Assessment of Increased River Flows on Ground Water Quality in Wells Adjacent to the Kootenai River, Montana

By Kent B. Easthouse

U.S. Army Corps of Engineers, Seattle District
Hydrology and Hydraulics Section

Seattle, Washington
August, 2004

Contents

Tables

Figures

Introduction

The Kootenai River valley is located in Lincoln County, Montana. Since construction of Libby Dam in the early 1970s, the United States Army Corps of Engineers (COE) has regulated flows on the Kootenai River below the dam for flood control and power production. Prior to impoundment, daily mean flows in the Kootenai River at Libby, Montana ranged from about 65,000 cubic feet per second (cfs) in June to about 4,000 cfs in October. The impoundment of the river by Libby Dam in 1972 reduced the daily mean flow levels in the Kootenai River during the normal high runoff spring period to about 20,000 cfs, resulting in nearly 30 years of reduced flow conditions. During this period of time, Lincoln County experienced increased growth and development of properties adjacent to the Kootenai River.

Since the early 1990s, the COE has released greater flows from Libby Dam during the spring to benefit Kootenai River white sturgeon spawning and survival. These increased flows have been limited to the Libby Dam powerhouse capacity of 25,000 to 28,000 cfs. The United States Fish and Wildlife Service issued a 2000 Biological Opinion in which they recommended the COE increase sturgeon flows from Libby Dam to 35,000 cfs by 2007.

The quality of ground water in the Kootenai River valley is important because many residents of the valley rely on ground water for drinking water. Typically, homes located outside of urban centers in the Kootenai River valley have drinking water wells and on-site wastewater disposal systems located on their property. In addition, homes located on properties adjacent to the Kootenai River generally have drinking water wells located close to the river. Consequently, Lincoln County expressed concerns that increased discharge flows from Libby Dam may increase hydraulic pressure resulting in infusion of river waters into the surrounding ground water system, potentially resulting in contamination of drinking water wells or saturation of on-site wastewater treatment and disposal systems on properties adjacent to the Kootenai River. To address these concerns, the COE and Lincoln County designed a ground water study to quantify more precisely the effect of river flows on the ground water system adjacent to the Kootenai River.

Purpose and Scope

The Seattle District Corps of Engineers, in cooperation with Lincoln County, conducted a ground water quality assessment of selected wells in the Kootenai River valley during 2002. The purpose of the study was to determine whether increased discharge volumes from Libby Dam, and the resulting high flows in the Kootenai River affected ground water resources in the Kootenai River valley through direct contamination of drinking water wells, or by saturating on-site wastewater treatment and disposal systems on properties adjacent to the Kootenai River. The major objectives of this study were:

- To evaluate the water quality of drinking water wells during high flow and base flow, to determine whether significant differences exist
- To determine whether drinking water wells were contaminated by on-site wastewater disposal systems during high flow conditions
- To evaluate how high flows in the Kootenai River affect surface water and ground water exchange along the Kootenai River valley
- To identify the source(s) of ground water in the Kootenai River valley
- To determine whether drinking water wells are under the direct influence of surface waters.

These objectives were addressed using data collection and analysis methods to evaluate ground water quality, surface water quality, and ground water-surface water exchange characteristics. Data were collected from eight (8) drinking water wells, seven (7) river stations, six (6) monitoring wells, and four (4) river stage gages. The study was conducted from June through December 2002 and focused on the Kootenai River valley from Libby Dam to Troy, Montana.

Methods and Materials

Description of Study Area

The Kootenai River valley is located in Lincoln County, northwestern Montana (Figure 1). The Kootenai River originates in the Rocky Mountains of British Columbia at an elevation exceeding 11,000 feet, flows southward toward Montana, and enters Lake Koocanusa approximately 40 miles north of the international border. Lake Koocanusa is the 90-mile long reservoir formed by Libby Dam, a COE project located in the Kootenai River Valley at river mile (RM) 221.9, approximately 11 miles east of the town of Libby. The reservoir has a gross storage capacity of 5.81 million acre feet (MAF), a maximum depth of 350 feet, and a mean water residence time of about 9 months. Downstream of Libby Dam, the Kootenai River flows south for about 3 miles to the mouth of the Fisher River and then flows northwest through the towns of Libby and Troy, Montana before entering Idaho. This study was conducted in the Kootenai River valley from Libby Dam downstream to Troy, Montana (Figure 2).

The study area is dominated by high, forested, northwest trending mountain ranges separated by narrow river valleys. Elevations range from about 1,900 feet in the Kootenai River valley west of the town of Troy to over 8,000 feet in the Cabinet Mountains south of the town of Libby. The Kootenai River valley is characterized by relatively flat terraces that lie at intervals between the river and steep mountain slopes. The mountains rise as much as 2,000 feet per mile from the valley and vegetation is dominated by Ponderosa Pine, Douglas-fir, western larch, western redcedar, western hemlock, and lodgepole pine (USDA 1995). The valley width ranges from about 1/2 mile at Libby Dam to about 5 miles in the vicinity of the town of Libby.

The Kootenai River downstream of Libby Dam follows a free flowing course with an average slope of about 5 feet per mile. The river is broken intermittently by rapids and white water at the confluences of tributary streams, and by Kootenai Falls at RM 193. The falls are a 200-foot high series of stepped falls located in a narrow section of the valley. The major tributaries to the Kootenai River in the study area are the Fisher River, Libby Creek, Quartz Creek, Lake Creek, and Callahan Creek (see Figure 2). In general, these tributary streams are steeper than the Kootenai River, with a typical slope of about 50 feet per mile (Boettcher and Wilke 1978).

Population centers in the study area include the towns of Libby and Troy. Individual homes and trailer parks are located on the flat terraces that are immediately adjacent to the Kootenai River and tributaries from Libby Dam to the Idaho border (see Figure 2). Ground water is the source of drinking water for many residents in the Kootenai River valley.

Geologic Characteristics

The geology of the Kootenai River valley varies from rocks of Precambrian age to consolidated and unconsolidated alluvial and glacial deposits of Quaternary age (Harrison et al. 1992). Bedrock consists largely of metasedimentary rocks of the Middle Proterozoic Belt Supergroup and limited exposures of Paleozoic, Mesozoic, and Tertiary strata. Harrison et al. (1992) estimated the bedrock to be about 48,000 feet thick. Unconsolidated and consolidated valley deposits consist of Holocene alluvial deposits, as well as Pleistocene glacial and fluvioglacial deposits and Pleistocene lakebed deposits. The alluvial and glacial deposits compose the principal water bearing units in the Kootenai River valley (Boettcher and Wilke, 1978).

Fluvioglacial and glacial deposits overlie the Precambrian rocks. In general, the glacial deposits are composed primarily of broken and crushed Precambrian rocks that were deposited as till by the ice. The glacial deposits consist largely of poorly sorted boulders, gravel, sand, silt, and clay. Boettcher and Wilke (1978) estimated the thickness of these deposits to exceed 500 feet in the middle of the Libby Creek valley. These authors noted that wells tapping these glacial deposits generally produce less than 30 gal/min.

Lakebed deposits of clay, silt, and fine sand overlie the glacial deposit (Boettcher and Wilke 1978). Local deposits of gravel can be found at the top and base of these lakebed sediments. Lakebed deposits are known to yield little to no water because of their low permeability and because the formation has been drained due to downcutting of the Kootenai River. Estimated thickness of these deposits is more than 350 feet thick.

Alluvial deposits consist largely of relatively well sorted and reworked silt, sand, gravel, and cobbles (Boettcher and Wilke 1978). Reworking separates the finer from the coarser materials leading to coarser materials being deposited in the stream channels and the finer materials being deposited along the edge. The alluvium has been unevenly deposited on top of the glacial deposits, leading to wide ranges in the alluvium thickness and grain size in the valley. Boettcher and Wilke (1978) estimate the thickness of the alluvium in the vicinity of the town of Libby to be 100 feet locally, but the maximum thickness and shape of the alluvium in the Kootenai River valley are unknown. Because of the coarse grained texture of the alluvium, these deposits are more permeable than the glacial deposits, yielding from less than 100 gal/min to more than 500 gal/min. The variable yields are due to the variable thickness of the alluvial deposits.

Hydrologic Characteristics

The climate of the study area is influenced by easterly moving weather systems from the Pacific Ocean. Winters are generally cloudy, cool, and wet, with November through March being the wettest months. Most of the snowpack in the mountains falls between November and April. Summers are typically warm and dry, with little rainfall occurring from June through September. The mean annual precipitation at Troy (elevation 1,929 ft.) is 25.5 inches, and at Libby (elevation 2,080 ft.) is 19.4 inches (USDA 1995). Annual snowfall varies from about 40 inches in the valleys to an estimated 300 inches in some mountain areas.

Boettcher and Wilke (1978) note that ground water levels in the Kootenai River valley respond rapidly to changes in stream stage. In general, ground water levels begin to rise in the spring in response to the increased stream stage as a result of spring snowmelt runoff. During May and June, ground water levels are at their highest, and the water table begins to decline in July when runoff decreases and evaporation and transpiration increase. Ground water levels can rise in October and November due to increased precipitation and decreased evapo-transpiration rates. However, ground water levels generally decline in December and typically remain low during the winter because the water is stored as snow or ice and does not reach the ground water until melting occurs in the spring. Recharge to the ground water system is dominated by precipitation and streamflow (Boettcher and Wilke 1978).

Much of the annual runoff in the Kootenai River valley occurs in spring with the snowmelt. The impoundment of the Kootenai River by Libby Dam in 1972 for flood control and hydroelectric power production altered the seasonal flow patterns of the river (Bonde and Bush 1982). The annual pre-impoundment runoff conditions for the Kootenai River at the town of Libby showed high flows from April through June time period, with relatively low runoff the rest of the year, especially in the dry late summer/fall period, and the cold winter periods (Bonde and Bush 1982). Average pre-impoundment (1912 – 1971) flows in the Kootenai River ranged from about 65,000 cfs in late May and early June to about 4,000 cfs in January (USGS 2003). Post-impoundment conditions (1972 – 2001) have resulted in retaining water during historical high flow periods and discharging water during historical low flow periods. Since the early 1990s the COE has increased spring discharge levels to benefit downstream sturgeon survival. In general, the Kootenai River experiences reduced flows for most of the year, with peak flows of up to 26,000 cfs in late May through June for sturgeon survival, and again in December for power production.

The maximum discharge from Libby Dam through the powerhouse is about 26,000 cfs, considerably less than pre-impoundment Kootenai River peak flows. Under normal operating conditions, Libby Dam must spill water to provide flows in excess 26,000 cfs in the Kootenai River. Because of water quality concerns associated with spilling water at Libby Dam, the dam had not spilled water since 1983 and flows in the Kootenai River have remained relatively low since 1984. However, during 2002, the Kootenai River experienced substantially higher flows due to the voluntary and involuntary spill of water from Libby Dam in June and July (Figure 3). The spill conditions resulted in flows in the Kootenai River over 26,000 cfs from June 25 through July 7, and from July 13 through July 17, 2002, with a peak flow of 40,000 cfs on July 4, 2002. Because of the limited lake storage, flows remained higher than normal throughout the months of July and August. Baseflow conditions were achieved during October and November 2002. A second peak flow event occurred in December, with flows in the Kootenai River reaching 26,000 cfs for a period of about two weeks. This winter peak was to meet power production demands, and not due to winter runoff.

Data Collection

The study was conducted from June through December 2002 and focused on the Kootenai River valley from Libby Dam to Troy, Montana. The study was designed to collect ground water and surface water quality information in the Kootenai River valley during periods of high flow and base flow discharges from Libby Dam. Groundwater quality data were collected from eight (8) drinking water wells, surface water quality data were collected from seven (7) river stations, and hydrologic data were collected from six (6) monitoring wells and four (4) river stage gages (See Figure 2).

Ground water and surface water samples were collected at drinking water wells and in the Kootenai River four to six times from June through December during high and low flow conditions (Figure 3). Water quality parameters monitored in the drinking water wells and Kootenai River are shown in Table 1. Ground water levels and corresponding surface water stage heights were collected at approximately monthly intervals during the study, with increased frequencies during peak river flows (Figure 3).

Ground Water Monitoring

Eight drinking water wells were selected to represent shallow (less than 60 feet deep) and deep (greater than 60 feet deep) ground water resources in the Kootenai River valley downstream of Libby Dam (see Figure 2). Well installation details are summarized in Table 2. Water quality parameters monitored in the drinking water wells (see Table 1) were designed to (1) evaluate potential contamination plumes from impacted on-site wastewater treatment and disposal systems, (2) evaluate the source(s) of the ground water, and (3) determine if ground water in the Kootenai River valley was under the direct influence of surface water.

On-site wastewater treatment and disposal systems influence on ground water can often be inferred from the presence of analytes typically found in high concentrations in on-site wastewater systems. The use of a specific parameter to distinguish wastewater influences on ground water will depend largely on the chemical characteristics of the ambient ground water. Concentrations of ammonia nitrogen, nitrate + nitrite nitrogen, potassium, chloride, calcium, magnesium, sodium, and boron have all been useful in tracing on-site wastewater treatment and disposal systems (Wang et al. 2000, Pitt et al. 2000). For this study, ammonia nitrogen, nitrate + nitrite nitrogen, potassium, chloride, total coliform bacteria, and fecal coliform bacteria were used to identify groundwater contamination associated with effluent plumes from on-site wastewater systems.

The probable source(s) of ground water were evaluated by analyzing oxygen isotopes ($\delta^{18}O$) and hydrogen isotopes (δD) in the drinking water wells and in the Kootenai River. Using this approach, the stable isotopic composition of water is used as a natural tracer to determine the hydrologic relationship between the ground water and the Kootenai River (McCarthy et al. 1992; Kendall et al. 1995; Apodaca et al. 2000). For example, if the ground water oxygen and hydrogen isotope composition is similar to the Kootenai River composition then the source of the ground water is likely the river. However, if the ground water isotope composition plots to the left or the right of the river water's isotope composition, then the ground water has either undergone a change (evaporation or chemical interactions) or is being derived from a different source(s). Water that remains at the surface for any length of time is often subjected to some evaporation and becomes enriched in oxygen and hydrogen isotopes. In addition, the isotope composition of source water is greatly influenced by variations in altitude and latitude. Higher altitudes and latitudes will have precipitation that is depleted in oxygen and hydrogen isotopes compared to lower altitude precipitation. Similarly, precipitation becomes increasingly depleted in oxygen and hydrogen isotopes with increasing distance from the coast (Coplen et al. 2000).

Two drinking water wells (DW4 and DW5) were monitored during high flow conditions in July and December to investigate whether ground water in wells adjacent to the Kootenai River valley was under the direct influence of surface water. The United States Environmental Protection Agency (EPA) and the Montana Department of Environmental Quality (DEQ) use the Microscopic Particulate Analysis (MPA) test to assess if drinking water wells are being directly influenced by any nearby surface waters (DEQ 1999; U.S. EPA 2000). The MPA test processes large volumes of water (generally 1000 gallons) through a filter and examines the sediment and particles captured by the filter for the presence of indicator materials (i.e. Giardia, algae, insect parts, rotifers, plant debris etc.) associated with surface waters. A relative risk factor score from 0 (low) to 40 (high) for the drinking water well is determined from the number and type of indicator material found in the sample. Sources receiving low risk scores from multiple samples collected at times of seasonal variation are generally considered to be at low risk for the direct influence of surface water (U.S. EPA 2000). However, because the MPA test only evaluates water quality constituents that are solid and capable of being retained on a filter, the test provides little information pertaining to the influence of dissolved constituents in surface and ground waters.

Ground Water Sampling Procedures

Ground water samples were collected at drinking water wells DW1 through DW8 from outdoor spigots according to the following procedures:

- Wells were purged prior to sampling by fully opening the spigot and purging at a rate of about 5 gallons per minute. If the spigot was located before a pressure/storage tank, the well water was pumped to waste a minimum of 20 minutes or until pH, turbidity, and conductivity readings stabilized. If the spigot was located after a pressure/storage tank, the well was pumped to waste a minimum of 30 minutes or until pH, turbidity, and conductivity readings stabilized. Field parameters, purge volume, purge rate, and time were recorded in the field notebook.

- Equipment used for field measurements was calibrated prior to each sampling event. Water quality parameters (pH, conductivity, and turbidity) were monitored every three to five minutes during purging.

Stabilization was achieved after all three parameters stabilized for three successive readings within ± 0.1 for pH, ± 3 percent for conductivity, and ± 10 percent for turbidity.

- Upon sample stabilization, sampling was initiated by field technicians wearing new vinyl gloves at each sampling location. Sampling flow rate was maintained at the established purge rate and samples were collected from the spigot into containers prepared by the analytical laboratory for the given parameters.

- Prior to collecting the bacteriological sample, the spigot was turned off and the spigot was disinfected inside and outside with a 10 percent chlorine bleach solution followed by a de-ionized water rinse. The spigot was turned back on at the established purge rate and pumped to waste a minimum of 5 minutes prior to sample collection.

- Duplicate ground water samples were collected at a frequency of 10 percent, or one per sampling event. Duplicate samples were labeled similar to the other samples and submitted blind to the laboratory. The locations for a duplicate sample collection were determined in the field.

- One sample per sampling event was split into two samples to assess the analytical variability for stable isotope analysis.

- All sampling containers were appropriately labeled, immediately placed on ice in a cooler, and delivered to the appropriate laboratory following proper chain of custody procedures.

- All stable isotope analysis were performed by the University of Arizona's Laboratory of Isotope Geochemistry in Tucson, Arizona. The oxygen ($\delta^{18}O$) and hydrogen (δD) isotopes are reported as delta (δ) values in parts per thousand (per mill, or ‰) relative to Vienna Standard Mean Ocean Water (VSMOW) reference water and normalized to the hydrogen and oxygen isotopic composition of Standard Light Antarctic Precipitation (SLAP) reference water of –428 ‰ and –55.5 ‰, respectively (Eastoe 2002).

Microscopic Particulate Analysis (MPA) Sampling Procedures

Ground water samples intended for MPA testing were collected at drinking water wells DW4 and DW5 from outdoor spigots using U.S. EPA (2000) procedures as outlined below.

- The Montana Department of Environmental Quality provided all MPA sampling equipment, including hoses, flow restrictors, filter housings, and filters. Sampling equipment was decontaminated prior to collection with a mild phosphate-free detergent, a first rinse with potable water, and a final rinse with deionized water.

- The equipment was set up and flushed with source water without a filter in the housing for a minimum of 10 minutes.

- Source water was filtered through a 10-inch, 1µm polypropylene yarn wound (string), nominal porosity cartridge filter at a flow rate of about 1 gallon per minute.

- Samples were filtered from 12 to 24 hours to filter a sample volume of about 1000 gallons.

- After filtering, the filter and about 200 mL of water were placed in a plastic Ziploc bag and securely sealed.

- Filters were packed in a cooler with ice, making sure that no part of the filter was in direct contact with the ice, and sent to the EPA Region 10 Laboratory within 24 hours of collection for sample analysis.

Surface Water Monitoring

Five river cross-section transects and two tributary stations were selected to represent surface water resources in the Kootenai River valley downstream of Libby Dam (see Figure 2). River sampling location details are summarized in Table 3.

Surface Water Sampling Procedures

Surface water grab samples were collected from the left, center, and right bank of the river channel at each cross-section transect station, and from the right bank of the river channel at the two tributary stations. Samples were collected at each station either by submerging laboratory-cleaned, prelabled sample containers below the water surface to a depth of 0.5 meters or by lowering a depth integrated sampler to the bottom of the river. Sample containers were rinsed once prior to filling, capped, and immediately placed on ice in a cooler. Measurements of field parameters (see Table 1) were performed by submerging the meter probes directly into the flowing water or from a sample withdrawn from the river. Equipment used for field measurements was calibrated prior to each sampling event. One set of field duplicates was collected during each monitoring event to assess both environmental and analytical variability. In addition, one sample per monitoring event was spilt into two samples to further assess analytical variability.

Hydrologic Monitoring

Hydrologic monitoring consisted of measuring river stage and ground water levels throughout the Kootenai River valley (Figure 2). Ground water levels were measured at six existing monitoring wells representing shallow (less than 60 feet deep) ground water in the Kootenai River Valley downstream of Libby Dam. Well installation details are summarized in Table 4. Monitoring wells were located in three groupings. Well MW1 was located farthest upstream at a distance from the river of approximately 50 feet. Wells MW4, MW5, and MW9 were located in the town of Libby and were oriented in a transect perpendicular to the river at distances of approximately 400, 425, and 500 feet from the river, respectively. Wells MW6 and MW7 were located in the town of Libby and were oriented in a transect horizontal to the river at a distance of about 3000 feet from the river, respectively. The static water level was measured using a manual water level meter and calculated as the distance from the top of the well casing (TOC) to the water level in the well column.

River gaging station details are summarized in Table 3. Gaged river flows were measured at the USGS gaging station (No. 12301933) located below Libby Dam (Figure 2). Discharge at the USGS station was determined from continuous monitoring of stage (water surface elevation) and periodic measurements of streamflow using methods developed by the USGS (Kennedy 1983). In addition, temporary gaging stations (S1, S2, and S3) were established for the Kootenai River at three locations to enable comparisons between the river stage and ground water levels measured in adjacent wells (Figure 2). For this study, gage S1 was located near well MW1, gage S2 was located near wells MW4, MW5, and MW9, and gage S3 was located near wells MW6 and MW7. However, because back eddy effects made it difficult to accurately measure stage at S3, gage S2 was used for comparisons with MW6 and MW 7.

Quality Assurance Procedures

Quality assurance of water quality samples followed procedures set forth in the *Libby Dam Ground Water Quality Monitoring Project Sample and Analysis Plan* (USCOE 2002). Data were validated according to the sampling and analysis plan, and quality control data provided by the laboratory were combined with results of field duplicate and split analysis to check the precision and accuracy of the data. Data validation results are presented in Appendix A. Values qualified as estimates were used in the evaluation, and none of the values were rejected.

Results and Discussion

Hydrological Characterization

Hydrographs of average daily discharge for the Kootenai River at the USGS gaging station below Libby Dam for 2002 and for the post-impoundment period from 1984 – 2001 are presented in Figure 4. Compared to the median post-impoundment river flow conditions, the Kootenai River in 2002 experienced a substantially higher peak flow in July and an extended period of higher than average flows from June through August. River flows began to increase in mid June in response to rapid snowmelt in the watershed and high inflows to Lake Koocanusa. Maximum powerhouse flows at Libby Dam of about 26,000 cfs were achieved by June 14, 2002 and were maintained through June 24, 2002. Libby Dam operations were originally scheduled to be systematically varied through a series of spillway releases from June 25 to June 28, 2002 as part of a planned spillway test. The planned spill test began in the morning on June 25, 2002 with flows being maintained at 26,000 cfs during the test. However, continued high inflows and limited reservoir storage capacity necessitated Libby Dam to begin to involuntarily spill water starting in the late afternoon on June 25, 2002 for flood control operations. The flood control operations resulted in flows in the Kootenai River over 26,000 cfs from June 25 through July 7, and from July 13 through July 17, 2002. Peak flows of 40,000 cfs were measured on July 4, 2002 (Figure 4). Kootenai River flows remained higher than normal throughout the months of July and August.

River flows declined through the summer and fall, and baseflow conditions were achieved during October and November 2002 (Figure 4). During this period, Kootenai River flows varied from about 4,000 to 8,000 cfs. A second high flow period occurred in mid-December to meet power production demands. During this high flow event, all water discharged from the dam was passed through the powerhouse and no involuntary spill occurred. Peak flows with in the Kootenai River ranged from 24,000 to 26,000 cfs for a period of about two weeks.

Ground water levels and river stage heights are shown in Tables 5 and 6. Ground water levels in monitoring well MW1, located about 50 feet from the river, responded rapidly to changes in river stage as measured at S1, and were consistently similar to the river stage throughout the year (Figure 5). Water levels at monitoring wells MW4, MW5 and MW9, located about 400 to 500 feet from the river, also responded rapidly to changes in river stage as measured at S2 (Figure 6). Ground water levels at wells MW4 and MW5 were similar to river stage throughout the year, while the level of MW9 remained higher than river stage. Because MW9 lies farther away from the river (See Figure 2), it is less influenced by short-term river stage variations and reflects the apparent natural groundwater level at this location. Ground water levels were consistently higher than river stage, suggesting that ground water was moving towards the river at this location. Water levels at monitoring wells MW6 and MW7, located about 3000 feet from the river, showed little relationship to river stage at S2 during peak flows in June, July and December, but followed the falling river stage in the late summer and fall (Figure 7). These wells appeared to be not influenced by short term river stage variations and likely represent natural ground water level fluctuations in the Libby area. Ground water levels at MW6 and MW7 indicate that water was moving towards the river at this location during the spring and summer high flow conditions.

Surface Water Quality

Surface water quality results are presented in Table 7. In general, Kootenai River water quality was good, with low concentrations of nitrate, ammonia, chloride, and potassium measured at the USGS station. River water quality varied little laterally at each station or longitudinally between Libby Dam and the town of Troy (Table 7). However, at station SW4, river water quality during the June 28 and July 3 sampling events showed a pronounced lateral gradient for conductivity, with lower conductivities measured on the left bank of the river. These data suggest that an upstream source of low conductivity water was influencing the left bank of the Kootenai River in the vicinity of station SW4. As seen in Figure 2, Lake Creek and Callahan Creek are immediately upstream of SW4 and enter the Kootenai River along the left bank. Water quality data collected at Lake Creek (SW5) and Callahan Creek (SW6) in December showed these two tributary creeks to have substantially lower conductivities than the Kootenai River. Stable isotope data presented in the Ground Water Sources section of this report support this conclusion regarding the influence of Lake and Callahan creeks on the Kootenai River at SW4.

Temporal variations in temperature, conductivity, and turbidity were apparent in the Kootenai River (Table 7). Temperatures in the Kootenai River below Libby Dam are controlled by a selective withdrawal system that releases water from varying depths in the reservoir throughout the year to mimic natural river temperature fluctuations. In general, temperatures were lowest in the spring, increased during the summer, and decreased during the fall. Conductivities were greatest during the spring, decreased during the summer and fall, and increased during the winter. This pattern in conductivity reflects the natural fluctuations in conductivity in Lake Koocanusa, the reservoir behind Libby Dam, which generally experiences a decease in conductivity in the water column in the summer and fall. Turbidity values were greatest during the high flow spring and early summer period and reduced in the low flow fall period, likely due to the increase in suspended solids during the spring runoff.

Ground Water Quality

Ground water quality results are presented in Table 8. Field parameters monitored include temperature, conductivity, pH, and turbidity. These parameters displayed little spatial variation except for conductivity and pH (Figure 8). Conductivity levels ranged from 222 microsiemens per centimeter (µS/cm) at DW2 to 683 µS/cm at DW7, with the lowest conductivities measured at wells located around the town of Troy (DW1 and DW2). In general, conductivity levels for wells between the dam and the town of Libby (DW3 – DW8) showed minor spatial variations, with the highest conductivity levels measured at the deeper wells (DW3 and DW7). The pH levels measured in the wells ranged from 6.9 at DW1 to 7.9 at DW2. For wells in the vicinity of the town of Libby (DW3 – DW8), pH levels were stable and ranged from about 7.3 to 7.5.

Minor temporal variations in most field parameters were evident at all wells sampled, but no trend was apparent (Figure 9). Additionally, field parameters measured in the ground water showed little relationship to the Kootenai River except at DW2 (Tables 7 and 8). Conductivity, and pH levels measured at DW2 and in the Kootenai River at station SW4 were similar throughout the study period. However, temperatures at DW2 were generally cooler than in the river.

Total coliform bacteria were used to assess the sanitary quality of the drinking water because they are often associated with water borne diseases and can be an indicator of contamination from human or animal waste. Total coliform bacteria were detected on two occasions at DW2, at concentrations of 2 and 8 colonies per 100 milliliters (col/100ml) (Table 8). However, because total coliform bacteria are naturally present in the soil, analysis for fecal coliform bacteria or *E. coli* were needed to confirm a human or animal source. Analysis for fecal coliform bacteria were negative for these samples, suggesting that the bacteria were not derived from human or animal waste at DW2.

Major ions occur naturally in ground waters from the chemical interactions between the water and the overlying soil or bedrock. Chloride and potassium may be associated with on-site wastewater system contamination because concentrations of these ions are high in human waste and they are not be effectively removed by on-site wastewater systems. Potassium concentrations were similar at all wells except at DW7 (Figure 10). Potassium concentrations at DW7 showed little temporal variation, suggesting a local geologic source of potassium rather than contamination from a wastewater system during high flow conditions on the Kootenai River (Figure 11). Potassium concentrations in the ground water were substantially greater than concentrations measured in the Kootenai River (Tables 7 and 8).

In general, chloride concentrations in the ground water were greater than concentrations measured in the Kootenai River (Tables 7 and 8). Concentrations were similar at wells DW1 through DW4, with substantially greater concentrations detected at wells DW5 through DW8, suggesting a local geologic sources of chloride in the ground water in the vicinity of these wells (Figure 10). Chloride concentrations showed little temporal variations at all wells except DW8 (Figure 11). Concentrations at DW8 were greatest during the October 2, 2002 base flow sampling event and were lowest during the high flow sampling events. The chloride spike at DW8 during base flow may be due to either (1) elevated chloride concentrations in the local ground water or (2) a possible domestic source of chloride.

Nitrate and ammonia concentrations in groundwater are usually low, but can be elevated from human sources such as lawn fertilizer, and human and animal waste. Ammonia concentrations were elevated only at DW3, with concentrations ranging from 0.13 to 0.21 mg/L (Figure 10). The lack of any temporal variation in ammonia concentrations at DW3, and the low ammonia concentration in the Kootenai River (Tables 7 and 8) suggests that increased flows in the

Kootenai River were not responsible for the elevated ammonia concentrations (Figure 11). Because DW3 was the deepest well sampled (98 feet) the elevated ammonia concentrations and undetectable nitrate concentrations are likely due to oxidation-reduction conditions favoring the presence of ammonia over nitrate.

Ground water concentrations of nitrate were greater than surface water concentrations measured in the Kootenai River (Tables 7 and 8). Boettcher and Wilke (1978) concluded that ground water nitrate concentrations in the Libby area greater than 1.5 mg/L may indicate that the ground water is affected by human activities. Nitrate concentrations were less than 1.5 mg/L for all wells except DW1 and DW8 (Figure 10). Nitrate concentrations at DW1 were greatest during the high summer flows on the Kootenai River, but were not elevated during the high winter flows suggesting that increased flow in the river may not be the sole cause for the high nitrate concentrations (Figure 11). Because DW1 is not located near an on-site wastewater treatment system, it is likely that other human activities in the area were affecting nitrate concentrations. For example, fertilizer applications to playground fields located adjacent to DW1 may have contributed to the elevated nitrate concentrations (Norman 2002). At DW8, nitrate concentrations greater than 1.5 mg/L only occurred during the October low flow sampling period (Figure 11). This nitrate spike was correlated with a spike in chloride suggesting that either (1) the natural base flow ground water concentrations of nitrate and chloride are elevated at this location, or (2) a possible on-site wastewater treatment system influence on the ground water.

Ground Water Sources

Naturally occurring oxygen isotopes ($\delta^{18}O$) and hydrogen isotopes (δD) were used to help infer the source(s) of ground water and surface water in the Kootenai River valley. The ratio of heavier oxygen-18 (^{18}O) and deuterium (^{2}H) to lighter oxygen-16 (^{16}O) and hydrogen (H) are expressed as delta (δ) values ($\delta^{18}O$ and δD) in parts per thousand (per mill, or ‰) relative to Vienna Standard Mean Ocean Water (VSMOW) reference water and normalized to the hydrogen and oxygen isotopic composition of Standard Light Antarctic Precipitation (SLAP) reference water of –428 ‰ and –55.5 ‰, respectively (Eastoe 2002). The stable isotope ratios are compared with the global meteoric water line of Rozanski et al. (1993), which represents the global average precipitation $\delta^{18}O$ and δD composition:

$$\delta^{2}H = 8.13\delta^{18}O + 10.8$$

Water that has experienced little evaporation will tend to plot near the global meteoric water line, while water that has experienced evaporation will have isotopic values that are enriched in $\delta^{18}O$ and δD and plot to the right of the line towards less negative $\delta^{18}O$ and δD values. Additionally, the isotopic composition of precipitation is influenced by many other factors, such as temperature, altitude, latitude and distance from the coast (Kendall and Coplen 2001). In general, precipitation from higher altitudes, higher latitudes, and cooler temperatures tends to be depleted in $\delta^{18}O$ and δD (more negative). Similarly, precipitation becomes increasingly depleted in $\delta^{18}O$ and δD with increasing distance from the coast (Coplen et al. 2000).

Water in most rivers have two main source components: (1) recent precipitation that has reached the river either by surface runoff or flow through shallow subsurface flowpaths, and (2) ground water flow. The relative contribution of these two sources differs in watersheds depending on the physical setting, climatic elements, and human activities (Kendall and Coplen 2001). For the Kootenai River Valley near Libby and Troy, Montana, the headwaters of the Kootenai River are at a higher elevation and latitude than the ground water sources in the Libby and Troy areas. Therefore, the Kootenai River water should be depleted in $\delta^{18}O$ and δD (more negative) compared to local ground water derived from precipitation falling in the Libby and Troy areas.

The oxygen and hydrogen isotope values in water sampled from various stations in the Kootenai River ranged from –17.9 to –18.7 and –132 to –138, respectively (Figure 12). Oxygen and hydrogen isotope values measured at SW5 (Lake Creek) and SW6 (Callahan Creek) ranged from –15.6 to –115, respectively (Figure 12). In general, these values plot above and parallel to the global meteoric water line. Surface water values plot in a tight group except for two samples collected from the left bank at station SW4 and samples collected at SW5 and SW6 (Figure 12).

The samples from SW5 and SW6 plot farthest to the right along the global meteoric water line and are thus the isotopically heaviest (i.e. most positive) water. The samples from the left bank at SW4 plot slightly to the right of the Kootenai River grouping and likely represent a mixture of more negative (i.e. isotopically lightest) Kootenai River water with the more positive Lake Creek and Callahan Creek waters. It is likely that Lake Creek and Callahan Creek represent shallow ground water derived from precipitation falling in the Cabinet Mountains near Troy, Montana. Because the Cabinet Mountains are lower in elevation and latitude than the headwaters of the Kootenai River, ground water derived from these mountains would be isotopically lighter than Kootenai River water.

Slight seasonal variations in oxygen and hydrogen isotope composition of water from the Kootenai River were apparent. In general, river samples collected during the fall (October) and winter (December) time periods were isotopically heavier (i.e. more positive) than river samples collected during the spring/summer (June and July) time periods (Figure 12). Flows on the Kootenai River are regulated by Libby Dam and Lake Koocanusa. During June and early July 2002 inflows to Lake Koocanusa were high and discharges from the reservoir largely represented high elevation snowmelt runoff in the watershed. During October and December 2002, inflows to Lake Koocanusa were low and the reservoir was being drawn down for flood control. Discharges from the reservoir largely represented water that had experienced a greater residence time in the reservoir compared to water discharged in June and July. The isotopically heavier fall/winter river samples suggest that some of the observed variation in isotopic composition in the Kootenai River may be due to the evaporative effects of the reservoir.

Ground water oxygen ($\delta^{18}O$) and hydrogen (δD) isotope values ranged from –15.6 to –18.6 and from –115 to –139, respectively (Figure 13). In general, differences in ground water isotope compositions likely reflect mixing from different sources of aquifer recharge rather than from evaporative effects. For the Kootenai River valley, potential major sources of recharge to the local ground water system include stream flow and precipitation.

Slight seasonal variations in isotopic composition were apparent at all wells (Figure 13). In general, well water sampled during June and July plotted farther to the left along the Global Meteoric Water Line and represents isotopically lighter water than from the October and December samples. Evaporative effects are minimal in ground water, and the seasonal shift in isotopic composition seen at all wells likely represents reflects changes in the mixing of source waters to the wells. During high runoff experienced in June and July, the Kootenai River was likely a greater source of well water than during October and December, when ground water derived from local precipitation originating at a lower altitude and latitude than the Kootenai River was a greater source. For wells that showed less of an impact from the Kootenai River (DW1 and DW4), samples from June and July trended towards the isotopically lighter Kootenai River water suggesting that there is some input from the river during high flow conditions.

Isotope data suggests that the ground water in the study area can be separated into two distinct groups (Figure 14). Group I (DW2, DW3, DW5, DW6, DW7, DW8) represents well water largely derived from the Kootenai River, whereas Group II (DW1, DW4) represents well water that is a mixture of the Kootenai River and ground water derived from local precipitation. Group I samples plot along the Global Meteoric Water Line and trend towards the composition of the Kootenai River samples. Group IA samples are a subset of Group I and represent samples collected during October base flow and December high flow conditions. These samples plot slightly to the right of the high flow June and July isotope composition, and represent isotopically heavier water. The slightly heavier isotopic composition of samples collected in October and December likely reflects a greater influence from local ground water sources.

Group II samples plot to the right of Group I and represent isotopically heavier water. The isotopic composition of DW1 is similar to baseflow surface water samples collected in December at SW5 and SW6, suggesting ground water derived from local precipitation was the major source of water at DW1. Recognizing that there are likely two distinct sources of water in the study area, the Kootenai River and local ground water, it is likely that DW1 was primarily composed of locally derived ground water during much of the year, except during the high flow June and July time period when there is some input from the Kootenai River as seen by isotopic ratios that are more depleted (Figure 14). The isotopic composition of DW4 is slightly heavier than the Kootenai River, suggesting that ground water derived from local precipitation is influencing the well. Water from DW4 appears to be closer to an even mixture of Kootenai River water and local ground water compared to water from DW1. The fraction of river water versus ground water varies seasonally, with a greater influence from the Kootenai River during the high flow June and July time period (Figure 14).

Ground Water/Surface Water Interactions

Data from ground water monitoring wells and river stage heights suggest that ground water level fluctuations are closely related to river level fluctuations (see Table 6 and Figures 5, 6, and 7). Ground water levels were highest in June and July, likely due to a combination of high river flows and a response to watershed runoff from rain and melting snow. Ground water levels were lowest in October during low flow river conditions and rose slightly in December during high flow river conditions. The close relationship between ground water levels and adjacent river stage heights suggests that water moves freely between the river system and the ground water system in the Kootenai River valley.

The water quality influence of surface waters on two drinking water wells (DW4 and DW5) was evaluated using the Microscopic Particulate Analysis (MPA) test method of the EPA (U.S. EPA 2000). MPA tests conducted during high flow conditions in July and December assigned a relative risk score of zero (0) to DW4 and DW5 on each sampling date, indicating that little surface water suspended and particulate matter was detected in these wells at the time of sampling. Because both wells received low risk scores from multiple samples collected during high flow conditions at times of seasonal variation, they are likely at low risk for being degraded by surface water particulate material during high flow conditions. Similar MPA tests results were determined by Montana Department of Environmental Quality at DW1 during high flow conditions in June and July (Kilbreath 2002). These data suggest that even though the ground water in the Kootenai River valley may be hydraulically connected to the Kootenai River, suspended and particulate material from the river did not enter the wells under high flow conditions.

Conclusions

The evaluation and analysis of data gathered and presented during the Kootenai River valley ground water sampling project are summarized as follows:

- Water quality in the drinking water wells sampled was good and was not degraded by high flow volumes in the Kootenai River.

- Chemical data suggests that DW1 and DW8 may have been affected by human activities such as fertilization (D1) or on-site wastewater systems (D8). These impacts were not related to flows in the Kootenai River.

- Total coliform bacteria detected in DW2 on two of five samples tested negative for fecal coliform bacteria and was not from a human or animal source. Positive coliform results were not related to flows in the Kootenai River.

- Isotope data suggest that the wells sampled the study can be separated into two distinct groups. Group I (DW2, DW3, DW5, DW6, DW7, DW8) represents well water largely derived from the Kootenai River, whereas Group II (DW1, DW4) represents well water that is largely a mixture of the Kootenai River and ground water derived from local precipitation. DW1 is composed primarily of local ground water while DW4 appears to be an even mixture of river water and ground water.

- Limited data suggest that shallow ground water derived from local precipitation is the source of base flow water to Lake Creek and Callahan Creek, and ground water to DW1.

- Seasonal variations in isotopic composition were apparent at all wells. In general, well water sampled during June and July plotted farther to the left along the Global Meteoric Water Line and represents isotopically lighter water than from the October and December samples. The slightly lighter composition in June and July reflects a greater influence from the Kootenai River to the wells during high flow conditions.

- MPA tests conducted at DW4 and DW5 indicated that suspended and particulate material from the Kootenai River did not reach these wells during high flow conditions.

References

APHA, AWWA, WEF. 1992. Standard methods for the examination of water and wastewater. 18th edition. Edited by A.E. Greenberg, American Public Health Association; A.D. Eaton, American Water Works Association; and L.S. Clesceri, Water Environment Federation.

Apodaca, L. E., Smith, C. M., and J. B. Bails. 2000. Ground-water-quality assessment of selected wells in the Fraser River watershed, Colorado, August 1998. United States Geological Survey Water Resources Investigations Report 99-4243.

Boettcher, A.J. and K.R. Wilke. 1978. Ground water resources in the Libby area, northwestern Montana. State of Montana Bureau of Mines and Geology Bulletin 106.

Bonde, T. J. H. and R. M. Bush. 1982. Limnological investigations: Lake Koocanusa, Montana, Part 1 pre-impoundment study, 1967-1972. United States Army Corps of Engineers Cold Regions Research and Engineering Laboratory-Special Report 82-21.

Coplen, T.B., Herczeg, A.L., and C. Barnes. 1999. Isotope engineering-using stable isotopes of the water molecule to solve practical problems.   In *Environmental Tracers in Subsurface Hydrology*, Peter G. Cook and Andrew L. Herczeg (eds), pp. 79-110. Kluwer Academic Publishers, Boston.

Coplen, T.B. and C. Kendall. 2000. Stable hydrogen and oxygen isotope ratios for selected sites of the U.S. Geological Survey's NASQAN and benchmark surface-water networks. U.S. Geological Survey Open File Report 00-160, Reston, Virginia.

DEQ. 1995. Water quality monitoring standard operating procedures. Montana Department of Environmental Quality, Helena, Montana.

Eastoe, C. 2002. Personal communication (e-mail to Kent Easthouse, US Army Corps of Engineers, Seattle District). University of Arizona, Laboratory of Isotope Geochemistry, Tucson, Arizona.

Harrison, J. E., Cressman, E. R., and J. W. Whipple. 1992. Geologic and structure maps of the Kalispell 1°x2° quadrangle, Montana and Alberta, and British Columbia. United States Geological Survey Miscellaneous Investigations Series, Map I-2267.

Kendall, C., Sklash, M. G., and T. D. Bullen. 1995. Isotope tracers of water and solute sources in catchments. In: Solute Modelling in Catchment Systems (Ed. S. T. Trudgill). John Wiley & Sons Ltd.

Kennedy, E.J. 1983. Discharge ratings at gaging stations. Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3 Applications of Hydraulics Chapter A-10.

Kilbreath, S. 2002. Personal communication (e-mail to Kent Easthouse, US Army Corps of Engineers, Seattle District). Montana Department of Environmental Quality, Helena, Montana.

McCarthy, K. A., McFarland, W. D., Wilkinson, J. M., and L. D. White. 1992. The dynamic relationship between ground water and the Columbia River: using deuterium and oxygen-18 as tracers. Journal of Hydrology 135: 1-12.

Norman, D. 2002. Personal communication (Conversation with Kent Easthouse, US Army Corps of Engineers, Seattle District). City of Troy.

Pitt, R., Lalor, M., Harper, J., Nix, C., and D. Barbe. 2000. Potential new tools for the use of tracers to indicated sources of contaminants to storm drainage systems. Paper presented at the National Conference on Tools for Urban Water Resource Management and Protection Proceedings, United States Environmental Protection Agency Technology Transfer and Support Division.

Rozanski , K., Araguas-Araguas, L., Gonfiantini, R. 1993. Isotopic patterns in modern global precipitation. In: Climate change in continental isotopic records (Eds: Swart, P. K., Lohmann, K.C., McKenzie, J. and S. Savin), American Geophysical Union, Washington D.C.

U.S. COE. 2002. Libby Dam Ground Water Quality Monitoring Project Sample and Analysis Plan. United States Army Corps of Engineers, Seattle District, Seattle, Washington.

U.S. EPA. 1983. Methods for chemical analysis of water and wastes. EPA-600/4-79-020. U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

U.S. EPA. 1984. Guidelines Establishing Test Procedures for the Analysis of Pollutants under the Clean Water Act; Final Rule and Interim Final Rule. U.S. Environmental Protection Agency. CFR Part 136. Friday, October 26, 1984.

U.S. EPA. 1990. Recommended protocols for measuring conventional water quality variables and metals in fresh water of the Puget Sound region. Puget Sound Estuary Program, U.S. Environmental Protection Agency, Region 10, Office of Puget Sound, Seattle, Washington.

U.S. EPA. 1992. NPDES [National Pollutant Discharge Elimination System] stormwater sampling guidance document. EPA 833-B-92-001. U.S. Environmental Protection Agency, Office of Water, Washington D.C.

U.S. EPA. 1996. Recommended protocols for measuring selected environmental variables in Puget Sound. U.S. Environmental Protection Agency, Region 10, Office of Puget Sound, Seattle, Washington.

U.S. EPA. 1998. Guidance for quality assurance project plans. EPA-QA/G-5. U.S. Environmental Protection Agency, Office of Research and Development, Washington D.C.

U.S. EPA. 2000. Consensus method for determining groundwaters under the direct influence of surface water using microscopic particulate analysis (MPA). U.S. Environmental Protection Agency, Region 10, Manchester Environmental Laboratory.

USDA. 1995. Soil survey of Kootenai National Forest area, Montana and Idaho. United States Department of Agriculture, Forest Service, and Natural Resources Conservation Service.

USGS. 2003. Surface water data for Montana. United States Geological Survey, Water Resources web site: http://waterdata.usgs.gov/mt/nwis/sw.

Wang, B., Strelakos, P. M., and B. Jokela. 2000. Nitrate source indicators in ground water of the Scimitar subdivision, Peters Creek area, Anchorage Alaska. United States Geological Survey Water Resources Investigations Report 00-4137.

Tables

Table 1. Methods and detection limits for water quality analyses.

	Sample Type	Method	Method Number [a]	Detection Limit/Unit
Field Parameters				
Temperature	GW,SW	Thermistor	SM 2550-B	0.1°C
pH	GW,SW	Electrometric	SM 4500-H	–
Conductivity	GW,SW	Platinum electrode	SM 2510-B	1 µS/cm
Turbidity	GW,SW	Nephelometric	SM 2130-B	0.1 NTU
Dissolved Oxygen	GW,SW	Membrane electrode	SM 4500-O-G	0.1 mg/L
Laboratory Parameters				
Total coliform bacteria	GW	Membrane filter	SM 9222-B	1 col/100 mL
Fecal coliform bacteria	GW	Membrane filter	SM 9222-D	1 col/100 mL
Potassium	GW,SW[1]	Inductively coupled plasma	EPA 200.7	1.0 mg/L
Ammonia nitrogen	GW,SW[1]	Automated phenate	EPA 350.1	0.01 mg/L
Nitrate+nitrite nitrogen	GW,SW[1]	Automated cadmium reduction	EPA 353.2	0.01 mg/L
Chloride	GW,SW[1]	Ion chromatography	SM 4500-Cl	1.0 mg/L
Oxygen isotope	GW,SW	Mass spectrometer	–	–
Hydrogen isotope	GW,SW	Mass spectrometer	–	–
Microscopic Particulate Analysis	GW[1]	Filtration	[b]	–

[a] SM method numbers are from APHA et al. (1992); EPA method numbers are from U.S. EPA (1983, 1984).
[b] U.S. EPA (2000)
GW Ground Water Sample
GW[1] Ground Water Sample collected only at wells DW4 and DW5 on 7/16/2002 and 12/10/2002.
SW Surface Water Sample
SW[1] Surface Water Sample collected only at the USGS Gaging station
mg/L Milligrams per liter
µS/cm Microsiemens per centimeter
NTU Nephelometric turbidity unit
Col Colony

Table 2. Summary of drinking water well installation information.

Well Number	Latitude	Longitude	Installation Date	Total Well Depth (feet)	Screen Interval Depth (feet)	Well Diameter	Approximate Distance from Kootenai River (feet)
DW-1	48.46951	115.89098	12/15/1954	57.0	31.5 - 57.0	20-inch	1000
DW-2	48.51943	115.94061	8/3/1983	38	No screen, open bottom	6-inch	50
DW-3	48.39684	115.52350	8/22/1995	98.0	No screen, open bottom	6-inch	100
DW-4	48.44329	115.65327	10/31/1984	37.0	No screen, open bottom	6-inch	50
DW-5	48.39547	115.52702	NA	NA	NA	6-inch	50
DW-6	48.41776	115.48191	10/4/1966	41.0	No screen, open bottom	6-inch	500
DW-7	48.40275	115.45099	8/25/1994	64.0	59.0 - 64.0	6-inch	200
DW-8	48.36475	115.40045	8/29/1985	66.0	50.0 - 65.0	6-inch	50

Notes:

NA Data not available.

Table 3. Kootenai River water quality and hydrological monitoring stations.

Station Description	Latitude	Longitude	Number of Sampling Locations	Location Comments
Water Quality Monitoring Stations				
USGS Gage	48.40083	115.31972	4	Kootenai River 0.6 miles downstream of Libby Dam: Quarter Point Composite Sample
SW-1	48.37203	115.42586	3	Kootenai River 0.1 miles upstream of old Haul Bridge site: Left Bank, Middle, Right Bank Samples
SW-2	48.39982	115.52274	3	Kootenai River 0.1 miles upstream of Libby Creek: Left Bank, Middle, Right Bank Samples
SW-3	48.44289	115.65308	3	Kootenai River 0.2 miles downsttream of Quartz Creek: Left Bank, Middle, Right Bank Samples
SW-4	48.47022	115.88750	3	Kootenai River 0.1 miles upstream of old Haul Bridge site: Left Bank, Middle, Right Bank Samples
SW-5	48.44915	115.87793	1	Lake Creek 0.1 miles upstream of US Highway 2: Right Bank Sample
SW-6	48.45589	115.89162	1	Callahan Creek 0.1 miles upstream of US Highway 2: Right Bank Sample
Hydrological Monitoring Stations				
USGS Gage	48.40083	115.31972	1	Kootenai River: Right Bank
S-1	48.36416	115.39807	1	Kootenai River: Right Bank
S-2	48.39757	115.54910	1	Kootenai River: Left Bank
S-3	48.39815	115.54982	1	Kootenai River: Left Bank

Table 4. Summary of monitoring well installation information.

Well Number	Latitude	Longitude	Top of Well Casing Elevation (feet-MSL)	Installation Date	Total Well Depth (feet)	Screen Interval Depth (feet)	Well Diameter	Approximate Distance from Kootenai River (feet)
MW-1	48.36417	115.39749	2112.36	7/14/1994	24	No screen, open bottom	6-inch	50
MW-4	48.39457	115.54674	2064.28	10/9/1995	20	5.0 - 20.0	2-inch	400
MW-5	48.39444	115.54624	2064.69	10/10/1995	20	5.0 - 20.0	2-inch	425
MW-6	48.39450	115.56568	2070.24	3/28/1996	18.5	8.5 - 18.5	2-inch	3000
MW-7	48.39464	115.56601	2071.07	3/27/1996	19.3	9.3 - 19.3	2-inch	3000
MW-9	48.39423	115.54633	2064.39	10/9/1995	20	5.0 - 20.0	2-inch	500

Notes:

MSL Mean Sea Level

Table 5. Ground water monitoring well elevation data.

Well Number	Date	Time	Top of Well Casing Elevation (feet-MSL)	Depth to Water (feet)	Groundwater Elevation (feet-MSL)	River Flow (cfs)	River Elevation (feet)
MW-1	6/14/02	11:50	2112.36	14.96	2097.40	26,000	2097.35
	6/25/02	13:50	2112.36	15.11	2097.25	23,700	2097.04
	6/25/02	19:15	2112.36	14.72	2097.64	28,800	2097.74
	6/27/02	15:05	2112.36	14.17	2098.19	31,900	2098.14
	7/1/02	9:30	2112.36	13.55	2098.81	38,000	2098.69
	7/3/02	7:30	2112.36	13.27	2099.09	40,000	2098.97
	7/17/02	9:15	2112.36	14.74	2097.62	25,000	2097.39
	8/29/02	8:00	2112.36	16.57	2095.79	14,700	2095.4
	10/3/02	14:00	2112.36	18.10	2094.26	6,100	2093.91
	10/15/02	8:00	2112.36	17.84	2094.52	8,000	NA
	11/20/02	8:00	2112.36	18.35	2094.01	4,800	NA
	12/11/02	11:30	2112.36	15.15	2097.21	26,000	2097.34
MW-4	6/14/02	9:30	2064.28	6.89	2057.39	26,000	2057.2
	6/25/02	14:30	2064.28	6.97	2057.31	23,700	NA
	6/25/02	20:35	2064.28	6.73	2057.55	28,800	2057.65
	6/27/02	12:10	2064.28	6.34	2057.94	31,900	2058.16
	7/1/02	10:00	2064.28	5.78	2058.50	38,000	2058.86
	7/3/02	8:45	2064.28	5.56	2058.72	40,000	2059.06
	7/17/02	12:45	2064.28	6.81	2057.47	25,000	2056.95
	8/29/02	8:00	2064.28	8.95	2055.33	14,700	2054.35
	10/2/02	13:15	2064.28	11.15	2053.13	6,100	2052.96
	10/15/02	8:00	2064.28	10.88	2053.40	8,000	NA
	11/20/02	8:00	2064.28	11.78	2052.50	4,800	NA
	12/11/02	9:30	2064.28	8.22	2056.06	26,000	2057.1
MW-5	6/14/02	9:30	2064.69	7.71	2056.98	26,000	2057.2
	6/25/02	14:30	2064.69	7.73	2056.96	23,700	NA
	6/25/02	20:35	2064.69	7.57	2057.12	28,800	2057.65
	6/27/02	12:10	2064.69	7.16	2057.53	31,900	2058.16
	7/1/02	10:00	2064.69	6.63	2058.06	38,000	2058.86
	7/3/02	8:45	2064.69	6.45	2058.24	40,000	2059.06
	7/17/02	12:45	2064.69	7.60	2057.09	25,000	2056.95
	8/29/02	8:00	2064.69	9.62	2055.07	14,700	2054.35
	10/2/02	13:15	2064.69	11.76	2052.93	6,100	2052.96
	10/15/02	8:00	2064.69	11.60	2053.09	8,000	NA
	11/20/02	8:00	2064.69	12.38	2052.31	4,800	NA
	12/11/02	9:30	2064.69	9.13	2055.56	26,000	2057.1
MW-6	6/14/02	11:10	2070.24	9.57	2060.67	26,000	2056
	6/25/02	20:00	2070.24	9.36	2060.88	28,800	2056.45
	6/27/02	11:50	2070.24	9.36	2060.88	31,900	2056.85
	7/1/02	10:30	2070.24	9.31	2060.93	38,000	NA
	7/3/02	9:00	2070.24	9.36	2060.88	40,000	NA
	7/17/02	13:00	2070.24	9.68	2060.56	25,000	2056
	8/29/02	8:00	2070.24	12.65	2057.59	14,700	2054.35
	10/2/02	14:00	2070.24	15.40	2054.84	6,100	2052.65
	10/15/02	8:00	2070.24	15.28	2054.96	8,000	NA
	11/20/02	8:00	2070.24	16.15	2054.09	4,800	NA
	12/11/02	10:00	2070.24	15.50	2054.74	26,000	2056.05

Table 5. Ground water monitoring well elevation data (continued).

Well Number	Date	Time	Top of Well Casing Elevation (feet-MSL)	Depth to Water (feet)	Groundwater Elevation (feet-MSL)	River Flow (cfs)	River Elevation (feet)
MW-7	6/14/02	11:10	2071.07	10.42	2060.65	26,000	2056
	6/25/02	20:00	2071.07	10.20	2060.87	28,800	2056.45
	6/27/02	12:00	2071.07	10.20	2060.87	31,900	2056.85
	7/1/02	10:30	2071.07	10.18	2060.89	38,000	NA
	7/3/02	9:00	2071.07	10.36	2060.71	40,000	NA
	7/17/02	13:00	2071.07	10.64	2060.43	25,000	2056
	8/29/02	8:00	2071.07	13.54	2057.53	14,700	2054.35
	10/2/02	14:00	2071.07	16.28	2054.79	6,100	2052.65
	10/15/02	8:00	2071.07	16.15	2054.92	8,000	NA
	11/20/02	8:00	2071.07	17.03	2054.04	4,800	NA
	12/11/02	10:00	2071.07	16.40	2054.67	26,000	2056.05
MW-9	6/14/02	9:30	2064.39	4.32	2060.07	26,000	2057.2
	6/25/02	14:30	2064.39	4.32	2060.07	23,700	NA
	6/25/02	20:35	2064.39	4.26	2060.13	28,800	2057.65
	6/27/02	12:10	2064.39	4.13	2060.26	31,900	2058.16
	7/1/02	10:00	2064.39	3.88	2060.51	38,000	2058.86
	7/3/02	8:45	2064.39	3.82	2060.57	40,000	2059.06
	7/17/02	12:45	2064.39	4.32	2060.07	25,000	2056.95
	8/29/02	8:00	2064.39	8.74	2055.65	14,700	2054.35
	10/2/02	13:15	2064.39	7.59	2056.80	6,100	2052.96
	10/15/02	8:00	2064.39	7.63	2056.76	8,000	NA
	11/20/02	8:00	2064.39	8.22	2056.17	4,800	NA
	12/11/02	9:30	2064.39	6.41	2057.98	26,000	2057.1

Notes:
NA Data not available
MSL Mean Sea Level

Table 6. Kootenai River staff gage and river elevation data.

Staff Gauge	Date	Time	Staff Gage Level (feet)	River Elevation (feet-MSL)	River Flow (cfs)
S1	6/14/02	16:45	2.06	2097.35	26,000
	6/25/02	13:50	1.75	2097.04	23,700
	6/25/02	19:15	2.45	2097.74	28,800
	6/27/02	15:05	2.85	2098.14	31,900
	7/1/02	9:00	3.4	2098.69	38,000
	7/3/02	7:30	3.68	2098.97	40,000
	7/17/02	9:15	2.1	2097.39	25,000
	8/29/02	8:00	0.11	2095.4	14,700
	10/3/02	14:00	-1.3	2093.91	6,100
	12/11/02	11:30	2.05	2097.34	26,000
S2	6/14/02	18:30	1.6	2057.2	26,000
	6/25/02	19:40	2.05	2057.65	28,800
	6/27/02	12:40	2.56	2058.16	31,900
	7/1/02	9:30	3.26	2058.86	38,000
	7/3/02	8:45	3.46	2059.06	40,000
	7/17/02	13:00	1.35	2056.95	25,000
	8/29/02	8:00	-1.25	2054.35	14,700
	10/3/02	11:50	-2.6	2052.96	6,100
	12/11/02	10:45	1.5	2057.1	26,000
S3	6/14/02	18:30	2.65	2056	26,000
	6/25/02	19:40	3.1	2056.45	28,800
	6/27/02	12:40	3.5	2056.85	31,900
	7/1/02	9:30	NA	NA	38,000
	7/3/02	8:45	NA	NA	40,000
	7/17/02	13:00	2.65	2056	25,000
	8/29/02	8:00	1	2054.35	14,700
	10/3/02	11:50	-0.66	2052.65	6,100
	12/11/02	10:45	2.7	2056.05	26,000

Notes:
NA Data not available
MSL Mean Sea Level

Table 7. Summary of surface water data collected in the Kootenai River valley.

Sample ID	Sample Location	Date	Temperature (°C)	Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	Total Potassium (mg/L)	Chloride (mg/L)	Oxygen Isotope ($\delta^{18}O$ ‰)	Hydrogen Isotope (δD ‰)	Kootenai River Flow (cfs)	Deuterium Excess
SW-1	Left Bank	6/14/02	9.8	238	8.1	10.1	7.2	---	---	---	---	-18.3	-135	26,000	11.4
	Middle	6/14/02	9.8	244	8.1	10.1	4.8	---	---	---	---	-18.3	-136	26,000	10.4
	Right Bank	6/14/02	9.5	255	8.1	11.6	4.2	---	---	---	---	-18.4	-136	26,000	11.2
	Left Bank	7/3/02	9.9	209.5	7.95	9.5	6.3	---	---	---	---	-18.7	-136	40,000	13.4
	Middle	7/3/02	9.8	211.4	7.96	11.4	6	---	---	---	---	-18.7	-138	40,000	11.2
	Right Bank	7/3/02	9.8	212.5	7.96	10.2	6	---	---	---	---	-18.6	-138	40,000	11.2
	Left Bank	10/3/02	11.8	179	8.0	8.8	0.9	---	---	---	---	-18.2	-137	6,000	8.9
	Middle	10/3/02	11.9	177	8.0	8.8	1	---	---	---	---	-18.3	-137	6,000	9.6
	Right Bank	10/3/02	11.9	177	8.0	8.7	0.8	---	---	---	---	-18.3	-137	6,000	9.6
	Left Bank	12/9/02	7.3	220	8.1	9.7	1.5	---	---	---	---	-18.1	-136	26,000	9.1
	Middle	12/9/02	7.3	218	8.1	9.8	1.1	---	---	---	---	-18.2	-136	26,000	8.8
	Right Bank	12/9/02	7.3	218	8.1	9.6	1	---	---	---	---	-18.2	-136	26,000	9.1
SW-2	Left Bank	6/14/02	10.2	245	8.1	12.0	7.2	---	---	---	---	-18.5	-137	26,000	11.0
	Middle	6/14/02	10.3	249	8.01	11.2	6.2	---	---	---	---	-18.3	-136	26,000	10.4
	Right Bank	6/14/02	10.1	249	8.06	12.1	8	---	---	---	---	-18.4	-134	26,000	13.2
	Left Bank	7/3/02	10.0	210.1	7.97	10.9	7	---	---	---	---	-18.6	-137	40,000	11.5
	Middle	7/3/02	9.9	211.6	7.97	11.1	6.9	---	---	---	---	-18.7	-138	40,000	11.3
	Right Bank	7/3/02	9.9	211.8	7.98	11.8	6.3	---	---	---	---	-18.6	-137	40,000	11.9
	Left Bank	10/3/02	11.7	179	8.0	9.2	0.9	---	---	---	---	-18.3	-137	6,000	9.1
	Middle	10/3/02	11.7	178	8.0	8.8	0.8	---	---	---	---	-18.1	-137	6,000	8.1
	Right Bank	10/3/02	11.7	179	8.0	8.8	0.8	---	---	---	---	-18.1	-137	6,000	8.0
	Left Bank	12/9/02	7.2	219	8.1	9.8	1.6	---	---	---	---	-18.1	-135	26,000	10.5
	Middle	12/9/02	7.3	219	8.1	10.2	1.7	---	---	---	---	-18.2	-135	26,000	10.1
	Right Bank	12/9/02	7.2	218	8.1	10.2	1.1	---	---	---	---	-18.2	-135	26,000	10.0
SW-3	Left Bank	6/14/02	10.4	230	8.1	12.6	9.3	---	---	---	---	-18.3	-135	26,000	11.2
	Middle	6/14/02	10.4	242	8.08	12.2	7.3	---	---	---	---	-18.5	-136	26,000	11.7
	Right Bank	6/14/02	10.3	248	8.0	12.8	7.2	---	---	---	---	-18.4	-136	26,000	11.1
	Left Bank	7/3/02	10.1	207.5	7.97	11.2	9.2	---	---	---	---	-18.6	-138	40,000	10.6
	Middle	7/3/02	10.0	210.2	7.99	11.0	9	---	---	---	---	-18.6	-138	40,000	10.8
	Right Bank	7/3/02	10.0	212.8	8.0	11.2	8.9	---	---	---	---	-18.6	-138	40,000	11.1
	Left Bank	10/3/02	11.6	179	8.0	9.2	1.1	---	---	---	---	-18.2	-136	6,000	9.7
	Middle	10/3/02	11.6	179	8.0	9.0	1.1	---	---	---	---	-18.2	-137	6,000	8.4
	Right Bank	10/3/02	11.5	178	8.1	8.9	1.2	---	---	---	---	-18.1	-136	6,000	8.8
	Left Bank	12/9/02	7.2	218	8.1	9.8	1.5	---	---	---	---	-18.1	-136	26,000	9.6
	Middle	12/9/02	7.2	217	8.1	10.0	1.5	---	---	---	---	-18.2	-135	26,000	10.0
	Right Bank	12/9/02	7.2	218	8.1	9.8	1.6	---	---	---	---	-18.0	-136	26,000	8.7

Table 7. Summary of surface water data collected in the Kootenai River valley (continued).

Sample ID	Sample Location	Date	Temperature (°C)	Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Turbidity (NTU)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	Total Potassium (mg/L)	Chloride (mg/L)	Oxygen Isotope ($\delta^{18}O$‰)	Hydrogen Isotope (δD‰)	Kootenai River Flow (cfs)	Deuterium Excess
SW-4	Left Bank	6/28/02	10.8	148	7.8	10.7	---	---	---	---	---	-18.0	-133	30,000	10.8
	Middle	6/28/02	---	---	---	---	---	---	---	---	---	-18.3	-136	30,000	10.3
	Right Bank	6/28/02	11.0	230	7.9	10.3	5.1[a]	---	---	---	---	-18.4	-136	30,000	11.1
	Left Bank	7/3/02	11.3	149.8	7.85	9.4	9.4	---	---	---	---	-17.9	-132	40,000	11.1
	Right Bank	7/3/02	11.5	214.7	7.97	10.3	8.9	---	---	---	---	-18.7	-138	40,000	11.4
	Left Bank	10/3/02	11.9	166	8.1	10.7	0.5	---	---	---	---	-18.0	-136	6,000	8.0
	Middle	10/3/02	11.9	170	8.2	10.1	0.6	---	---	---	---	-18.1	-136	6,000	8.9
	Right Bank	10/3/02	11.9	169	8.3	9.2	0.6	---	---	---	---	-18.1	-136	6,000	8.9
	Left Bank	12/11/02	7.2	217	8.1	11.8	2.2	---	---	---	---	-18.1	-135	26,000	10.1
	Middle	12/11/02	7.2	217	8.2	11.8	2.2	---	---	---	---	-18.2	-134	26,000	11.2
	Right Bank	12/11/02	7.2	217	8.2	11.0	1.7	---	---	---	---	-18.2	-136	26,000	9.7
SW-5	Right Bank	12/11/02	4.1	100	7.92	10.0	1.1	---	---	---	---	-15.6	-115	26,000	10.2
SW-6	Right Bank	12/11/02	2.3	47	7.5	8.8	0.6	---	---	---	---	-15.6	-114	26,000	10.4
USGS Gage[b]	Composite	4/19/02	3.8	270	8.4	---	---	0.077	<0.015	---	---	---	---	4,200	---
	Composite	5/15/02	4.5	263	7.4	11.0	---	0.077	<0.015	0.56	3.01	---	---	7,800	---
	Composite	6/12/02	9.5	251	8.8	9.3	---	0.076	0.009E	---	---	---	---	24,300	---
	Composite	7/17/02	11.5	206	8.1	9.4	---	0.108	0.010E	0.46	1.61	---	---	26,900	---
	Composite	8/14/02	14.5	198	8.5	8.6	---	0.071	<0.015	---	---	---	---	17,000	---
	Composite	9/18/02	13.1	206	7.6	8.2	---	0.081	<0.015	---	---	---	---	6,130	---
	Composite	10/17/02	11.5	206	8.5	9.3	---	0.05	<0.015	---	---	---	---	6,010	---
	Composite	12/17/02	7.3	222	8.0	9.4	---	0.121	<0.015	---	---	---	---	26,000	---

Notes:

[a] Sample collected by the City of Troy

[b] Samples collected by the USGS

E Estimated Value

< Less than detection limit

Table 8. Summary of ground water data collected in the Kootenai River valley.

Sample ID	Date	Temperature (°C)	Conductivity (µS/cm)	pH	Turbidity (NTU)	Total Coliform (col/100mL)	Fecal Coliform (present or absent)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	Total Potassium (mg/L)	Chloride (mg/L)	Oxygen Isotope ($\delta^{18}O$ ‰)	Hydrogen Isotope (δD ‰)	MPA Rank (0-40)	Kootenai River Flow (cfs)	Dueterium Excess
DW1	06/13/02	9.3	313	7	0.36	<1	Absent	2.14	0.04	2	4	-16.2	-116	---	26,000	13.6
DW1	06/26/02	9.1	318	6.9	1.24	<1	Absent	2.51	<0.01	2	4	-16.2	-118	---	30,000	11.7
DW1	07/02/02	9	310	6.9	0.71	<1	Absent	2.48	0.03	2	4	-16.2	-118	---	40,000	11.5
DW1	10/02/02	9.6	280	7.2	0.22	<1	Absent	1.4	0.07	2	4	-15.6	-116	---	6,000	8.8
DW1	12/10/02	9.8	310	7.1	0.19	<1	Absent	1.2	<0.01	2	3	-15.6	-115	---	26,000	9.8
DW2	06/13/02	7.1	222	7.9	0.75	**8**	Absent	0.27	0.04	<1	2	-17.8	-130	---	26,000	12.4
DW2	06/26/02	7.3	222	7.8	0.56	<1	Absent	0.14	<0.01	<1	2	-18.0	-133	---	30,000	10.9
DW2	07/02/02	7.5	230	7.8	0.67	**2**	Absent	0.17	0.02	<1	3	-18.2	-136	---	40,000	9.6
DW2	10/02/02	10	247	7.7	0.3	<1	Absent	0.47	0.06	1	3	-17.7	-134	---	6,000	7.6
DW2	12/10/02	8.6	228	7.8	0.4	<1	Absent	0.16	<0.01	<1	2	-18.0	-135	---	26,000	9.0
DW3	06/13/02	10.2	603	7.4	0.18	<1	Absent	<0.04	0.2	2	3	-18.1	-136	---	26,000	8.8
DW3	06/26/02	10.9	606	7.2	0.21	<1	Absent	<0.01	0.13	2	3	-18.2	-137	---	30,000	8.9
DW3	07/02/02	11.1	582	7.3	0.24	<1	Absent	<0.01	0.17	2	3	-18.1	-138	---	40,000	7.1
DW3	10/02/02	10.9	500	7.4	0.15	<1	Absent	<0.01	0.21	2	3	-17.5	-134	---	6,000	6.0
DW3	12/10/02	8.4	581	7.3	0.18	<1	Absent	<0.01	0.12	2	3	-17.4	-133	---	26,000	6.2
DW4	06/13/02	9.2	460	7.4	0.65	<1	Absent	1.31	0.07	1	2	-16.8	-125	---	26,000	9.4
DW4	06/26/02	9.5	416	7.3	0.77	<1	Absent	0.96	<0.01	<1	2	-17.2	-126	---	30,000	11.4
DW4	07/02/02	9.5	412	7.3	0.34	<1	Absent	1.01	0.06	<1	2	-17.1	-128	---	40,000	8.6
DW4	07/16/02	10.3	406	7.2	0.52	---	---	---	---	---	---	---	---	0	28,500	
DW4	10/02/02	10	398	7.4	0.24	<1	Absent	0.59	0.05	<1	2	-16.1	-125	---	6,000	3.8
DW4	12/10/02	9.5	419	7.4	0.15	<1	Absent	0.88	<0.01	<1	2	-16.3	-124	0	26,000	6.4
DW5	06/13/02	9.8	539	7.6	0.66	<1	Absent	0.44	0.04	2	10	-18.3	-136	---	26,000	10.4
DW5	06/26/02	10.5	545	7.4	0.28	<1	Absent	0.46	<0.01	2	9	-18.3	-137	---	30,000	9.3
DW5	07/02/02	10.2	526	7.4	0.22	<1	Absent	0.43	0.02	2	10	-18.4	-138	---	40,000	8.9
DW5	07/16/02	11.3	527	7.3	0.41	---	---	---	---	---	---	---	---	0	28,500	
DW5	10/02/02	9.6	440	7.5	0.28	<1	Absent	0.34	0.06	2	7	-17.6	-136	---	6,000	4.8
DW5	12/10/02	8.3	512	7.5	0.22	<1	Absent	0.32	<0.01	1	7	-17.4	-134	0	26,000	5.2
DW6	06/13/02	10.1	415	7.4	0.28	<1	Absent	0.96	0.05	2	8	-18.1	-137	---	26,000	7.8
DW6	06/26/02	10.1	424	7.5	0.19	<1	Absent	0.96	<0.01	2	7	-18.5	-138	---	30,000	9.8
DW6	07/02/02	10.2	395	7.4	0.2	<1	Absent	0.78	0.04	2	6	-18.6	-139	---	40,000	9.5
DW6	10/02/02	10.3	378	7.6	0.19	<1	Absent	0.92	0.04	2	8	-17.6	-135	---	6,000	5.8
DW6	12/10/02	9.9	385	7.6	0.2	<1	Absent	0.79	<0.01	1	6	-17.7	-133	---	26,000	8.6

Table 8. Summary of ground water data collected in the Kootenai River valley (continued).

Sample ID	Date	Temperature (°C)	Conductivity (µS/cm)	pH	Turbidity (NTU)	Total Coliform (col/100mL)	Fecal Coliform (present or absent)	Nitrate + Nitrite (mg/L)	Ammonia (mg/L)	Total Potassium (mg/L)	Chloride (mg/L)	Oxygen Isotope ($\delta^{18}O$ ‰)	Hydrogen Isotope (δD ‰)	MPA Rank (0-40)	Kootenai River Flow (cfs)	Dueterium Excess
DW7	06/13/02	12.6	600	7.4	0.15	<1	Absent	0.69	0.07	7	11	-18.2	-137	—	26,000	8.6
DW7	06/26/02	12.6	638	7.5	0.96	<1	Absent	0.76	<0.01	6	11	-18.2	-138	—	30,000	7.4
DW7	07/02/02	12.6	586	7.4	0.12	<1	Absent	0.67	0.05	6	11	-18.2	-139	—	40,000	6.7
DW7	10/02/02	12.2	615	7.5	0.24	<1	Absent	1.38	0.04	7	16	-17.4	-136	—	6,000	3.2
DW7	12/10/02	11.9	683	7.5	0.18	<1	Absent	1.07	<0.01	6	16	-17.4	-133	—	26,000	6.2
DW8	06/13/02	10.1	448	7.5	0.15	<1	Absent	0.55	0.05	3	8	-18.0	-133	—	26,000	11.0
DW8	06/26/02	10.4	417	7.5	0.1	<1	Absent	0.55	<0.01	2	6	-18.0	-134	—	30,000	10.2
DW8	07/02/02	10.2	406	7.5	0.82	<1	Absent	0.43	0.03	2	5	-18.2	-135	—	40,000	10.2
DW8	10/02/02	11.3	586	7.5	0.97	<1	Absent	3.41	0.04	3	22	-17.0	-132	—	6,000	4.0
DW8	12/10/02	10.4	404	7.6	0.4	<1	Absent	0.6	<0.01	2	7	-17.7	-134	—	26,000	7.6

Notes:

< Less than detection limit

Table 9. Ground water MPA test results.

	DW4		DW5	
	7/16/02	12/09/02	7/16/02	12/09/02
Total Gallons Filtered	1070	800	1114	810
Primary Indicators				
Giardia	0[a]	0	0	0
Coccidia	0	0	0	0
Diatoms	0	0	0	0
Other algae	0	0	0	0
Insect/larvae	0	0	0	0
Rotifers	0	0	0	0
Plant debris	1	1	0	0
Secondary Indicators				
Large amorphous debris	M	M	H	M
Fine amorphous debris	M	H	M	H
Minerals	M	H	H	H
Plant pollen	0	1	0	1
Nematodes	1	0	3	27
Crustacia	0	0	0	0
Amoeba	2	1	0	0
Ciliate/Flagellates	0	0	0	0
Nuisance bacteria	11	—	—	—
Iron bacteria	—	30	—	—
Other	—	—	—	—
Risk Factor	0	0	0	0

Notes:
[a] Numbers represent the total number of organisms/particulates counted in the sample
H High concentration
M Medium concentration
L Low concentration

Figures

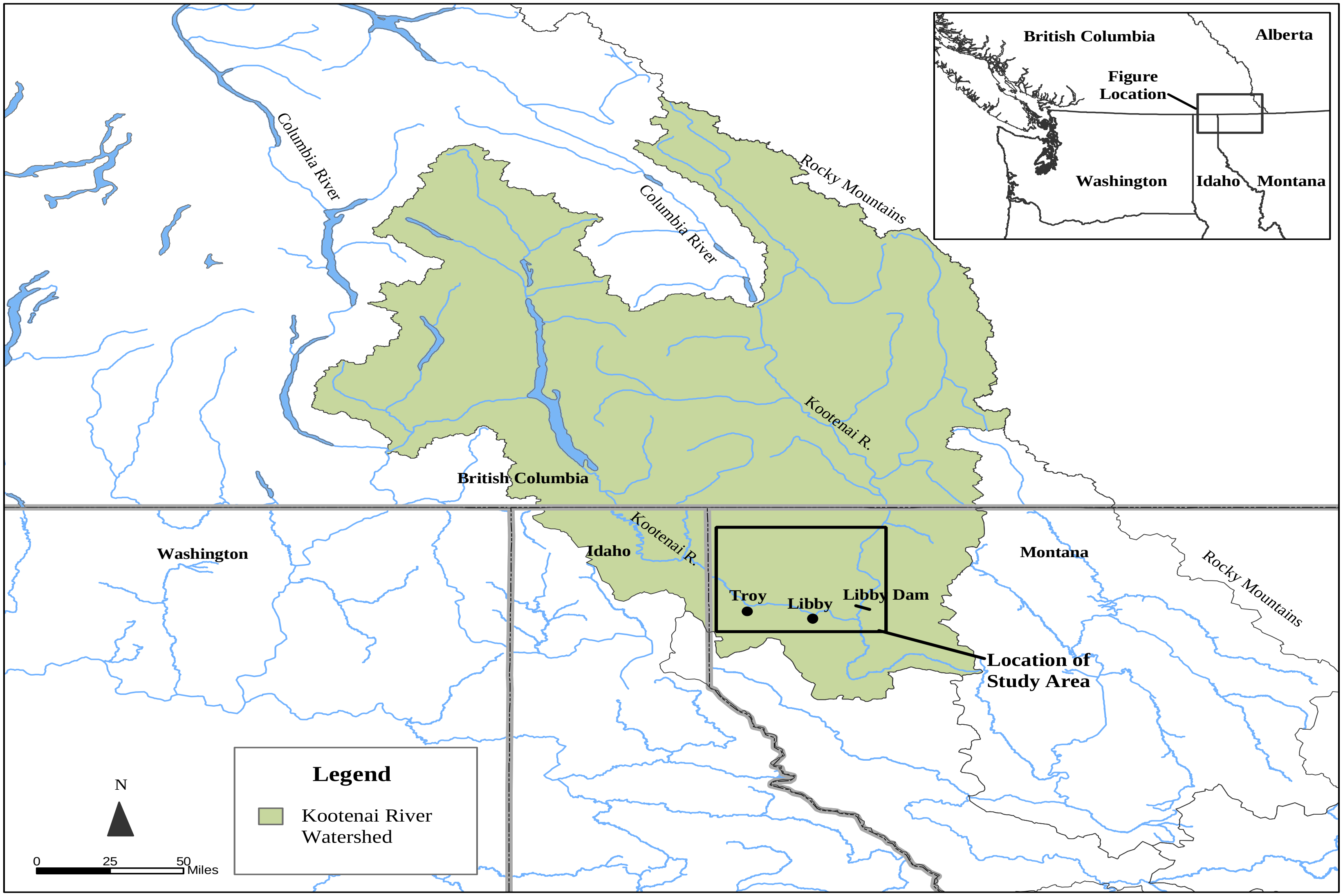


Figure 1. Location of study area within the Kootenai River watershed.

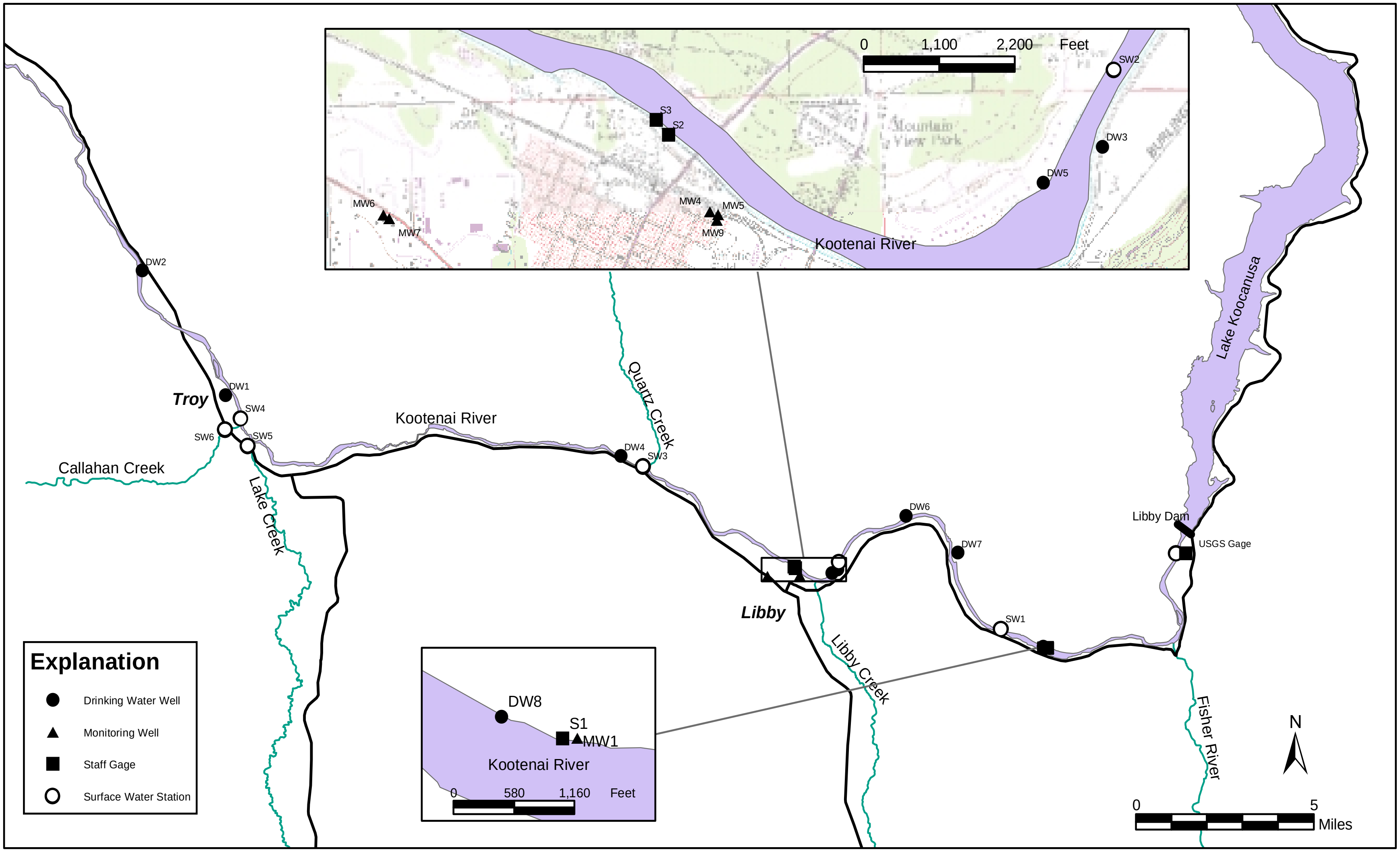


Figure 2. Locations of ground water, surface water, and hydrological monitoring stations.

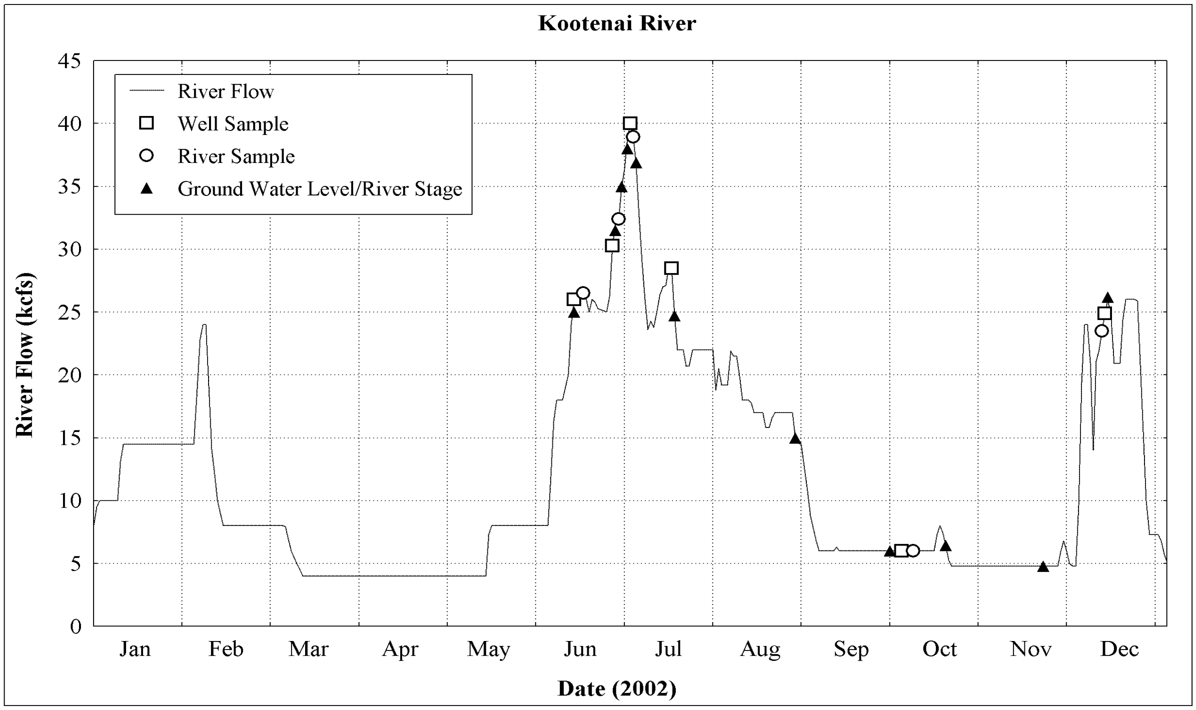


Figure 3. **Relationship between Kootenai River flows and ground water monitoring events during 2002.**

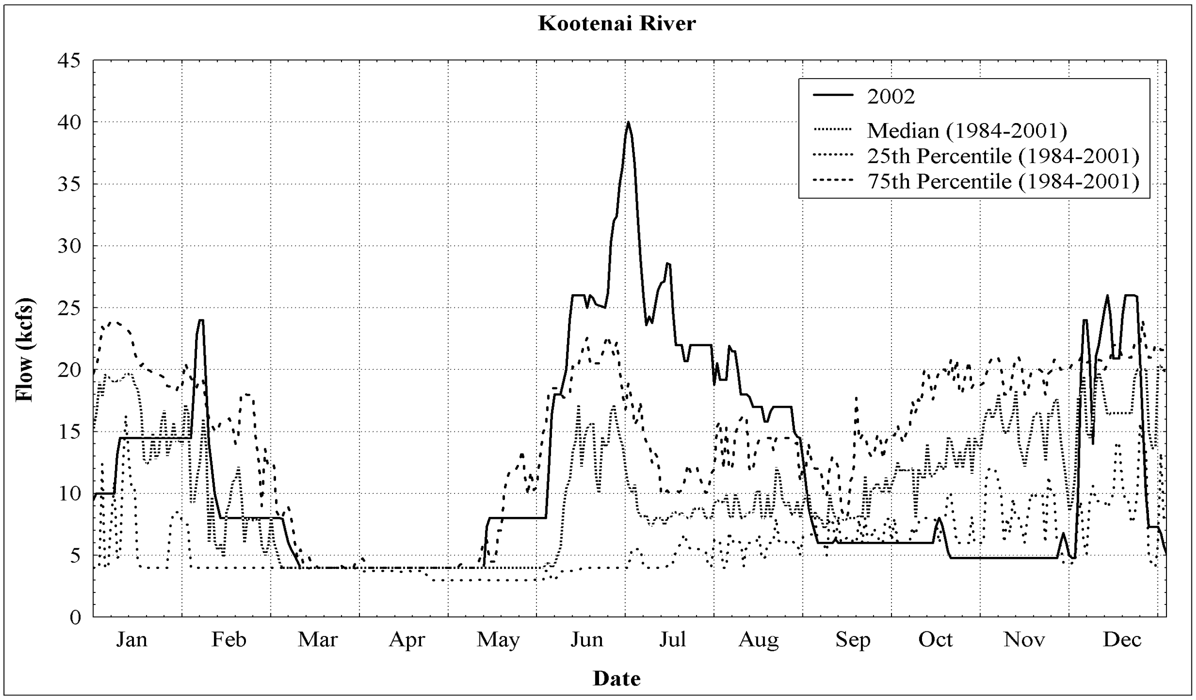


Figure 4. Historical (1984-2001) and year 2002 Kootenai River flows below Libby Dam.

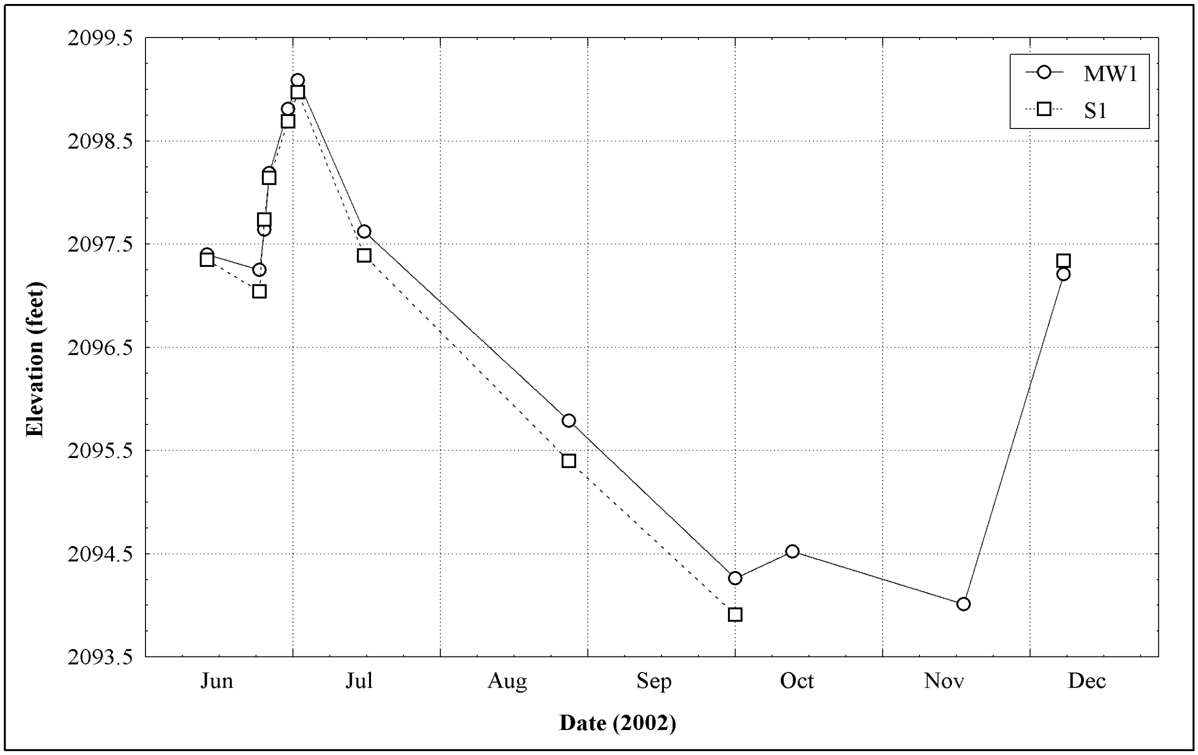


Figure 5. Ground water and surface water elevations at MW1 and S1.

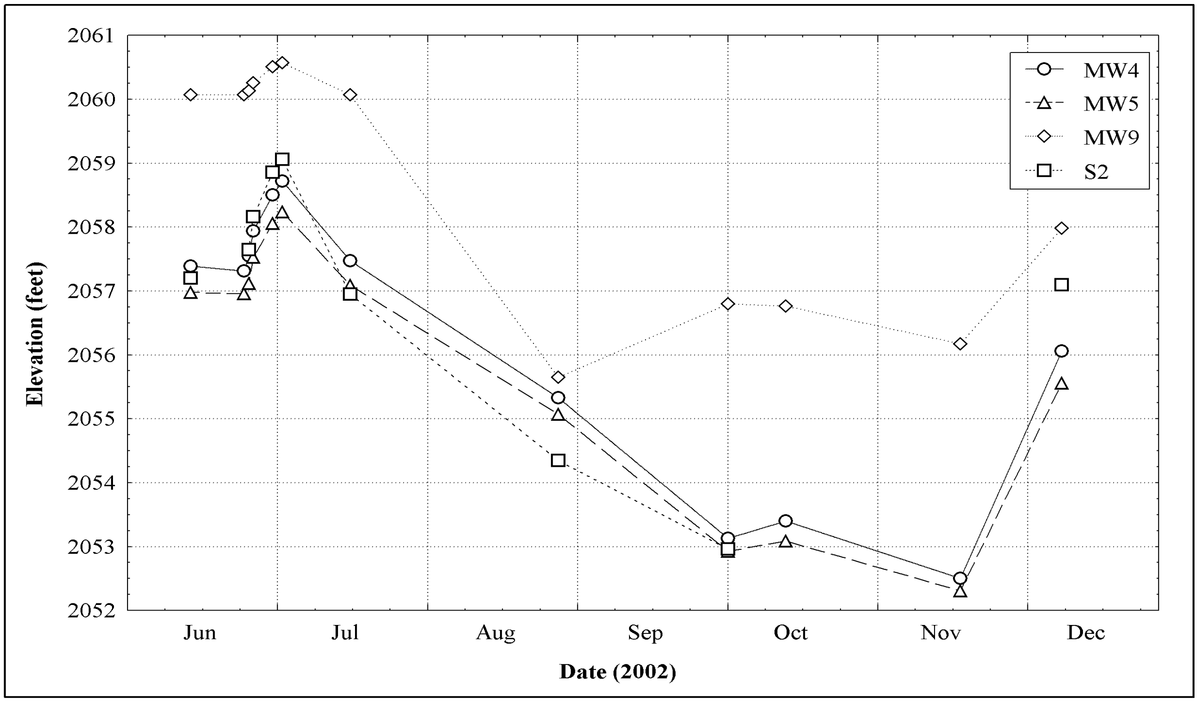


Figure 6. Ground water and surface water elevations at MW4, MW5, MW9 and S2.

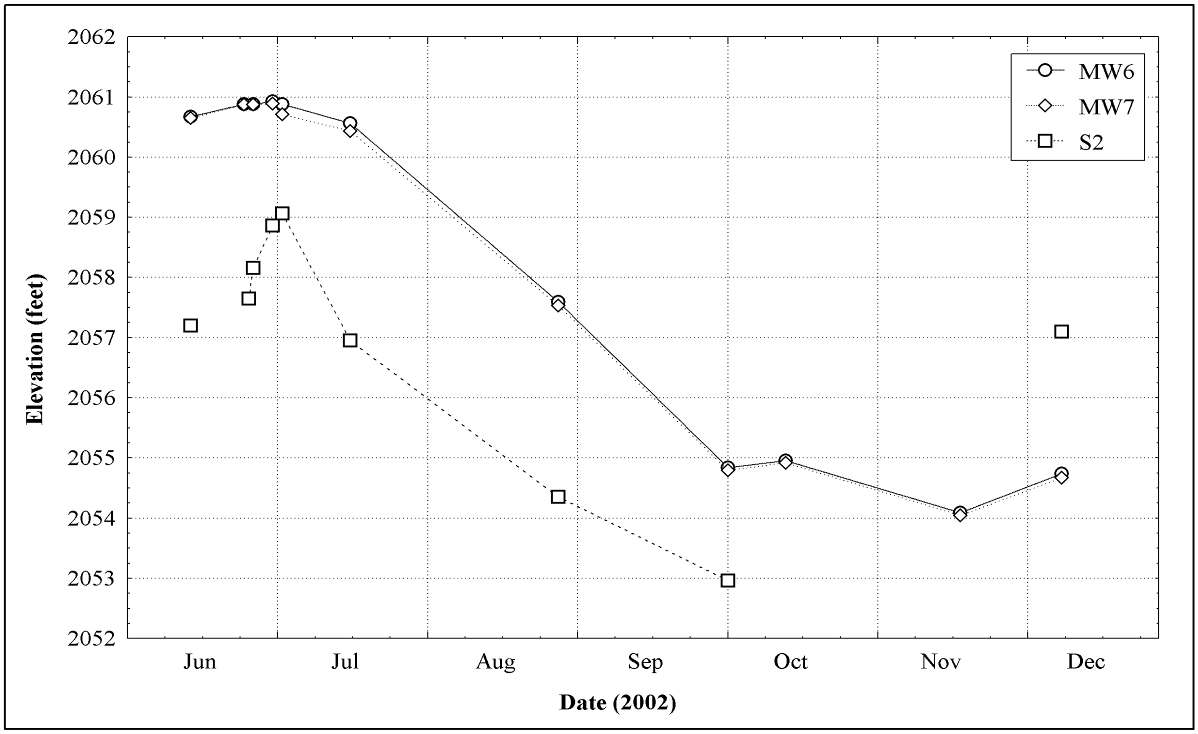


Figure 7. Ground water and surface water elevations at MW6, MW7 and S2.

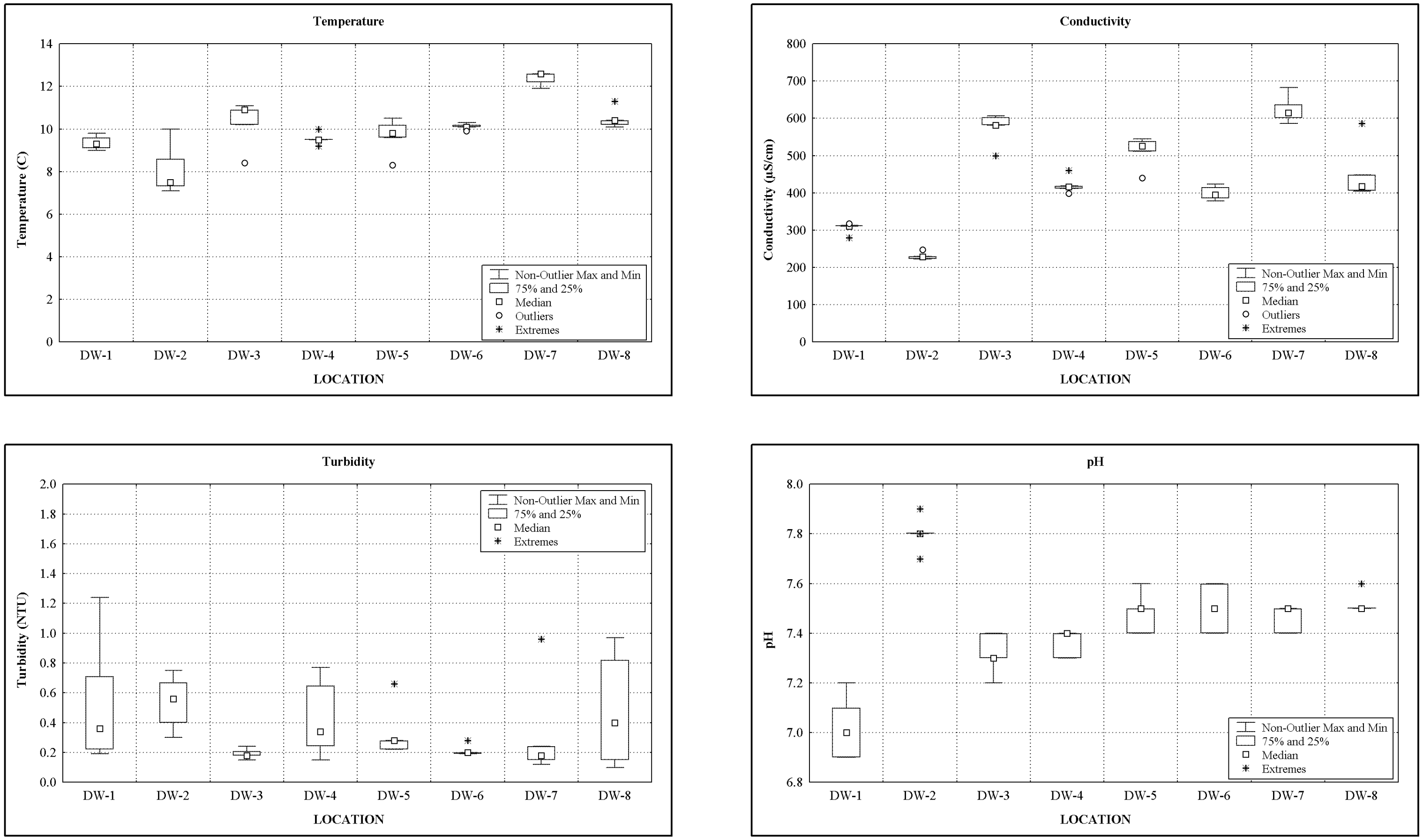


Figure 8. Box plots of temperature, conductivity, turbidity, and pH at well stations DW1 through DW8.

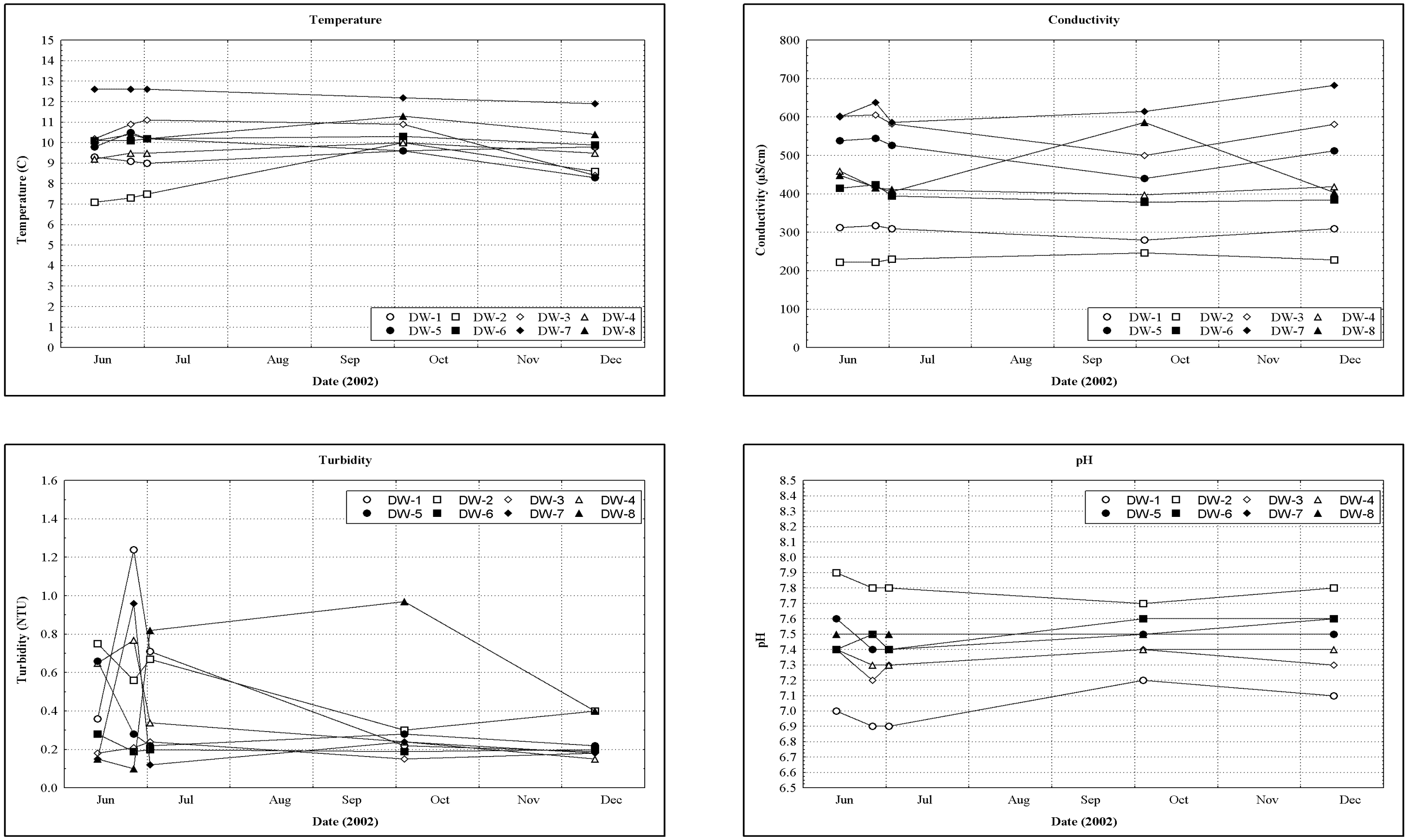


Figure 9. Temporal variations of temperature, conductivity, turbidity, and pH at well stations DW1 through DW8.

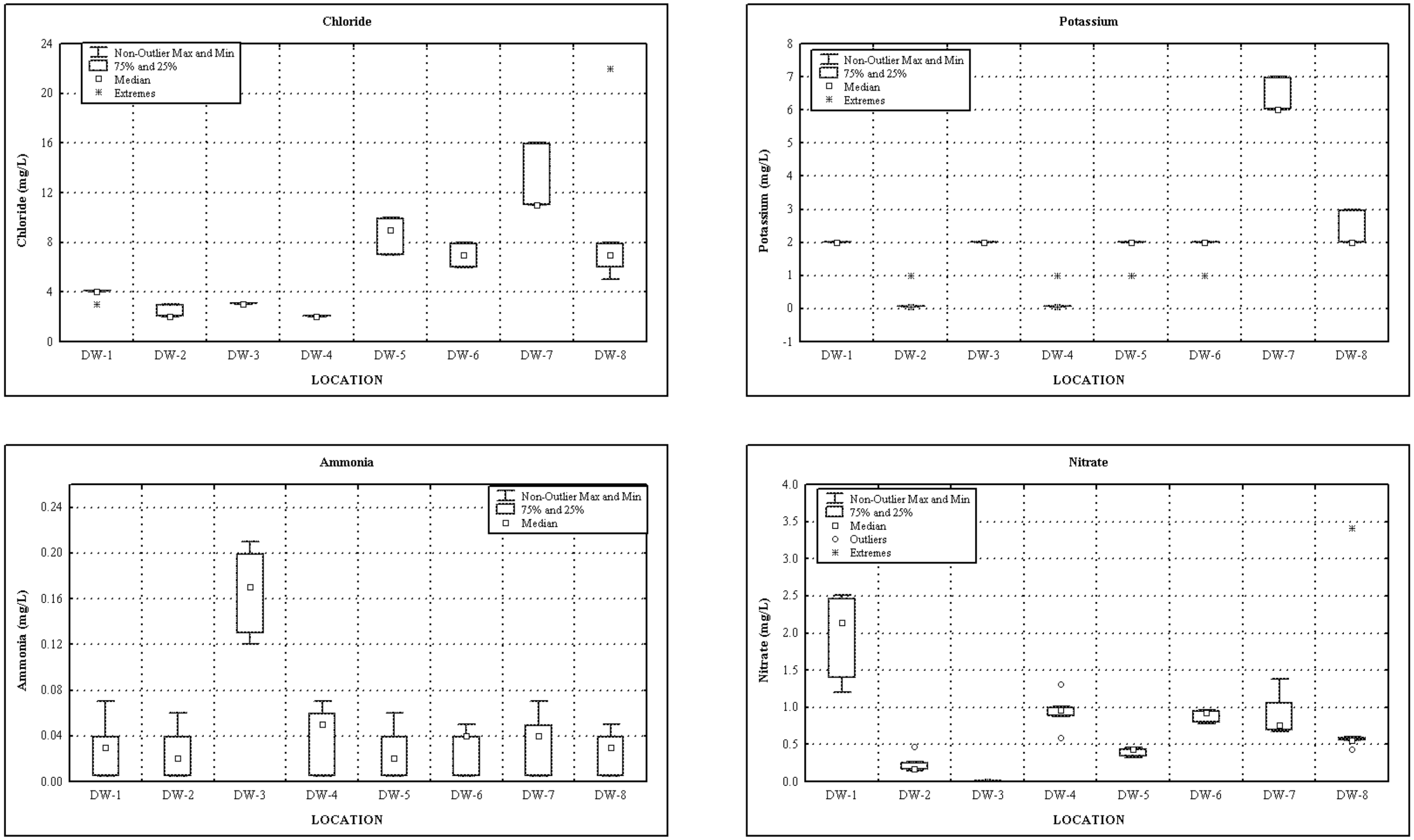


Figure 10. Box plots of chloride, potassium, ammonia, and nitrate at well stations DW1 through DW8.

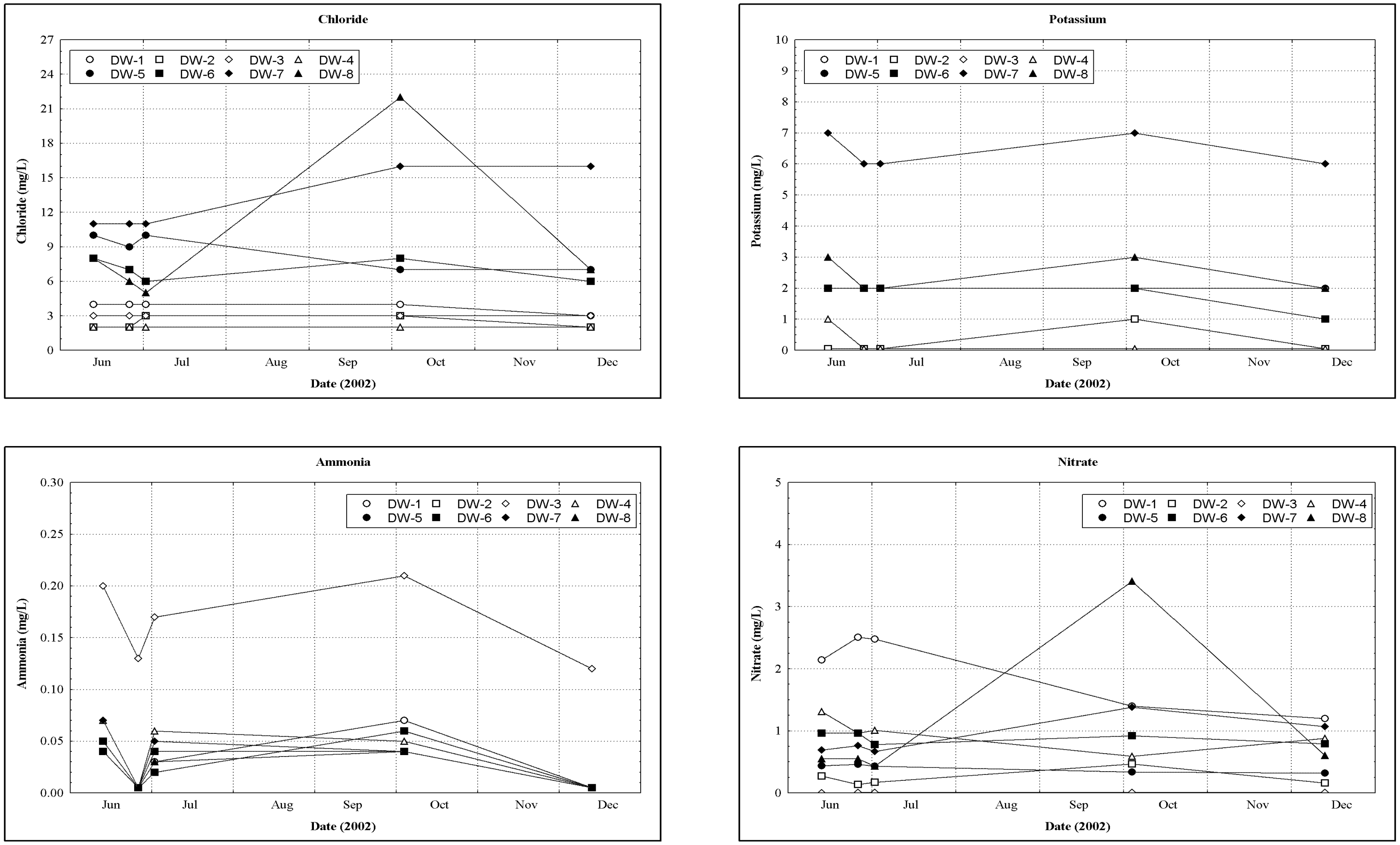


Figure 11. Temporal variation of chloride, potassium, ammonia, and nitrate at well stations DW1 through DW8.

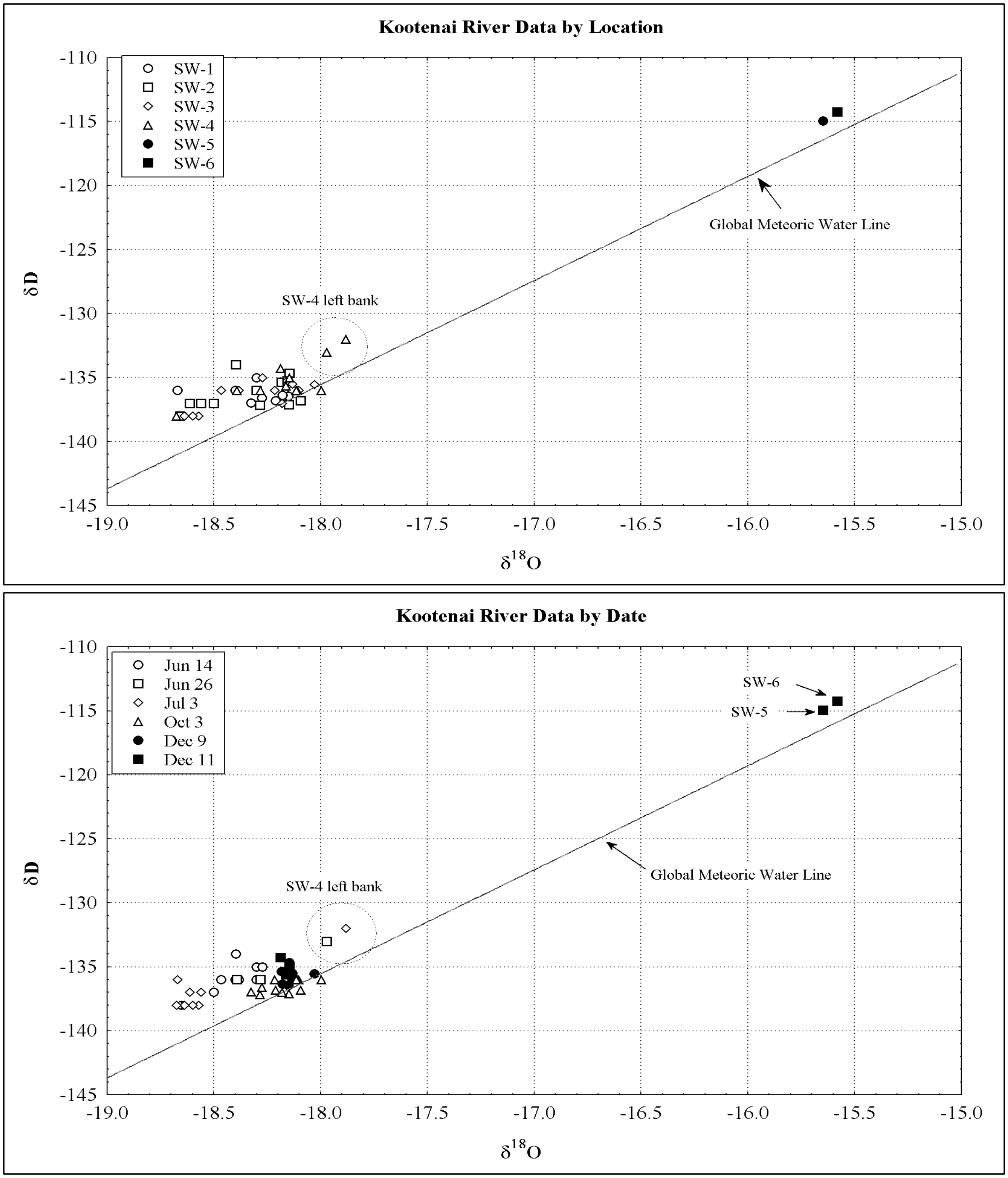
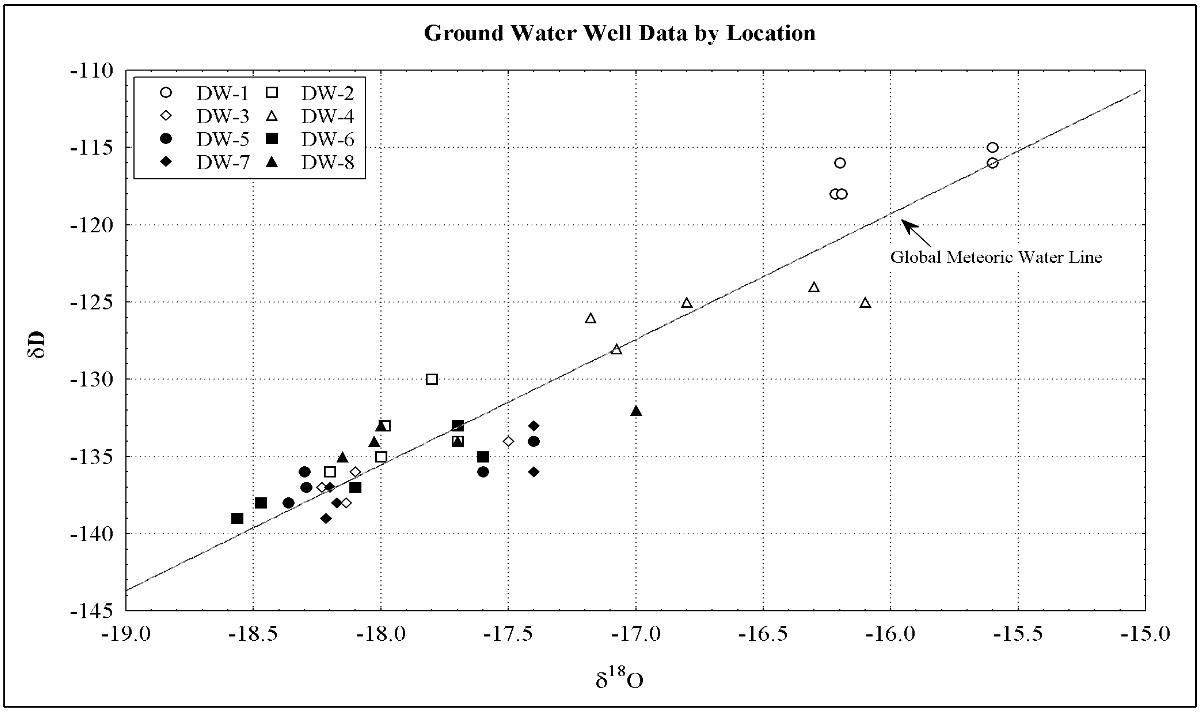


Figure 12. Hydrogen (δD) and oxygen ($\delta^{18}O$) isotopic composition of the Kootenai River downstream of Libby Dam, by station and date.



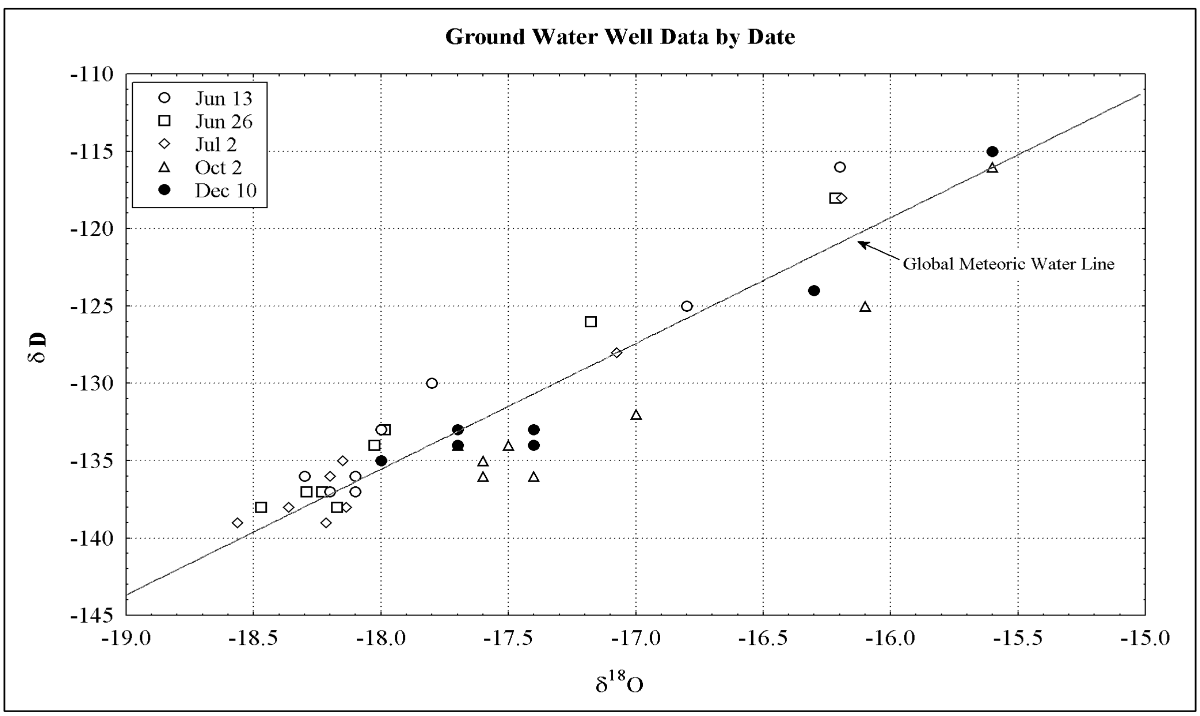


Figure 13. Hydrogen (δD) and oxygen ($\delta^{18}O$) isotopic composition of the ground water wells downstream of Libby Dam, by station and date.

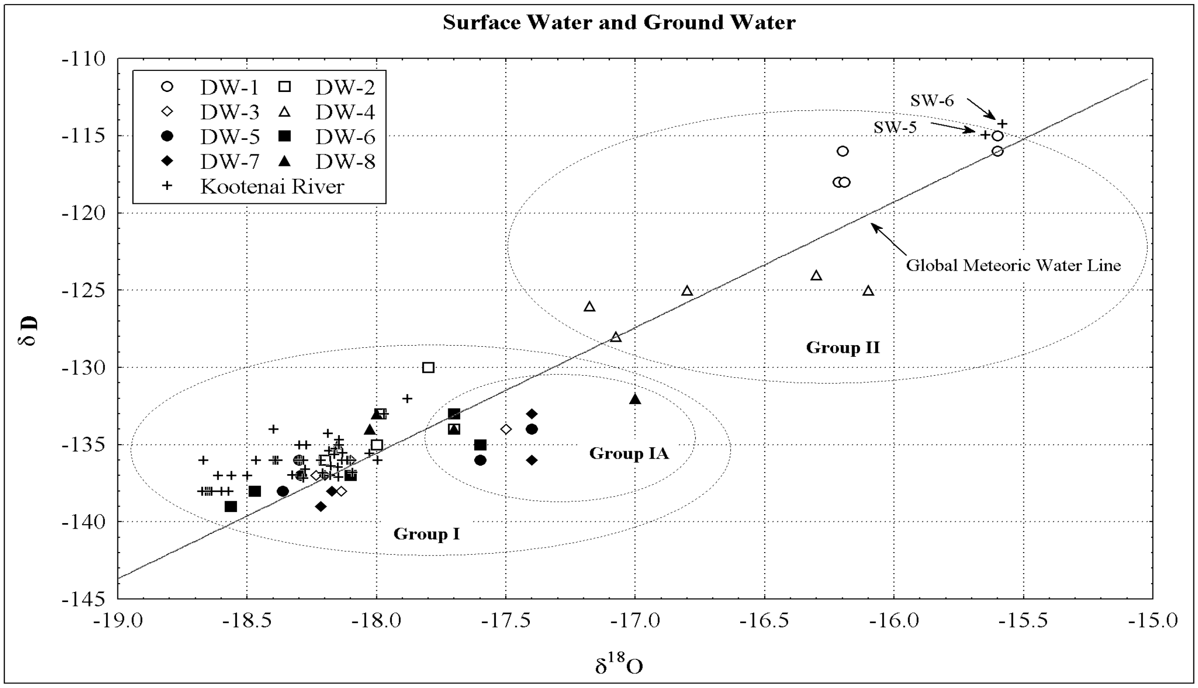


Figure 14. Relationship between surface water and ground water hydrogen (δD) and oxygen (δ^{18}O) stable isotope data, June 2002 through December 2002.

Appendix A

Quality Assurance Report

This report presents results from the quality assurance review of data collected for the Libby Dam Ground Water Quality Monitoring Project. Data assessment procedures used in this quality assurance review are based on the following eight control elements:

- Completeness
- Methodology
- Holding times
- Detection limit
- Blanks
- Duplicates
- Matrix spikes
- Control samples.

No problems were associated with the data collected in connection with this project. The following sections provide specific details for each of the quality control elements reviewed and any resultant corrective action required.

Completeness

Completeness was assessed by comparing valid sample data values with total number of sample values. Because the number of valid sample data divided by the total number of samples was greater than the quality assurance objective of 95 percent, no corrective actions were required to address problems related to completeness.

Methodology

Methodology was assessed by examining field notebooks, sampling data sheets, and laboratory reports for deviations from the monitoring plan and quality assurance plan. Subsequent to this review, it was concluded that there were no significant deviations in methodology that required corrective action.

Holding Times

Holding times were assessed by comparing analytical dates to sample collection dates. Corrective action was implemented for all values that exceeded the maximum holding times required by U.S. EPA. Subsequent to this review, it was concluded that there were no holding time problems that required corrective action.

Blanks

Preparation blanks, which are composed of reagent water that is prepared as a sample, were analyzed with collected samples, and the results were reported in each laboratory report. If a blank value exceeded the detection limit, corrective actions were to be implemented for the associated samples. Because all blanks were below the method detection limit for their respective analytes, no corrective actions were required for this quality control element.

Detection Limits

Laboratory data were reported with a method detection limit (MDL) and a reporting detection limit (RDL). The laboratory MDL represents the minimum concentration of a constituent that can be detected. All data values that were below the MDL were qualified as below detection with a < symbol next to the reported detection limit.

Duplicates

Laboratory duplicates are two aliquots of a sample processed concurrently and identically. Corrective action was implemented for all laboratory duplicates with a relative percent difference (RPD) greater than 20 percent. No duplicate problems were encountered.

Matrix Spikes

Matrix spikes are used as an indicator of matrix effects on sample recovery and precision. If a percent recovery from a matrix spike was not within 80 to 120 percent for metals or a pre-determined laboratory range for organics, corrective actions were implemented where necessary. No matrix spike problems were encountered.

Control Samples

Control samples refer to check standards, blank spikes, or standard reference materials. If the percent recovery for a control standard was not within 80 to 120 percent for metals and a pre-determined laboratory range for organics, corrective actions were implemented, where necessary. All control sample recoveries were within acceptable limits.