inches

Month	Total Monthly ET (3)	Dry Year 80% Chance (1)		Normal Year 50% Chance (1)		Average Daily ETc	Peak Daily ETPk
		Effective Precipitation	Net Irrigation Reqirements	Effective Precipitation	Net Irrigation Reqirements		
	inches	inches	inches (2)	inches	inches (2)	inches	inches
January	0.00	0.00	0.00	0.00	0.00	0.00	
February	0.00	0.00	0.00	0.00	0.00	0.00	
March	0.00	0.00	0.00	0.00	0.00	0.00	
April	0.75	0.27	0.00	0.34	0.00	0.07	
May	3.09	1.20	1.37	1.54	0.95	0.10	0.12
June	4.43	1.34	3.09	1.72	2.71	0.15	0.17
July	5.61	0.91	4.70	1.17	4.45	0.18	0.22
August	5.14	0.63	4.51	0.81	4.33	0.17	0.20
September	2.88	0.63	1.99	0.81	1.72	0.09	0.11
October	1.07	0.33	0.00	0.42	0.00	0.05	
November	0.00	0.00	0.00	0.00	0.00	0.00	
December	0.00	0.00	0.00	0.00	0.00	0.00	
TOTAL	**22.97**	**5.31**	**15.66**	**6.81**	**14.16**		

(1) For 80 percent occurrence, growing season effective precipitation will be equaled or exceeded 8 out of 10 years. For 50 percent chance occurrence, effective precipitation will be equaled or exceeded 1 out of 2 years.

(2) Net irrigation requirements is adjusted for carryover moisture used at the beginning of the season and carryover moiature used at the end of the growing season.

(3) ET Evapotranspiration) is adjusted upwards 10% per 1000 meters above sea level.

Date: 11/13/2008