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MOAB UTAH UMTRA

UMTRA Project

2006 Performance Assessment of the Ground Water Interim Action Well Field Moab, Utah

June 2007

U.S. Department of Energy

Office of Environmental Management

Work Performed Under DOE Contract No. DE–AC01–02GJ79491
for the U.S. Department of Energy Office of Environmental Management.

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Moab UMTRA Project Site

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Work Performed by S.M. Stoller Corporation under DOE Contract No. DE–AC01–02GJ79491 for
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Appendixes are available upon request at moabcomments@gjem.doe.gov

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1.0 Introduction

This document presents an updated evaluation of pumping well systems used to extract contaminated ground water as part of the Ground Water Interim Action (Ground Water IA) at the Moab Uranium Mill Tailings Remedial Action (UMTRA) Project Site (Moab Site). A previous evaluation of ground water extraction during 2004 (DOE 2005b) accounted for pumping from the IA system referred to as Configuration 1 and an updated study last year examined the continued use of the Configuration 1 system in 2005 as well as the time-limited use of a newer extraction system (Configuration 3) installed in the summer of 2005. Additional reports on the performance of Configuration 2 operated in injection mode were prepared in 2005 (DOE 2005c and 2005d). This report provides additional information for the entire Ground Water IA well field, which now includes Configuration 4 and an infiltration trench, both installed in 2006. Pumping from the well field and/or injecting fresh water into the infiltration trench, both located near the west bank of the Colorado River (Figure 1–1), has the potential to mitigate potential environmental effects of contaminated alluvial ground water that, under natural conditions, discharges to potential fish habitat in the Colorado River near its west bank. This habitat is ephemeral, consisting of backwaters in side channels of the river that are present only under certain flow conditions.

Contamination found in ground water at the Moab Site was caused by local uranium milling operations between the 1950s and 1980s. Some of the contaminants were contributed by seepage from the Moab tailings pile, located about 700 to 750 feet (ft) west-northwest of the river. The most notable contaminant from tailings seepage is dissolved ammonia, which occurs in a wide swath downgradient of the pile and discharges to the river, where it can affect the well being of endangered fish species. Another constituent of concern is dissolved uranium, which also discharges to the river in the area impacted by ammonia.

1.1 Previous Studies

Studies of the Moab Site over the past 5 years have shown that the local ground water chemistry has been and continues to be affected by a variety of hydrologic and geochemical processes, many of which are unique to Moab Valley in which the site is located. As a result of these processes, contamination associated with historical milling activities is found not only in shallow ground water that contributes the ammonia found in potential fish habitat of the river but also in relatively deep ground water containing brine. The brine, which is caused mostly by natural phenomena, tends to mix with both contaminated ground water and relatively fresh water entering the site to the west and north of the tailings pile, which in turn causes shallow ground water discharging to the river to also be quite saline. This mixing of waters leads to a complex geochemical system, which becomes further complicated when site ground water reaches the river. This is because the ground water does not discharge directly to the river, but rather first passes through another area of water mixing located adjacent to and below the river that contains surface water that has infiltrated the subsurface. This latter mixing area, termed the hyporheic zone, is noteworthy for the large number of chemical reactions that potentially occur within it, many of which are mediated by microorganisms. Such biogeochemical activity has the potential to greatly attenuate the concentrations of ammonia and other dissolved constituents in ground water.

A variety of site studies have led to the current conceptual model of ground water flow and chemistry. Many of the results from those studies are contained in the *Site Observational Work Plan for the Moab, Utah, Site* (DOE 2003d). Preliminary information regarding ground water in the Configuration 1 area after this system was installed in spring 2003 is presented in the *Operations, Maintenance, and Performance Monitoring Plan for the Interim Action Ground Water Treatment System, Moab Utah* (DOE 2005a) and a subsequent calculation entitled *Evaluation of September 2003 Preliminary Performance Data for the Interim Action* (DOE 2004a). The first detailed evaluation of Configuration 1 performance examined its operation between June and October of 2004, as reported in the *Fall 2004 Performance Assessment of the Ground Water Interim Action Well Fields at the Moab, Utah, Project Site* (DOE 2005b).

In conjunction with the 2004 performance assessment of Configuration 1, data from a series of pumping tests in the Configuration 2 area during September and October 2004 were analyzed (DOE 2005b) after this system was installed in July 2004. Configuration 2 was subsequently converted into a system for injecting relatively fresh water (diverted from the river) into ground water, also for the purpose of mitigating potential environmental impacts in backwaters of the Colorado River near its west bank. Full-time injection of river water began in Configuration 2 on October 6, 2004, and its initial operation (through mid-March 2005) was reported in *Performance of the Ground Water Interim Action Injection System at the Configuration 2 Well Field* (DOE 2005c). A subsequent study documented in *Performance of the Ground Water Interim Action Injection System at the Configuration 2 Well Field, October 2004-October 2005* (DOE 2005d) examined the continued performance of the system into fall 2005. Though the processes by which freshwater injection affects river chemistry in river backwaters are different from those resulting from ground water extraction, the results of the two performance assessments of the Configuration 2 system conducted to date help shed light on this updated assessment of ground water extraction under the IA. Due to poor well performance regarding fresh water injection and construction activities for a new fresh water storage pond, injection into Configuration 2 wells was discontinued in spring 2006 and these wells were utilized for ground water extraction, albeit at a low volume. Their extraction performance in 2006 is described in this document.

Installation of Configuration 3 wells was completed in August 2005 and pumping of ground water from them began in early October 2005. The *Fall 2005 Performance Assessment of the Ground Water Interim Action Well Fields at the Moab, Utah, Project Site* (DOE 2006a) report described the components of the Configuration 3 system and its early operation through December 2005. An update to the *Operations, Maintenance, and Performance Monitoring Plan for the Interim Action Ground Water Treatment System, Moab, Utah, Site* (DOE 2005a) was completed in 2006 (DOE 2006b). The update contains system drawings and well construction diagrams for Configuration 3.

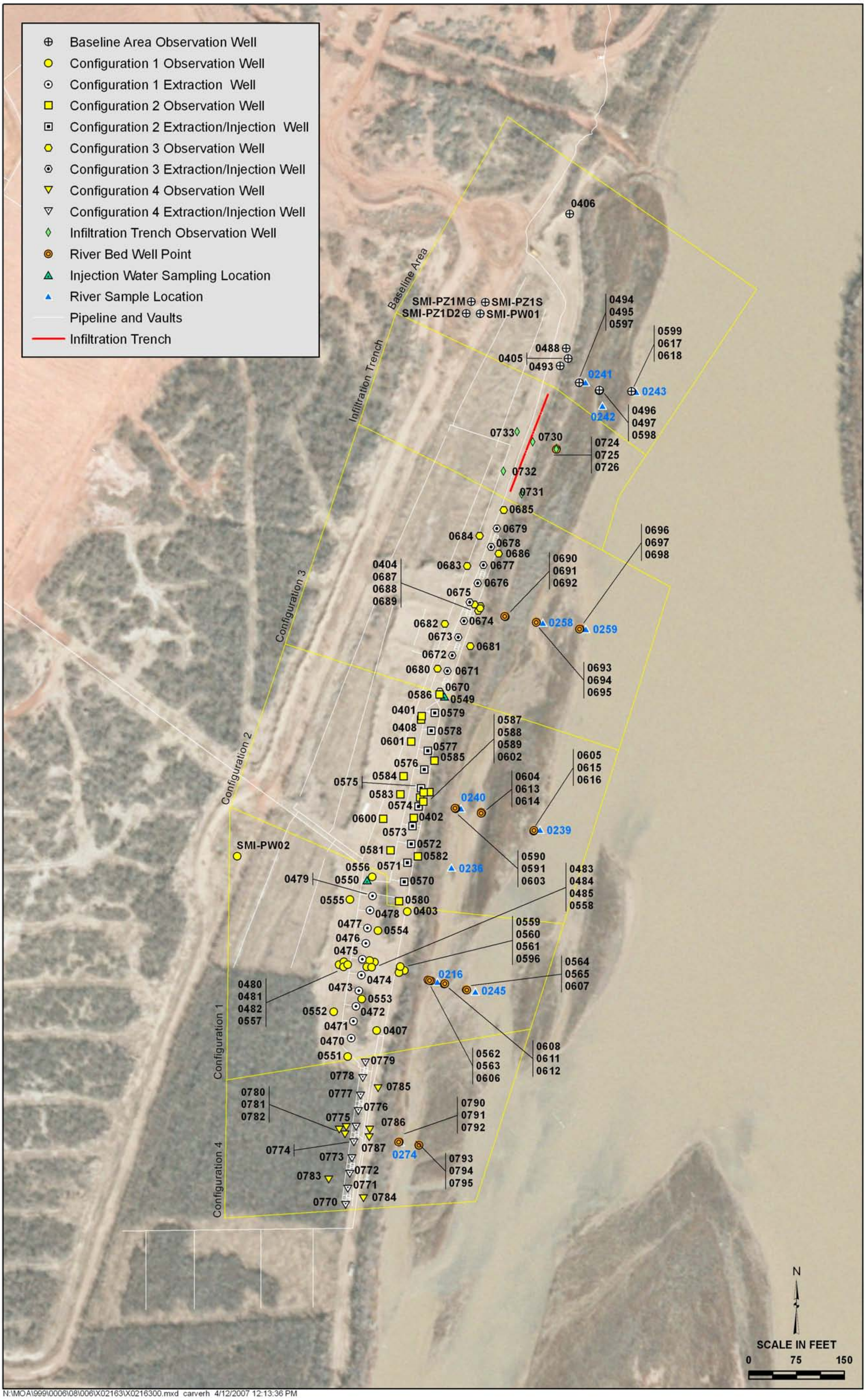

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Figure 1–1. Map View of Interim Action Components and Well Locations

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Installation of Configuration 4 wells was completed in July 2006 and pumping of ground water from them began in late August 2006. This report is the first formal description of the components of Configuration 4 and its early operation into December 2006. Also, an infiltration trench was installed in August and it began receiving diverted river water in late September 2006. Another update (revision 3) to the *Operations, Maintenance, and Performance Monitoring Plan for the Interim Action Ground Water Treatment System, Moab, Utah, Site* (DOE 2006b) was completed in February 2007. That update contains system drawings and well construction diagrams for Configuration 4 and the infiltration trench as well as retaining all of the previous drawings.

1.2 Performance Assessment Methods

The performance of ground water extraction methods in contributing to the mitigation of environmental effects is based on comparisons of hydraulic and water chemistry data collected since extraction began with equivalent data reflective of pertinent “baseline” conditions at the Moab Site. Such baseline information is drawn from two sources. In most instances, baseline conditions are based on data collected at the well field before the wells were used for ground water extraction (or injection). In other instances, baseline information is drawn from observations made in a separate part of the Moab site called the Baseline Area, which is located north of both the well field and the infiltration trench and about 400 ft south-southwest of the confluence of Moab Wash and the Colorado River (Figure 1–1). The Baseline Area is used to portray ambient hydraulic and water chemistry conditions that occur between the tailings pile and the river; the conditions in the Baseline Area reflect the effects of ammonia and uranium contamination originating in the area of the tailings pile but are unaffected by either ground water pumping or the injection of relatively fresh water diverted from upstream portions of the river.

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2.0 Purpose and Scope

The primary purpose of this document is to describe the response of ground water in alluvium at the site to pumping in areas just upgradient of the Colorado River, particularly as it affects discharge of contaminated ground water to the river. This purpose is primarily met through the analysis of concentration data for key ground water chemistry parameters (e.g., total dissolved solids [TDS], ammonia, and uranium) and measured water levels in a variety of observation wells and piezometers in the vicinity of the well field (Figure 1–1). However, other types of chemical data are also examined with the intent of characterizing transport phenomena that until last year's assessment report may not have been identified.

The main objective of this study is to evaluate the performance of each well field configuration, mainly Configurations 1, 2, and 3 because they operated most of the year, and also to provide initial performance data results for Configuration 4 wells and the infiltration trench. The previous performance assessment report (DOE 2006a) evaluated possible differences in the performance of the Configuration 3 extraction system versus that of Configuration 1. This was based on an earlier evaluation of Configuration 1 extraction wells while they were pumping during 2004 that showed their hydraulic efficiency tended to decline with continued use (DOE 2005b). This meant that the rate at which ground water was removed from each well progressively declined though the drawdown in water level in the well tended to remain relatively constant. Configuration 3 wells were installed using construction methods that were intended to overcome some of the efficiency problems with Configuration 1. The screened intervals of Configuration 3 wells span depths of about 15 to 45 ft below ground surface (bgs), whereas the screened intervals in most Configuration 1 wells are much shallower, generally between depths of about 10 and 20 ft bgs (screens in two Configuration 1 wells extended to a depth of about 24 ft bgs). The longer screen interval in the Configuration 3 wells was expected to result in larger pumping rates than those achieved in Configuration 1 wells while keeping drawdown of water levels relatively small. In addition, a 20-slot (0.02 inch) screen size was used with the Configuration 3 wells as compared to a 10-slot (0.01 inch) size used at Configuration 1. The larger slot size was intended to minimize potential clogging of screen openings by suspended sediment drawn inward from the aquifer or possible chemically induced precipitation of dissolved solids near the openings (DOE 2005b).

Though a preliminary assessment of Configuration 3 well efficiencies was performed last year, time limitations prevented detailed analysis of the wells' hydraulic performance over several months in comparison to those in the Configuration 1 system. Pumping of the Configuration 3 wells was limited to approximately 3 months in 2005, but they operated for about 9 months in 2006. Another factor also made it difficult to discern whether improvements in well efficiency observed in the Configuration 3 system could be attributed to changes in well construction. Previous investigations had indicated that the salinity of ground water pumped into Configuration 3 wells might be significantly less than the salinity in ambient ground water surrounding Configuration 1. This distinction was important because a previous performance assessment of the Configuration 1 system (DOE 2005b) indicated that declining well efficiencies might also be correlated with high salinity values.

The Configuration 4 wells that were installed in 2006 were constructed in a manner closer to that of Configuration 3 than Configuration 1. Because of an anticipated shallower depth to the brine layer in the Configuration 4 area, the wells were drilled to only 36 ft bgs and the 20-slot well screen was installed at depths between approximately 15 and 35 ft bgs. Initial pumping from these wells indicated rates of 10 gallons per minute (gpm) per well were achievable and sustained pumping rates of 4 to 5 gpm were utilized in 2006.

Last year's assessment (DOE 2006a) was distinguished from previous evaluations of ground water extraction (DOE 2004a, DOE 2005b) in that chemical data were examined in considerable detail to identify potential chemical reactions occurring in site ground water. During 2005, the list of chemical parameters used to characterize ground water in the vicinity of the three configurations comprising the IA (at that time) was expanded. This expanded list included dissolved oxygen (DO) and dissolved bromide concentrations. In addition, parameters potentially indicative of biogeochemical activity in subsurface water were collected and analyzed in relatively great detail. Many of these latter data provided new ways of analyzing concentration data and shed light on a variety of contaminant attenuation processes that occur in the hyporheic zone located below and adjacent to the Colorado River. The relevance of these processes and their potential influence on ground water affected by extraction from Configuration 1 and 3 wells were discussed. The expanded analyte list used in 2005 was continued in 2006, and a few additional parameters indicative of biogeochemical conditions were also examined in 2006. A discussion of these data and their relevance to previous findings is provided in this report.

The contaminated water withdrawn from the IA extraction wells is treated in an on-site evaporation pond located atop the tailings pile. Information regarding the operation of this pond and its capacity to remove ammonia and uranium mass from water is also discussed in this report.

3.0 Conceptual Model of Ground Water Flow and Chemistry

Performance of the ground water extraction system at the Moab Site is best understood if it is presented in the context of distinct environmental conditions that exist in the Moab Valley. The valley's hydrogeology is relatively unique in that discharge of ground water to the river is affected by density-dependent flow induced by the presence of very saline to briny water. In addition, evidence for the presence of a hyporheic zone below the river, as discussed in previous performance evaluations of the Ground Water IA (DOE 2005b, DOE 2005d, DOE 2006a), indicates that the chemistry of this ground water is significantly altered before it enters the river. Much of the information presented in the preceding performance assessment report (DOE 2006a) to describe these issues is repeated here for completeness of understanding of the site. Where applicable, additional assessment has been included as derived from 2006 data.

3.1 Alluvial Aquifer

Most of the ground water found in the Moab Valley appears to originate as recharge from atmospheric precipitation on or surface water flow across bedrock areas located away from the valley (Blanchard 1990, Freethy and Cordy 1991, Eisinger and Lowe 1999, DOE 2003d). The majority of the recharge water appears to enter the valley as subsurface discharge to the alluvium that dominates the unconsolidated deposits found throughout most of the valley. As a consequence, shallow ground water is locally dominated by flow processes in an alluvial aquifer system. In general, flow in the alluvium converges on the Colorado River from both the southeast (from near the City of Moab) and the northwest (the Moab Site) (DOE 2003d).

The uppermost 10 ft of alluvium in the vicinity of the Ground Water IA generally consists of sandy silt and silty sand deposits. These silt-bearing sediments are typically underlain by 5 to 6 ft of fine- to coarse-grained sand. Between depths of approximately 15 and 29 ft bgs, gravelly sands predominate, but thin clayey gravelly sand units are also occasionally encountered. Below to depths approaching hundreds of feet, the alluvium appears to consist primarily of gravelly sands and sandy gravels. The top of the saturated zone in Ground Water IA areas is located about 10 to 12 ft bgs; consequently, ground water flow in the alluvial aquifer occurs mostly within gravelly sand and sandy gravel materials. Stratification within the alluvial aquifer causes the aquifer to exhibit anisotropy, with the effective hydraulic conductivity in the vertical direction being perhaps 10 to 100 times smaller than the horizontal hydraulic conductivity (DOE 2003d).

3.2 Density-Dependent Ground Water Flow

Levels of salinity in ground water on both sides of and below the river can be described with respect to TDS concentrations in units of milligrams per liter (mg/L). Ground water is typically characterized as being either mildly saline (TDS = 1,000 to 3,000 mg/L), moderately saline (TDS = 3,000 to 10,000 mg/L), very saline (TDS = 10,000 to 35,000 mg/L), or briny (TDS > 35,000 mg/L) (McCutcheon et al. 1993). These TDS concentrations are larger than the TDS levels commonly reported for river water (500 to 1,000 mg/L), which is referred to as freshwater in this report.

Salinity data collected from ground water in alluvium on both sides of the river show that TDS concentrations in both areas are in a wide range, from as low as 700 mg/L to greater than 110,000 mg/L (DOE 2003d, Gardner and Solomon 2003, DOE 2006a, DOE 2007a).

Brine waters dominate the deepest parts of the alluvium and are attributed to chemical dissolution of the underlying Paradox Formation, a large and relatively deep evaporite unit that has been deformed to create a salt-cored anticline aligned with and underlying the Moab Valley (Doelling et al. 2002). On the west side of the river (i.e., at the Moab Site), moderately saline and very saline waters result mostly from the mixing of southeastward-moving shallow ground water with the deeper brine. However, some of the highly saline ground water close to the river is also attributed to historical seepage of high-TDS fluids from the base of the Moab tailings pile located to the west, which occurred mostly during and immediately after the years of milling operations at the Moab Site (DOE 2003d). The observed general spatial variations in salinity observed at the site today reflect both historical density-dependent flow processes, which probably varied substantially over time during mill operation years, and relatively steady density-affected processes in recent years. These flow processes cause currently observed TDS concentrations to increase with depth in the vicinity of the Ground Water IA (DOE 2006a).

As previously reported (DOE 2006a) the Colorado River reach within Moab Valley appears to be typical of a gaining watercourse, and ground water discharge to the river shows a tendency to occur mostly within relatively narrow bands on either side of the river. The occurrence of highly saline water in shallow ground water near the river along both its west and east shores appears to result from concentrated discharge over relatively small portions of the river's full width (DOE 2006a).

Analyses of salinity in ground water under the Moab Site (DOE 2003d) indicate that the brine surface is deepest in the western portion of the site and becomes shallower in the direction of the river. Data collected to the south and east of the river indicate a similar pattern in that depth to brine is greatest in wells located some distance from the river and much smaller near the river's east bank (DOE 2003d, DOE 2007a). Such observations, when combined with studies showing the river acting as a site of regional ground water discharge, suggest that the larger TDS concentrations in shallow ground water at the river result from saltwater upconing (e.g., McElwee 1985), with the river acting much like a well that induces the upward migration of brine when it is pumped (Domenico and Schwartz 1998). Assessments of IA Configurations 1 and 2 indicate that, under non-pumping conditions, brine is usually found in these areas at about 25 to 40 ft bgs (DOE 2004a, DOE 2005b, DOE 2005d, DOE 2006a), and extrapolation of the brine surface in these areas shows it intersecting the river close to its west bank (Figure 3–1). The Configuration 4 wells that were installed in 2006 show similar conditions, but with the brine surface at slightly shallower depths than Configurations 1 or 2.

Because of the large range of TDS concentrations on both sides of the river, ground water flow from both the Moab Site and its mirror image, Matheson Wetlands Preserve, is density-dependent. The density-dependent hydraulics associated with this flow system are similar to those presented by Konikow et al. (1997) as part of a study of deep-circulating ground water passing over a buried salt source, such as sedimentary rock containing evaporate deposits, followed by upward water migration and discharge to the ground surface. Such a system is associated with ground water velocities that decrease with depth below the ground water surface, and velocities below the brine surface are extremely low (e.g., Konikow et al. 1999). These hydraulic phenomena in turn cause flow convergence near the river's bank, and the presence of very slow-moving brine just below the river. (Figure 3–1) represents an additional obstacle to ground water flow from one river bank to another (DOE 2006a, DOE 2007a).

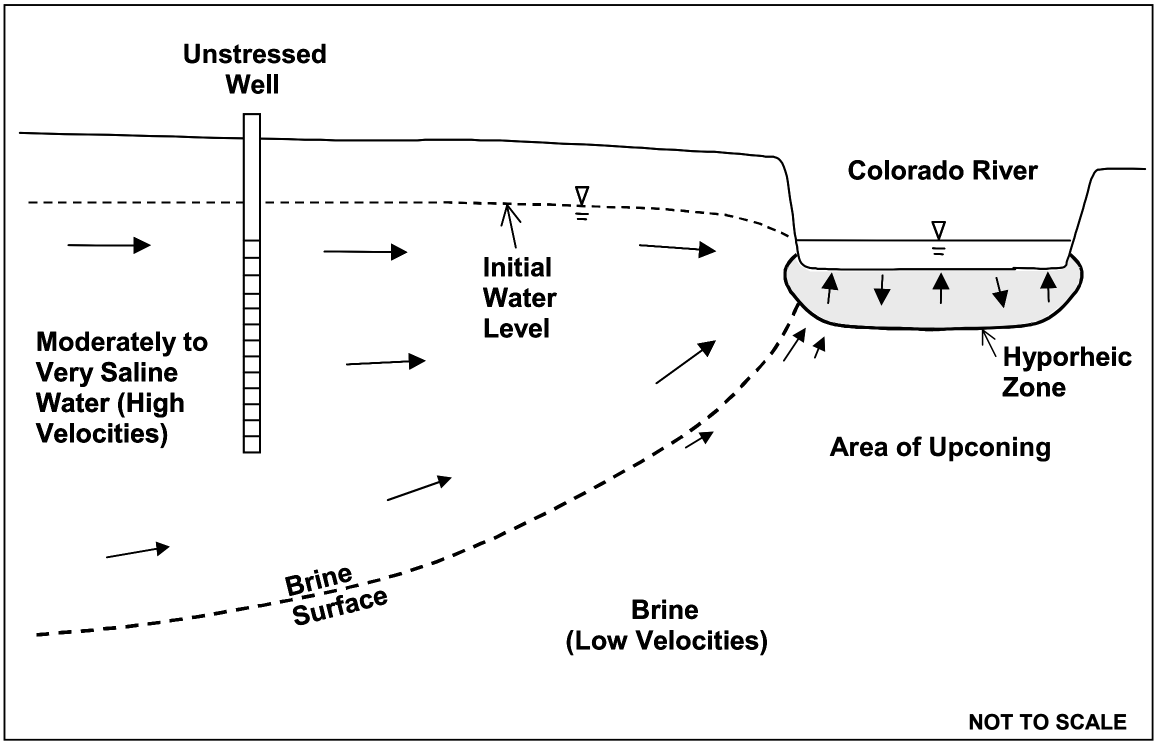

Figure 3–1. Conceptualization of Ground Water Flow Near the Colorado River Under Non-Pumping Conditions

3.3 Processes Affecting Ground Water Salinity

The preceding performance assessment (DOE 2006a) mentioned processes and phenomena that can affect ground water salinity. There are influences from the hydrogeology and the actual salinity source (natural versus man-made historical site usage). Descriptions of the influences from the preceding report (DOE 2006a) are repeated and updated in the two sections below.

3.3.1 Hydrogeologic Influences

As discussed later in Section 3.4.1, changing water level in the river varies with runoff conditions will affect ground water salinity. The resulting fluctuations in the distribution of brine can be relatively smooth or rather abrupt, depending on the rate with which surface water levels are affected. However, even during periods of relatively stable river flow, which can last for several months, at least three different hydrogeologic factors other than proximity to the river can potentially influence spatial variations in depth to brine.

One of the hydrogeologic influences on brine surface elevation is the volumetric rate of flow toward the river. Along those portions of the river where such flows tend to be relatively large, density-affected ground water hydraulics at the site indicate that the brine will be found at a greater depth than at another location where the flow is less. In contrast, areas where flow to the river is minimal, the brine should be observed at the water table since there is no fresh water available to suppress it. In past years, brine exhibiting TDS concentrations approaching

100,000 mg/L have been observed in near-river shallow wells located south of the site's south boundary, suggesting that ground water discharges to the river in this area are very small (DOE 2006a).

Because most of the brine in site ground water is attributed to dissolution of Paradox Formation sediments the depth at which the dissolution first occurs is another hydrogeologic factor that affects depth to brine near the Colorado River. This is illustrated with a cross-sectional depiction of the conceptual model of ground water flow (Figure 3–2) that has been adopted for the Moab Site (DOE 2003d). With this model, depth to brine along a steep bedrock wall found below the western portion of the site depends on the depth at which downwelling freshwater first encounters the Paradox Formation: the deeper the contact between Paradox and overlying sediments, the deeper the brine surface is in the western portion of the site (DOE 2006a). Though the manifestations of this phenomena become less obvious with proximity to the river, it can play a role in determining salinity distribution near the river.

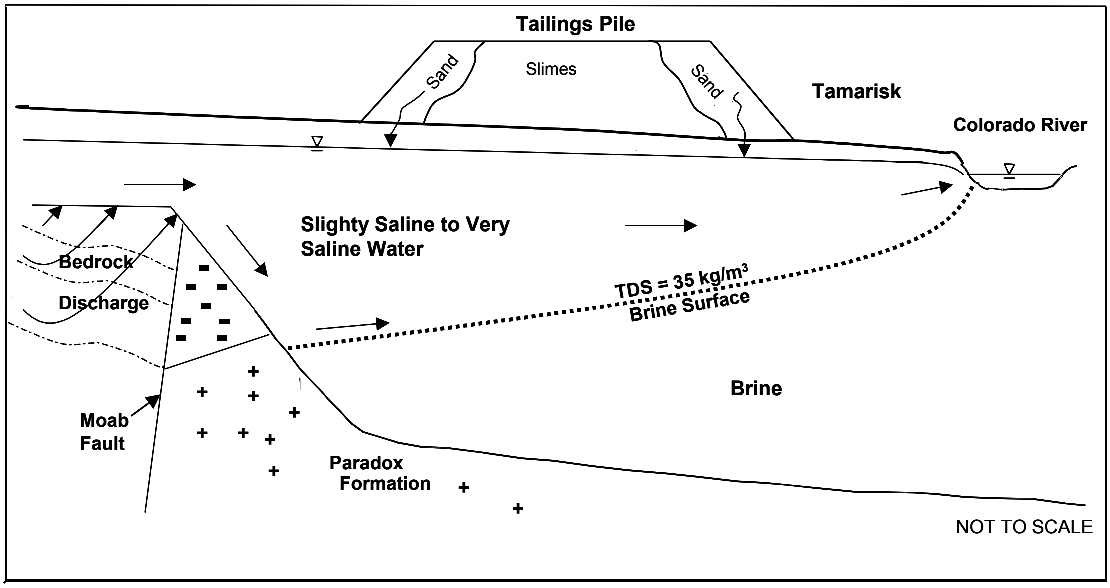

Figure 3–2. Conceptualization of Ground Water Flow at the Moab Site

As reported (DOE 2003d), drilling at the Moab Site and near the river has indicated the depth, locally, to the Paradox Formation is at least 400 ft bgs, but is still unknown. Doelling et al. (2002) discuss this observation and use borehole logs from other wells in the valley, beginning near the eastern boundary of the Matheson Wetlands, to show that the depth to the Paradox Formation is greatest near the Colorado River but decreases with distance to the southeast. Based on this information, the conceptual model shown in Figure 3–2 was expanded (DOE 2007a) to illustrate how density-dependent ground water flow occurs on both sides of the river, as shown in Figure 3–3. With this updated conceptualization, both the total distance and depth over which dissolution of Paradox Formation sediments occurs south and east of the river can be quite different from what occurs on the west side at the river. As a result, the profile of the brine surface in the vicinity of the river can be asymmetric (DOE 2007a).

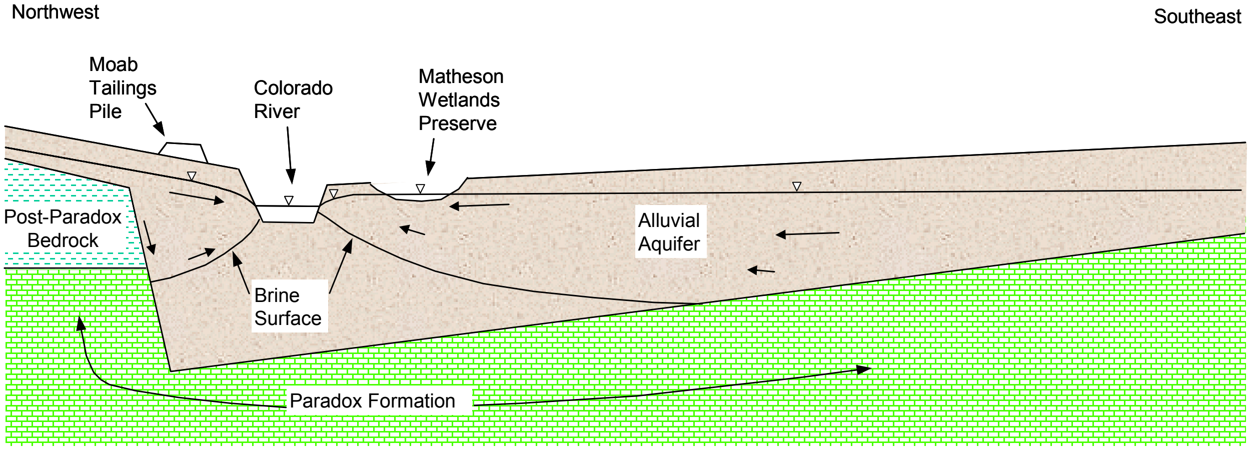

Figure 3–3. Conceptual Model of Density-Dependent Flow on Both Sides of the Colorado River (based partly on Figure 6 in Doelling et al. [2002])

A third hydrogeologic factor that potentially affects brine surface elevation is related to sedimentation processes that occur near the river's west bank. During years in which high ammonia concentrations have been detected in surface water, they have typically been found in river side channels (backwaters) that are separated from the main river channel and are located close to a steep bank that separates the riverbed from the floodplain on which the Moab Site sits (Figure 3–4a). These occurrences indicate that the contaminated ground water discharging to the river tends to converge on the side channels rather than migrating to the main channel where surface water flows tend to be larger. However, because the river processes that helped create the backwaters vary over time, some side channels near the river's west bank have eventually filled in with sediment, and ground water has been forced to migrate farther east to discharge to the river's main channel (Figure 3–4b). Under these circumstances, the brine surface also migrates farther to the east and the depth to brine near the steep bank increases. Such riverbed infilling appears to have occurred over the past several years adjacent to the Baseline Area and Configuration 3. If depths to the brine surface in these areas deepened as a result of sedimentation processes, the changes could be technically attributed to increases in distance from the river (i.e., proximity to the river). Nonetheless, this phenomenon is singled out because of a tendency for site stakeholders to treat the steep bank along the eastern edge of the floodplain as the river's western extent (DOE 2006a). Assessment of both salinity and ammonia data from riverbed piezometers from late 2006 (DOE 2007b) indicates that the freshwater/brine interface has migrated farther towards the main river channel in the Configuration 3 area as compared to locations where sediment infilling has not eliminated river side channels.

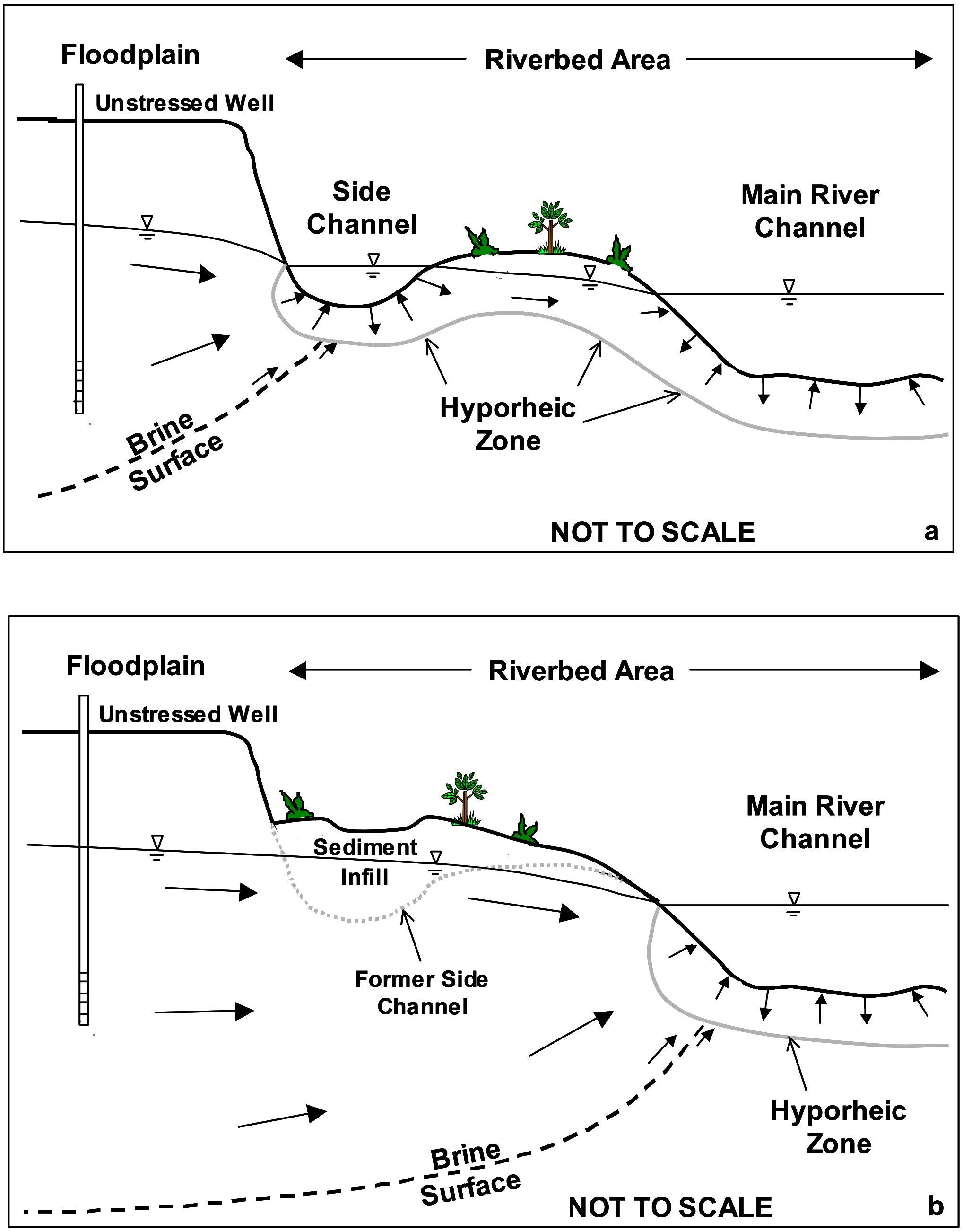

Figure 3–4. Conceptualization of Brine Surface Behavior in Response to River Sedimentation: (a) Before Sedimentation and (b) After Sedimentation

3.3.2 Salinity Sources

Similar to an approach used by others (Gardner and Solomon 2003) to identify flow processes in the Moab Valley, analyses of ground water chemistry have been conducted by DOE (2006a) to characterize the movement of subsurface water at the Moab Site. Some of the methods used have been based on geochemical fingerprinting techniques that help distinguish saline water derived solely via dissolution of Paradox Formation sediments from other salinity sources (DOE 2006a, DOE 2007a). One type of fingerprinting that has proved useful and is easy to apply is based on the ratio of simultaneously measured concentrations of dissolved chloride (Cl) and bromide (Br). These ions are highly soluble and conservative (i.e., non-reactive) and can, therefore, be applied to study dissolution of salts and the mixing of waters from different sources (Hem 1985, Davis et al. 1998). Of the two ions, Br is more soluble.

The chloride/bromide (Cl/Br) ratio is sensitive to mineral and chemical sources or provenance. It tends to be low in most natural systems like seawater (0290), meteoric water (50−180), organic materials (20−200), and water circulating through igneous and metamorphic rocks (100−500) (Davis et al. 1998). Higher Cl/Br ratios are often associated with anthropogenic sources (e.g., road salt, sewage, industrial chemicals or waste, agriculture processes). However, some of the highest ratios are attributed to the natural dissolution of evaporite minerals, such as halite (sodium chloride). Cl/Br ratios between 1,000 and 10,000 are relatively common in ground water that has come in contact with halite (Davis et al. 1998). Some of the largest ratios tend to be observed near the downstream end of alluvial basins that rivers pass through (Phillips et al. 2002), where bedrock highs, such as that occurring in the Moab Valley at the Portal, force deep ground water to the surface (DOE 2007a).

The very high Cl/Br ratios associated with evaporite bedrock result from the differential solubility between Br and Cl. When briny water evaporates, halite precipitates first and the more soluble Br tends to remain in solution. Thus, if fresher waters of different origin subsequently contact halite-containing rocks millions of years after their origin, dissolution of the rock produces higher Cl/Br ratios. The ratios can become increasingly larger if the rock is subjected to multiple cycles of evaporation followed by dissolution (Davis et al. 1998).

Another likely source of bromide at the Moab Site was the tailings leachate that contributed to ground water during and immediately after the years that milling occurred. Though the relative quantities of chloride and bromide in the leachate at the time were unknown, Cl/Br ratios in water samples collected during the last few months of 2005 showed that the shallow brine south of the Moab Site maintained ratios around 3,000 and higher (DOE 2006a). In contrast, shallow ground water near the river and downgradient of the tailings pile typically exhibited ratios on the order of 300 to 1,000. These significantly different results indicated that the shallow briny waters south of the site were derived solely from dissolution of Paradox Formation sediments, whereas shallow ground water farther to the north comprised a mixture of waters with origins including dissolution of shallower sandstone sediments, tailings seepage, and possibly some local recharge from precipitation (DOE 2007a).

3.4 River-Aquifer Relationships

As described in the previous performance assessment report (DOE 2006a), there are three influences on the river-aquifer relationship. These include a simple response to changes in the river stage, hyporheic zone mixing, and biogeochemical processes in the hyporheic zone.

3.4.1 Hydraulic Responses to Changes in River Stage

Previous investigations have shown that surface water flow in the Colorado River can strongly affect ground water elevations in the alluvial aquifer at the Moab Site (DOE 2003d). In particular, as river flow increases, causing the river's water surface to rise, ground water levels in the aquifer also increase. Conversely, hydraulic heads in the alluvial aquifer decrease with decreasing river flows. A lag time on the order of as much as a day is typically observed between river rise and increases in ground water levels in wells located hundreds of feet from the river. However, the response time of ground water close to the river is relatively short, making it likely that river effects on water levels in the Ground Water IA wells would be observed within periods of a few to tens of minutes.

Changes in river surface elevation also affect the elevation of the brine surface in ground water west of the river (DOE 2003d). Salinity data collected in wells between 2001 and 2004 indicated that the brine surface elevation generally increased during periods of peak flow in the river (typically in the spring) and subsequently declined upon passage of high runoff conditions. Consequently, the most notable effect that an increase in river level had on aquifer chemistry in each affected well during those years was an increase in the average TDS concentration within the screened interval of the well. Though an opposite relationship between river stage and brine surface elevation was occasionally observed for periods of a few to several days in wells located within 50 to 100 ft of the river (DOE 2003d), wells located farther from the river did clearly increase in salinity when the river reached peak flow conditions. Such observations suggested that, as the water table increases with increasing river stage, the vertical thickness of the water located above the brine surface essentially remains constant so that the net flow of ground water to the river is also constant (DOE 2006a).

The above-mentioned increases in brine surface elevation in response to high spring runoff during the 2001−2004 period appear to be largely the consequence of the relatively low peak river flows that were observed in each of those years. This period was dominated by drought conditions in the southwest U.S., and flows in the river tended to reflect the pervasive dryness. In contrast, 2005 was considered a wet year and the brine surface at moderate distances from the river did not respond to changes in river flow as predictably as observed in the previous 4 years. This was attributed to the rapid rise in river stage during the peak.

The year 2006 again had peak flows that were less than normal. A notable occurrence in 2006 was the presence of a second significant peak flow event in early October that was a result of several days of heavy rain. That peak flow, which resulted in a mean daily flow of 17,400 cubic feet per second (cfs) (the actual peak flow measured was 21,100 cfs on October 7), was nearly equal to the mean daily spring peak flow of 21,400 cfs. However, the fall peak occurred over a period of little more than a day, whereas the spring peak was over a period of approximately 90 days. A noticeable effect of the high runoff in October 2006 was a distinctive decrease in constituent concentrations in shallow ground water located close to the river. These concentration decreases, which were attributed to significant water losses from the river to the subsurface in the form of bank storage, persisted for a few months. Similar constituent decreases in ground water near and at moderate distances from the river were observed during 2005 (DOE 2006a) following the spring runoff peak that year.

3.4.2 Hyporheic Zone Mixing

Other than occasions when the river temporarily recharges the alluvial aquifer in the form of bank storage, the observed relationships between river level and ground water elevation do not reflect significant changes in ambient flow direction. That is, on-site ground water generally continues to migrate eastward toward the river, even during spells of high river flow despite the concomitant increase in ground water levels. However, changes in river level can theoretically alter flow exchanges between the hyporheic zone and the river. Previous analyses of the potential for vertical flow components in the hyporheic zone (DOE 2005b) using techniques that take into account salinity-affected water density (Jorgensen et al. 1982) suggest that flow is upward to the river in some locations and downward from the river to ground water in others. Because spatially and temporally variable river scour and sedimentation and associated changes in riverbed morphometry can affect where these upward and downward flows occur, it is logical to assume that changes in river flow alter the exchange of river and hyporheic zone waters (DOE 2006a).

Mixing of river water with ambient ground water in the hyporheic zone is expected. Much of this mixing is attributed to mechanical dispersion, which is enhanced when the sediments comprising the hyporheic zone are quite heterogeneous. However, it is also likely that dispersive processes and the resulting mixing of waters is further promoted by the tendency of areas of hyporheic zone influx and outflux to vary temporally as well as spatially. To some extent, it is this mixing of waters of different origin that facilitates the various biogeochemical processes that can cause attenuation of contaminant concentrations prior to their discharge to surface water (DOE 2006a).

3.4.3 Biogeochemical Processes in the Hyporheic Zone

Many different types of biogeochemical processes can occur in the hyporheic zone (Dahm et al. 1998). The DO and dissolved inorganic carbon (DIC) (i.e., carbon dioxide [CO_2]) contained in surface water entering the zone is theoretically available to support nitrification, in which microorganisms referred to as nitrifiers oxidize dissolved ammonia and ultimately produce dissolved nitrate (NO_3) (EPA 1993). Nitrification is an autotrophic process since the carbon source upon which it depends is inorganic. The alkalinity of ground water, reported in units such as mg/L of calcium carbonate ($CaCO_3$), provides an approximate measure of the amount of DIC available for nitrification. In zones of nitrification, alkalinity (and DIC) decreases due to the consumption of CO_2 (EPA 1993). Nitrite (NO_2) is an intermediate product of the nitrification process and can occasionally be used to help identify the biotransformation of ammonia.

It is also common for many chemical reactions in the hyporheic zone to be mediated by heterotrophic bacteria (Dahm et al. 1998, Duff and Triska 2000). Heterotrophic microbes are distinguished from autotrophs by their use of dissolved organic carbon (DOC) as a substrate for growth. The most energetically favorable electron acceptor for heterotrophic activity is oxygen, which is used by a class of bacteria called aerobes. If the oxygen supply is depleted by aerobes, another type of heterotrophic metabolism called denitrification becomes possible. During denitrification, microbes synthesize DOC using nitrate (NO_3) as the preferred electron acceptor, ultimately producing nitrogen gas (N_2). As with autotrophic nitrification, denitrification generates NO_2 as an intermediate product that can sometimes be detected in ground water at significant levels. In contrast to nitrification, denitrification causes an increase in alkalinity (and DIC) (EPA 1993).

Upon depletion of available oxygen and nitrate, other types of heterotrophs can utilize solid-phase manganese, solid-phase iron, and dissolved sulfate as electron acceptors. This latter sequence of bacterial respiration forms has the potential to create more chemically reducing zones in the hyporheic zone. With such a change in redox status, some dissolved metals such as uranium can become less mobile and exhibit lower concentrations than would occur under more chemically oxidizing conditions.

A predictable sequence of heterotrophic activity can be envisioned along a flow path in the hyporheic zone (Figure 3–5). In upgradient portions of the path, DO supports aerobic metabolism and the associated consumption of DOC in the inflowing river water. As the supplies of oxygen are depleted, nitrate becomes the most thermodynamically favorable electron acceptor, which facilitates its conversion into NO_2 and dissolved nitrogen gas by denitrifying microbes. If nitrate is consequently depleted while some organic carbon remains, the populations of other types of bacteria, starting with manganese-reducers and sequencing through iron-reducers, sulfate-reducers and methanogens (Figure 3–5), could also grow from the consumption of organic carbon substrate at locations farther along the flow path (Dahm et al. 2000).

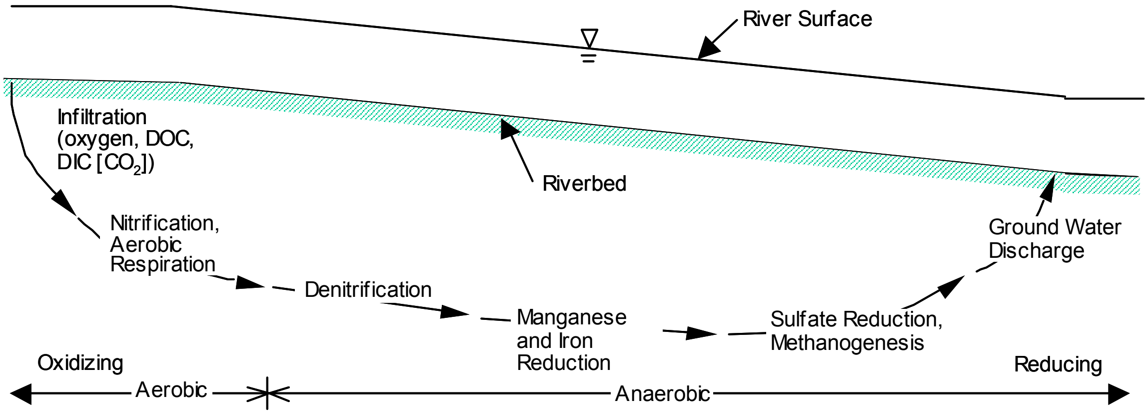

Figure 3–5. Microbially Mediated Processes in the Hyporheic Zone

Oxidation-reduction potential (ORP) is sometimes used as a relative indicator of the above-mentioned biogeochemical sequence associated with heterotrophic respiration. Typically, ORP values of +100 to +200 millivolts (mV) are observed in areas of aerobic and nitrate-reducing activity. Gradually decreasing ORP values are subsequently seen in areas of manganese-reducing and iron-reducing activity, and negative ORP values may be associated with microbially mediated sulfate reduction. Dissolved methane may be generated (methanogenesis) in areas where ORP values as low as –200 to –300 mV are observed. Previous evaluations of the Ground Water IA (DOE 2005b, DOE 2006a) have revealed that ORP in the hyporheic zone underlying the Colorado River is wide-ranging, with values as low as –200 mV being observed almost as frequently as values approaching +100 to +200 mV. Thus it appears that several different types of bacterial metabolism, including nitrification and denitrification, can potentially occur locally beneath the river.

Measures of Bacterial Activity

As part of the Fall 2005 Performance Evaluation (DOE 2006a), a screening method was used to assess the possible occurrence of nitrifying bacteria (nitrifiers) in IA wells and riverbed piezometers. The technique used is one of series of a Biological Activity Response Tests (BART™) that are distributed by Droycon Bioconcepts, Inc. to identify the presence of different classes of microbes. In addition to identifying general bacteria types, these tests provide relatively simple approaches to providing "order-of-magnitude" estimates of bacterial quantities. As a consequence, the tests are more qualitative than quantitative, but are nevertheless useful for identifying relative quantities of microbial activity for specific bacterial groups (Canadian Association of Petroleum Producers 2002).

The test used to detect nitrifiers in ground water during the Fall 2005 Performance Evaluation (DOE 2006a) is referred to as N-BART™. Application of the technique to water samples collected during October and December of 2005 indicated that nitrifying bacteria were present, in some cases at significant levels, in wells at the Baseline Area, Configuration 1, and Configuration 3, and in riverbed piezometers at the Baseline Area and Configuration 3. However, the N-BART™ results indicated that few, if any, nitrifiers were present at riverbed piezometers associated with Configuration 1. Though the reason for this apparent lack of nitrifying activity in the hyporheic zone at Configuration 1 was unclear, it was likely related to strong mixing of river water with hyporheic water beneath and adjacent to the river side channel in this area, something that was not occurring at the Baseline Area and Configuration 3 in fall 2005 because of sedimentation infilling of any side channels that may have previously occurred in these areas. Despite the paucity of evidence for nitrification at Configuration 1 piezometers, N-BART™ results at all other wells and well nest locations did suggest that ammonia in local ground water is converted to nitrate, which may in turn be subject to biodegradation downgradient in the hyporheic zone where mixing of river water and ground water produces an environment conducive to heterotrophic respiration.

The benefits of detecting nitrifying microbes in late 2005 prompted the use of three additional methods for identifying bacterial types in water samples collected during 2006 and early 2007. DNB-BART™ has been used to identify the presence of denitrifying bacteria, and SRB-BART™ the occurrence of sulfate-reducing bacteria. One additional screening test applied during the past several months, IRB-BART™, is capable of detecting iron-related bacteria, but does not provide a distinct method for distinguishing iron-reducing activity from iron-oxidizing activity.

Anaerobic Oxidation of Ammonia

In late summer 2006, a microcosm study was conducted by Colorado School of Mines personnel to further investigate the types of biogeochemical reactions that potentially occur in Moab Site ground water, particularly in the hyporheic zone underlying the Colorado River (Landkamer and Figueroa 2006, Landkamer et al. 2007). Six different microcosms were examined, with each consisting of a mixture of sediment collected from the riverbed, ground water extracted from well 0480, and river water. The six sets of experimental conditions established in the sediment microcosms comprised three different water mixtures under both anaerobic and aerobic conditions. The ground water and river water mixtures used were (1) 100% ground water, (2) 50% ground water, and (3) 10% ground water, with river water making up the balance of the water mixture. Over the course of 39 days of incubation, total nitrogen and ammonia concentrations decreased dramatically in all microcosms. However, the presence of oxygen accelerated the biological transformation of the nitrogen species and the relative amounts of ground water and river water in the microcosms affected nitrogen removal.

The nitrogen/ammonia removal in the microcosms was found to likely be the result of microbial nitrification, denitrification, and another microbially mediated reaction known as anammox (e.g., Ahn 2006). Anammox is an autotrophic process where bacteria use ammonia as an electron donor and nitrite (NO_2) as an electron acceptor and produce nitrogen gas and a smaller amount of nitrate. Though the exact stoichiometry of anammox is uncertain, the following reaction has been proposed (Ahn 2006).

$$1\ NH_4^+ + 1.32\ NO_2^- + 0.066\ HCO_3^- + 0.13\ H^+ \Rightarrow 1.02\ N_2 + 0.26\ NO_3^- + 0.066\ CH_2O_{0.5}N_{0.15} + 2.03\ H_2O \quad \textbf{(1)}$$

As can be seen from this equation, the reaction requires a substantial amount of NO_2, which may be available as an intermediate product of either nitrification or denitrification, or both. The consumption of hydrogen ions during anammox indicates that pH can increase as a result. A type of bacteria known as *planctomycetes* facilitates the process.

Anammox is described as "anaerobic ammonia oxidation," which sets it apart from nitrification, a process characteristically limited to aerobic environments. However, Landkamer and Figueroa (2006) indicated that anammox also occurred in the Moab riverbed microcosms under aerobic conditions. As a result, they suggested that all three nitrogen removal mechanisms—nitrification, denitrification, and anammox – occur in the hyporheic zone of the Colorado River, where both aerobic and anaerobic conditions tend to be observed. As described in the Fall 2005 Performance Evaluation (DOE 2006a) and subsequently in Chapter 8 of this report, parameters reflective of biogeochemical conditions in the hyporheic zone are highly variable. Such chemical variability probably makes all three of the bacterially mediated nitrogen removal processes possible, not to mention several other biogeochemical phenomena that affect constituent concentrations for ground water discharging to the river.

3.5 Effects of Pumping (and Injecting) on Ground Water

3.5.1 Hydrodynamics of Ground Water Extraction

Upconing of very saline and briny ground water has typically been observed at the Moab Site in response to ground water pumping (e.g., DOE 2002), and a previous report on the performance of ground water extraction (DOE 2005b) examined the degree to which upconing near the river could result from Ground Water IA operations. The total depths of most Configuration 1 extraction wells were purposefully limited to about 21 ft bgs (Section 4.2) with the intent of minimizing induced inflow of brine found near depths of 30 to 35 ft bgs. The total depths of Configuration 2 wells alternated between 30 and 45 ft bgs (Section 4.3), with the even-numbered wells being the shallow wells. The total depths of Configuration 3 extraction wells (Section 4.4) are considerably larger (~ 45 ft bgs) and those in Configuration 4, installed in May and June 2006, are approximately 35 ft bgs. Most of the Configuration 4 wells intercept ground water containing TDS levels less than 25,000 mg/L, but at times in 2006 TDS concentrations up to 36,000 mg/L have been observed at the extraction system. In general, induced inflow of brine to the Ground Water IA system was relatively minor.

The flow conditions created by pumping from the well field, including upconing, are shown conceptually in cross-sectional form in Figure 3–6. As this figure indicates, the ground water withdrawn through extraction wells comes not only from upgradient sources but also from the river, where pumping has induced infiltration of surface water. Hydraulic analysis of ground water response during a previous evaluation of ground water extraction (DOE 2005b) determined that the time required for induced flow of water from the river to be initiated is relatively small, perhaps on the order of a few minutes. In addition, the amount of time needed to reach a state of relative equilibrium, wherein ambient ground water levels appears to stabilize and the combined rate of volumetric flow from upgradient ground water and the river equals the total pumping rate at the well field, is also relatively short. Though this apparent equilibrium implies that the flow field reaches a steady state shortly after the start of pumping, true steady-state conditions are unlikely to be achieved until several months of pumping have elapsed. This latter observation is attributed to the fact it can take as long as 100 days or more for river water entering the aquifer at the river bank to migrate to the extraction wells (DOE 2005b). During this interim phase, TDS concentrations in ground water downgradient of the well field constantly change, thus leading to a continually evolving density-dependent flow field. The transport of river water in the subsurface in response to pumping-induced infiltration of surface water is of interest, not only because of the potential effects it has on contaminant levels in river side channels, but also with regard to biogeochemical activity that might occur along flow paths between the river and the well field (DOE 2006a).

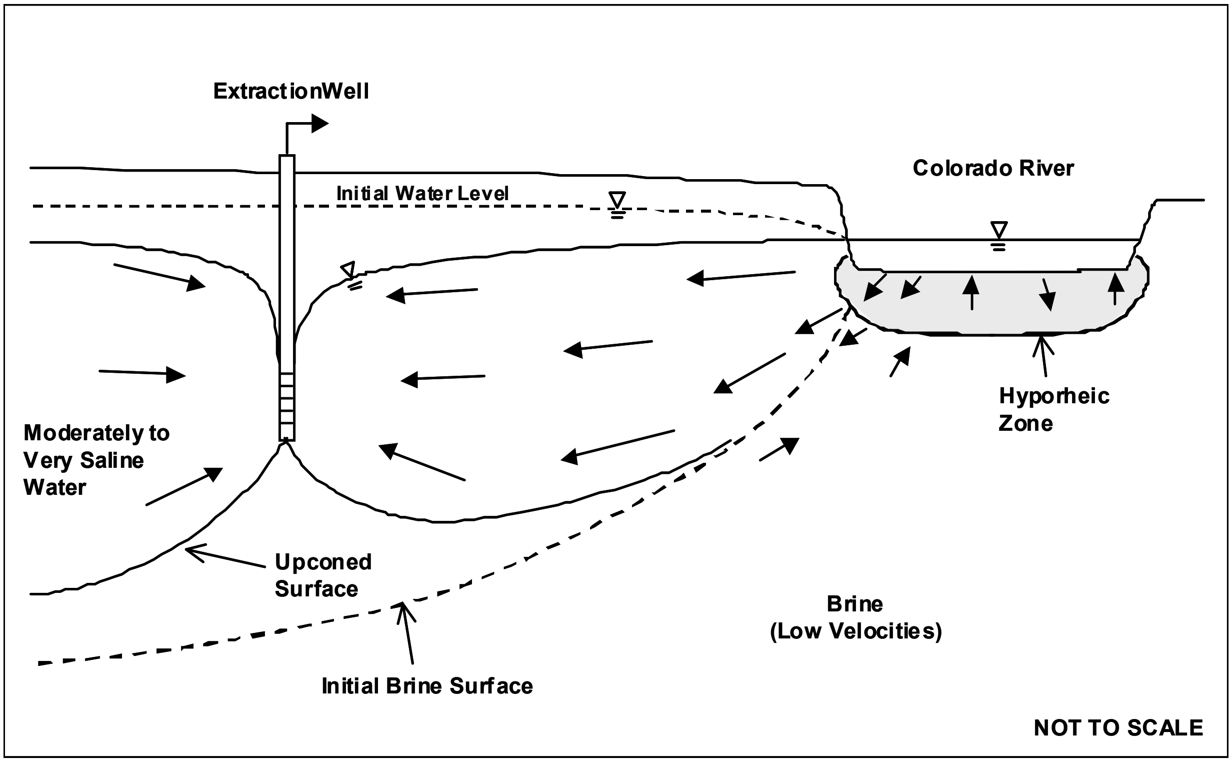

Figure 3–6. Conceptual Model of the Flow Field Resulting from Ground Water Extraction Near the River

It is hypothesized that ground water pumping at IA wells leads to attenuation of contaminant concentrations in river side channels because the infiltration of surface water in response to the pumping replaces the ground water discharge processes that would normally occur under ambient flow conditions. In order for this attenuation to be fully successful, the rate of pumping should be sufficiently large to eliminate virtually all ground water discharge to backwater side channels (DOE 2006a).

3.5.2 Hydrodynamics of Freshwater Injection

General flow conditions induced by freshwater injection in a shallow well are shown the cross-sectional view shown as Figure 3–7. As a result of the injection, a small amount of mounding of the ground water surface occurs in the area surrounding each well. The injection also tends to depress the brine surface in a process that is the opposite of saltwater upconing. Because the river water injected into each well (i.e., Configuration 2) flows radially through the well screen, freshwater enters the aquifer in an upgradient direction as well as laterally toward other injection wells and downgradient toward the river. Because the injected water tends to create a hydraulic barrier, shallow, eastward-moving ground water near the centerline of the configuration is diverted downward and below the injection wells before continuing its migration toward the river (Figure 3–7). As a result of this flow diversion, much of the shallow contaminated ground water that would normally discharge directly to the river's west edge under ambient conditions now discharges farther toward the river center. Some of the eastward-flowing ground water upgradient of the injection wells is also diverted laterally around the north and south ends of the well field (DOE 2005c).

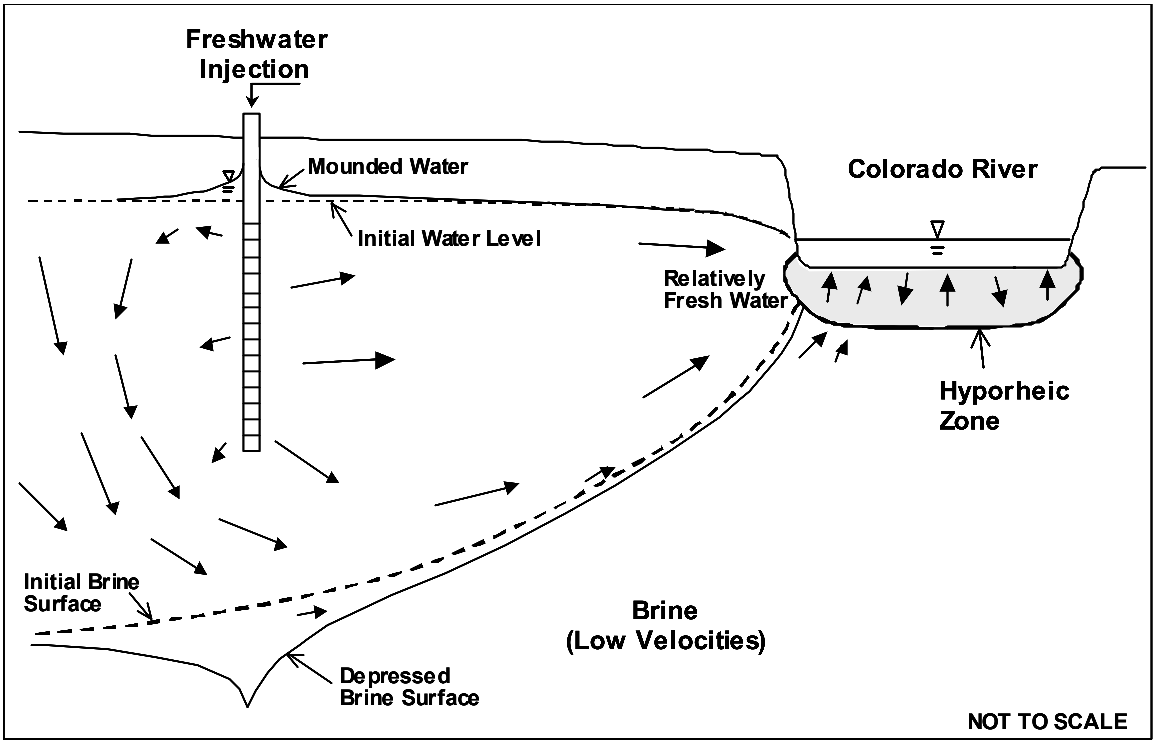

Figure 3–7. Conceptual Model of the Configuration 2 Flow Field Resulting from Freshwater Injection in a Shallow Well

Ground water was injected into Configuration 2 wells from January to mid-March 2006. These wells were then converted to extraction mode due to demolition of the old river water storage pond and construction activities for a new freshwater storage pond. The infiltration trench was installed in August 2006 and made operational by the end of September. Injection into the trench was halted for the winter in early December. The trench, which contained a 4-inch perforated PVC pipe, was installed at a depth of 10 ft bgs. This depth encountered the coarser sands that overlie the sandy gravels and gravelly sands typically found in boreholes throughout the well field area. It is anticipated that the diverted river water placed in the infiltration trench will behave similarly to the water placed in shallow injection wells. The total volume of and rate of infiltration at the trench were much greater than those at Configuration 2 wells, resulting in some mounding of the ground water surface. It is surmised that the resultant flow downward and laterally away from the trench creates a hydraulic barrier, which, in turn, causes shallow, eastward-moving ground water to be diverted downward and below the trench before continuing its migration toward the river. And, as noted above, much of the shallow contaminated ground water is discharged farther to the east and beneath the river. Riverbed piezometers were installed in fall 2006 downgradient of the trench and will be used in 2007 to monitor the effects of trench infiltration on water chemistry.

3.5.3 Pumping Induced Biogeochemical Activity

Induced inflow of river water toward extraction wells has the capacity to reduce concentrations of dissolved ground water contaminants via both dilution and chemical processes. Chemically driven attenuation of contaminant concentrations, if occurring, is largely driven by the introduction of constituents found in river water and the hyporheic zone at moderate to high levels into site ground water. For example, conversion of ammonia to nitrate via nitrification might be enhanced if pumping initiates influx of significant amounts of DO, CO_2, and nitrifying bacteria.

The relatively large levels of oxygen in river and hyporheic zone water that are drawn toward active extraction wells are likely to be progressively reduced with increased travel distance (e.g., Tufenkji et al. 2002). If the DO is effectively depleted at some point between the river and extraction wells, anaerobic heterotrophic respiration can be initiated, particularly if DOC and nutrients drawn from the river are maintained at levels capable of supporting heterotrophic activity. This in turn signifies that denitrification can succeed aerobic metabolism, and possibly lead to enzymatically driven manganese reduction (Tufenkji et al. 2002), and perhaps even iron and sulfate reduction if more chemically reducing conditions are created.

3.5.4 Injection-Induced Biogeochemical Activity

Freshwater injection has the capacity to not only dilute the concentrations of dissolved ground water constituents via hydrodynamic mechanisms, but also to induce changes in concentration as a result of chemical processes. Such chemical phenomena are largely driven by the introduction of oxygenated river water into the subsurface. Delivery of oxygenated water to ground water, such as at Configuration 2 or the infiltration trench, might increase the mobility of dissolved constituents like uranium and selenium. However, such increased mobility may not result in increased concentrations of these constituents if mixing of the injected water with the ground water leads to significant dilution (DOE 2005c).

Another mechanism possibly affected by the introduction of river water in the subsurface is a change in the sorption capacity of dissolved ammonia. The ability of this constituent to sorb to subsurface media tends to be variable and is strongly affected by local geochemical conditions (Duff and Triska 2000). Previous assessments of ammonia transport in ground water at the Moab Site (DOE 2003d) indicated that ammonia sorption is relatively minor under backwater flow conditions (DOE 2005c).

3.6 Surface Irrigation West of the Ground Water IA

The chemistry of ground water downgradient of the Moab tailings pile and near the Colorado River is potentially affected by surface irrigation of native vegetation test plots that have been constructed anywhere from 50 to 150 ft upgradient of the edge of the flood plain. Monthly irrigation deliveries to the plots (C3, C4, C5, C6, and Tree Area in Figure 4–1, Figure 4–2, and Figure 4–3) began in spring 2005, continued through the 2005 growing season (to September 2005), and recommenced in spring 2006. The locations of these test plots make it possible that water applied to them can not only influence the chemistry of shallow ground water upgradient of IA extraction wells, but also the chemistry of ground water in the vicinity of the injection trench and the Baseline Monitoring Area. The current source of the irrigation water is a pond located north of Moab Wash that is fed by uncontaminated surface water diverted from the river.

Unsaturated zone salinity data collected in the vicinity of the vegetated plots during the 2005 irrigation season suggested that recharge of local ground water occurs as a result of the irrigation. In addition, estimates of average linear ground water velocity in the alluvial aquifer and chemical data collected in wells downgradient of the test plots (but upgradient of extraction wells) indicate that irrigation water seeping to the water table during spring months migrates as far east as the extraction well fields over succeeding summer months. This source of freshwater recharge shows a potential to not only dilute ground water near the water table but also to induce or enhance biogeochemical processes locally. Partly because data regarding the volumes of irrigation water delivered to the vegetated plots during the growing season are not available, it is difficult to quantify the degree to which irrigation-related recharge contributes to the attenuation of dissolved constituent concentrations in ground water. However, chemical data and BART™ results from sampling events over the past few years do provide evidence that irrigation water has the capacity to enhance several biodegradation processes, including those associated with nitrification, anammox, denitrification, iron and manganese reduction, and sulfate reduction.

It should be mentioned that recharge of irrigation water on the vegetation test plots has the potential to increase the levels of some ground water constituents rather than reducing their concentrations. Such increases are considered possible for solid-phase metals that tend to dissolve more readily in ground water when contacted by oxygenated water. An example of such a metal is uranium (Anderson and Lovley 2002). During the Fall 2005 Performance Evaluation and this most recent evaluation, some data collected from IA areas and the Baseline Area have indicated increased uranium dissolution and mobility as a result of irrigation water influx, while other constituents have generally responded with concentration decreases.

3.7 Influence of Return Flow

Given that river water is mixing with ground water in IA areas, whether through bank storage during months of high runoff, pumping-induced flow of water from the river toward extraction wells, or a result of irrigation in vegetation test plots, some consideration should be given to the potential influence of this water on surface water when it returns to the river. In those areas associated with a river side channel that represents potential habitat for endangered fish species (Configurations 1, 2, and 4), such "return flow" is generally expected to reduce contaminant concentrations in the side channel. This is because many of the phenomena resulting from the mixing of surface water and ground water (dilution, biogeochemical processes) tend to reduce the concentrations of dissolved constituents, like ammonia, in ground water. Thus, during the period of time it takes for the mixed water to flow back to the river side channel, continued attenuation of constituent concentrations in surface water can be expected. Such attenuation is similar to the contaminant dilution that occurs due to tidal-driven water exchange in ground water systems adjoining bodies of seawater (e.g., Yim and Mohsen 1992; Neville et al. 2002), with the exception that the time periods associated with return flow at the Moab Site is on the order of weeks to months instead of periods of a day or less at tidally affected sites.

The increased mobility of uranium in shallow ground water in response to irrigation on the vegetation test plots represents a possible exception to the tendency for return flow to attenuate constituent concentrations in a river side channel. However, oxidation of uranium is unlikely to cause problems in the vicinity of Ground Water IA systems since (1) the extraction wells at each of the IA locations intercept irrigation-derived recharge during summer months, and (2) irrigation typically ends in the month of September while ground water extraction continues into late November or early December.

Data collected during this performance evaluation were examined for evidence of contaminant attenuation in a river side channel as a result of return flow of river water. The attenuation effects stemming from return flow of bank storage were expected in the summer months following peak river runoff in spring 2006, whereas the continued attenuation associated with return flow of river water drawn toward extraction wells during the pumping season was expected in the weeks and months following the termination of pumping.

End of current text

4.0 Ground Water Interim Action Components and Operation

As of 2006, five components of the Ground Water IA had been installed; these were referred to as Configuration 1 (installed in 2003), Configuration 2 (installed in 2004), Configuration 3 (installed in 2005), and Configuration 4 and the infiltration trench (both installed in 2006). Configuration 1 was designed exclusively for ground water extraction to intercept ground water that was contaminated by seepage from fluids in the Moab tailings pile. Configurations 2, 3, and 4 were designed as dual-purpose ground water extraction and freshwater injection well systems. Each of the configurations and the Baseline Area are described in some detail in this section of the report.

A map view of the components of the Ground Water IA is presented in Figure 1–1. The system includes an infiltration trench, remediation wells, manifold systems connecting the wells, a pipeline that conveys contaminated water to the top of the Moab tailings pile, and an evaporation pond used for treating the water. A sprinkler system is used on the tailings pile to enhance evaporation of the contaminated water.

All wells comprising the four IA configurations are installed in an alluvial aquifer that occurs throughout most of the Moab Site. Though relatively deep wells have been installed at the site, all IA extraction and observation wells are confined to the uppermost 60 ft of alluvial sediments. Descriptions of the materials that comprise the alluvial aquifer in the vicinity of the IA are provided in Section 3.1.

Lithologic logs and well completion information for most of the wells that comprise the Ground Water IA are presented in the *Operations, Maintenance, and Performance Monitoring Plan for the Interim Action Ground Water Treatment System, Moab Utah* (DOE 2006b).

4.1 Baseline Area

The Baseline Area (Figure 4–1) is located upstream of the well field configurations and the infiltration trench, just south of the confluence of Moab Wash and the Colorado River. This area is used to portray hydraulic and water chemistry conditions in the alluvial aquifer that are unaffected by ground water pumping or injection. The types of aquifer materials encountered in the Baseline Area are generally the same as those observed in the vicinities of the IA configurations. Observed phenomena in the Baseline Area such as ground water level variations in response to changing river flows, concomitant changes in brine surface elevation, and hyporheic zone processes are useful for comparison with equivalent phenomena in the IA areas.

A summary of the construction of observation wells and piezometers installed in the Baseline Area is presented in Table 4–1. A chronology of activities that occurred in the Baseline Area during 2006 is presented in Table 4–2**.**

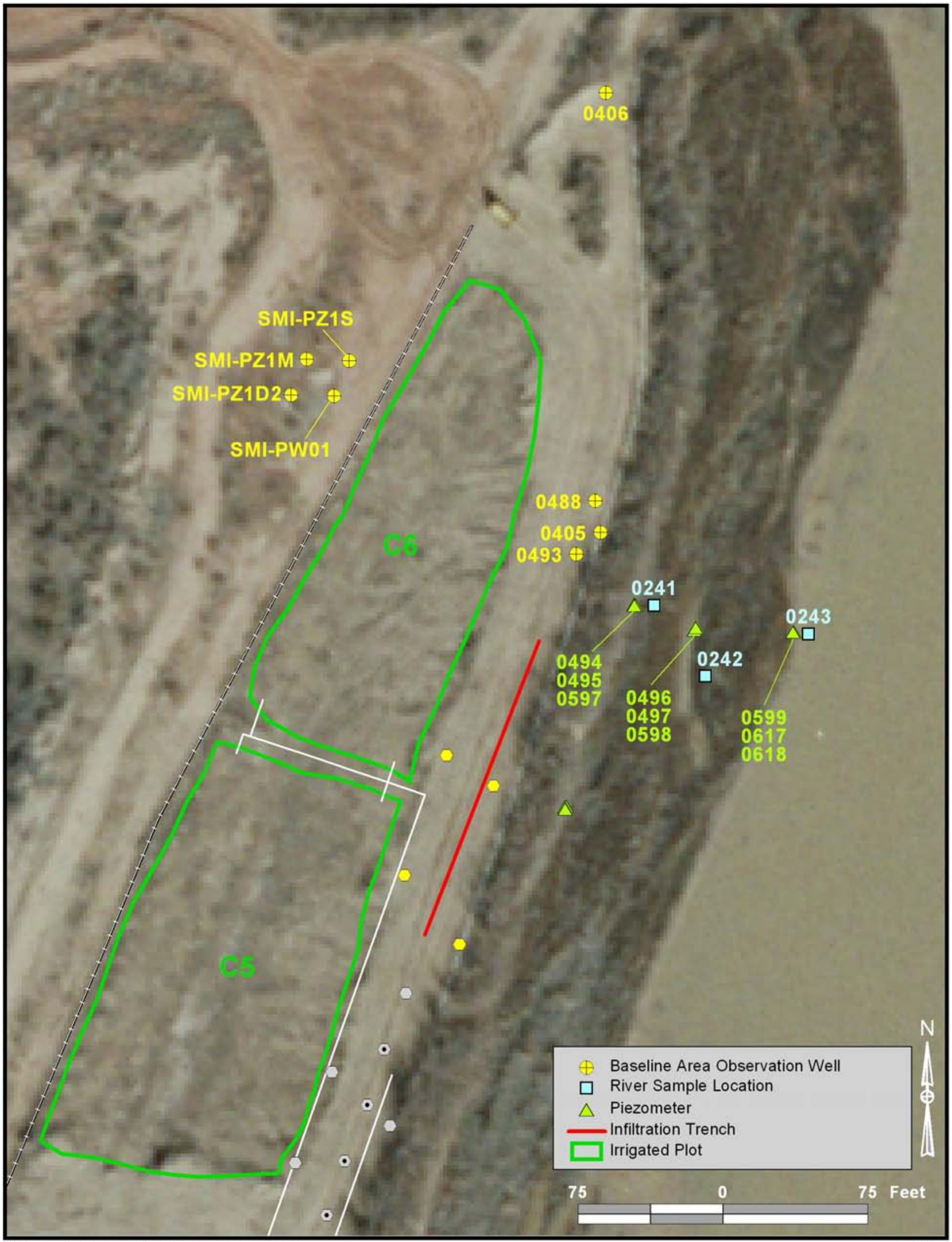

Figure 4–1. Map View of Baseline Area Wells and Sampling Locations

Table 4–1. Summary of Well and Piezometer Construction in the Baseline Area

Well	Well Type/Relative Depth	Diameter (inches)	Ground Surface Elevation (ft above msl)	Screen Interval (ft bgs)	Total Depth (ft bgs)
0405	Observation / Shallow	1	3,966.40	15.1 - 20.0	20.3
0406	Observation / Shallow	1	3,967.90	13.1 – 18.0	18.3
0488	Observation / Intermediate	6	3,966.82	25.0 - 40.0	40.3
0493	Observation / Deep	6	3,966.08	45.0 - 55.0	55.3
SMI-PW01	Observation / Deep	4	3,966.40	20.1 – 60.1	60.2
SMI-PZ1S	Observation / Shallow	2	3,966.70	13.9 – 18.9	19.1
SMI-PZ1M	Observation / Intermediate	2	3,966.30	55.5 – 60.5	60.8
SMI-PZ1D2	Observation / Deep	2	3,966.40	69.8 – 74.8	75.0
0494	Piezometer / Shallow	1	3,957.41	2.4 – 3.4	3.4
0495	Piezometer / Intermediate	1	3,957.41	4.6 – 5.6	5.6
0597	Piezometer / Deep	1	3,957.41	9.3 – 10.3	10.3
0496	Piezometer / Shallow	1	3,955.62	2.2 – 3.2	3.2
0497	Piezometer / Intermediate	1	3,955.62	4.0 – 4.9	4.9
0598	Piezometer / Deep	1	3,955.62	9.1 – 10.1	10.1
0617	Piezometer / Shallow	1	3,954.24	1.7 – 2.7	2.7
0618	Piezometer / Intermediate	1	3,954.24	5.3 – 6.3	6.3
0599	Piezometer / Deep	1	3,954.24	9.4 – 10.4	10.4

4.2 Configuration 1

The Configuration 1 extraction system consists of ten wells located approximately 100 ft from a steep bank that forms the west bank of the Colorado River (Figure 4–2) during high runoff periods. The wells were installed parallel to the river along a straight line and with a 25-ft spacing. In addition, 19 observation wells and nine riverbed piezometers were installed in the Configuration 1 area for monitoring aquifer responses to pumping and other hydraulic stresses.

In early April 2005, a pump was installed in well SMI-PW02 (Figure 4–2) and ground water extracted from the well was added to the IA remediation system. Though this well is not officially within any of the IA areas, it is considered a part of Configuration 1 for the purposes of performance assessment because of its proximity to the Configuration 1 extraction wells (~225 ft northwest of well 0479). Since 2005, ground water extraction at well SMI-PW02 helped increase the mass of ammonia and uranium removed from the aquifer and made more water available to the sprinkler system on top of the tailings pile.

Table 4–2. Chronology of Baseline Area Activities in 2006

Date	River Flow (daily mean cfs)	Activity	Samples Collected
Feb 14 thru 16, 2006	3,020 to 3,120	Monthly sampling	6 observation wells (0488, 0493, SMI-PW01, SMI-PZ1S, SMI-PZ1M, and SMI-PZ1D2), 6 pzs (0496, 0497, 0598, 0599, 0617, and 0618), and 1 surface water location (0243).
Feb 14 thru 16, 2006	3,020 to 3,120	Biogeochemical sampling	2 observation wells (0405 and 0488 [26 ft bgs]) and 2 pzs (0495 and 0597).
Mar 20 thru 23, 2006	3,410 to 3,630	Monthly sampling	6 observation wells (0488, 0493, SMI-PW01, SMI-PZ1S, SMI-PZ1M, and SMI-PZ1D2), 6 pzs (0496, 0497, 0598, 0599, 0617, and 0618), and 1 surface water location (0243).
Mar 27 thru 30, 2006	3,360 to 4,180	Biogeochemical sampling	2 observation wells (0405 and 0488 [26 ft bgs]) and 2 pzs (0495 and 0597).
Apr 6 and 20, 2006	5,570 and 9,650	Monthly sampling	6 observation wells (0488, 0493, SMI-PW01, SMI-PZ1S, SMI-PZ1M, and SMI-PZ1D2), 1 pz (0494), and 1 surface water (0242). Other pzs not accessible due to high water, surface water location 0243 was dry.
Apr 17 and 18, 2006	10,800 to 11,200	Biogeochemical sampling	2 observation wells (0405 and 0488 [26 ft bgs]) and 2 pzs (0495 and 0597).
May 8 and 9, 2006	10,300 and 10,500	Monthly sampling	6 observation wells (0488, 0493, SMI-PW01, SMI-PZ1S, SMI-PZ1M, and SMI-PZ1D2), 1 pz (0494), and 1 surface water (0242). Other pzs and SW 0243 not accessible due to high water, surface water location 0241 was dry.
May 23 thru 25, 2006	18,700 to 21,400	Biogeochemical sampling	2 observation wells (0405 and 0488 [26 ft bgs]). Pzs not sampled due to high river stage.
June 12 thru 14, 2006	10,800 to 12,500	Monthly sampling	6 observation wells (0488, 0493, SMI-PW01, SMI-PZ1S, SMI-PZ1M, and SMI-PZ1D2), 3 pzs (0494, 0495, and 0597), and 1 surface water (0241).
July 24 thru 26, and 31, 2006	3,300 to 3,740 and 3,630	Monthly sampling	7 observation wells (0405, 0488, 0493, SMI-PW01, SMI-PZ1S, SMI-PZ1M, and SMI-PZ1D2), 5 pzs (0497, 0598, 0599, 0617, and 0618), and 1 surface water (0243).
July 17−20, 2006	4,230 to 5,030	Biogeochemical sampling	2 observation wells (0405 and 0488 [26 ft bgs]) and 2 pzs (0495 and 0597).
Sept 11−12, 2006	4,860 to 4,980	All 9 river bed PZs upgraded to well points	NA
Sept 13 and 15, 2006	4,660 and 4,870	Monthly sampling	6 observation wells (0405, 0488, SMI-PW01, SMI-PZ1S, SMI-PZ1M, and SMI-PZ1D2), 4 pzs (0598, 0599, 0617, and 0618), and 1 surface water (0243).
Sept 25−28, 2006	3,740 to 5,590	Biogeochemical sampling	2 observation wells (0405 and 0488 [26 ft bgs]) and 2 pzs (0495 and 0597).
Oct 11 and 23, 2006	7,550 and 5,790	Monthly sampling	3 observation wells (0405, 0488, and 0493), 3 pzs (0496, 0497, and 0598). SW 0241 was dry.
Nov 3, 2006	4,800	Monthly sampling	7 observation wells (0405, 0488, 0493, SMI-PW01, SMI-PZ1S, SMI-PZ1M, and SMI-PZ1D2).
Nov 6−7, 2006	4,540 to 4,630	Biogeochemical sampling	7 pzs (0495, 0496, 0597, 0598, 0599, 0617, and 0618).
Dec 12−13, 2006	4,680	Monthly sampling	3 observation wells (0405, 0488, and 0493), 2 pzs (0495 and 0597), and 1 sw (0243).

gpm = gallons per minute; cfs = cubic feet per second; na = not applicable

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Figure 4–2. Map View of Configuration 1 Wells and Sampling Locations

Table 4–3 summarizes the construction of all wells and riverbed piezometers comprising Configuration 1. As this table indicates, extraction wells 0470 through 0479 are installed to depths of about 21 to 25 ft bgs. Wells 0470 through 0477 are screened over identical intervals of 10.3 to 19.7 ft bgs, and well 0478 and 0479 are screened over depths of about 9 to 24 ft bgs. Well SMI-PW02 is screened from 20 to 60 ft bgs, with the pump intake set at a depth of 55 ft bgs. In contrast to the extraction wells, the depths and screened intervals of Configuration 1 observation wells vary. As a consequence, information collected from the observation wells can be used to portray three-dimensional (3-D) responses of the alluvial aquifer and the Colorado River to ground water pumping.

A chronology of activities that occurred in the Configuration 1 area during 2006 is presented in Table 4–4. Flows in the river at the time of each activity are also listed.

4.3 Configuration 2

The Configuration 2 system (Figure 4–3) was installed just north of Configuration 1 in July 2004. Configuration 2 remediation wells, used for both pumping and fresh water injection, were placed closer to the river than Configuration 1 wells (about 50 ft from the steep bank marking the edge of the floodplain) than Configuration 1 wells with the intent of minimizing the time for injected freshwater to reach backwater areas of the Colorado River near its west bank. Spacing between the remediation wells was a uniform 30 ft.

In addition to being closer to the Colorado River, Configuration 2 remediation wells differ from those in Configuration 1 with regard to their construction and possible operation. Half of the ten Configuration 2 remediation wells are considered to be shallow, whereas the remaining five are classified as deep. All shallow wells are screened between depths of 15 and 30 ft bgs, which places them noticeably deeper than Configuration 1 extraction wells (mostly screened between 10 and 20 ft bgs). The deep well screens span depths of 25 to 40 ft bgs. The shallow and deep wells alternate with one another along the well field; even numbered wells are shallow, and odd-numbered wells are deep. A total of 13 observation wells and 9 riverbed piezometers are used to monitor alluvial aquifer and Colorado River responses to pumping in Configuration 2. Table 4–5 summarizes construction information for Configuration 2 wells and piezometers.

The deep remediation wells were added to this IA configuration for the purpose of assuring that river water injected into the alluvial aquifer would spread laterally toward the river over a wide vertical interval. It was believed that injection of uncontaminated water in both shallow and deep wells would cause a larger portion of backwaters in the river to experience more dilution of ammonia than would occur using shallow wells only (DOE 2004b). Greater mass removal of ammonia contamination during pumping was also surmised as being a possible benefit of using deep wells.

Due to construction activities of a new fresh water storage pond, diverted Colorado River water was not available in the spring and summer months for injection purposes at Configuration 2. Therefore, Configuration 2 wells were operated in injection mode until mid-March, then in extraction mode, but at a reduced flow rate until October 2, 2006, when the configuration was shut down for the season.

Table 4–3. Summary of Well and Piezometer Construction in the Configuration 1 Area

Well	Well Type/Relative Depth	Diameter (inches)	Ground Surface Elevation (ft above msl)	Screen Interval (ft bgs)	Total Depth (ft bgs)
0470	Extraction	4	3,966.56	10.3–19.7	21.3
0471	Extraction	4	3,966.59	10.3–19.7	21.3
0472	Extraction	4	3,966.62	10.3–19.7	21.3
0473	Extraction	4	3,966.67	10.3–19.7	21.3
0474	Extraction	4	3,967.02	10.3–19.7	21.3
0475	Extraction	4	3,967.13	10.3–19.7	21.3
0476	Extraction	4	3,967.38	10.3–19.7	21.3
0477	Extraction	4	3,967.30	10.3–19.7	21.3
0478	Extraction	4	3,966.82	9.6–23.9	25.5
0479	Extraction	4	3,966.60	9.3–23.6	25.2
SMI-PW02	Extraction	4	3,965.60	20–60	60.3
0403	Observation / Shallow	1	3,966.90	13.3–18.2	18.4
0407	Observation / Shallow	1	3,967.20	13.3–18.3	18.5
0480	Observation / Shallow	4	3,966.94	15.5–19.8	20.3
0481	Observation / Intermediate	4	3,967.01	25.4–29.7	31.3
0482	Observation / Deep	4	3,967.03	55.4–59.7	61.3
0483	Observation / Shallow	4	3,967.00	15.5–19.8	20.3
0484	Observation / Intermediate	4	3,967.19	25.5–29.8	30.3
0485	Observation / Deep	4	3,966.99	55.6–59.9	60.4
0551	Observation / Shallow	1	3,966.65	10.3–20.3	20.6
0552	Observation / Shallow	1	3,966.33	10.2–20.2	20.4
0553	Observation / Shallow	1	3,966.87	10.6–20.5	20.8
0554	Observation / Shallow	1	3,967.63	10.4–20.4	20.6
0555	Observation / Shallow	1	3,967.32	10.2–20.1	20.4
0556	Observation / Shallow	1	3,966.69	10.2–20.1	20.4
0557	Observation / Intermediate	6	3,967.01	35.0–45.0	45.9
0558	Observation / Intermediate	6	3,966.85	35.0–45.0	45.1
0559	Observation / Shallow	1	3,967.84	10.5–20.5	20.7
0560	Observation / Intermediate	6	3,966.95	30.0–40.0	40.4
0561	Observation / Deep	6	3,966.46	45.2–55.2	55.3
0596	Observation / Shallow	1	3,966.91	15.3–25.3	25.5
0562	Piezometer / Shallow	1	3,953.82	1.3−2.3	2.3
0563	Piezometer / Intermediate	1	3,953.82	4.6−5.6	5.6
0606	Piezometer / Deep	1	3,953.79	9.3−10.3	10.3
0611	Piezometer / Shallow	1	3,954.57	2.2−3.2	3.2
0612	Piezometer / Intermediate	1	3,954.57	4.3−5.3	5.3
0608	Piezometer / Deep	1	3,954.57	8.9−9.9	9.9
0564	Piezometer / Shallow	1	3,953.50	1.2−2.2	2.2
0565	Piezometer / Intermediate	1	3,953.50	4.0−5.0	5.0
0607	Piezometer / Deep	1	3,952.99	9.6−10.6	10.6

Table 4–4. Chronology of Configuration 1 Activities in 2006

Date	Co River Flow (daily mean cfs)	Activity	Samples Collected
Dec 7, 2005	2,800	System shut down for the winter	NA
March 7 and 8, 2006	3,610 to 3,840	Pre startup profile sampling	The 10 CF1 extraction wells (0470 thru 0479), sampled near pump intake depth, field parameters measured at shallow depths.
March 9, 2006	**3,940**	**System re-started for 2006**	**NA**
Mar 20−23, 2006	3,410 to 3,630	Monthly Sampling	5 Obs wells (0484, 0557, 0558, 0560, and 0596), 5 pzs (0562, 0564, 0608, 0611, and 0612), 1 surface water (0216), and 2 treatment system locations (0547 and 0548).
Mar 27−30, 2006	3,500 to 4,180	Biogeochemical sampling	4 Obs wells (0403, 0407, 0483, and 0559), and 4 pzs (0563, 0565, 0606, and 0607).
Apr 3−6, 2006	4,430 to 5,570	Monthly Sampling	The 10 CF1 extraction wells (0470 thru 0479), 10 Obs wells (0480, 0481, 0482, 0484, 0485, 0557, 0558, 0560, 0561, and 0596), 1 surface water location (0216), and 2 treatment system locations (0547 and 0548). Pzs not sampled due to river stage
Apr 18 and 19, 2006	10,800 to 10,900	Biogeochemical sampling	4 Obs wells (0403, 0407, 0483, and 0559). Not able to sample pzs due to high river stage.
May 1−2 and 10−11, 2006	9,660 to 10,400	Monthly Sampling	The 10 CF1 extraction wells (0470 thru 0479), 10 Obs wells (0480, 0481, 0482, 0484, 0485, 0557, 0558, 0560, 0561, and 0596), 1 surface water location (0216), and 2 treatment system locations (0547 and 0548).
May 23 thru 25, 2006	18,700 to 21,400	Biogeochemical sampling	4 Obs wells (0403, 0407, 0483, and 0559). Not able to sample pzs due to high river stage.
May 26, 2006	**18,300**	**SMI-PW02 started pumping at ~ 30 gpm**	**NA**
June 8, 14, 15, and 19, 2006	10,100 to 12,500, and 7,980 on 6/19	Monthly Sampling	The 11 CF1 extraction wells (0470 thru 0479 and SMI-PW02), 14 Obs wells (0403, 0407, 0480−0485, 0557−0561, and 0596), 1 surface water location (0216), and 2 treatment system locations (0547 and 0548). Pzs not sampled due to high river stage
July 14, 24−27, 31 to Aug 3, 2006	6,510 (7/14), 3,300 to 3,740 (7/24 to 7/27), 3,630 to 5,440 (7/31 to 8/3)	Monthly Sampling	The 11 CF1 extraction wells (0470 thru 0479 and SMI-PW02), 10 Obs wells (0480−0482, 0484, 0485, 0557, 0558, 0560, 0561, and 0596), 5 pz (0562, 0564, 0608, 0611, and 0612) 2 surface water locations (0216 and 0245), and 2 treatment system locations (0547 and 0548).
July 17−20, 2006	4,230 to 5,030	Biogeochemical sampling	4 Obs wells (0403, 0407, 0483, and 0559) and 3 pzs (0563, 0565, and 0606).
Sept 5−6, 2006	3,840 to 4,050	All 9 riverbed PZs upgraded to well points	NA

Table 4−4 (continued). Chronology of Configuration 1 Activities in 2006

Date	Co River Flow (daily mean cfs)	Activity	Samples Collected
Sept 5, 11−12, and 20, 2006	4,050, 4,980 – 4,860, and 5,020	Monthly Sampling	The 11 CF1 extraction wells (0470 thru 0479 and SMI-PW02), 10 Obs wells (0480−0482, 0484, 0485, 0557, 0558, 0560, 0561, and 0596), 5 pz (0562, 0564, 0608, 0611, and 0612) 2 surface water locations (0216 and 0245), and 2 treatment system locations (0547 and 0548).
Sept 25−28, 2006	3,740 to 5,590	Biogeochemical sampling	5 Obs wells (0403, 0407, 0480, 0483, and 0559) and 4 pzs (0563, 0565, 0606, and 0607).
Oct 4−9, 12, 19, and 24, 2006	4,980 to 8,330, 6,910, 7,350, and 5,620	Monthly Sampling	The 6 CF1 extraction wells (0470, 0472, 0474, 0476, 0478, and SMI-PW02), 8 Obs wells (0480, 0481, 0483, 0484, 0557, 0558, 0560, and 0596), 3 pzs (0562, 0563, and 0606), 1 surface water location (0216), and 2 treatment system locations (0547 and 0548).
Oct 30−Nov 3 and 13, 2006	4,800 to 5,120 and 4,330	Monthly Sampling	The 11 CF1 extraction wells (0470−0479 and SMI-PW02), 16 Obs wells (0403, 0407, 0480 - 0485, 0552, 0555, 0557−0561, and 0596), 2 surface water locations (0216 and 0245), and 2 treatment system locations (0547 and 0548).
Nov 6, 2006	**4,540**	**Shut down 0471, 0473, 0475, 0477, and 0479 for the winter**	**NA**
Nov 9−10, 2006	4,290 to 4,360	Biogeochemical sampling	6 pzs (0562, 0563, 0606, 0608, 0611, and 0612).
Nov 17, 2006	4,560	Restarted 0475, shut down 0476 (for telemetry purposes)	NA
Nov 27, 2006	**4,510**	**SMI-PW02 shut down for the winter**	**NA**
Dec 5−6 and 14, 2006	4,100 to 4,110	Monthly Sampling	The 6 CF1 extraction wells (0470, 0472, 0474, 0476, and 0478), 7 Obs wells (0480, 0481, 0483, 0484, 0557, 0558, and 0559), 3 pzs (0562, 0563, and 0606), 1 surface water location (0216), and 2 treatment system locations (0547 and 0548)
Dec 18, 2006	**4,660**	**Remaining Extraction wells (0470, 0472, 0474, 0475, and 0478) shut down for the winter**	**NA**

gpm = gallons per minute; cfs = cubic feet per second; na = not applicable

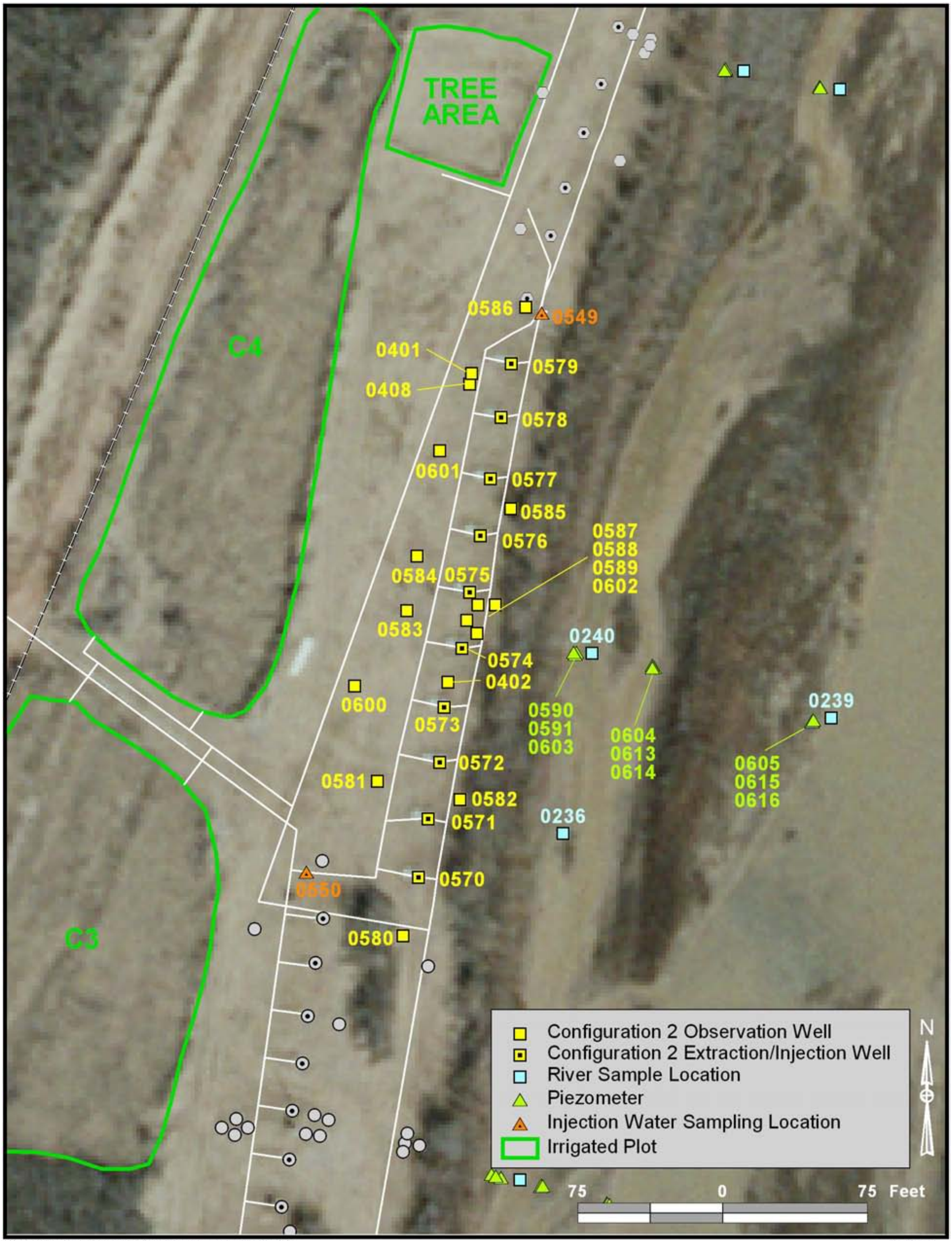

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Figure 4–3. Map View of Configuration 2 Wells and Sampling Locations

Table 4–5. Summary of Well and Piezometer Construction in the Configuration 2 Area

Well	Well Type/Relative Depth	Diameter (inches)	Ground Surface Elevation (ft above msl)	Screen Interval (ft bgs)	Total Depth (ft bgs)
0570	Remediation / Shallow	6	3,967.52	15.0–30.0	31.3
0571	Remediation / Deep	6	3,967.01	25.0–40.0	41.3
0572	Remediation / Shallow	6	3,967.01	15.0–30.0	31.3
0573	Remediation / Deep	6	3,967.70	25.0–40.0	41.3
0574	Remediation / Shallow	6	3,967.30	15.0–30.0	31.3
0575	Remediation / Deep	6	3,967.30	25.0–40.0	41.3
0576	Remediation / Shallow	6	3,967.17	15.0–30.0	31.3
0577	Remediation / Deep	6	3,967.59	25.0–40.0	41.3
0578	Remediation / Shallow	6	3,967.80	15.0–30.0	31.3
0579	Remediation / Deep	6	3,967.21	25.0–40.0	41.3
0401	Observation / Shallow	1	3,967.70	13.0–17.9	18.9
0402	Observation / Shallow	1	3,967.70	13.4–18.3	18.5
0408	Observation / Shallow	1	3,967.80	23.0–27.9	28.0
0580	Observation / Shallow	1	3,967.52	10.2–20.2	20.4
0581	Observation / Shallow	1	3,967.01	10.3–20.3	20.5
0582	Observation / Shallow	1	3,967.67	9.8–19.7	20.0
0583	Observation / Shallow	1	3,967.53	8.9–18.8	19.1
0584	Observation / Shallow	1	3,967.17	10.3–20.2	20.5
0585	Observation / Shallow	1	3,967.59	10.4–20.3	20.6
0586	Observation / Shallow	1	3,967.21	10.0–19.9	20.2
0587	Observation / Shallow	1	3,967.30	10.0–19.6	20.2
0588	Observation / Intermediate	6	3,967.22	24.8–34.8	35.0
0589	Observation / Deep	6	3,966.98	42.7–52.7	53.0
0600	Observation / Shallow	1	3,966.88	19.5–29.5	29.7
0601	Observation / Shallow	1	3,967.09	19.5–29.5	29.7
0602	Observation / Shallow	1	3,967.57	9.5–19.5	19.7
0590	Piezometer / Shallow	1	3,953.82	1.0–2.0	2.0
0591	Piezometer / Intermediate	1	3,953.82	3.9–4.9	4.9
0603	Piezometer / Deep	1	3,953.82	9.2–10.2	10.2
0613	Piezometer / Shallow	1	3,955.59	1.2–2.2	2.2
0614	Piezometer / Intermediate	1	3,955.59	5.1–5.1	6.1
0604	Piezometer / Deep	1	3,955.59	7.3–8.3	8.3
0615	Piezometer / Shallow	1	3,954.96	1.4–2.4	2.4
0616	Piezometer / Intermediate	1	3,954.96	5.3–6.3	6.3
0605	Piezometer / Deep	1	3,954.96	9.4–10.4	10.4

A chronology of activities that occurred in the Configuration 2 area during 2006 is presented in Table 4–6.

Table 4–6. Chronology of Configuration 2 Activities in 2006

Date	River Flow (daily mean cfs)	Activity	Samples Collected
Jan 1, 2006	N/A	Freshwater injection carried over from 2005	NA
Jan 17–19, 2006	2,900 to 2,980	Biogeochemical sampling	3 Observation wells (0588 [26 ft bgs], 0589 [44 ft bgs], and 0602 [18 ft bgs]), 4 pzs (0591, 0603, 0604, and 0614).
Jan 19, 23–26, 2006	2,670 to 2,960	Injection test monthly sampling	15 Observation wells (0401, 0402, 0408, 0580 through 0589, 0600, and 0601), 5 pzs (0590, 0605, 0613, 0615, 0616), 3 surface locations (0236, 0239, and 0240) and 1 injection water location (0550).
Feb 14 to 17, 2006	2,820 to 3,110	Injection wells 0570 thru 0579 redeveloped	NA
Mar 13 to 16, 2006	3,300 to 3,590	Injection test monthly sampling	15 Observation wells (0401, 0402, 0408, 0580 through 0589, 0600, and 0601).
Mar 16, 2006	**3,300**	**Suspended Fresh Water Injection @ 17:00**	**NA**
Mar 21 to 23, 2006	3,410 to 3,630	Monthly Sampling	4 pzs (0605, 0613, 0615, 0616), and 2 surface locations (0239, and 2040). SW location 0236 was dry.
Mar 23, 2006	**3,410**	**Started Ground Water Extraction (Initially 4 wells only)**	**NA**
Mar 27–30, 2006	3,500 to 4,180	Biogeochemical sampling	3 Observation wells (0588 [26 ft bgs], 0589 [44 ft bgs], and 0602 [18 ft bgs]), 4 pzs (0591, 0603, 0604, and 0614).
Apr 20 and 24, 2006	9,650 and 10,700	Monthly Sampling	6 extraction wells (0571, 0573, 0575, 0576, 0577, and 0579). Measured field parameters only from 15 Observation wells (0401, 0402, 0408, 0580 through 0589, 0600, and 0601).
May 3–9, 2006	10,300 to 11,100	Monthly Sampling	6 extraction wells (0572, 0573, 0575, 0577, and 0579), 15 Observation wells (0401, 0402, 0408, 0580 through 0589, 0600, and 0601), and 2 surface water locations (0236 and 0240). Pzs not sampled due to high river stage.
May 23 thru 25, 2006	18,700 to 21,400	Biogeochemical sampling	3 Observation wells (588 [26 ft bgs], 0589 [44 ft bgs], and 0602 [18 ft bgs]). Pzs not sampled due to high river stage.
June 6–12, 2006	12,300 to 12,600	Monthly Sampling	7 extraction wells (0570 - 0573, 0575, 0577, and 0579), 14 Observation wells (0402, 0408, 0580−0582, 0584−0589, 0600−0602), and 2 surface water locations (0236 and 0240). Pzs not sampled due to high river stage.
July 24–Aug 2, 2006	3,300 to 5,170	Monthly Sampling	8 extraction wells (0570 - 0573, 0575 - 0577, and 0579), 15 Observation wells (0401, 0402, 0408, 0580−0589, 0600, and 0601), 3 pzs (0605, 0615, and 0616), and 2 surface water locations (0239 and 0240). SW location 0236 was dry.
July 17–20, 2006	4,230 to 5,030	Biogeochemical sampling	3 Observation wells (0588 [26 ft bgs], 0589 [44 ft bgs], and 0602 [18 ft bgs]) and 3 pzs (0591, 0603, and 0604).

Table 4−6 (continued). Chronology of Configuration 2 Activities in 2006

Date	River Flow (daily mean cfs)	Activity	Samples Collected
Sept 6–7, 2006	3,840 to 3,860	All 9 riverbed piezometers upgraded to well points	NA
Sept 7, 11–12, 18, 2006	3,860, 4,980 to 4,860, and 5,320	Monthly Sampling	8 extraction wells (0570−0573, 0575−0577, and 0579), 15 Observation wells (0401, 0402, 0408, 0580−0589, 0600, and 0601), 3 pzs (0605, 0615, and 0616), and 2 surface water locations (0239 and 0240). SW location 0236 was dry.
Sept 25–28, 2006	3,740 to 5,590	Biogeochemical sampling	3 Observation wells (0588 [26 ft bgs], 0589 [44 ft bgs], and 0602 [18 ft bgs]) and 4 pzs (0591, 0603, 0604, and 0614).
Oct 2, 2006	4,390	**All CF2 extraction wells shut down for the season, well field not injecting or extracting**	NA
Oct 2 and 23, 2006	4,390 and 5,790	Monthly Sampling	6 Observation wells (0408, 0583, 0584, 0587, 0588, and 0589), 2 pzs (0591 and 0603), and 2 surface water locations (0236 and 0240).
Nov 2, 2006	4,940	Monthly Sampling	12 Observation wells (0401, 0408, 0581−0589, and 0600).
Nov 8–9, 2006	4,360 to 4,430	Biogeochemical sampling	6 pzs (0590, 0591, 0603, 0605, 0614, and 0615).
Dec 6–7, 2006	4,110 to 4,360	Monthly Sampling	6 Observation wells (0408, 0583, 0584, 0587, 0588, and 0589), 2 pzs (0591 and 0603), and 1 sw location (0239).
Dec 26–29, 2006	4,140 to 4,600	CF2 wells 0570 thru 0579 developed	NA

gpm = gallons per minute; cfs = cubic feet per second; na = not applicable

4.4 Configuration 3

Configuration 3 remediation wells were installed just north of Configuration 2 in June 2005. As with Configuration 2, these ten wells were designed to be dual-purpose in that they could be used for both ground water extraction and freshwater injection. The remediation wells are spaced 30 ft apart from one another and are located approximately 50 ft from the steep bank that marks the west edge of the floodplain (Figure 4–4).

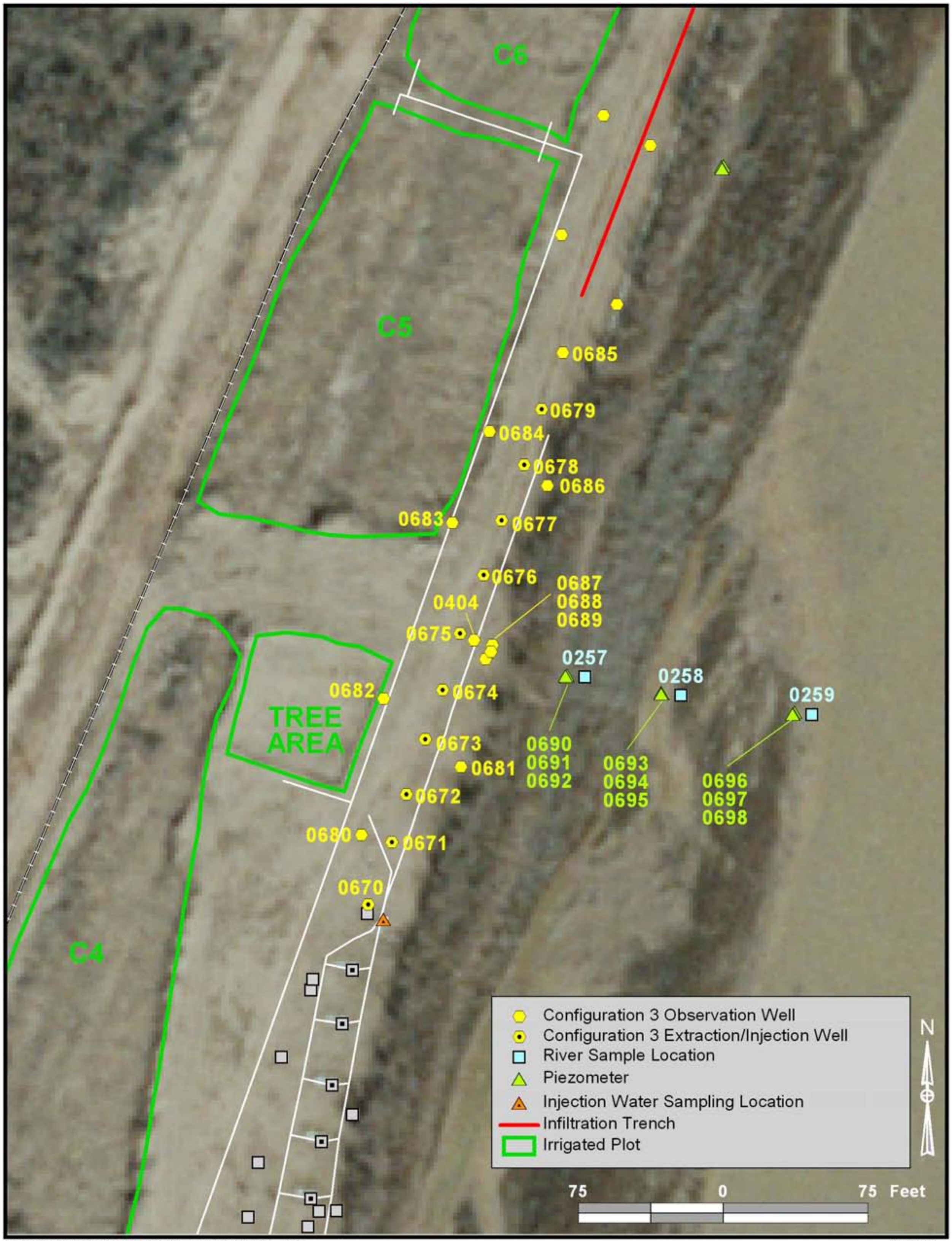

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Figure 4–4. Map View of Configuration 3 Wells and Sampling Locations

Each of the Configuration 3 remediation wells is screened between depths of 15 and 45 ft bgs. A total of 11 observation wells and nine riverbed piezometers (Figure 4–4) are used to monitor alluvial aquifer and Colorado River responses to pumping or water injection at the remediation wells. Table 4–7 summarizes construction information for Configuration 3 wells and piezometers.

Table 4–7. Summary of Well and Piezometer Construction in the Configuration 3 Area

Well	Well Type/Relative Depth	Diameter (inches)	Ground Surface Elevation (ft above msl)	Screen Interval (ft bgs)	Total Depth (ft bgs)
0670	Remediation / Deep	6	3,967.05	15.9–45.9	46.3
0671	Remediation / Deep	6	3,967.31	14.4–44.4	44.8
0672	Remediation / Deep	6	3,967.27	15.0–45.0	45.4
0673	Remediation / Deep	6	3,967.19	16.3–46.3	46.7
0674	Remediation / Deep	6	3,967.11	15.1–45.1	45.5
0675	Remediation / Deep	6	3,966.99	16.0–46.0	46.4
0676	Remediation / Deep	6	3,967.27	15.9–45.9	46.3
0677	Remediation / Deep	6	3,967.17	15.2–45.2	45.6
0678	Remediation / Deep	6	3,967.11	16.3–46.3	46.6
0679	Remediation / Deep	6	3,967.03	15.0–45.0	45.4
0404	Observation / Shallow	1	3,967.70	13.0–17.9	18.9
0680	Observation / Shallow	1	3,967.75	9.9–19.8	20.0
0681	Observation / Shallow	1	3,967.65	10.2–20.2	20.4
0682	Observation / Shallow	1	3,968.25	19.6–29.5	29.7
0683	Observation / Shallow	1	3,968.76	21.2–31.2	31.4
0684	Observation / Shallow	1	3,968.48	11.3–21.3	21.5
0685	Observation / Shallow	1	3,967.11	20.0–30.0	30.2
0686	Observation / Shallow	1	3,967.08	10.0–20.0	20.2
0687	Observation / Shallow	1	3,966.74	20.0–30.0	30.2
0688	Observation / Intermediate	6	3,966.57	30.6–40.6	41.0
0689	Observation / Deep	6	3,966.62	46.0–56.0	56.4
0690	Piezometer / Shallow	1	3,957.15	3.3–4.3	4.3
0691	Piezometer / Intermediate	1	3,957.15	6.5–7.5	7.5
0692	Piezometer / Deep	1	3,957.15	9.7–10.1	10.1
0693	Piezometer / Shallow	1	3,955.36	2.0–3.0	3.0
0694	Piezometer / Intermediate	1	3,955.36	4.3–5.3	5.3
0695	Piezometer / Deep	1	3,955.36	9.3–10.3	10.3
0696	Piezometer / Shallow	1	3,954.50	1.3–2.3	2.3
0697	Piezometer / Intermediate	1	3,954.50	4.3–5.3	5.3
0698	Piezometer / Deep	1	3,954.50	9.9–10.3	10.3

Borehole and well logs for Configuration 3 show that alluvial aquifer materials in the area are similar to those observed in the vicinities of Configurations 1 and 2. Very permeable gravelly sands and sandy gravels dominate the alluvium below a depth of 15 ft bgs.

A chronology of activities that occurred in the Configuration 3 area during 2006 is presented in Table 4–8.

Table 4–8. Chronology of Configuration 3 Activities in 2006

Date	River Flow (daily mean cfs)	Activity	Samples Collected
Dec 7, 2005	2,800	System shut down for the winter	NA
Mar 9, 10, and 13, 2006	3,610 to 3,940	Pre-startup profile sampling	10 extraction wells (0670 thru 0679) sampled from pump intake depth, plus field parameters from shallow depths
Mar 14, 2006	**3,560**	**System re-started for 2006**	**NA**
Mar 14 and 21, 2006	3,540 and 3,410	Monthly Sampling	4 observation wells (0404, 0682, 0688, and 0689), 4 pzs (0639, 0696, 0697, and 0698), and 1 surface water (0259).
Mar 27 - 30, 2006	3,500 to 4,180	Biogeochemical sampling	2 observation wells (0686 and 0687) and 4 pzs (0691, 0692, 0694, and 0695).
Apr 3 thru 5, 2006	4,430 to 4,580	Monthly sampling	10 extraction wells (0670 thru 0679), 5 observation wells (0404, 0682, 0683, 0688 and 0689), and 1 surface water location (0258). Not able to access pzs due to high water.
Apr 17 and 18, 2006	10,800 to 11,200	Biogeochemical sampling	2 observation wells (0686 and 0687) and 2 pzs (0691 and 0692). Other pzs not sampled due to high river stage.
Apr 18, 2006	10,900	Increased well field total flow from ~22 to ~35 gpm	NA
May 1 and 8, 2006	10,400 to 10,500	Monthly sampling	10 extraction wells (0670 thru 0679) and 5 observation wells (0404, 0682, 0683, 0688 and 0689). Not able to access pzs and sw locations due to high water.
May 23 thru 25, 2006	18,700 to 21,400	Biogeochemical sampling	2 observation wells (0686 and 0687). Pzs not sampled due to high river stage.
June 5−6 and 12, 2006	11,900 to 12,500	Monthly sampling	10 extraction wells (0670 thru 0679) and 11 observation wells (0404, 0680 – 0689), and 2 pzs (0691 and 0692). Not able to access sw locations due to high water, 0257 was dry.
July 14, 24, and 26, 2006	6,510, 3,740, and 3,300	Monthly sampling	10 extraction wells (0670 thru 0679) and 5 observation wells (0404, 0682, 0683, 0688, and 0689), 1 surface water (0259), and 4 pzs (0693, 0696, 0697, and 0698).
July 17−20, 2006	4,230 to 5,030	Biogeochemical sampling	2 observation wells (0686 and 0687) and 4 pzs (0691, 0692, 0694, and 0695).

Date	River Flow (daily mean cfs)	Activity	Samples Collected
Sept 7−8, 2006	3,860 to 4,080	All 9 riverbed piezometers upgraded to well points	NA
Sept 6, 11, and 13, 2006	3,840, 4,980, and 4,660	Monthly sampling	10 extraction wells (0670 thru 0679) and 5 observation wells (0404, 0682, 0683, 0688, and 0689), 2 surface water locations (0258 and 0259), and 3 pzs (0693, 0696, and 0697).
Sept 25−28, 2006	3,740 to 5,590	Biogeochemical sampling	2 observation wells (0686 and 0687) and 4 pzs (0691, 0692, 0694, and 0695).
Oct 10 and 16, 2006	8,510 and 6,370	Monthly sampling	5 extraction wells (0670, 0672, 0674, 0676, and 0678) and 5 observation wells (0682, 0683, 0687, 0688, and 0689), 1 surface water location (0258), and 2 pzs (0691 and 0692).
Oct 31−Nov 1, 2006	5,020 to 5,120	Monthly sampling	10 extraction wells (0670 thru 0679) and 11 observation wells (0404, 0680 - 0689).
Nov 6, 2006		**Extraction wells 0671, 0673, 0675, 0677, and 0679 shut down for the winter**	**NA**
Nov 7−8, 2006	4,430 to 4,630	Biogeochemical sampling	8 pzs (0691−0698) and sw location 0243.
Dec 11−12, 2006	4,600 to 4,680	Monthly sampling	5 extraction wells (0670, 0672, 0674, 0676, and 0678) and 5 observation wells (0682, 0683, 0687, 0688, and 0689), 1 surface water location (0259), and 2 pzs (0691 and 0692).
Dec 18, 2006	**4,660**	**Remaining extraction wells (0670, 0672, 0674, 0676, and 0678) shut down for the winter.**	**NA**

gpm = gallons per minute; cfs = cubic feet per second; na = not applicable

4.5 Configuration 4

Configuration 4 remediation wells were installed just south of Configuration 1 in May and June 2006. As with Configurations 2 and 3, these ten wells were designed to be dual-purpose in that they could be used for both ground water extraction and freshwater injection. The remediation wells are spaced 30 ft apart from one another and are located approximately 50 ft from the steep bank that marks the west edge of the floodplain (Figure 4–5).

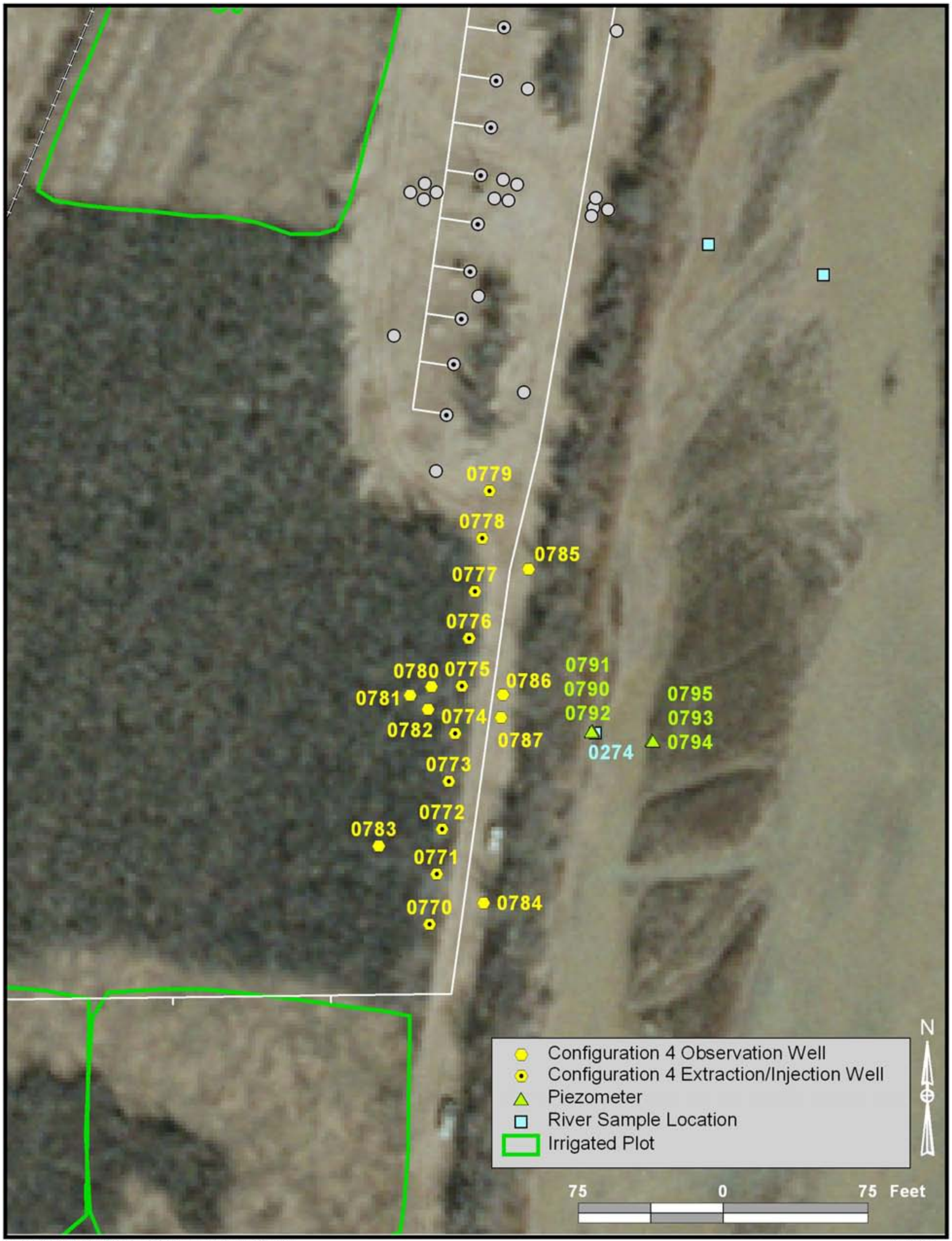

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Figure 4–5. Map View of Configuration 4 Wells and Sampling Locations

Each of the Configuration 4 remediation wells is screened between depths of 15 and 35 ft bgs. A total of eight observation wells and six riverbed piezometers (Figure 4–5) are used to monitor alluvial aquifer and Colorado River responses to pumping or water injection at the remediation wells. Table 4–9 summarizes construction information for Configuration 4 wells and piezometers.

Table 4–9. Summary of Well and Well Point Construction in the Configuration 4 Area

Well	Well Type/Relative Depth	Diameter (inches)	Ground Surface Elevation (ft above msl)	Screen Interval (ft bgs)	Total Depth (ft bgs)
0770	Remediation / Deep	6	3,968.86	14.9–34.8	35.2
0771	Remediation / Deep	6	3,969.04	15.0–34.9	35.3
0772	Remediation / Deep	6	3,969.21	15.2–35.1	35.5
0773	Remediation / Deep	6	3,969.15	15.2–35.1	35.5
0774	Remediation / Deep	6	3,968.77	15.5–35.4	35.8
0775	Remediation / Deep	6	3,969.18	15.1–35.0	35.4
0776	Remediation / Deep	6	3,968.97	15.2–35.1	35.5
0777	Remediation / Deep	6	3,968.76	15.3–35.2	35.6
0778	Remediation / Deep	6	3,968.93	15.1–35.0	35.4
0779	Remediation / Deep	6	3,968.34	15.7–35.6	36.0
0780	Observation / Shallow	6	3,968.45	20.3–30.1	30.5
0781	Observation / Deep	6	3,968.56	44.8–54.5	55.0
0782	Observation / Deep	6	3,968.46	31.0–40.8	41.2
0783	Observation / Shallow	2	3,968.82	8.6–18.6	19.1
0784	Observation / Shallow	2	3,968.73	9.4–19.4	19.9
0785	Observation / Shallow	2	3,968.24	9.6–19.6	19.9
0786	Observation / Shallow	6	3,968.14	20.5–30.3	30.7
0787	Observation / Deep	6	3,968.43	35.4–45.2	45.7
0790	Well Point / Shallow	1	3,953.91	2.0–3.0	3.0
0791	Well Point / Intermediate	1	3,953.91	4.3–5.3	5.3
0792	Well Point / Deep	1	3,953.91	9.3–10.3	10.3
0793	Well Point / Shallow	1	3,952.69	2.0–3.0	3.0
0794	Well Point / Intermediate	1	3,952.69	4.3–5.3	5.3
0795	Well Point / Deep	1	3,952.69	9.3–10.3	10.3

A chronology of activities that occurred in the Configuration 4 area during 2006 is presented in Table 4–10**.**

Table 4–10. Chronology of Configuration 4 Activities in 2006

Date	Co River Flow (daily mean cfs)	Activity	Samples Collected
May 10, 2006	10,100	Installed obs well 0785	NA
May 15−22, 2006	11,100 to 17,000	Extraction Wells 0770-0779 installed, observation wells 0780, 0781, 0782, 0784, 0786, and 0787 installed	NA
May 17–25, 2006	13,800 to 21,400	Developed 0784 and 0785	NA
June 6–8, 2006	12,200 to 13,000	All extraction wells developed	NA
June 21–22, 2006	7,150 to 7,240	Developed 0780, 0781, 0782, 0786, and 0787	NA
Aug 28−31, 2006	4,440 to 5,130	Profile sampling	Collected samples from 2 depths (15 and 32 ft bgs) from extraction wells 0770 – 0779, and sampled obs wells 0780 (21 and 28 ft bgs), 0781 (46 and 53 ft bgs), 0782 (31 and 38 ft bgs), 0784 (18 ft bgs), 0785 (18 ft bgs), 0786 (28 ft bgs), and 0787 (43 ft bgs). Field parameters measured from 0786 (21 ft bgs) and 0787 (36 ft bgs)
Aug 31, 2006	4,440	Started initial pumping from CF4 at low flows	NA
Sept 11, 2006	**4,980**	**CF4 brought online**	**NA**
Sept 12, 2006	4,860	Well points 0790 thru 0795 installed	NA
Sept 14–15, and 29, 2006	4,530 to 4,870, and 4,530	Completed monthly sampling	5 CF4 extraction wells (0770, 0772, 0774, 0776, and 0778), 5 Obs wells (0780, 0781, 0782, 0786, and 0787), and 4 PZ's (0790 thru 0795).
Sept 20, 2006	5,020	Installed obs well 0783	NA
Sept 20–21, 2006	5,020 to 5,240	Step Tests on Extr wells 0771, 0773, 0776, and 0779	NA
Sept 28–29, 2006	4,530 to 4,610	Step Tests on Extr wells 0770, 0772, and 0778	NA
Oct 3–4, and 16, 2006	4,530 to 4,980 and 6,370	Completed monthly sampling	5 CF4 extraction wells (0770, 0772, 0774, 0776, and 0778), 5 Obs wells (0780, 0781, 0782, 0786, and 0787), and 1 surface water location (0274). Could not reach pzs due to high river stage.
Nov 1–2, 2006	4,940 to 5,020	Completed monthly sampling	5 CF4 extraction wells (0770, 0772, 0774, 0776, and 0778), 8 Obs wells (0780−0787), and 1 surface water location (0274).
Nov 6, 2006	**4,540**	**Extraction wells 0771, 0773, 0775, 0777, and 0779 shut down for the winter**	**NA**
Nov 10, 2006	4,290	Biogeochemical sampling	6 pzs (0790−0795)
Dec 4–5, 2006	4,100 to 4,410	Completed monthly sampling	5 CF4 extraction wells (0770, 0772, 0774, 0776, and 0778), 5 Obs wells (0780, 0781, 0782, 0786, and 0787), 3 pzs (0790, 0791, and 0793), and 1 surface water location (0274).
Dec 18, 2006	**4,660**	**Remaining active extraction wells (0770, 0772, 0774, 0776, and 0778) shut down for the winter**	**NA**

gpm = gallons per minute; cfs = cubic feet per second; na = not applicable

4.6 Infiltration Trench

The infiltration trench was installed in August and September 2006. This 160 ft perforated pipe buried approximately 10 ft bgs is located to the north of Configuration 3. Construction details were provided in the *Operations, Maintenance, and Performance Monitoring Plan* (DOE 2006b). There are four observation wells and three riverbed piezometers (Figure 4–6) that are used to monitor alluvial aquifer responses to water injection into the trench. Table 4–11 summarizes construction information for infiltration trench wells and piezometers.

Table 4–11. Summary of Observation Well and Well Point Construction in the Infiltration Trench Area

Well	Well Type/Relative Depth	Diameter (inches)	Ground Surface Elevation (ft above msl)	Screen Interval (ft bgs)	Total Depth (ft bgs)
0730	Observation / Shallow	2	3,965.90	8.6–18.6	19.1
0731	Observation / Shallow	2	3,966.95	9.4–10.4	19.9
0732	Observation / Shallow	2	3,967.02	9.6–10.6	20.1
0733	Observation / Shallow	2	3,966.31	20.5–30.3	30.7
0724	Well Point / Shallow	1	3,957.50	2.4–3.4	3.4
0725	Well Point / Intermediate	1	3,957.50	4.6–5.6	5.6
0726	Well Point / Deep	1	3,957.50	9.5–10.5	10.5

The trench was operated from late September to early December 2006, when it was shut down for the winter. Table 4–12 provides a summary of the infiltration rate and total quantities to date of river water that were injected. Also provided are the water level measurements from the surrounding observation wells that were installed primarily to monitor the degree of ground water mounding associated with the river water infiltration.

Table 4–12. Chronology of Infiltration Trench Activities in 2006

Date	Co River Flow (daily mean cfs)	Activity	Samples Collected
May 31 and June 1, 2006	11,800 and 10,600	Installed obs wells 0732 and 0733	NA
May 31 and June 1 and 12, 2006	11,800, 10,600, and 12,400	Developed obs wells 0732 and 0733	NA
Aug , 2006		Infiltration Trench Installed (depth ~ 8.5 ft bgs)	NA
Sept 7, 2006	3,860	**Started injecting into 0741 port**	NA
Sept 20, 2006	5,020	Installed obs wells 0730, 0731	NA
Sept 25, 2006	5,520	Added lg sand filter to system, problems with pond intake clogging	NA
Sept 27 and 28, 2006	4,680 and 4,610	Developed obs wells 0730 and 0731	NA
Sept 28, 2006	4,610	**Started injecting into 0740, 0742, and 0743 ports**	NA
Oct 9, 2006	9,190	Injection line broken at Moab Wash during flood event	NA
Oct 12, 2006	6,910	Injection line repaired	NA
Nov 16, 2006	4,680	Installed well points 0724, 0725, and 0726	NA
Dec 1, 2006	4,260	**Injection suspended for winter**	NA
Dec 12, 2006	4,680	Well point sampling	0725 and 0726 (0724 did not recharge)

gpm = gallons per minute; cfs = cubic feet per second; na = not applicable

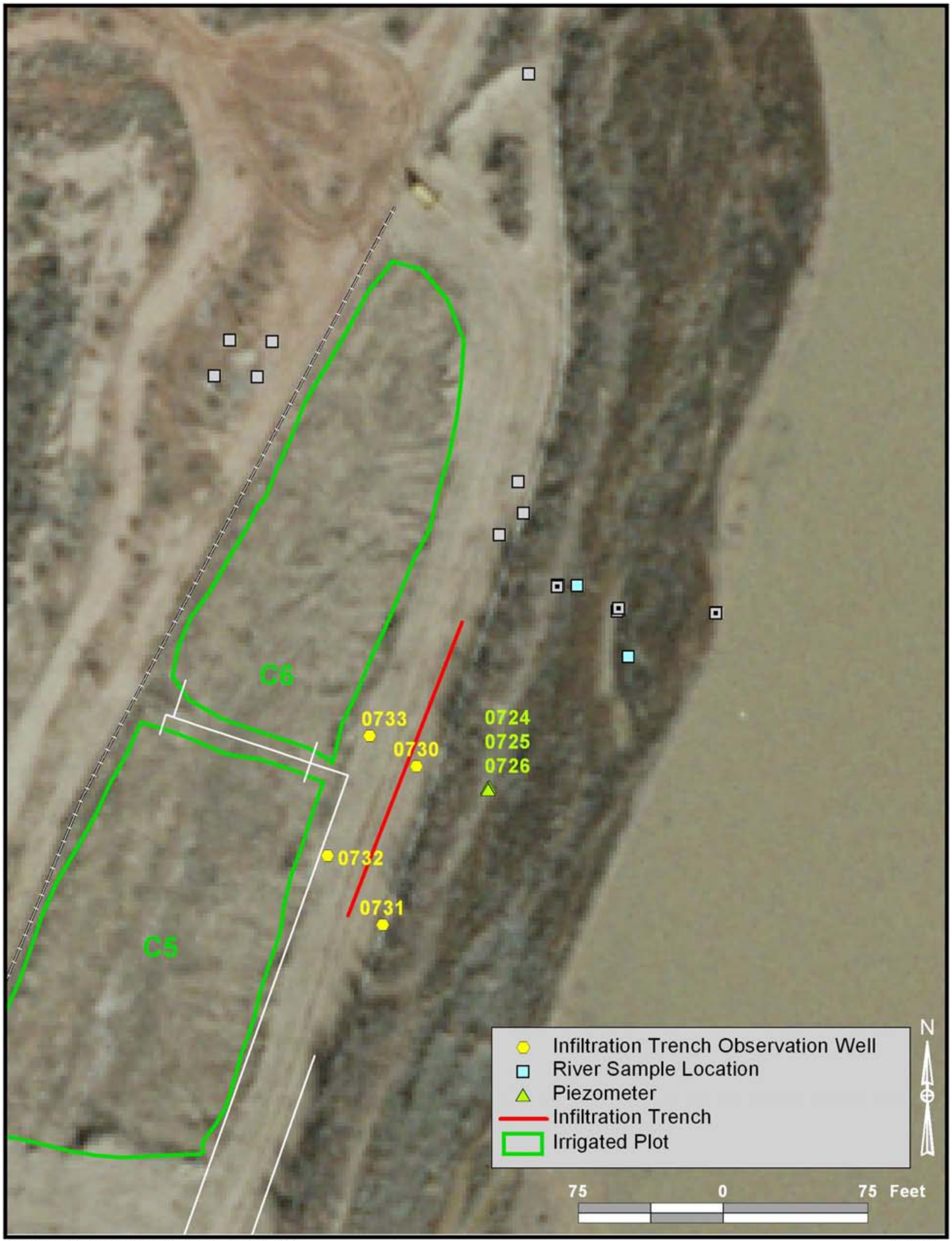

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Figure 4–6. Map View of Infiltration Trench Observation Well and Sampling Locations

4.7 Operation and Testing Activities in 2006

During most of 2006, Configurations 1 and 3 were operated as a ground water extraction system and limited extraction was conducted at Configurations 2 and 4. Most testing activities during the year were associated with Configuration 4 after it was installed in the summer. The following sections describe the initial sampling of Configuration 4 wells in August 2006 and the results of subsequent step-drawdown testing of some of the remediation wells.

4.7.1 Initial Ground Water Sampling at Configuration 4

Ground water samples were collected from various depths in a few Configuration 4 observation wells and the remediation wells during early August 2006. At this time, the Colorado was flowing at rates between 4,500 to 5,200 cfs.

The TDS concentrations measured in Configuration 4 wells in late August 2006 (Figure 4–7) ranged from 12,000 (well 0770 at 15 ft bgs) to 59,000 milligram per liter (mg/L) (well 0777 at 32 ft bgs). As expected, TDS levels increased with depth in the aquifer, and the brine surface, defined by a TDS concentration of 35,000 mg/L, was encountered at a depth of 32 ft bgs in the southern end of the well field and at a more shallow unspecified depth (between 15 and 32 ft bgs) at the northern end. This result was expected based on the preceding performance evaluation (DOE 2006a) that indicated the brine surface becomes shallower with proximity to the Moab Site's south boundary. These results are also comparable with observations made in the Configuration 2 area, where previous studies placed the ambient brine surface at depths of about 25 to 40 ft bgs. It should also be noted that unlike other configurations, Configuration 4 is not located directly downgradient of an irrigated plot.

The lowest uranium concentration measured in Configuration 4 wells during the initial sampling event in August 2006 was observed at remediation well 0779 (1.4 mg/L at 32 ft bgs) and the highest concentration (3.2 mg/L) was detected in a sample collected from well 0775 at depths of 15 and 32 ft bgs. Uranium concentrations in remediation wells comprising the southern half of the remediation system ranged from 1.7 to 3.1 mg/L. Configuration 4 remediation wells in the northern half had uranium concentrations that ranged from 1.4 to 3.2 mg/L. No distinct trends in uranium concentration with depth were observed in the Configuration 4 wells.

The lowest ammonia (as nitrogen) concentration during the initial sampling event was 170 mg/L (well 0770 at 15 ft bgs) and the highest ammonia concentration was 1,300 mg/L (well 0776 at 32 ft bgs). These concentrations reflected the tendency for ammonia concentrations to increase with depth below the top of the saturated zone. On the whole, ammonia concentrations in the Configuration 4 area were significantly lower compared to those observed in the vicinity of Configuration 2, where ammonia concentrations of 1,000 to 2,000 mg/L under non-pumping conditions and at depths of 20 to 30 ft bgs are common. In addition, the results indicated the largest ammonia concentrations in site ground water tend to be observed at and immediately below the brine surface as discussed in previous investigations (DOE 2005b, 2005d).

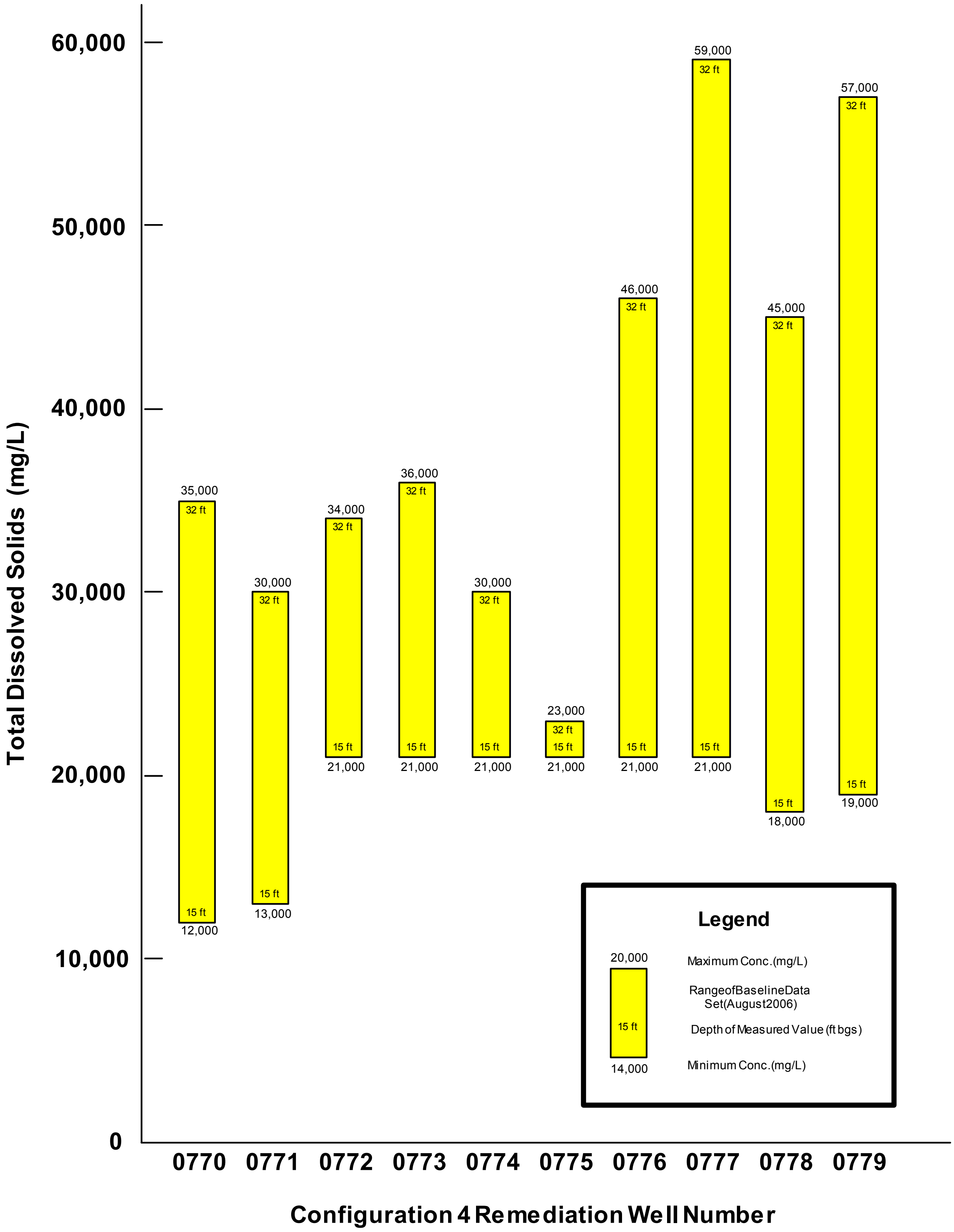

Figure 4–7. TDS Concentrations from Configuration 4 Profile Sampling, August 2006

4.7.2 Step-Drawdown Test

The Configuration 4 remediation wells were hydraulically developed in June 2006 using surge and bail techniques, as recommended in Appendix B of the *Operations, Maintenance, and Performance Monitoring Plan for the Interim Action Ground Water Treatment System, Moab Utah* (DOE 2005a). After initial sampling of Configuration 4 wells in late August, step-drawdown aquifer tests were conducted at some of the remediation wells. These tests made it possible to develop estimates of aquifer hydraulic conductivity and provided some information regarding well efficiency.

Testing was performed on wells 0770, 0771, 0772, 0773, 0776, 0778, and 0779. During each of the tests, the pump intake was set at a depth of approximately 30 ft bgs. In general, the first step at each well was set at 3 gpm, 5 gpm for the second step, and 10 gpm for the third (and final) step. Due to equipment problems, it was not possible to pump consistently at a rate of 10 gpm for the third step for wells 0778 and 0779. As a result, tests for the final steps were completed at rates of 8 and 6 gpm, respectively. In addition it should be noted that during the 0778 step test, it was not possible to shut off adjacent well 0779. As a result, well 0779 was pumping during the entire time the 0778 test was being completed.

The pumping rates and drawdowns monitored during each step were used to assess the degree to which each well's specific capacity (Domenico and Schwartz 1990) decreased with increased pumping rate (Table 4–13).

Table 4–13. Pumping Rates, Drawdowns, and Calculated Specific Capacities During Hydraulic Testing of Configuration 4 Extraction Wells, September 2006

Well	**1st Step**			**2nd Step**			**3rd Step**		
	Q (gpm)	**s (ft)**	**Specific Capacity (gpm/ft)**	**Q (gpm)**	**s (ft)**	**Specific Capacity (gpm/ft)**	**Q (gpm)**	**s (ft)**	**Specific Capacity (gpm/ft)**
0770	3	0.17	17.6	5	0.27	18.5	10	0.58	17.2
0771	3	0.18	16.7	5	0.31	16.1	10	0.68	14.7
0772	3	0.25	12.0	5	0.44	11.4	10	0.87	11.5
0773	3	0.21	14.3	5	0.34	14.7	10	0.68	14.7
0776	3	0.25	12.0	5	0.4	12.5	10	0.81	12.3
0778	3	0.64	4.7	5	1.13	4.4	8	1.87	4.3
0779	3	0.34	8.8	5	0.53	9.4	6	0.63	9.5
Average =			12.3	**Average =**		12.4	**Average =**		12.0

Q = pumping rate; s = drawdown; gpm = gallons per minute; ft = feet; gpm/ft = gallons per minute per foot.

4.7.3 Hydraulic Conductivity Estimates

The specific capacities listed in Table 4–13 for the seven Configuration 4 wells tested during September 2006 can be translated into hydraulic conductivities by first estimating the transmissivity of the tested portion of an aquifer (Heath 1989).

$$T \approx 300\frac{Q}{s} \tag{1}$$

where T = transmissivity (ft^2/day),
Q/s = specific capacity (gpm/ft),
Q = pumping rate (gpm), and
s = drawdown (ft).

Hydraulic conductivity is in turn estimated with

$$K = \frac{T}{b} \tag{2}$$

where K = aquifer hydraulic conductivity (ft/day), and
b = the thickness of the tested portion of the aquifer (ft).

Assuming that the screen length of each of tested well (25 ft) represented the tested portion of the aquifer, application of equations (1) and (2) to the average specific capacities listed in Table 4–13 for each step resulted in estimated hydraulic conductivities of about 148, 149, and 144 ft/day. These values are similar to hydraulic conductivities calculated for Configuration 1 step-drawdown tests on Configuration 1 wells (92−132 ft/day) when they were first installed (These hydraulic conductivities are also similar to previous estimates of K [DOE 2003d] for the gravelly sand and sandy gravel materials comprising most of the alluvial aquifer [100 to 180 ft/day]).

The data in Table 4–13 provide some measure of the relative productivity of individual remediation wells in the Configuration 4 system. Well 0770 appears to be the most productive, and well 0771 is the second most productive. Due to the fact that well 0779 was pumping while the 0778 test was being completed, the results indicate well 0778 was the least productive.

5.0 System Performance

This section provides information regarding the well field performance during the 2006 pumping season when Configurations 1, 2, 3, and 4 were actively extracting ground water and the infiltration trench was injecting fresh water. In addition, this section includes a discussion regarding the total well field ground water extraction rate, evaporation pond storage volume, and sprinkler system discharge rate for the 2006 season.

As part of this system performance assessment, each individual extraction or remediation well's ground water extraction rate and volume of ground water extracted are presented. In addition, extraction/remediation well drawdown data were used to determine the specific capacity of each well, and the drawdown data collected from observation wells were used to assess the lateral zone of influence generated by each Configuration.

The individual pumping rates and associated volume of ground water extracted by each well contained within each Configuration will be discussed separately. Some of the monthly extracted ground water volumes presented this section are estimates. The data listed were generally based on flow rates recorded at meters installed at each extraction wellhead. These flow meters occasionally malfunctioned, which meant that some pumping rates had to be assumed using rates that were accurately captured prior to and after periods of malfunction. In addition, even when flow meter readings appeared to be accurate, they did not always fall on the last day of a month.

The ability of extraction/remediation wells to capture shallow ground water migrating toward the Colorado River during 2006 was assessed by examining water elevation data collected from these wells and nearby observation wells. To account for the effects of changing river stage, continuously monitored ground water elevations at observation wells were compared to equivalent water level information collected from background well 0405, located along the river bank within the Baseline Area (Figure 4–1). Up until late September 2006, the water chemistry and ground water elevation data collected from this location were not influenced by well field operations. However, once the full-scale infiltration trench freshwater injection was started on September 28, 2006, the shallow zone of the Baseline Area started experiencing diluted analyte concentrations and minimal ground water mounding on the order of 0.1 to 0.2 ft by the end of October. Because ground water elevations at this location were used to represent background conditions for the entire year, computed drawdowns during October through December 2006 based on these data (such as the drawdowns due to pumping at extraction wells) were expected to be slightly larger than actual. However, the influence of this error on the overall assessment of each configuration's hydraulic performance was expected to be minor.

The ground water elevation measured from well 0405 does fluctuate in response to changes in the Colorado River stage, as shown in Figure 5–1. The ground water elevation measured in well 0405 represents the background ground water elevation for all the wells located within the IA well field.

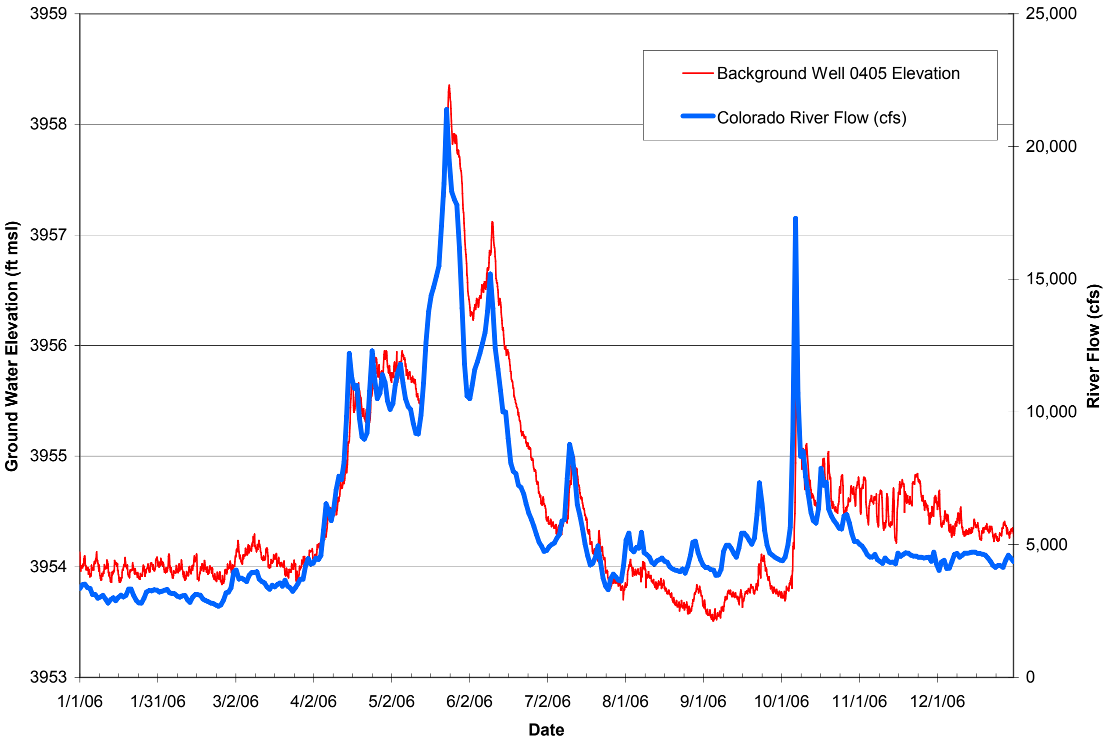

Figure 5–1. Baseline Area Well 0405 Ground Water Elevation and Colorado River Flow Data During 2006.

Plots were generated showing measured ground water levels collected from the well in question with comparable water elevations from background well 0405 and applicable pumping rates for 2006. The background water elevation data were adjusted so that both wells are assigned the same starting ground water elevation prior to the time period when pumping began and after the pumping was suspended for the winter. Differences between the two curves represent the estimated drawdown in response to pumping. Appendices C, D, E, and F contain the individual wells pumping rate data, temporal plots, and ground water elevation data for Configuration 1, 2, 3, and 4 (respectively) wells used in this performance assessment. These temporal plots show that it becomes difficult to gage extraction/remediation and observation well drawdowns during months of high runoff in the river. The peak mean daily flow in the river in 2006 was 21,400 cfs (on May 24), which represents the average annual peak flow. During the month leading up to the peak and for a few months following it, little, if any drawdown due to pumping, could be discerned using temporal graphs of ground water elevation.

The pumping rate data collected at the same time at which the drawdown was measured were used when calculating the specific capacity. Comparisons of 2006 specific capacity estimates to 2005 estimates (where applicable) provide information regarding the well efficiency trends over time. In addition, these data also provide some measure of the interference effects that the extraction wells have on each other when pumped simultaneously. Due to overlapping drawdown effects estimates indicate wells located at the northern and southern ends of the Configurations have a higher specific capacity compared to wells located near the center.

Pumping rate and volume data collected from the infiltration trench and the evaporation pond sprinkler system are contained in Appendices G and H, respectively.

5.1 Configuration 1 Performance

Configuration 1 extraction wells (Figure 4–2) 0470 through 0477 are screened from approximately 10 to 20 ft bgs, and wells 0478 and 0479 are screened from approximately 10 to 25 ft bgs. These extraction wells were restarted for the 2006 season on March 9. Wells 0471, 0473, 0476, 0477, and 0479 were shut down for the winter on November 6, and the remaining wells were shut down for the season on December 18. Well SMI-PW02, which is also discussed in this section and is considered a component of Configuration 1, was restarted on May 26 and shut down for the winter on November 27.

5.1.1 Configuration 1 Pumping Rates and Ground Water Extraction Volumes

Monthly extraction volumes between March and December 2006 for each of the ten wells comprising the Configuration 1 system and SMI-PW02 are listed in Table 5–1. More complete data for each well are provided in Appendix C−1.

The data presented in Table 5–1 show that Configuration 1 wells extracted a combined volume of about 8.3 million gallons of ground water during 2006. Similar to the 2005 remediation season, well 0470, the southernmost extraction well in the system, removed the largest quantity of ground water during 2006 while well 0474, located near the middle of system, provided the smallest pumped volume.

Pumping from well SMI-PW02, which did not begin until late May 2006, removed more than 6 million gallons of ground water during the year. This quantity reflected the capacity of well SMI-PW02 to be pumped at higher rates than those that were achieved at individual Configuration 1 wells.

It should be noted that the estimated total ground water extraction volume attributed to Configuration 1 wells (8.3 million gallons) using wellhead meters is considerably less than a total volume of 10.6 million gallons indicated by a totalizer flow meter for the system. This discrepancy reflects the uncertainty associated with flow measurements at individual extraction wells.

Average monthly pumping rates at Configuration 1 wells were analyzed with the intent of characterizing individual well contributions to contaminant mass removal. Because, as previously mentioned, pumps were sometimes shut off during the February to December 2006 period, the pumping rate analysis was based solely on measured pumping rates when wellhead meters were operating properly, rather than using cumulative pumping volumes provided by the meters. Monthly average pumping rates at each well and average rates for the March through December 2006 period (Table 5–1 and Figure 5–2), illustrate how ground water withdrawals from the system can vary both temporally and spatially.

Table 5–1. Monthly Average Pumping Rates and Extraction Volumes at Configuration 1 Remediation Wells, March through December 2006

Month	Well 0470		Well 0471		Well 0472		Well 0473		Well 0474	
	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)
Mar 2006	3.15	112,065	1.96	69,287	2.04	72,767	1.87	66,895	0.88	31,734
Apr 2006	3.70	148,019	3.37	134,865	2.43	97,465	2.33	93,961	0.98	39,585
May 2006	3.62	172,009	3.41	161,857	2.03	96,529	1.97	93,567	0.89	42,545
June 2006	3.06	141,270	2.86	130,051	2.04	95,272	2.17	98,482	0.85	38,373
July 2006	3.23	143,648	3.07	136,902	2.34	104,364	2.41	107,196	0.87	38,401
Aug 2006	3.12	125,559	2.99	120,660	2.30	92,923	2.31	93,073	0.98	39,439
Sept 2006	2.15	89,836	2.21	91,526	1.64	68,172	1.70	70,613	0.75	31,661
Oct 2006	2.86	136,788	2.71	130,244	1.44	95,021	2.10	100,971	0.88	42,651
Nov 2006	3.08	125,556	0.96	26,330	1.93	78,721	0.87	23,639	1.14	49,104
Dec 2006	2.36	93,594	0.00	0	1.42	56,386	0.00	0	1.09	43,175
Annual Avg / Total	3.13	1,288,344	2.84	1,001,722	2.03	857,620	2.12	748,397	0.93	396,668

Month	Well 0475		Well 0476		Well 0477		Well 0478		Well 0479	
	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)
Mar 2006	2.26	80,504	1.71	61,111	1.52	54,052	0.40	13,503	1.25	42,741
Apr 2006	2.56	100,650	2.70	104,221	1.89	74,219	3.56	139,116	1.88	71,145
May 2006	2.69	127,092	2.80	133,171	1.88	89,420	5.32	254,519	1.72	83,515
June 2006	2.59	111,755	1.93	82,176	1.67	70,514	4.22	194,753	1.75	78,768
July 2006	2.54	113,052	2.31	103,531	1.52	67,174	2.89	128,659	2.00	91,138
Aug 2006	2.59	104,423	2.02	81,331	1.59	64,159	1.91	77,161	1.97	79,579
Sept 2006	1.86	79,387	1.54	63,229	1.13	47,235	1.39	57,189	1.42	59,218
Oct 2006	2.09	100,908	1.86	91,125	1.48	70,918	2.17	101,858	1.81	86,891
Nov 2006	1.59	60,502	1.38	49,733	0.70	21,237	2.13	84,556	0.86	26,043
Dec 2006	1.58	62,379	0.00	0	0.00	0	1.80	71,905	0.00	0
Annual Avg / Total	2.34	940,652	2.15	769,628	1.60	558,928	2.77	1,123,219	1.75	619,038

Month	Well SMI-PW02	
	Q (gpm)	Vol (gal)
May 2006	23.4	170,120
June 2006	28.2	1,276,931
July 2006	27.0	1,220,520
Aug 2006	28.2	1,125,416
Sept 2006	20.5	894,914
Oct 2006	19.9	865,000
Nov 2006	16.4	628,984
Avg / Total	23.3	6,181,885

Notes: Q = pumping rate; gpm = gallons per minute; Vol = volume; gal = gallons

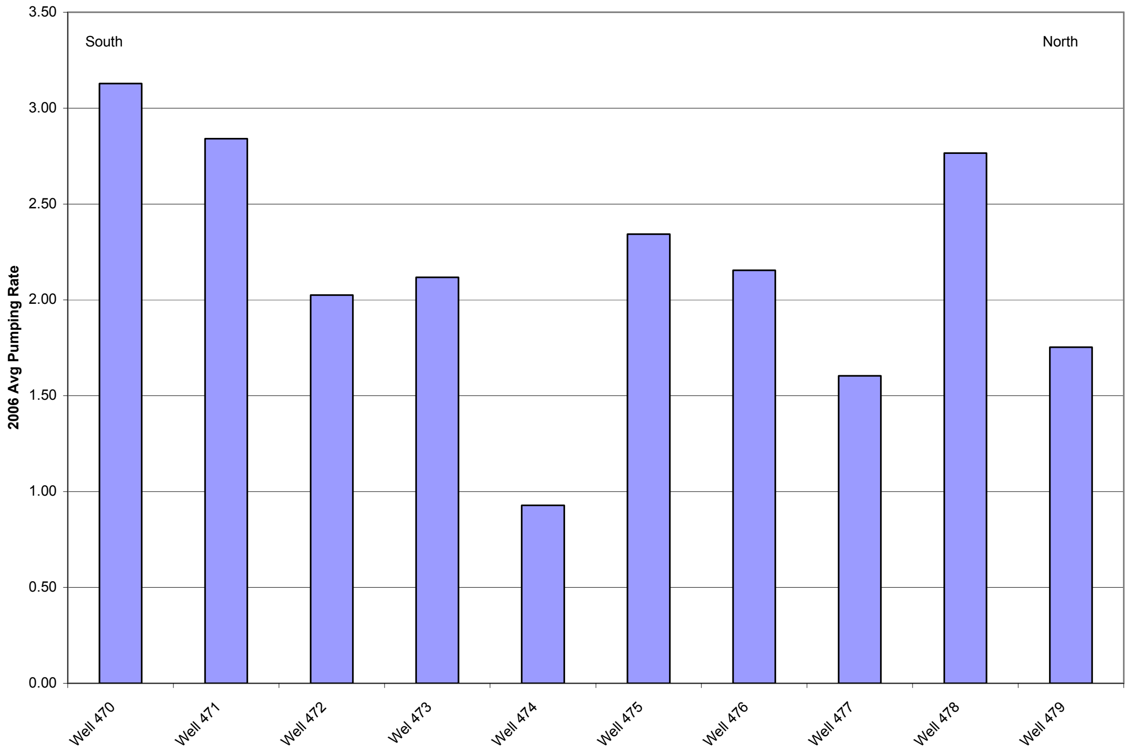

Figure 5–2. Average Pumping Rates from Configuration 1 Wells Between March and December 2006

5.1.2 Configuration 1 Extraction Well Ground Water Drawdowns

Figure 5–3 is an example plot showing the discernible drawdowns at well 0470. Plots generated for each of the extraction wells are contained in Appendix C−2. As this figure shows, ground water elevation data collected from well 0470 drops below the background fluctuation elevation data (which represents the ground water elevation that would be measured in the well if ground water was not being extracted), especially during the months leading up to peak runoff in the river and in the months following the peak flow. During the peak runoff time frame the ground water elevation is more influenced by the river stage, and not the pumping rate. On December 18, 2006, the water elevation matches back up to the pre-pumping elevation fluctuation measured in well 0405.

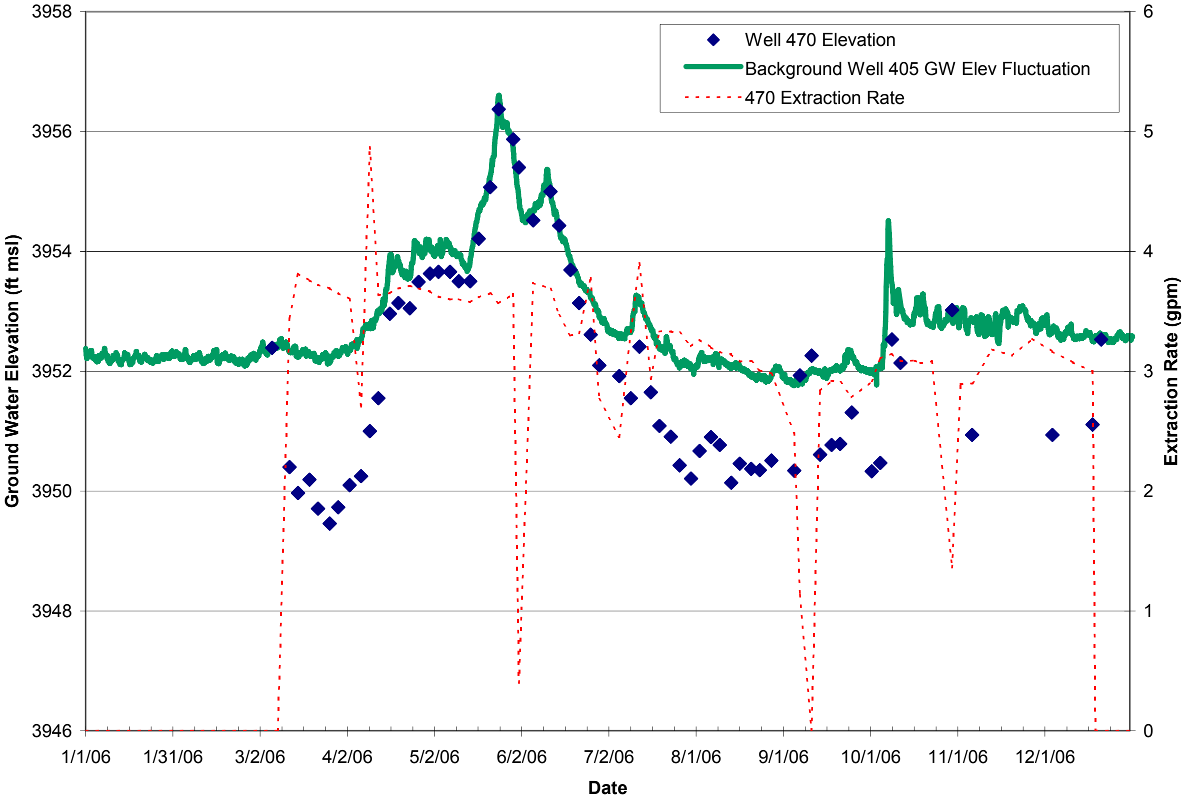

Figure 5–3. Ground Water Elevations at Extraction Well 0470 and Background Well 0405 During 2006

The graphs contained in Appendix C−2 were used to compute drawdowns in each well at two different times during the pumping season. Drawdowns measured April 3 were considered representative of ground water conditions shortly after the start of full system pumping and prior to the high spring runoff, whereas drawdowns measured on October 2 were representative of conditions late in the pumping season and after the period of high river flows. The resulting drawdowns are presented in Table 5–2 along with corresponding pumping rates at each well.

The data presented in Table 5–2 reveal that the extraction wells located near the center of Configuration 1 generally have lower specific capacities, which is likely a function of overlap interference caused by pumping from adjacent wells. Of some interest is that specific capacities at most wells appear to increase late in the year as compared to the previous April. Only the wells located on the northern end of the well field (0478 and 0479) slightly decrease or remain constant. This response can be explained by the pumping of Configuration 2 remediation well 0570, which lies approximately 50 ft northeast of well 0479. Well 0570 was not actively extracting ground water during April 2006, but was operating in October 2006.

Table 5–2. Computed Drawdowns and Specific Capacities at Configuration 1 Extraction Wells at Two Different Times During 2006

Well	Pre-Peak Flow (April 3, 2006)			Post-Peak Flow (October 2, 2006)		
	Pumping Rate (gpm)	**Measured Drawdown (ft)**	**Spec Cap (gpm/ft)**	**Pumping Rate (gpm)**	**Measured Drawdown (ft)**	**Spec Cap (gpm/ft)**
0470	3.6	2.3	1.6	2.9	1.7	1.8
0471	3.3	2.4	1.4	2.9	1.9	1.6
0472	2.3	2.2	1.0	2.1	1.2	1.8
0473	2.4	2.8	0.8	2.3	1.7	1.3
0474	1.0	1.3	0.8	1.0	0.9	1.2
0475	2.6	3.1	0.8	2.4	2.1	1.2
0476	1.9	3.3	0.6	2.1	1.9	1.1
0477	1.8	2.2	0.8	1.5	1.7	0.9
0478	2.6	4.9	0.5	1.8	4.4	0.4
0479	1.7	2.1	0.8	1.9	2.5	0.8
Average			**0.9**	**Average**		**1.2**

Spec Cap = specific capacity; gpm = gallons per minute; ft = feet; gpm/ft = gallons per minute per foot.

As exhibited previously (DOE 2006a), the computed specific capacities of Configuration 1 wells when all wells are being pumped (Table 5–2) are smaller than specific capacities determined from step-drawdown testing of individual extraction wells immediately after they were installed in 2003 (3.1 to 4.4 gpm/ft). This difference is attributed partly to the additive effects of drawdown created by pumping multiple wells at the same time and partly to a gradual decrease in well efficiencies over the course of the 2004 pumping season (DOE 2005b). However, the range of specific capacity values listed in Table 5–2 (0.4−1.8 gpm/ft) is similar to an equivalent range of values computed during the 2005 pumping season (0.3−2.3 gpm/ft). The 2005 pre-peak average specific capacity was 1.1 (2006 average was 0.9), and the post-peak average was 1.0 (the 2006 average was 1.2). This observation indicates that Configuration 1 well efficiencies did not significantly decline during the 2006 pumping season.

The water level data used to prepare Figure 5–3 (and similar graphs in Appendix C−2) and the data included in Table 5–2 are contained in Appendix C−3.

5.1.3 Configuration 1 Observation Well Ground Water Drawdowns

Figure 5–4 presents a plot of measured ground water levels at observation well 0480 along with comparable water elevations from background well 0405 and Configuration 1 total pumping rates for 2006. Differences between the two curves between March and November 2006 indicate that drawdowns of up to 1 ft were generated in the area of well 0480 as a result of Configuration 1 pumping. Appendix C−4 contains similar plots for all of the Configuration 1 observation wells whose water levels were continuously monitored during the study period.

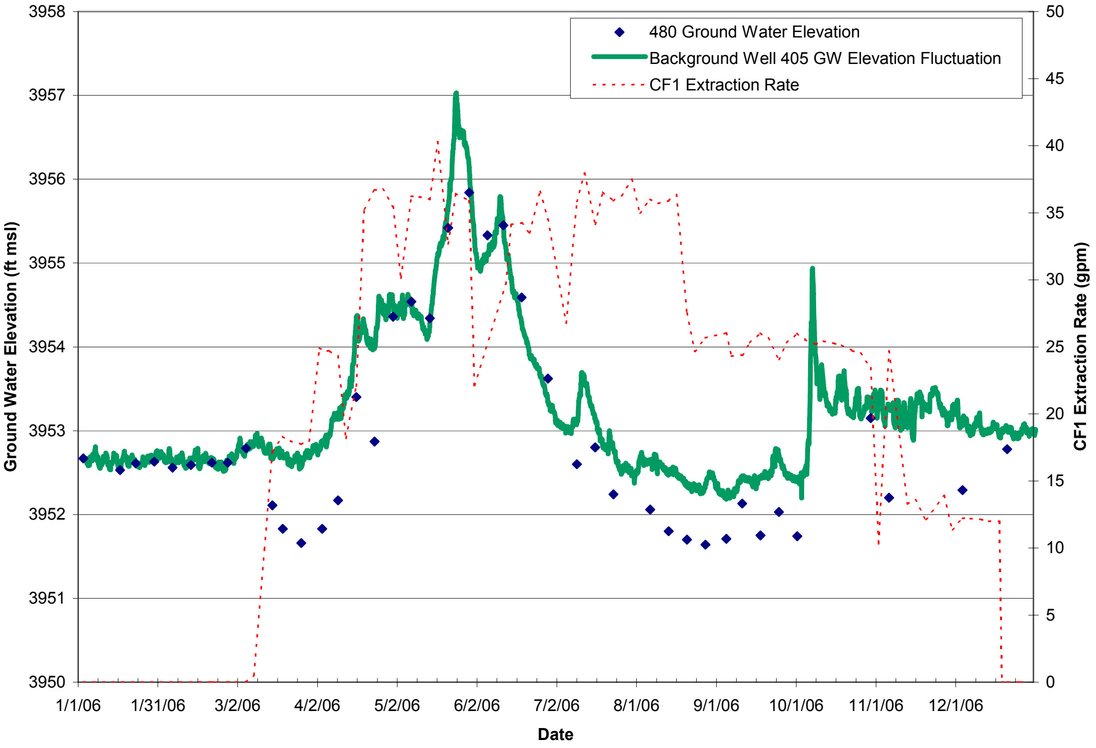

Figure 5–4. Ground Water Elevations at Observation Well 0480 and Background Well 0405 During 2006

Measured drawdowns at numerous wells located at different distances from the extraction well system's axis were examined to assess the zone of influence created by Configuration 1 pumping. This exercise was carried out for two separate times, March 27 and August 28, which were selected to represent conditions prior to and after high spring runoff in the river, respectively. The resulting computed drawdowns are presented in Table 5–3, along with ancillary information describing each well's screened interval and location relative to the extraction well system.

As expected, shallow observation wells located close to the extraction system show the largest drawdowns. The wells screened below 30 ft bgs (0482, 0485, 0557, 0558, 0560, and 0561) do not appear to respond to pumping. Overall, the data presented in Table 5–3 suggest that the drawdowns created by ground water extraction at Configuration 1 wells are discernible as far as 35 ft upgradient of the extraction system and about 70 ft downgradient of the system.

Table 5–3. Measured Drawdowns at Configuration 1 Observation Wells in 2006

Well	Relative Location	Distance from Well Field Axis (ft)	Screen Interval (ft bgs)	Measured Drawdown (ft)	
				Mar 27, 2006	Aug 28, 2006
0403	Downgradient	56	13.3−18.2	0.7	0.8
0480	Upgradient	23	15.5−19.8	0.9	0.7
0481	Upgradient	26	25.4−29.7	0.2	0.5
0482	Upgradient	26	55.4−59.7	0.0	0.3
0483	Downgradient	11	15.5−19.8	1.1	0.7
0484	Downgradient	11	25.5−29.8	0.3	0.3
0485	Downgradient	19	55.6−59.9	0.0	0.2
0551	Off southern end	30	10.3−20.3	0.5	0.0
0552	Upgradient	30	10.2−20.2	0.8	0.8
0553	Downgradient	8	10.6−20.5	1.0	0.5
0554	Downgradient	15	10.4−20.4	0.5	0.5
0555	Upgradient	34	10.2−20.1	0.6	0.3
0556	Off northern end	30	10.2−20.1	0.7	0.7
0557	Upgradient	30	35.0−45.0	0.0	0.5
0558	Downgradient	23	35.0−45.0	0.0	0.0
0560	Downgradient	60	30.0−40.0	0.0	0.5
0561	Downgradient	60	45.2−55.2	0.0	0.0
0596	Downgradient	60	15.3−25.3	0.4	0.0

Note: Data collected from wells 0407 and 0559 were not used in this table.

The water level data used to prepare Figure 5–4 (and similar graphs in Appendix C−4) and the data included in Table 5–3 are contained in Appendix C−5.

5.2 Configuration 2 Performance

Configuration 2 remediation wells (Figure 4–3) are designed to both inject fresh water and extract ground water. Wells 0570, 0572, 0574, 0576, and 0578 are screened from 15 to 30 ft bgs and wells 0571, 0573, 0575, 0577, and 0579 are screened from 25 to 40 ft bgs. At the beginning of 2006 Configuration 2 wells were still injecting fresh water (fresh water injection was started in October 2004). On March 16, fresh water injection activities were suspended due to construction activities for a new fresh water storage pond. By March 23 four of the Configuration 2 remediation the wells had started extracting ground water. By May 2006, three additional wells were extracting ground water. Equipment problems plagued wells 0574 and 0578 when operating in the extraction mode, and these wells did not operate once the system was switched over to extraction. Mechanical problems also limited the operation of wells 0571, 0573, 0576, and 0579. All Configuration 2 ground water extraction was suspended on October 2, 2006, for the remainder of the year due to decreased storage capacity in the evaporation pond.

5.2.1 Configuration 2 Pumping Rates and Ground Water Extraction Volumes

Monthly extraction volumes between March and December 2006 for the Configuration 2 system are listed in Table 5–4. More complete data for each well are provided in Appendix D−1. As shown in Table 5–4, well 0579 had the highest flow rate (5.4 gpm) while well 0577 extracted the largest volume (approximately 463,000 gal). This is due to the fact that well 0579 operated only a short time during the 2006 pumping period.

The data presented in Table 5–4 show that Configuration 2 wells extracted a combined volume of about 2.1 million gallons of ground water during 2006. This volume, while inhibited by mechanical problems impacting various Configuration 2 wells, was also limited by the low efficiency of each of the Configuration 2 remediation wells. Efficiency problems with these wells have been previously documented (DOE 2005c, DOE 2005d), and despite re-development of these wells in February 2006, these wells remain inefficient.

Table 5–4. Monthly Average Pumping Rates and Extraction Volumes at Configuration 2 Remediation Wells, March through December 2006

Month	**Well 0570**		**Well 0571**		**Well 0572**		**Well 0573**	
	Q (gpm)	**Vol (gal)**	**Q (gpm)**	**Vol (gal)**	**Q (gpm)**	**Vol (gal)**	**Q (gpm)**	**Vol (gal)**
Mar 2006	0.00	0	4.34	45,735	0.00	0	0.91	9,549
Apr 2006	0.00	0	3.00	120,401	0.41	15,600	0.78	32,469
May 2006	1.18	24,915	2.65	27,020	1.08	51,000	1.66	80,116
June 2006	1.42	59,660	0.01	557	1.21	48,000	1.03	52,536
July 2006	1.14	48,725	0.00	103	1.18	53,000	0.00	0
Aug 2006	1.18	46,908	0.00	0	0.82	33,000	0.00	0
Sept 2006	0.58	24,579	0.00	0	0.71	27,000	0.00	0
Oct 2006	0.64	6,823	0.00	0	0.60	6,000	0.00	0
Annual Avg / Total	1.09	211,610	2.81	193,816	1.01	233,600	1.27	174,670

Month	**Well 0575**		**Well 0576**		**Well 0577**		**Well 0579**	
	Q (gpm)	**Vol (gal)**	**Q (gpm)**	**Vol (gal)**	**Q (gpm)**	**Vol (gal)**	**Q (gpm)**	**Vol (gal)**
Mar 2006	0.00	0	0.00	0	1.44	15,293	1.40	25,000
Apr 2006	1.04	40,724	0.29	11,184	1.48	60,339	5.07	201,500
May 2006	1.90	91,446	0.00	0	1.55	73,977	5.45	140,000
June 2006	1.85	84,824	0.00	0	1.47	63,360	0.00	0
July 2006	1.66	75,041	0.00	0	1.67	76,286	0.00	0
Aug 2006	1.56	61,015	0.00	0	1.69	68,424	0.00	0
Sept 2006	1.13	46,849	0.00	0	1.90	74,998	0.00	0
Oct 2006	0.74	7,864	0.00	0	2.36	30,332	0.00	0
Annual Avg / Total	1.62	407,763	0.29	11,184	1.63	463,009	5.40	366,500

Notes: Q = pumping rate; gpm = gallons per minute; Vol = volume; gal = gallons

Due to the fact that pumps were sometimes shut off during the March to December 2006 period; the pumping rate analysis was based solely on measured pumping rates when the pumps were in operation (i.e., the average flow rates presented in Table 5–4 and Figure 5–5 were calculated based on pump operation time, and not averaged over the entire pumping season). In many instances the flow rate had to be estimated when the pump was running but the flow meter was not operating properly.

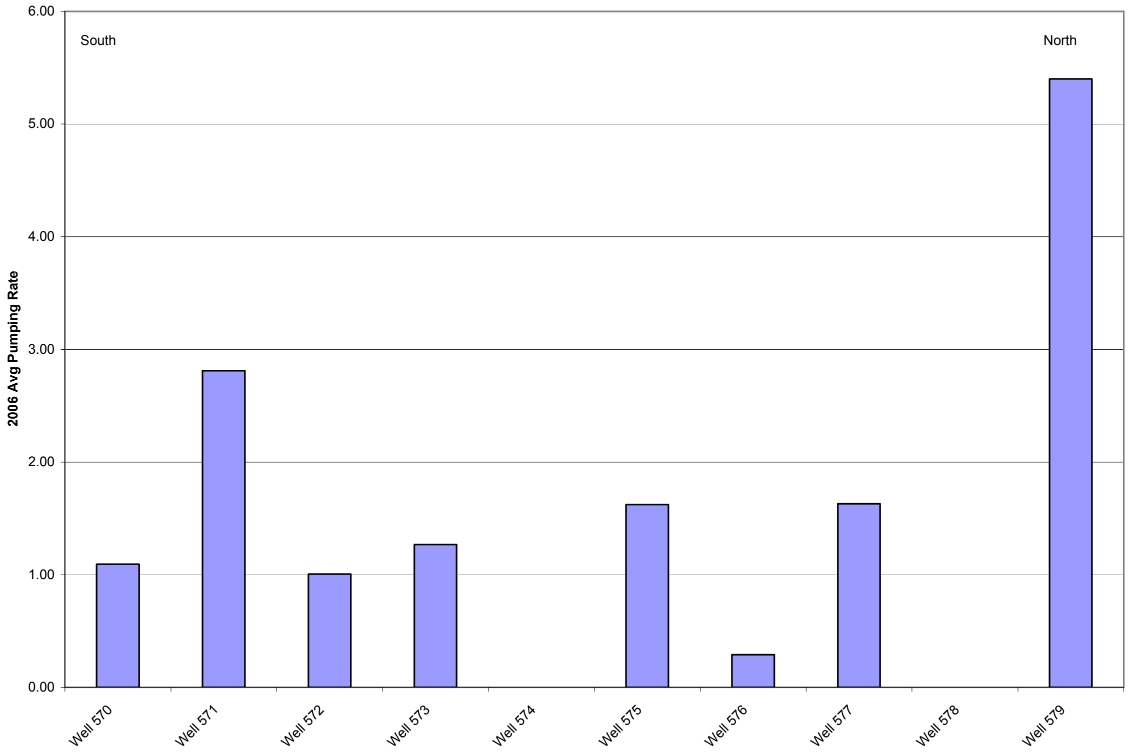

Figure 5–5. Average Pumping Rates from Configuration 2 Wells Between March and December 2006

5.2.2 Configuration 2 Remediation Well Ground Water Drawdowns

Figure 5–6 is a graph of the drawdown measured in well 0577 during 2006. As discussed in Section 5.2, fresh water injection into Configuration 2 remediation wells was stopped (on March 16) and ground water extraction was initiated on March 23 using only four of the ten wells. From that date, wells were switched over to the extraction mode at various times during 2006.

As shown in Figure 5–6, at the beginning of 2006 the water level was above the background ground water elevation fluctuation in response to fresh water injection. The elevation rebounds to the static elevation prior to the start of ground water extraction, and then returns to the static elevation once the pump was turned off.

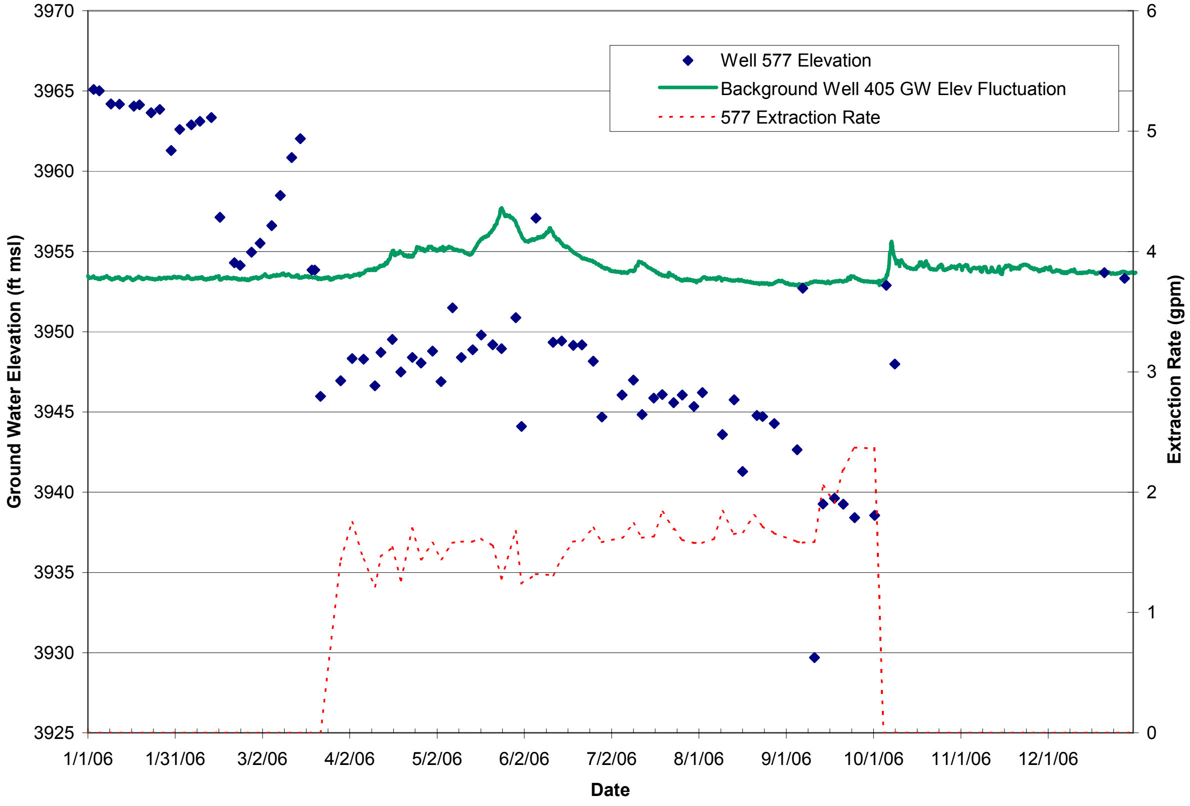

Figure 5–6. Ground Water Elevations at Remediation Well 0570 and Background Well 0405 During 2006

Similar plots to the graph shown in Figure 5–6 were prepared for all Configuration 2 remediation wells and are contained in Appendix D–2. Unlike the Configuration 1 extraction wells, these graphs were used to compute drawdowns in each well at only one time during the 2006 pumping season because of the limited time some wells were in operation. Drawdowns were measured near the middle of the time frame in which the well was actively extracting ground water. The resulting drawdowns, pumping rates, specific capacities and the time at which these measurements were taken are presented in Table 5–5.

Table 5–5. Computed Drawdowns and Specific Capacities at Configuration 2 Remediation Wells During 2006

Well	Date	Pumping Rate (gpm)	Measured Drawdown (ft)	Spec Cap (gpm/ft)
0570	7/20/06	1.5	14.2	0.11
0571	4/7/06	2.2	21.7	0.10
0572	7/17/06	1.1	15.2	0.07
0573	5/25/06	2.1	22.2	0.09
0575	7/6/06	1.7	12.3	0.14
0576	4/20/06	0.3	17.1	0.02
0577	7/6/06	1.6	7.7	0.21
0579	5/1/06	5.2	24.2	0.22
Average				**0.12**

Spec Cap = specific capacity; gpm = gallons per minute; ft = feet;
gpm/ft = gallons per minute per foot.

Note: Wells 0574 and 0578 did become operational in 2006

The specific capacity results presented in Table 5–5 cannot be compared to previous step test data because step tests were not completed for individual Configuration 2 wells (DOE 2006b). As expected, the data suggest that the Configuration 2 wells are significantly less efficient compared to the Configuration 1 extraction wells.

The water level data used to prepare Figure 5–6, similar graphs in Appendix D−2, and the data included in Table 5–5, are contained in Appendix D−3.

5.2.3 Configuration 2 Observation Well Ground Water Drawdowns

Similar to the Configuration 2 remediation well plots, the observation well plots differ from those of Configuration 1 due to fresh water injection prior to ground water extraction. As a result, ground water mounding was observed January through mid-March 2006. Once the system was switched over to ground water extraction on March 23, a time period in which measurable drawdown was observed was evident. Figure 5–7 presents a plot showing observation well 0583 ground water elevation data plotted with background well 0405 ground water elevation fluctuations and the Configuration 2 total extraction rate for 2006.

Both Figure 5–7 and the additional temporal plots in Appendix D−4 show that it becomes difficult to gage observation well drawdowns during months of high runoff in the river. During the month leading up to the peak and for a few months following it, little, if any, drawdown due to pumping could be discerned using temporal graphs of water elevation.

Using the graphical method described in Section 5.2, measured drawdowns at numerous wells located at different distances from the extraction well system's axis were examined to assess the zone of influence created by Configuration 2 pumping. This exercise was carried out for two separate times, April 3 and September 18, which were selected to represent conditions prior to and after high spring runoff in the river, respectively. The resulting computed drawdowns are presented in Table 5–6, along with each well's screened interval and location relative to the extraction well system.

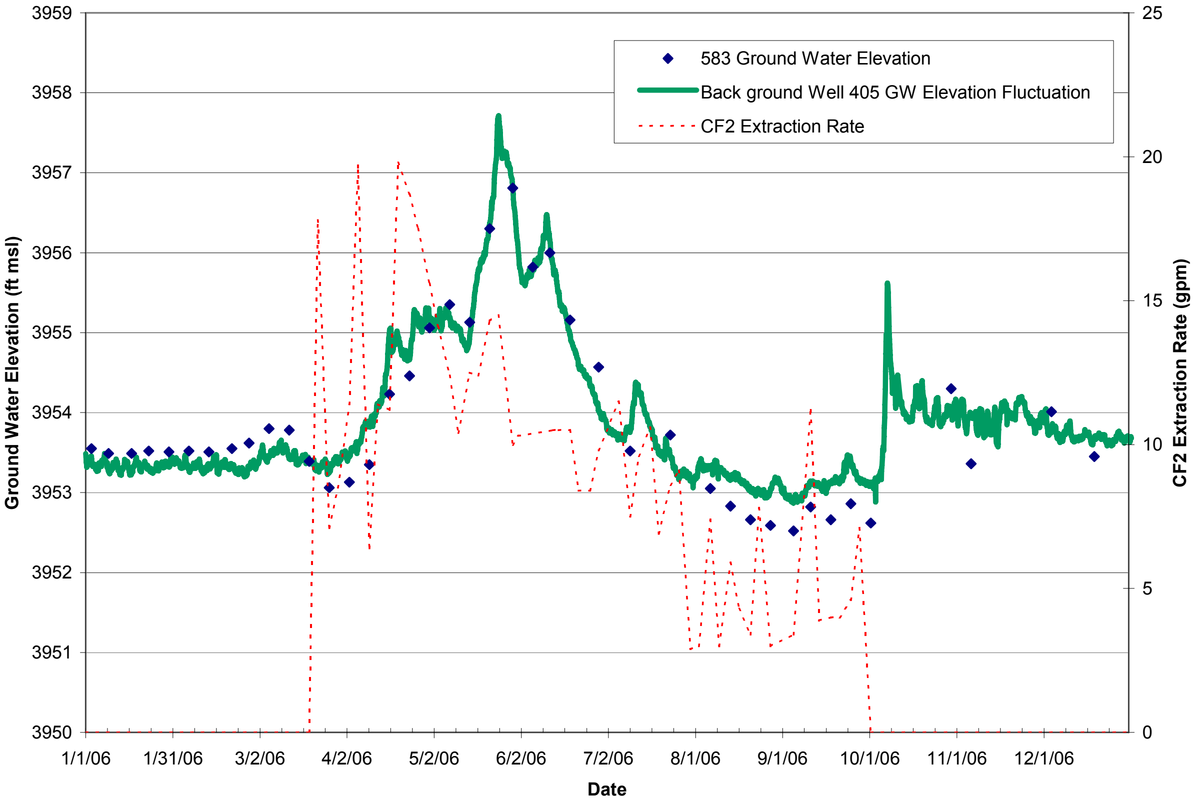

Figure 5–7. Ground Water Elevations at Observation Well 0583 and Background Well 0405 During 2006

Table 5–6. Measured Drawdowns at Configuration 2 Observation Wells in 2006

Well	Relative Location	Distance from Well Field Axis (ft)	Screen Interval (ft bgs)	Measured Drawdown (ft)	
				Apr 3, 2006	Sept 18, 2006
0401	Upgradient	20	13.0–17.9	0.4	0.5
0402	Along Axis	Na	13.4–18.3	0.3	0.5
0408	Upgradient	20	23.0–27.9	0.3	0.5
0580	Off southern end	30	10.2–20.2	0.4	0.3
0581	Upgradient	25	10.3–20.3	0.3	0.4
0582	Downgradient	20	9.8–19.7	0.4	0.4
0583	Upgradient	25	8.9–18.8	0.5	0.5
0584	Upgradient	25	10.3–20.2	0.4	0.5
0585	Downgradient	20	10.4–20.3	0.6	0.6
0586	Off northern end	30	10.0–19.9	0.5	0.9
0587	Downgradient	20	10.0–19.6	0.4	0.5
0588	Downgradient	20	24.8–34.8	0.5	0.7
0589	Downgradient	20	42.7–52.7	0.2	0.5
0600	Upgradient	40	19.5- 29.5	0.2	0.4
0601	Upgradient	25	19. 6–29.5	0.5	0.7
0602	Downgradient	15	9.5–19.5	0.4	0.5

In general, each observation well experienced between 0.2 and 0.7 ft of drawdown in response to Configuration 2 pumping. Overall, the data presented in Table 5–6 suggest that the drawdowns created by ground water extraction at Configuration 2 wells are discernible as far as 40 ft upgradient of the extraction system and more than 30 ft downgradient of the system.

Well 0586, which is located within 10 ft of Configuration 3 remediation well 0670, experienced 0.9 ft of drawdown in response to primarily Configuration 3 pumping after mid-May, at which time Configuration 2 remediation well 0579 had stopped extracting ground water due to mechanical problems. It should also be noted that well 0402, located between wells 0573 and 0574, had minimal drawdown considering it is located along the axis of the well field. However, well 0573 was actively extracting ground water only from late-March through late-June, at an average of only approximately 1.3 gpm. Well 0574 did not extract ground water during 2006 due to mechanical problems. As a result, the drawdown measured in well 0402 was primarily the result of pumping from wells 0572 and 0575.

The water level data used to prepare Figure 5–7 (and similar graphs in Appendix D−4) and the data included in Table 5–6, are contained in Appendix D−5.

5.3 Configuration 3 Performance

Configuration 3 remediation wells (0670 through 0679), screened from approximately 15 to 45 ft bgs and designed to both extract ground water and inject fresh water, exclusively extracted ground water during 2006. In general, the larger saturated thickness and larger slot size and sand pack designed to increase well efficiency provided higher sustainable flow rates and associated volumes of ground water extraction compared to Configurations 1 and 2. The Configuration 3 remediation wells started extracting ground water on March 14, 2006. By November 6, the odd-numbered wells were shut down for the winter, and the remaining wells were shut down on December 18.

5.3.1 Configuration 3 Pumping Rates and Ground Water Extraction Volumes

Estimated monthly pumping rates and extraction volumes between March and December 2006 for each of the ten wells comprising Configuration 3 (Figure 4–4) are listed in Table 5–7 and presented in Figure 5–8. Data regarding individual well pumping rates are contained in Appendix E−1.

As indicated in Table 5–7, the Configuration 3 wells individually extracted between approximately 1.6 (well 0670) and 1.0 million gallons (well 0679). Though the difference between these volumes might suggest problems with well efficiency in well 0679, this is not the case. In fact, none of the Configuration 3 wells were pumped at a sufficiently large rate that production was limited. Rather the differences for estimated pumped volumes for well 0670 and 0679 are better explained by the speed at which the control box was set for each individual well. Other factors may include accuracy problems encountered with wellhead flow meters during the early weeks of full system operation.

Table 5–7. Monthly Average Pumping Rates and Extraction Volumes at Configuration 3 Remediation Wells, March through December 2006

Month	Well 0670		Well 0671		Well 0672		Well 0673		Well 0674	
	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)
Mar 2006	2.08	47,127	2.20	49,786	2.00	45,029	2.17	48,984	2.01	45,349
Apr 2006	2.26	89,340	2.41	96,604	2.33	91,834	2.40	96,028	2.31	92,696
May 2006	4.23	199,786	4.13	195,702	4.18	197,810	4.62	211,818	3.61	168,137
June 2006	4.04	186,260	3.40	166,589	3.52	166,950	3.94	186,905	2.58	119,558
July 2006	4.43	203,407	3.98	155,848	3.64	143,565	4.35	170,132	3.80	149,780
Aug 2006	3.47	148,857	3.52	134,928	3.01	120,124	3.73	148,745	2.64	104,764
Sept 2006	3.12	129,784	2.74	113,873	2.35	98,143	3.06	126,965	2.29	94,614
Oct 2006	4.04	193,507	3.89	177,797	3.42	154,004	3.83	216,301	3.41	154,211
Nov 2006	4.28	270,725	2.83	57,501	2.94	86,822	3.71	43,860	3.65	147,925
Dec 2006	4.77	144,698	0.00	0	4.04	122,735	0.00	0	4.12	166,375
Annual Avg / Total	3.63	1,613,491	3.07	1,148,628	3.07	1,227,016	3.23	1,249,738	2.97	1,243,409

Month	Well 0675		Well 0676		Well 0677		Well 0678		Well 0679	
	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)	Q (gpm)	Vol (gal)
Mar 2006	2.46	45,687	2.13	48,088	2.35	53,182	2.76	62,445	2.02	45,414
Apr 2006	2.76	104,089	2.18	102,833	2.70	108,014	3.25	132,152	2.15	86,266
May 2006	4.76	205,065	4.57	210,842	4.58	215,098	4.96	232,767	4.32	202,578
June 2006	1.99	137,033	3.83	177,114	4.09	188,318	4.39	202,016	3.74	172,826
July 2006	3.76	130,448	4.32	198,824	4.67	212,955	4.80	188,177	2.45	130,116
Aug 2006	3.48	136,144	3.72	145,759	4.57	184,582	4.20	164,924	2.29	90,920
Sept 2006	2.82	118,734	3.02	125,815	4.57	184,345	3.43	141,944	2.39	99,169
Oct 2006	3.87	132,016	3.94	187,739	2.91	147,678	4.59	211,462	3.12	149,430
Nov 2006	2.78	117,160	4.22	174,751	3.00	30,040	3.84	111,445	3.21	37,675
Dec 2006	0.00	0	4.72	143,065	0.00	0	5.00	152,134	0.00	0
Annual Avg / Total	2.99	1,126,376	3.56	1,514,830	3.50	1,324,212	4.12	1,599,466	2.64	1,014,394

Notes: Q = pumping rate; gpm = gallons per minute; Vol = volume; gal = gallons

Average monthly pumping rates at each well (Table 5–7) and average per-well pumping rates for the March through December 2006 time period (Figure 5–8) indicates that, in general, all wells in the Configuration 3 system were equally productive in 2006. Average pumping rates ranged from 2.6 (well 0679) to 4.1 gpm (well 0678). With the exception of well 0679, each well was pumped at an average pumping rate of at least 3 gpm. This small range of values reflects the fact that pumping rates were not affected by saturation thickness limitations (i.e., the wells were not pumped at high enough rates to impact all available drawdown).

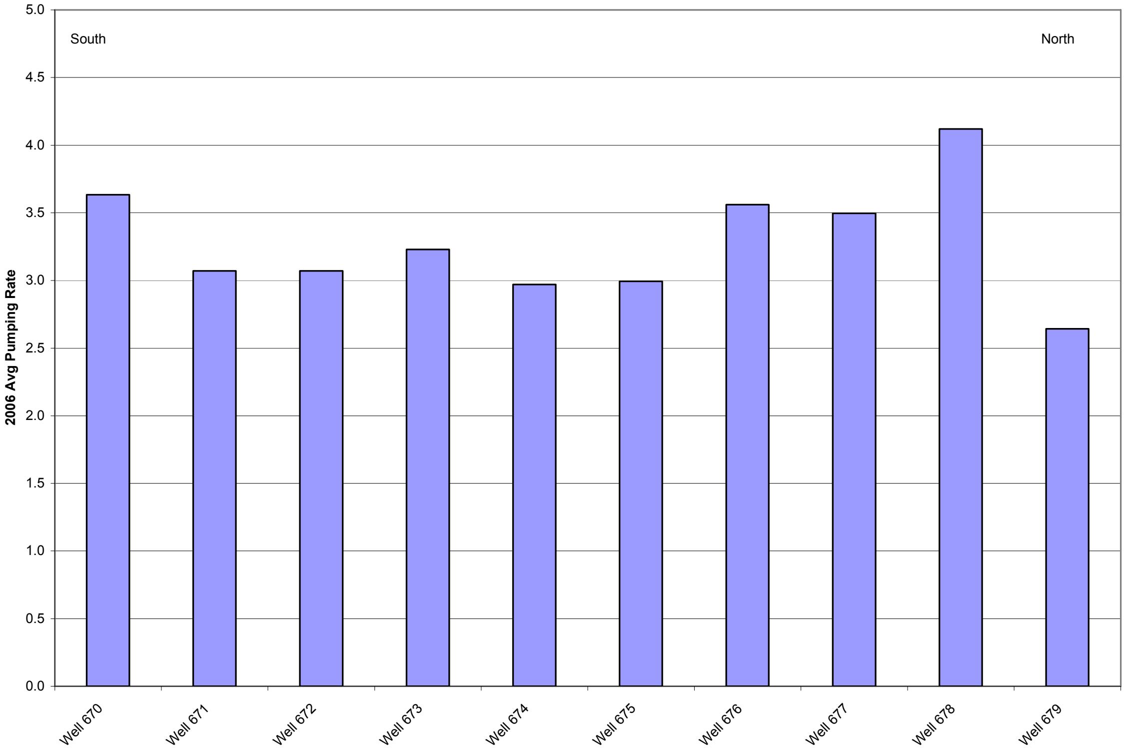

Figure 5–8. Average Pumping Rates from Configuration 3 Wells Between March and December 2006

Like Configuration 1, discrepancies were observed between the total pumped volume recorded by a totalizer meter and the comparable quantity based on readings at individual wellhead meters. The totalizer that measures the flow rate and volume for Configuration 3 also measures the volume and rate for Configuration 2. The totalizer meter indicated a total volume of extracted ground water for the 2006 pumping season of approximately 14.1 million gallons, whereas the sum of volumes at individual extraction wells was 15.1 million gallons.

5.3.2 Configuration 3 Extraction Well Ground Water Drawdowns

Figure 5–9 illustrates the resulting water levels measured at one of the Configuration 3 wells (well 0679) along with adjusted water elevations at background well 0405 and pumping rate data collected during 2006. Appendix E−2 includes similar plots to the one in Figure 5–9 for the remaining Configuration 3 remediation wells.

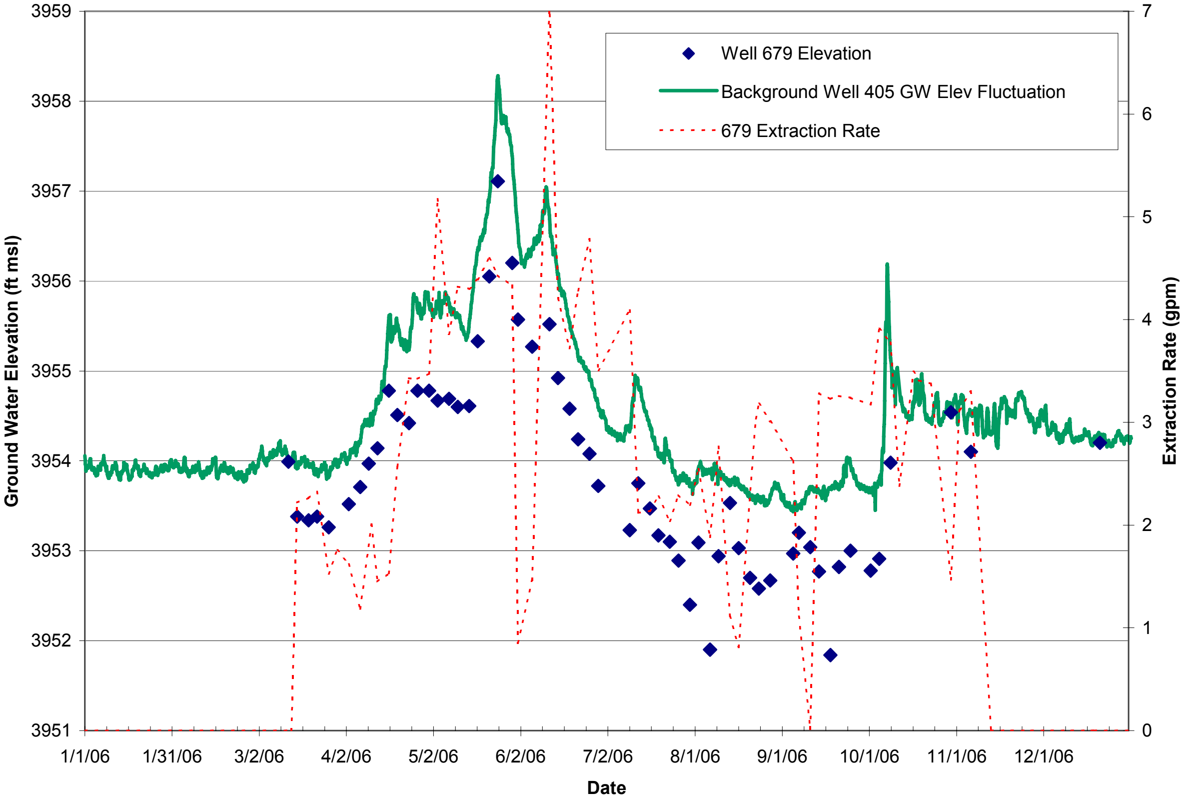

Figure 5–9. Ground Water Elevations at Remediation Well 0679 and Background Well 0405 During 2006

In an effort to discern the effects of Configuration 3 pumping on well efficiencies, drawdowns for each remediation well were examined on April 3 and September 25, during pre- and post-peak (respectively) Colorado River flows. The resulting drawdowns, pumping rates, and computed specific capacities at each well are presented in Table 5–8.

Table 5–8. Computed Drawdowns and Specific Capacities at Configuration 3 Remediation Wells at Two Different Times During 2006

Well	**Pre-Peak Flow (April 3, 2006)**			**Post-Peak Flow (September 25, 2006)**		
	Pumping Rate (gpm)	**Measured Drawdown (ft)**	**Spec Cap (gpm/ft)**	**Pumping Rate (gpm)**	**Measured Drawdown (ft)**	**Spec Cap (gpm/ft)**
0670	2.1	0.9	2.3	4.3	1.5	2.9
0671	2.0	1.0	2.0	3.8	1.9	2.0
0672	2.0	0.9	2.2	3.0	2.1	1.4
0673	1.4	0.8	1.8	4.2	2.1	2.0
0674	1.8	1.0	1.8	3.1	1.9	1.6
0675	2.3	0.8	2.7	3.8	1.7	2.3
0676	2.0	0.7	2.9	4.1	1.3	3.3
0677	2.2	0.8	2.6	4.6	1.3	3.6
0678	2.5	0.5	5.1	4.9	1.1	4.7
0679	1.6	0.6	2.9	3.2	0.9	3.6
Average			**2.6**	**Average**		**2.7**

Spec Cap = specific capacity; gpm = gallons per minute; ft = feet; gpm/ft = gallons per minute per foot.

The 2006 average specific capacities listed in Table 5–8 (2.6 and 2.7 gpm/ft) are similar to the values calculated for the short 2005 pumping season for Configuration 3 wells (2.5 and 2.3 gpm/ft) (DOE 2006a). It should be noted that these wells could be pumped at much higher rates because of the available saturated thickness. At rates approaching 5 gpm, less than 10% of the available saturated thickness was drawn down. The water level data used to prepare Figure 5–9 are contained in Appendix E−3.

5.3.3 Configuration 3 Observation Well Ground Water Drawdowns

Similar to Configurations 1 and 2, the zone of hydraulic influence associated with Configuration 3 extraction wells was also assessed using ground water elevation data from individual observation wells and comparable data from background well 0405.

Figure 5–10 shows one of the plots resulting from the assessment of Configuration 3 drawdowns. In this case, water elevations at well 0684, as determined from hand-measured depths to ground water, are compared to well 0405 water levels that have been adjusted to match well 0684 data. The Configuration 3 total ground water extraction rate is also included on these plots to provide the time frame when the well field was active.

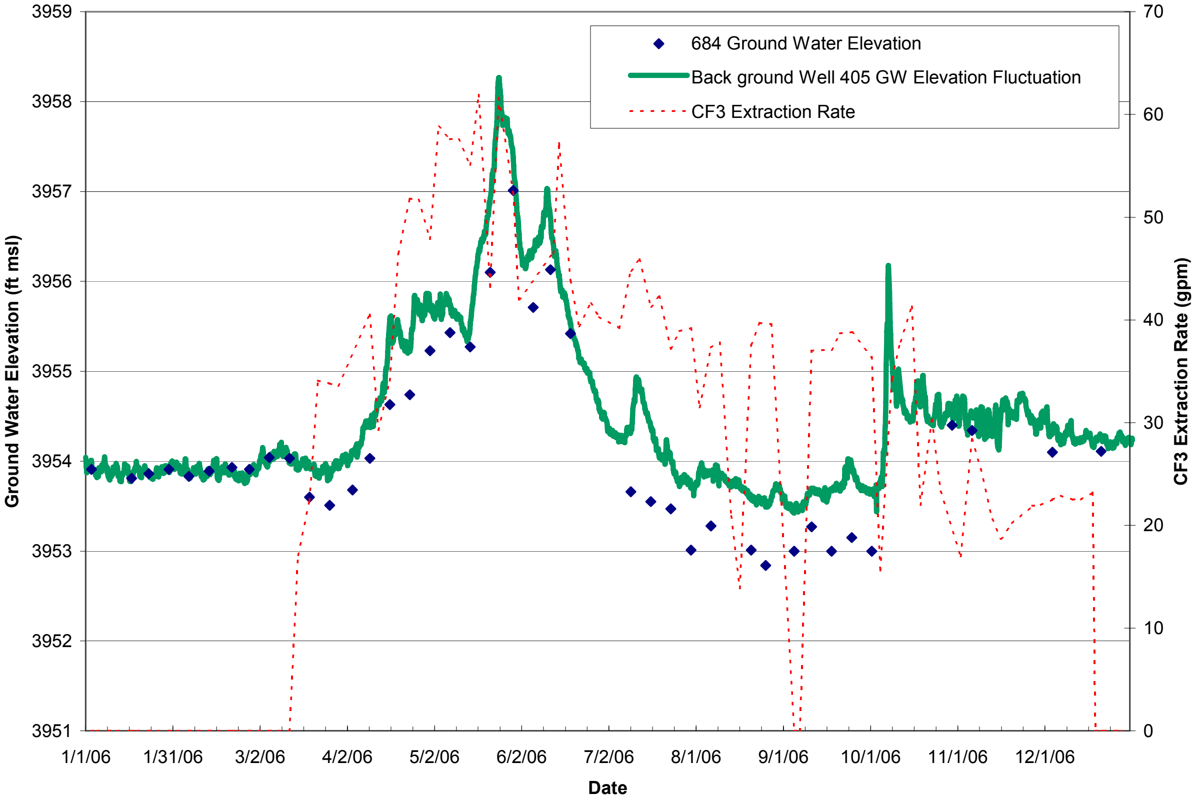

Figure 5–10. Ground Water Elevations at Observation Well 0684 and Background Well 0405 During 2006

Similar graphs to the one presented in Figure 5–10 are included in Appendix E−4 for the additional observation wells associated with Configuration 3. Using graphs similar to the one in Figure 5–10, measured drawdowns at several Configuration 3 observation wells were examined to assess the zone of influence created by Configuration 3 pumping (Table 5–9). Drawdowns were calculated for two separate dates, April 4 and October 2, to assess the hydraulic impacts associated with the early and late periods of the 2006 pumping season.

Table 5–9. Measured Drawdowns at Configuration 3 Observation Wells in 2006

Well	Relative Location	Distance from Well System Axis (ft)	Screen Interval (ft bgs)	Measured Drawdown (ft)	
				April 4, 2006	October 2, 2006
0404	Downgradient	8	13.0−17.9	0.6	1.3
0680	Upgradient	15	9.9−19.8	0.8	1.1
0681	Downgradient	23	10.2−20.2	0.7	1.3
0682	Upgradient	26	19.6−29.5	0.6	0.9
0683	Upgradient	23	21.2−31.2	0.5	0.9
0684	Upgradient	23	11.3−21.3	0.4	0.6
0685	Off northern end	30	20.0−30.0	0.3	0.4
0686	Downgradient	15	10.0−20.0	0.5	0.8
0687	Downgradient	20	20.0−30.0	0.7	1.3
0688	Downgradient	20	30.6−40.6	0.6	1.3
0689	Downgradient	20	46.0−56.0	0.5	1.0

The results of this analysis (Table 5–9) indicate that drawdowns in areas located close to the extraction wells fall within the range of 0.3 to 1.3 ft. It is noteworthy to point out that, unlike Configuration 1, the farthest distance from Configuration 3 extraction wells at which drawdowns could be measured was 30 ft. This was attributed to space limitations, as the Configuration 3 extraction wells are located near a steep riverbank to the east and a short distance separates them from vegetation test plot C5 to the west. The data presented in Table 5–9 suggest that drawdowns created by pumping of Configuration 3 wells are easily discernible at a distance of 25 ft from the extraction well axis and are probably detectable up to 50 ft from the axis.

The water level data used to prepare all the temporal plots for Configuration 3 observation wells are presented Appendix E−5.

5.4 Configuration 4 Performance

Configuration 4 remediation wells 0770 through 0779 (designed for both fresh water injection and ground water extraction) were installed in May 2006 with approximate screen intervals of 15 to 35 ft bgs. These wells (Figure 4–5) operated under ground water extraction conditions during 2006 starting on September 11. The even number wells were shut down for the winter on November 6, and the remaining wells were shut down on December 18. Due to electrical problems well 0775 operated for only approximately 1 week and well 0777 was not brought online during the 2006 pumping season.

5.4.1 Configuration 4 Pumping Rates and Ground Water Extraction Volumes

Limited data were available in this study for evaluating the Configuration 4 system because the short time frame when the wells were in operation. Estimated monthly pumping rates and extraction volumes between September and December 2006 for each of the ten wells comprising Configuration 4 are listed in Table 5–10. Similar to the other Configurations, these quantities were developed using only data collected when wellhead meters were operating properly. As a result, the listed extraction volumes are considered sufficiently accurate to develop rough estimates of contaminant mass withdrawals on a per-well basis.

Table 5–10. Monthly Average Pumping Rates and Extraction Volumes at Configuration 4 Remediation Wells, September through December 2006

Month	**Well 0770**		**Well 0771**		**Well 0772**		**Well 0773**		**Well 0774**	
	Q (gpm)	**Vol (gal)**	**Q (gpm)**	**Vol (gal)**	**Q (gpm)**	**Vol (gal)**	**Q (gpm)**	**Vol (gal)**	**Q (gpm)**	**Vol (gal)**
Sept 2006	1.30	5,607	3.36	102,175	0.00	0	3.49	64,400	0.00	0
Oct 2006	3.26	137,444	3.30	128,610	3.08	141,496	3.11	155,156	0.10	441
Nov 2006	3.67	164,139	1.08	42,164	3.39	141,238	1.86	38,167	5.00	177,635
Dec 2006	5.06	154,113	0.00	0	4.12	117,910	0.00	0	5.44	165,539
Avg / Total	3.60	461,303	3.23	272,949	2.84	400,644	3.04	257,723	1.80	343,615

Month	**Well 0775**		**Well 0776**		**Well 0777**		**Well 0778**		**Well 0779**	
	Q (gpm)	**Vol (gal)**	**Q (gpm)**	**Vol (gal)**	**Q (gpm)**	**Vol (gal)**	**Q (gpm)**	**Vol (gal)**	**Q (gpm)**	**Vol (gal)**
Sept 2006	0.00	0	4.43	82,697	0.00	0	2.83	30,397	1.08	14,973
Oct 2006	0.00	0	4.46	222,070	0.00	0	2.02	94,438	2.89	87,106
Nov 2006	3.42	26,683	5.26	203,221	0.00	0	2.08	85,346	0.94	52,450
Dec 2006	0.00	0	5.23	159,660	0.00	0	2.17	66,074	0.00	0
Avg / Total	3.42	26,683	4.26	667,648	0.00	0	2.22	276,255	1.91	154,529

Notes: Q = pumping rate; gpm = gallons per minute; Vol = volume; gal = gallons

As indicated in Table 5–10, well 0776 yielded the largest quantity of ground water between September and December 2006 (~ 667,000 gallons). It should be noted that none of the Configuration 4 wells were pumped at a sufficiently large rate that production was limited by available saturated thickness.

Average monthly pumping rates at each well (Table 5–4) and average per-well pumping rates for the September through December 2006 period (Figure 5–11) indicates that, with the exception of wells 0775 and 0777, wells in the Configuration 4 system were equally productive in 2006.

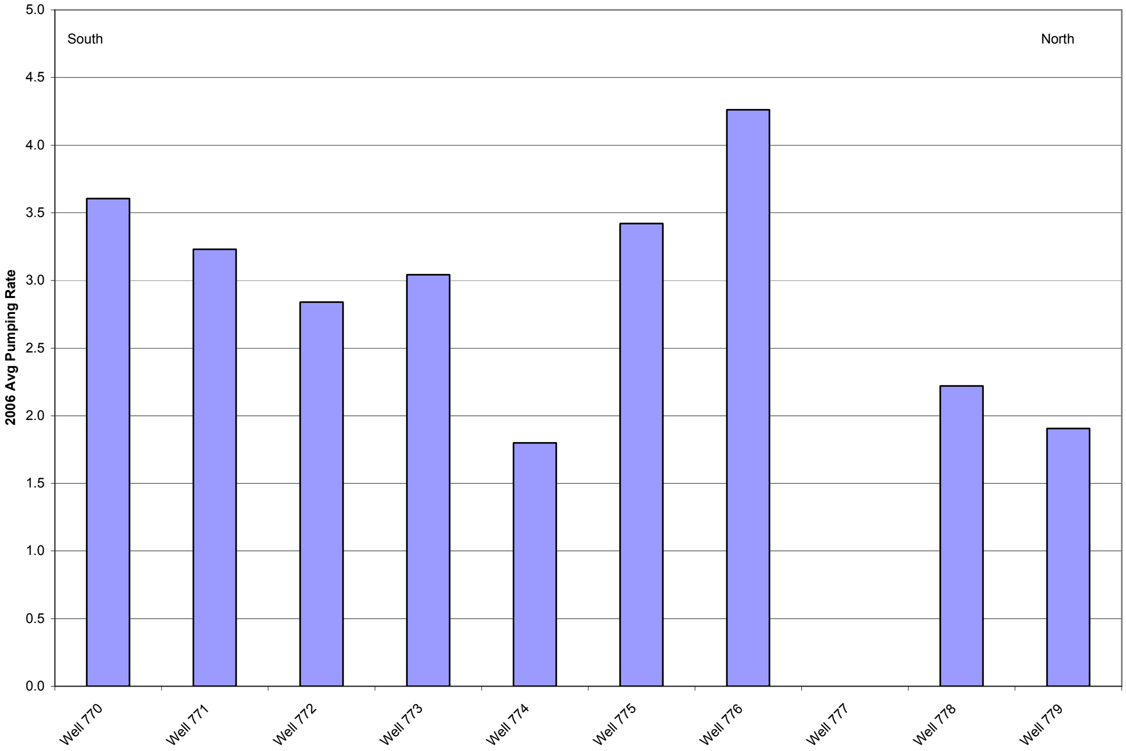

Figure 5–11. Average Pumping Rates from Configuration 4 Wells Between September and December 2006

The total pumped volume (approximately 2.8 million gallons) recorded by a totalizer meter was similar to the volume measured at individual wellhead meters. More complete hydraulic data for each Configuration 4 remediation well are provided in Appendix F−1.

5.4.2 Configuration 4 Extraction Well Ground Water Drawdowns

Figure 5–12 illustrates the resulting water levels measured at one of the Configuration 4 wells (well 0679) along with adjusted water elevations at background well 0405 and pumping rate data collected during 2006. Appendix F−2 includes similar plots to the one in Figure 5–12 for each Configuration 4 remediation well.

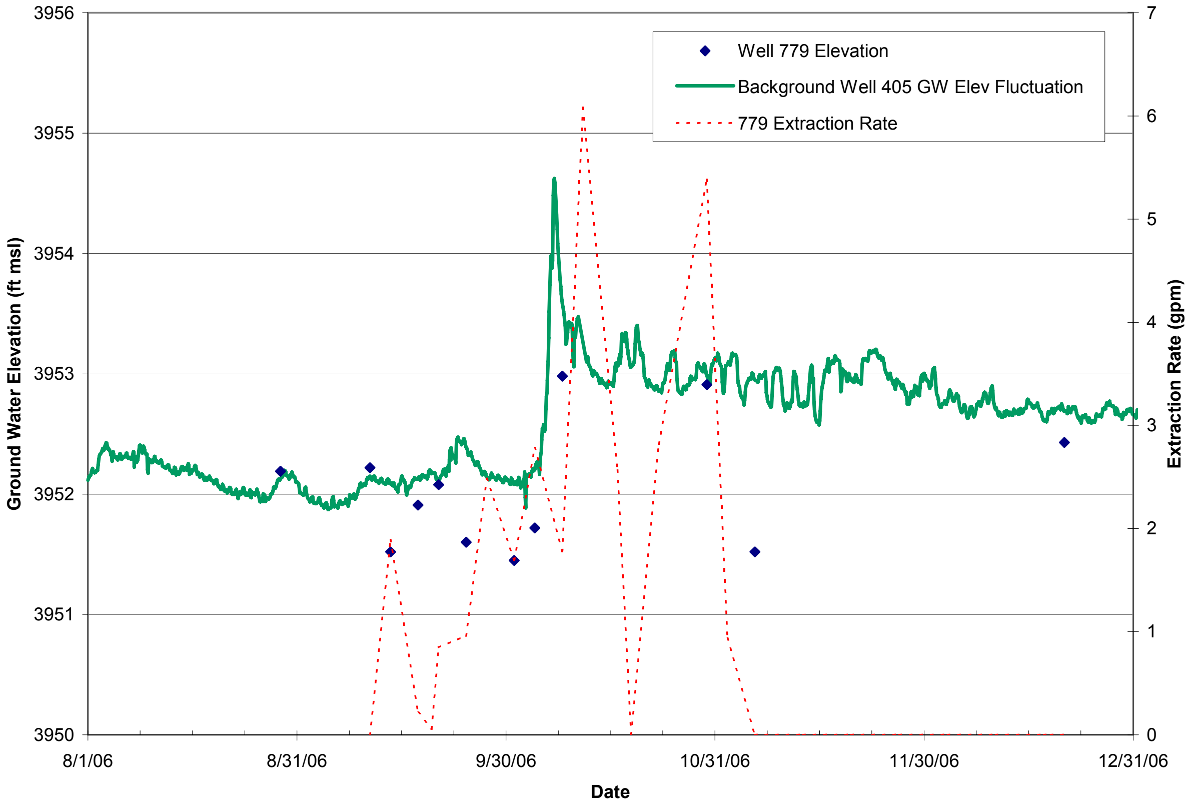

Figure 5–12. Ground Water Elevations at Extraction Well 0779 and Background Well 0405 During 2006

The resulting drawdowns, pumping rates, and computed specific capacities at each well are presented in Table 5–11.

Table 5–11. Computed Drawdowns and Specific Capacities at Configuration 4 Remediation Wells During 2006

Well	Pumping Rate (gpm)	Measured Drawdown (ft)	Spec Cap (gpm/ft)
0770	4.7	1.0	4.9
0771	4.7	1.2	4.1
0772	3.6	1.3	2.8
0773	3.1	1.4	2.1
0774	5.0	1.3	3.8
0775	3.4	1.1	3.2
0776	5.2	1.3	4.0
0778	2.2	1.4	1.6
0779	5.4	1.4	3.8
Average			**3.4**

Spec Cap = specific capacity; gpm = gallons per minute; ft = feet;
gpm/ft = gallons per minute per foot.

The 2006 average specific capacity listed in Table 5–11 (3.4 gpm/ft) is significantly lower compared to the average based on Configuration 4 step test data presented in Section 4.7.2. This discrepancy can be attributed to the fact that the step tests (with the exception of well 0778) were conducted when no adjacent wells were actively pumping. In order to determine well efficiency changes the data presented in Table 5–11 needs to be compared to data collected during the 2007 pumping season.

5.4.3 Configuration 4 Observation Well Ground Water Drawdowns

The zone of influence created in response to Configuration 4 ground water extraction was generated over a shorter time frame compared to Configurations 1, 2, and 3 (due to the fact that these remediation wells were not actively pumping until mid-September 2006). Figure 5–13 is a graph of the ground water elevation data measured from observation well 0787 plotted with the ground water elevation fluctuation measure in background well 0405 and the Configuration 4 total extraction rate. As shown in Figure 5–13, the water elevation drops below the background elevation in response to pumping, and then rebounds once the ground water extraction was suspended for the winter. Plots of data collected from other Configuration 4 observation wells are included in Appendix F−4.

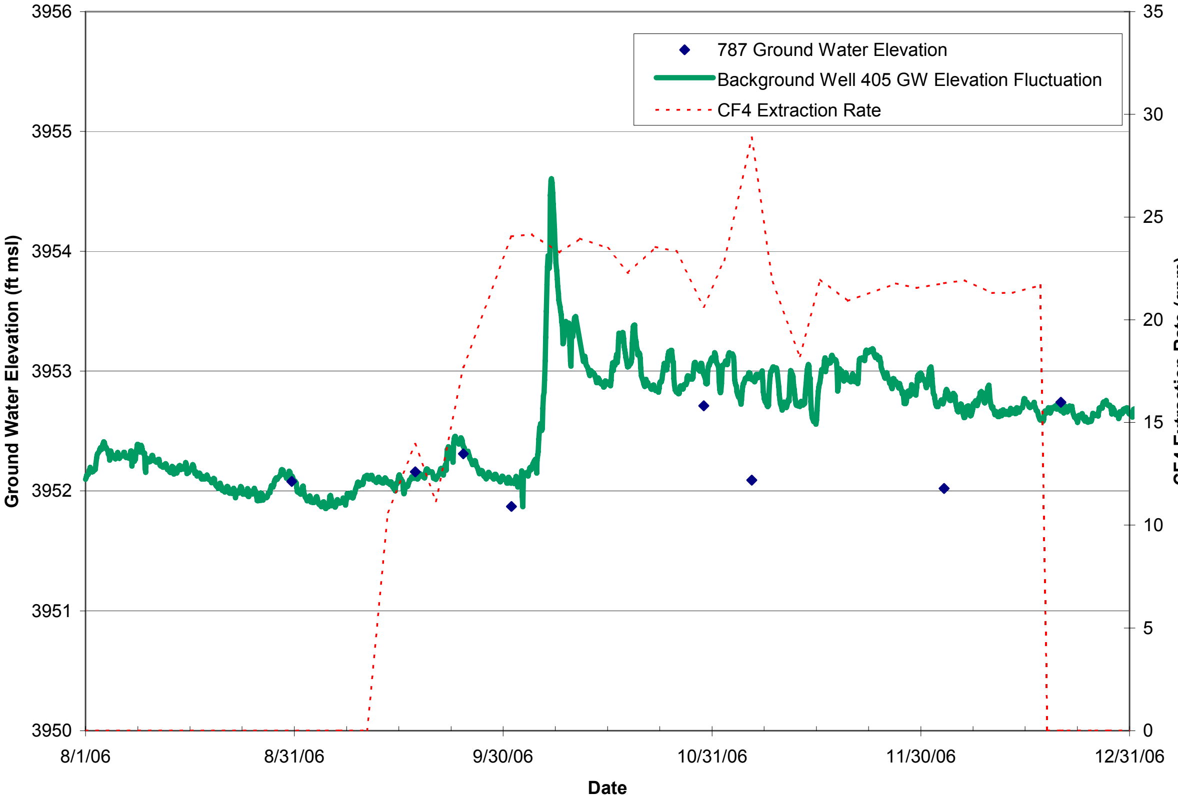

Figure 5–13. Ground Water Elevations at Observation Well 0787 and Background Well 0405 During 2006

The Configuration 4 assessment took into account measured water levels just after the start of pumping (October 2) and near the end of the Configuration 4 pumping period (December 4). The results are presented in Table 5–12.

Table 5–12. Measured Drawdowns at Configuration 4 Observation Wells in 2006

Well	Relative Location	Distance from Well System Axis (ft)	Screen Interval (ft bgs)	Measured Drawdown (ft)	
				Oct 2, 2006	Dec 4, 2006
0780	Upgradient	20	20.3 –30.1	0.5	0.9
0781	Upgradient	20	44.8–54.5	0.2	0.4
0784	Downgradient	30	9.4–19.4	0.3	0.3
0785	Downgradient	30	9.6–19.6	0.3	0.9
0787	Downgradient	30	35.4–45.2	0.2	0.8

Note: Data collected from wells 0782, 0783, and 0786 were not used in this evaluation

The results of this analysis indicate drawdowns in areas located close to the extraction wells fall in the range of 0.2 to 0.9 ft. The data presented in Table 5–12 suggest that drawdowns created by pumping of Configuration 4 wells are easily discernible at a distance of 20 ft from the extraction well axis and are probably detectable up to 50 ft from the axis.

The water level data used to prepare the temporal plots are presented Appendix F−5.

5.5 Infiltration Trench Performance

The infiltration trench (Figure 4–6) was installed in August 2006, and fresh water (diverted Colorado River water) was first injected into the trench from one of the four injection ports on September 7. By September 28 fresh water was being injected in to the trench from all four ports, and by December 1 injection was suspended for the 2006 season.

5.5.1 Fresh Water Injection Rates and Volumes

Early stages of fresh water injection were hampered by re-occurring filter clogging at the fresh water settling pond and a break in the injection water line due to high runoff in Moab Wash on October 9. Once these issues were addressed, fresh water was injected into the trench at rates between 25 and 45 gpm.

Table 5–13 summarizes the measured infiltration rates and volumes for the four injection ports located at the infiltration trench. All fresh water injection rates and volumes for 2006 are included in Appendix G−1. The overall average injection rate for 2006 was 17.6 gpm with a total of over 2.2 million gallons of injected fresh water. Individual port average injection rates ranged from 4.6 to 6.2 gpm, and the volume of injected fresh water at each port ranged from 443,803 (port 0740) to just over 677,002 gallons (port 0741).

Table 5–13. Infiltration Trench Injection Rates and Volumes in 2006

Month	**Infiltration Trench Injection Port**									
	0740		**0741**		**0742**		**0743**		**Totals**	
	Inj Rate (gpm)	**Vol (gal)**	**Inj Rate (gpm)**	**Vol (gal)**	**Inj Rate (gpm)**	**Vol (gal)**	**Inj Rate (gpm)**	**Vol (gal)**	**Inj Rate (gpm)**	**Vol (gal)**
Sept 2006	2.0	2,700	1.9	61,341	2.5	3,366	3.3	4,510	9.7	71,925
Oct 2006	1.9	83,320	2.9	131,809	2.6	115,810	2.5	112,034	9.9	442,981
Nov 2006	7.5	333,847	10.0	445,654	9.9	442,047	8.1	358,281	35.5	1,579,857
Dec 2006	4.4	23,936	7.1	38,198	7.1	38,143	5.2	28,190	23.8	128,486
Avg / Total	**4.6**	**443,803**	**5.4**	**677,002**	**6.2**	**599,366**	**5.2**	**503,015**	**17.6**	**2,223,203**

Inj Rate = Injection Rate; gpm = gallons per minute; gal = gallons

5.5.2 Ground Water Mounding Measured in Observation Wells

Ground water elevation data collected from two observation wells (0730 and 0731) located near the infiltration trench provided information regarding ground water mounding generated by fresh water injection. Data collected from observation wells 0732 and 0733 did not provide representative data (well 0732) due to well head damage or the data were not collected at a high enough frequency (well 0733) to contribute to this assessment. All water elevation data are also included in Appendix G−2.

Figure 5–14 and Figure 5–15 are graphs showing observation wells 0730 and 0731 response to fresh water injection, respectively. The elevation fluctuations measured in the observations are in response to changes in the injection rates, and periods when the filter clogged and injection had to be temporarily suspended. Using the same method to estimate drawdown as described in Section 5.0, the mounding generated can also be estimated, as presented in Table 5–14.

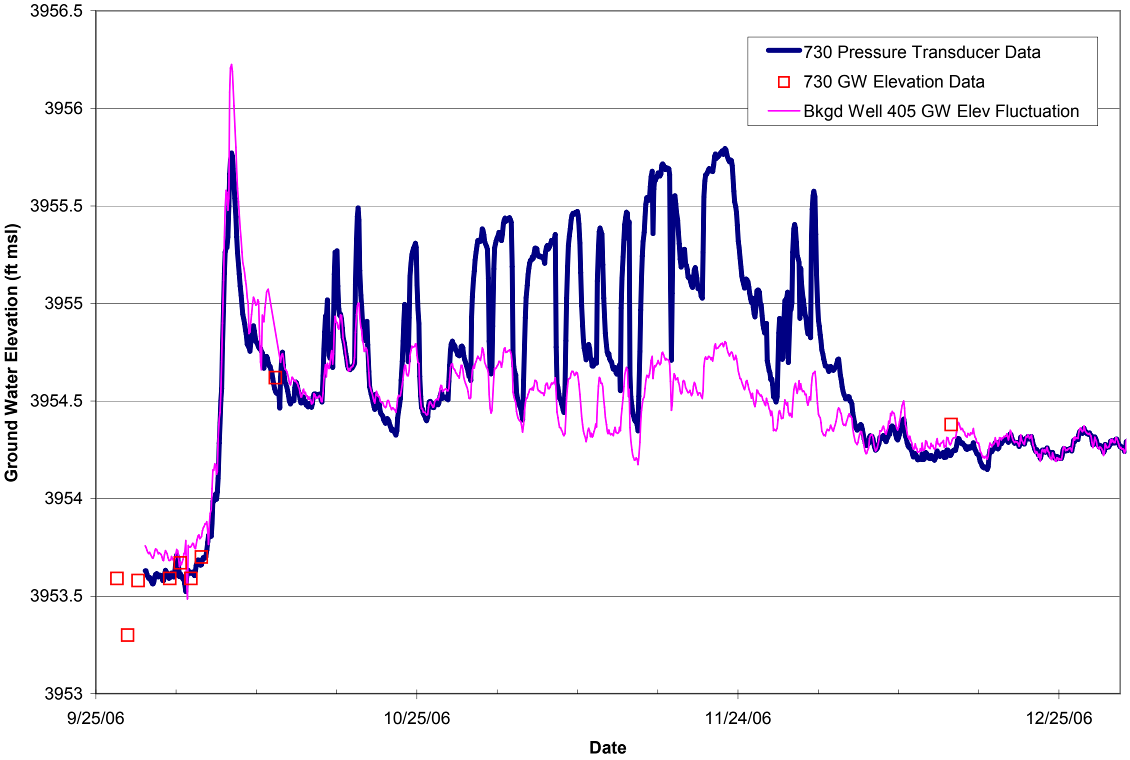

Figure 5–14. Ground Water Elevations at Observation Well 0730 and Background Well 0405 During 2006

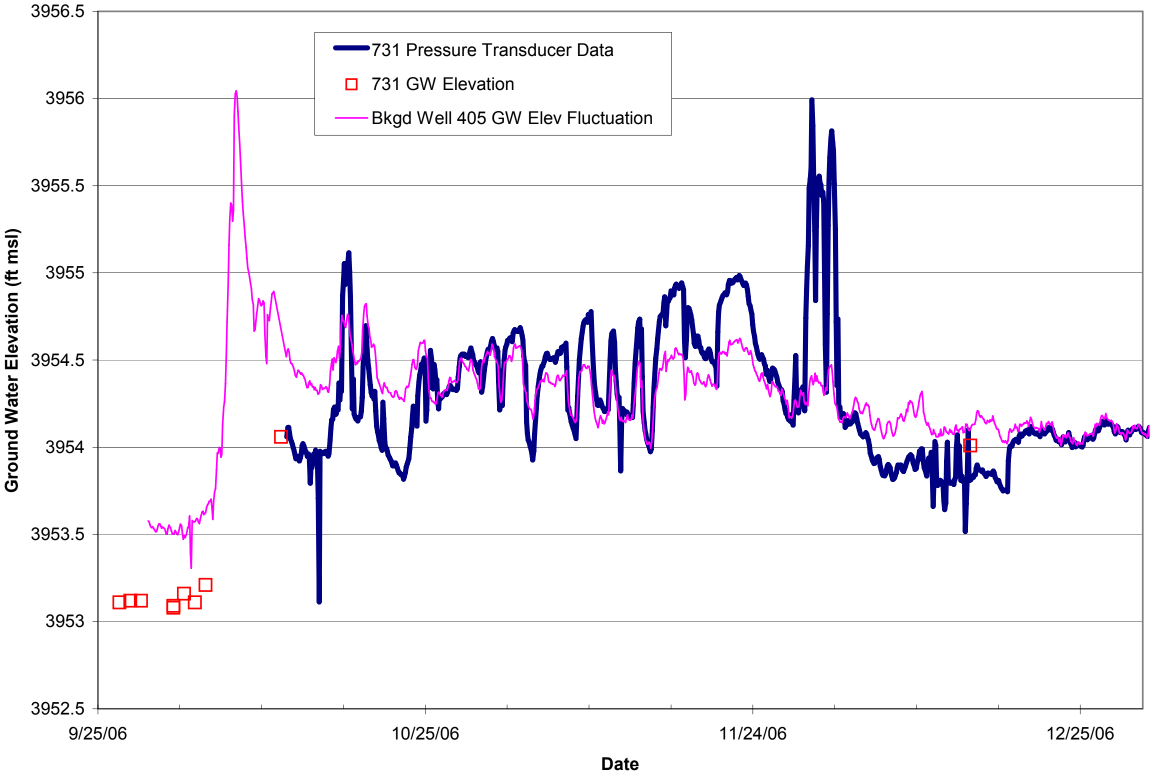

Figure 5–15. Ground Water Elevations at Observation Well 0731 and Background Well 0405 During 2006

Table 5–14. Measured Ground Water Mounding at the Infiltration Trench in 2006

Well	Relative Location	Distance from Trench Axis (ft)	Screen Interval (ft bgs)	Measured Drawdown (ft)	
				Oct 2, 2006	Dec 4, 2006
0730	Downgradient	Less than 5	9.9 – 19.9	0.7	1.0
0731	Downgradient	10	9.0 – 19.0	0.1	0.3

As expected, observation well 0730 experienced higher ground water mounding due to its proximity to the center of the trench. Well 0731 is located farther from the axis of the trench and near the southern end. While the mounding was not as high in the vicinity of well 0731, the water elevation appears to respond just as quickly to changes in the injection rate as observed in well 0730.

5.6 Treatment System Performance

The main components of the IA treatment system include the remediation wells in Configurations 1, 2, 3, and 4, the infiltration trench, the evaporation pond on the tailings pile, and the sprinkler system also on the tailings pile (Figure 5–16). Ground water extracted at the well field is pumped up the southeast side of the tailings pile to the evaporation pond, which is the source of water for the sprinkler system.

During 2006, the sprinkler system was operated each week on a 7-day work schedule during the high evaporation-potential months (May through September). An increasing rate of decline in the pond level was seen immediately after the sprinkler system was started in late March. At that time the pond was nearly at capacity. Although most of the decrease in pond depth reflected discharge to the sprinkler system, some of the decrease could also be related to the gradual rise in ambient air temperatures that increased evaporation from the pond surface.

5.6.1 Well Field and Sprinkler System Pumping Rates and Volumes

Table 5–15 summarizes important dates associated with operation of the IA treatment system during 2006. By the end of March all ground water extraction wells at Configurations 1, 2, and 3 were operating to maximize the amount of ground water removed along with reducing ammonia and uranium mass. The sprinkler system was brought online on February 28, 2006, once the potential for overnight below-freezing temperatures was considered minimal. The system was operated through November 20 and the well field was completely shut down by December 18 for the winter.

Table 5–15. Important Dates, Evaporation Pond Levels, and Activities Associated with the IA Treatment System During 2006

Date	Pond Level (ft)	Activity
January 1, 2006	8.2	Start of 2006
February 28, 2006	~7.8	Started sprinkler system
March 9, 2006	6.5	CF1 ground water extraction started
March 14, 2006	~6.6	CF3 ground water extraction started
March 16, 2006	6.8	CF2 fresh water injection stopped
March 23, 2006	6.5	CF2 ground water extraction started
May 26, 2006	~5.6	SMI-PW02 ground water extraction started
July 10, 2006	5.0	Intense storm event, estimated 2” of rain
July 24, 2006	6.8	Approx 1.4 mil gal of runoff transferred from top of pile to evap pond
September 11, 2006	2.0	CF4 ground water extraction started
September 7, 2006	4.0	Started fresh water injection at infiltration trench
September 28, 2006	3.2	Full scale fresh water injection at trench
October 2, 2006	3.5	CF2 ground water extraction shut down
October 6 and 7, 2006	3.6	Intense storm event, river stage increased to near runoff height
November 11, 2006	~4.6	All odd-numbered wells for CF1, 3, and 4 shut down
November 20, 2006	4.7	Sprinkler system shut down
November 27, 2006	6.0	SMI-PW02 shut down
December 1, 2006	~6.5	Fresh water injection at trench suspended
December 18, 2006	8.2	Remaining ground water extraction wells shut down

Figure 5–17 shows a graphical record of well field delivery rates to the evaporation pond, delivery rates from the evaporation pond to the sprinkler system, and pond levels during 2006. The data used to prepare this figure are presented in Appendix H−1. The delivery rates to the sprinkler system shown in Figure 5–17 were based on flow volumes recorded at meters on sprinkler delivery lines.

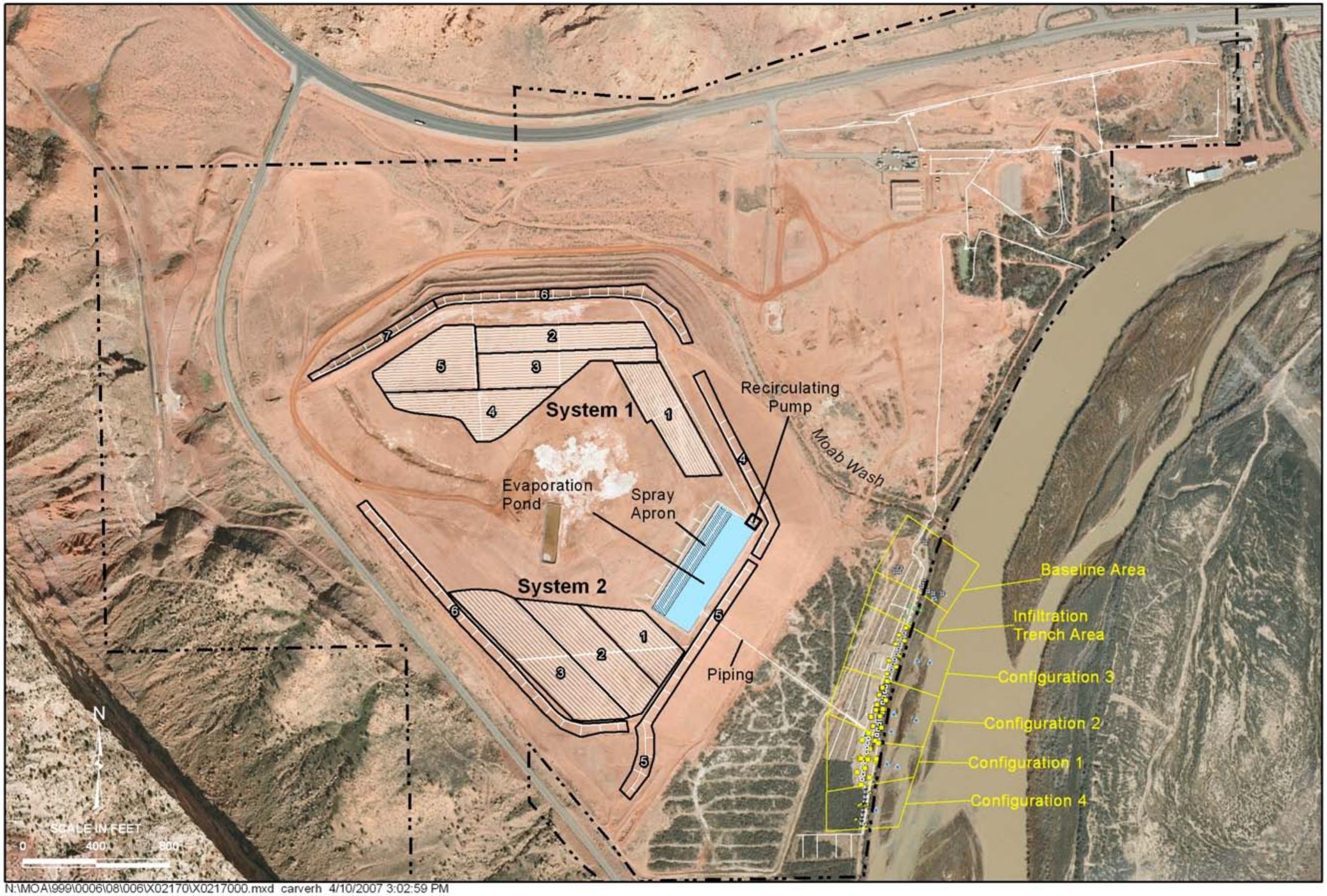

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Figure 5–16. Treatment System Components

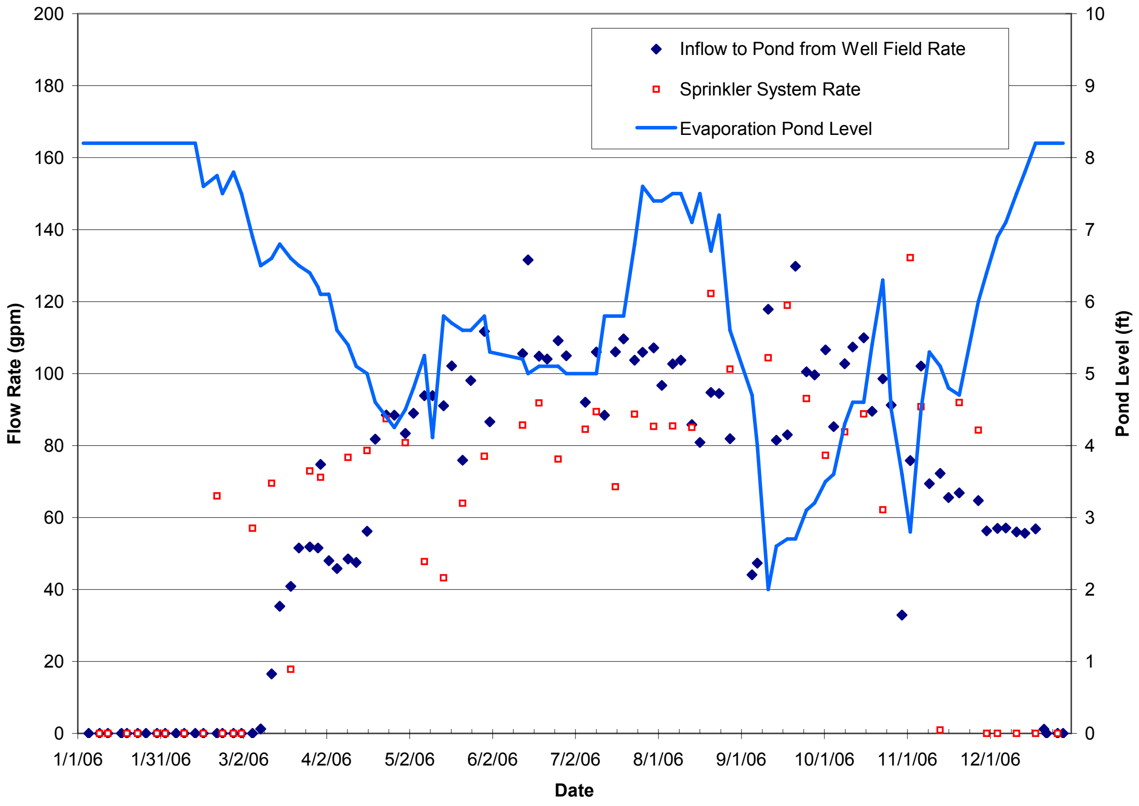


Figure 5–17. Rates of Water Delivery to the Evaporation Pond and the Sprinkler System and Pond Depths During 2005

As indicated in the figure, the pond level stabilized at a depth of about 5.0 ft for approximately one month (between June 15 and July 10). During this period, the delivery rate from the well field remained relatively constant, averaging approximately 104 gpm, and the sprinkler system was operated such that the average rate of delivery from the pond to the sprinkler system was approximately 83 gpm. These data make it possible to estimate the evaporation rate from the pond at the time.

A summary of the monthly water volumes delivered to the evaporation pond and the sprinkler system during 2006 is presented in Table 5–16. This schedule shows the flexibility of the treatment system, as deliveries to the pond exceed sprinkler system rates during some months and the reverse is true during others. While the evaporation pond started and ended the 2006 season at the same level (8.2 ft), there was a positive 2.1 million gallon difference between the volume of ground water recorded as pumped into the pond and the volume of water recorded as distributed by the sprinkler system. This difference can be explained by inherent inaccuracies in the various types of flow meters used for measurement and possibly due to evaporation directly from the pond.

Table 5–16. Summary of Monthly Water Deliveries to the Evaporation Pond and the Sprinkler System

Month	Volume pumped to pond (gals)	Volume pumped to sprinkler system (gals)
Feb 2005	0	544,058
Mar 2005	1,305,325	2,578,349
Apr 2005	2,478,149	3,260,974
May 2005	4,438,168	2,347,672
June 2005	4,566,070	4,326,485
July 2005	4,675,407	3,347,005
Aug 2005	3,725,877	3,970,910
Sept 2005	3,711,540	5,025,819
Oct 2005	4,212,184	4,428,426
Nov 2005	3,193,121	1,800,345
Dec 2005	1,470,321	0
Total	33,776,162	31,630,043

gals = gallons

6.0 Contaminant Mass Removal

This section presents the estimated ammonia and uranium mass removed by Configuration 1, 2, 3, and 4 extraction/remediation wells. These estimates are based on the ground water extraction rate and volumes recorded by flow meters located along the well head discharge lines at each well. These data are presented in Sections 5.1.1, 5.2.1, 5.3.1, and 5.4.1 for Configuration 1, 2, 3, and 4 extraction/remediation wells, respectively. As discussed in Section 5.0, there is discrepancy between the volumes of ground water extracted based on individual well measurements and that recorded at the system totalizers (differences of up to 20%). However, the individual extraction volumes provide the best means and are considered sufficiently accurate to develop rough estimates of contaminant mass withdrawals on a per-well basis.

The masses of ammonia and uranium removed from ground water by the pumping of extraction/remediation wells during 2006 were estimated by multiplying the monthly extraction volumes by corresponding concentrations of ammonia (NH_3-N) and uranium (U) measured in each well. The concentrations used in these calculations were drawn from analytical data presented in Appendices C−6, D−6, E−6, and F−6 for Configurations 1, 2, 3, and 4, respectively.

6.1 Configuration 1

Configuration 1 extraction wells were actively extracting ground water between March and December during the 2006 pumping season. The ammonia and uranium mass removed from the ground water as result of this pumping is discussed in Sections 6.1.1 and 6.1.2.

6.1.1 Configuration 1 Ammonia Mass Removal

The resulting monthly estimates of ammonia mass removed by Configuration 1 wells (0470 through 0479) are listed in Table 6–1. Similar to the 2005 pumping season (DOE 2006a), the largest mass quantities were associated with the three wells with the highest average flow rates (wells 0470, 0471, and 0478), and the smallest amount of mass removed from ground water was observed at the well with the lowest average rate (well 0474). The ten Configuration 1 extraction wells removed an estimated total of 8,913 kilograms (kg) of NH_3-N during 2006.

The monthly ammonia masses removed by pumping well SMI-PW02 (Table 6–1) were considerably larger than comparable values for Configuration 1 extraction wells. This was attributed to the combined effects of the higher rate at which well SMI-PW02 was pumped (see Section 5.1.1) and the higher NH_3-N concentrations observed at this well. The estimated total ammonia mass removed from ground water at well SMI-PW02 between May and November 2006 was 18,626 kilograms (kg). Similar to the 2005 pumping season (which resulted in 11,262 and 24,271 kg removed from Configuration 1 extraction wells and SMI-PW02, respectively) approximately double the mass was extracted from SMI-PW02 as compared to the Configuration 1 wells.

As expected, the capacity of Configuration 1 wells to deliver ammonia mass to the IA treatment system was greatly reduced during the period of high runoff in the Colorado River between May and June 2006. In addition, concentrations significantly decreased during early October 2006 in response to a precipitation event that increased the Colorado River flows to near 2006 spring runoff levels. As indicated in Table 6–1, temporary bank storage of river water during these

Table 6–1. Estimated Ammonia Mass Withdrawals at Configuration 1 Extraction Wells and Well SMI-PW02 During 2006

Month	Well 0470[a]		Well 0471[b]		Well 0472[a]		Well 0473[b]		Well 0474[a]	
	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)
Mar 2006	350	148	220	58	170	47	200	51	230	28
Apr 2006	620	347	660	337	540	199	380	135	370	55
May 2006	340	221	380	233	340	124	320	113	320	52
June 2006	190	102	330	162	260	94	270	101	270	39
July 2006	420	228	590	306	360	142	180	73	180	26
Aug 2006	365	173	450	206	265	93	145	51	155	23
Sept 2006	310	105	310	107	170	44	110	29	130	16
Oct 2006	120	62	295	145	71	26	115	44	87	14
Nov 2006	230	109	280	28	210	63	120	11	160	30
Dec 2006	380	135	0	0	250	53	0	0	300	49
Total		**1,632**		**1,582**		**885**		**608**		**332**

Month	Well 0475[b]		Well 0476[a]		Well 0477[b]		Well 0478[a]		Well 0479[b]	
	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)
Mar 2006	260	79	250	58	390	80	840	43	910	147
Apr 2006	280	107	230	91	250	70	400	211	360	97
May 2006	390	188	330	166	290	98	380	366	320	101
June 2006	220	93	170	53	170	45	200	147	250	75
July 2006	200	86	110	43	120	31	280	136	240	83
Aug 2006	170	67	115	35	120	29	280	82	230	69
Sept 2006	140	42	120	29	120	21	280	61	220	49
Oct 2006	165	63	100	34	140	38	270	104	225	74
Nov 2006	190	44	190	36	160	13	310	99	230	23
Dec 2006	310	73	0	0	0	0	350	95	0	0
Total		**841**		**545**		**425**		**1,345**		**718**

Notes: Applied baseline sample concentration for March, average concentrations from July and September used for August concentration for all wells.

[a] Concentration applied to November actually collected on October 31, 2006.

[b] Used average concentrations from September and November for October concentration.

Month	Well SMI-PW02	
	NH_3-N Conc (mg/L)	Mass Removed (kg)
May 2006	720	464
June 2006	720	3,480
July 2006	770	3,558
Aug 2006	820	3,493
Sept 2006	810	2,744
Oct 2006	860	2,816
Nov 2006	870	2,071
Dec 2006	0	0
Total		**18,626**

Note: Averaged June and August concentrations for July concentration.

months caused ammonia concentrations in local ground water (especially in the southern half of Configuration 1) to decrease substantially, which in turn reduced each extraction's wells ammonia mass removal from site ground water. In contrast, the capacity of SMI-PW02 to remove ammonia mass did not appear to be affected by the high river flows because it is located farther inland from the river and screened over a greater depth.

6.1.2 Configuration 1 Uranium Mass Removal

Estimated masses of uranium removed from ground water during 2006 by pumping of Configuration 1 extraction wells and well SMI-PW02 (Table 6–2) were developed using the same techniques applied to ammonia. The ten Configuration 1 wells removed an estimated total of 64.6 kg of uranium from ground water during 2006, approximately the same mass removed during 2005 (66.7 kg). As expected, extracted masses of uranium were generally proportional to the pumping rates achieved at individual extraction wells.

Pumping of well SMI-PW02 between May and November 2006 resulted in an estimated additional 58.5 kg of uranium mass being delivered to the IA treatment system. While SMI-PW02 removed more than two times the mass of ammonia removed by the Configuration 1 wells, the mass of uranium removed from SMI-PW02 was approximately equal to the mass removed by the ten Configuration 1 extraction wells. However, the Configuration 1 wells extracted a lower volume of water. The same trend was observed during the 2005 pumping season (DOE 2006a) and can be attributed to uranium concentrations in ground water withdrawn from well SMI-PW02 that were generally of the same magnitude as those measured at Configuration 1 wells. Uranium concentrations at well SMI-PW02 were largely constant throughout the pumping season and did not decrease in response to high Colorado River flows between May and June 2006.

6.2 Configuration 2

Due to the low sustainable pumping rates and limited 2006 operation time period (Section 5.2.1), Configuration 2 removed only a small amount of ammonia and uranium mass compared to Configurations 1, 3, and 4. As discussed previously, Configuration 2 remediation wells had been injecting diverted fresh water beginning October 2004. On March 16, 2006, the injection was suspended and the well field was converted into the ground water extraction mode by March 23. Sections 6.2.1 and 6.2.2 discuss the ammonia and uranium mass removed as result of Configuration 2 pumping.

6.2.1 Configuration 2 Ammonia Mass Removal

The resulting monthly estimates of ammonia mass removed by Configuration 2 wells are listed in Table 6–3. An estimated 4,705 kg of ammonia was removed from Configuration 2 remediation wells in 2006. While this represents only roughly one-half of the mass removed by Configuration 1, when taking into consideration the significantly longer Configuration 1 operation time, the Configuration 2 wells were more efficient at removing mass compared to Configuration 1. This observation is the result of higher ground water ammonia concentrations in the vicinity of Configuration 2. The continued operation of Configuration 2 is important because it is located adjacent to a backchannel area of the river with the most persistent fish habitat (DOE 2007c).

Table 6–2. Estimated Uranium Mass Withdrawals at Configuration 1 Extraction Wells and Well SMI-PW02 During 2006

Month	Well 0470[a]		Well 0471[b]		Well 0472[a]		Well 0473[b]		Well 0474[a]	
	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)
Mar 2006	3.9	1.7	3.6	0.9	4.1	1.1	4.5	1.1	4.2	0.5
Apr 2006	3.2	1.8	2.7	1.4	2.5	0.9	2.4	0.9	2.7	0.4
May 2006	1.6	1.0	1.6	1.0	1.6	0.6	1.7	0.6	1.8	0.3
June 2006	1.2	0.6	1.7	0.8	1.3	0.5	1.6	0.6	1.8	0.3
July 2006	2.3	1.3	2.3	1.2	1.8	0.7	1.3	0.5	1.2	0.2
Aug 2006	2.1	1.0	2.0	0.9	1.5	0.5	1.1	0.4	1.1	0.2
Sept 2006	1.8	0.6	1.7	0.6	1.1	0.3	1.0	0.3	1.0	0.1
Oct 2006	0.7	0.3	1.8	0.9	0.3	0.1	1.2	0.5	0.4	0.1
Nov 2006	1.3	0.6	1.8	0.2	1.5	0.4	1.4	0.1	1.4	0.3
Dec 2006	2.1	0.7	0.0	0.0	1.8	0.4	0.0	0.0	1.8	0.3
Total		**9.7**		**7.9**		**5.5**		**5.0**		**2.5**

Month	Well 0475[b]		Well 0476[a]		Well 0477[b]		Well 0478[a]		Well 0479[b]	
	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)
Mar 2006	4.2	1.3	3.7	0.9	3.6	0.7	2.7	0.1	3.2	0.5
Apr 2006	2.2	0.8	2.0	0.8	2.2	0.6	2.4	1.3	2.3	0.6
May 2006	2.4	1.2	2.0	1.0	2.3	0.8	2.7	2.6	3.1	1.0
June 2006	2.1	0.9	1.8	0.6	2.0	0.5	2.7	2.0	3.5	1.0
July 2006	1.1	0.5	1.1	0.4	1.6	0.4	2.2	1.1	4.6	1.6
Aug 2006	1.1	0.4	1.3	0.4	1.7	0.4	2.2	0.6	3.6	1.1
Sept 2006	1.1	0.3	1.4	0.3	1.8	0.3	2.2	0.5	2.6	0.6
Oct 2006	1.3	0.5	0.8	0.3	1.8	0.5	1.9	0.7	2.9	1.0
Nov 2006	1.4	0.3	1.4	0.3	1.8	0.1	2.2	0.7	3.2	0.3
Dec 2006	1.9	0.4	0.0	0.0	0.0	0.0	2.6	0.7	0.0	0.0
Total		**6.6**		**4.9**		**4.4**		**10.3**		**7.7**

Notes: Applied baseline sample concentration for March, average concentrations from July and September used for August concentration for all wells.

[a] Concentration applied to November actually collected on October 31, 2006.

[b] Used average concentrations from September and November for October concentration.

Month	Well SMI-PW02	
	U Conc (mg/L)	Mass Removed (kg)
May 2006	2.6	1.7
June 2006	2.6	12.6
July 2006	2.5	11.3
Aug 2006	2.3	9.8
Sept 2006	2.5	8.5
Oct 2006	2.6	8.5
Nov 2006	2.6	6.2
Dec 2006	0	0
Total		**58.5**

Note: Averaged June and August concentrations for July concentration.

Table 6–3. Estimated Ammonia Mass Withdrawals at Configuration 2 Extraction Wells During 2006

Month	Well 0570		Well 0571[a]		Well 0572		Well 0573	
	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)
Mar 2006	0	0	1200	208	0	0	730	26
Apr 2006	0	0	1200	547	310	18	730	90
May 2006	160	15	870	89	310	60	630	191
June 2006	210	47	870	2	250	45	570	113
July 2006	440	81	540	0	410	82	0	0
Aug 2006	500	89	0	0	435	54	0	0
Sept 2006	560	52	0	0	460	47	0	0
Oct 2006	560	14	0	0	0	0	0	0
Total		**299**		**846**		**307**		**421**

Month	Well 0575		Well 0576		Well 0577		Well 0579	
	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)
Mar 2006	0	0	0	0	640	37	570	54
Apr 2006	600	92	400	17	640	146	570	435
May 2006	590	204	0	0	650	182	480	254
June 2006	450	144	0	0	460	110	0	0
July 2006	640	182	0	0	620	179	0	0
Aug 2006	715	165	0	0	675	175	0	0
Sept 2006	790	140	0	0	730	207	0	0
Oct 2006	790	24	0	0	730	84	0	0
Total		**952**		**17**		**1,121**		**743**

Notes: Average concentrations from July and September used for August concentration for applicable wells.

[a] Concentrations applied to May and June are the average of April and July concentrations.

6.2.2 Configuration 2 Uranium Mass Removal

As shown in Table 6–4, the Configuration 2 wells removed an estimated total of 16.2 kg of uranium from ground water during 2006. While the ammonia concentrations for Configuration 2 were significantly higher compared to Configuration 1, the uranium concentrations for these two well fields are comparable. As a result, Configuration 2 wells removed approximately 25% of the uranium mass compared to Configuration 1 because of operation time differences between the two systems.

Table 6–4. Estimated Uranium Mass Withdrawals at Configuration 2 Extraction Wells During 2006

Month	Well 0570		Well 0571[a]		Well 0572		Well 0573	
	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)
Mar 2006	0.0	0.0	1.4	0.2	0.0	0.0	2.0	0.1
Apr 2006	0.0	0.0	1.4	0.6	1.7	0.1	2.0	0.2
May 2006	0.7	0.1	2.1	0.2	1.7	0.3	1.9	0.6
June 2006	1.5	0.3	2.7	0.0	1.6	0.3	1.8	0.4
July 2006	2.2	0.4	2.7	0.0	3.0	0.6	0.0	0.0
Aug 2006	2.3	0.4	2.7	0.0	3.0	0.4	0.0	0.0
Sept 2006	2.3	0.2	2.9	0.0	2.9	0.3	0.0	0.0
Oct 2006	2.3	0.1		0.0	2.9	0.1	0.0	0.0
Total		**1.5**		**1.1**		**2.1**		**1.3**

Month	Well 0575		Well 0576		Well 0577		Well 0579	
	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)
Mar 2006	0.0	0.0	0.0	0.0	2.2	0.1	2.1	0.2
Apr 2006	1.9	0.3	1.6	0.1	2.2	0.5	2.1	1.6
May 2006	2.1	0.7	0.0	0.0	2.4	0.7	2.1	1.1
June 2006	1.6	0.5	0.0	0.0	1.8	0.4	0.0	0.0
July 2006	2.4	0.7	0.0	0.0	2.7	0.8	0.0	0.0
Aug 2006	2.5	0.6	0.0	0.0	2.5	0.6	0.0	0.0
Sept 2006	2.5	0.4	0.0	0.0	2.3	0.7	0.0	0.0
Oct 2006	2.5	0.1	0.0	0.0	2.3	0.3	0.0	0.0
Total		**3.3**		**0.1**		**4.1**		**2.9**

Notes: Average concentrations from July and September used for August concentration for applicable wells.
[a] Average concentrations from April and June used for May concentration.

6.3 Configuration 3

Similar to Configuration 1, Configuration 3 remediation wells (screened from 15 to 45 ft bgs) extracted ground water from March through December during the 2006 pumping season. The ammonia and uranium mass removed from the ground water as result of this pumping is discussed in Sections 6.3.1 and 6.3.2.

6.3.1 Configuration 3 Ammonia Mass Removal

The mass of ammonia removed from ground water by the pumping of Configuration 3 remediation wells during 2006 were estimated by multiplying the monthly extraction volumes presented in Section 5.3.1 by corresponding concentrations of NH_3-N measured in each well.

The resulting estimates of ammonia mass removal (Table 6–5) indicated that an estimated total of just over 25,900 kg of NH_3-N were extracted from ground water at Configuration 3 wells during the 2006 pumping season. This mass removal represents almost three times the mass removed by Configuration 1 over approximately the same time frame. The apparently greater capacity of the Configuration 3 system to extract ammonia can be attributed to the higher pumping rates attained with these wells, since the concentrations are similar.

Table 6–5. Estimated Ammonia Mass Withdrawals at Configuration 3 Extraction Wells During 2006

Month	Well 0670		Well 0671[a]		Well 0672		Well 0673[a]		Well 0674	
	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)
Mar 2006	430	77	380	72	810	138	940	174	750	129
Apr 2006	450	152	490	179	560	195	630	229	590	207
May 2006	500	378	530	393	580	434	640	513	570	363
June 2006	310	219	450	284	500	316	540	382	470	213
July 2006	410	316	480	283	610	332	690	444	610	346
Aug 2006	440	248	495	253	630	286	665	374	595	236
Sept 2006	470	231	510	220	650	241	640	308	580	208
Oct 2006	500	366	505	340	640	373	625	512	620	362
Nov 2006	500	512	500	109	550	181	610	101	510	286
Dec 2006	480	263	0	0	570	265	0	0	540	340
Total		**2,762**		**2,132**		**2,761**		**3,038**		**2,688**

Month	Well 0675[a]		Well 0676		Well 0677[a]		Well 0678		Well 0679[a]	
	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)	NH_3-N Conc (mg/L)	Mass Removed (kg)
Mar 2006	360	62	380	69	870	175	820	194	890	153
Apr 2006	510	201	430	167	570	233	550	275	490	160
May 2006	520	404	440	351	620	505	590	520	550	422
June 2006	460	239	370	248	560	399	500	382	380	249
July 2006	500	247	450	339	680	548	530	378	600	296
Aug 2006	510	263	445	246	595	416	480	300	570	196
Sept 2006	520	234	440	210	510	356	480	258	540	203
Oct 2006	500	250	510	362	495	277	430	344	450	255
Nov 2006	480	213	520	344	480	55	220	93	360	51
Dec 2006	0	0	400	217	0	0	290	167	0	0
Total		**2,112**		**2,553**		**2,963**		**2,910**		**1,984**

Notes: Average concentrations from July and September used for August concentration for all wells.
[a] Average concentrations from September and November used for October concentration.

As the data presented in Table 6–5 show, the Configuration 3 concentrations did not decrease during times of higher Colorado River flows (during May and October) as Configuration 1 wells exhibited. The greater distance between the Configuration 3 wells and the nearby Colorado River side channel (compared to Configuration 1) may explain this lack of response. Sediments have filled in former side channels in the vicinity of Configuration 3 over the past five years, and as a result have increased the migration pathway distance for fresh water from the river to the well field. Another contributing factor is the Configuration 3 wells are screened over a deeper portion of the aquifer (from approximately 15 to 45 ft bgs), while the Configuration 1 wells are screened over a shallower interval.

6.3.2 Configuration 3 Uranium Mass Removal

Estimated mass withdrawals of uranium at Configuration 3 extraction wells (Table 6–6) indicate that a total of 148.9 kg of uranium was removed by this system between March and December 2006. This quantity represents more than two times the mass removed by Configuration 1. The data indicate Configuration 3 wells contained higher uranium concentrations compared to Configuration 1. This fact, in combination with higher flow rates explains the differences between the two systems.

Table 6–6. Estimated Uranium Mass Withdrawals at Configuration 3 Extraction Wells During 2006

Month	**Well 0670**		**Well 0671[a]**		**Well 0672**		**Well 0673[a]**		**Well 0674**	
	U Conc (mg/L)	**Mass Removed (kg)**	**U Conc (mg/L)**	**Mass Removed (kg)**	**U Conc (mg/L)**	**Mass Removed (kg)**	**U Conc (mg/L)**	**Mass Removed (kg)**	**U Conc (mg/L)**	**Mass Removed (kg)**
Mar 2006	2.7	0.5	3.0	0.6	3.3	0.6	3.2	0.6	3.3	0.6
Apr 2006	2.6	0.9	2.8	1.0	2.5	0.9	2.8	1.0	3.0	1.1
May 2006	2.9	2.2	3.1	2.3	2.9	2.2	2.9	2.3	3.4	2.2
June 2006	3	2.1	2.8	1.8	2.2	1.4	2.3	1.6	3.2	1.4
July 2006	3.1	2.4	2.7	1.6	2.5	1.4	2.5	1.6	3.0	1.7
Aug 2006	2.9	1.6	2.7	1.4	2.4	1.1	2.6	1.5	3.1	1.2
Sept 2006	2.7	1.3	2.7	1.2	2.3	0.9	2.7	1.3	3.1	1.1
Oct 2006	2.7	2.0	2.6	1.7	2.2	1.3	2.6	2.1	2.8	1.6
Nov 2006	2.5	2.6	2.4	0.5	2.5	0.8	2.5	0.4	2.7	1.5
Dec 2006	2.6	1.4	0.0	0.0	2.7	1.3	0.0	0.0	3.0	1.9
Total		**17.0**		**12.0**		**11.7**		**12.5**		**14.3**

Month	**Well 0675[a]**		**Well 0676**		**Well 0677[a]**		**Well 0678**		**Well 0679[a]**	
	U Conc (mg/L)	**Mass Removed (kg)**	**U Conc (mg/L)**	**Mass Removed (kg)**	**U Conc (mg/L)**	**Mass Removed (kg)**	**U Conc (mg/L)**	**Mass Removed (kg)**	**U Conc (mg/L)**	**Mass Removed (kg)**
Mar 2006	3.1	0.5	3.0	0.5	3.1	0.6	2.9	0.7	3.0	0.5
Apr 2006	2.8	1.1	2.7	1.1	3.2	1.3	3.5	1.8	3.5	1.1
May 2006	3.8	2.9	3.7	3.0	4.1	3.3	4.3	3.8	4.6	3.5
June 2006	3.4	1.8	3.3	2.2	3.3	2.4	3.6	2.8	4.0	2.6
July 2006	3	1.5	2.6	2.0	3.1	2.5	3.7	2.6	3.9	1.9
Aug 2006	2.9	1.5	2.8	1.5	3.4	2.4	3.8	2.3	4.0	1.4
Sept 2006	2.8	1.3	2.9	1.4	3.7	2.6	3.8	2.0	4.0	1.5
Oct 2006	2.7	1.3	2.9	2.1	3.0	1.6	3.2	2.6	3.1	1.7
Nov 2006	2.6	1.2	2.8	1.9	2.2	0.3	1.5	0.6	2.1	0.3
Dec 2006	0.0	0.0	2.4	1.3	0.0	0.0	1.3	0.7	0.0	0.0
Total		**13.1**		**16.8**		**17.0**		**19.9**		**14.6**

Notes: Average concentrations from July and September used for August concentration for all wells.
[a] Average concentrations from September and November used for October concentration.

6.4 Configuration 4

As a result of the addition of this system to the Interim Action well field in 2006, Configuration 4 remediation wells (screened from 15 to 35 ft bgs) extracted ground water from only September until mid-December during the 2006 pumping season. The ammonia and uranium mass removed from the ground water as result of this pumping is discussed in Sections 6.4.1 and 6.4.2.

6.4.1 Configuration 4 Ammonia Mass Removal

The resulting estimates of ammonia mass removal (Table 6–7) indicated that an estimated 5,676 kg of ammonia were extracted from ground water at Configuration 4 wells during the 2006 pumping season. This mass removal represents almost one-third of the mass removed by Configuration 3. However, when taking into consideration the well field was operating at 80% capacity (well 0775 actively extracted ground water for only one month and well 0777 never came online during 2006) and operated approximately 30% of the 2006 pumping season, Configuration 4 remediation wells were nearly as effective at mass removal as Configuration 3 wells.

Table 6–7. Estimated Ammonia Mass Withdrawals at Configuration 4 Extraction Wells During 2006

Month	**Well 0770**		**Well 0771[a]**		**Well 0772**		**Well 0773[a]**		**Well 0774**	
	NH_3-N Conc (mg/L)	**Mass Removed (kg)**	**NH_3-N Conc (mg/L)**	**Mass Removed (kg)**	**NH_3-N Conc (mg/L)**	**Mass Removed (kg)**	**NH_3-N Conc (mg/L)**	**Mass Removed (kg)**	**NH_3-N Conc (mg/L)**	**Mass Removed (kg)**
Sept 2006	660	14	500	193	0	0	450	110	0	0
Oct 2006	590	307	500	243	360	193	450	264	440	1
Nov 2006	620	385	500	80	420	225	450	65	510	343
Dec 2006	590	344	0	0	420	187	0	0	490	307
Total		**1,050**		**517**		**605**		**439**		**651**

Month	**Well 0775[a]**		**Well 0776**		**Well 0777[a]**		**Well 0778**		**Well 0779[a]**	
	NH_3-N Conc (mg/L)	**Mass Removed (kg)**	**NH_3-N Conc (mg/L)**	**Mass Removed (kg)**	**NH_3-N Conc (mg/L)**	**Mass Removed (kg)**	**NH_3-N Conc (mg/L)**	**Mass Removed (kg)**	**NH_3-N Conc (mg/L)**	**Mass Removed (kg)**
Sept 2006	0	0	770	241	0	0	800	92	680	39
Oct 2006	0	0	440	370	0	0	510	182	680	224
Nov 2006	670	68	490	377	0	0	550	178	680	135
Dec 2006	0	0	590	357	0	0	610	153	0	0
Total		**68**		**1,344**		**0**		**605**		**398**

[a]Applied November concentrations to September and October.

As noted in Table 6–7, only limited discharge samples for chemical analysis were collected from wells 0771, 0773, 0775, and 0779. For mass removal estimates sample results collected during November 2006 had to be applied to September and October. Configuration 4 wells in which samples were collected September through December (wells 0770, 0776, and 0778) suggest ammonia concentrations decreased in response to increased Colorado River flows in early October 2006, especially in the northern end of the configuration.

6.4.2 Configuration 4 Uranium Mass Removal

Estimated mass withdrawals of uranium at Configuration 4 extraction wells (Table 6–8) indicate that a total of 18.5 kg of uranium was removed by this system between September and December 2006. This mass represents less than 15% of the Configuration 3 2006 uranium mass removal. The fact the Configuration 4 did not operate at full capacity and over a shorter time period still cannot explain the significantly lower uranium mass removed compared to Configuration 3. The data presented in Table 6–8 indicate the Configuration 4 wells contained lower uranium concentrations compared to Configuration 3, especially in the northern end of the configuration. This was likely in response to the increased river stage in the fall.

Table 6–8. Estimated Uranium Mass Withdrawals at Configuration 4 Extraction Wells During 2006

Month	Well 0770		Well 0771[a]		Well 0772		Well 0773[a]		Well 0774	
	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)
Sept 2006	2.6	0.1	1.6	0.6	2.6	0.0	1.9	0.5	0	0.0
Oct 2006	1.7	0.9	1.6	0.8	1.4	0.7	1.9	1.1	1.6	0.0
Nov 2006	1.8	1.1	1.6	0.3	1.8	1.0	1.9	0.3	1.9	1.3
Dec 2006	1.8	1.1	0	0.0	1.9	0.8	0	0.0	2.4	1.5
Total		**3.1**		**1.7**		**2.6**		**1.9**		**2.8**

Month	Well 0775[a]		Well 0776		Well 0777[a]		Well 0778		Well 0779[a]	
	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)	U Conc (mg/L)	Mass Removed (kg)
Sept 2006	0.0	0.0	2.5	0.8	0.0	0.0	2.1	0.2	1.3	0.1
Oct 2006	0.0	0.0	1.4	1.2	0.0	0.0	1.3	0.5	1.3	0.4
Nov 2006	2.0	0.2	1.6	1.2	0.0	0.0	1.2	0.4	1.3	0.3
Dec 2006	0.0	0.0	1.6	1.0	0.0	0.0	1.4	0.4	0	0.0
Total		**0.2**		**4.2**		**0.0**		**1.4**		**0.8**

[a] Applied November concentrations to September and October.

7.0 Temporal Influences on Water Chemistry

This section discusses temporal changes in water chemistry observed in the Baseline Area and Configurations 1, 2, 3, and 4 during 2006. Temporal changes in water chemistry regarding the Evaporation Pond are also discussed. The changes are identified using chemical analyses of samples collected from a variety of extraction wells, observation wells, riverbed well points (formerly termed piezometers), and surface water sampling locations associated with the five areas. The field parameter and laboratory analytical data from the Baseline Area and Configurations 1, 2, 3, and 4 used to assess temporal changes in chemistry are contained in Appendices B, C, D, E, and F, respectively. Comparable data collected from Evaporation Pond sampling are contained in Appendix H.

7.1 Baseline Area

The Baseline Area is located just south of where Moab Wash discharges into the Colorado River (Figure 1–1), and to the north of the infiltration trench. This area consists of four upgradient wells, three downgradient wells, and nine riverbed well points (Table 4–1). While the water chemistry in this area is not impacted by ground water extraction (Configuration 3 is the closest well field, more than 200 ft to the south), the concentrations may be influenced by fresh water injection (the northern end of infiltration trench is less than 50 ft from the down gradient well cluster) and irrigation practices (irrigation plot C-6 is located between the upgradient and downgradient observation well clusters).

The analytical results associated with the upgradient observation wells, observation wells, riverbed well points, and surface water sampling are presented and interpreted in Sections 7.1.1, 7.1.2, 7.1.3, and 7.1.4, respectively. Appendix B−2 contains all the 2006 analytical data collected from the Baseline Area locations.

7.1.1 Upgradient Observation Wells SMI-PZ1S/-PZ1M/-PZ1D2/-PW01

Figure 7–1 presents the 2006 time versus concentration plots for (a) TDS, (b) ammonia, and (c) uranium. Samples were collected from 18 ft bgs (well SMI-PZ1S), 40 ft bgs (SMI-PW01), 57 ft bgs (SMI-PZ1M), and 73 ft bgs (SMI-PZ1D2) at this upgradient cluster located approximately 150 ft inland from the river bank. During the first half of 2006 water chemistry data indicate the TDS concentrations [Figure 7–1(a)] follow the trend of increasing concentration with increasing depth. However, after July the samples collected from 18 ft bgs contained TDS concentrations that were higher compared to the concentrations measured in samples collected from 40 ft bgs.

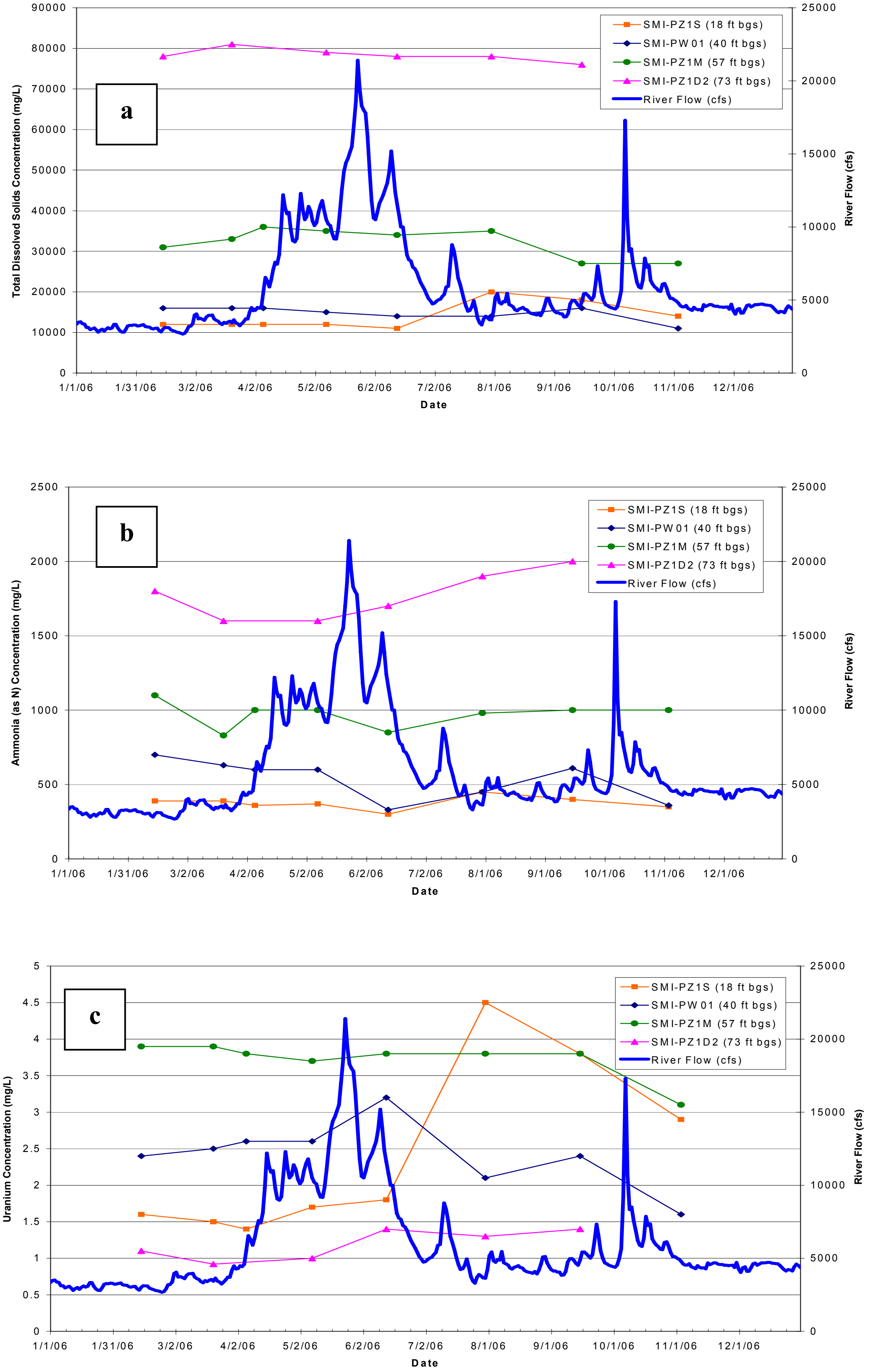


Figure 7–1. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Observation Wells SMI-PZ1S, SMI-PZ1M, SMI-PZ1D2, and SMI-PW01 During 2006

Changes in the Colorado River flow do not appear to have impacted analyte concentrations. The TDS concentration at 18 ft bgs apparently increased just after the spring runoff peak, with concentrations increasing from 11,000 to 20,000 mg/L from mid-May to late June. After late June, the concentration from 18 ft bgs remained higher compared to the concentration at 40 ft bgs. Historically the TDS concentrations for samples collected from 18 and 40 ft bgs range between 10,000 and 20,000 mg/L. During 2006, TDS concentrations in the samples collected from 40 ft bgs had a very narrow range, from 11,000 to 16,000 mg/L.

Similar to the TDS, ammonia concentrations [Figure 7–1(b)] also increase with increasing depth. This trend has been observed in previous investigations (DOE 2002). Water chemistry data indicate a gradual increase in ammonia concentrations at a depth of 73 ft bgs after early May through the end of the year. Samples collected from 18, 40, and 57 ft bgs did not exhibit the increase exhibited in the 73 ft bgs sample, but rather slightly fluctuated throughout the year. Ammonia concentrations from samples collected from 18 ft bgs ranged from 300 to 450 mg/L, from 40 ft bgs from 360 to 630 mg/L, and from 57 ft bgs the concentrations ranged from 830 to 1,100 mg/L.

Uranium concentrations [Figure 7–1(c)] during the first half of 2006 followed the same trend observed during the initial brine characterization study (DOE 2002) such that the lowest uranium concentrations were collected from the sample collected from 73 ft bgs and the highest concentration was detected in the sample collected from 57 ft bgs. After mid-June the uranium concentration in the sample collected from 18 ft bgs sharply increased from 1.8 to 4.5 mg/L by the end of July. By November the concentration decreased, but remained approximately the same as the concentration detected in the sample collected from 57 ft bgs.

This increase may have been in response to irrigation of plot C-6. The upgradient cluster is located just 30 ft from the boundary of C-6, where flood irrigation was started in mid-April for the 2006 season. It is possible that by late June some fresh water used for irrigation had also migrated slightly upgradient and impacted only the shallowmost zone of the aquifer. As reported previously (DOE 2006a), oxygenated water added to the aquifer system promotes the mobility of uranium in ground water, and increases the uranium concentrations. This may explain why the uranium concentration increases are limited to the sample collected from 18 ft bgs.

7.1.2 Downgradient Observation Wells 0405/0488/0493

The 405, 488, and 493 cluster is located at the top of the riverbank and consists of wells that are screened from 15 to 20 ft bgs, 25 to 40 ft bgs, and 45 to 55 ft bgs, respectively. Figure 7–2 presents the 2006 time concentration plots for (a) TDS, (b) ammonia, and (c) uranium. Samples were collected from 18 ft bgs (well 0405), 39 ft bgs (0488), and 54 ft bgs (0493).

TDS concentrations [Figure 7–2(a)] follow the trend of increasing concentration with increasing depth. Samples collected from each of the three depths detected a significant decrease in November. This is likely in response to either the short-lived peak in river flow in early October or fresh water injection activity at the nearby infiltration trench (the northern end of the trench is only 50 ft south of this well cluster). TDS concentrations did not decrease in response to the longer-lasting spring runoff peak during May and June. Clearly the shallower zone of the aquifer was more impacted compared to the deeper zones. Such a response suggests the cause for the decrease is dilution from the slug of fresh water injected into the subsurface.

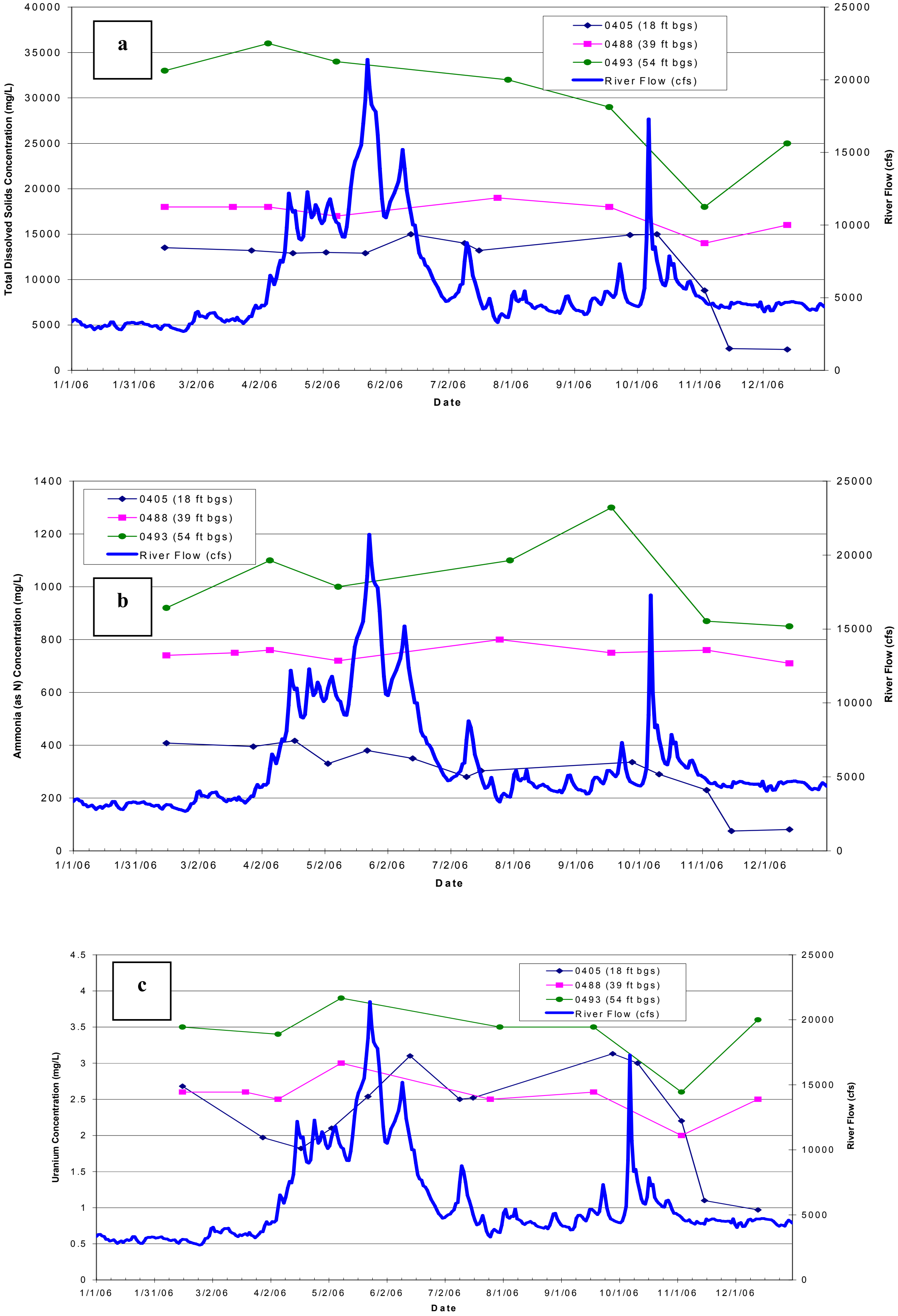


Figure 7–2. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Observation Wells 0405, 0488, and 0493 During 2006

In general, the ammonia concentrations [Figure 7–2(b)] follow the same trend as exhibited in the TDS time concentration plots. Ammonia concentrations started decreasing late in the year prior to the October river stage increase, further suggesting fresh water injection had started diluting the water chemistry of the native ground water and reduced ammonia concentrations in the shallow zone.

Uranium concentration fluctuations [Figure 7–2(c)] in samples collected from 39 and 54 ft bgs mirrored each other, with the samples collected from 54 ft bgs consistently approximately 1 mg/L higher compared to the 39 ft bgs samples. However, the uranium concentrations detected in samples collected from 18 ft bgs did not follow the same trends exhibited by the samples collected from deeper aquifer zones. After having a similar concentration to the sample from 39 ft bgs in mid-February, there was a gradual decrease through mid-April for concentrations from 18 ft bgs followed by an increase into mid-June. After mid-October the uranium concentration sharply decreased (from more than 3 mg/L to less than 1 mg/L), again possibly in response to fresh water dilution by the infiltration trench.

7.1.3 Riverbed Well Points

Baseline Area well points are split into three clusters containing three well points each that are installed at different depths. Refer to Table 4–11 for well point construction details and Figure 4–6 for locations. Appendix H-1 contains all the analytical data.

Figure 7–3 presents the analytical results of samples collected from riverbed well points 0494, 0495, and 0597, all of which are located at the base of the bank (i.e., closest to the well field axis). Figure 7–4 presents similar plots for the well points 0496, 0497, and 0598 (which are located at an intermediate distance between the base of the riverbank and the Colorado River), and Figure 7–5 presents the plots for well points 0599, 0617, and 0618 (located off the Colorado River). The TDS, ammonia, and uranium concentration data are all plotted with the Colorado River flow data.

Well point 0494 was occasionally dry; therefore, only limited samples were collected from this location. Water chemistry results indicate samples that were collected from 0494 contained approximately 45,000 mg/L TDS, which is two times that concentration detected from samples collected in deeper screened well points 0495 and 0597. In this area of the riverbed, TDS concentrations tend to increase with decreasing depth. Increases in the river stage due to spring runoff did not appear to impact TDS concentrations. Decreases in TDS concentrations in samples collected from 0495 and 0597 (a sample was not collected during this time of year from 0494) are likely in response to infiltration trench based fresh water injection starting in late September. A similar response was exhibited in the TDS concentration decrease late in the year in samples collected from observation well 0405, located just 40 ft from these well points.

As opposed to TDS concentrations, ammonia concentrations [Figure 7–3(b)] exhibited a trend of increasing concentration with depth. Increases in the river stage appeared to decrease concentrations, with the most significant decrease occurring in the sample collected from 0597. Prior to the October river stage increase, ammonia concentrations at this location ranged from 330 to 419 mg/L, with a minor decrease in response to the spring runoff. However, from late September to early November the ammonia concentration decreased from 388 to 50 mg/L.

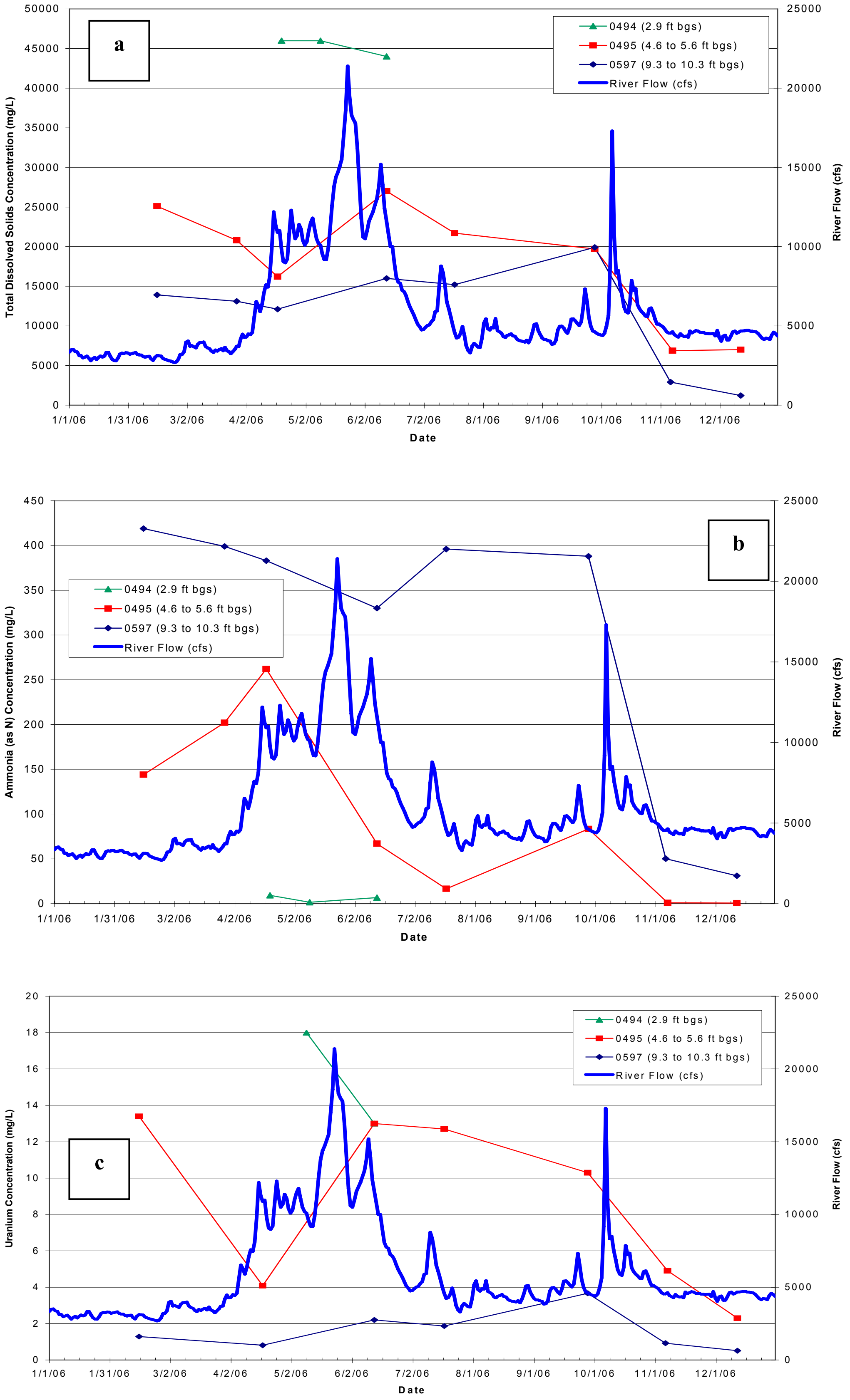


Figure 7–3. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Riverbed Well Points 0494, 0495, and 0597 During 2006

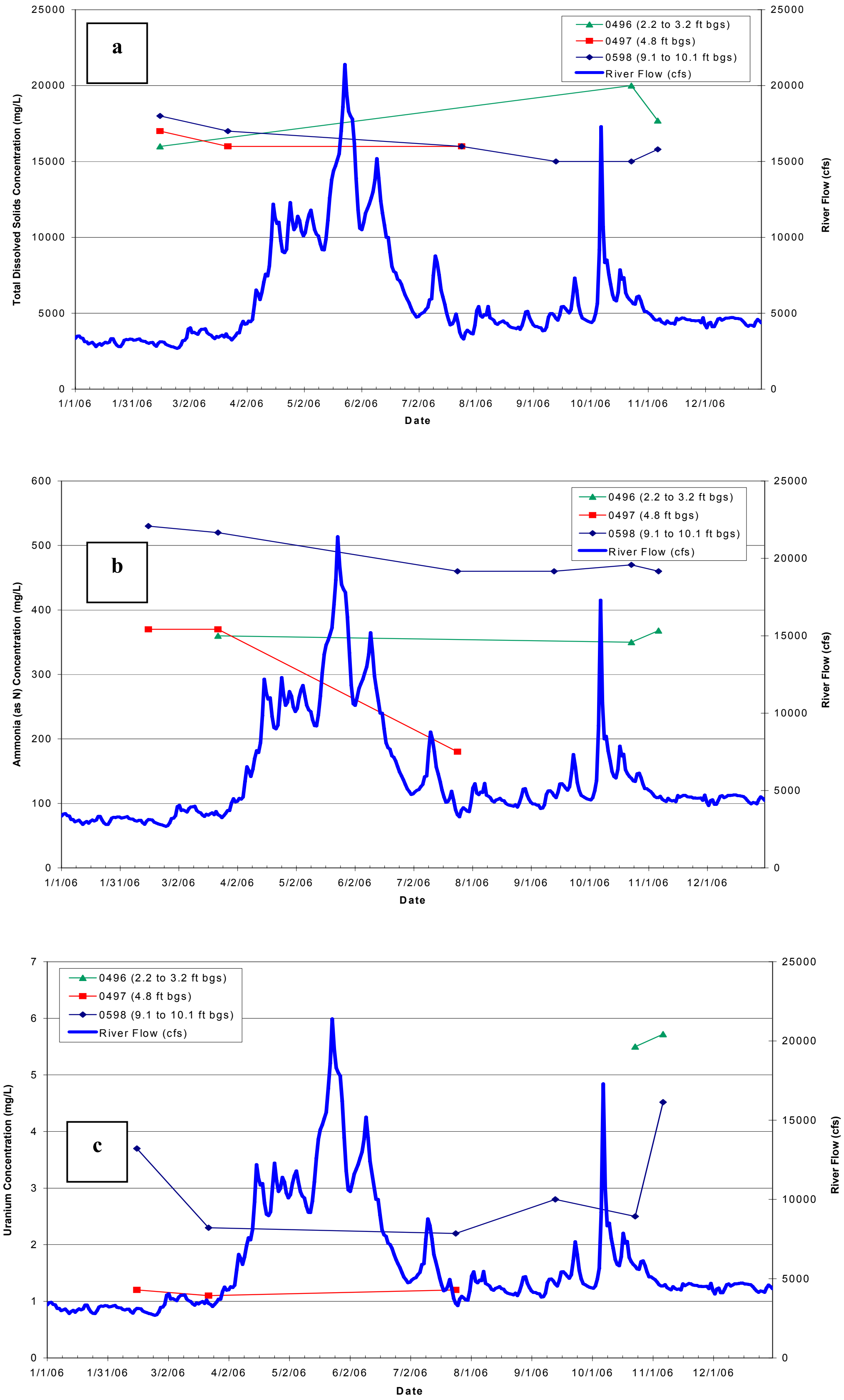


Figure 7–4. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium Plotted at Well Points 0496, 0497, and 0598 During 2006

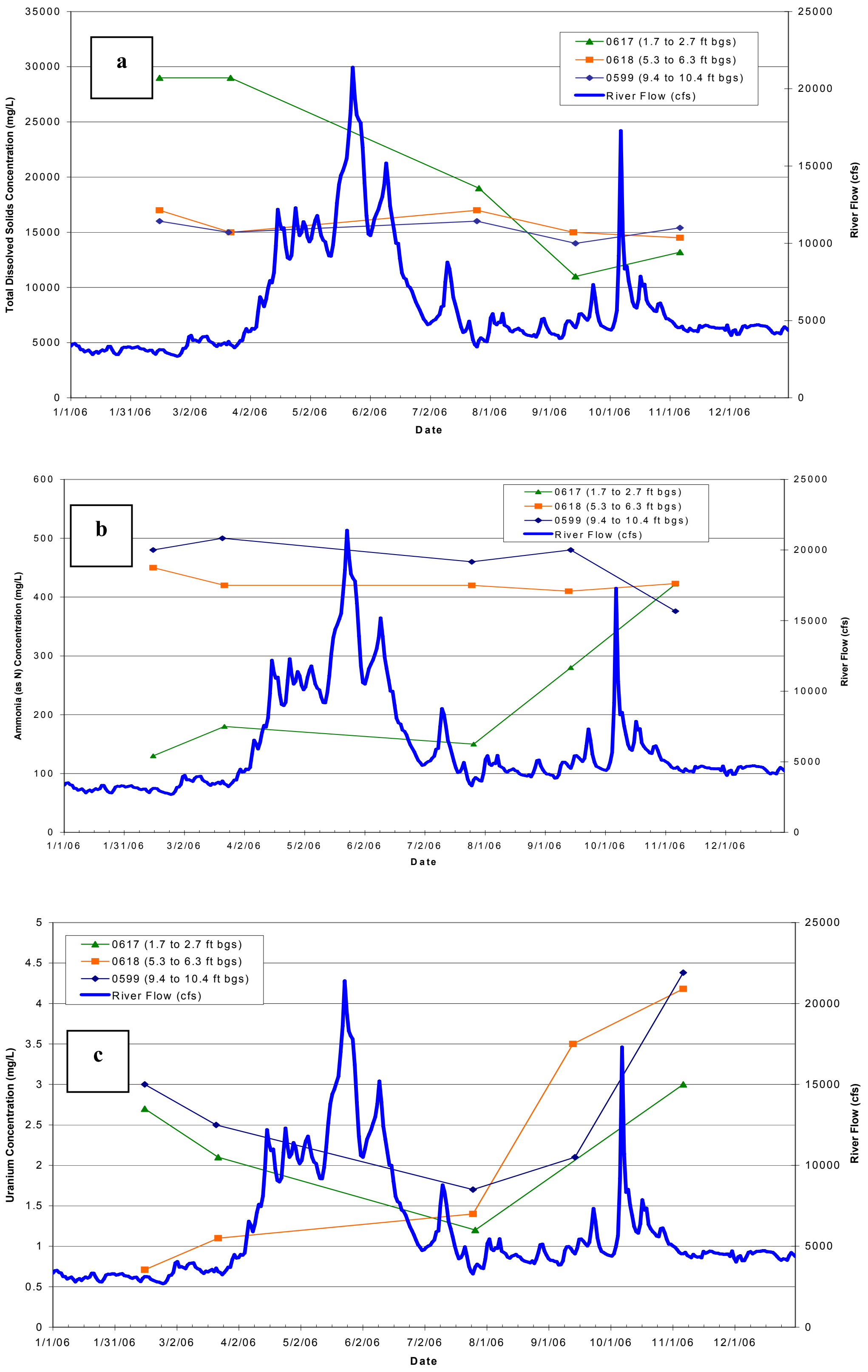


Figure 7–5. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Riverbed Well Points 0599, 0617, and 0618 During 2006

Uranium concentrations [Figure 7–3(c)] differed significantly between the three well points, with up to 18 mg/L uranium in the sample collected from 0494 in early May. Of the seven samples collected from 0495 in 2006, four were greater than 10 mg/L. After September 2006, the original piezometers were replaced with well points. These high uranium concentrations are not typical of the concentrations encountered within the riverbed areas adjacent to the well field concentrations. Uranium concentrations above 5 mg/L are rarely encountered onsite; however, between 10 and 20 mg/L uranium have historically been detected in samples collected from observation well TP-02 (located 1,200 ft to the north of Moab Wash). After September, concentrations in 0495 and 0597 have decreased to nearly 2 mg/L, which is within the range of concentrations detected at other riverbed locations.

The data associated with well points 0496, 0497, and 0598 indicate TDS concentrations in February increased with increasing depth. Over the course of the year, the data did not exhibit this trend; however, TDS concentrations in samples collected from all three well points ranged from 15,000 to 20,000 mg/L. In general, ammonia concentrations also increased with increasing depth in 2006, while the highest uranium concentrations were measured in samples collected from 0496 (samples collected in late in 2006 only) and 0598. Some of the higher concentrations were over 5 mg/L for 0496 and 4.5 mg/L for 0598. These relatively high uranium concentrations may be the result of the influx of oxygenated fresh water from the infiltration trench and from the irrigated plots C5 and C6.

Each of the well points located adjacent to the Colorado River in the Baseline Area were initially installed in September 2005 and upgraded to well points in September 2006. Unlike the general site-wide trend, and similar to the trend exhibited by well points 0494, 0495, and 0597, the shallowest well point had the highest TDS concentrations. By the time the last sample was collected in November, all three well points had TDS concentrations that ranged from 13,200 to 15,400 mg/L (i.e., the concentrations were similar at each location).

Ammonia concentrations exhibited the opposite trend, increasing concentration with increasing depth. As noted for the TDS data, the ammonia concentrations were similar in samples collected in November (concentrations for all three well points ranged from 376 to 423 mg/L). Uranium data did not exhibit a definite trend between sample depth versus concentrations. Samples collected from all three well points sharply increased between late July and November in response to the influx of fresh water from the infiltration trench. Although the trench is expected to possibly only affect the shallowest zone.

7.1.4 Surface Water Locations

The Baseline Area has three surface water locations as shown on Figure 4–1. Location 0241 is located directly off the bank, 0242 is a side channel sampling location, and 0243 is located at the bank of the main channel of the Colorado River. Because of the fluctuating river stage and the configuration of the riverbed in this area, Colorado River water does not consistently flow through the side channels. Surface water samples were collected from 0243 on a consistent basis; however, a sample was collected from 0241 only once during 2006 and only three times from location 0242. As a result, the focus of this discussion will be on the 0243 water chemistry.

Figure 7–6 includes the time concentration plots generated from data collected during 2006 for these Baseline Area surface water locations. TDS concentrations ranged from approximately 700 to 800 mg/L, which is typical of main channel concentrations. Ammonia concentrations were consistently below 0.3 mg/L for most of 2006; however, the sample collected in December contained 0.85 mg/L ammonia. Uranium concentrations exhibited a similar trend as ammonia, with the majority of the year concentrations approximately 0.01 mg/L. Starting in November and into December the uranium concentration gradually increased to greater than 0.02 mg/L.

It is difficult to explain the reason behind the ammonia and uranium concentration increases. Review of the data associated with samples collected from well points 0617, 0618, and 0599 indicate the ammonia concentrations in the shallow completed well point increased after late July. A similar increase was observed in uranium concentrations from each of the well points at this location during this same time.

7.2 Configuration 1

7.2.1 Extraction Wells 0470−0479

Configuration 1 extraction wells (Figure 4–2) were sampled monthly during full-scale operation of this system between March and December 2006 (Appendix C−6). Prior to the start of pumping, samples were collected from each of the ten extraction wells in early March 2006. Wells 0470 through 0477 (screened from approximately 10 to 20 ft bgs) were sampled at a depth of 17 ft bgs and wells 0478 and 0479 (screened from approximately 9 to 24 ft bgs) were sampled at a depth of 20 ft bgs. During system operation, samples were collected directly from the discharge of the dedicated submersible pump in each well. Pump intake depths at wells 0470 through 0477 are located about 18 ft bgs; pump intakes are located at a depth of approximately 21 ft bgs in wells 0478 and 0479.

An example graphical depiction of TDS, ammonia, and uranium concentrations observed at Configuration 1 extraction wells during 2006 is presented in Figure 7–7 (in this case for well 0470). Corresponding flows in the Colorado River are superimposed on the plot of TDS concentration [Figure 7–7(a)], total system pumping rate is superimposed on the graph of ammonia concentrations [Figure 7–7)b)], and measured ground water elevations in the extraction well are co-plotted with uranium concentrations [Figure 7–7(c)]. Because the same time scale is used in each of these graphs, the effects of river flow, total system pumping rate, and ground water elevation in the extraction well on all three analytes can be assessed. Comparable plots for the remaining extraction wells in Configuration 1 (wells 0471−0479) are presented in Appendix C−7.

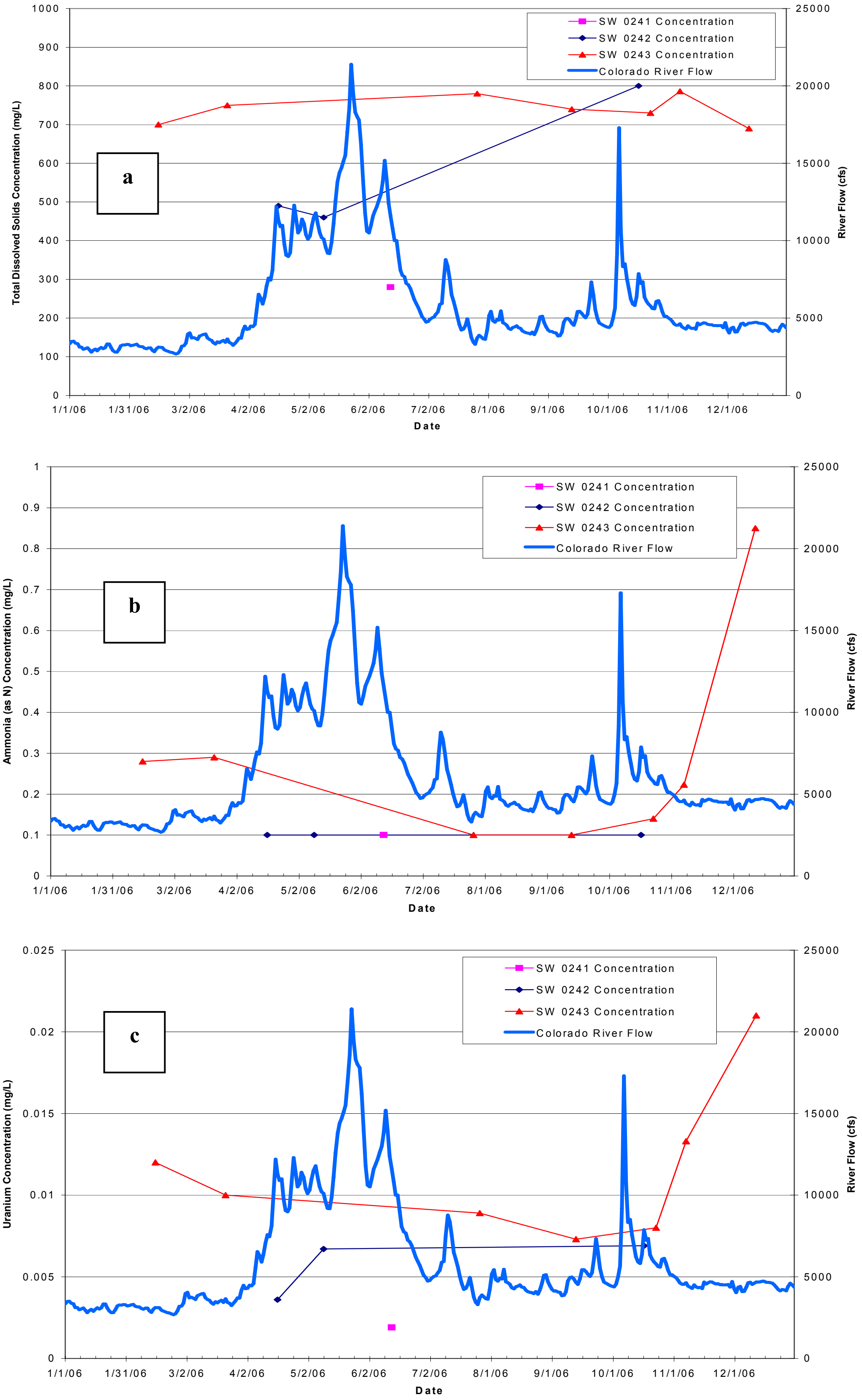


Figure 7–6. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Surface Water Locations 0241, 0242, and 0243 During 2006

As was the case in 2005 (DOE 2006a), the temporal history of water chemistry at well 0470 (Figure 7–7) is fairly representative of all Configuration 1 extraction wells. Inspection of the graphs in this figure reveals some clear patterns. One of the most obvious patterns is that the temporal behavior of all three constituents (TDS, NH_3-N, uranium) is similar. That is, as TDS concentrations increase in the water extracted from well 0470, so do the concentrations of ammonia and uranium. This behavior is typical of water withdrawn from shallow parts of the alluvial aquifer (DOE 2003d).

Another obvious pattern seen in Figure 7–7 is the uniform decrease in analyte concentrations in response to high flows in the Colorado River. In previous years during operation of Configuration 1, the river peaked only once. In 2006, the river peaked twice—between April and July and again in October. The response of contaminant levels to both of these events clearly illustrate the strong influence of the river on the ground water system. The concentration decreases are significant, as levels of TDS, ammonia, and uranium during high flow periods tend to be about a third of what they were during the previous winter. The lowest concentrations of TDS, ammonia, and uranium all appear to coincide with these periods of peak flow. These observations clearly show that river water migrates into the ground water system during periods of high river runoff, and the Configuration 1 extraction wells mostly withdraw river water at these times. Decreases in concentration were not as dramatic in 2006 as they were in 2005 (DOE 2006a) when the river flow peaked at nearly twice the maximum observed in 2006.

Previous performance reports (e.g., DOE 2006a) have suggested that hydraulic conductivity decreases from south to north along the Configuration 1 well field (i.e., highest conductivity in the vicinity of extraction well 0470, decreasing north to 0479). Extraction wells 0470, 0471, and 0472 all show a fairly rapid response of contaminant concentrations to increased river flows (e.g., Figure 7–7), supporting the presence of high hydraulic conductivities in this area. The response in well 0473 (Figure 7–8), 0474, 0475 (Figure 7–9), and 0476 appear to have a time lag between high spring flow conditions and lowest contaminant concentrations. A second decrease in contaminant levels due to high flow conditions in October is not observed. Wells at the northernmost end of the configuration (e.g., 0477 [Figure 7−10] and 0478) show a limited concentration range with only a weak response, if any, to changes in river stage. These observations support previous conclusions that hydraulic conductivities do, indeed, decrease toward the northern end of Configuration 1.

It is interesting to note that nearly all samples collected from the extraction wells during pumping operations had TDS concentrations that were lower than their respective baseline (pre-pumping) concentrations. This is an indication that pumping of wells as shallow as those in Configuration 1 (screened from 10 to 20 ft) does not produce enough upconing to see a TDS increase at such shallow levels.

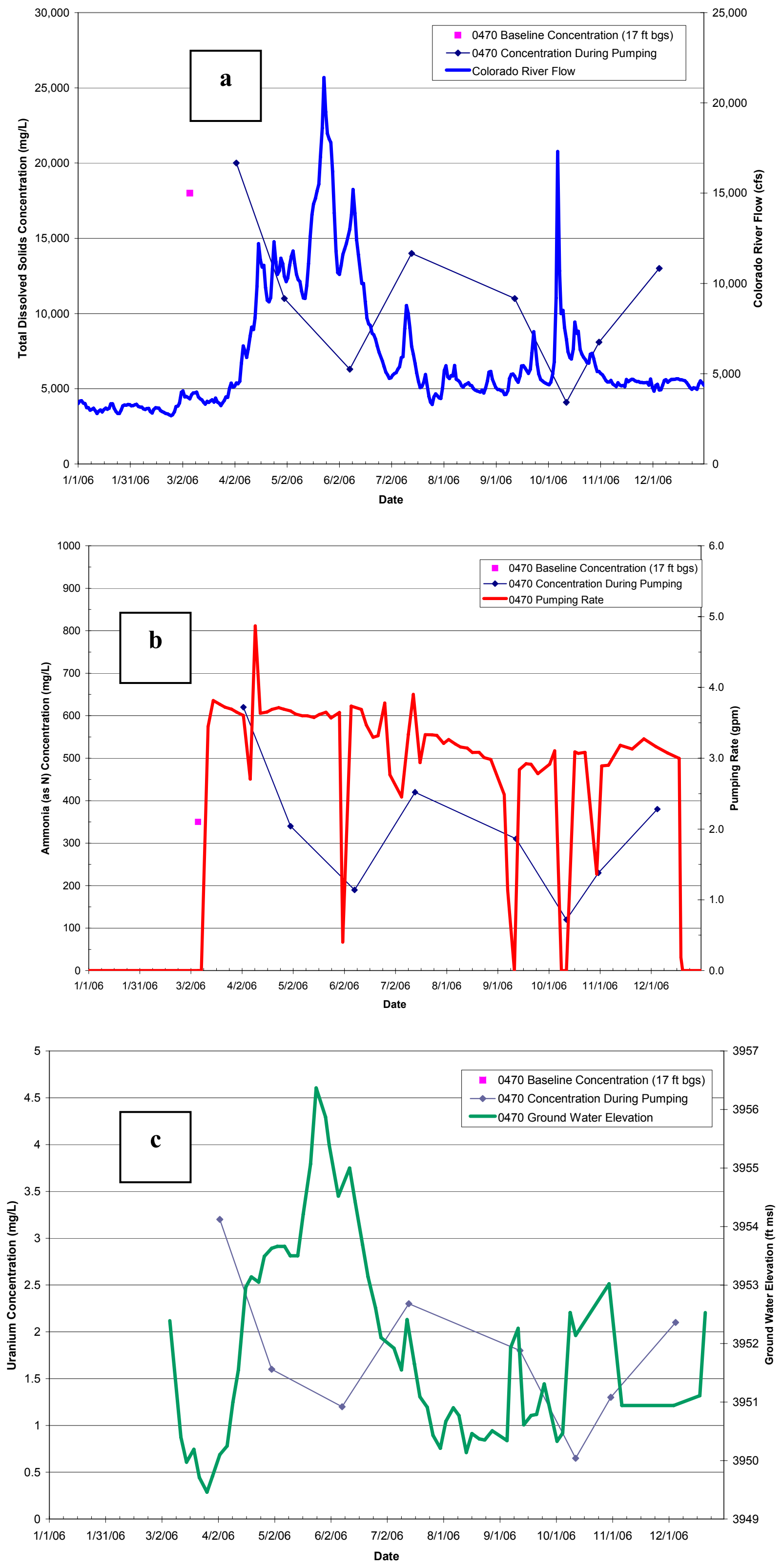


Figure 7–7. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Extraction Well 0470 During 2006

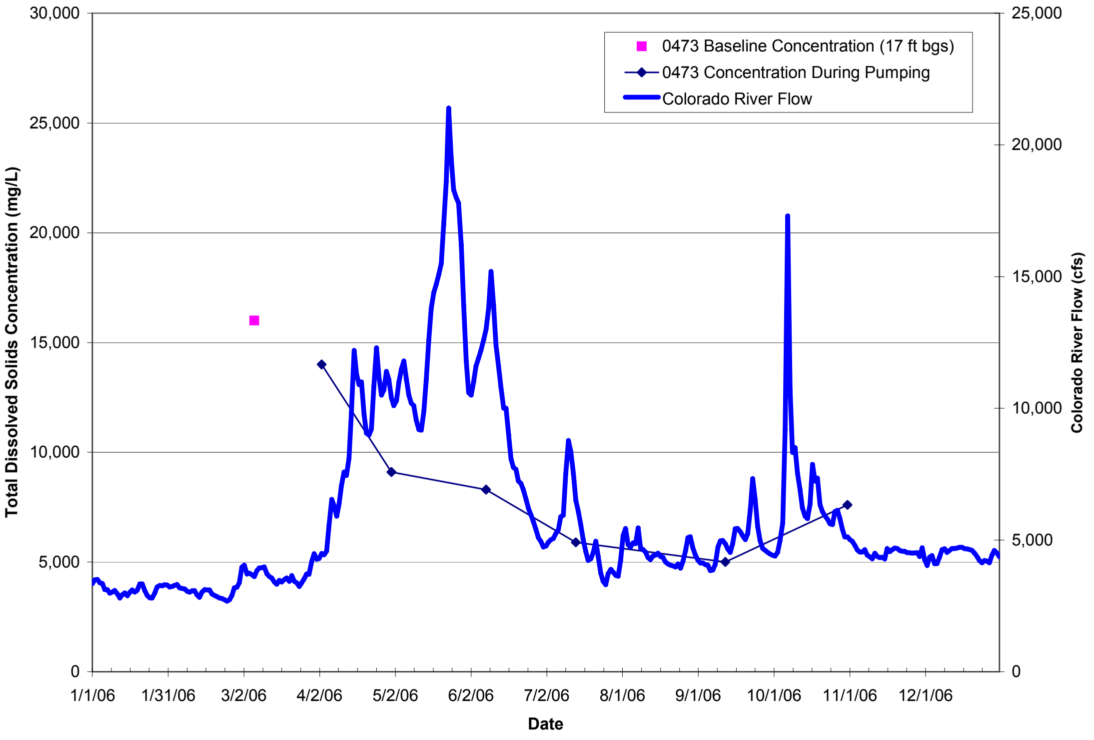


Figure 7–8. TDS Concentrations at Extraction Well 0473 and Colorado River Flow During 2006

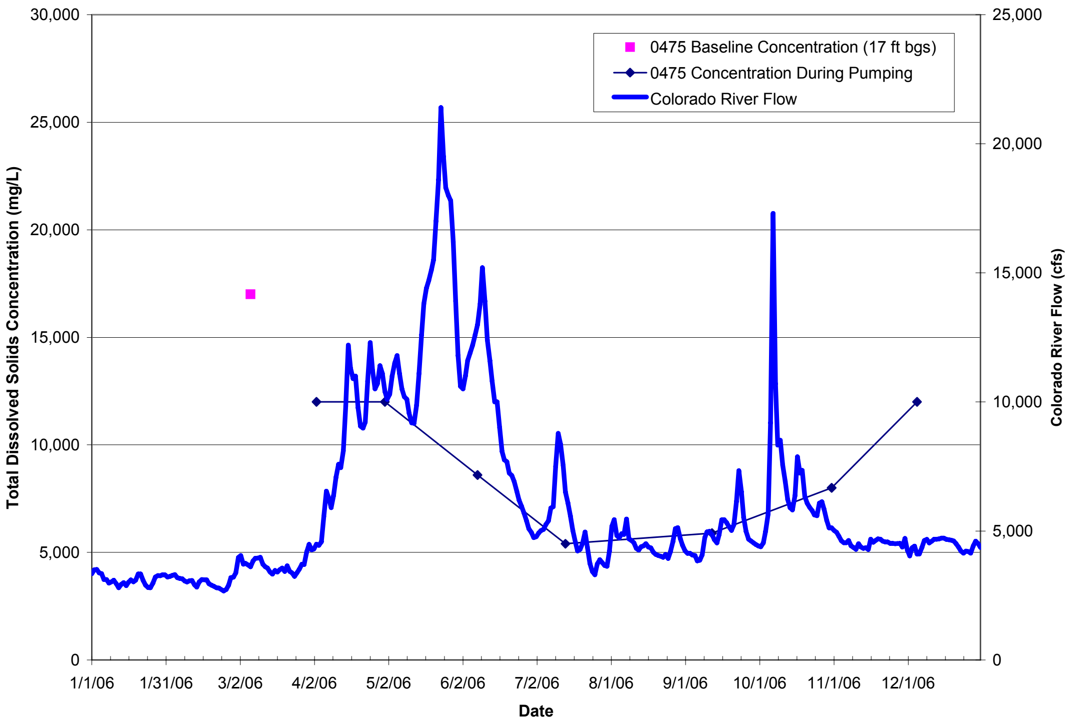


Figure 7–9. TDS Concentrations at Extraction Well 0475 and Colorado River Flow During 2006

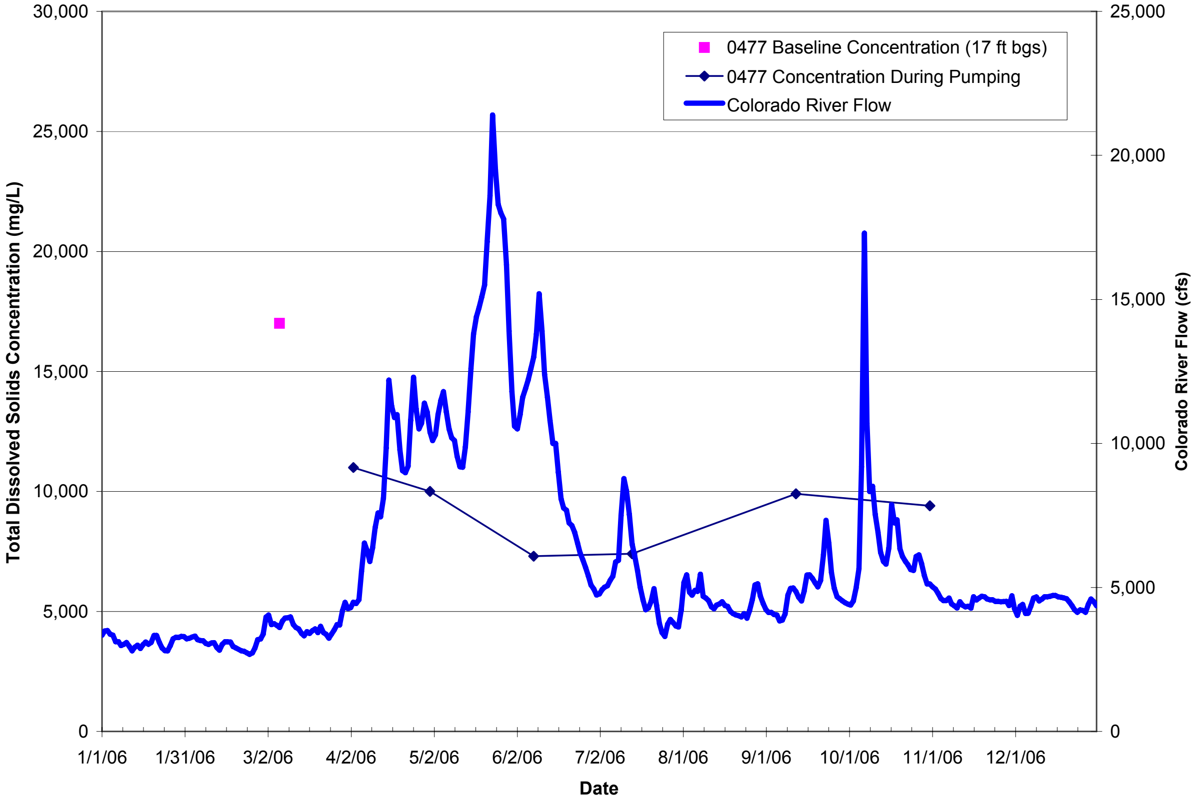


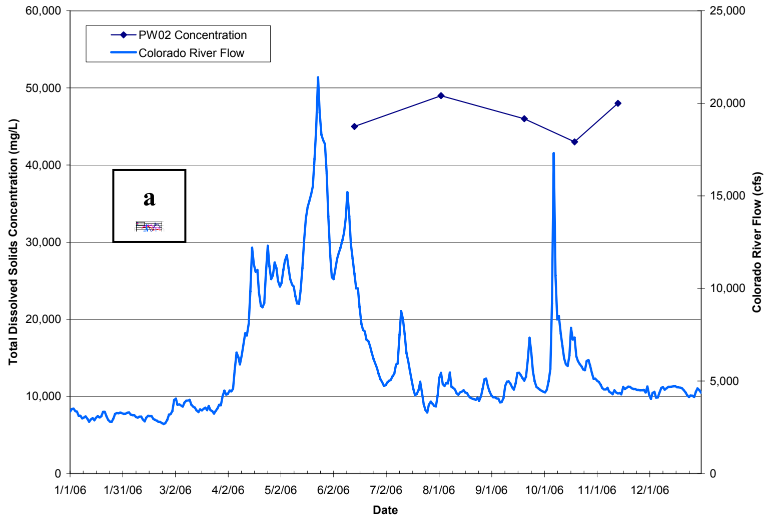
Figure 7–10. TDS Concentrations at Extraction Well 0477 and Colorado River Flow During 2006

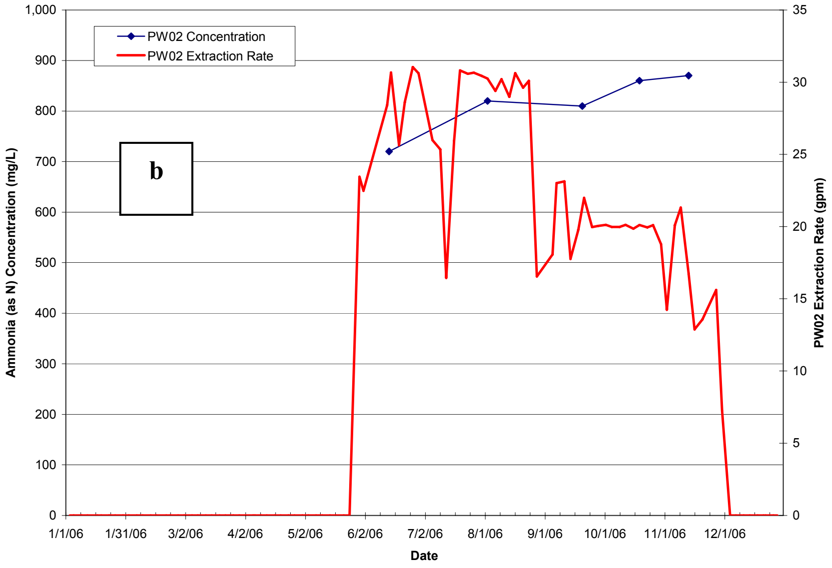
7.2.2 Extraction Well SMI-PW02

Extraction well SMI-PW02 (Figure 4–2) was generally sampled on a monthly basis after it was added to the ground water extraction system in late May 2006 (Appendix C−6). SMI-PW02 continued to operate until late November when it was shut down for the winter. During the active pumping timeframe samples were collected directly from the discharge line of the dedicated submersible pump that has its intake set at a depth of approximately 55 ft bgs.

Figure 7–11 presents the TDS, ammonia, and uranium time versus concentration plot generated for data collected during 2006. Similar to the other Configuration 1 extraction wells, the TDS concentration is plotted with the Colorado River flow data (a), the ammonia data are plotted with the extraction rate data (b), and uranium concentration data are plotted with ground water elevation data (c).

Baseline samples were not collected from this location prior to initiating pumping. However, previous sampling has demonstrated that, compared to wells 0470 through 0479, the Colorado River flow caused minimal changes in the analyte concentrations (DOE 2006a). Data collected in 2006 reinforced this observation. The difference in behavior between SMI-PW02 and the Configuration 1 extraction wells can be explained by the depth at which SMI-PW02 samples were collected (55 ft bgs) and the increased distance SMI-PW02 is located away from the bank of the Colorado River compared to Configuration 1. Sampling results indicate the TDS concentration ranged from about 45,000 to 50,000 mg/L, ammonia ranged from 700 to





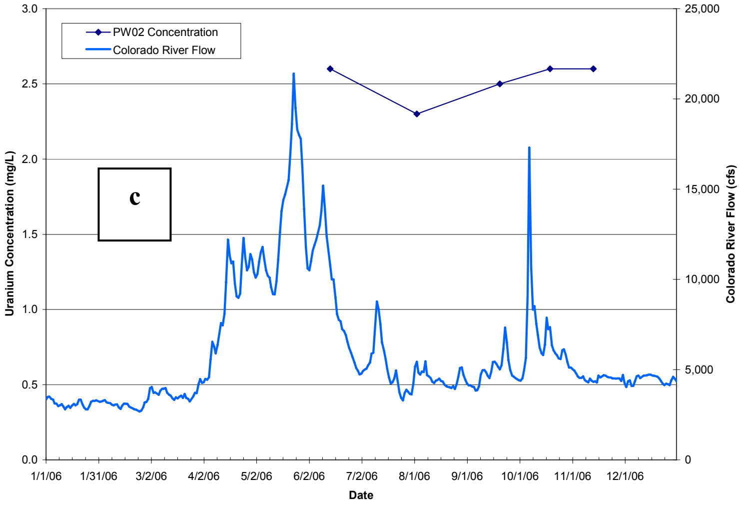


Figure 7–11. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Well SMI-PW02 During 2006

900 mg/L, and uranium ranged from 2.3 to 2.6 mg/L during the 2006 pumping season. Compared to 2005, the concentrations ranges for TDS and ammonia were lower during 2006 while the uranium range was higher.

Well SMI-PW02 is screened from 20 to 60 ft. Though this well has not been sampled at multiple discrete depths, information obtained from other wells indicates that it is screened across the brine interface. Observation well 0480, located downgradient from SMI-PW02, indicated that the brine interface is deeper than 18 ft bgs (TDS in this well was <35,000 mg/L). Because the brine interface increases in depth with distance from the riverbank, the top of the SMI-PW02 well screen is undoubtedly above the interface (under 2006 non-pumping conditions). However, the majority of the screened interval is likely below the interface in order to produce the average TDS concentrations between 40,000 and 50,000 mg/L that were observed. As noted above, TDS and ammonia were lower in SMI-PW02 during 2006 while the uranium range was higher. Because river flows were much lower in 2006 compared to 2005, the brine surface was likely at a lower elevation; therefore the well sampled a higher proportion of ground water above the interface than during the previous year.

7.2.3 Observation Wells

Configuration 1 observation wells (Figure 4–2) located in the upgradient well cluster (0480, 0481, 0482, and 0557), just downgradient of the well field axis well cluster (0483, 0484, 0485, and 0558), and farther downgradient well cluster (0559, 0560, 0561, and 0596) were sampled more or less on a monthly basis while the well field was operating between March and December 2006. All analytical data are presented in Appendix C−8.

7.2.3.1 Upgradient Well Cluster 0480/0481/0482/0557

Figure 7–12 presents analytical results of samples collected upgradient of Configuration 1 from depths of 18 ft bgs (well 0480), 28 ft bgs (well 0481), 36, 40, and 44 ft bgs (well 0557), and 58 ft bgs (well 0482). The TDS and uranium concentration data are plotted with the Colorado River flow data and the ammonia data are plotted with the extraction rate data. The portions of the plots from March through June show relatively constant concentrations of constituents. The deepest well maintains these concentrations through the entire monitoring period. However, the three shallow wells, while initially fairly close in concentration, show variable and diverging trends beginning in June. These trends do not coincide with changes in river levels or Configuration 1 pumping rates. However, these changes do occur shortly after the onset of pumping of well SMI-PW02, located upgradient of these observation wells. SMI-PW02 pumping may be pulling the brine interface upward as evidenced by increasing TDS in the shallower observation wells. While SMI-PW02 pre-pumping conditions indicated the brine interface was deeper than 40 ft bgs in this observation well cluster (and above 58 ft bgs), by September the interface had risen to above 28 ft bgs. The fact that the Configuration 1 extraction wells continue to have TDS concentrations less than their baseline conditions during this timeframe indicates that the trends noted in the observation wells is not as a result of Configuration 1 pumping. These observations support the premise that SMI-PW02 pumping is causing upconing of the brine surface and is having a greater effect on the interface than pumping of Configuration 1 extraction wells.

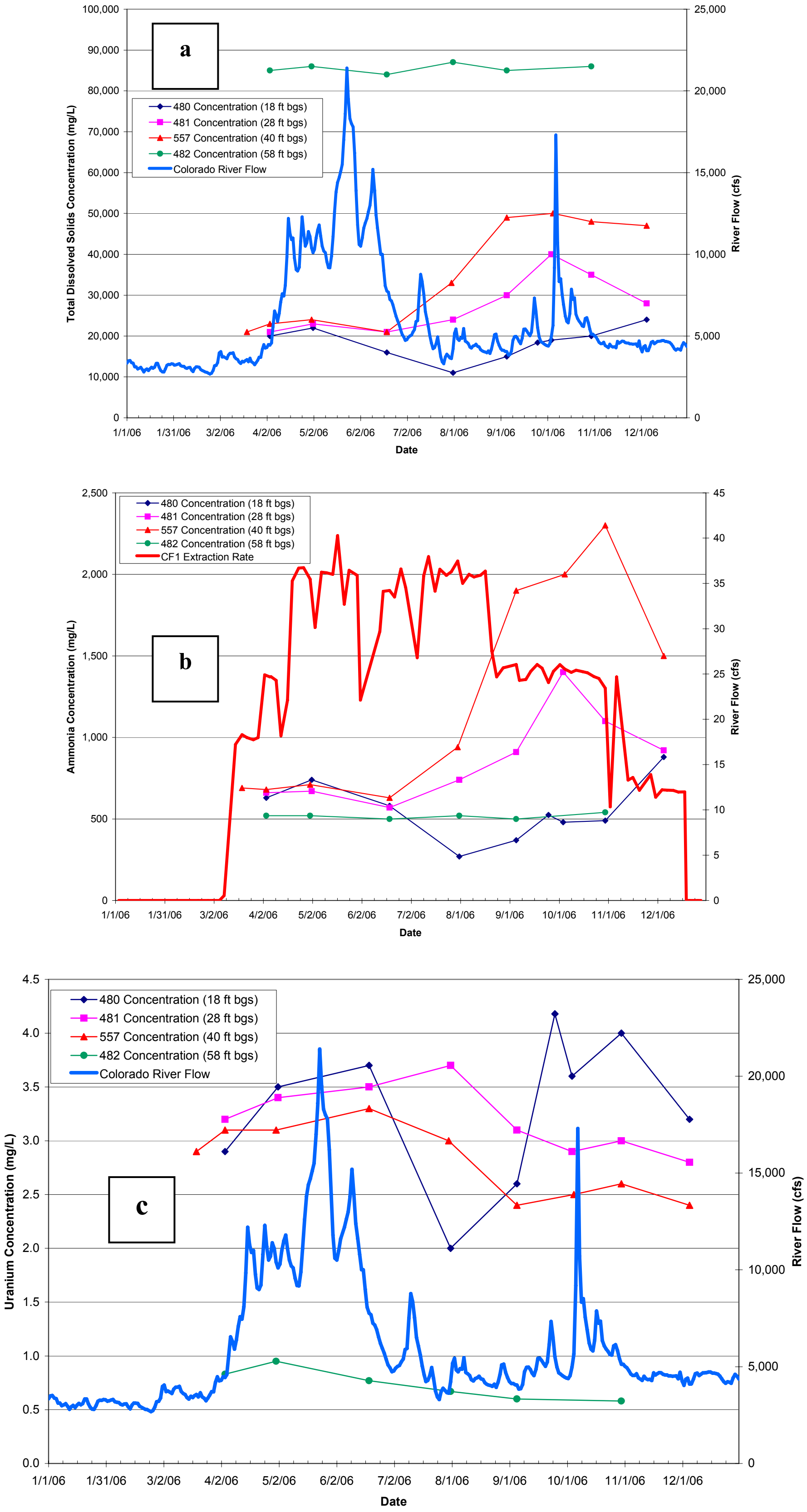


Figure 7–12. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Observation Wells 0480, 0481, 0482, and 0557 During 2006

Irrigation of plot C3 took place during operation of Configuration 1 in 2006. Unlike the flood irrigation practices used during 2005, irrigation water was applied more uniformly during 2006. This, coupled with the lower hydraulic conductivity in the northern portion of Configuration 1, makes it unlikely that the irrigation had a significant impact on operation or monitoring of the Configuration 1 system.

7.2.3.2 Downgradient Well Cluster 0483/0484/0485/0558

The downgradient well cluster located closest to the well field (less than 25 ft from the axis) provided data from depths of 18 ft bgs (well 0483), 28 ft bgs (well 0484), 36 and 44 ft bgs (well 0558), and 58 ft bgs (well 0485). The most complete data sets collected from 2006 were associated with samples collected from wells 0483, 0484, and 0558 at a depth of 36 ft bgs (Figure 7–13).

The TDS plot [Figure 7–13(a)] indicates concentrations increase with depth, with the brine interface lying initially between 28 ft bgs and 36 ft bgs during non-pumping Colorado River base flow conditions (March 2006). By the end of the pumping period, the interface rose to a level shallower than 29 ft bgs. This may be due to pumping of well SMI-PW02, possibly combined with the late peak in river flow (serving to cause an increase in elevation of the interface).

Ammonia concentrations [Figure 7–13(b)] generally followed the same pattern as TDS with depth, with the exception of well 0485. This well is the deepest in the cluster and has the highest concentration of TDS. However, by this depth below the interface (58 ft bgs) ammonia concentrations have begun to decline, consistent with the conceptual model for the site (DOE 2003d). The shallowest well in the cluster (0483 at 18 ft bgs) appears to show slight variation in response to river flow conditions. The well showing the highest degree of variability in this cluster is 0558 at 36 ft bgs.

7.2.3.3 Downgradient Well Cluster 0559/0560/0561/0596

The downgradient well cluster located closest to the river bank (approximately 65 ft off the well field axis) were sampled from depths of 19 ft bgs (well 0559), 24 ft bgs (well 0596), 31, 35, and 39 ft bgs (well 0560), and 46, 50, and 54 ft bgs (well 0561).

The TDS plot [Figure 7–14(a)] indicates concentrations increase with depth, with the brine interface lying between 24 ft bgs (3,600 mg/L) and 31 ft bgs (61,000 mg/L) during non-pumping Colorado River base flow conditions (March 2006). The interface fluctuated around the 31 ft depth (well 0560) during the 2006 monitoring period. The interface was located at deeper levels in 2006 compared to 2005, when river flows were significantly higher.

The highest ammonia concentrations [Figure 7–14 (b)] under the same non-pumping conditions were measured from 31 ft bgs with the lowest from 19 ft bgs, and the highest the uranium concentration [Figure 7–14 (c)] was measured again at 31 bgs and the lowest concentration measured from 19 bgs. Concentrations of ammonia and uranium were most variable in well 0560, which was located alternately above and below the brine interface.

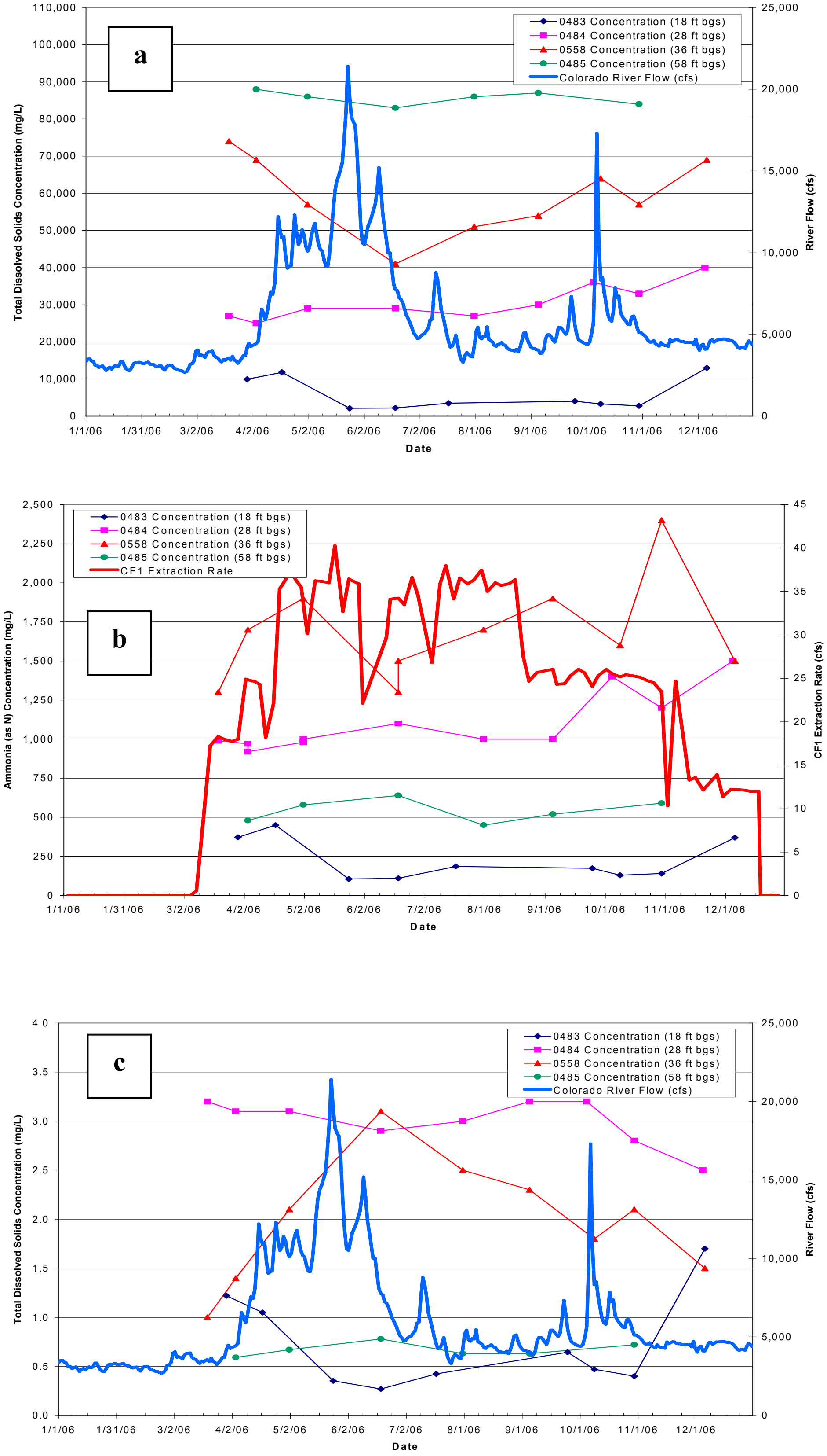


Figure 7–13. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Observation Wells 0483, 0484, 0485, and 0558 During 2006

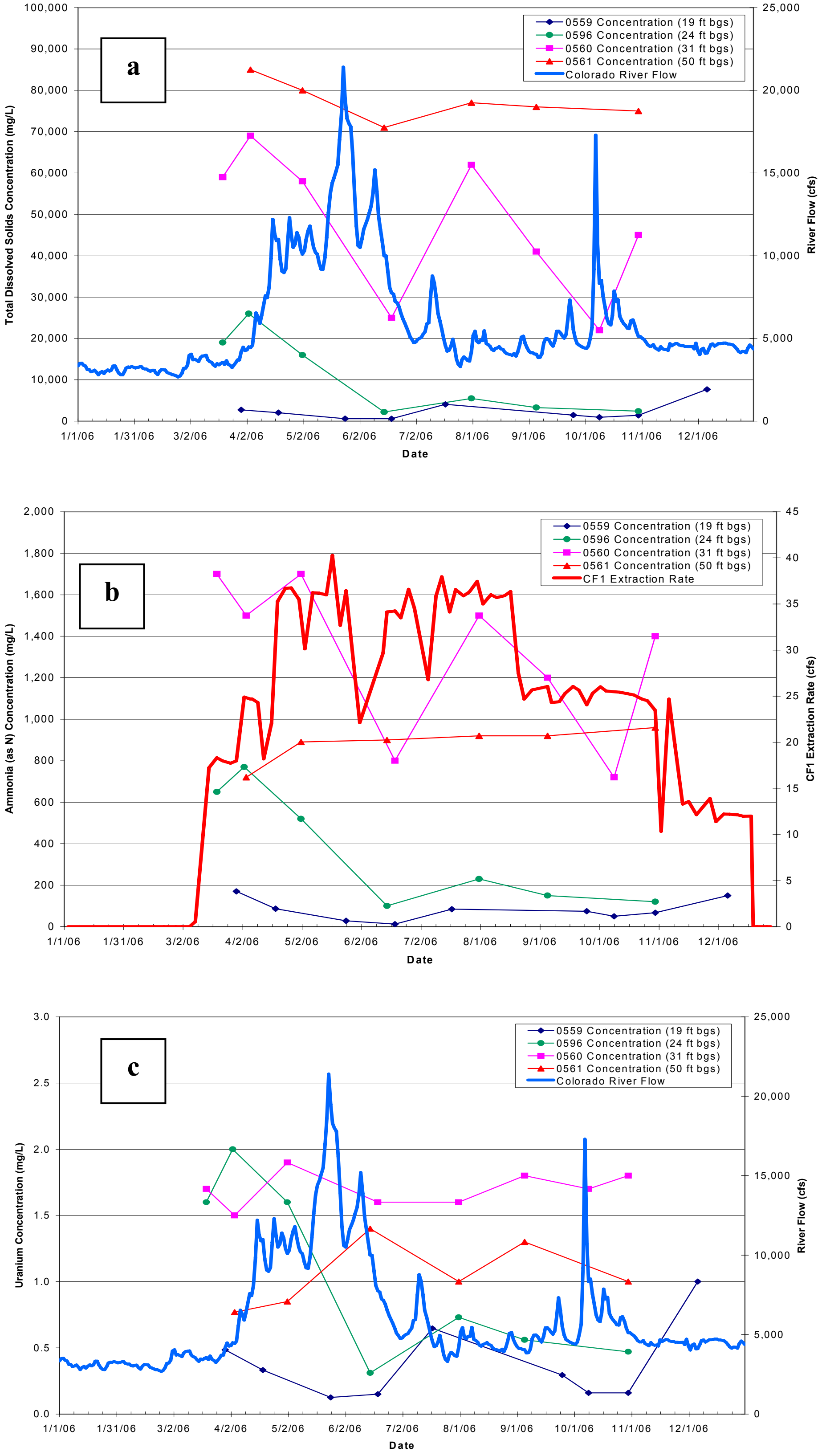


Figure 7–14. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Observation Wells 0559, 0560, 0561, and 0596 During 2006

7.2.3.4 Observation Wells 0403 and 0407

Observation wells 0403 and 0407 (Figure 7–15) are located at the north and south ends of Configuration 1, respectively. These wells each exhibit trends similar to extraction wells found at the opposite ends of the configuration. Well 0407 shows an initial decline in concentration of TDS, ammonia, and uranium at the onset of pumping; concentrations of these constituents then remain fairly uniform. In contrast, contaminant concentrations in well 0403 track more closely with river flow conditions, with highest concentrations coinciding with baseflow conditions. Similar trends exhibited in extraction wells at opposite ends of the configuration were attributed to differences in hydraulic conductivity of the aquifer from south (high) to north (lower).

Trends in wells 0403 and 0407 can be explained in terms of competing influence of the extraction system versus river flow conditions. The initial drop of constituent concentrations in well 0407 occurs in response to the onset of extraction from Configuration 1 wells, as would be expected in a highly conductive portion of the aquifer. The fact that relatively uniform concentrations are observed in this well during large fluctuations in river flow conditions indicates that the extraction wells are effective in maintaining a relatively constant influx of river water to the aquifer during pumping. It should be noted that well 0407 is located closer to Configuration 1 extraction wells than well 0403 and that ground water in the vicinity of well 0407 may also be influenced, in part, by the operation of extraction wells (e.g., 0779) at the northern end of Configuration 4.

As discussed in Section 9.1.1, extraction wells at the northern end of Configuration 1 appeared to be little affected by changes in river flow conditions and that relatively uniform concentrations were maintained in these wells throughout the monitoring period. Little, if any, river water is able to influence this portion of the aquifer either through pumping or natural bank storage. However, based on the response in well 0403, the river can influence the ground water in this area in locations sufficiently close to the river channel. The distance separating well 0403 and the closest extraction well (well 0477) is less than 75 ft. This provides a measure of the limited effectiveness of shallow pumping in this portion of the aquifer.

7.2.4 Riverbed Well Points

The Configuration 1 well points are split into three clusters containing three well points each that are installed at different depths. Refer to Figure 4–3 for well point construction details and Figure 4–2 for locations. Appendix C−8 contains all the analytical data.

Figure 7–16 presents the analytical results of samples collected from riverbed well points 0562, 0563, and 0606, all of which are located at the base of the bank (i.e., closest to the well field axis). Figure 7–17 presents similar plots for the well points 0608, 0611, and 0612 (which are located at an intermediate distance between the base of the riverbank and the Colorado River). Few data could be collected from well points farther from the bank; those data are included in Appendix C−8, but are not discussed here. The TDS and uranium concentration data are plotted with the Colorado River flow data and the ammonia data are plotted with the Configuration 1 extraction rate data.

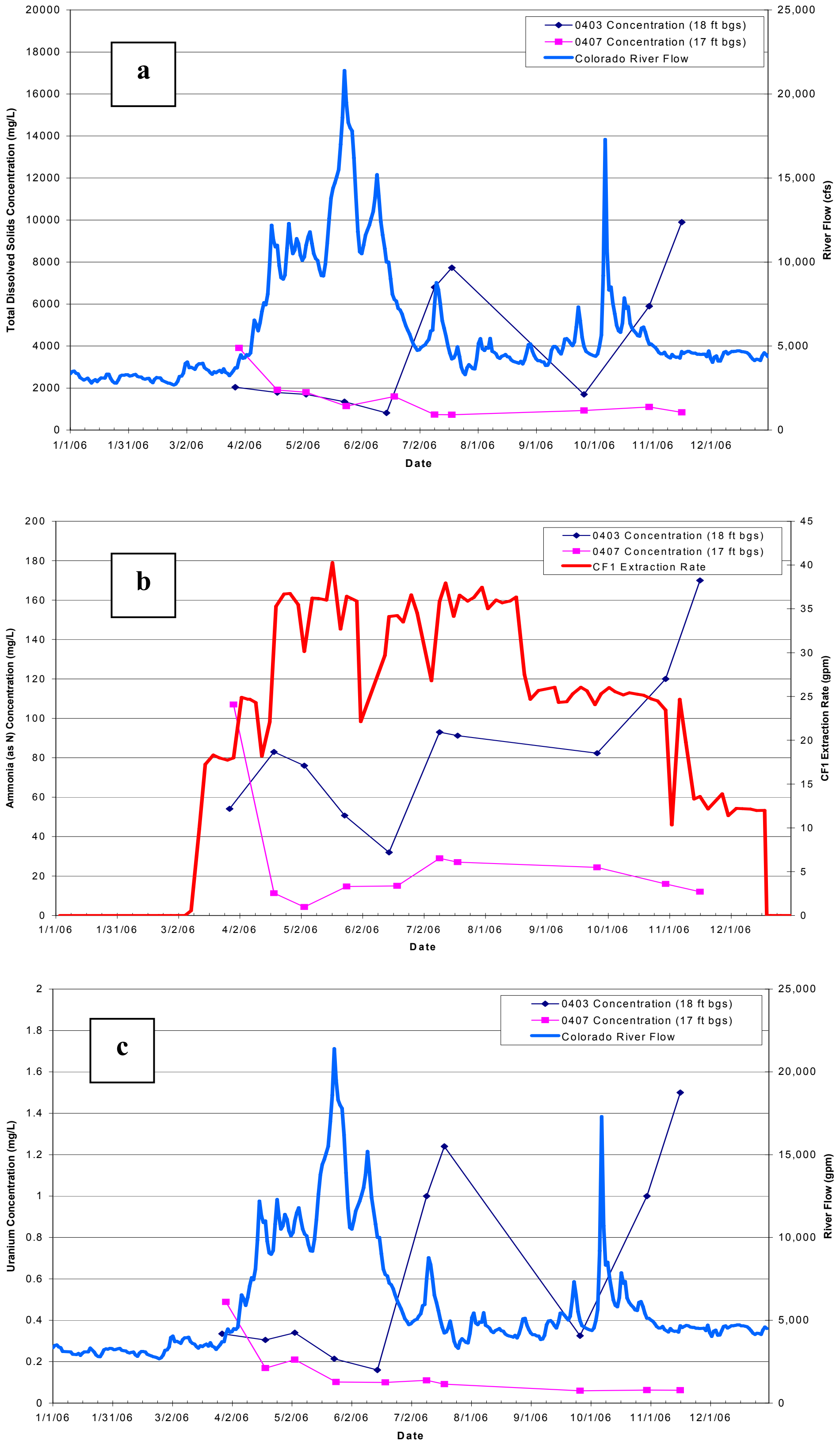


Figure 7–15. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Observation Wells 0403 and 0407 During 2006

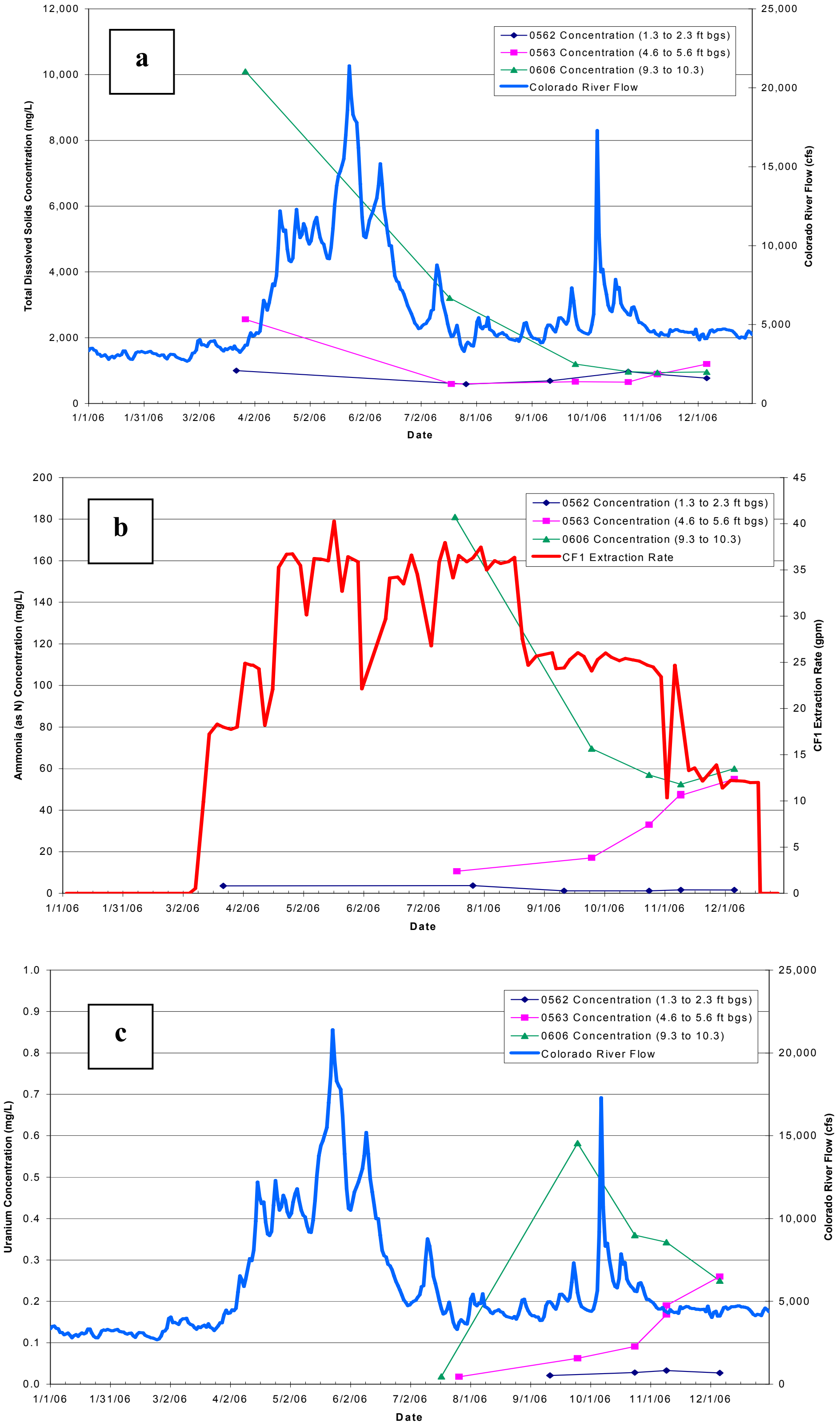


Figure 7–16. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Riverbed Well Points 0562, 0563, and 0606 During 2006

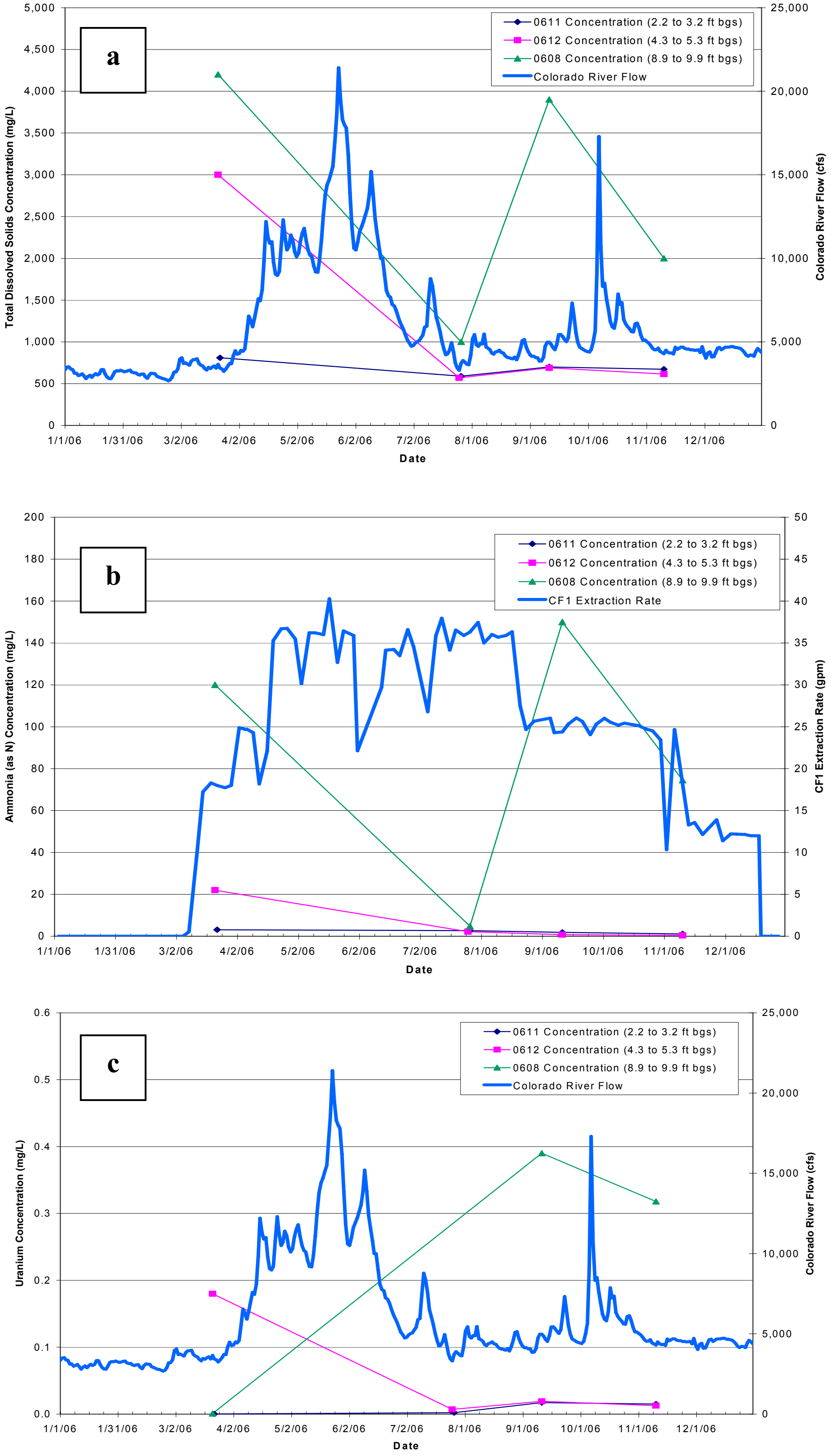


Figure 7–17. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Riverbed Well Points 0608, 0611, and 0612 During 2006

As with the observation wells, TDS and ammonia generally increase with depth in the piezometers. All piezometers were located above the brine interface. Concentrations of TDS, ammonia, and uranium all vary considerably in samples collected from piezometers, though no apparent trends are noted, partly because of the limited data collected. The deepest piezometers show the greatest chemical variation and maximum concentrations. The deeper piezometers appear to have contaminant concentrations in a similar range to the shallowest downgradient observation wells (e.g., 0559).

7.2.5 Surface Water Locations

Surface water samples were collected at the base of the riverbank near the 0562/0563/0606 piezometer cluster (location 0216) and along the edge of a main side channel of the Colorado River, off the 0564/0565/0607 piezometer cluster (location 0245) on a fairly regular basis in 2006. Figure 4–2 shows these locations in relationship to Configuration 1. The analytical results (Appendix C−8) obtained from the samples collected at surface water locations 0216 and 0245 are presented as Figure 7–18.

Surface water concentrations were lower than those observed in even the shallowest piezometers on each side of surface location 0216. Thus, even though little surface water was present at this location during some sampling events, there appears to be some dilution of ground water as it discharges, either by the river or from precipitation events. TDS concentrations observed at location 0216 during 2006 were all within the range of background for the Colorado River (DOE 2003d). The highest levels of all constituents were observed during baseflow conditions. Generally low concentrations of ammonia and uranium were maintained during the summer months, though it is not possible to conclude that these were attributable to operation of the Configuration 1 extraction system. Monitoring of the surface water over the last several years has indicated that elevated contaminant concentrations are observed only rarely and are usually confined to isolated areas of stagnant water (DOE 2007c). The presence of such areas tend to be the exception rather than the norm.

Surface water concentrations are normally fairly low adjacent to the Configuration 1 wells. Concentrations tend to peak during baseflow conditions. Pumping at the southern portion of Configuration 1 effectively draws in river water and prevents discharge of contaminated ground water from this portion of the riverbank. If any nearshore habitat should develop adjacent to this portion of the configuration, operation of the extraction system should provide adequate protection of water quality.

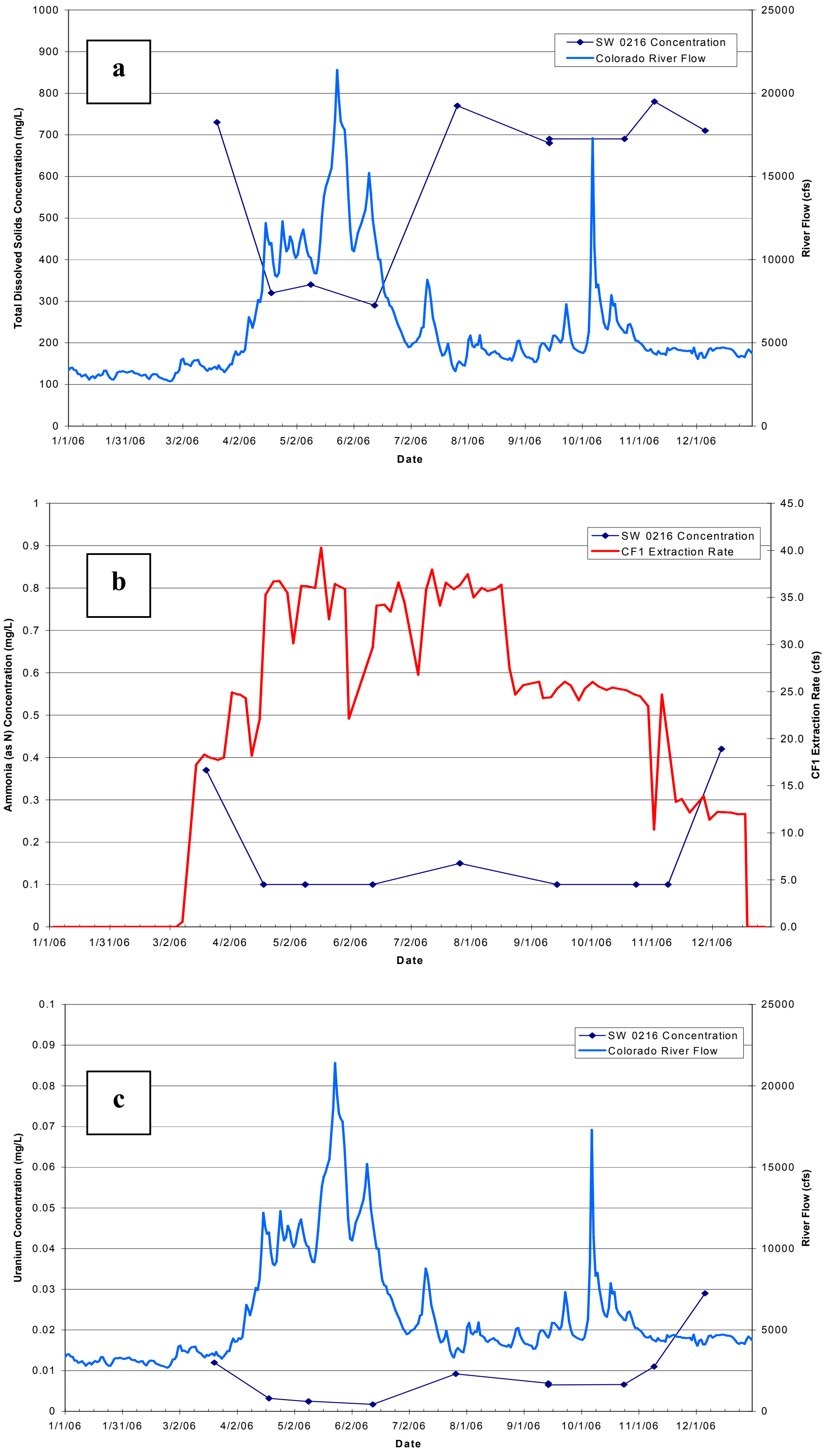


Figure 7–18. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Surface Water Location 0216 During 2006

7.3 Configuration 2

7.3.1 Remediation Wells 0570/0572/0573/0575/0577

Configuration 2 remediation wells (Figure 4–3) were sampled while operating in extraction mode, from April to September, 2006. The remediation wells were operated in injection mode from October 6, 2004 until March 16, 2006. Seven days later, on March 23, the remediation wells were switched to extraction mode. One reason for this was the fresh water storage pond was being demolished and a new pond constructed in spring 2006. Wells 0570 and 0572 (screened from approximately 15 to 30 ft bgs) were sampled at a depth of 27 ft bgs. Wells 0573, 0575, and 0577 (screened from approximately 25 to 40 ft bgs) were sampled at a depth of 37 ft bgs. During system operation, samples were collected directly from the discharge of the dedicated submersible pump in each well.

An example graphical depiction of TDS, ammonia, and uranium concentrations observed at Configuration 2 extraction wells during 2006 is present in Figure 7–19 (in this case for well 0575). Corresponding flows in the Colorado River are superimposed on the plot of TDS concentration [Figure 7–19(a)], a total system pumping rate is superimposed on the graph of ammonia concentration [Figure 7–19(b)], and measured ground water elevations in the extraction well are co-plotted with uranium concentrations [Figure 7–19(c)]. Because the same time scale is used in each of the graphs, the effects of river flow, total system pumping rate, and ground water elevation in the extraction well on all three analytes can be assessed. Comparable plots for the remaining remediation wells in Configuration 2 are presented in Appendix D−7.

The temporal history of water chemistry at well 0575 (Figure 7–19) is fairly representative of all Configuration 2 extraction wells (both shallow and deep). Inspection of the graphs in this figure reveals some clear patterns. One of the most obvious patterns is that the temporal behavior of all three constituents (ammonia, TDS, uranium) is similar, concentrations decrease with increasing river level.

7.3.1.1 Shallow Remediation Wells 0570/0572

During the maximum extraction rate, prior to the spring peak run-off, the shallow extraction well 0570 contained a lower concentration of analytes than shallow extraction well 0572. Shortly after the spring peak run-off, well 0570 displayed an increase in uranium (from 0.74 mg/L in early May to 1.5 mg/L in early June) and ammonia (from 160 mg/L in early May to 210 mg/L in early June), and a decrease in TDS (from 9,500 mg/L in early May to 5,400 mg/L in early June). Well 0572 showed a slight decrease in uranium soon after the spring peak run-off, while there was a decrease in ammonia (310 mg/L in early May to 250 mg/L in early June) and TDS (15,000 mg/L in early May to 12,000 mg/L in early June) concentration. The decrease in TDS and increase in ammonia and uranium in well 0570 represents a lowering of the brine interface due to the introduction of river water into the extraction system.

Both shallow extraction wells 0570 and 0572 displayed a general increase in analyte concentration from July to September. The rise in concentration correlates to lower extraction rates (gpm) and a lower river flow. The increase in uranium (in well 0570), ammonia, and TDS may possibly represent an upconing of the brine surface due to shallow aquifer extraction.

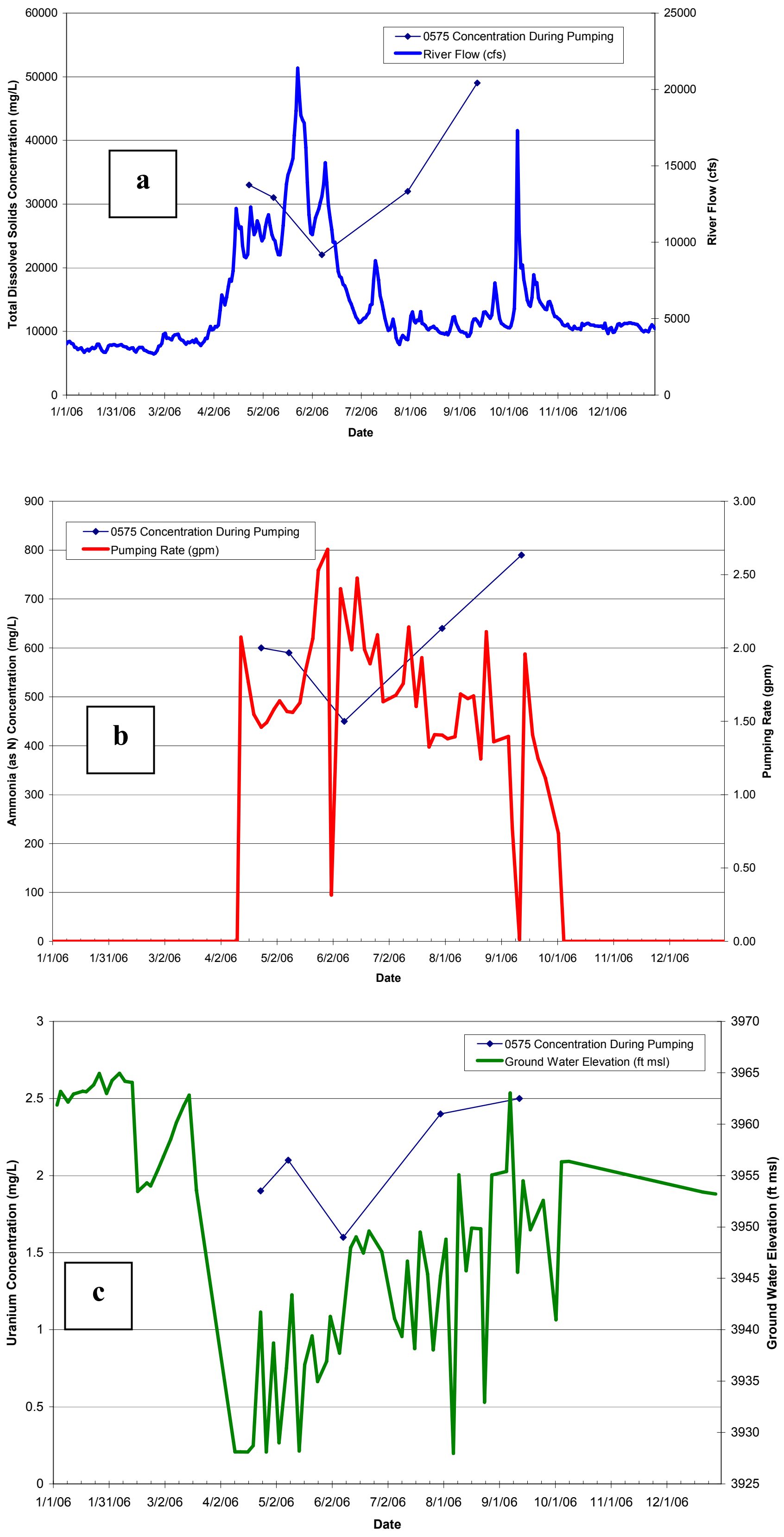


Figure 7–19. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Remediation Well 0575 During 2006

7.3.1.2 Deep Remediation Wells 0573/0575/0577

The deep Configuration 2 remediation wells were sampled five times throughout 2006. In late April, soon after the wells were switched from injection to extraction, well 0573 exhibited a higher ammonia and TDS concentration than 0577. In late April, the brine interface was located at 37 ft bgs in the vicinity of wells 0573 and 0575 and decreased in elevation to the north, as expected.

By early May, the extraction system had been operating longer than a month. The analytes slightly decreased or remained nearly the same (ammonia in well 0577), with the exception of uranium in wells 0575 (2.1 mg/L) and 0577 (2.4 mg/L), and ammonia in well 0577, which increased. River flow had ranged between 9,000 to 12,000 cfs from mid-April to early May and the increase in uranium is likely due to the introduction of oxygenated river water into the ground water system. At this time, the brine was situated within the screened interval of well 0573 (TDS concentration was 37,000 mg/L).

After the spring peak run-off, the analyte concentration decreased in all wells. This is due to the dilution of the analytes by the introduction of surface river water into the ground water system. As a result, the brine interface lowered in elevation, as signified by the decrease in TDS in the Configuration 2 deep remediation wells (22,000 mg/L in well 0575 on June 8).

In late July, the concentrations for ammonia, TDS, and uranium increased. The river flow had decreased and the extraction of the ground water resulted in an upconing, of the brine interface. By mid-September, the TDS, ammonia, and uranium (well 0575) concentration had increased to levels higher than the pre-run-off peak levels. The uranium concentration in well 0577 increased slightly from 2.4 mg/L in July to 2.5 mg/L in mid-September.

7.3.2 Observation Wells

Configuration 2 observation wells (Figure 4–3) located in the upgradient well cluster (0583 and 0600) and downgradient cluster (0587, 0588, 0589, 0602) were sampled intermittently during the time when Configuration 2 was on injection mode, extraction mode, and under non-pumping conditions. During 2006, samples were collected from key wells within each cluster in order to monitor the movement of the brine interface during pumping. All analytical data are presented in Appendix D−8.

7.3.2.1 Upgradient Wells 0583 and 0600

The upgradient well cluster located closest to Configuration 2 provided data from depths of 18 ft (well 0583) and 27 ft (well 0600). The most complete data sets collected from 2006 were associated with samples collected from wells 0583 and 0600.

From January to mid-March 2006, Configuration 2 operated in injection mode. During this time-frame, the analyte concentration was higher in well 0600 and the levels remained fairly constant until the fresh water injection was suspended. The TDS at 27 ft during injection was 19,000 mg/L, indicating that the brine interface was located below 27 ft bgs. Prior to the initiation of the extraction system, samples were collected from both of the upgradient wells. The only analyte that altered from January to mid March was ammonia, which increased from 610 mg/L to 800 mg/L in well 0600 and from 240 mg/L to 330 mg/L in well 0583 (Figure 7–20).

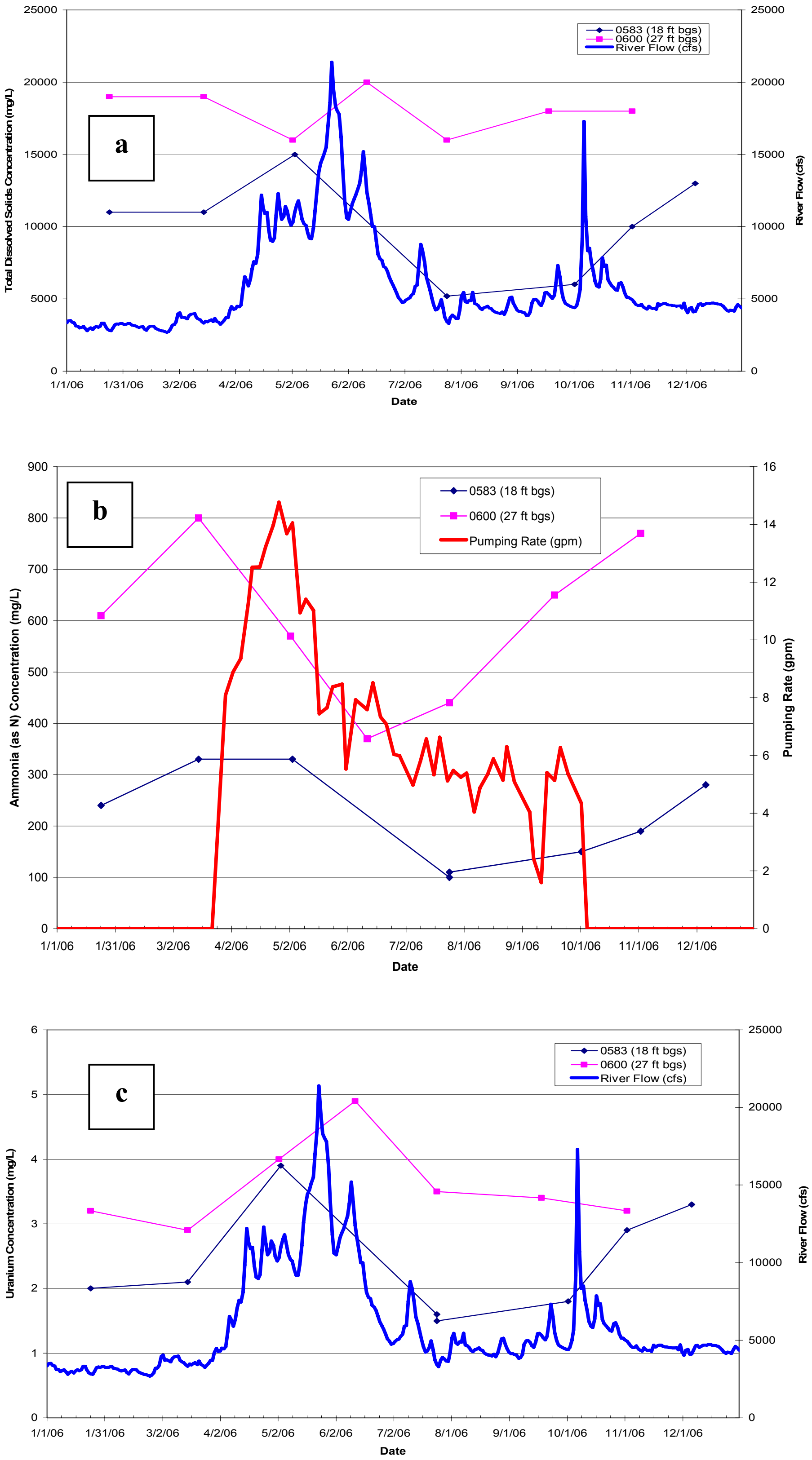


Figure 7–20. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Observation Wells 0583 and 0600

The Configuration 2 remediation wells were switched to extraction mode on March 23 and samples were collected from the upgradient cluster the first week in May. As a result, the uranium concentration increased from 2.1 mg/L (in March) to 3.9 mg/L (in May) in well 0583 and from 2.9 mg/L (in March) to 4.0 mg/L (in May) in well 0600. The TDS concentration increased in well 0583 to 15,000 mg/L and decreased in well 0600 to 16,000 mg/L, which indicates that the elevation of the brine interface had increased. A decrease in ammonia concentration in wells 0600 and 0583 also corresponds to the initiation of the nearby vegetated plots irrigation system.

The uranium concentration remained fairly consistent with post-peak flow values. Uranium concentration began to increase in late October into November after the extraction wells had been shut off and irrigation had ceased. The TDS values in well 0583 began to increase from 6,000 mg/L on October 2, to 13,000 mg/L on December 6, 2006. The TDS values in well 0600 remained fairly constant with the post-peak flow values. From October to December, the ammonia values in well 0583 increased from 150 mg/L in early October to 280 mg/L in early December, and well 0600 increased from 650 mg/L in mid-September to 770 mg/L in early November. After the freshwater irrigation system was suspended in August, the analyte concentration began to rebound back to pre-spring runoff and irrigation levels.

7.3.2.2 Downgradient Well Cluster 0587/0602/0588/0589

The downgradient well cluster located closest to the well field provided data from depths of 18 ft (wells 0587 and 0602), 34 ft (well 0588), and 52 ft (well 0589). The most complete data sets collected from 2006 were associated with samples collected from wells 0587, 0588, 0589, and 0602.

From January to mid-March 2006, Configuration 2 operated in injection mode. During this time-frame, wells 0587 and 0602 both exhibit mildly saline TDS values, and the brine interface was situated between 34 ft bgs and 52 ft bgs. Downgradient wells 0587 and 0588 were sampled the week prior to the wells being switched over to extraction mode. These samples documented a significant decrease in all analyte concentrations at 34 ft, while the levels at 18 ft remained consistent with the January data.

The Configuration 2 remediation wells were switched over to extraction mode on March 23 and samples were collected from the downgradient cluster the first week in May. The TDS values indicate that the brine interface was situated near 34 ft bgs, which corresponds to the peaks in all analyte concentrations for well 0588, as well as the maximum extraction rate for the year. This is likely the result of upconing of the brine interface during extraction. A rapid increase in uranium is documented at 18 ft in May. It is possible that the rapid increase in uranium was due to the introduction of oxygenated water river water into the upper aquifer, which resulted in the dissolution of solid-phase metals, such as uranium.

After the peak Colorado River runoff on May 24, the analyte concentration decreased in well 0588, likely due to the introduction of river water into the ground water system, leading to dissolution. The analyte concentration in wells 0587 and 0602 remained fairly constant after the peak run-off with the exception of uranium (Figure 7–21). After the initiation of irrigation of diverted surface water into plot C4 in April, the uranium concentration in wells 0587 and 0602 greatly increased and peaked to concentrations of 2.33 and 2.7 mg/L by July, possibly the result

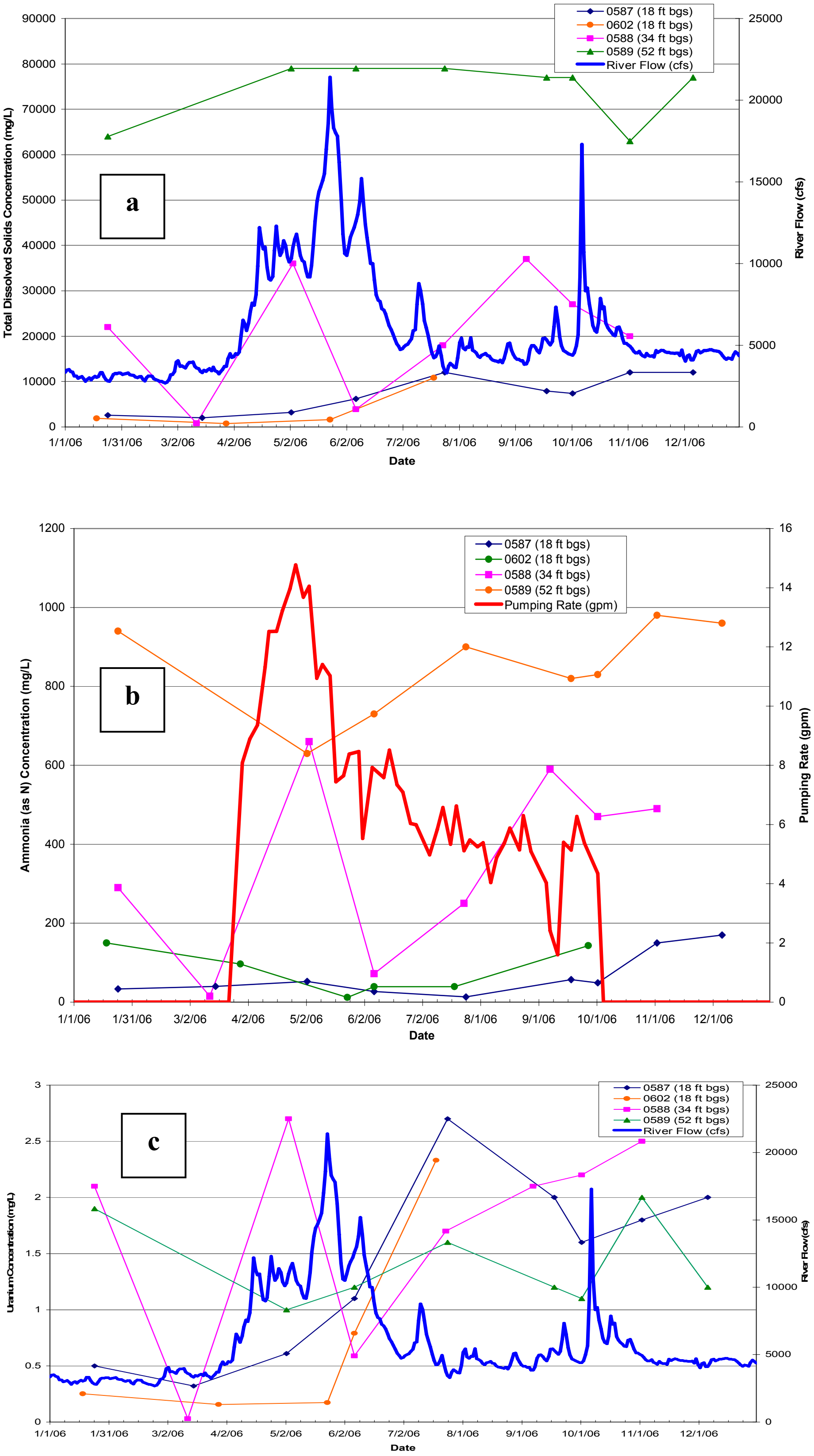


Figure 7–21. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Observation Wells 0587, 0588, 0589, 0602 During 2006

of oxygenated water in the upper aquifer. The analyte concentration in well 0589 does not appear to have been greatly influenced by the spring run-off. During the peak run-off, the brine interface was situated between 34 and 52 ft bgs.

By mid-July to September the analyte concentration in wells 0588 and 0589 began to rebound back to pre-peak, extraction mode levels. Well 0588 exhibits a peak in ammonia and TDS concentration in early September. The TDS concentration, 37,000 mg/L, indicates that the brine interface was situated near 34 ft bgs during this time. The fluctuations between the ammonia and uranium concentrations for wells 0588 and 0589 represent an oscillation of the brine interface during varying of the river flow and pumping conditions. A large-scale precipitation event occurred in early October. As a result, the brined interface decreased in elevation, which is indicated by a decrease in TDS an increase in uranium in well 0589. By December, the uranium concentration had decreased and TDS concentrations increased, which signifies that the brine interface had increased in elevation once again.

The upgradient observation wells were most impacted by river flow and the irrigated plots, directly west of the wells. Analyte concentrations began to decrease in May and increased again in August to September to near pre-spring runoff peak values.

7.3.3 Riverbed Well Points

The river bank well point cluster located closest to the well field provided data from depths of 3.9 to 4.9 ft bgs ft (0591) and 9.2 to 10.2 ft bgs (well 0603). The most complete data sets collected from 2006 were associated with samples collected from wells 0591 and 0603 (Figure 7–22).

During injection mode of the remediation wells, well points 0591 and 0603 contained similar levels of uranium (0.091 mg/L for well point 0591 and 0.029 for well point 0603). The TDS value for the river bank well points during injection was 2,020 mg/L for 0603 and 5,300 mg/L for 0591, or mildly saline. The ammonia concentration was 145 mg/L for well point 0591 and 384 mg/L for well point 0603.

Samples were not collected from the river bank well points between late March and July due to accessibility issues; therefore, the initial response extraction system was not recorded. In July, the TDS concentration in well points 0591 and 0603 decreased, likely in response to the seasonal increase in river flow. On July 18, the TDS concentration was nearly the same for well points 0591 (3,030 mg/L) and 0603 (2,970 mg/L). The uranium concentration in both well points appears to have remained relatively unchanged from the onset of extraction, through the peak flow, and into July, though the uranium concentration between late May and July is unknown due to accessibility.

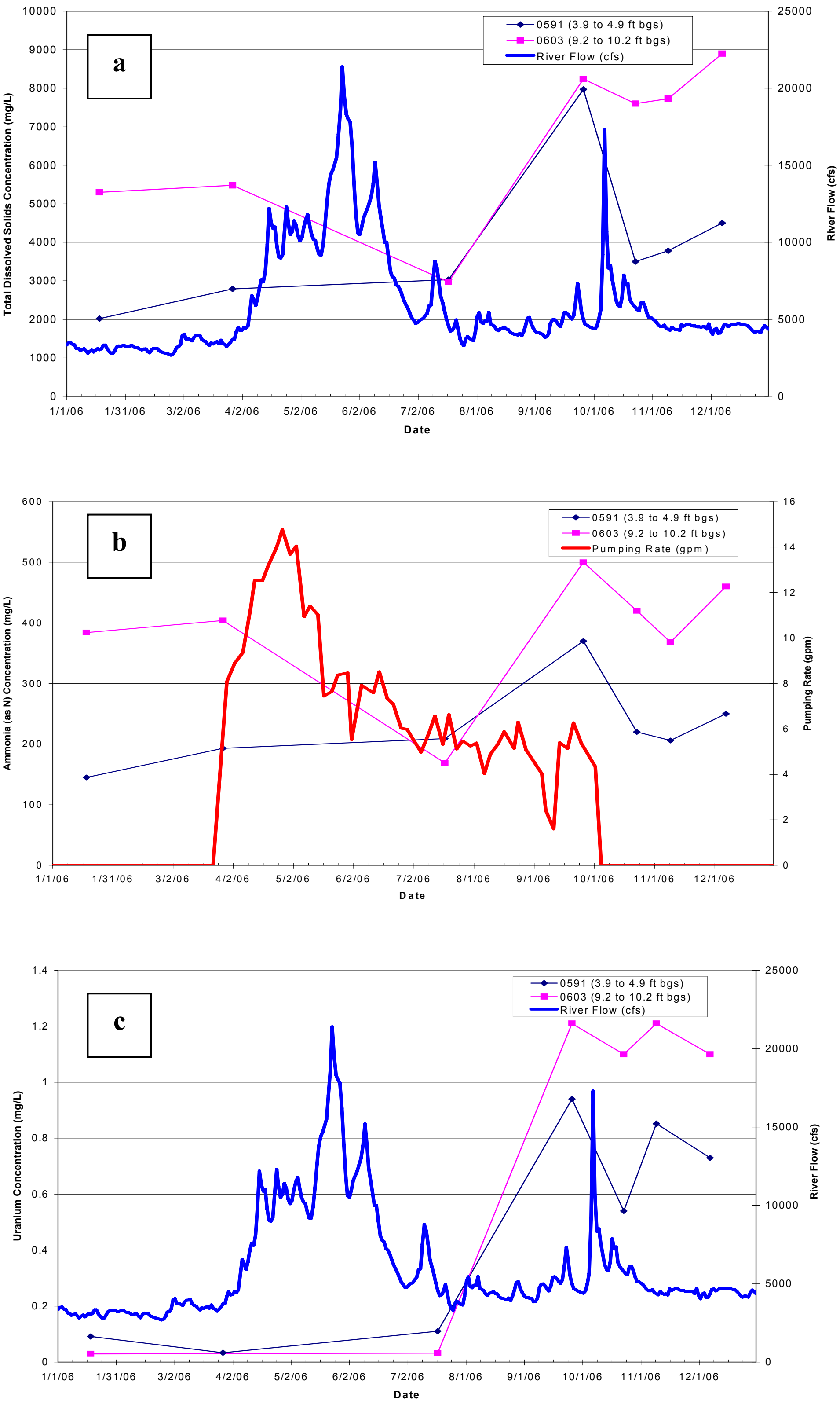


Figure 7–22. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Riverbank Well Points 0591 and 0603

The concentration of all of the analytes greatly increased in late-September. Samples were not collected from July to September; therefore, it is uncertain if the increase was rapid or gradual. One possible explanation is that the analyte concentration was lower during injection and then peak river flow also diluted the analyte concentration. By late-September, the river flow varied between 4,000 cfs and 7,000 cfs.

The concentration of all of the analytes decreased again by mid-October, after a significant rainfall event on October 6 through 8 increased the river flow to an unseasonable 17,300 cfs. The peak in river flow in early October is nearly synchronous with the suspension of the extraction system in Configuration 2. It is unknown which of these processes led to the decrease of the analyte concentration. By early November, the analyte concentration increased once again. While TDS and ammonia concentration increased in well points 0591 and 0603, the uranium concentration began to decrease in December. This is likely the result of either the brine interface moving up in elevation or temporal variation.

The river edge well point cluster provided data from depths of 1.4 to 2.4 ft bgs (well point 0615), 5.3 to 6.3 ft bgs (well point 0616), and 9.4 to 10.4 ft bgs (0605). The most complete data sets collected from 2006 were associated with samples collected from well points 0615, 0616, and 0605 (Figure 7–23).

The analyte concentration in the Configuration 2 river edge well points is dissimilar to the downgradient observation wells and river bank piezometers. During injection in 2005, the TDS and ammonia concentrations were higher and the uranium concentration was lower compared to the concentrations during extraction. This is likely the result of the transition zone of the shallow and brine aquifer being pushed out further towards the river as a result of the freshwater injection.

During injection mode of the remediation wells, the river edge well points contained analyte concentrations that increased with depth from 1.9 to 9.9 ft bgs. These well points were sampled again in late-March, 2 days after the injection had been suspended and on the day that the extraction mode had been initiated. The analyte concentration greatly increased to the highest levels observed in the river bank well points for all of 2006. The cause of the increase is unknown. The river levels had remained fairly consistent from January to March (2,730 to 4,050 cfs). It is likely that the increase in analyte concentration is the result of temporal variation.

Due to accessibility, the river edge well points were not sampled during the peak spring runoff from April to June. By the end of July, the concentration of the analytes was much lower in well points 0616 and 0605 and slightly lower in well point 0615, with the exception of uranium. The uranium concentration in well 0615 varied from 0.095 mg/L in March to 0.1 mg/L in July.

From July to November, the analyte concentration did not vary considerably. Well point 0605 experienced a slight increase in uranium from 0.2 mg/L in July to 0.39 mg/L in September.

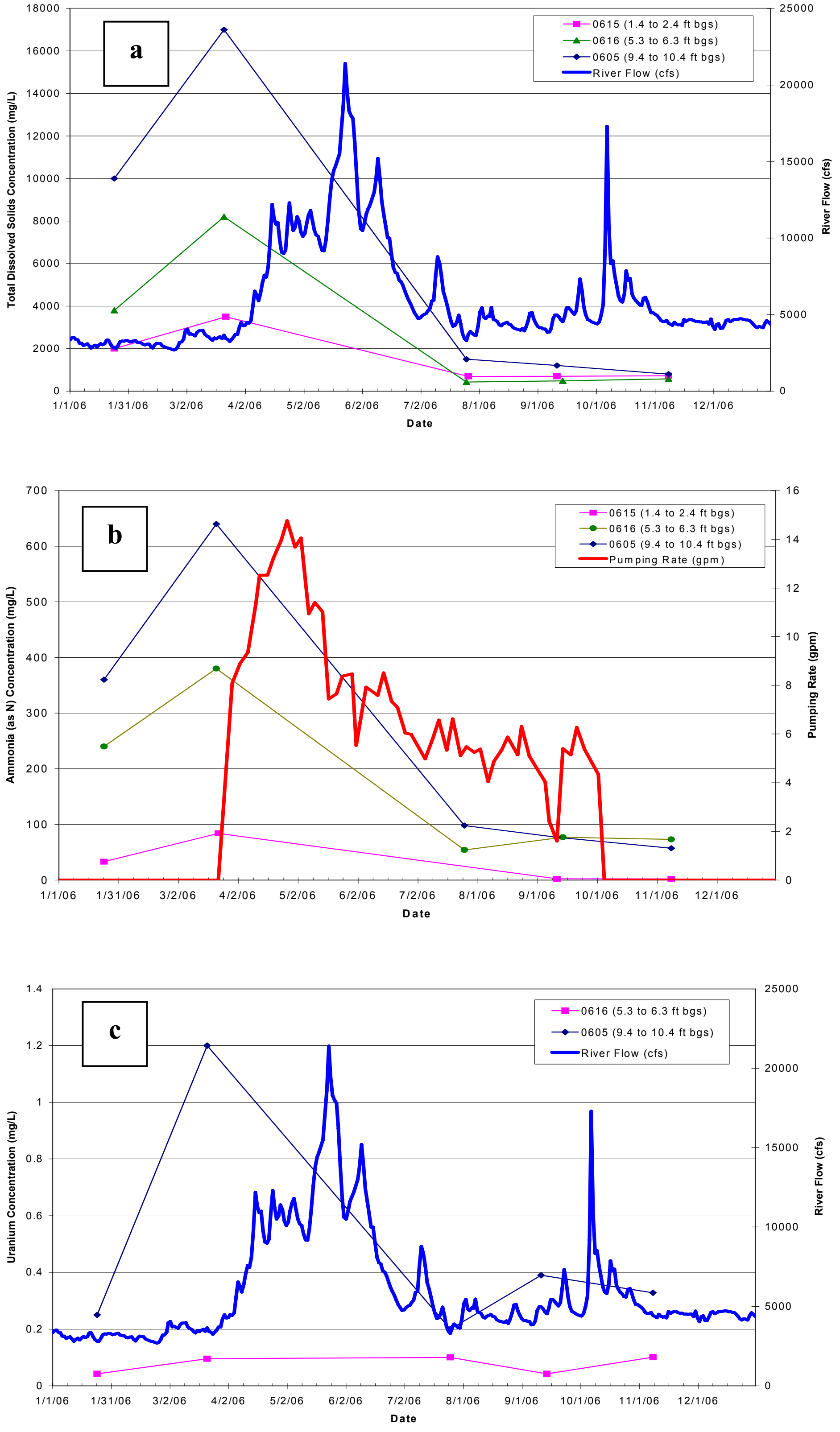


Figure 7–23. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at River Edge Well Points 0605, 0615, and 0616

7.3.4 Surface Water

Surface water samples were collected at the base of the riverbank near the 0590/0591/0603 piezometer cluster (location 240), in a depression (location 0236) found in the backwater channel between the riverbank and intermediate piezometers, and near the river edge piezometer cluster 0605/0615/0616 (location 239). Figure 4–3 shows these locations in relationship to Configuration 2. The analytical results obtained from the samples collected at surface water locations 0236, 0239, and 0240 are presented as Figure 7–24.

The uranium, TDS, and ammonia concentration at surface water locations 239 and 236 experienced peak levels for 2006 on January 26. As the plots indicate, the river stage at the time just prior to and after this concentration peak remained fairly constant, ranging from 2,800 to 3,510 cfs.

The surface water analyte concentration in Configuration 2 does not vary greatly between 2005 and 2006. Ammonia, TDS, and uranium concentrations were comparably high in January in both 2005 and 2006 and then dropped rapidly soon thereafter. In the winter months the backwater areas occasionally contain pockets of water that are isolated from one another. Since the water is not flowing through the backwater area, the analyte concentrations may increase with the assimilation of ground water.

When comparing the analyte concentration with the neighboring riverbank piezometers, it is evident that uranium levels were higher in the surface water than in the neighboring piezometers (0.74 mg/L at location 236 vs. 0.091 at piezometer 0591). The ammonia concentration was lower in the surface water than in the neighboring piezometers. The TDS concentration was also higher in the surface water than in the riverbank piezometers, 5,800 to 6,000 mg/L in the surface water locations 0236 and 0240, and 2,020 to 5,300 mg/L in the adjacent piezometers. At this time, the TDS concentration in the surface water location on the river edge was 830 mg/L (0239).

During the peak runoff, the analyte concentration had dropped significantly and remained fairly constant for the rest of the year. The only anomaly is a slight peak in uranium (0.071 mg/L) and TDS (960 mg/L) concentration on July 1 at surface water location 0240. This peak occurred 2 weeks after an increase in the river flow, as a result of an intense summer rainfall event.

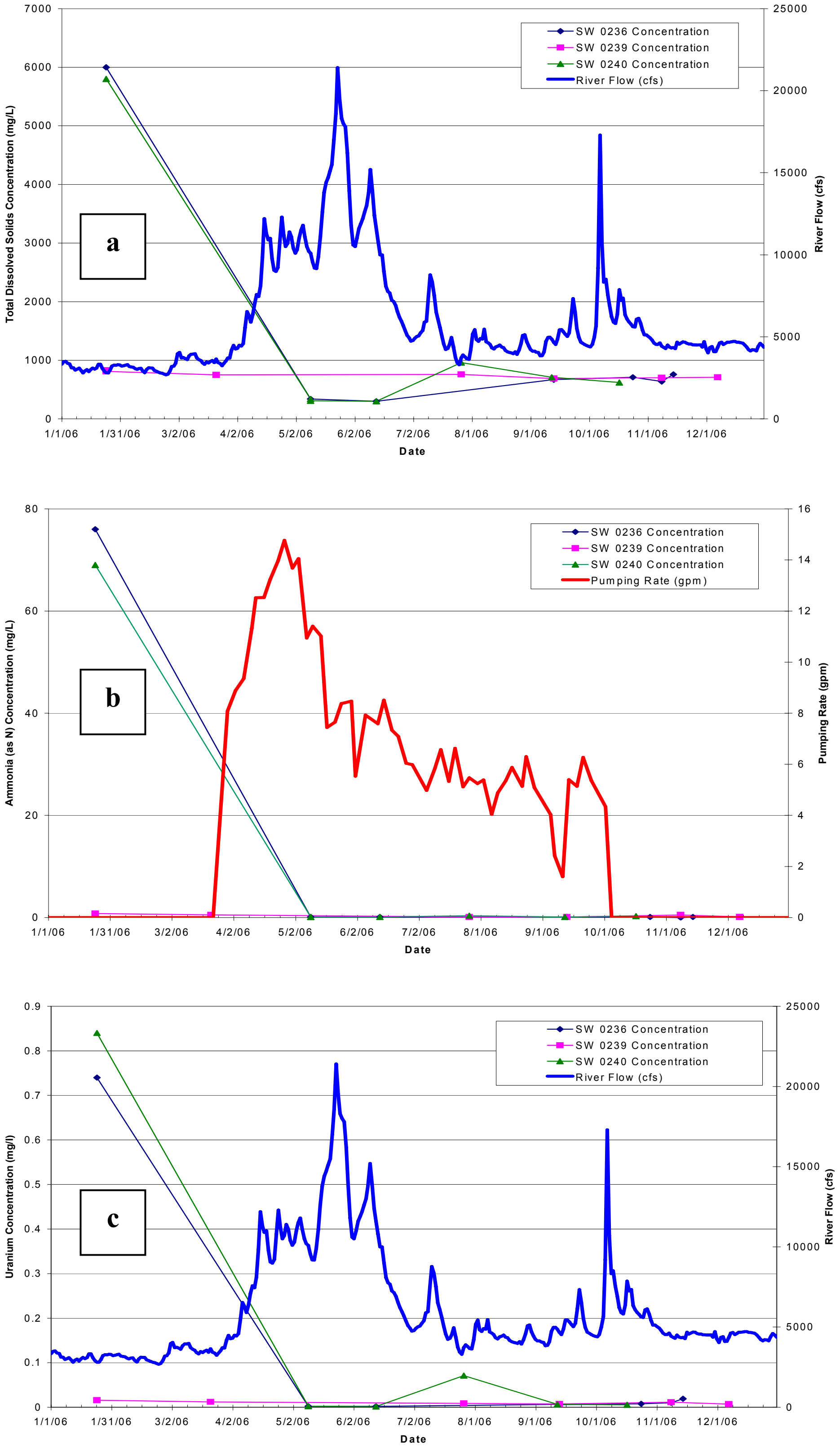


Figure 7–24. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Surface Water Locations 236, 239, and 240 During 2006

7.4 Configuration 3

Analytical results from ground water discharge samples were used to assist in evaluating the performance of the Configuration 3 ground water extraction system. The analytical results associated with the remediation wells, upgradient observation wells, downgradient observation wells, riverbed well points, and surface water sampling are presented and interpreted in Sections 7.4.1, 7.4.2, 7.4.3, 7.4.4, and 7.4.5, respectively. Appendix E−6 contains all the analytical data collected from remediation well sampling during 2006, and Appendix E−8 contains the observation well, riverbed well point, and surface water 2006 analytical data.

7.4.1 Remediation Wells 0670−0679

The Configuration 3 remediation wells were initially sampled during the 2006 pumping season in early February from 44 ft bgs. This sampling event was completed in order to collect background water chemistry data prior to the March 14 ground water extraction start date. Dedicated submersible pumps are installed with the pump intakes set at a depth of approximately 40 ft bgs inside wells 0670 through 0679. Samples were collected on a nearly monthly basis (samples were not collected during August and November 2006) during the 2006 pumping season.

Figure 7–25 is an example of a TDS, ammonia, and uranium time versus concentration plot generated for data collected during 2006. The TDS concentration is plotted with the Colorado River flow data (a), the ammonia data are plotted with the extraction rate data (b), and uranium concentration data are plotted with ground water elevation data (c). Each analyte concentration plot is presented using the same time scale. As a result the TDS data can be easily compared to the extraction rate and ground water elevation data. Likewise, the ammonia data can be easily compared to the Colorado River flow data and the ground water elevation data, and so on.

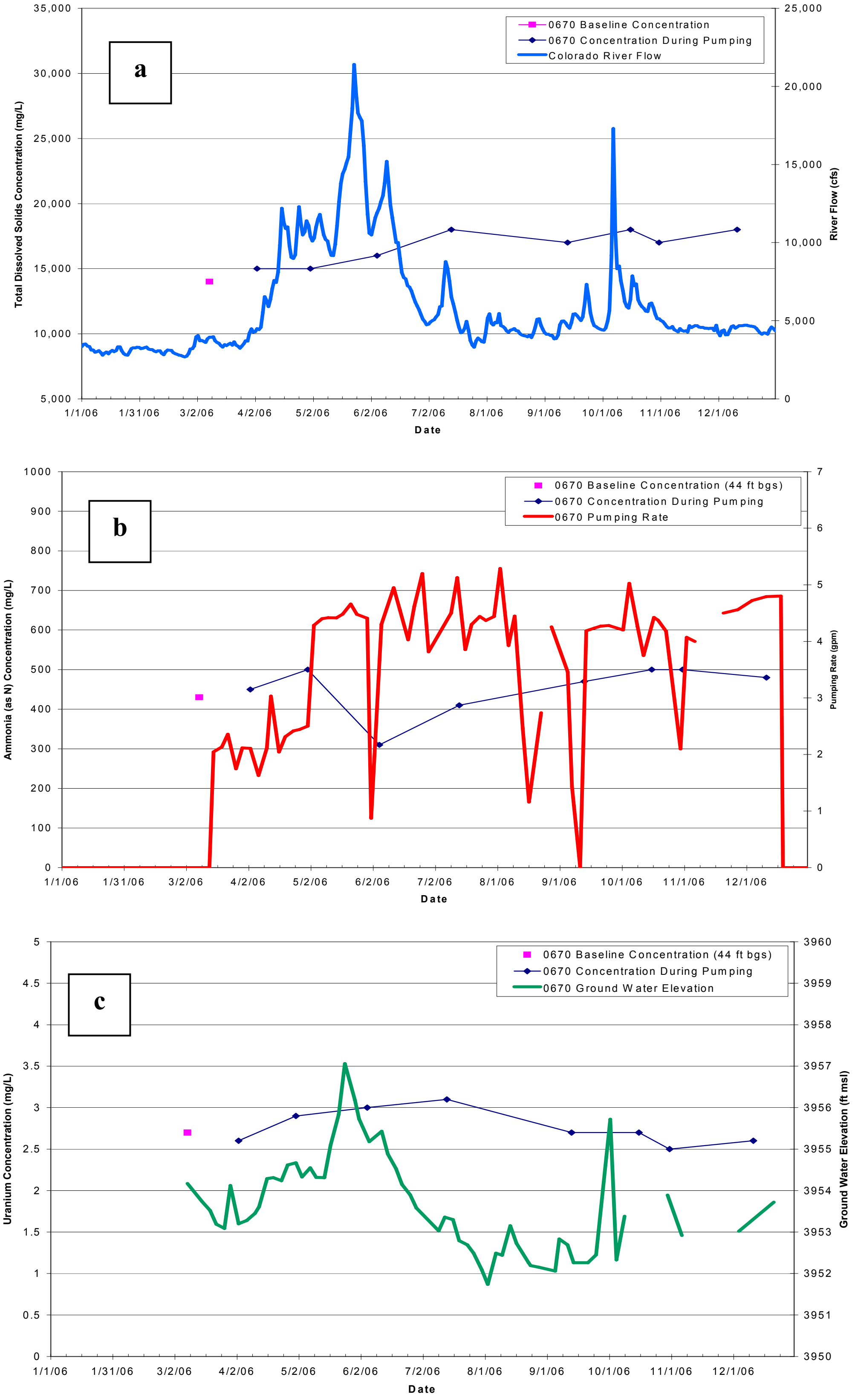


Figure 7–25. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Remediation Well 0670 During 2006

Figure 7–25 presents the data associated with extraction well 0670, while comparable plots for wells 0671 through 0679 are contained in Appendix E−7 The water chemistry data collected from well 0670 is representative to some degree of the data collected from the other nine Configuration 3 remediation wells.

The water chemistry data indicate the initial sample collected prior to the start up of active ground water remediation may have been influenced by Configuration 2 (located to the south of Configuration 3) fresh water injection. In general, the lowest February 2006 TDS, ammonia, and uranium concentrations were associated with samples collected from wells 0670, 0671, and 0672. Background concentrations tended increase towards the northern end of the configuration.

Configuration 3 remediation well concentrations did not appear to respond to changes in the Colorado River stage. Figure 7–26 is a TDS time concentration plot for well 0675, which is located near the center of the Configuration 3 well field. Compared to Configurations 1 and 4, Configuration 3 is located farther away from any Colorado River side channel and the wells are deeper (to 45 ft), and therefore does not tend to respond to changes in the river stage in the same manner as the other configurations.

This trend reversed near the end of the 2006 pumping season. By the end of October 2006 wells 0677, 0678, and 0679 TDS, ammonia, and uranium concentrations significantly decreased compared to the other Configuration 3 wells. This decrease can be explained by the fresh water injection associated with the infiltration trench, located just 60 ft to the north of well 0679. The trench initially started injecting fresh water from one of four injection ports in early September 2006. By the end of September, fresh water was being injected to all four ports. The analytical results indicate the water chemistry in the vicinity of wells 0677, 0678, and 0679 was diluted starting mid-September and the TDS, ammonia, and uranium concentrations abruptly decreased in mid-October 2006. Data suggests well 0676 was not impacted by this fresh water injection to a lesser degree (Figure 7–27).

During 2005 there was evidence that irrigation of the C-5 plot just upgradient migrated into the northern end of Configuration 3 (DOE 2006a). A similar analysis of the data was completed using data collected between April and September 2006. Ground water samples collected from wells located near the northern end after September were not used due to the proximity of the infiltration trench.

The data suggest there is decrease in TDS concentrations for remediation wells located north of well 0675. A review of the data indicate wells 0671 through 0675 have an average TDS concentration of approximately 24,280 mg/L, while wells 0676 through 0679 have an average concentration of approximately 19,750 mg/L. Wells 0672 through 0675 have an average uranium concentration of 2.9 mg/L, while wells 0676 through 0679 have an average concentration of 3.6 mg/L. This increase may be the result of oxygenated water added to this end of the configuration by flood irrigation of adjacent plot C5, which dilutes the TDS concentration and promotes the mobility of uranium in ground water and increases the uranium concentration.

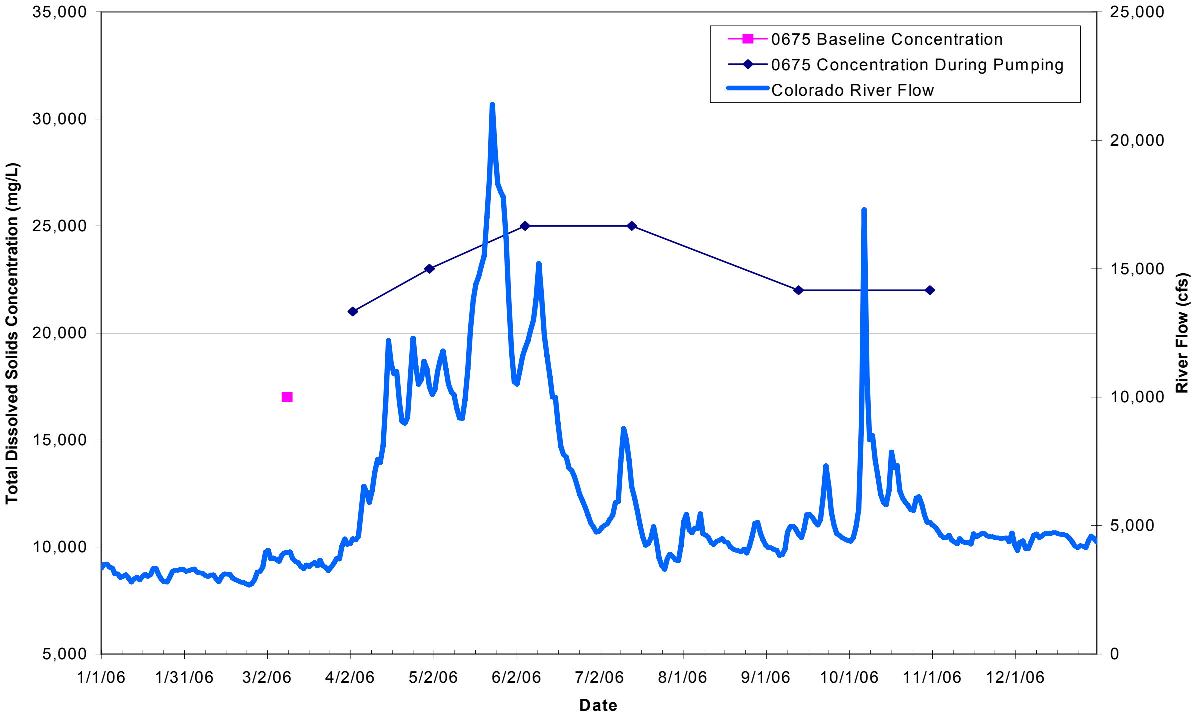


Figure 7–26. TDS Concentrations at Extraction Well 0675 During 2006

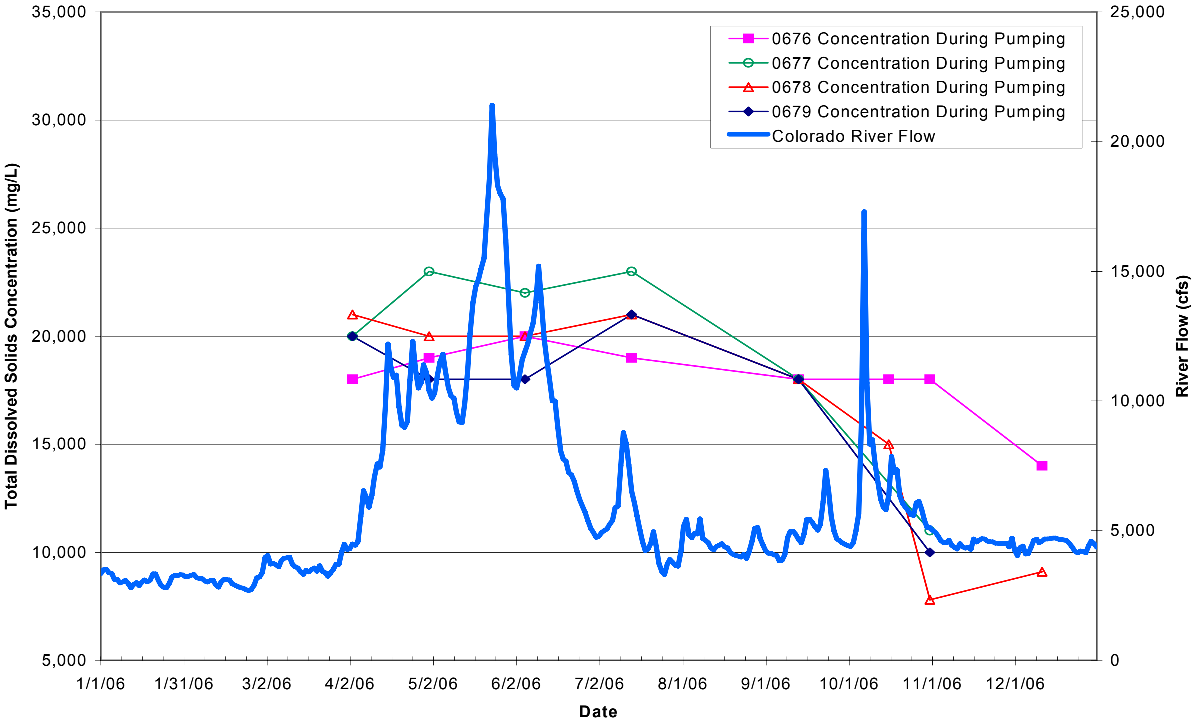


Figure 7–27. TDS Concentrations at Extraction Wells 0676, 0677, 0678, and 0679 During 2006

7.4.2 Observation Wells

7.4.2.1 Upgradient Observation Wells 0680/0682/0683/0684

As shown in Figure 4–4 observation wells 0680 and 0682 are located on the southern half of the well field (adjacent to the tree area irrigation plot) and wells 0683 and 0684 are located in the northern half (along the eastern edge of irrigated plot C5). Wells 0680 and 0684 are screened from 10 to 20 ft bgs and wells 0682 and 0683 are screened from 20 to 30 ft bgs. Appendix E-8 contains all the analytical data.

Figure 7–28 presents analytical results of samples from depths of 18 ft bgs (well 0404), 28 ft bgs (well 0687), 31 and 39 ft bgs (well 0688), and 46 and 54 ft bgs (well 0689). The TDS and uranium concentration data are plotted with the Colorado River flow data and the ammonia data are plotted with the extraction rate data.

As the time concentration plots show, only limited samples were collected from wells 0680 and 0684. Wells 0680, 0682, and 0683 TDS concentrations ranged between 15,000 and 19,000 mg/L through out 2006, all showing a decreasing trend at the end of the year. In general, TDS concentrations in these upgradient wells did not respond to changes in the Colorado River stage or Configuration 3 pumping rates.

Well 0684 TDS concentrations were significantly lower compared to the other upgradient wells, less than 5,000 mg/L. This may be in response to the wells shallow screen interval and the different volumes of irrigated water applied to area C5 and the tree area. Well 0683, screened over a deeper portion of the aquifer, apparently was not diluted by the irrigated fresh water despite being located in the same general area as well 0684. Well 0682 is located just off another irrigated plot and is screened over the same interval. However, the volume of water used to irrigate the tree area is significantly less compared to the volume applied to plot C-5.

Ammonia and uranium concentrations followed the same trend observed as the TDS concentrations (Figure 7–28). Well 0684 had less than 3 mg/l ammonia while the other upgradient wells had concentrations ranging from 300 to 500 mg/L, and less than 1.1 mg/L uranium compared to between 2.4 and 4.9 mg/L uranium.

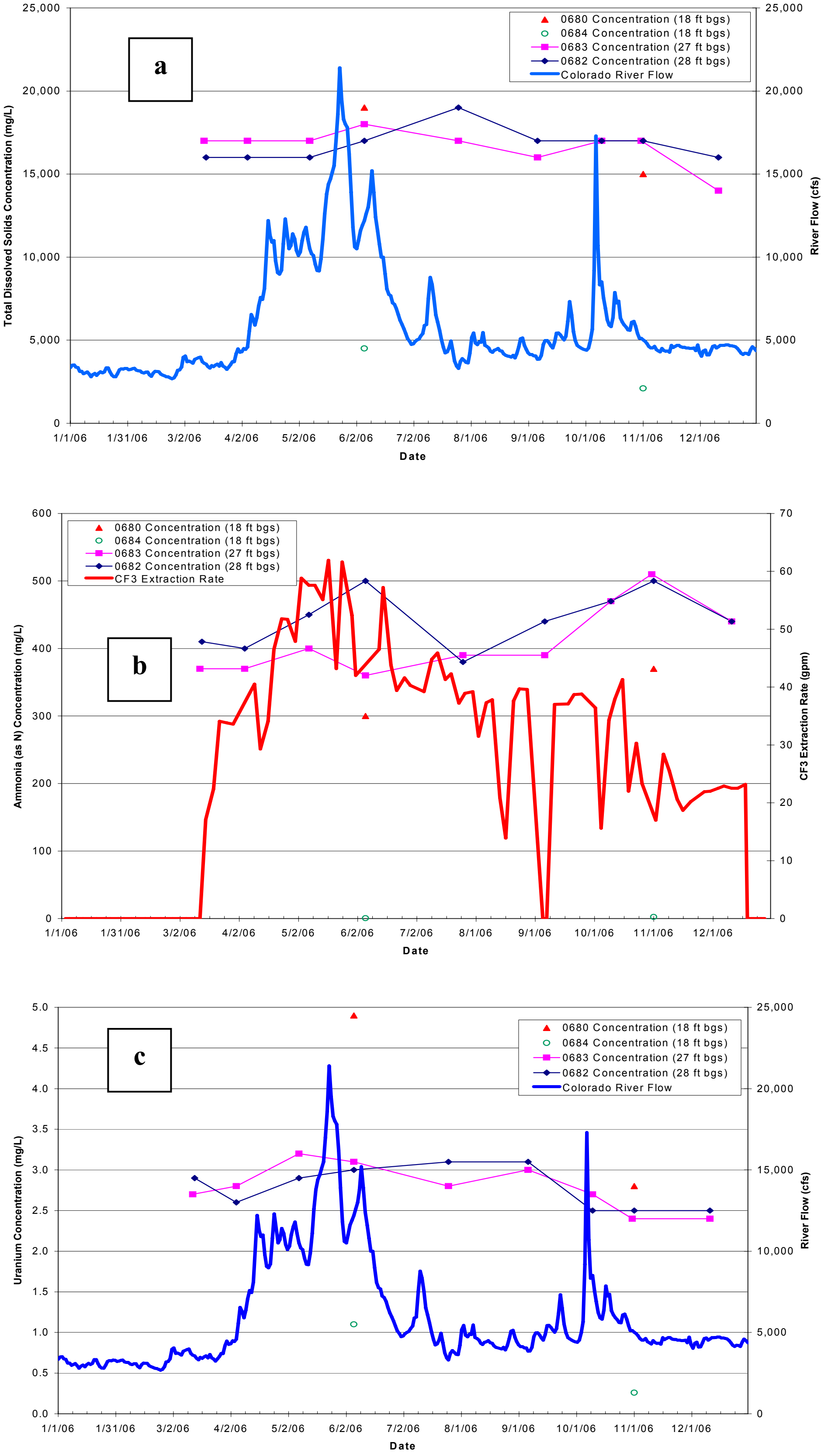


Figure 7–28. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium in Observation Wells 0680, 0682, 0683, and 0684 During 2006

7.4.2.2 Downgradient Observation Well Cluster 0404/0687/0688/0689

The Configuration 3 downgradient cluster is located less than 25 ft downgradient (southeast) of the well field axis, and consists of wells 0404, 0687, 0688, and 0689 that are screened from 13 to 18 ft bgs, 20 to 30 ft bgs, 31 to 41 ft bgs, and 46 to 56 ft bgs, respectively. These wells were sampled just prior to the start up of the Configuration 3 2006 pumping period, and sampled intermittently throughout the end of 2006 (Appendix E−8).

Figure 7–29 presents analytical results of samples from depths of 18 ft bgs (well 0404), 28 ft bgs (well 0687), 31 and 39 ft bgs (well 0688), and 46 and 54 ft bgs (well 0689). Similar to the extraction well time versus concentrations plots the TDS and uranium concentration data are plotted with the Colorado River flow data and the ammonia data are plotted with the extraction rate data.

The TDS plot [Figure 7–29(a)] indicates concentrations increase with depth under non-pumping conditions in March. Throughout 2006 the highest TDS concentration was measured from the samples collected from 46 and 54 ft bgs while the lowest concentration was measured from 18 and 28 ft bgs. The TDS concentrations increase in the well cluster samples collected from 39, 46, and 54 ft bgs apparently in response to Configuration 3 pumping. As shown in Figure 7–29(a), the Colorado River stage also increases approximately at this same time. However, the TDS concentrations at these depths abruptly increased from March 16 (prior to the start of pumping) to April 5. In early April the river flow was approximately 5,000 cfs, which is close to base flow conditions, and historically flows at this level have not significantly altered the well field water chemistry.

While the TDS concentrations from 39, 46, and 54 ft bgs responded to pumping, concentrations in samples collected from 18 and 28 ft bgs did not significantly change during the 2006 pumping season. TDS concentrations in samples collected from 18 ft bgs ranged from 12,000 to 17,000 mg/L, and concentrations in samples collected from 28 ft bgs ranged from 16,000 to 23,000 mg/L. Samples collected from 31 ft bgs steadily increased once pumping started from 17,000 to 28,000 mg/L, and once one-half of the wells were shut down and the pumping rate decreased the TDS concentration dropped to 24,000 mg/L. Similar changes in TDS concentrations at these depths in response to pumping were observed during the 2005 pumping season (DOE 2006a).

Ammonia concentrations [Figure 7–29(b)] do not follow the trend displayed in the TDS time concentration plot for the 2006 pumping season. Prior to pumping the ammonia concentrations in general increased with depth (the exception being the sample from 46 ft bgs was lower compared to the sample from 39 ft bgs). Once pumping started the sample collected from 54 ft bgs decreased (similar to the response observed in 2005) while the sample from 46 ft bgs more than doubled. After this initial increase the concentration abruptly decreased over the next 2 months before sharply increasing again from October through December. Ammonia samples collected from 31 and 39 ft bgs gradually increased once pumping started and leveled out during the June/July time frame (the same trend was observed during 2005) while concentrations of samples collected from 18 and 28 ft bgs fluctuated between 190 and 410 mg/L and 323 and 580 mg/L, respectively.

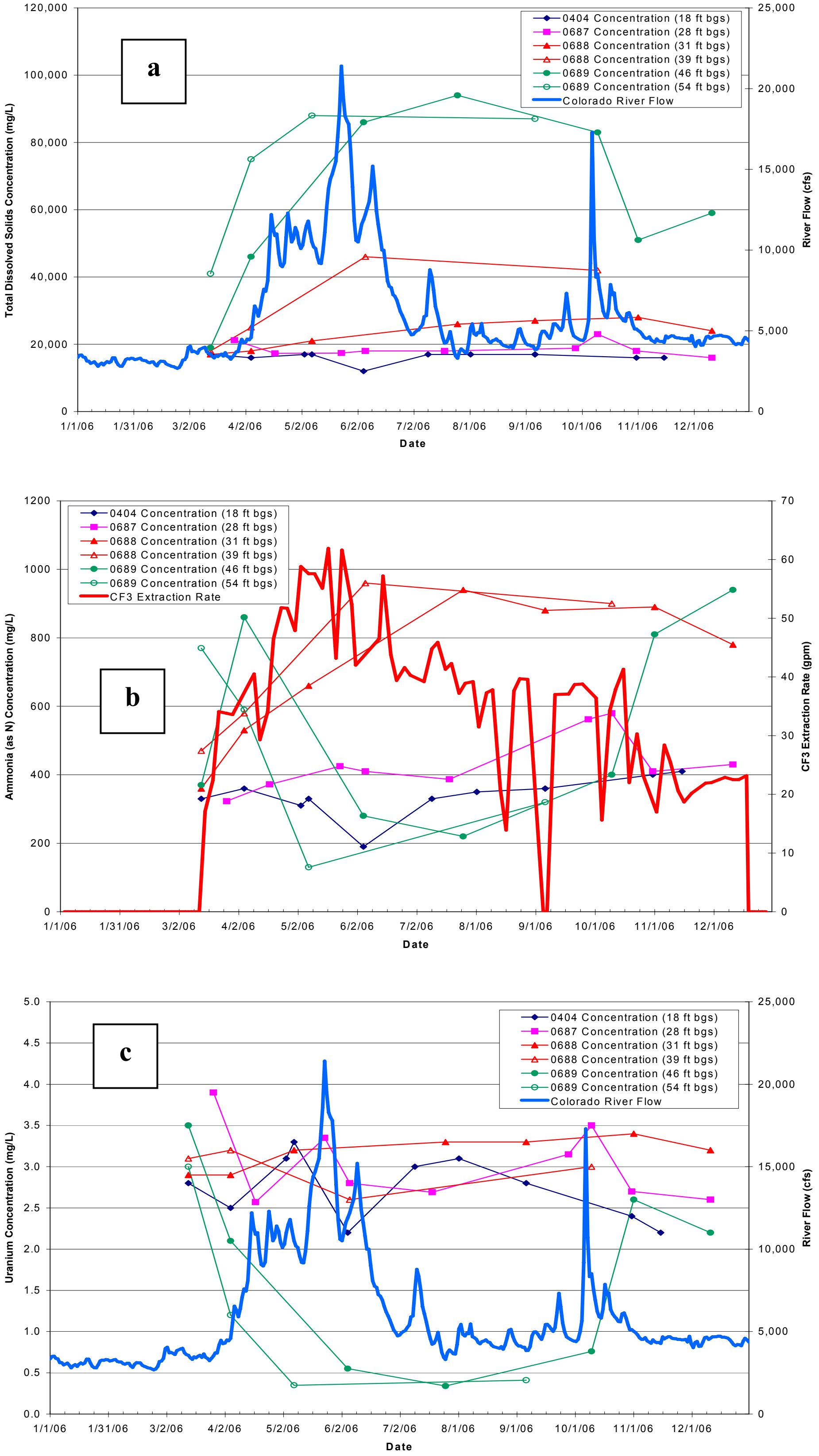


Figure 7–29. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Observation Wells 0404, 0687, 0688, and 0689 During 2006

Uranium concentrations [Figure 7–29(c)] in general followed ammonia concentration trends and those observed during 2005 (DOE 2006a), the samples collected from the deeper zones sharply decreased (from 3 to 3.5 mg/L to approximately 0.5 mg/L between March and May). This decrease was followed by an abrupt increase near the end of the pumping season for the sample from 46 ft bgs (samples were not collected from 54 ft bgs after early September 2006). Samples collected from 18, 28, 31, and 39 ft bgs in general fluctuated between 2 and 3.5 mg/L during 2006. During 2005 ammonia concentrations collected at these same depths fluctuated between 2 and 4 mg/L during the abbreviated pumping season.

The timing of the start of the 2006 pumping season (March 14th), the point where the Colorado River stage sharply increased above 10,000 cfs in response to the 2006 spring runoff (mid-April), and the date of the first sampling after pumping began for the 2006 season (April 5) all suggest the changes in TDS, ammonia, and uranium concentrations are in response to Configuration 3 ground water extraction. Changes in the Colorado River stage appear to have minimal, if any, impact on the upgradient or downgradient Configuration 3 observation wells. This appears to be in contrast to previous observations of the dilution effect caused by the rise in the river and also the brine surface.

7.4.3 Riverbed Well Points

The Configuration 3 well points are split into three clusters containing three well points each that are installed at different depths. Refer to for Table 4–7 for well point construction details and Figure 4–4 for locations. Appendix E-8 contains the analytical results.

Figure 7–30 presents the analytical results of samples collected from riverbed well points 0690, 0691, and 0692, all of which are located at the base of the bank (i.e., closest to the well field axis). presents similar plots for well points 0693, 0694, and 0695 (which are located at an intermediate distance between the base of the riverbank and the Colorado River), and Figure 7–31 presents the plots for well points 0696, 0697, and 0698 (located off the Colorado River).

These were initially installed as piezometers in late September 2005, and upgraded to well points in early September 2006.

The TDS and uranium concentration data are plotted with the Colorado River flow data and the ammonia data are plotted with the extraction rate data. In same cases limited sample volumes available for laboratory analysis resulted in limited water chemistry data associated with a number of these locations.

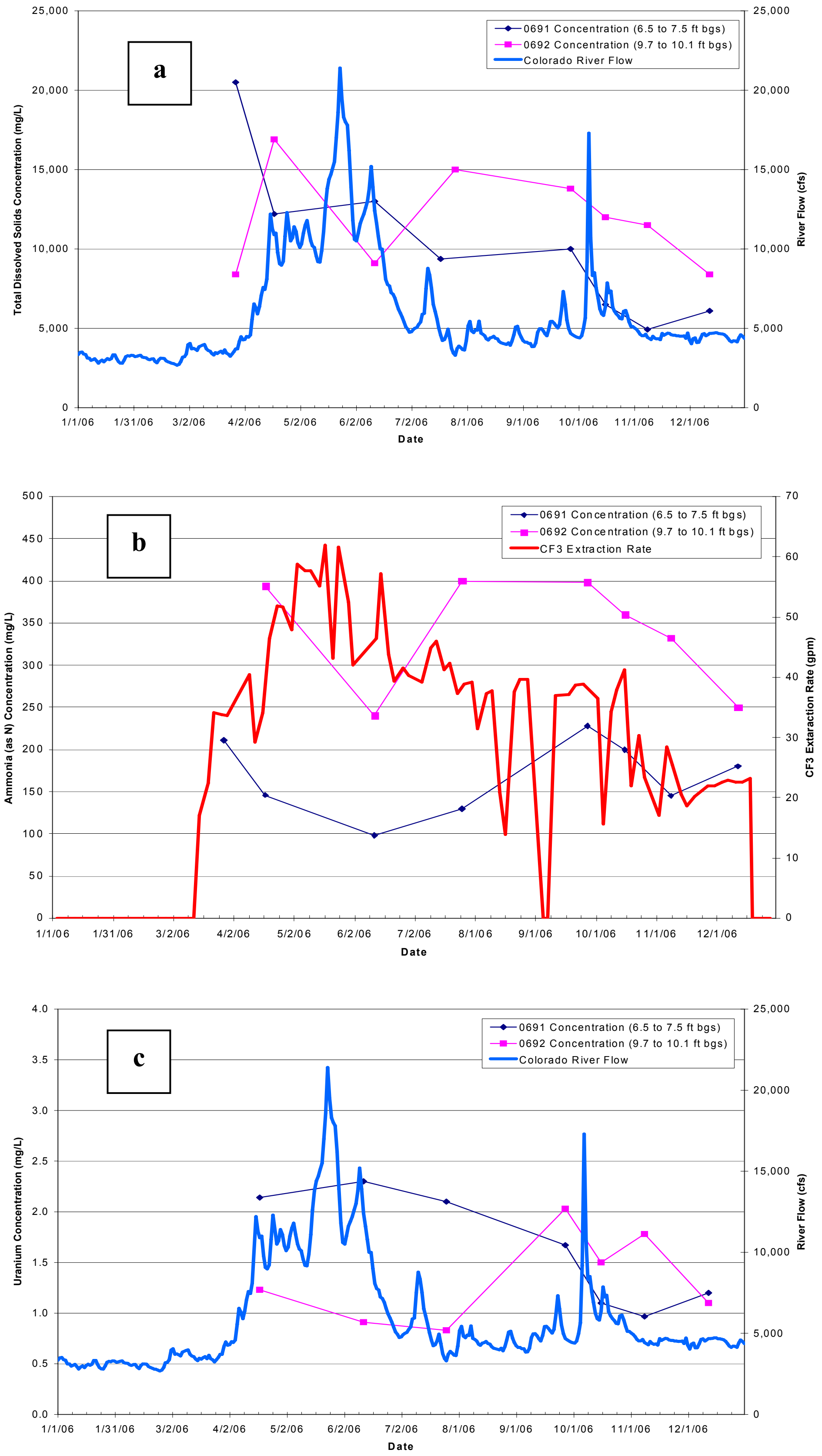


Figure 7–30. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Riverbed Well Points 0691, and 0692 During 2006

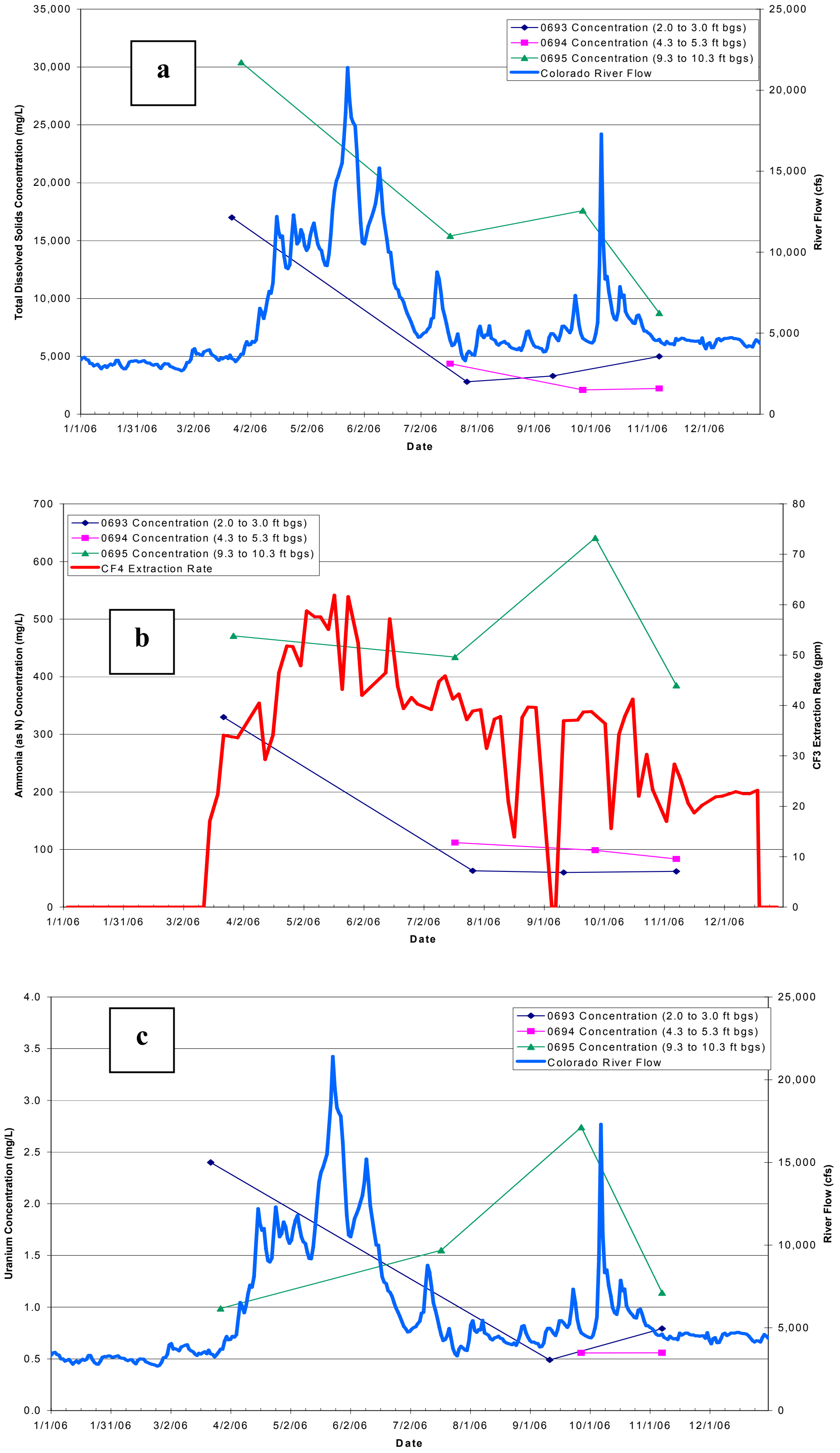


Figure 7–31. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Riverbed Well Points 0693, 0694, and 0695 During 2006

Well point 0690 was consistently dry during 2006; therefore, samples were not collected. Initial TDS concentrations [Figure 7–30(a)] did not follow the increasing with depth trend exhibited throughout the site; however, after July the data indicates the sample collected from well point 0692 consistently had a higher TDS concentration compared to well point 0691. In general, the TDS concentration data collected from the well points located closest to the well field axis indicate the concentration gradually decreased over the 2006 pumping season.

Ammonia concentrations [Figure 7–30(b)] were consistently higher in the deeper well point (0692) compared to the more shallow one (0691), and generally followed the trend displayed in the last half of the 2006 pumping season by the TDS time concentration plot. Concentrations gradually decreased through June, and then increased or stabilized through September, and then decreased through December.

Uranium concentrations [Figure 7–30(c)] also followed the TDS trend during the last half of the 2006 pumping season. The highest concentrations initially were detected in the shallow completion through September, when this trend reversed and the highest concentrations were contained in the deepest well point.

The time concentration plots based on TDS, ammonia and uranium concentrations for the middle well point cluster (0693, 0694, and 0695) are presented as Figure 7–31.

The TDS concentrations [Figure 7–31(a)] increased with increasing depth at this location, with March concentrations ranging from 17,000 to 30,400 mg/L. TDS concentrations apparently decreased from March through late July, and in well points 0693 and 0694 the concentrations stabilized into November, while in 0695 the concentrations continued to decrease.

Ammonia concentrations [Figure 7−31(b)] in well points 0693 and 0694 followed the same trend as the TDS concentrations. However, 0695 concentrations in late September increased from 434 to 641 mg/L before dropping back to 385 mg/L in November. Uranium concentration [Figure 7–31(c)] fluctuations followed the same trend as exhibited by ammonia.

Water chemistry data also indicate well points 0696, 0697, and 0698 (Figure 7–32) had increasing analyte concentrations with increasing depth. TDS, ammonia, and uranium concentrations all sharply decreased from March to late July, and leveled off at these lower concentrations.

Colorado River flows apparently impacted these well point concentrations as opposed to the Configuration 3 ground water extraction rates. These well points are located within the riverbed, and during high flows fresh water is able to migrate downward into the subsurface and alter the water chemistry.

7.4.4 Surface Water Locations

As shown on Figure 4–4, Configuration 3 surface water location 0258 is located approximately 60 ft of the bank in a side channel that contains river water when the river stage is above approximately 4,500 cfs, and location 0259 is located off western side of the main channel. Figure 7–33 presents the analytical results (in the form of time concentration plots) of samples

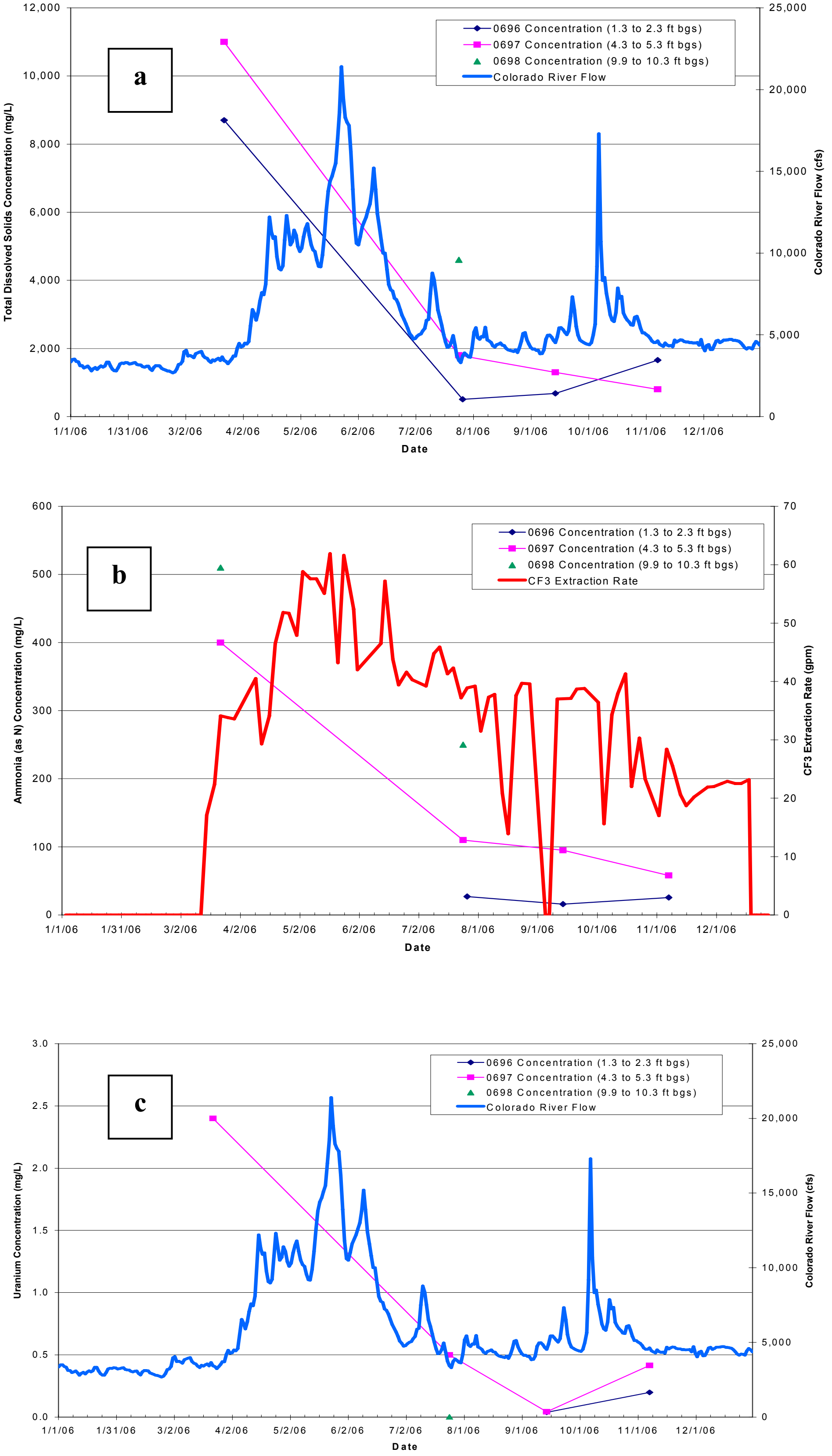


Figure 7–32. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Riverbed Well Points 0696, 0697, and 0698 During 2006

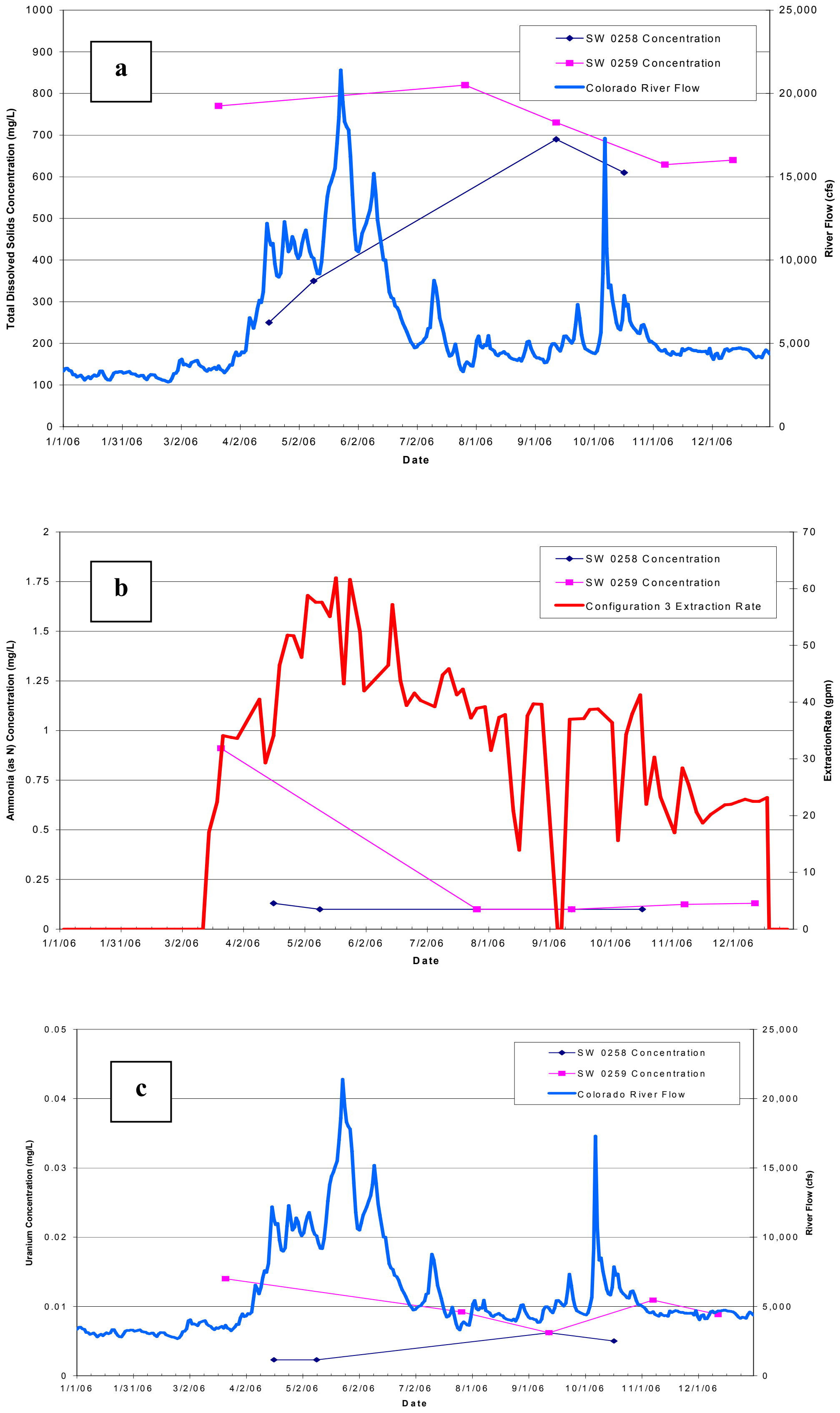


Figure 7–33. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Surface Water Locations 0258 and 0259 During 2006

collected in 2006 from surface water locations 0258 and 0259. Appendix B-6 contains the analytical results.

Water chemistry results indicate TDS concentrations were consistently higher in the sample collected from location 0259 compared to 0258. Prior to the spring runoff peak, concentrations were significantly higher (770 mg/L in 0259, 250 mg/L from 0258). However, after September the TDS concentrations, while still higher in the 0259 sample, were within a closer range (610 to 730 mg/L).

Ammonia and uranium concentrations followed the same pattern, with significantly higher concentrations in samples collected from 0259 prior to the peak runoff, and comparable concentrations after the runoff subsided. Prior to the runoff peak the sample collected from location 0259 had an ammonia concentration of 0.91 mg/L, while the sample from 0258 was 0.13 mg/L. After late July the ammonia concentrations in samples collected from both locations ranged from 0.1 to 0.13 mg/L through the end of the year. As shown in Figure 7–33(c), uranium concentrations did not exceed 0.015 mg/L in samples collected from either location during 2006. The above noted concentrations were well below acutely toxic levels for aquatic species.

7.5 Configuration 4

Analytical results from ground water discharge samples were used to assist in evaluating the performance of the Configuration 4 ground water extraction system. The analytical results associated with the extractions wells, upgradient observation wells, downgradient observation wells, riverbed well points, and surface water sampling is presented and interpreted in Sections 7.5.1, 7.5.2, 7.5.3, 7.5.4, and 7.5.5, respectively. Appendix F−6 contains all the analytical data collected from remediation well sampling during 2006, and Appendix F−8 contains the observation well, riverbed well point, and surface water 2006 analytical data.

7.5.1 Remediation Wells 0770−0779

As previously mention, the Configuration 4 remediation wells (screened from approximately 15 to 35 ft bgs) were installed in May 2006 (Figure 4–5 and Table 4–9). Ground water samples were collected from these wells from depths of 15 and 32 ft bgs in late August under non-pumping conditions. During 2006 ground water was extracted between mid-September and mid-December. Dedicated submersible pumps are installed with the pump intakes set at a depth of approximately 30 ft bgs inside wells 0770 through 0779.

Due to the short pumping season for this Configuration, only limited sampling occurred during 2006. Wells 0771, 0773, 0775, 0777, and 0779 were sampled only once while the wells were actively extracting ground water. The even numbered wells were sampled a total of four times, and are the focus of this discussion. Figure 7–34 is an example of a TDS, ammonia, and uranium time versus concentration plot generated for data collected during 2006. Similar to the data presented in Sections 7.2, 7.3, and 7.4, the TDS concentration is plotted with the Colorado River flow data (a), the ammonia data are plotted with the extraction rate data (b), and uranium concentration data are plotted with ground water elevation data (c).

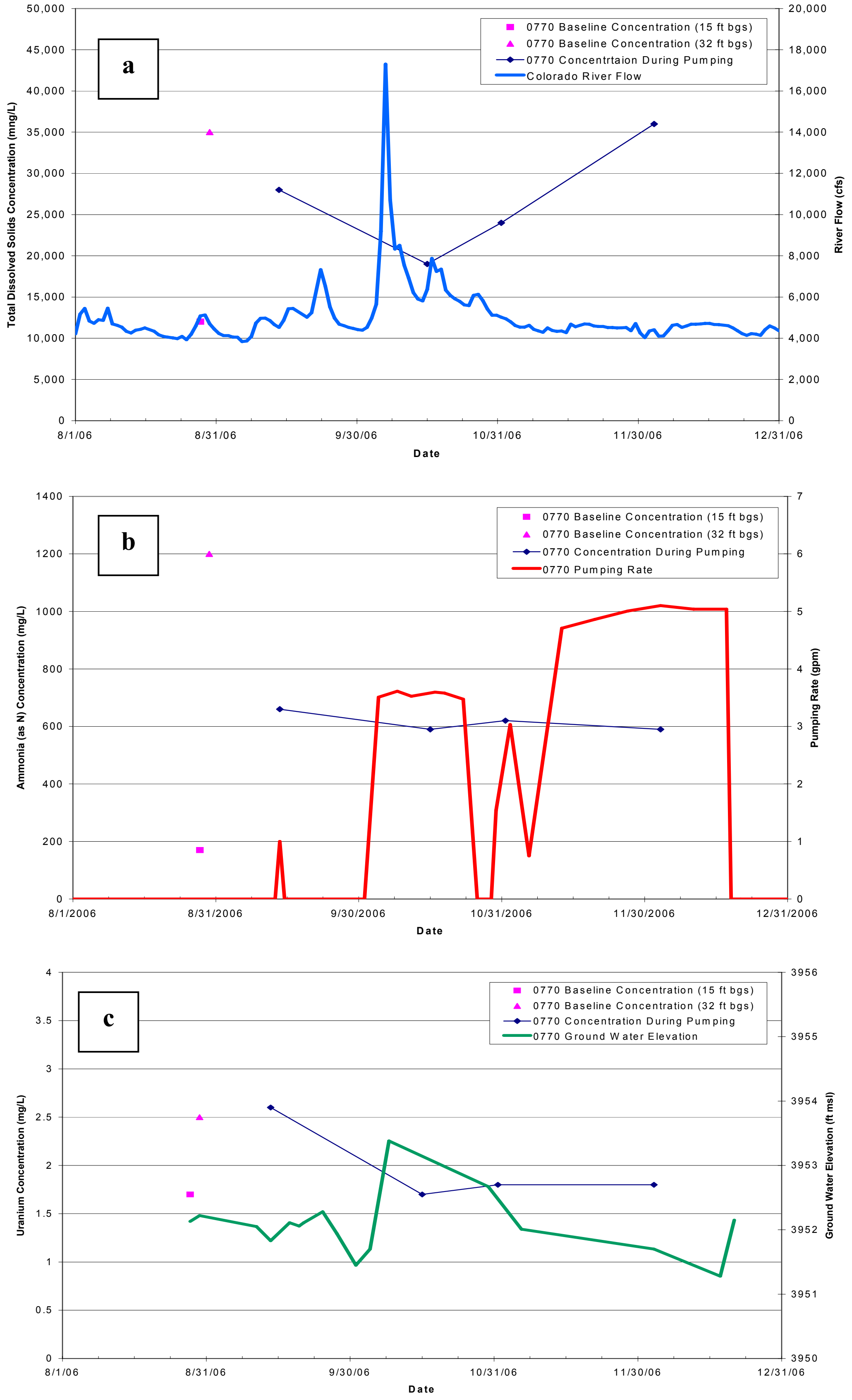


Figure 7–34. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Remediation Well 0770 During 2006

Figure 7–34 presents the data associated with extraction well 0770, while comparable plots for wells 0772, 0774, 0776, and 0778 are contained in Appendix F−7 (limited data did not warrant the generation of plots for the odd-numbered wells). The water chemistry data collected from well 0770 is representative to some degree of the data collected from the other nine Configuration 4 extraction wells.

The water chemistry results obtained from the baseline profile sampling in August indicates TDS concentrations increase with increasing depth, a trend consistent with results from previous investigations (DOE 2002 and DOE 2006a). At the southern end of Configuration 4 the brine surface was encountered at a depth of approximately 32 ft bgs. Results obtained from samples collected at the northern end indicate the brine surface was encountered at some unspecified more shallow depth (Figure 4–7). However, these depth variations are particular to this configuration, the overall conceptual site model of shallower brine depths south of the well field than to the north holds true.

Samples collected while Configuration 4 remediation wells were actively extracting ground water indicate TDS concentrations [Figure 7–34(a)] decreased in response to the Colorado River October flood event. In general, TDS concentration rebounded to pre-flood levels by December. During the limited 2006 pumping season the TDS concentrations for all ten Configuration 4 remediation wells ranged from 15,000 to 35,000 mg/L.

Similar to the trend displayed by the TDS concentrations, the water chemistry results indicate ammonia concentrations [Figure 7–34(b)] increased with increasing depth (based on the profile sampling) and decreased in response to the October flood event. Uranium concentrations [Figure 7–34(c)] also exhibited a decrease in response to the increase in river stage; however, there was no correlation between the uranium concentration and sample depth.

7.5.2 Observation Wells

7.5.2.1 Upgradient Observation Well Cluster 0780/0781/0782

As shown in Figure 4–5 the observation well cluster 0780/0781/0782 is located just upgradient of the middle of the well field. Unlike Configurations 1, 2, and 3 and the Baseline Area, there are no irrigation plots in the vicinity of Configuration 4. Wells 0780, 0781, and 0782 are screened from 20 to 30 ft bgs, 45 to 55 ft bgs, and 30 to 40 ft bgs, respectively. All analytical data are contained in Appendix F−8.

Figure 7–35 presents analytical results of samples from depths of 28 ft bgs (well 0780), 33 ft bgs (well 0782), and 46 ft bgs (well 0781). Similar to the remediation well time versus concentration plots, the TDS and uranium concentration data are plotted with the Colorado River flow data while the ammonia data are plotted with the extraction rate data.

Water chemistry results collected at depths ranging from 28 to 46 ft bgs upgradient of the well field indicate TDS concentrations [Figure 7–35(a)] did not respond to changes in the Colorado River stage. Sample collected from 28 ft bgs ranged from 20,000 to 22,000 mg/L during the short 2006 pumping season. This increase in river stage was very abrupt, increasing from near base flow conditions (5,560 cfs) on October 5 to 17,300 cfs on October 7. A sample was collected from 28 ft bgs on October 4th and then again on November 1. It is possible that the TDS concentration at this shallow depth did fluctuate in response to the increase in river stage

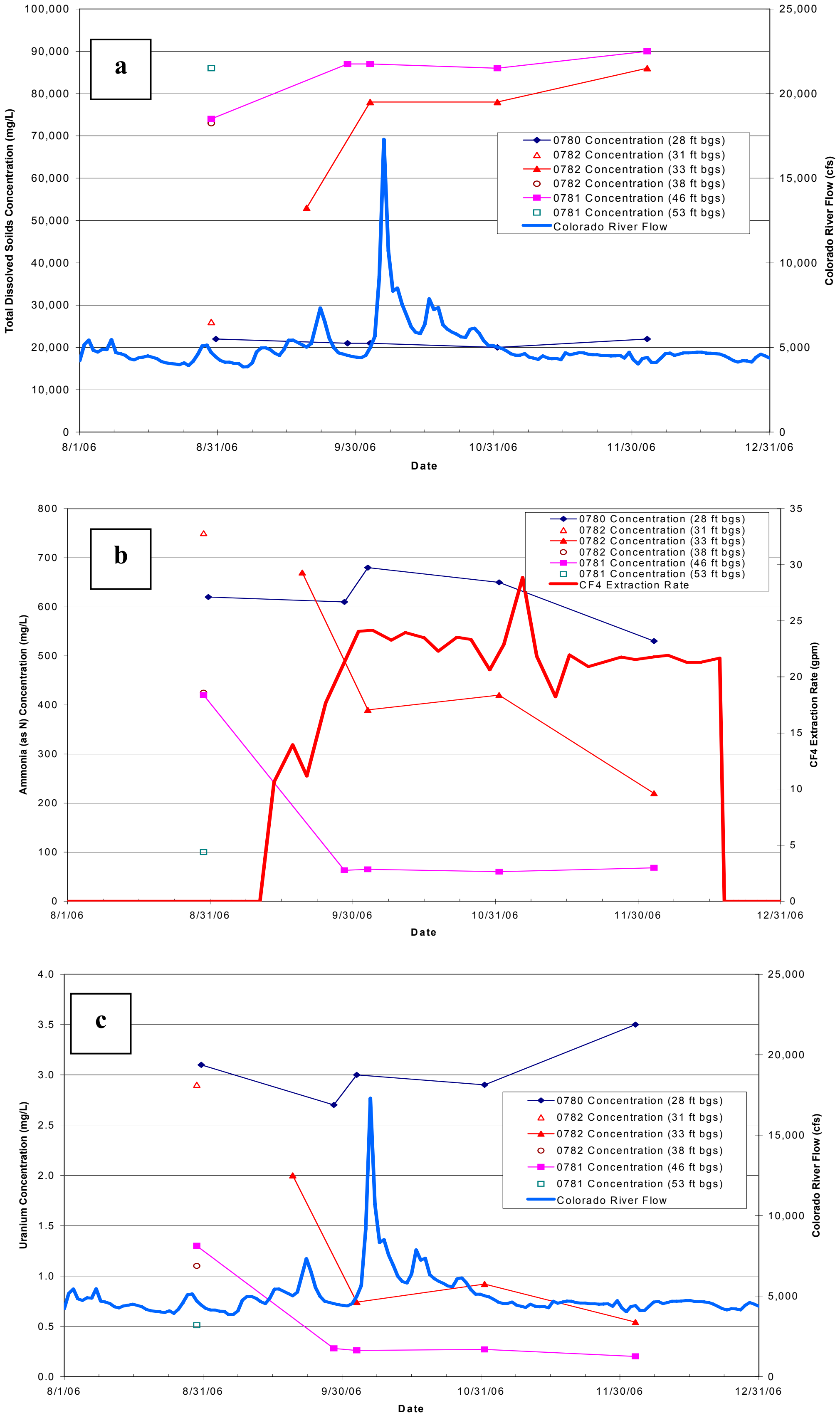


Figure 7–35. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Upgradient Observation Wells 0780, 0781, and 0782 During 2006

and then rebounded back to pre-flood levels; however, the timing in which the sampling events occurred did not provide supporting evidence.

Samples collected from 33 ft bgs exhibited an increase from 53,000 to 78,000 mg/L from September 20 to October 4 and samples collected from 46 ft bgs had TDS concentrations that increased from 74,000 to 87,000 mg/L between August 30 and September 29. This increase in concentration at depth is likely in response to pumping from Configuration 4, where the remediation wells are equipped with submersible pump with intakes set at a depth of approximately 30 ft bgs.

Water chemistry results indicate ammonia [Figure 7–35(b)] exhibits a different trend regarding depth versusconcentration. The highest ammonia concentration prior to pumping was detected in samples collected from 31 ft bgs (750 mg/L) and the lowest in the sample collected from 53 ft bgs (100 mg/L). During this same sampling event samples collected from 38 and 46 ft bgs contained 420 mg/L ammonia and the sample collected from 28 ft bgs contained 620 mg/L.

Once the pumping started (and prior to the October flood event) ammonia concentrations in samples collected from 33 and 46 ft bgs decreased significantly (from 670 to 390 mg/L and from 420 to 63 mg/L, respectively). Concentrations remained below 70 mg/L after September in samples collected from 46 ft bgs and gradually decreased in samples collected from 28 and 33 ft bgs as pumping continued. Unfortunately samples were not collected between the time the well field was shut down for the winter and the end of the year; however, based on a sampling event that occurred in the first week of January 2007 the ammonia concentrations remained below 70 mg/L in the sample collected from 46 ft bgs and started to rebound in sample collected from 28 and 33 ft bgs.

Uranium concentrations [Figure 7–35(c)] generally exhibited the same trend as ammonia. Prior to pumping uranium concentrations decreased with increasing depth. The lowest concentration was detected in the sample collected from 53 ft bgs (0.51 mg/L) and the highest in the sample collected from 28 ft bgs (3.1 ft bgs). During pumping, concentrations in samples collected from 46 ft bgs decreased and remained below 0.3 mg/L throughout the pumping period and the samples collected from 33 ft bgs gradually decreased as pumping continued. Water chemistry data associated with samples collected from 28 ft bgs indicated uranium concentrations fluctuated between 2.7 and 3.5 mg/L, with a slight gradual increase as pumping continued in 2006.

7.5.2.2 Downgradient Observation Wells 0784/0786/0787

As shown in Figure 4–5 observation well 0784 is located downgradient near the southern end of the well field and the wells 0786 and 0787 are located downgradient of the middle of the configuration. Another downgradient observation well, 0785, is located near the northern end of the configuration; however, during 2006 samples for water chemistry analysis were not collected from this location and this well will not be included in this discussion. Wells 0784, 0786, and 0787 are screened from 10 to 20 ft bgs, 20 to 30 ft bgs, and 35 to 45 ft bgs, respectively. All analytical data are contained in Appendix F−8.

Figure 7–36 presents analytical results of samples from depths of 18 ft bgs (well 0784), 28 and 30 ft bgs (well 0786), and 36 and 43 ft bgs (well 0787). Similar to the remediation well time

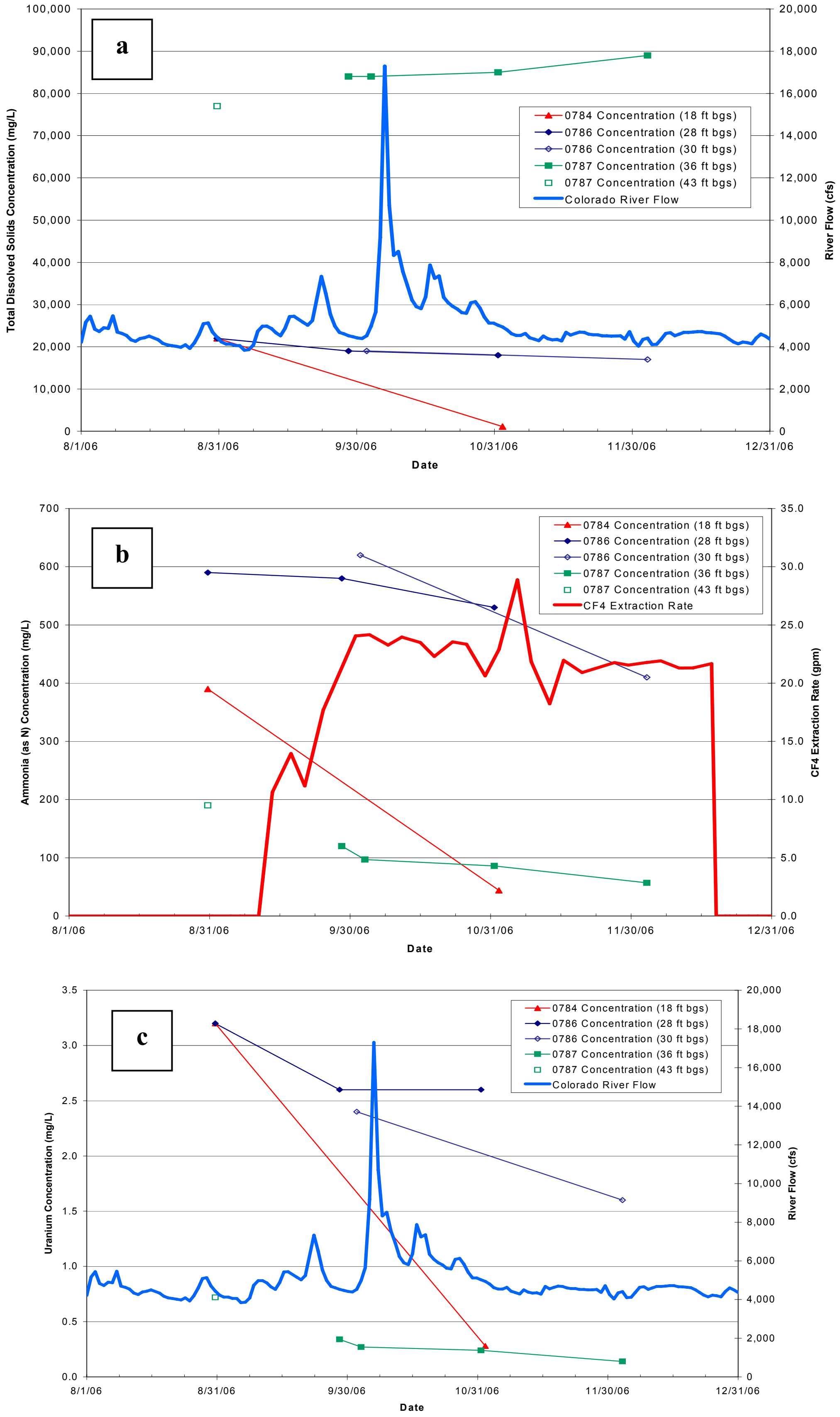


Figure 7–36. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Downgradient Observation Wells 0784, 0786, and 0787 During 2006

concentration plots the TDS and uranium concentration data are plotted with the Colorado River flow data while the ammonia data are plotted with the extraction rate data.

Similar to trends observed in the upgradient and remediation wells, water chemistry data indicates TDS concentrations increase with depth [Figure 7–36(a)]. Near the middle of the configuration TDS concentrations do not appear to have been influenced by Configuration 4 pumping or changes in the river stage at depths below 28 ft bgs. At the southern end of the configuration, samples collected from 18 ft bgs indicate TDS concentration decreased from 22,000 to 1,100 mg/L between the end of August and early November. With the limited water chemistry data it is not possible to determine if this significant decrease was the result of ground water extraction, changes in the river stage, or a combination of the two.

Prior to pumping ammonia concentrations [Figure 7–36(b)] ranged from 190 (43 ft bgs) to 590 mg/L (from 28 ft bgs). Near the middle of the configuration ammonia concentrations at depths of 28, 30, and 36 ft bgs gradually decreased, in response to either pumping or the October flood event. Samples collected from 28 ft bgs decreased from 590 to 530 mg/L between the end of August and early November. Water chemistry data from 36 ft bgs (and applying the concentration measured in late August from 43 ft bgs) indicate ammonia concentrations decreased from 190 to 57 mg/L. The most significant drop in ammonia concentration was detected from samples collected from 18 ft bgs at the southern end of the configuration (from 390 to 44 mg/L).

Water chemistry results also indicate uranium concentrations [Figure 7–36(c)] followed the same trend exhibited by ammonia concentrations. Pre-pumping uranium concentrations ranged from 0.72 (from 43 ft bgs) to 3.2 mg/L (from 18 and 28 ft bgs). Gradual decreases were observed in samples collected from 28, 30, and 36 ft bgs. Again an abrupt decrease was detected in the sample from 18 ft bgs (from 3.2 to 0.28 mg/L).

7.5.3 Riverbed Well Points

The Configuration 4 well points are split into two clusters containing three well points each that are installed at different depths; however, only one of the clusters was sampled more than twice during 2006. As a result, time versus concentration plots were generated only for the near river bank well point cluster 0790/0791/0792. Refer to for Section 4 for well point construction details (Table 4–9) and for locations. Appendix F−8 contains the analytical results.

Figure 7–37 presents the analytical results of samples collected from riverbed well points 0790, 0791, and 0792, all of which are located at the base of the bank (i.e., closest to the well field axis). Limited available sample volume, in combination with the shorter 2006 pumping season at Configuration 4, resulted in limited water chemistry data. The TDS and uranium concentration data are plotted with the Colorado River flow data and the ammonia data are plotted with the extraction rate data.

The initial sampling event indicated TDS concentration increased with increasing depth, a trend typically observed in the remediation and observation wells, but not always in the well points. The limited data indicate the TDS concentrations remained below 1,300 mg/L between mid-September and early November in samples collected from 0790, exhibited a sharp decrease followed by a rebound to initial levels in 0791, and gradually decreased from 22,000 to 17,000 mg/L between mid-September and early December. Ammonia and uranium

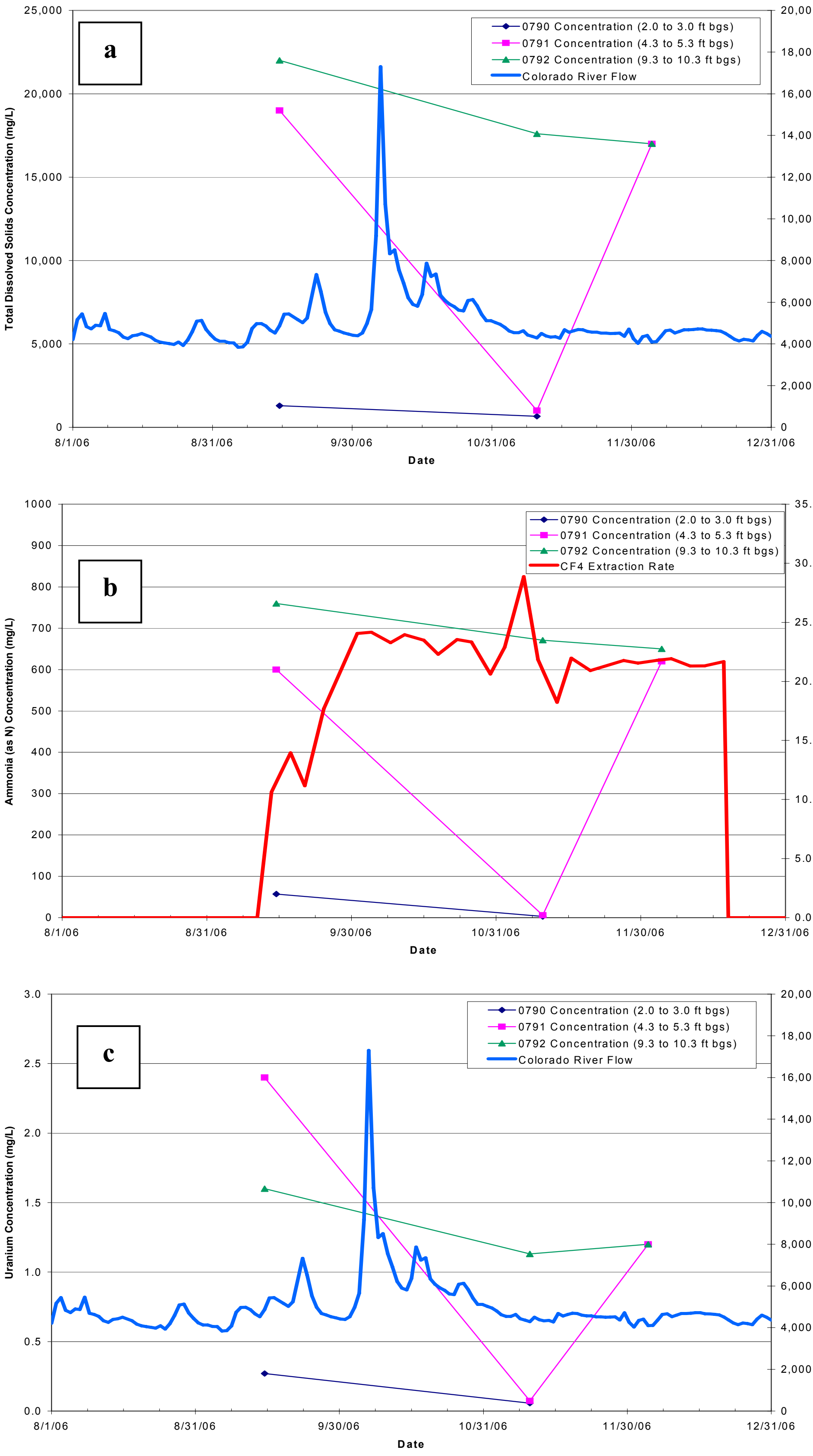


Figure 7–37. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Well Points 0790, 0791, and 0792 During 2006

concentrations in general followed this same trend. The TDS, ammonia, and uranium concentrations all rebound to pre-flood levels, during which time ground water extraction continued.

Well point 0793 was the only location sampled in the other well point cluster. TDS concentrations increased from mid-September to mid-November from 700 to 900 mg/L. During the same time period ammonia and uranium concentrations slightly increased from 0.21 to 0.29 mg/L and from 0.0089 to 0.0096 mg/L, respectively.

7.5.4 Surface Water Location

As shown on Figure 4–5, Configuration 4 surface water location 0274 is located along the western edge of the side channel that runs below Configuration 4. Figure 7–38 presents the analytical results (in the form of time concentration plots) of samples collected in 2006 from surface water location 0274. Appendix F−8 contains the analytical results.

This location was sampled only three times during 2006, all of which were after the October flood event and within the time frame when Configuration 4 was actively extracting ground water. As a result, the time concentration plots provide little more than information regarding natural concentration fluctuations during active pumping. More water chemistry data are required to determine impacts on the surface water chemistry from changing river stage and ground water extraction.

7.6 Evaporation Pond

During the 2006 pumping season samples were collected during the time frame when the IA well field was actively extracting ground water (March through November). Samples were collected of the ground water discharging into the Evaporation Pond and from the recirculation pump. The inlet sample (0547) is representative of the ground water transported to the pond from the well field and the sample collected off the recirculation pump (0548) is representative of the water stored in the pond. All analytical data is contained in Appendix H−2.

Figure 7–39 presents the time versus concentration plots generated for data collected during 2006. Similar to the other plots contained in this section, the TDS concentration is plotted with the Colorado River flow data [Figure 7–39(a)], the ammonia data are plotted with the total well field ground water extraction rate data [Figure 7–39(b)], and uranium concentration data are plotted with pond level data [Figure 7–39(c)].

Water chemistry data indicate TDS concentrations in samples collected from both locations tend to fluctuate in the same manner. Prior to June the pond concentration was typically greater than the inlet concentration. After July the inlet TDS concentration was higher compared to the pond. This reversal may be explained by the transfer of an estimated 1.4 million gallons of fresh water that settled on top of the pile after an intense precipitation event in July. This fresh water diluted the water stored (approximately 1.9 million gallons) in the pond at that time. After October the pond TDS concentration was higher compared to the inlet, possibly signifying the point where the diluted water was distributed by the sprinkler system.

Ammonia concentrations also exhibited the same relative change between the two locations after July. Water chemistry results indicate in April, May and June ammonia concentrations between

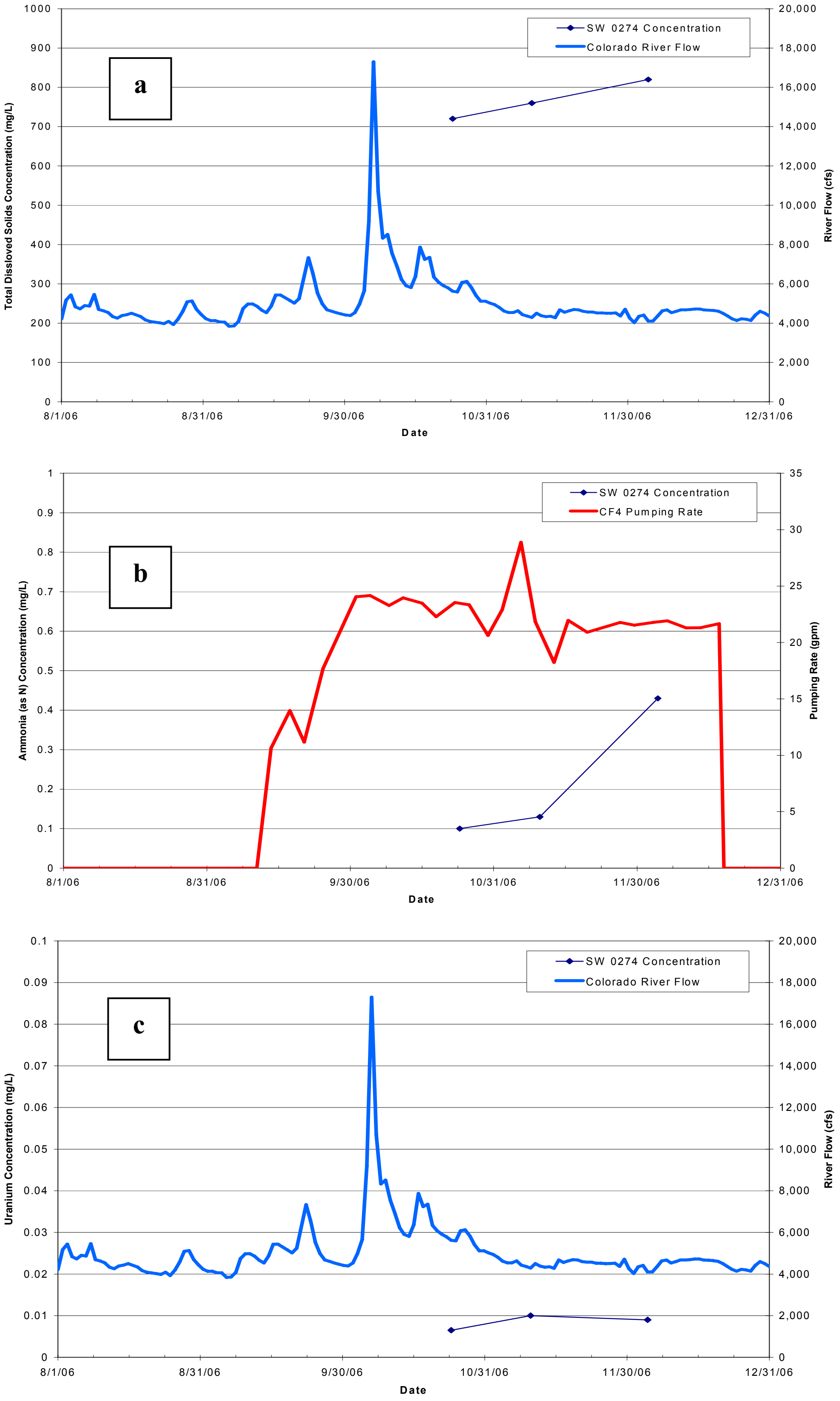


Figure 7–38. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at Surface Water Location 0274 During 2006

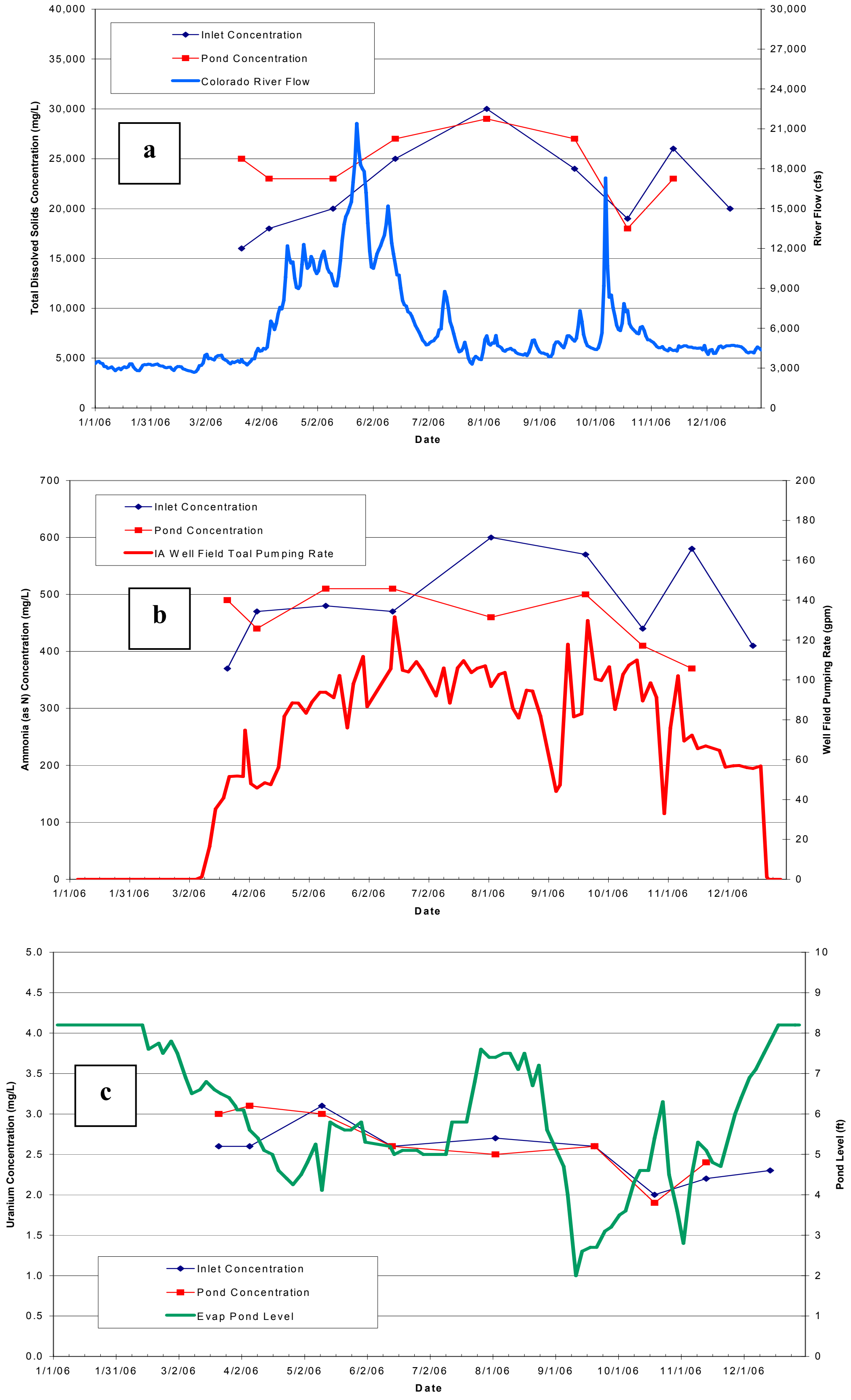


Figure 7–39. Measured Concentrations of (a) TDS, (b) Ammonia, and (c) Uranium at 0547(Pond Inlet) and 0548 (Pond Storage) During 2006

the two locations varied less than 40 mg/L (concentrations ranged from 440 to 510 mg/L). After July, the ammonia concentration in the sample collected from pond was 140 mg/L less than the sample collected from the inlet. Subsequent sampling indicated the difference became less, until November at which time the pond concentration was 370 mg/L and the inlet was 580 mg/L.

Uranium concentrations never varied more than 0.5 mg/L between the two locations. TDS, ammonia, and uranium concentrations all decreased between the September and October sampling events. This may have been in response to the October precipitation event, which may have diluted both the water stored in the pond and the ground water pumped to the pond.

End of current text

8.0 Biogeochemistry

Assessment of biogeochemical activity in ground water is based on data collected at the various portions of the Ground Water IA during all of 2006 and the first 2 months of 2007. In addition to covering a longer time span than that examined for general water chemistry (Chapter 7), this assessment is much more comprehensive than an earlier assessment of background biogeochemical conditions during the Fall 2005 performance evaluation (DOE 2006a), which was based solely on data collected in October and December 2005. The biogeochemical analysis is also based on data for several analytical parameters that were not available in 2005, including the BART™ screening methods for detecting denitrifying, iron-related and sulfate-reducing bacteria (see Section 3.4.3). Where helpful, similarities and differences between the information collected specifically for this updated evaluation and the findings from the previous one are mentioned.

With the exception of the area of the injection trench, biogeochemical data were collected at all parts of the Ground Water IA during 2006 and early 2007, including the Baseline Area. Following text in this chapter describes how biogeochemical processes appear to be significant contributors to contaminant transformation processes at the Baseline Area, suggesting that much of the contaminant attenuation in ground water that occurs naturally at the Moab Site involves much more than simple dilution. In addition, the data presented herein indicate that flow of surface water from the Colorado River toward extraction wells at Configurations 1 through 4 manages to enhance the natural contaminant attenuation, and that the effects of this induced inflow in response to extraction well operation appear to be more significant at IA locations associated with a river side channel (Configurations 1, 2, and 4). In addition, biogeochemical parameters at riverbed well points where the side channel is present tend to show greater influence of surface water infiltration on hyporheic zone processes than is observed in either the Baseline or Configuration 3 areas.

8.1 Biogeochemical Indicators in the Baseline Area

A summary of the biogeochemical parameter data from this evaluation period from Baseline Area observation wells is presented in Table 8–1. Inspection of this table indicates that anaerobic conditions tended to prevail in the ground water collected from the wells. Most DO levels at the cluster consisting of wells PZ1S, PZ1M, and PZ1D2 fell in the range of 0.5 to 3 mg/L, and the same observation held true for deep well 0493, located close to the steep bank forming the west boundary of the river, and to nearby shallower wells 0405 and 488 during the winter and early springs months of January through March. However, larger DO concentrations of about 5 mg/L were observed at wells 0405 and 0488 during late spring, summer and fall months in 2006, apparently in response to recharge of oxygenated water in vegetation test plot C6 (located about 50 ft hydraulically upgradient of the 0405/0488/0493 cluster). Table 8–1 also indicates that chemically oxidizing conditions were prevalent at the Baseline Area wells during the study period, as ORP values continually remained positive, ranging between about 30 and 270 mV and averaging about 185 mV. Thus, the relatively low DO values observed in many of the area's wells were not necessarily considered indicators of reducing conditions or heterotrophic microbial activity that might be associated with such conditions (e.g., denitrification, iron reduction, manganese reduction, sulfate reduction).

Table 8–1. Biogeochemical Parameters at Observation Wells in the Baseline Area

Analyte		**Well**						**Range for all Wells**	**Mean for all Wells**
		PZ1S	**PZ1M**	**PZ1D2**	**405**	**488**	**493**		
Alkalinity, Total as CaCO3 (mg/L)	Range	616-720	800-1300	260-488	316-920	802-990	986-1230	260-1300	836.82
	Mean	685.75	1183.25	408.29	658.79	911.12	1079.18		
Ammonia, Total as N (mg/L)	Range	300-450	830-1100	472-2000	75-417	550-857	710-1300	75-2000	778.93
	Mean	376.25	970.00	1546.50	293.80	728.15	987.06		
Biochemical Oxygen Demand (mg/L)	Range	NA	NA	NA	0.2-1.41	0.1-4.42	NA	0.1-4.42	1.03
	Mean	NA	NA	NA	0.71	1.46	NA		
Chemical Oxygen Demand (mg/L)	Range	NA	NA	NA	217-510	279-514	NA	217-514	323.69
	Mean	NA	NA	NA	288.86	364.33	NA		
Denitrifying Bacteria (cfu/mL)	Range	NA	NA	NA	10000-200000	10000-50000	NA	10000-200000	61666.67
	Mean	NA	NA	NA	86666.67	36666.67	NA		
Dissolved Organic Carbon (mg/L)	Range	NA	NA	NA	3.6-8.4	4.8-12	NA	3.6-12	6.24
	Mean	NA	NA	NA	5.33	7.47	NA		
Dissolved Oxygen (mg/L)	Range	0.98-2.88	0.38-1.9	0.4-1.92	0.54-5.2	0.6-5.1	0.44-2.85	0.38-5.2	2.14
	Mean	1.78	1.10	1.03	2.44	0.97	1.31		
Total Iron (mg/L)	Range	NA	NA	NA	0.05-0.05	0.03-0.06	NA	0.03-0.06	0.04
	Mean	NA	NA	NA	0.05	0.04	NA		
Ferrous Iron (mg/L)	Range	NA	NA	NA	0.5-0.5	0.5-0.5	NA	0.5-0.5	0.50
	Mean	NA	NA	NA	0.50	0.50	NA		
Iron-Related Bacteria (cfu/mL)	Range	NA	NA	NA	9000-35000	9000-140000	NA	9000-140000	39500.00
	Mean	NA	NA	NA	17666.67	61333.33	NA		
Total Manganese (mg/L)	Range	NA	NA	NA	5.2-7.14	5.87-7.59	NA	5.2-7.59	6.46
	Mean	NA	NA	NA	6.32	13.79	NA		
Manganous Manganese (mg/L)	Range	NA	NA	NA	5-11	5.8-11	NA	5-11	8.77
	Mean	NA	NA	NA	8.58	8.96	NA		
Nitrate as Nitrogen (mg/L)	Range	NA	NA	NA	40.8-109	36-50	NA	36-109	69.68
	Mean	NA	NA	NA	93.13	42.32	NA		
Nitrifying Bacteria (cfu/mL)	Range	NA	NA	NA	10000-100000	10000-100000	NA	10000-100000	67272.73
	Mean	NA	NA	NA	46000.00	85000.00	NA		
Nitrite as Nitrogen (mg/L)	Range	NA	NA	NA	0.007-0.017	0.011-0.07	NA	0.007-0.07	0.02
	Mean	NA	NA	NA	0.01	0.03	NA		
Oxidation Reduction Potential (mV)	Range	102-271	112-267	96-234	28.9-248	56-273	107-242	28.9-273	184.91
	Mean	176.18	182.45	166.36	172.97	206.95	185.90		

Table 8−1 (continued). *Biogeochemical Parameters at Observation Wells in the Baseline Area*

Analyte		**Well**						**Range for all Wells**	**Mean for all Wells**
		PZ1S	**PZ1M**	**PZ1D2**	**405**	**488**	**493**		
Phosphorus (mg/L)	Range	NA	NA	NA	0.0386-0.403	0.0996-0.211	NA	0.0386-0.403	0.18
	Mean	NA	NA	NA	0.19	0.15	NA		
Sulfate (mg/L)	Range	6600-9500	14000-17000	7600-8400	1300-8600	8590-12000	12000-16000	1300-17000	10494.13
	Mean	7625.00	15875.00	7871.43	6369.33	10371.00	14176.47		
Sulfate Reducing Bacteria (cfu/mL)	Range	NA	NA	NA	5000-700000	18000-700000	NA	5000-700000	320142.86
	Mean	NA	NA	NA	205750.00	472666.67	NA		
Sulfide (mg/L)	Range	NA	NA	NA	0.01-0.01	0.01-0.02	NA	0.01-0.02	0.01
	Mean	NA	NA	NA	0.01	0.01	NA		
Total Dissolved Solids (mg/L)	Range	11000-20000	27000-36000	76000-82000	2300-15000	13800-19000	18000-36000	2300-82000	25365.33
	Mean	13875.00	32750.00	78857.14	11373.33	16590.00	937.93		
Total Inorganic Carbon (mg/L)	Range	NA	NA	NA	70.5-238	126-259	NA	70.5-259	140.98
	Mean	NA	NA	NA	124.24	164.40	NA		
Total Kjeldahl Nitrogen (mg/L)	Range	NA	NA	NA	213-553	598-1110	NA	213-1110	546.46
	Mean	NA	NA	NA	370.57	664.00	NA		
Total Organic Carbon (mg/L)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium (mg/L)	Range	1.4-4.5	3.1-3.9	0.92-1.4	0.97-3.13	0.4-3	2.6-3.9	0.92-4.5	2.61
	Mean	2.40	3.73	1.16	2.29	2.42	3.29		
Orthophosphate (mg/L)	Range	NA	NA	NA	0.5-0.5	0.4-0.4	NA	0.4-0.5	0.45
	Mean	NA	NA	NA	0.50	0.40	NA		
pH (standard units)	Range	6.57-6.86	6.62-6.88	1.4-6.68	6.39-7.82	6.55-7.1	6.56-7.05	6.32-7.82	6.82
	Mean	6.78	6.81	5.93	6.91	6.87	6.83		

NA = not applicable

The presence of nitrate (NO3-N) at Baseline Area wells (Table 8–1) at concentrations between 36 and 109 mg/L suggests that nitrification in local ground water was occurring in 2006 and early 2007. This possibility is supported by the detection of nitrifying bacteria (nitrifiers) in shallow wells 0405 and 0488 during the year-plus study period. At each of these wells, order-of-magnitude measures of nitrifiers using BARTs ranged from 10,000 to 100,000 colony-forming units per milliliter (cfu/mL). Though the above-mentioned maximum DO concentrations of about 5 mg/L at these wells do not suggest that oxygen was readily available to facilitate nitrification, measured concentrations of total inorganic carbon (TIC) at wells 0405 and 0488, ranging between about 70 and 260 mg/L, do indicate that this additional required component of nitrification activity is relatively plentiful. Unlike nitrate, nitrite (NO2 N) concentrations in these wells during 2006 and early 2007 (Table 8–1) never exceeded 0.07 mg/L, suggesting that any nitrite created during the first stage of nitrification was likely to have been fully utilized in the subsequent stage. However, it is also possible that anammox was consuming nitrite (Section 3.4.3) that might have been produced by either nitrification or denitrification.

In addition to providing evidence of nitrification, the data presented in Table 8–1 show that at least a portion of the ingredients and conditions ostensibly indicative of anammox are present in the vicinity of the Baseline Area wells. Specifically, the relatively low DO levels mentioned above are reflective of the anaerobic conditions associated with anammox, and certainly adequate quantities of bicarbonate (in the form of alkalinity) are available to facilitate this autotrophic process. As mentioned in the preceding paragraph, it is also possible that low levels of nitrite in local ground water are reflective of this constituent being consumed through anammox when it is generated as an intermediate product of nitrification. Accordingly, the relatively low levels of nitrite could be an indicator that the anammox process at the site is nitrite-limited. Short of having direct measures of dissolved nitrogen gas, which is one of the key products of anammox (see Equation [1] in Section 3.4.3), it is difficult to quantify the degree to which this form of ammonia degradation is occurring, but the significant quantities of nitrate (Table 8–1), another major product of the process, does suggest that it can occur.

The limited biogeochemical data collected during the previous performance assessment (DOE 2006a) showed signs that heterotrophic microbe respiration might be occurring in Baseline Area ground water in late 2005, and the data collected for this updated evaluation provide additional lines of evidence to indicate that heterotrophic activity in local shallow ground water is significant. BART™ measures of denitrifying bacteria during the year-and-a-quarter evaluation period (Table 8–1) ranged from 10,000 to 200,000 cfu/mL, and comparable measures of sulfate-reducing bacteria ranged from 5,000 to 700,000 cfu/mL. Dissolved sulfate concentrations in Baseline Area ground water (6,600 to 15,000 mg/L, Table 8–1) are more than adequate to support enzymatic sulfate reduction even if ORP values in local wells (29 to 273 mV) appear too large to be representative of such activity. If indeed sulfate reduction is occurring in Baseline Area ground water, it does suggest that within micro-zones of the alluvial aquifer, heterotrophic activity is occurring to the degree that the oxidation-reduction (redox) status is relatively reducing rather than oxidizing. Moreover, the presence of sulfate-reducing bacteria would also indicate that iron-, and possibly manganese-, reducing heterotrophic respiration is occurring as well. BART™-derived counts of iron-related bacteria were also substantial in 2006 and early 2007 (Table 8–1), ranging from 9,000 to 140,000 cfu/mL. However, as stated in Section 3.4.3, the nature of the IRB-BART™ is such that iron-reducing bacteria cannot be readily distinguished from iron-oxidizing bacteria.

Given the evidence for the presence of heterotrophic microbes in detectable quantities, the question remains as to what source(s) of organic carbon in the Baseline Area would be available to drive heterotrophic activity. It is possible that recharge of irrigation water at vegetation test plot C-6 provides such a source, and possibly the only significant source of organic carbon. Concentrations of dissolved organic carbon (DOC), ranging from 3.6 to 12 mg/L in shallow wells 0405 and 0488 (Table 8–11), support this hypothesis.

Observed concentrations of dissolved manganese and iron in Baseline Area ground water were mentioned in the Fall 2005 performance assessment (DOE 2006a) as being inconclusive indicators of the presence of either manganese- or iron-reducing microbial activity. Though relatively high concentrations of both total and manganous manganese were measured at wells 0405 and 0488 (between 5 and 10 mg/L) at the time, and similar values have since been re-observed in this evaluation (5 to 14 mg/L, Table 8–1), they could just be representative of background levels of this constituent resulting from the leaching of mill tailings during past years rather than manganese-reducing bacterial activity. Concentrations of total dissolved iron and ferrous iron also provide ambiguous information, as relatively low concentrations for these constituents in wells 0405 and 0488 in late 2005 (0.007 to 0.9 mg/L, DOE 2006a) and again in 2006 and early 2007 (0.03 to 0.5 mg/L, Table 8–1) do not necessarily indicate a lack of iron-reducing microbial respiration. It is possible that, if enzymatic reduction of dissolved (ferrous) iron occurs in Baseline Area ground water, much of it could be precipitated out of solution in the form of iron sulfides. Further investigation of the biogeochemistry of iron and manganese would be necessary before some of the ambiguities presented by concentration data for these constituents can be resolved.

A summary biogeochemical data collected during this study's performance period at riverbed well points in the Baseline Area is presented in Table 8–2. One of the most notable features of this summary is the large variation in values observed for certain parameters, not only between well points but also over the study period at individual well points. As alluded to in the Fall 2005 performance evaluation (DOE 2006a), this is largely attributed to the temporally varying influence that the Colorado River can have on the sediments beneath the riverbed in this area and the ground water contained therein. Because a river side channel does not currently occur in the area due to sediment infill (see Section 4.3.1), eastward-flowing ground water from the vicinity of the Baseline Area wells discharges to the main river channel (located east of the well points) during most of each year. However, during months of high river runoff (typically between March and June), the area monitored by the well points does become inundated by river water, which infiltrates the underlying subsurface creating a temporary hyporheic zone, the effects of which might be observed months after the passing of high runoff.

Examples of chemical parameters that exhibit strong variation at the Baseline Area well points include alkalinity, ammonia (NH3-N), biochemical oxygen demand (BOD), chemical oxygen demand, DO, nitrate (NO3-N), ORP, sulfate, TDS, and uranium. Though a very large portion of this variation can be attributed to the temporally variable dilution effects brought on by infiltration of river water into the subsurface during high runoff months, some of it likely also reflects the biogeochemical processes made possible by such infiltration. For example, oxygenated river water, with DO concentrations commonly ranging between 8 and 11 mg/L, is capable of facilitating aerobic microbial processes, such as nitrification. In addition, river water typically contains DOC at concentrations ranging from 5 to 15 mg/L, which, upon entering the subsurface, becomes available for heterotrophic respiration in riverbed sediments. If

Table 8–2. Biogeochemical Parameters at Riverbed Well Points in the Baseline Area

Analyte		**Well Point**								**Range for All Wells**	**Mean for All Wells**
		495	**496**	**497**	**597**	**598**	**599**	**617**	**618**		
Alkalinity, Total as CaCO3 (mg/L)	Range	110-110	400-720	636-1002	NA	218-580	596-854	676-1022	404-760	110-1022	618.64
	Mean	110.00	546.67	766.00	NA	352.67	730.40	815.33	582.00		
Ammonia, Total as N (mg/L)	Range	1.4-9.2	0.64-262	180-368	180-370	31-419	120-530	343-500	92.1-422	0.64-530	353.10
	Mean	5.73	86.75	292.20	306.67	258.24	399.71	431.80	3916.78		
Biochemical Oxygen Demand (mg/L)	Range	NA	0.03-3.39	1.2-1.6	NA	1.6-3.4	NA	0.3-0.9	0.5-2.6	0.03-5.3	1.98
	Mean	NA	2.01	1.40	NA	2.31	NA	0.6	1.55		
Chemical Oxygen Demand (mg/L)	Range	NA	108-1190	54-264	NA	19-183	NA	261-291	54-234	18-1190	254.60
	Mean	NA	427.25	159.00	NA	101.00	NA	276.00	144.00		
Denitrifying Bacteria (cfu/mL)	Range	NA	10000-200000	50000-50000	NA	50000-200000	50000-50000	50000-50000	10000-50000	10000-200000	78888.89
	Mean	NA	77500.00	50000.00	NA	125000.00	50000	50000	30000		
Dissolved Organic Carbon (mg/L)	Range	NA	8.6-17.2	14.4-14.4	NA	4.8-12.7	10-10	NA	10.4-10.4	4.7-17.2	10.42
	Mean	NA	13.83	14.40	NA	8.43	10.00	NA	10.40		
Dissolved Oxygen (mg/L)	Range	4.97-5.77	0.04-7.59	2.47-14.6	4.74-9.24	1.16-13	NA	1.58-4.35	2.92-6.87	0.04-14.6	4.60
	Mean	5.33	4.91	6.08	6.53	5.00	NA	2.76	5.05		
Total Iron (mg/L)	Range	NA	0.0287-0.23	0.0256-0.05	NA	0.031-0.85	0.05-0.08	0.05-0.09	0.05-0.08	0.0256-0.85	0.17
	Mean	NA	0.10	0.04	NA	0.34	0.07	0.07	0.07		
Ferrous Iron (mg/L)	Range	NA	0.2-0.4	NA	NA	NA	NA	NA	NA	0.2-0.4	0.30
	Mean	NA	0.30	NA	NA	NA	NA	NA	NA		
Iron-Related Bacteria (cfu/mL)	Range	NA	9000-540000	9000-35000	NA	9000-35000	9000-35000	2300-35000	2300-35000	2300-540000	54350.00
	Mean	NA	194666.67	22000.00	NA	26333.33	22000	18650	18650		
Total Manganese (mg/L)	Range	NA	0.429-5.58	2.98-6.62	NA	0.427-6.76	1.75-6.09	NA	0.753-0.753	0.427-8.32	3.76
	Mean	NA	2.61	4.80	NA	3.29	2.72	NA	0.75		
Manganous Manganese (mg/L)	Range	NA	1.2-9.9	NA	NA	4.2-8.8	0.693-8	NA	NA	1.2-9.9	6.15
	Mean	NA	5.70	NA	NA	6.60	4.35	NA	NA		
Nitrate as Nitrogen (mg/L)	Range	NA	33-200	44.3-119	NA	2.5-114	8.24-110	85.2-116	NA	2.5-200	78.59
	Mean	NA	74.47	81.65	NA	63.09	59.12	100.60	NA		
Nitrifying Bacteria (cfu/mL)	Range	NA	1000-1000	1000-10000	NA	1000-100000	1000-10000	10000-100000	1000-10000	1000-100000	21000.00
	Mean	NA	1000.00	5500.00	NA	38500.00	5500	55000	5500		

Table 8−2 (continued). Biogeochemical Parameters at Riverbed Well Points in the Baseline Area

Analyte		**Well Point**								**Range for All Wells**	**Mean for All Wells**
		495	**496**	**497**	**597**	**598**	**599**	**617**	**618**		
Nitrite as Nitrogen (mg/L)	Range	NA	0.01-0.23	0.015-0.025	NA	0.018-1.44	0.012-0.333	0.37-0.68	0.03-0.263	0.01-1.44	0.32
	Mean	NA	0.07	0.02	NA	0.73	0.17	0.53	0.15		
Oxidation Reduction Potential (mV)	Range	43.9-260	75.4-209	34-172	-46 to 135	-18.3-224	42-230	1.64-171.7	-50-147	-65 to 260	110.35
	Mean	125.97	166.24	94.19	41.00	3242.34	127.83	113.04	55.32		
Phosphorus (mg/L)	Range	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mean	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate (mg/L)	Range	20000-21000	3320-13500	4340-11000	8200-9700	516-8900	2250-9700	4980-8800	1250-15000	516-21000	7958.18
	Mean	20333.33	8657.50	7962.00	8933.33	5542.00	7102.86	7928.00	9450.00		
Sulfate Reducing Bacteria (cfu/mL)	Range	NA	100000-700000	100000-100000	NA	1200-700000	100000-100000	100000-700000	100000-100000	1200-700000	274957.89
	Mean	NA	400000.00	100000.00	NA	254033.33	100000	400000	100000		
Sulfide (mg/L)	Range	NA	0.01-0.02	NA	NA	0.01-0.01	NA	NA	0.01-0.01	0.01-0.02	0.01
	Mean	NA	0.01	NA	NA	0.01	NA	NA	0.01		
Total Dissolved Solids (mg/L)	Range	44000-46000	6860-27000	10000-20000	16000-17000	1200-16000	4180-18000	10700-16000	2570-29000	1200-46000	16160.41
	Mean	45333.33	16640.00	14940.00	16333.33	9468.75	12882.86	14620.00	18554.00		
Total Inorganic Carbon (mg/L)	Range	NA	112-304	138-138	NA	66.7-213	132-132	145-145	95.2-95.2	66.7-304	144.11
	Mean	NA	182.25	138.00	NA	134.68	132.00	145.00	95.20		
Total Kjeldahl Nitrogen (mg/L)	Range	NA	2-227	136-136	NA	36.9-36.9	138-138	370-370	87.6-87.6	2-370	147.12
	Mean	NA	81.90	136.00	NA	193.95	138.00	370.00	87.60		
Total Organic Carbon (mg/L)	Range	NA	NA	14.3-14.3	NA	7.8-7.8	11.1-11.1	12.9-12.9	9-9	7.8-39.1	15.11
	Mean	NA	NA	14.30	NA	7.80	11.10	12.90	9.00		
Uranium (mg/L)	Range	13-18	0.849-17.4	0.00045-6.92	0.6-1.4	0.51-3.67	0.5-4.52	1.64-4.38	1-3	0.0045-18	3.18
	Mean	15.50	7.10	3.82	1.07	1.47	2.33	2.42	1.99		
Orthophosphate (mg/L)	Range	NA	0.8-4.2	0.8-0.8	NA	0.6-2.3	1.4-1.4	0.8-2	0.8-0.8	0.4-4.2	1.55
	Mean	NA	2.32	0.80	NA	1.28	1.40	1.40	0.80		
pH (standard units)	Range	6.64-7.49	6.15-7.71	5.5-6.92	7.39-9.19	7.27-8.59	6.67-8.18	6.91-7.37	6.83-8.18	6.15-9.19	7.52
	Mean	7.49	7.02	5.99	8.41	7.88	7.50	7.06	7.57		

NA = not applicable

heterotrophic activity is carried out over the full range of potential electron accepting phases in the hyporheic zone (Figure 4–5), the possibility exists for more chemically reducing conditions to dominate the subsurface. Observations of negative ORP values in some of the Baseline Area well points (-46 and -50 mV in well points 0497 and 0618, respectively) support this possibility. Such data indicate that the hyporheic subsurface in the vicinity of the Baseline Area riverbed well points comprises a very dynamic environment, both hydraulically and chemically, even though ground water extraction does not occur here. It follows logically that ground water pumping at active IA locations (Configurations 1 through 4) has the potential to cause additional variability in the biogeochemical parameters observed at them.

As with Baseline Area wells, BART™ results at the Baseline Area well points (Table 8–2) suggest that bacteria in the form of nitrifiers, denitrifiers, iron-related bacteria, and sulfate reducers are all active in riverbed sediments near the west edge of the river. The fact that ORP values tend to be lower in well-point ground water than those measured at Baseline Area wells lends further support that to the hypothesis that biologically mediated iron and sulfate reduction is occurring in some zones monitored by the well points.

As pointed out in the Fall 2005 Performance Evaluation (DOE 2006a), pH values at the riverbed well points in the Baseline Area during fall 2005 tended to be larger than those measured at the Baseline Area wells. Comparison of Table 8–1and Table 8–2 suggest that the same observation held true during 2006 and early 2007. This provides further indication that river water infiltrates the nearby subsurface since Colorado river water typically exhibits a pH of 7.6 to 8.5, and pH in Baseline Area ground water ranges from about 6.3 to 7.8.

8.2 Biogeochemical Indicators in the Configuration 1 Area

Biogeochemical parameters measured during 2006 and early 2007 at Configuration 1 observation wells between the extraction system and the river show strong evidence that the extraction well pumping in 2006 induced seepage losses from the river. This evidence appears mostly in the form of shallow ground water chemistry reflective of both the river and the nearby hyporheic zone. For example, DO concentrations in shallow wells 0403, 0407, 0483, and 0559 reached as high as 6 to 8 mg/L (Table 8–3) during the study period, whereas equivalent DO levels in intermediate-depth and deep wells typically remained below 2 mg/L. In addition, mean pH values at all shallow wells (0403, 0407, 0483, 0559, 0596) were above 7, in contrast to the pHs of less than 7 in the remaining wells. Negative ORP values in shallow wells 0407 and 0559, (Table 8–3) suggested that much of the shallow induced flow toward extraction wells was chemically reduced, ostensibly as a result of occurring within the hyporheic zone before migrating westward. Mean ammonia concentrations in shallow wells were also significantly smaller than those in deeper wells. Though this latter observation might have merely indicated the local presence of river water or dilution from the mixing of surface water with ground water, it could have also resulted from nitrification as enhanced by the presence of relatively large DO concentrations in river water.

BART™ results during 2006 and early 2007 (Table 8–3) indicate that all four types of microbes tested for—denitrifiers, nitrifiers, oxygen-related bacteria, and sulfate reducers—were present in ground water between the west edge of the riverbed and Configuration 1 extraction wells. Because this finding was similar to observations made at the Baseline Area during the study period (Section 8.1), it is difficult to tell whether any of the autotrophic and heterotrophic

Table 8–3. Biogeochemical Parameters at Observation Wells in the Configuration 1 Area

Analyte		**Well**										**Range for all Wells**	**Mean for all Wells**
		403	**407**	**483**	**484**	**485**	**558**	**559**	**560**	**561**	**596**		
Alkalinity, Total as CaCO3 (mg/L)	Range	244-654	192-424	250-720	740-922	256-334	340-776	184-560	320-680	226-560	190-720	184-922	464.63
	Mean	385.27	294.27	454.91	836.18	283.71	561.82	334.00	545.60	381.00	476.25		
Ammonia, Total as N (mg/L)	Range	32-170	4.3-170	105-450	920-1500	450-640	1300-2400	12-250	720-1700	630-960	100-770	4.3-2400	637.50
	Mean	93.53	37.14	243.36	1104.62	541.43	1708.33	104.35	1372.00	848.57	310.00		
Biochemical Oxygen Demand (mg/L)	Range	0.4-5.5	1.2-8.5	1.63-5.5	NA	NA	NA	0.79-7	NA	NA	NA	0.4-8.5	2.92
	Mean	2.39	3.82	2.23	NA	NA	NA	3.25	NA	NA	NA		
Chemical Oxygen Demand (mg/L)	Range	33-143	23-46	100-647	NA	NA	NA	25-93	NA	NA	NA	23-647	124.89
	Mean	83.67	31.75	298.40	NA	NA	NA	57.00	NA	NA	NA		
Denitrifying Bacteria (cfu/mL)	Range	50000-200000	10000-50000	50000-200000	NA	NA	NA	50000-200000	NA	NA	NA	10000-200000	84166.67
	Mean	100000.00	36666.67	100000.00	NA	NA	NA	100000.00	NA	NA	NA		
Dissolved Organic Carbon (mg/L)	Range	3-3.7	3.7-5.5	3-5.4	NA	NA	NA	3.6-13	NA	NA	NA	3-13	5.11
	Mean	3.35	4.60	4.20	NA	NA	NA	8.30	NA	NA	NA		
Dissolved Oxygen (mg/L)	Range	0.89-5.4	1.28-6.1	0.98-8.1	0.73-1.65	0.2-1.59	0.5-1.87	0.73-7.6	0.28-1.95	0.53-1.41	0.48-2.06	0.2-8.1	2.01
	Mean	2.61	2.65	2.83	1.18	1.02	1.32	2.72	1.25	1.06	1.11		
Total Iron (mg/L)	Range	0.0258-0.05	0.0356-0.567	0.0307-0.04	NA	NA	NA	0.0381-0.109	NA	NA	NA	0.0258-0.567	0.13
	Mean	0.04	0.26	0.04	NA	NA	NA	0.07	NA	NA	NA		
Ferrous Iron (mg/L)	Range	0.3-2.1	0.3-0.3	0.2-0.3	NA	NA	NA	0.2-0.2	NA	NA	NA	0.2-2.1	0.51
	Mean	1.20	0.30	0.25	NA	NA	NA	0.20	NA	NA	NA		
Iron-Related Bacteria (cfu/mL)	Range	500-35000	35000-35000	9000-140000	NA	NA	NA	9000-140000	NA	NA	NA	500-140000	45291.67
	Mean	23500.00	35000.00	61333.33	NA	NA	NA	61333.33	NA	NA	NA		
Total Manganese (mg/L)	Range	0.409-4.2	0.101-4.8	0.258-5.4	8-8	6.6-6.6	10-10	0.219-5.5	9.4-9.4	9.5-9.5	2.1-2.1	0.101-10	2.96
	Mean	2.12	1.33	2.22	8.00	6.60	10.00	1.65	9.40	9.50	2.10		
Manganous Manganese (mg/L)	Range	0.4-6.8	0.1-1.7	0.3-3.5	NA	NA	NA	0.5-2.1	NA	NA	NA	0.1-6.8	1.88
	Mean	2.81	0.80	1.82	NA	NA	NA	1.27	NA	NA	NA		
Nitrate as Nitrogen (mg/L)	Range	0.656-95.7	0.157-31.8	1.88-46.9	NA	NA	NA	0.0805-35.2	NA	NA	NA	0.0805-95.7	20.66
	Mean	35.88	15.98	14.72	NA	NA	NA	10.21	NA	NA	NA		
Nitrifying Bacteria (cfu/mL)	Range	1000-100000	1000-1000	1000-100000	NA	NA	NA	1000-100000	NA	NA	NA	1000-100000	23200.00
	Mean	50500.00	1000.00	30250.00	NA	NA	NA	24400.00	NA	NA	NA		

Table 8−3 (continued). Biogeochemical Parameters at Observation Wells in the Configuration 1 Area

Analyte		**Well**										**Range for all Wells**	**Mean for all Wells**
		403	**407**	**483**	**484**	**485**	**558**	**559**	**560**	**561**	**596**		
Nitrite as Nitrogen (mg/L)	Range	0.01-0.011	0.007-0.007	0.005-0.027	NA	NA	NA	0.005-0.022	NA	NA	NA	0.005-0.027	0.01
	Mean	0.01	0.01	0.01	NA	NA	NA	0.01	NA	NA	NA		
Oxidation Reduction Potential (mV)	Range	7.7-236	-85 to 208.5	6.1-222	23.3-167	17.3-212	31.7-250	-56.4 to 196.6	101-246	58-255	87-238	-85 to 255	114.49
	Mean	112.59	-9.07	132.36	96.31	112.19	145.06	61.00	182.70	188.57	170.86		
Phosphorus (mg/L)	Range	0.0151-0.0621	0.0428-0.0973	0.0329-0.0645	NA	NA	NA	0.0478-0.0949	NA	NA	NA	0.0151-0.0973	0.06
	Mean	0.04	0.07	0.05	NA	NA	NA	0.07	NA	NA	NA		
Sulfate (mg/L)	Range	390-4500	231-3500	778-7700	8700-11000	5900-6900	8000-11000	210-5700	7400-9800	5800-8700	940-8000	210-11000	5344.92
	Mean	2186.00	946.42	3323.45	9730.77	6500.00	9841.67	2049.00	8780.00	7628.57	3815.56		
Sulfate Reducing Bacteria (cfu/mL)	Range	18000-700000	18000-700000	700000-700000	NA	NA	NA	100000-700000	NA	NA	NA	18000-700000	511000.00
	Mean	472666.67	427200.00	700000.00	NA	NA	NA	500000.00	NA	NA	NA		
Sulfide (mg/L)	Range	0.01-0.01	0.01-0.01	0.01-0.01	NA	NA	NA	0.01-0.01	NA	NA	NA	0.01-0.01	0.01
	Mean	0.01	0.01	0.01	NA	NA	NA	0.01	NA	NA	NA		
Total Dissolved Solids (mg/L)	Range	820-9900	725-9200	2130-15000	25000-40000	83000-88000	41000-74000	590-13000	22000-69000	71000-85000	2200-26000	590-88000	28775.15
	Mean	4831.54	2123.75	7333.64	30230.77	85714.29	57583.33	4458.42	51000.00	77571.43	10077.78		
Total Inorganic Carbon (mg/L)	Range	37.4-96	56.1-72.8	33.2-130	NA	NA	NA	54.8-133	NA	NA	NA	33.2-133	73.74
	Mean	67.20	60.55	85.03	NA	NA	NA	87.20	NA	NA	NA		
Total Kjeldahl Nitrogen (mg/L)	Range	41.7-78	11.8-54.4	82.6-361	NA	NA	NA	22.2-99.7	NA	NA	NA	11.8-361	86.25
	Mean	62.00	24.10	199.52	NA	NA	NA	64.24	NA	NA	NA		
Total Organic Carbon (mg/L)	Range	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mean	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Uranium (mg/L)	Range	0.16-1.8	0.0597-0.93	0.27-3.4	2.5-3.2	0.59-0.78	1-3.1	0.125-2	1.5-1.9	0.77-1.4	0.31-2	0.0597-3.4	1.27
	Mean	0.80	0.21	1.09	3.00	0.67	2.07	0.65	1.71	1.03	1.04		
Orthophosphate (mg/L)	Range	0.3-1.5	0.3-1.3	0.6-1.6	NA	NA	NA	0.3-4.8	NA	NA	NA	0.3-4.8	1.13
	Mean	0.97	0.68	1.10	NA	NA	NA	1.73	NA	NA	NA		
pH (standard units)	Range	6.7-7.65	6.95-7.45	6.81-7.89	6.58-6.92	6.5-6.84	6.49-6.89	6.98-7.76	6.53-7	6.46-6.84	7.09-8.19	6.46-8.19	7.02
	Mean	7.21	7.17	7.31	6.77	6.67	6.68	7.33	6.78	6.69	7.48		

NA = not applicable

processes potentially identified by these tests are either enhanced or slowed by the induced infiltration of river water in response to pumping. Nonetheless, the presence of negative ORPs in shallow ground water (see preceding paragraph) does suggest that sulfate reduction may be enhanced as a result of the induced inflow.

Low nitrite concentrations at Configuration 1 wells in 2006 (Table 8–3) make it difficult to discern whether ammonia degradation via anammox occurs in the area. The previously discussed laboratory findings by Landkamer and Figueroa (2006) do suggest that anammox in shallow ground water is possible, particularly given the induced inflow of river water. Moreover, as in the case of Baseline Area monitor wells, chemical components that might be indicative of this form autotrophic process are certainly present in the Configuration 1 area. Nitrate, one of the products of anammox, is observed in all wells for which it is sampled. A very large range in NO3-N concentrations (Table 8–3) at each of these wells (0403, 0407, 0483, and 0559) suggest all potential biologically mediated reactions involving this constituent (nitrification, denitrification, and anammox) could be occurring.

As with the Baseline Area, measured concentrations of dissolved iron and manganese at Configuration 1 wells provide little evidence as to whether iron-reducing or manganese-reducing bacteria are locally active. A concentration for ferrous iron of 2.1 mg/L during the study period (Table 8–3) at one well (0403) does at least indicate that iron reduction is possible. Typically higher concentrations for total manganese, which range between 0.1 and 10 mg/L are just as easily attributable to ambient levels for this constituent in local ground water as they are to manganese reduction.

The summary of biogeochemical parameters for riverbed well points at Configuration 1 (Table 8–4) shows that, like the Baseline Area, an array of potential processes in the hyporheic zone causes wide variations in observed concentrations, not only between well points but also at each well point over the course of several months. For example, alkalinity levels at all well points during the study period ranged from 90 to 896 mg/L, and ammonia (NH3-N) concentrations ranged from 0.35 to 181 mg/L. Though much of the observed variability can be attributed to dilution by inflowing surface water, particularly in the shallowest portions of the hyporheic zone, it is very likely that biodegradation mechanisms are at least partly responsible for some of the lowest observed concentrations.

DO levels and ORP values at Configuration 1 riverbed well points during the evaluation period indicate the coexistence of both chemically oxidizing and reducing conditions. Such coexistence was also observed at the Baseline Area well points, but not to the degree observed in the Configuration 1 area. This is most evident in the preponderance of negative ORP values at Configuration 1 well points in 2006 and early 2007 (Table 8–4), which reached values as low as -200 mV. In contrast, the occurrences of negative ORP values at Baseline Area well points (Table 8–2) were less frequent and never as low as the smallest measured values for this parameter at Configuration 1. The presumed cause of the more reducing conditions in the Configuration 1 hyporheic zone is active mixing of surface water from the river side channel in this area with underlying ground water, which does not occur at the Baseline Area. This mixing is driven by a constant supply of DOC in surface water to the subsurface, which in turn facilitates the heterotrophic microbial processes that can eventually lead to a strongly reducing environment. It stands to reason that the induced infiltration of river water from the side channel in response to Configuration 1 pumping increases the DOC influx.

Table 8–4. Biogeochemical Parameters at Riverbed Well Points in the Configuration 1 Area

Analyte		**Well Points**									**Range for all Wells**	**Mean for all Wells**
		562	**563**	**564**	**565**	**606**	**607**	**608**	**611**	**612**		
Alkalinity, Total as CaCO3 (mg/L)	Range	183-570	228-402	220-220	180-180	280-896	490-490	372-424	182-223	90-280	90-896	321.27
	Mean	323.83	300.00	220.00	180.00	471.33	490.00	398.00	198.33	202.00		
Ammonia, Total as N (mg/L)	Range	1.2-8.6	10.6-142	0.35-0.87	3.65-8.55	52.5-181	43.5-135	4.8-150	1.1-3.1	0.427-22	0.35-181	44.45
	Mean	19.07	61.07	0.58	6.10	88.30	95.17	76.88	2.10	6.31		
Biochemical Oxygen Demand (mg/L)	Range	0.3-11.7	0.8-2.6	NA	5.1-5.1	0.3-0.5	0.7-0.7	2.4-4	4.2-4.2	0.7-0.7	0.3-11.7	2.65
	Mean	6.00	1.53	NA	5.10	0.40	0.70	3.20	4.20	0.70		
Chemical Oxygen Demand (mg/L)	Range	50-268	15-285	NA	37-37	42-106	40-40	25-94	10-50	12-88	10-285	80.00
	Mean	159.00	109.60	NA	37.00	72.67	40.00	59.50	30.00	50.00		
Denitrifying Bacteria (cfu/mL)	Range	10000-10000	200000-200000	NA	200000-200000	10000-200000	50000-50000	10000-10000	10000-10000	NA	10000-200000	79000.00
	Mean	10000.00	200000.00	NA	200000.00	77500.00	50000.00	10000.00	10000.00	NA		
Dissolved Organic Carbon (mg/L)	Range	11.4-11.4	9.3-10.4	NA	8.8-8.8	9-9	4.3-4.3	NA	10.3-10.3	8.3-8.3	4.3-11.4	8.975
	Mean	11.40	9.85	NA	8.80	9.00	4.30	NA	10.30	8.30		
Dissolved Oxygen (mg/L)	Range	0.79-7.12	1.82-7.09	4.01-8.81	2.9-7.94	3.2-8.51	4.02-5.25	2.64-5.88	0.78-7.65	2.92-8.4	0.78-8.81	4.66
	Mean	3.78	4.33	6.74	5.42	5.22	4.59	4.01	3.87	5.31		
Total Iron (mg/L)	Range	0.07-0.23	0.04-0.174	NA	0.03-0.03	0.0261-0.36	0.03-0.0558	0.0261-0.0261	0.16-0.405	0.08-0.25	0.0261-0.405	0.15
	Mean	0.15	0.14	NA	0.03	0.15	0.04	0.03	0.32	0.19		
Ferrous Iron (mg/L)	Range	NA	2.5-2.5	NA	0.2-0.2	NA	0.0347-8.6	NA	NA	NA	0.2-8.6	3.10
	Mean	NA	2.50	NA	0.20	NA	3.24	NA	NA	NA		
Iron-Related Bacteria (cfu/mL)	Range	9000-540000	25-540000	NA	9000-9000	2300-540000	35000-35000	2300-9000	9000-9000	2300-9000	25-540000	91096.25
	Mean	274500.00	146006.25	NA	9000.00	146575.00	35000.00	5650.00	9000.00	5650.00		
Total Manganese (mg/L)	Range	0.122-1.07	0.34-2.23	NA	0.313-0.332	0.0358-5.13	0.0089-0.125	0.0813-0.177	1.95-2.95	0.867-1.51	0.0089-5.13	0.93
	Mean	0.60	1.06	NA	0.32	1.36	0.08	0.13	2.45	1.19		
Manganous Manganese (mg/L)	Range	NA	0.5-0.8	NA	0.1-0.4	0.2-0.6	0.106-1.3	NA	NA	NA	0.1-1.3	0.50
	Mean	NA	0.67	NA	0.25	0.33	0.54	NA	NA	NA		
Nitrate as Nitrogen (mg/L)	Range	52.9-52.9	6.59-25.5	NA	0.283-0.283	0.077-17.2	0.0631-0.0905	0.0431-0.0431	0.0434-0.0434	0.0438-0.0438	0.0431-52.9	8.89
	Mean	52.90	19.03	NA	0.28	4.56	0.08	0.04	0.04	0.04		
Nitrifying Bacteria (cfu/mL)	Range	100000-100000	1000-10000	NA	NA	10000-100000	NA	1000-1000	NA	NA	1000-100000	31857.14
	Mean	100000.00	5500.00	NA	NA	55000.00	NA	1000.00	NA	NA		

Table 8−4 (continued). Biogeochemical Parameters at Riverbed Well Points in the Configuration 1 Area

Analyte		Well Points									Range for all Wells	Mean for all Wells
		562	563	564	565	606	607	608	611	612		
Nitrite as Nitrogen (mg/L)	Range	0.014-0.014	0.009-0.368	NA	0.005-0.023	0.008-4.15	0.007-0.007	0.043-0.043	NA	NA	0.005-4.15	0.42
	Mean	0.01	0.13	NA	0.01	1.39	0.01	0.04	NA	NA		
Oxidation Reduction Potential (mV)	Range	-50 to 42	-67 to 84	-44 to 86	-203 to 102	-105 to 100	-62 to 59	-95 to 13	-122 to 33	-138.5 to 7	-203 to 102	-10.19
	Mean	-8.41	18.50	16.90	-46.03	17.43	-1.33	-43.25	-43.20	-52.70		
Phosphorus (mg/L)	Range	NA	NA	NA	0.0214-0.0214	0.123-0.123	0.125-0.125	NA	NA	NA	0.0214-0.125	0.09
	Mean	NA	NA	NA	0.02	0.12	0.13	NA	NA	NA		
Sulfate (mg/L)	Range	220-4600	140-2430	230-270	192-366	346-5420	175-1200	240-1500	200-446	200-1200	140-5420	795.20
	Mean	952.50	917.80	243.33	248.50	1322.13	855.00	927.60	315.80	534.80		
Sulfate Reducing Bacteria (cfu/ml)	Range	5000-18000	1200-100000	NA	1200-700000	500-700000	5000-5000	500-500	1200-1200	200-200	200-700000	82200.00
	Mean	11500.00	20960.00	NA	239733.33	176675.00	5000.00	500.00	1200.00	200.00		
Sulfide (mg/L)	Range	NA	0.01-0.01	NA	0.01-0.02	0.01-0.01	0.01-0.01	NA	0.01-0.02	0.01-0.02	0.01-0.02	0.01
	Mean	NA	0.01	NA	0.02	0.01	0.01	NA	0.02	0.02		
Total Dissolved Solids (mg/L)	Range	590-10800	594-5870	650-780	607-726	941-10100	695-4010	1000-3900	590-1210	570-3000	570-10800	1906.65
	Mean	2263.50	2146.40	713.33	660.75	2652.63	2698.33	2540.00	796.60	1377.00		
Total Inorganic Carbon (mg/L)	Range	59.2-129	52.2-107	NA	110-110	93.4-93.8	22.2-99.2	95.5-95.5	63.8-63.8	73.8-73.8	22.2-129	83.76
	Mean	94.10	83.20	NA	110.00	93.60	60.70	95.50	63.80	73.80		
Total Kjeldahl Nitrogen (mg/L)	Range	122-122	14.3-96.3	NA	4.1-4.4	54.2-102	30.6-30.6	83.8-83.8	4.5-4.5	6.6-6.6	4.1-122	51.31
	Mean	122.00	67.83	NA	4.25	78.10	30.60	83.80	4.50	6.60		
Total Organic Carbon (mg/L)	Range	9.5-9.5	8.9-11.1	NA	NA	9.2-9.2	NA	8.5-8.5	9.3-9.3	NA	8.5-11.1	9.42
	Mean	9.50	10.00	NA	NA	9.20	NA	8.50	9.30	NA		
Uranium (mg/L)	Range	0.021-0.348	0.018-0.793	0.0056-0.0056	0.0189-0.0235	0.0187-1.12	0.223-0.537	0.00068-0.39	0.00014-0.017	0.0069-0.18	0.00014-1.12	0.22
	Mean	0.11	0.32	0.01	0.02	0.43	0.33	0.26	0.01	0.07		
Orthophosphate (mg/L)	Range	NA	0.4-2.1	NA	0.3-0.8	1.3-1.7	0.5-0.5	0.9-0.9	NA	NA	0.3-2.1	0.98
	Mean	NA	1.10	NA	0.55	1.50	0.50	0.90	NA	NA		
pH (standard units)	Range	7.05-7.62	7.86-8.56	7.66-8.36	7.42-10.23	8.41-9.64	7.85-9.37	8.31-9.34	7.38-10.66	7.44-7.73	7.05-10.66	8.30
	Mean	7.40	8.25	8.09	9.05	8.84	8.76	8.68	8.32	7.59		

NA = not applicable

As would be expected of hyporheic-zone water sampling, the results of all four BART™ methods (N-BART, DNB-BART, IRB-BART, and SRB-BART) applied to samples from Configuration 1 well points suggest that both autotrophic and heterotrophic microbes are active below and near the river side channel in this area. The combined presence of nitrifying bacteria (Table 8–4) and relatively low ammonia levels in the well points during the study period (NH3-N concentration averages about 44 mg/L) suggests that nitrification in the hyporheic zone is an active process. However, for reasons presented previously, it is also likely that some of the ammonia degradation apparent at Configuration 1 well points can be attributed to anammox.

8.3 Biogeochemical Indicators in the Configuration 2 Area

Measures of potential biogeochemical activity at Configuration 2 observation wells during 2006 and early 2007 (Table 8–5) were similar to those at Configuration 1 wells (Table 8–3). With the exception of TDS, the observed ranges of most pertinent dissolved constituents at Configuration 2 were close in value to equivalent ranges at Configuration 1 and all four types of bacteria identified with the BART™ methods were seen at Configuration 2 as well. However, despite the fact that Configuration 2 extraction wells are located closer to the Colorado River (approximately 50 ft west of the steep bank on the river's west edge) than Configuration 1 pumping wells (100 ft from the bank), less evidence was seen for the induced inflow of river and hyporheic zone water in Configuration 2 ground water. This was particularly true for ORP, as values of this parameter never decreased to the negative values that occurred in the Configuration 1 area. This was attributed the fact that pumping rates from Configuration 2 extraction wells during 2006 were significantly smaller than those achieved at Configuration 1. Consequently, though it was likely that ground water extraction was helping to reduce surface water concentrations of ammonia in the river side channel associated with Configuration 2, biodegradation in the area between the river and the extraction wells as enhanced by induced inflow was expected to be relatively minor.

Evidence for a variety of potential biodegradation processes are seen in the summary of biogeochemical parameters measured at Configuration 2 well points in 2006 and early 2007 (Table 8–6). All but one of the mean pH values at the well points is greater than 8, indicating that mixing of river water with ground water is significant. In addition, all bacterial types tested for are present and attenuation of ammonia concentrations in upgradient ground water (Table 8–5) appears to be occurring in the hyporheic zone underlying the river side channel in this area. However, the degree of attenuation appears to be somewhat less than that observed in equivalent locales at the Configuration 1 area. This latter observation could be another indicator that the lower pumping rates achieved at the Configuration 2 area during the study period had less effect on near- and sub-river chemistry. Nonetheless, it is likely that the constituent degradation mechanisms associated with heterotrophic activity were significant in the Configuration 2 hyporheic zone since negative ORP values as small as -180 mV were observed in at least two of the nine local well points.

Table 8–5. Biogeochemical Parameters at Observation Wells in the Configuration 2 Area

Analyte		Well						Range for all Wells	Mean for all Wells
		582	**585**	**587**	**588**	**589**	**602**		
Alkalinity, Total as CaCO3 (mg/L)	Range	170-760	200-950	340-778	190-903	360-880	184-640	170-950	486.26
	Mean	396.25	472.50	524.91	561.31	478.50	374.33		
Ammonia, Total as N (mg/L)	Range	14-230	3.7-370	13-260	15-890	630-1110	11.9-150	3.7-1110	352.86
	Mean	82.44	132.71	79.38	307.34	900.89	79.93		
Biochemical Oxygen Demand (mg/L)	Range	NA	NA	NA	0.79-2.5	1.3-1.3	0.44-0.44	0.44-2.5	1.26
	Mean	NA	NA	NA	1.65	1.30	0.44		
Chemical Oxygen Demand (mg/L)	Range	NA	NA	NA	30-176	1220-4400	25-141	25-4400	924.33
	Mean	NA	NA	NA	112.60	2153.33	57.50		
Denitrifying Bacteria (cfu/mL)	Range	NA	NA	NA	50000-50000	10000-50000	10000-50000	10000-50000	40000.00
	Mean	NA	NA	NA	50000.00	30000.00	36666.67		
Dissolved Organic Carbon (mg/L)	Range	NA	NA	NA	1.3-3.6	3.1-3.1	1.2-2.7	1.2-3.6	2.38
	Mean	NA	NA	NA	2.45	3.10	1.95		
Dissolved Oxygen (mg/L)	Range	1.28-3.43	0.72-2.92	1.07-3.51	0.68-5	0.45-4.5	0.64-6.4	0.45-6.4	2.06
	Mean	2.04	1.90	2.18	2.08	1.75	2.74		
Total Iron (mg/L)	Range	NA	NA	NA	0.0251-0.04	0.014-0.09	0.0198-0.04	0.014-0.09	0.04
	Mean	NA	NA	NA	0.03	0.06	0.03		
Ferrous Iron (mg/L)	Range	NA	NA	NA	0.2-0.2	0.4-0.4	NA	0.2-0.4	0.30
	Mean	NA	NA	NA	0.20	0.40	NA		
Iron-Related Bacteria (cfu/mL)	Range	NA	NA	NA	35000-140000	150-35000	35000-35000	150-140000	39161.11
	Mean	NA	NA	NA	70000.00	12483.33	35000.00		
Total Manganese (mg/L)	Range	4.2-4.2	4.5-4.5	2.9-2.9	0.838-5.1	5.35-9.44	0.107-4.11	0.107-9.44	4.34
	Mean	4.20	4.50	2.90	2.53	7.91	1.63		
Manganous Manganese (mg/L)	Range	NA	NA	NA	1-2.9	0.4-14	0.2-4.1	0.2-14	3.52
	Mean	NA	NA	NA	1.93	6.02	1.80		
Nitrate as Nitrogen (mg/L)	Range	NA	NA	NA	2.93-116	18.9-39.1	1.39-144	1.39-144	34.31
	Mean	NA	NA	NA	29.33	31.20	43.63		
Nitrifying Bacteria (cfu/mL)	Range	NA	NA	NA	1000-100000	NA	1000-100000	1000-100000	29285.71
	Mean	NA	NA	NA	20800.00	NA	50500.00		

Table 8−5 (continued). Biogeochemical Parameters at Observation Wells in the Configuration 2 Area

Analyte		**Well**						**Range for all Wells**	**Mean for all Wells**
		582	**585**	**587**	**588**	**589**	**602**		
Nitrite as Nitrogen (mg/L)	Range	NA	NA	NA	0.008-0.012	0.016-0.03	0.005-0.033	0.005-0.033	0.02
	Mean	NA	NA	NA	0.01	0.02	0.02		
Oxidation Reduction Potential (mV)	Range	8-224	106-219	93.7-226	51.1-251	21.9-222	44.2-223	8-251	145.86
	Mean	151.64	166.61	147.37	144.65	131.00	151.97		
Phosphorus (mg/L)	Range	NA	NA	NA	0.0329-0.0929	0.0478-0.411	0.0552-0.204	0.0329-0.411	0.10
	Mean	NA	NA	NA	0.06	0.13	0.11		
Sulfate (mg/L)	Range	470-5800	340-8300	880-6500	240-9500	7200-11000	354-4960	240-11000	4892.89
	Mean	2347.78	3891.25	3431.54	4989.44	8479.47	2040.57		
Sulfate Reducing Bacteria (cfu/mL)	Range	NA	NA	NA	100000-700000	500-500	18000-700000	500-700000	292062.50
	Mean	NA	NA	NA	500000.00	500.00	209000.00		
Sulfide (mg/L)	Range	NA	NA	NA	0.01-0.02	0.01-0.01	0.01-0.01	0.01-0.02	0.01
	Mean	NA	NA	NA	0.02	0.01	0.01		
Total Dissolved Solids (mg/L)	Range	1100-12000	870-15000	2000-14000	750-37000	35000-79000	767-10800	750-79000	24258.59
	Mean	4811.11	7571.25	7346.15	15527.06	67336.84	4021.00		
Total Inorganic Carbon (mg/L)	Range	NA	NA	NA	3.8-83.4	52-102	5.1-55.8	3.8-102	54.59
	Mean	NA	NA	NA	50.82	81.15	37.10		
Total Kjeldahl Nitrogen (mg/L)	Range	NA	NA	NA	52.4-90.9	771-1440	11-240	11-1440	429.77
	Mean	NA	NA	NA	67.74	963.71	108.53		
Total Organic Carbon (mg/L)	Range	NA	NA	NA	NA	3.4-3.4	1.5-1.5	1.5-3.4	2.45
	Mean	NA	NA	NA	NA	3.40	1.50		
Uranium (mg/L)	Range	0.13-2.4	0.083-3.1	0.31-2.7	0.029-2.7	1-2.8	0.156-2.33	0.029-3.1	1.39
	Mean	0.92	1.60	1.40	1.51	1.61	0.78		
Orthophosphate (mg/L)	Range	NA	NA	NA	0.6-1.5	0.5-0.5	0.3-1.8	0.3-1.8	0.89
	Mean	NA	NA	NA	1.10	0.50	0.83		
pH (standard units)	Range	6.86-7.67	6.68-7.59	6.71-7.11	6.74-8.2	6.49-6.89	6.76-8.42	6.49-8.42	6.95
	Mean	7.08	6.95	6.84	7.04	6.73	7.33		

NA = not applicable

Table 8–6. Biogeochemical Parameters at Riverbed Well Points in the Configuration 2 Area

Analyte		Well Point									Range for all Wells	Mean for all Wells
		590	**591**	**603**	**604**	**605**	**613**	**614**	**615**	**616**		
Alkalinity, Total as CaCO3 (mg/L)	Range	376-876	450-700	396-650	NA	422-484	NA	NA	220-310	216-306	216-876	468.33
	Mean	564.00	570.33	524.00	NA	455.33	NA	NA	250.67	256.00		
Ammonia, Total as N (mg/L)	Range	36-135	145-370	169-648	327-404	57.1-640	76-140	408-408	1.95-84	54-380	1.95-648	224.23
	Mean	83.60	229.89	431.44	365.50	220.75	108	408.00	25.77	151.97		
Biochemical Oxygen Demand (mg/L)	Range	0.1-0.1	2.2-5.6	1.2-7.92	0.13-0.7	2.9-2.9	NA	3.33-3.33	2.3-7.68	0.6-0.6	0.1-7.92	2.88
	Mean	0.10	3.83	4.23	0.42	2.90	NA	3.33	3.05	0.60		
Chemical Oxygen Demand (mg/L)	Range	33-33	29-133	62-767	NA	23-52	NA	NA	33-33	12-12	12-767	154.79
	Mean	33.00	96.00	326.00	NA	37.50	NA	NA	33.00	12.00		
Denitrifying Bacteria (cfu/mL)	Range	50000-50000	10000-50000	10000-50000	200000-200000	10000-10000	NA	NA	10000-10000	10000-10000	10000-200000	45833.33
	Mean	50000.00	36666.67	36666.67	200000.00	10000.00	NA	NA	10000.00	10000.00		
Dissolved Organic Carbon (mg/L)	Range	9.6-9.6	1.6-8.2	3-3	NA	NA	NA	NA	13.9-13.9	8.2-8.2	1.6-13.9	7.42
	Mean	9.60	4.90	3.00	NA	NA	NA	NA	13.90	8.20		
Dissolved Oxygen (mg/L)	Range	4.29-7.63	0.47-8	0.29-8.62	2.8-9.04	1.83-8.28	6.72-7.53	5.6-7.5	1.41-7.84	2.34-7.64	0.29-9.04	5.03
	Mean	5.94	4.29	4.19	5.83	4.22	7.125	6.42	5.17	5.36		
Total Iron (mg/L)	Range	0.03-0.03	0.0111-0.1	0.0195-0.0742	0.19-0.19	0.0393-0.04	NA	0.98-0.98	1.6-3.86	0.05-0.05	0.0111-3.86	0.51
	Mean	0.03	0.05	0.04	0.19	0.04	NA	0.98	2.54	0.05		
Ferrous Iron (mg/L)	Range	NA	0.3-0.3	0.4-32	0.3-0.3	NA	NA	NA	NA	NA	0.3-32	8.48
	Mean	NA	0.30	11.20	0.30	NA	NA	NA	NA	NA		
Iron-Related Bacteria (cfu/mL)	Range	35000-540000	2300-540000	150-9000	35000-35000	9000-9000	NA	NA	2300-9000	150-2300	150-540000	79512.50
	Mean	287500.00	153075.00	6050.00	35000.00	9000.00	NA	NA	5650.00	1225.00		
Total Manganese (mg/L)	Range	NA	0.272-0.624	0.633-3.87	0.385-0.385	0.0741-0.0741	NA	NA	1.41-1.74	0.314-0.324	0.0454-3.87	0.83
	Mean	NA	0.41	1.65	0.39	0.06	NA	NA	1.58	0.32		
Manganous Manganese (mg/L)	Range	NA	0.6-2.8	0.9-10	0.1-3	NA	NA	6.3-6.9	NA	NA	0.1-10	3.28
	Mean	NA	1.35	4.40	1.55	NA	NA	6.60	NA	NA		
Nitrate as Nitrogen (mg/L)	Range	NA	0.374-54.3	0.75-82.7	0.0527-83.1	0.217-0.228	NA	319-365	0.0358-0.0358	0.462-0.462	0.0358-365	51.52
	Mean	NA	25.89	31.53	27.74	0.22	NA	342.00	0.04	0.46		
Nitrifying Bacteria (cfu/mL)	Range	1000-1000	1000-100000	1000-100000	100000-100000	NA	NA	100000-100000	NA	NA	1000-100000	46000.00
	Mean	1000.00	38500.00	42400.00	100000.00	NA	NA	100000.00	NA	NA		

Table 8−6 (continued). Biogeochemical Parameters at Riverbed Well Points in the Configuration 2 Area

Analyte		**Well Point**									**Range for all Wells**	**Mean for all Wells**
		590	**591**	**603**	**604**	**605**	**613**	**614**	**615**	**616**		
Nitrite as Nitrogen (mg/L)	Range	0.021-0.09	0.029-1.64	0.043-1.675	0.66-0.66	0.03-0.03	NA	3.05-3.05	NA	0.015-0.015	0.015-3.05	0.55
	Mean	0.06	0.55	0.46	0.66	0.03	NA	3.05	NA	0.02		
Oxidation Reduction Potential (mV)	Range	-66.1 to 166	-180 to 189	1.48-243	43-138.7	-75 to 12	12.5-108.4	2-251.2	-108 to 66.3	-191 to 26	-191 to 251.2	56.72
	Mean	79.82	61.86	118.91	79.68	-32.00	60.45	117.55	-24.07	-50.80		
Phosphorus (mg/L)	Range	NA	0.0412-0.06	0.0286-0.0782	NA	NA	NA	NA	NA	NA	0.0286-0.0782	0.05
	Mean	NA	0.05	0.05	NA	NA	NA	NA	NA	NA		
Sulfate (mg/L)	Range	740-2090	1140-4580	1770-7200	3560-4300	320-9300	1900-1900	7540-7580	240-1600	170-4200	170-9300	2774.89
	Mean	1556.00	2356.67	4832.22	4023.33	3001.67	1900	7560.00	599.00	1207.67		
Sulfate Reducing Bacteria (cfu/mL)	Range	100000-100000	200-700000	1200-700000	18000-18000	5000-700000	4100-4100	NA	500-700000	500-1200	200-700000	195711.76
	Mean	100000.00	180140.00	267066.67	18000.00	352500.00	4100	NA	350250.00	850.00		
Sulfide (mg/L)	Range	0.01-0.01	0.01-0.02	0.01-0.01	0.01-0.01	0.01-0.01	NA	NA	0.01-0.01	6-6	0.01-6	0.61
	Mean	0.01	0.02	0.01	0.01	0.01	NA	NA	0.01	6.00		
Total Dissolved Solids (mg/L)	Range	1700-4000	2020-7970	2970-16300	8070-9320	796-17000	NA	16200-24900	690-3500	430-8200	430-24900	5275.65
	Mean	3048.00	4033.33	8168.89	8695.00	5331.00	NA	20550.00	1438.50	2402.17		
Total Inorganic Carbon (mg/L)	Range	117-117	54.2-145	23.5-97.5	NA	97.7-114	NA	NA	64-70	54.6-58.9	23.5-145	82.76
	Mean	117.00	102.80	67.34	NA	105.85	NA	NA	67.00	54.60		
Total Kjeldahl Nitrogen (mg/L)	Range	128-128	217-247	169-640	NA	86-86	NA	NA	53.8-53.8	18.3-18.3	18.3-640	245.01
	Mean	128.00	234.00	426.75	NA	86.00	NA	NA	53.80	18.30		
Total Organic Carbon (mg/L)	Range	10.1-10.1	2.8-8.5	4-7.9	NA	8.8-8.8	NA	NA	10.2-10.2	NA	2.8-10.2	7.47
	Mean	10.10	5.65	5.95	NA	8.80	NA	NA	10.20	NA		
Uranium (mg/L)	Range	0.001-0.705	0.0331-0.94	0.0292-1.37	1.09-1.09	0.2-1.2	NA	NA	0.009-0.41	0.042-0.273	0.001-1.37	0.49
	Mean	0.42	0.52	0.89	1.09	0.49	NA	NA	0.12	0.11		
Orthophosphate (mg/L)	Range	0.4-1.7	0.4-1.7	0.4-0.7	NA	0.7-0.7	NA	0.4-0.4	NA	NA	0.4-1.7	0.78
	Mean	1.05	0.93	0.57	NA	0.70	NA	0.40	NA	NA		
pH (standard units)	Range	7.32-9.08	7.56-9.1	7.2-9.09	8.22-9.33	7.96-9.19	8.63-9.14	7.2-10.31	7.39-8.75	8.52-9.69	7.2-10.31	8.53
	Mean	8.18	8.67	8.39	8.99	8.69	8.885	8.32	7.84	9.17		

NA = not applicable

8.4 Biogeochemical Indicators in the Configuration 3 Area

Monitored biogeochemical parameters at Configuration 3 wells during the study period were expected to similar to those at wells in the Baseline Area because neither area has a river side channel and, as a consequence, river-aquifer water exchange during most of each year tends to occur at the river's main channel, located about 150 ft or more from the steep bank forming the river's west edge. Though such similarity was typically observed, a few observations at shallow wells 0681 and 0686 (Table 8–7) did show signs that ground water extraction from Configuration 3 wells had managed to induce a significant amount of inflow from the river which subsequently reduced some constituent concentrations below ambient levels. For example, ammonia and alkalinity levels at these two wells were considerably less than those measured at the remaining Configuration 3 wells. In addition, negative ORP values were observed at well 0681 in 2006, which provided at least some indication that hyporheic zone water was being drawn toward the Configuration 3 extraction system. As with observation wells at the Baseline Area and Configurations 1 and 2, BART™ results in all Configuration 3 wells where these tests were performed (Table 8–7) showed the presence of nitrifying, denitrifying, iron-related, and sulfate-reducing bacteria.

Data collected at well points in the Configuration 3 area during the study period (Table 8–8) also showed evidence of both autotrophic and heterotrophic activity. NH3-N concentrations at the well points were noticeably decreased in comparison to equivalent concentrations at Configuration 3 wells (Table 8–7), which could have been enhanced by either nitrification or anammox, or both. The occurrence of negative ORP values of -100 mV or less at three well points (0695, 0697, and 0698) suggested that sulfate-reducing conditions were present in sub-riverbed ground water. The average pH for all riverbed well points was 8.07, which further indicated that the pumping of Configuration 3 extraction wells was inducing inflow of river water to local ground water.

8.5 Biogeochemical Indicators in the Configuration 4 Area

Potential biogeochemical activity in ground water in the vicinity of Configuration 4 extraction wells is assessed by examining water chemistry at observation wells located both upgradient and downgradient of the system's extraction wells. The data involved are from sampling events that extend as far back as August 30, 2006, just a day before continuous low-flow pumping was started at the newly installed extraction wells, to mid-February 2007, about 2 months after all extraction wells had been shut down for the winter season. Given the relatively short sampling time span of about 5.5 months and the fact that step-drawdown tests were conducted on several of the extraction wells in late September 2006, it is difficult to say whether the chemical data from Configuration 4 observation wells reflect any distinct trends, possibly as a result of ground water pumping, or are mostly just representative of ambient conditions. Nevertheless, a few items are worth mentioning because of the potential implications they may have for local biogeochemical processes.

Table 8–7. Biogeochemical Parameters at Observation Wells in the Configuration 3 Area

Analyte		**Well**						**Range for all Wells**	**Mean for all Wells**
		404	**681**	**686**	**687**	**688**	**689**		
Alkalinity, Total as CaCO3 (mg/L)	Range	610-976	414-800	322-816	520-924	600-1006	107-1060	107-1060	717.29
	Mean	825.73	573.33	533.88	774.18	880.14	558.09		
Ammonia, Total as N (mg/L)	Range	190-410	0.67-130	0.13-164	323-580	360-960	130-940	0.13-960	405.07
	Mean	344.17	44.42	49.32	429.92	681.54	546.15		
Biochemical Oxygen Demand (mg/L)	Range	NA	NA	0.1-2	0.45-1.68	NA	NA	0.45-2	1.30
	Mean	NA	NA	1.11	1.07	NA	NA		
Chemical Oxygen Demand (mg/L)	Range	NA	NA	34-759	383-998	NA	NA	34-998	406.00
	Mean	NA	NA	299.63	576.20	NA	NA		
Denitrifying Bacteria (cfu/mL)	Range	NA	NA	10000-200000	50000-50000	NA	NA	10000-200000	68333.33
	Mean	NA	NA	86666.67	50000.00	NA	NA		
Dissolved Organic Carbon (mg/L)	Range	NA	NA	24.8-33.8	6.2-13.4	NA	NA	6.2-33.8	22.88
	Mean	NA	NA	29.43	9.80	NA	NA		
Dissolved Oxygen (mg/L)	Range	0.59-2.65	0.99-3.22	0.6-6.7	0.77-5	0.78-2.73	0.63-7.06	0.59-7.06	1.93
	Mean	1.71	1.88	2.96	2.05	1.54	1.60		
Total Iron (mg/L)	Range	NA	NA	0.0254-0.08	0.03-0.06	NA	NA	0.0254-0.08	0.05
	Mean	NA	NA	0.05	0.05	NA	NA		
Ferrous Iron (mg/L)	Range	NA	NA	0.2-0.2	0.3-0.3	NA	NA	0.2-0.3	0.23
	Mean	NA	NA	0.20	0.30	NA	NA		
Iron-Related Bacteria (cfu/mL)	Range	NA	NA	9000-140000	35000-35000	NA	NA	9000-140000	48166.67
	Mean	NA	NA	61333.33	35000.00	NA	NA		
Total Manganese (mg/L)	Range	5-5	1.8-1.8	0.228-3.64	4.9-7.4	4.2-4.2	5.7-5.7	0.228-7.4	3.76
	Mean	5.00	1.80	2.34	5.78	4.20	5.70		
Manganous Manganese (mg/L)	Range	NA	NA	1.2-12	0.2-8.5	NA	NA	0.2-12	4.23
	Mean	NA	NA	3.85	4.98	NA	NA		
Nitrate as Nitrogen (mg/L)	Range	NA	NA	37.1-529	115-341	NA	NA	37.1-529	246.92
	Mean	NA	NA	269.24	211.20	NA	NA		
Nitrifying Bacteria (cfu/mL)	Range	NA	NA	10000-100000	1000-10000	NA	NA	1000-100000	41500.00
	Mean	NA	NA	64000.00	4000.00	NA	NA		
Nitrite as Nitrogen (mg/L)	Range	NA	NA	0.007-0.378	0.007-0.054	NA	NA	0.007-0.378	0.09
	Mean	NA	NA	0.15	0.02	NA	NA		

Table 8−7 (continued). Biogeochemical Parameters at Observation Wells in the Configuration 3 Area

Analyte		**Well**						**Range for all Wells**	**Mean for all Wells**
		404	**681**	**686**	**687**	**688**	**689**		
Oxidation Reduction Potential (mV)	Range	92.1-242	-64.1 to 197	35-295.3	105.4-250	64-284	54.3-272	-64.1 to 295.3	156.76
	Mean	148.72	102.30	175.25	196.72	150.89	147.36		
Phosphorus (mg/L)	Range	NA	NA	0.0478-0.0901	0.0354-0.308	NA	NA	0.0354-0.308	0.11
	Mean	NA	NA	0.07	0.15	NA	NA		
Sulfate (mg/L)	Range	6200-9900	1500-5800	2300-10900	8900-11000	8800-13000	5100-14000	1500-14000	8594.84
	Mean	8733.33	3700.00	6062.73	9398.33	10630.77	8961.54		
Sulfate Reducing Bacteria (cfu/mL)	Range	NA	NA	1200-700000	200-700000	NA	NA	200-700000	248733.33
	Mean	NA	NA	284080.00	204550.00	NA	NA		
Sulfide (mg/L)	Range	NA	NA	0.01-0.02	0.01-0.04	NA	NA	0.01-0.04	0.02
	Mean	NA	NA	0.02	0.02	NA	NA		
Total Dissolved Solids (mg/L)	Range	12000-17000	2900-13000	5260-25800	12000-23000	16000-46000	19000-94000	2900-94000	26364.22
	Mean	16166.67	7733.33	12310.00	17725.00	24923.08	61384.62		
Total Inorganic Carbon (mg/L)	Range	NA	NA	40-158	61.6-162	NA	NA	40-162	103.32
	Mean	NA	NA	90.19	124.32	NA	NA		
Total Kjeldahl Nitrogen (mg/L)	Range	NA	NA	1.1-66	215-344	NA	NA	1.1-344	114.89
	Mean	NA	NA	28.09	197.29	NA	NA		
Total Organic Carbon (mg/L)	Range	NA	NA	NA	50.7-50.7	NA	NA	50.7-50.7	50.70
	Mean	NA	NA	NA	182.63	NA	NA		
Uranium (mg/L)	Range	2.1-3.3	0.39-2.7	0.86-5.2	1.9-3.5	2.2-3.4	0.34-3.5	0.34-5.2	2.54
	Mean	2.68	1.43	2.83	2.72	2.97	1.75		
Orthophosphate (mg/L)	Range	NA	NA	0.5-2.2	0.9-3.2	NA	NA	0.5-3.2	1.60
	Mean	NA	NA	1.38	2.05	NA	NA		
pH (standard units)	Range	6.69-6.84	6.72-6.97	6.13-6.91	6.58-6.83	6.59-6.93	6.53-6.95	6.13-6.97	6.75
	Mean	6.76	6.84	6.65	6.71	6.76	6.77		

NA = not applicable

Table 8–8. Biogeochemical Parameters at Riverbed Well Points in the Configuration 3 Area

Analyte		Well Point									Range for all Wells	Mean for all Wells
		690	691	692	693	694	695	696	697	698		
Alkalinity, Total as CaCO3 (mg/L)	Range	876-916	565-806	620-850	540-580	246-580	470-900	214-398	326-448	NA	214-916	602.85
	Mean	896.00	683.17	710.00	564.00	451.33	680.00	325.33	387.00	NA		
Ammonia, Total as N (mg/L)	Range	0.501-0.72	98-229	240-400	52.4-330	83.7-112	343-641	16-45.1	58-400	250-568	0.501-641	223.95
	Mean	0.61	168.67	325.82	113.46	97.83	454.80	28.45	193.40	442.67		
Biochemical Oxygen Demand (mg/L)	Range	4.3-4.3	1.4-3.67	2.33-2.33	5.9-5.9	4.4-4.4	0.45-1.7	0.4-0.4	0.6-0.6	NA	0.4-5.9	2.32
	Mean	4.30	2.54	2.33	5.90	4.40	1.08	0.40	0.60	NA		
Chemical Oxygen Demand (mg/L)	Range	87-87	54-250	150-292	57-73	30-66	215-491	41-41	17-96	NA	17-491	158.55
	Mean	87.00	153.25	201.80	65.00	50.00	336.25	41.00	56.50	NA		
Denitrifying Bacteria (cfu/mL)	Range	50000-50000	50000-200000	10000-1000000	10000-10000	10000-200000	10000-200000	10000-50000	50000-50000	NA	10000-1000000	121052.63
	Mean	50000.00	100000.00	403333.33	10000.00	86666.67	77500.00	30000.00	50000.00	NA		
Dissolved Organic Carbon (mg/L)	Range	26.6-26.6	11.6-31.2	8.2-8.6	13.3-13.3	NA	8.5-8.5	8.6-8.6	NA	NA	8.2-31.2	14.58
	Mean	26.60	21.40	8.40	13.30	NA	8.50	8.60	NA	NA		
Dissolved Oxygen (mg/L)	Range	3.66-6.85	2.93-9.71	3.2-7.96	1.13-9.12	1.27-6.41	1.57-9.1	1.05-6.34	1.1-6.23	3.14-4.86	1.05-9.71	4.69
	Mean	5.27	5.48	5.14	5.95	3.84	3.61	3.28	3.91	3.80		
Total Iron (mg/L)	Range	0.101-0.12	0.03-0.05	0.03-0.08	0.0285-0.753	0.1-0.14	0.05-0.478	0.05-1.39	0.03-0.07	NA	0.0285-0.753	0.14
	Mean	0.11	0.05	0.05	0.34	0.11	0.25	0.44	0.05	NA		
Ferrous Iron (mg/L)	Range	NA	0.4-0.4	NA	NA	NA	NA	NA	NA	NA	0.4-0.4	0.40
	Mean	NA	0.40	NA	NA	NA	NA	NA	NA	NA		
Iron-Related Bacteria (cfu/mL)	Range	35000-35000	9000-140000	9000-140000	9000-35000	2300-35000	2300-35000	2300-2300	150-2300	NA	150-140000	34332.50
	Mean	35000.00	81000.00	61333.33	22000.00	15433.33	15433.33	2300.00	1225.00	NA		
Total Manganese (mg/L)	Range	2.37-2.37	0.895-2.83	3-5.14	4.07-5.92	0.288-0.596	1.7-4.78	1.77-1.88	0.146-0.787	NA	0.146-5.92	2.60
	Mean	2.37	2.22	3.61	5.00	0.44	3.24	1.83	0.47	NA		
Manganous Manganese (mg/L)	Range	NA	0.1-3.9	2.8-9.4	NA	0.2-0.9	4.3-8.1	NA	NA	NA	0.1-9.4	3.24
	Mean	NA	1.73	4.95	NA	0.47	5.73	NA	NA	NA		
Nitrate as Nitrogen (mg/L)	Range	8.64-8.64	0.616-389	0.977-185	14.4-14.4	0.0578-120	67.8-171	0.0725-1.88	0.433-33	NA	0.0578-389	82.06
	Mean	8.64	145.32	103.05	14.40	27.73	113.92	1.08	16.72	NA		

Table 8–8 (continued). Biogeochemical Parameters at Riverbed Well Points in the Configuration 3 Area

Analyte		Well Point									Range for all Wells	Mean for all Wells
		690	691	692	693	694	695	696	697	698		
Nitrifying Bacteria (cfu/mL)	Range	NA	1000-100000	100000-100000	1000-1000	1000-100000	1000-100000	NA	100000-100000	NA	1000-100000	67500.00
	Mean	NA	52000.00	100000.00	1000.00	50500.00	80200.00	NA	100000.00	NA		
Nitrite as Nitrogen (mg/L)	Range	0.055-0.055	0.027-0.454	0.009-5.2	0.01-0.01	0.008-0.049	0.056-2.32	0.006-0.006	0.349-0.349	NA	0.006-5.2	0.80
	Mean	0.06	0.18	2.38	0.01	0.02	0.87	0.01	0.35	NA		
Oxidation Reduction Potential (mV)	Range	70-178	83-221	66-181	-75 to 129	-83 to 87	-205 to 100.4	-11 to 177	-109 to 221	-103 to 165	-205 to 221	82.72
	Mean	128.08	156.90	132.02	30.50	10.20	-16.72	77.94	65.00	37.00		
Phosphorous (mg/L)	Range	NA	0.0312-0.0355	NA	NA	NA	NA	NA	NA	NA	0.0312-0.0355	0.03
	Mean	NA	0.03	NA	NA	NA	NA	NA	NA	NA		
Sulfate (mg/L)	Range	5180-7300	3200-9330	4500-9580	1200-8300	956-2900	4220-9530	200-938	374-6200	2400-2400	200-9580	4704.94
	Mean	6240.00	4953.00	6912.31	3430.00	1531.50	8058.00	568.00	2086.80	2400.00		
Sulfate Reducing Bacteria (cfu/mL)	Range	700000-700000	100000-700000	500-700000	100000-100000	500-700000	1200-100000	5000-100000	1200-100000	NA	500-700000	203028.57
	Mean	700000.00	500000.00	239500.00	100000.00	233900.00	47440.00	52500.00	50600.00	NA		
Sulfide (mg/L)	Range	0.01-0.01	0.01-0.03	0.02-0.02	NA	0.02-0.02	0.01-0.01	0.01-0.01	NA	NA	0.01-0.03	0.02
	Mean	0.01	0.02	0.02	NA	0.02	0.01	0.01	NA	NA		
Total Dissolved Solids (mg/L)	Range	10900-14000	4930-20500	8400-16900	2800-17000	2100-4360	8740-30400	510-8700	802-11000	4600-4600	510-30400	8801.88
	Mean	12450.00	10024.00	11633.33	6826.00	2920.00	16418.00	2744.00	4066.40	4600.00		
Total Inorganic Carbon (mg/L)	Range	196-196	59.5-140	85.4-151	75.1-132	100-130	88.6-175	86.9-102	84.7-112	NA	59.5-196	115.68
	Mean	196.00	96.83	121.20	103.55	118.00	131.15	94.45	98.35	NA		
Total Kjeldahl Nitrogen (mg/L)	Range	2.6-2.6	83.7-324	233-272	48.5-48.5	33.3-90.5	297-503	42.1-42.1	221-221	NA	2.6-503	197.71
	Mean	2.60	204.90	243.67	48.50	61.90	394.00	42.10	221.00	NA		
Total Organic Carbon (mg/L)	Range	27.1-27.1	11.1-11.1	9.7-10.1	14.6-14.6	10.1-10.1	9.6-9.6	10.9-10.9	8.5-8.5	NA	8.5-27.1	12.41
	Mean	27.10	11.10	9.90	14.60	10.10	9.60	10.90	8.50	NA		
Uranium (mg/L)	Range	2.06-2.8	0.966-2.3	0.83-2.03	0.49-2.4	0.537-0.558	0.987-2.74	0.038-0.318	0.042-2.4	0.0012-0.0012	0.0012-2.8	1.26
	Mean	2.43	1.59	1.44	1.25	0.55	1.53	0.18	0.83	0.001		
Orthophosphate (mg/L)	Range	2.6-2.6	0.3-0.5	NA	0.5-0.5	0.9-0.9	0.6-1.6	0.6-0.6	0.6-0.6	NA	0.3-2.6	0.84
	Mean	2.60	0.43	NA	0.50	0.90	1.10	0.60	0.60	NA		
pH (standard units)	Range	7.46-8.24	7.11-8.65	7.3-8.55	6.78-8.2	8.29-8.92	7.18-8.44	7.62-9.34	7.69-9.28	8.14-9.92	6.78-9.92	8.07
	Mean	7.80	7.71	7.85	7.53	8.55	7.89	8.32	8.60	9.15		

NA = not applicable

Table 8–8 (continued). Biogeochemical Parameters at Riverbed Well Points in the Configuration 3 Area

Nitrifying Bacteria (cfu/mL)	Range	NA	1000-100000	100000-100000	1000-1000	1000-100000	1000-100000	NA	100000-100000	NA	1000-100000	67500.00
	Mean	NA	52000.00	100000.00	1000.00	50500.00	80200.00	NA	100000.00	NA		
Nitrite as Nitrogen (mg/L)	Range	0.055-0.055	0.027-0.454	0.009-5.2	0.01-0.01	0.008-0.049	0.056-2.32	0.006-0.006	0.349-0.349	NA	0.006-5.2	0.80
	Mean	0.06	0.18	2.38	0.01	0.02	0.87	0.01	0.35	NA		
Oxidation Reduction Potential (mV)	Range	70-178	83-221	66-181	-75 to 129	-83 to 87	-205 to 100.4	-11 to 177	-109 to 221	-103 to 165	-205 to 221	82.72
	Mean	128.08	156.90	132.02	30.50	10.20	-16.72	77.94	65.00	37.00		
Phosphorous (mg/L)	Range	NA	0.0312-0.0355	NA	NA	NA	NA	NA	NA	NA	0.0312-0.0355	0.03
	Mean	NA	0.03	NA	NA	NA	NA	NA	NA	NA		
Sulfate (mg/L)	Range	5180-7300	3200-9330	4500-9580	1200-8300	956-2900	4220-9530	200-938	374-6200	2400-2400	200-9580	4704.94
	Mean	6240.00	4953.00	6912.31	3430.00	1531.50	8058.00	568.00	2086.80	2400.00		
Sulfate Reducing Bacteria (cfu/mL)	Range	700000-700000	100000-700000	500-700000	100000-100000	500-700000	1200-100000	5000-100000	1200-100000	NA	500-700000	203028.57
	Mean	700000.00	500000.00	239500.00	100000.00	233900.00	47440.00	52500.00	50600.00	NA		
Sulfide (mg/L)	Range	0.01-0.01	0.01-0.03	0.02-0.02	NA	0.02-0.02	0.01-0.01	0.01-0.01	NA	NA	0.01-0.03	0.02
	Mean	0.01	0.02	0.02	NA	0.02	0.01	0.01	NA	NA		
Total Dissolved Solids (mg/L)	Range	10900-14000	4930-20500	8400-16900	2800-17000	2100-4360	8740-30400	510-8700	802-11000	4600-4600	510-30400	8801.88
	Mean	12450.00	10024.00	11633.33	6826.00	2920.00	16418.00	2744.00	4066.40	4600.00		
Total Inorganic Carbon (mg/L)	Range	196-196	59.5-140	85.4-151	75.1-132	100-130	88.6-175	86.9-102	84.7-112	NA	59.5-196	115.68
	Mean	196.00	96.83	121.20	103.55	118.00	131.15	94.45	98.35	NA		
Total Kjeldahl Nitrogen (mg/L)	Range	2.6-2.6	83.7-324	233-272	48.5-48.5	33.3-90.5	297-503	42.1-42.1	221-221	NA	2.6-503	197.71
	Mean	2.60	204.90	243.67	48.50	61.90	394.00	42.10	221.00	NA		
Total Organic Carbon (mg/L)	Range	27.1-27.1	11.1-11.1	9.7-10.1	14.6-14.6	10.1-10.1	9.6-9.6	10.9-10.9	8.5-8.5	NA	8.5-27.1	12.41
	Mean	27.10	11.10	9.90	14.60	10.10	9.60	10.90	8.50	NA		
Uranium (mg/L)	Range	2.06-2.8	0.966-2.3	0.83-2.03	0.49-2.4	0.537-0.558	0.987-2.74	0.038-0.318	0.042-2.4	0.0012-0.0012	0.0012-2.8	1.26
	Mean	2.43	1.59	1.44	1.25	0.55	1.53	0.18	0.83	0.001		
Orthophosphate (mg/L)	Range	2.6-2.6	0.3-0.5	NA	0.5-0.5	0.9-0.9	0.6-1.6	0.6-0.6	0.6-0.6	NA	0.3-2.6	0.84
	Mean	2.60	0.43	NA	0.50	0.90	1.10	0.60	0.60	NA		
pH (standard units)	Range	7.46-8.24	7.11-8.65	7.3-8.55	6.78-8.2	8.29-8.92	7.18-8.44	7.62-9.34	7.69-9.28	8.14-9.92	6.78-9.92	8.07
	Mean	7.80	7.71	7.85	7.53	8.55	7.89	8.32	8.60	9.15		
NA = not applicable												

A summary of the biogeochemical indicator data from Configuration 4 wells (Table 8–9) indicates that, as in the case of all other areas of the Ground Water IA, anaerobic conditions dominate non-hyporheic ground water and the water tends to be chemically oxidizing. Most pH values fall below 7, which is also typical of site ground water. Though no tests were performed to detect denitrifying, iron-related, nitrifying, or sulfate-reducing bacteria, there is no reason to doubt that all four types of microbes are likely to be present since the available biogeochemical data for the observation wells are quite similar to those reported for equivalent sampling locations at the Baseline Area and Configurations 1, 2 and 3. It should be noted, however, that heterotrophic activity might be less in Configuration 4 ground water than at the other areas because Configuration 4 is not affected by an upgradient vegetation test plot, which, if it were present, could be a source of organic carbon associated with recharge of diverted river water for irrigation.

Of the observation wells located downgradient of the Configuration 4 extraction system (0784, 0785, 0786, and 0787), the chemistry at wells 0784 and 0785 does show signs that pumping at extraction wells caused inflow of river water during fall 2006. TDS levels at each of these shallow wells approached low values near 1,000 mg/L in November 2006, which were well below ambient TDS concentrations for local shallow ground water of about 17,000 to 20,000 mg/L and more in line with concentrations in the river. In addition, ammonia (NH3-N) concentrations in wells 0784 and 0785 decreased to below 50 mg/L during November 2006, again indicating influx of river water. Such apparent declines in ammonia level in response to extraction well pumping should not be confused with additional relatively low values of ammonia concentration in deep wells 0782 (upgradient) and 0787 (downgradient), which probably reflective of decreasing ammonia concentrations below the ambient brine surface elevation.

Biogeochemical parameters for hyporheic-zone ground water at Configuration 4, as indicated by monitored analytes at riverbed well points (Table 8–10), are very similar to those seen at the other three Ground Water IA configurations and the Baseline Area. The pH levels in these well points range from about 7 to 9.3, and average about 8, which are indicative of river water influx. The presence of river water in the local subsurface is also manifested in the form of slightly higher DO levels (as high as 5 mg/L, Table 8–10) than those observed in hydraulically upgradient observation wells. Perhaps the most significant sign of river influence on hyporheic zone biogeochemistry is seen in the noticeably low ORP values observed at Configuration 4 wells points. This parameter is universally negative in all of the well points, has an average of approximately – 115 mV during fall 2006 and early 2007, and reaches a minimum of -260 mV. Such low values are clearly representative of chemically reducing conditions in sub-riverbed sediments, which in turn indicates significant heterotrophic microbial activity.

Noticeably low concentrations of NH3-N are observed at Configuration 4 well points 0790, 0791, and 0793 (Table 8–10) during the 5.5-month sampling time span for this area. Though these low levels might be simply attributable to pumping of Configuration 4 wells in fall 2006 and concomitant induced inflow of river water from the river side channel in the area, it is also possible that some of the ammonia attenuation could be caused by autotrophic ammonia oxidation via anammox. Similarly, generally lower concentrations of uranium at riverbed well points (Table 8–10) than observed at Configuration 4 wells (Table 8–9) could be indicative of sulfate-reducing bacteria creating chemically reducing conditions sufficient for uranium precipitation (Section 3.4.3). Application of the SRB-BART™ method to Configuration 4 well points during a few sampling events in late 2006 and early 2007 did indicate the presence of sulfate-reducing bacteria. In addition, denitrifying and iron-related bacteria were also detected at these times. Of some interest is the fact that nitrifying bacteria, though tested for, were not detected at the well points (Table 8–10). Further analytical work would help to determine why nitrifiers tend not to be active in the Configuration 4 hyporheic zone despite evidence from Configurations 1, 2 and 3 and the Baseline Area that they are generally present.

Table 8–9. Biogeochemical Parameters at Observation Wells in the Configuration 4 Area

Analyte		**Well**							**Range for all Wells**	**Mean for all Wells**
		780	**781**	**782**	**784**	**785**	**786**	**787**		
Alkalinity, Total as CaCO3 (mg/L)	Range	826-1010	215-480	300-910	226-1042	218-706	628-960	212-376	212-1042	562.28
	Mean	937.71	292.71	440.86	758.00	424.00	822.33	291.67		
Ammonia, Total as N (mg/L)	Range	530-760	60-420	220-750	44-390	19-360	410-760	57-190	19-760	341.81
	Mean	641.43	114.63	391.43	271.33	217.25	601.43	94.00		
Dissolved Oxygen (mg/L)	Range	1.17-2.03	0.58-1.26	0.78-2.71	1.81-2.86	0.91-1.76	0.85-2.23	0.83-2.26	0.58-2.86	1.50
	Mean	1.64	0.94	1.50	2.18	1.43	1.69	1.45		
Total Manganese (mg/L)	Range	6.3-6.3	6.1-6.1	8.3-8.3	8.2-8.2	5.2-6.4	6.6-6.6	5.9-5.9	5.2-8.3	6.63
	Mean	6.30	6.10	8.30	8.20	5.80	6.60	2.13		
Oxidation Reduction Potential (mV)	Range	95-214	138-217.4	94.1-185	104-200	-4-112	108-216	112-212	-4-217.4	144.89
	Mean	156.43	173.06	141.30	150.00	41.33	138.86	157.00		
Sulfate (mg/L)	Range	9900-13000	5600-9400	7100-10000	560-12000	470-7700	5400-12000	4800-6800	470-13000	7891.40
	Mean	10985.71	6725.00	8528.57	7853.33	4492.50	9471.43	5871.43		
Total Dissolved Solids (mg/L)	Range	20000-23000	74000-90000	26000-86000	1100-23000	950-16000	17000-35000	77000-89000	950-90000	50533.72
	Mean	21571.43	85625.00	72000.00	15366.67	9712.50	22428.57	84428.57		
Uranium (mg/L)	Range	2.9-3.5	0.2-1.3	0.54-2.9	0.28-3.7	0.059-3.2	1.6-3.2	0.14-0.72	0.059-3.7	1.55
	Mean	3.17	0.42	1.07	2.39	1.56	2.61	0.28		
pH (standard units)	Range	6.72-7.03	6.64-6.99	6.69-6.95	6.67-8	6.89-7.38	6.66-7.05	6.73-6.97	6.64-8	6.86
	Mean	6.82	6.78	6.77	7.16	7.18	6.85	6.80		

Table 8–10. Biogeochemical Parameters at Riverbed Well Points in the Configuration 4 Area

Analyte		Well Points						Range for all Wells	Mean for all Wells
		790	**791**	**792**	**793**	**794**	**795**		
Alkalinity, Total as CaCO3 (mg/L)	Range	178-328	190-880	365-900	168-188	NA	NA	168-900	429.94
	Mean	236.50	457.60	706.60	180.67	NA	NA		
Ammonia, Total as N (mg/L)	Range	2.88-57	5.78-620	195-760	0.21-0.29	NA	638-638	0.21-760	285.13
	Mean	28.42	314.70	567.20	0.25	NA	638		
Biochemical Oxygen Demand (mg/L)	Range	4.7-4.7	NA	1.1-1.1	0.5-0.5	NA	NA	0.5-4.7	2.10
	Mean	4.70	NA	1.10	0.50	NA	NA		
Chemical Oxygen Demand (mg/L)	Range	87-87	34-1090	639-921	26-28	NA	NA	26-1090	403.57
	Mean	87.00	562.00	780.00	27.00	NA	NA		
Denitrifying Bacteria (cfu/mL)	Range	10000-50000	10000-50000	10000-10000	10000-10000	NA	NA	10000-50000	23333.33
	Mean	30000.00	30000.00	10000.00	10000.00	NA	NA		
Dissolved Organic Carbon (mg/L)	Range	9.6-9.6	9.5-9.5	8.6-8.6	NA	NA	NA	8.6-9.6	9.23
	Mean	9.60	9.50	8.60	NA	NA	NA		
Dissolved Oxygen (mg/L)	Range	1.61-4.9	0.93-5.12	2.79-4.86	1.82-2.46	4.05-4.05	5.13-5.13	0.93-5.13	3.12
	Mean	2.51	2.98	3.72	2.19	4.05	5.13		
Total Iron (mg/L)	Range	0.08-0.132	0.0388-0.07	1.32-8.92	0.69-1.19	NA	NA	0.0388-8.92	1.81
	Mean	0.11	0.05	5.26	0.94	NA	NA		
Ferrous Iron (mg/L)	Range	NA	NA	NA	NA	NA	NA	NA	NA
	Mean	NA	NA	NA	NA	NA	NA		
Iron-Related Bacteria (cfu/mL)	Range	9000-9000	9000-9000	9000-9000	9000-9000	NA	NA	9000-9000	9000.00
	Mean	9000.00	9000.00	9000.00	9000.00	NA	NA		
Total Manganese (mg/L)	Range	0.74-0.825	0.79-5.18	2.45-4.01	0.943-1.57	NA	NA	0.74-5.18	2.06
	Mean	0.78	2.99	3.23	1.26	NA	NA		
Manganous Manganese (mg/L)	Range	NA	NA	NA	NA	NA	NA	NA	NA
	Mean	NA	NA	NA	NA	NA	NA		
Nitrate as Nitrogen (mg/L)	Range	0.0407-0.0407	9.7-9.7	0.218-0.218	0.0451-0.0451	NA	NA	0.0407-9.7	2.50
	Mean	0.04	9.70	0.22	0.05	NA	NA		
Nitrifying Bacteria (cfu/mL)	Range	ND	ND	ND	ND	NA	NA	NA	NA
	Mean	ND	ND	ND	ND	NA	NA		

Table 8−10 (continued). Biogeochemical Parameters at Riverbed Well Points in the Configuration 4 Area

Analyte		**Well Points**						**Range for all Wells**	**Mean for all Wells**
		790	**791**	**792**	**793**	**794**	**795**		
Nitrite as Nitrogen (mg/L)	Range	NA	0.01-0.01	0.005-0.005	0.285-0.285	NA	NA	0.005-0.285	0.10
	Mean	NA	0.01	0.01	0.29	NA	NA		
Oxidation Reduction Potential (mV)	Range	-242 to 46	-260 to -31	-174 to 24	-226 to -91	-156 to -156	-88 to -88	-260 to 46	-114.84
	Mean	-71.25	-140.00	-100.20	-150.67	-156	-88		
Phosphorous (mg/L)	Range	NA	NA	NA	NA	NA	NA	NA	NA
	Mean	NA	NA	NA	NA	NA	NA		
Sulfate (mg/L)	Range	287-490	346-8600	5030-8300	243-294	NA	3310-3310	243-8600	3527.61
	Mean	403.50	4883.20	6670.00	269.00	NA	3310		
Sulfate Reducing Bacteria (cfu/ml)	Range	1200-1200	100000-700000	18000-700000	500-5000	NA	NA	500-700000	190737.50
	Mean	1200.00	400000.00	359000.00	2750.00	NA	NA		
Sulfide (mg/L)	Range	0.02-0.02	0.02-0.02	0.02-6.2	0.02-0.02	NA	NA	0.02-6.2	1.26
	Mean	0.02	0.02	3.11	0.02	NA	NA		
Total Dissolved Solids (mg/L)	Range	661-1300	1010-19000	14600-22000	605-901	NA	38600-38600	605-38600	10568.72
	Mean	1055.25	11602.00	17440.00	735.33	NA	38600		
Total Inorganic Carbon (mg/L)	Range	64.4-64.4	172-172	150-150	58-58	NA	NA	58-172	111.10
	Mean	64.40	172.00	150.00	58.00	NA	NA		
Total Kjeldahl Nitrogen (mg/L)	Range	16.9-16.9	443-443	516-516	0.37-0.37	NA	NA	0.37-516	244.07
	Mean	16.90	443.00	516.00	0.37	NA	NA		
Total Organic Carbon (mg/L)	Range	NA	8.1-8.1	NA	9.9-9.9	NA	NA	8.1-9.9	9.00
	Mean	NA	8.10	NA	9.90	NA	NA		
Uranium (mg/L)	Range	0.0563-0.27	0.0734-2.4	0.622-1.6	0.0089-0.0138	NA	NA	0.0089-2.4	0.66
	Mean	0.13	1.05	1.08	0.01	NA	NA		
Orthophosphate (mg/L)	Range	0.4-0.4	0.3-0.3	NA	NA	NA	NA	0.3-0.4	0.35
	Mean	0.40	0.30	NA	NA	NA	NA		
pH (standard units)	Range	7.58-8.2	6.97-8.32	7.55-9.27	7.58-7.73	7.85-7.85	9.31-9.31	6.97-9.31	7.93
	Mean	7.87	7.55	8.27	7.64	7.85	9.31		
ND = not detected									
NA = not applicable									

End of current text

9.0 Conclusions

In summer 2006 the Ground Water IA system was expanded with the addition of Configuration 4 and an Infiltration Trench. Configuration 4 consists of 10 dual-purpose remediation wells, eight observation wells, and six riverbed well points. Configuration 4 is located south of Configuration 1 and the wells were constructed in a manner similar to Configuration 3, but at slightly shallower depths based on previous observations of the elevation of the brine interface. The infiltration trench was situated north of Configuration 3 and south of the Baseline Area and consists of approximately 160 linear feet of perforated pipe buried approximately 10 ft bgs. It was designed to allow injection of diverted Colorado River water into the subsurface and performance will be compared to previous injection rates for Configuration 2 remediation wells.

The Ground Water IA was operated predominantly in extraction mode during 2006. Configurations 1 and 3 were started in March and were shut down for the winter season in December. Configuration 2, which had been operating in injection mode since October 2004 was converted to extraction mode on March 23, 2006. This was done partly because of the demolition of the old freshwater holding pond and partly to assess extraction mode performance. Due to diminished need for water in the evaporation pond, extraction from Configuration 2 remediation wells was discontinued in early October 2006. Configuration 4 was brought on-line in September, as was the operation of the infiltration trench. Both of these portions of the IA system were also shut down in December for the winter.

With the exception of lowering the elevation of the evaporation pond recirculation pump intake (in order to increase the volume of water available to the sprinkler system from the pond), no changes were made to the evaporation pond or the sprinkler system located atop the tailings pile during 2006. The sprinkler system currently covers approximately 38 acres and is used for both dust control and enhanced evaporation capacity.

Assessment of ground water biogeochemistry data from 2006 and early 2007 indicates that several different microbially mediated processes are occurring at all four configurations of the Ground Water IA as well as at the Baseline Area, which is used to describe ambient water chemistry. Two autotrophic processes—nitrification and anammox—appear to significantly reduce dissolved concentrations of ammonia prior to ground water discharge to the Colorado River, thereby contributing to ammonia attenuation in the river itself. Summaries of biogeochemical data collected for this performance evaluation show that conditions in ground water affected by extraction wells are generally anaerobic and chemically oxidizing. In contrast, water sampled from downgradient riverbed well points has relatively high dissolved oxygen concentrations and negative ORP. The presence of oxygen in piezometer (well-point) water is attributed to the infiltration of river water to the hyporheic zone located below the riverbed and the chemically reducing conditions implied by negative ORPs are attributed to the respiration of heterotrophic bacteria.

9.1 General Observations/Conclusions

Some overall well field performance observations and conclusions are provided below. These are followed by conclusions specific to the Baseline Area, individual well field configurations, the infiltration trench, and the treatment system:

- The conceptual site model regarding location and response of the brine interface to pumping and river flow remains valid.
- The distribution of ammonia and uranium with respect to the brine interface remains valid. Uranium concentrations are highest in shallow ground water and decrease with depth. Ammonia concentrations increase from the water table to the interface, reach a maximum just below the interface, and decrease with depth from there.
- The data collected during the 2006 pumping season generally follows the site conceptual model for the Interim Action well field. While local variations within individual configurations regarding the depth to the brine surface occur, across the entire well field the depth to the brine surface decreases towards the southern end.
- Significant responses of ground water chemistry to river flows in the absence of pumping would only be expected in close proximity to consistently flowing Colorado River channels.
- Water chemistry data indicate that during ground water extraction Configuration 1 (not including SMI-PW02), Configuration 2, and Configuration 3 analyte concentrations fluctuate in response to changes in the Colorado River stage.
- The Configuration 4 remediation wells are the most efficient based on specific capacity calculations, while Configuration 2 wells are the least efficient. The highest producing (based on volume of ground water extracted and average extraction rate) remediation wells for 2006 were in Configuration 3, with Configuration 2 remediation wells producing the lowest. The Configuration 4 pumping season lasted only 95 days during 2006 compared to 277 days for Configuration 3. Well efficiency ultimately plays a key role in protecting Colorado River side channel habitat areas.
- Taking into account the length of time each configuration was actively extracting ground water, Configuration 3 remediation wells and well SMI-PW02 were the most efficient in ammonia and uranium mass removal during 2006. The bottom of the screened interval at these wells is relatively deep and the wells are less affected by an influx of river water during pumping than the wells at Configurations 1, 2, and 4. Shallower screened wells are more effective at pulling in river water and are expected to be more effective at manipulation of the ground water surface.
- When calculating the ratio of the volume of ground water extracted to the mass of ammonia removed from the aquifer, well SMI-PW02 and Configurations 2 and 3 remediation wells were significantly more efficient compared to Configurations 1 and 4. Configuration 3 was nearly twice as efficient for uranium mass removal compared to the other configurations. Configuration 4 was the least efficient at uranium mass removal based on this method. This is partly due to higher ammonia and uranium concentrations present near Configurations 2 and 3 as compared to Configuration 4.

9.1.1 Baseline Area

- Changes in the Colorado River stage do not appear to significantly impact the water chemistry in the upgradient observation well cluster (SMI-PZ1S, -PZ1M, -PZ1D2, and –PW01). Once fresh water was actively injected into the nearby infiltration trench, concentrations significantly decreased in the shallow zone at the downgradient cluster (0405/0488/0493).

- Analytical data collected from the riverbed well points do not exhibit the same water chemistry trends as those displayed by the observation wells, as decreasing TDS concentrations with increasing depth are observed in many of the well points. During 2006, the highest ammonia concentrations were consistently detected in samples collected from the deepest (approximately 10 ft bgs) completed well points, and there was no trend associated with the uranium concentrations and well point depth. These data provide evidence that, typically within the hyporheic zone, regular patterns regarding water chemistry are not followed.

9.1.2 Configuration 1

- Extraction wells 0470 through 0479 extracted approximately 8.3 million gal of ground water with an average pumping rate of 26.4 gpm during 2006. Well SMI-PW02 extracted ground water from its location closer to the tailings pile at an average rate of 23.3 gpm, and removed another 6.2 million gallons over a shorter pumping season compared to wells 0470 through 0479.
- Based on drawdown and extraction rate data collected during 2006, Configuration 1 extraction wells 0470 through 0479 operated with an average specific capacity of 1.1 gpm/ft, which is identical to the 2005 value for this parameter, indicating the wells are maintaining their level of efficiency.
- An estimated 8,913 kg of ammonia was extracted from wells 0470 through 0479 and another 18,626 kg from well SMI-PW02 during 2006. In addition, 64.6 and 66.7 kg of uranium were removed from extraction wells 0470 through 0479 and SMI-PW02, respectively, during this same time.
- The alluvial aquifer at the southern portion of Configuration 1 has a higher hydraulic conductivity and is more effective at drawing in river water and diluting nearshore ground water than is the northern portion. These local variations in hydraulic conductivity illustrate the heterogeneous nature of the aquifer.
- Constituent concentrations in extracted ground water in the northern portion of the configuration tend to be higher and more uniform (particularly for uranium) than in the southern portion. This is of limited use in habitat protection but may be beneficial in maintaining mass removal rates.
- Water chemistry results from wells 0470 through 0479 indicate TDS, ammonia, and uranium concentrations followed the same pattern (i.e., all increase or decrease at the same time) throughout the year. In addition, analyte concentrations decreased during extraction in response to increases in the Colorado River stage during the spring runoff and in October 2006 following a significant rain event, indicating an increased volume of river water was being extracted during these time periods. Well SMI-PW02 is located approximately 200 ft farther west of the riverbank and analyte concentrations were not significantly impacted by changes in the river stage.
- Samples collected from upgradient observation wells indicate there was an increase in analyte concentrations between 18 and 40 ft bgs during late months of the year. It appears that upconing of the brine surface results in increases of ammonia in shallow downgradient ground water. Concentrations of contaminants (particularly ammonia) in SMI-PW02 remain relatively constant and high during pumping. Operation of this well results in steady mass removal.

- Surface water concentrations in the river adjacent to Configuration 1 are normally fairly low. Concentrations tend to peak during baseflow river conditions. Pumping at the southern portion of Configuration 1 effectively draws in river water and prevents discharge of contaminated ground water to this portion of the riverbank.

9.1.3 Configuration 2

- Configuration 2 was switched from freshwater injection to ground water extraction during March 2006. This system had been exclusively injecting fresh water since October 2004. Due to various issues, extraction wells 0574 and 0578 were not brought online, and the remaining wells extracted ground water following various schedules until October 2006 when the configuration was shut down for the winter season.
- Remediation wells 0570 through 0579 (with the exception of 0574 and 0578) extracted approximately 2.1 million gal of ground water with an average pumping rate of only 7.5 gpm during 2006.
- Based on drawdown and extraction rate data, during 2006 Configuration 2 remediation wells operated with an average specific capacity of only 0.12 gpm/ft, indicating these wells are considerably less efficient compared to Configurations 1, 3, and 4.
- An estimated 4,705 kg of ammonia and 16.2 kg of uranium were removed by the active Configuration 2 remediation wells.
- Analyte concentrations in the shallow zone aquifer appear to decrease during ground water extraction, most likely due to the influx of river water.
- Downgradient observation wells were more affected by river stage and extraction rate than the upgradient wells. The downgradient shallow aquifer showed an increase in uranium concentration with increasing river flow, which is indicative of the introduction of oxygenated river water. Samples collected from a depth of 34 ft bgs indicate this depth was most impacted by river flow and extraction rates since the brine surface near this depth shifted vertically within the screened interval of well 0588 (TD = 36 ft).
- Comparison of analyte concentrations from 2005 and 2006 indicates that, in general, downgradient observation wells and river bank well points contained a higher uranium concentration, higher TDS concentration, and a slightly higher ammonia concentration during extraction mode. This increase in analyte concentration is likely due to an upconing of brine during extraction.
- Analyte concentrations in upgradient wells did not vary as much as observed at downgradient wells between injection and extraction modes. During extraction in the early part of 2006 (during the transition from injection to extraction), the uranium and TDS concentrations in well 583 (18 ft bgs) were slightly higher and the ammonia concentration was higher than observed in 2005. Concentrations of these constituents from July to December were generally lower than the 2005 concentration levels.
- Analyte concentrations in Configuration 2 river-edge well points are dissimilar to those at downgradient observation wells and well points closer to the remediation wells. During injection in 2005, TDS and ammonia concentrations were higher and the uranium concentration was lower compared to the concentrations during extraction. This likely results from the transition zone between shallow water and brine being pushed out farther towards the main river channel in response to the freshwater injection.

9.1.4 Configuration 3

- Extraction wells 0670 through 0679 extracted approximately 13.3 million gal of ground water with an average pumping rate of 35.3 gpm during 2006.
- Based on drawdown and extraction rate data during 2006, Configuration 3 remediation wells operated with an average specific capacity of 2.7 gpm/ft, indicating these wells were more efficient compared to Configurations 1 and 2.
- An estimated 25,903 kg of ammonia and 148 kg of uranium were removed by the Configuration 3 remediation wells.
- Water chemistry results collected in early 2006 from the southern end of Configuration 3 prior to ground water extraction indicate Configuration 2 freshwater injection decreased local analyte concentrations. Likewise, analytical results for samples collected from the northern portion of Configuration 3 near the end of the 2006 pumping season suggest infiltration trench freshwater injection decreased analyte concentrations in that area.
- Irrigation of adjacent vegetation plot C-5 in 2006 apparently resulted in increased uranium concentrations in the northern half of Configuration 3. Similar observations were made during the 2005 pumping season.
- Remediation well analyte concentrations do not appear to respond to changes in the Colorado River flows. The increased distance (compared to other configurations) from a consistently flowing river side channel and the extraction depth of ground water from Configuration 3 wells (as deep as 45 ft bgs) may be contributing factors.
- Water chemistry results for samples collected from downgradient observation wells indicate analyte concentrations between 39 and 54 ft bgs were impacted by upconing as a result of Configuration 3 ground water extraction. Water chemistry at upgradient observation wells exhibited minimal, if any, response to ground water extraction.
- Riverbed well point analyte concentrations decreased in response to an increase in river stage.

9.1.5 Configuration 4

- Extraction wells 0770 through 0779 were installed in May 2006 and only became fully extraction operational in September 2006. Because of equipment and system electrical issues, well 0775 operated for only a limited time period during 2006 and well 0777 never became operational. During the shortened pumping season in 2006, Configuration 4 remediation wells extracted approximately 2.8 million gal of ground water with an average pumping rate of 21.1 gpm.
- Drawdown and extraction rate data during 2006 showed that Configuration 4 remediation wells operated with an average specific capacity of 3.4 gpm/ft, indicating these wells are more efficient compared to Configurations 1, 2, and 3. The high specific capacity measured is a function of the larger screen slot size (0.020 inch PVC vee-wire wrap) and sand pack (10/20). These wells had been active for only a third of the 2006 pumping season, and subsequent drawdown data will determine if these wells maintain their efficiency.
- During the short pumping season an estimated 5,676 kg of ammonia and 18.5 kg of uranium were removed from the aquifer in the vicinity of Configuration 4.

- Remediation well analyte concentrations were apparently impacted by changes in the Colorado River flow, with the response being comparable to impacts observed in Configuration 1 extraction wells.
- Upgradient observation well analyte concentrations in samples collected from 33 and 46 ft bgs were influenced by upconing stemming from Configuration 4 ground water extraction. The shallow aquifer zone downgradient of Configuration 4 remediation wells was apparently affected to a larger degree by changes in the river stage than the deeper zones. Water chemistry results at a depth of 36 ft bgs and downgradient of the well field do not exhibit significant changes.

9.1.6 Infiltration Trench

- The infiltration trench did not fully start injecting fresh water until late September 2006. By the first week of December, at which time operation was suspended for the winter, a total of 2.2 million gallons of fresh water had been injected with an average injection rate of 21.1 gpm.
- Groundwater elevation data collected from nearby downgradient observation wells indicated fresh water injection generated approximately 1 ft of mounding less than 5 ft from the trench, and about 0.3 ft of mounding 10 ft from the trench.

9.1.7 Treatment System

- The sprinkler system was started during late February for dust control purposes, and ground water extraction from the well field started in early March 2006. During 2006, an estimated 33.7 million gallons of ground water was extracted from the well field, and 31.6 million gallons was distributed by the sprinkler system.
- Evaporation pond analyte concentrations decreased below inlet concentrations in response to the addition of an estimated 1.4 million gallons of fresh water to the pond that originated as surface runoff from a July 2006 heavy precipitation event.

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