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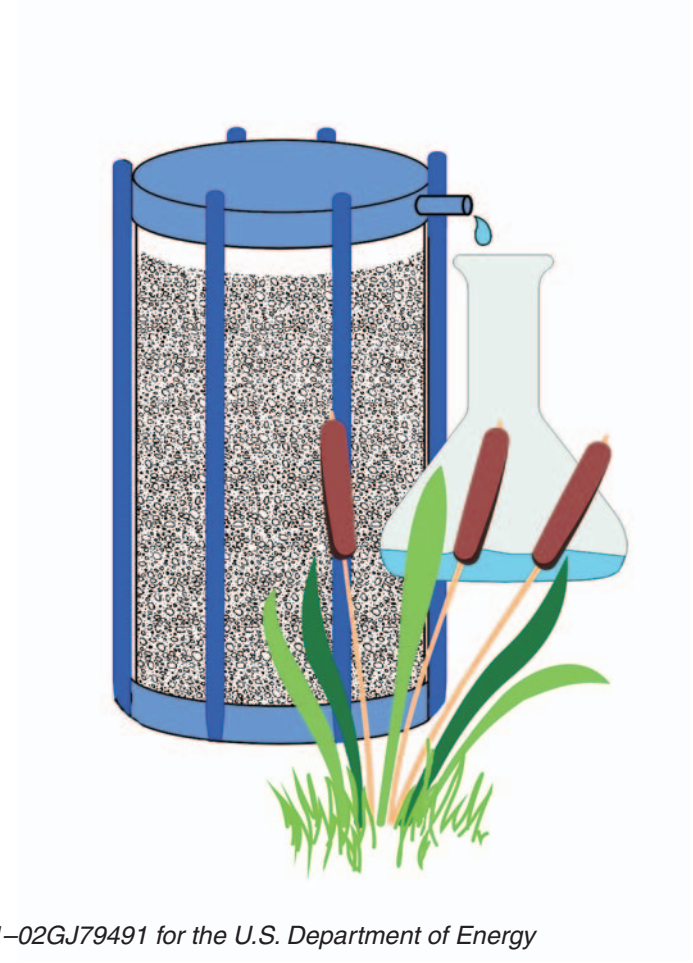
Environmental Sciences Laboratory

Vertical Distribution of Contamination in Ground Water at the Tuba City, Arizona, Site

August 2005



Prepared for
U.S. Department of Energy
Grand Junction, Colorado

Work Performed Under DOE Contract No. DE–AC01–02GJ79491 for the U.S. Department of Energy
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Vertical Distribution of Contamination in Ground Water at the Tuba City, Arizona, Site

August 2005

Work Performed by S.M. Stoller Corporation under DOE Contract No. DE–AC01–02GJ79491
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1.0 Introduction

This report evaluates the vertical distribution of contamination in ground water at the Tuba City Disposal Site, near Tuba City, Arizona (Figure 1). An improved understanding of contaminant distribution with depth may lead to more accurately evaluating the progress of ground water remediation at the site and more efficient contaminant recovery. At present, 25 wells shown in Figure 2 operate to extract ground water for on-site treatment by mechanical distillation.

The ground water extraction system meets design expectations of contaminant recovery. However, although capture of some uncontaminated water is probably unavoidable, the vertical influence of the extraction wells may be excessive. It is the goal of this report to determine if sufficient evidence of excessive capture at depth merits additional studies. Minimizing such capture, possibly by modifying (shortening) the extraction wells, may reduce long-term costs of remediation.

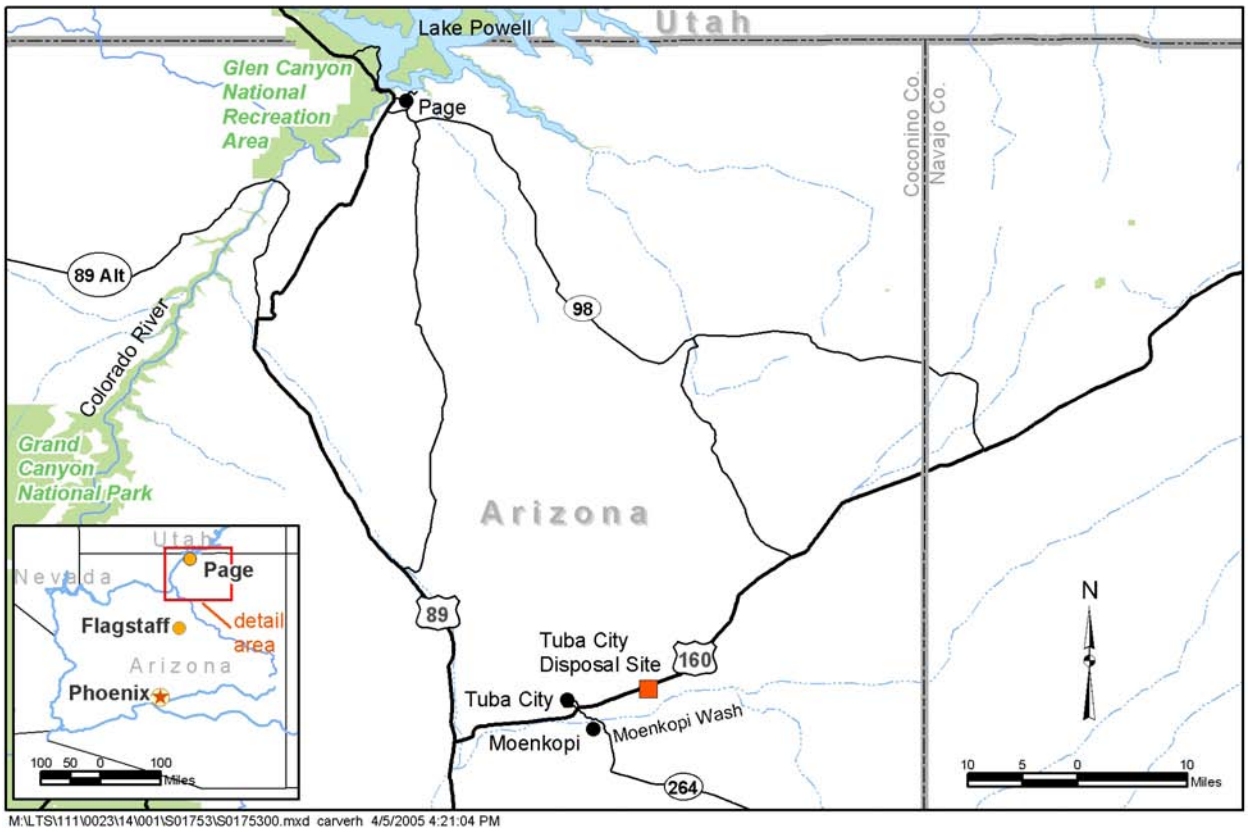


Figure 1. Site Location Map

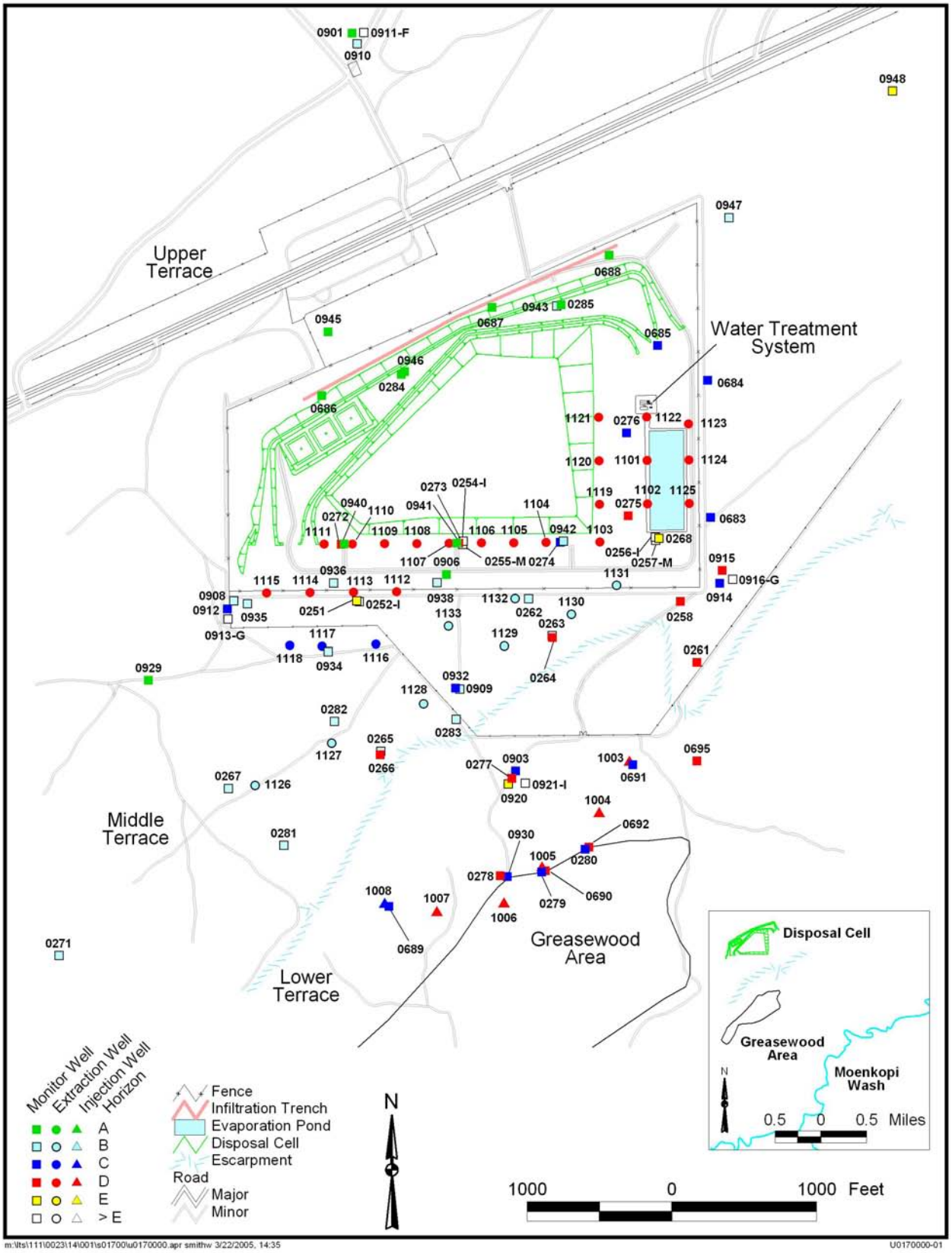


Figure 2. Site Features Map

2.0 Background Information

The Tuba City site lies on the middle of three alluvial terraces associated with ancestral flow in Moenkopi Wash, located about 1.25 miles southeast of the site. The regionally extensive Navajo Sandstone, a massively cross-bedded, fine to very fine friable sandstone and siltstone, underlies coarse, semi-indurated, remnant alluvium at most terrace locations. Loose dune sand and silt is prevalent to depths of up to 20 feet (ft), although bedrock slopes and cliffs dominate the terrace escarpments. Regional bedrock dip is about one degree to the northeast.

Within about 200 ft below ground, the eolian dune deposits of the “classic” Navajo Sandstone become interbedded with fine-grained alluvium more typical of the underlying Kayenta Formation. This “inter-tonguing interval” is 400 to 450 ft thick. Locally, the Kayenta Formation consists of 100 ft or more of slope-forming, flat-lying red silt and fine sand. From the ambient water table, at about 50 ft below ground at the site, the saturated zone extends through the inter-tonguing interval to the upper contact of the non-water bearing Kayenta Formation.

Moenkopi Wash occupies the axis of a broad bedrock valley. Ground water flow beneath the site is southeast to the wash. Aquifer thickness is reduced by about 40 percent (250 ft) over this distance. At the wash, regional discharge occurs from a laterally extensive (miles) spring zone that outcrops near the exposed base of the inter-tonguing interval. Some local discharge of ground water from higher in the formation likely occurs to sustain scattered populations of desert phreatophytes, such as in the “greasewood area” designated in Figure 2, where ground water is only about 20 ft below land surface. Figure A-1 in Appendix A depicts a conceptual model of the site hydrogeology.

2.1 Aquifer Discretization

Site hydrostratigraphy is discretized into 50-ft intervals, or “horizons,” each with a letter designation. The top of the middle terrace, nominally 5,050 feet in elevation, marks the top of the uppermost horizon (Horizon A). Horizons A, B, C, and possibly D span the interval of "classic" Navajo Sandstone beneath the site, whereas the depths of Horizons E through J include the regions of the inter-tonguing interval. Horizons K, L, and M include the lower inter-tonguing interval and possibly the upper Kayenta Formation. These stratigraphic relationships to aquifer horizon are shown in Figure A−1.

The uppermost horizon on the lower terrace progresses from Horizon C to D north to south with the downslope of surface topography. The steep terrain at Moenkopi Wash intersects Horizons E through G. Ground water remediation at the site focuses primarily on the upper 250 ft of the bedrock aquifer (Horizons A through E).

Color-coding in Figure 2 identifies the horizon in which the mid-point of each well screen is located for extraction wells (round symbols) and monitoring wells (square symbols). Figure A−2 of Appendix A is a cross-section schematic of the placement depth of well screens in relation to aquifer horizon for all project wells.

2.2 Ground Water Extraction

In Figure 2, the extraction wells of interest are those labeled 1101 to 1125. They are constructed of 6-inch diameter Schedule 40 PVC casing and 6-inch, vee-wrap stainless steel screen (0.017-inch slot). A filter pack of 20-40 graded silica sand completes the 2-in annulus to 30 or 40 ft above the screen slots. Screen lengths are 150-ft and extend from the bottom half of Horizon B to the mid-depth of Horizon E, except at wells 1116, 1117, and 1118, where 100-ft screens extend nearly to the base of Horizon D. Extraction wells 1126−1133, (Figure 2) installed in 2004, are of similar specification but consist of 4-inch diameter casing and screen and are much shallower, with 30 to 40-ft screens located in Horizon B. These wells will become operational in Summer 2005.

Current production of the 25 extraction wells is 80 to 100 gpm sustained over periods of months. Individual production ranges from 0.5 to 6 gpm. The 25-well average is 4 gpm. Concentrations of nitrate (as NO_3), sulfate, and uranium, the primary site contaminants, remain relatively steady in the bulk extract at about 400, 900, and 0.25 milligrams per liter (mg/L), respectively, during steady pumping. Remediation goals are 44 mg/L nitrate as NO_3, 250 mg/L sulfate, and 0.044 mg/L uranium.

2.3 Ground Water Contamination

Figure 3 and Figure 4 show the extent of uranium contamination in ground water in aquifer Horizons A and B, and Horizons C and D (extraction wells included), respectively, in February 2005. The distribution of nitrate and sulfate contamination has similar trends to that of uranium. Until the installation of wells 272 - 276 in 2004, there was no discrete-depth monitoring capability of Horizons C and D within the main region of the contaminant plume as defined by the more extensive network of shallower monitoring wells.

Uranium concentrations shown in Figure 4 for the extraction wells are from samples collected while the wells are pumping and so are composites of the entire intake interval and do not necessarily indicate that contamination in the aquifer extends to the full depth of the well. Samples collected from the extraction wells before full-scale extraction and treatment started in mid-2002 are also unsuitable for assessing the depth of contamination because of similar sampling conditions.

Discrete-depth sampling beneath contaminated regions of Horizons A and B indicates that the contamination extends into Horizon D at wells 273 and 275 but does not at wells 272, 274, and 276. Contamination at well 273 is limited to relatively low levels of nitrate (185 mg/L) and uranium (0.06 mg/L), whereas elevated concentrations of nitrate (1,056 mg/L), sulfate (2,100 mg/L), and uranium (0.44 mg/L) are present at well 275. At the paired monitor wells along the escarpment separating the middle and lower terraces (well pairs 263/264, 265/266, and 909/932), contamination is limited to the shallow well (A or B Horizon) and does not extend into Horizon C or D at each location. At the remaining location of a monitor well pair completed in the interval of the extraction wells, contaminant concentrations also decrease sharply with depth, in this case between Horizon B (wells 908 and 935) and Horizon C (well 912, not sampled in February 2005).

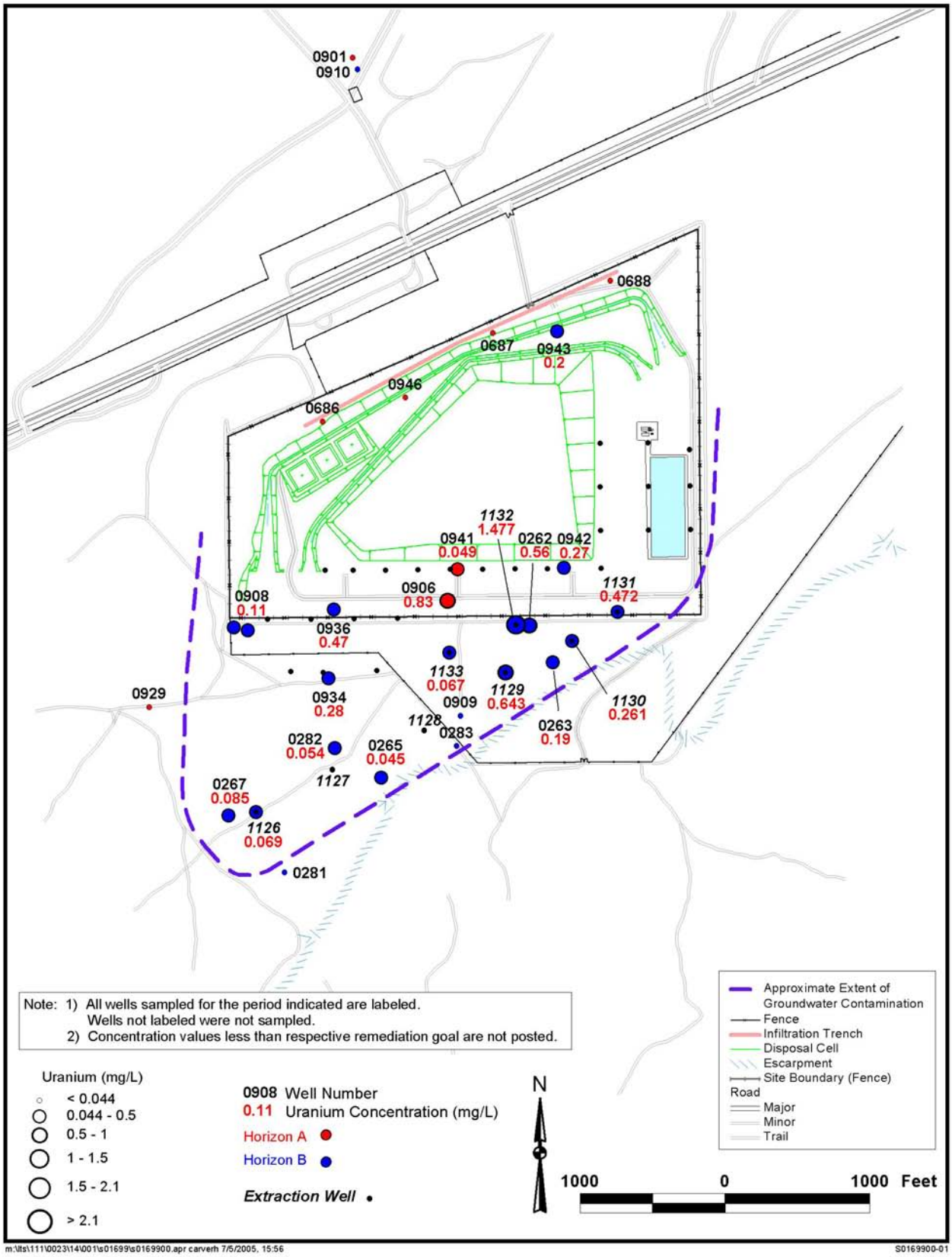


Figure 3. Uranium Concentrations in Ground Water, Horizons A and B, February 2005

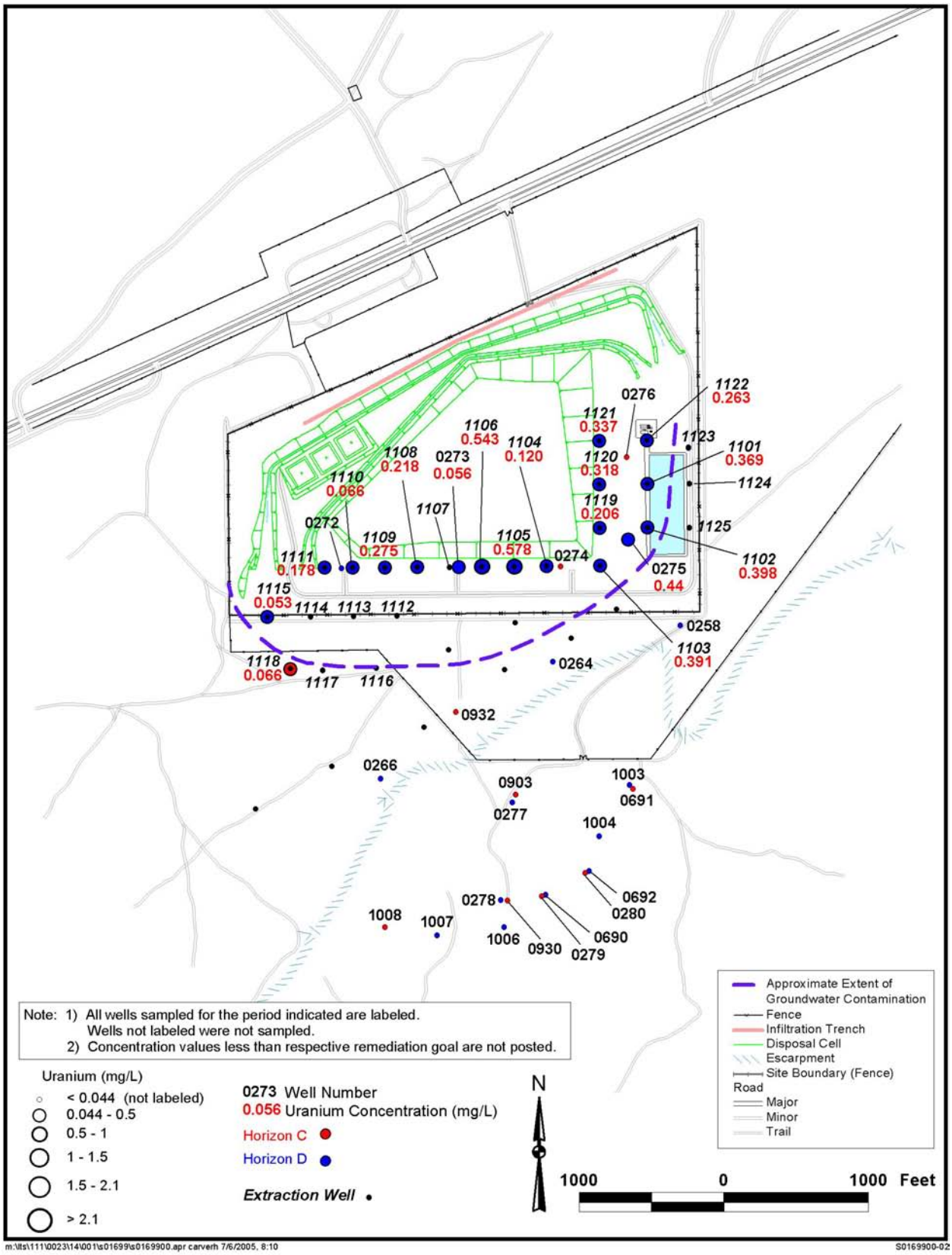


Figure 4. Uranium Concentrations in Ground Water, Horizons C and D, February 2005

Ground water is not contaminated at the sole Horizon E well (well 251) that is screened beneath significant shallow contamination. The brief period of contamination at that well that occurred several months after its installation (April 2000) presumably resulted from a failed annular seal and downward leakage of shallower contaminated ground water (DOE 2005). In response to ground water extraction, the vertical flow gradient has reversed from downward to upward and contamination is no longer present at well 251.

2.3.1 Contaminant Mass Balance at Extraction Wells

The tendency for contaminants to be concentrated in the shallowest horizons at the site, specifically Horizons A and B, can also be examined using approximate assessments of contaminant mass balance in extraction wells. As discussed in Section 2.2 and shown in Figure A−2, the screened intervals of most extraction wells begin in the bottom half of Horizon B and terminate either near the mid-point or the bottom of Horizon E. Thus, if it can be shown that contaminant concentrations in the water pumped from extraction wells in a specific area are considerably lower than comparable contaminant levels in nearby wells screened solely in Horizon B, the likelihood is strong that contaminant concentrations are less in the deeper horizons. A simple approach to this type of assessment assumes that the rate of inflow to the extraction well is uniform over its entire screened thickness, and that water mixing in the well can be represented by

$$C_{ext} = \frac{q\left(H_B C_B + H_{deep} C_{deep}\right)}{Q_{ext}} \qquad \textbf{(1)}$$

where C_{ext} = contaminant concentration in the extracted water (mass/volume),
q = rate of inflow to the extraction well per unit depth (length^2/time),
H_B = screened vertical interval in Horizon B (length),
H_{deep} = screened vertical interval below Horizon B (length),
C_B = measured contaminant concentration in Horizon B (mass/volume),
C_{deep} = average contaminant concentration over H_{deep} (mass/volume), and
Q_{ext} = $qH_B + qH_{deep}$ = extraction well pumping rate (volume/time).

Table 1, which presents representative concentrations for observation wells screened in distinct horizons and in nearby extraction wells, provides some data to which this simple mass balance logic can be applied. The data in this table for the 936/1113/1114 well combination were drawn from time series plots of contaminant concentrations at these wells (Figure 5, Figure 6, and Figure 7). Applying Equation (1) to the listed representative concentrations for nitrate, sulfate, and uranium in these wells suggests that the average contaminant concentrations in the deeper horizons (C_{deep}) of extraction wells 1113 and 1114 are, at the most, a small fraction of the concentrations occurring in Horizon B. The same finding also holds true for the 934/1116/1117/1118 and 942/11104 well combinations. At the locations of two other well combinations (935/1114/1115 and 940/1110/1111), this same conclusion is derived if it can be assumed that concentrations measured in wells screened in Horizon A are representative of local Horizon B concentrations.

Table 1. Contaminant Data for Shallow Wells and Nearby Extraction Wells

Well (Horizon)	Representative Concentration (mg/L)		
	Nitrate (as NO_3)	Sulfate	Uranium
934 (B)	2,400	2,200	0.32
1116	<50	100	0.007
1117	200	600	0.03
1118	600	1,400	0.059
935 (A)	650	2,700	0.11
912 (C)	375	600	0.03
1114	180	280	0.03
1115	250	350	0.05
936 (B)	2,300	3,000	0.5
1113	50-100	<50	<0.005
1114	180	250	0.03
940 (A)	1,700	9,000	0.43
272 (D)	15	12	0.002
1110	250	350	0.06
1111	400	850	0.14
941 (A)	600	800	0.08
273 (D)	207	245	0.07
1105	200-300	1000	0.5-1.5
1106	140	400	0.6
1107	200	250	0.04
1108	700	1,750	0.25
942 (B)	1,200	2,800	0.25
274 (C)	19	39	0.003
1104	800	1,250	0.12

The one remaining well combination in Table 1 (941/11105/1106/1107/1108) provides evidence that the trend of decreasing contaminant concentrations with depth is not universal within the extraction well field. For example, the representative concentrations of nitrate, sulfate, and uranium in water extracted from well 1108 exceed each of their comparable concentrations in Horizon A (measured in well 941). Also, the concentration of sulfate in water extracted from well 1105 is greater than the comparable Horizon A concentration, and the uranium concentrations in extraction wells 1105, 1106, and 1108 are greater than the nearby Horizon A concentration. These examples suggest that the vertical migration of contaminants can vary spatially at the Tuba City site, and that features such as preferential flow paths distributed randomly throughout the site's three-dimensional flow field might help to carry contaminants deeper in some areas than is observed in many others.

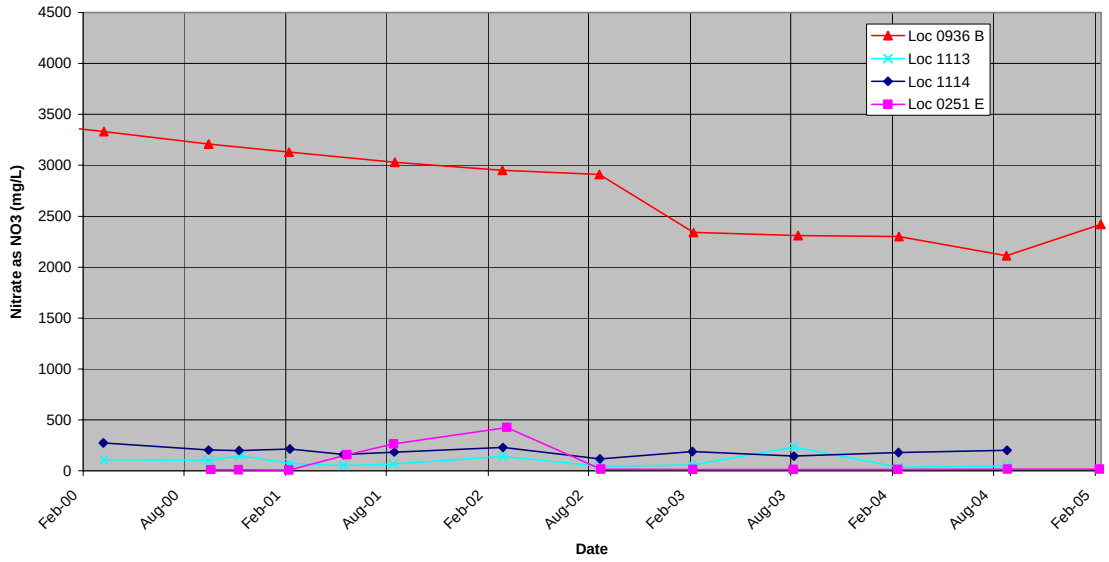


Figure 5. Nitrate Concentrations in Ground Water at Well Group 936/251/1113/1114

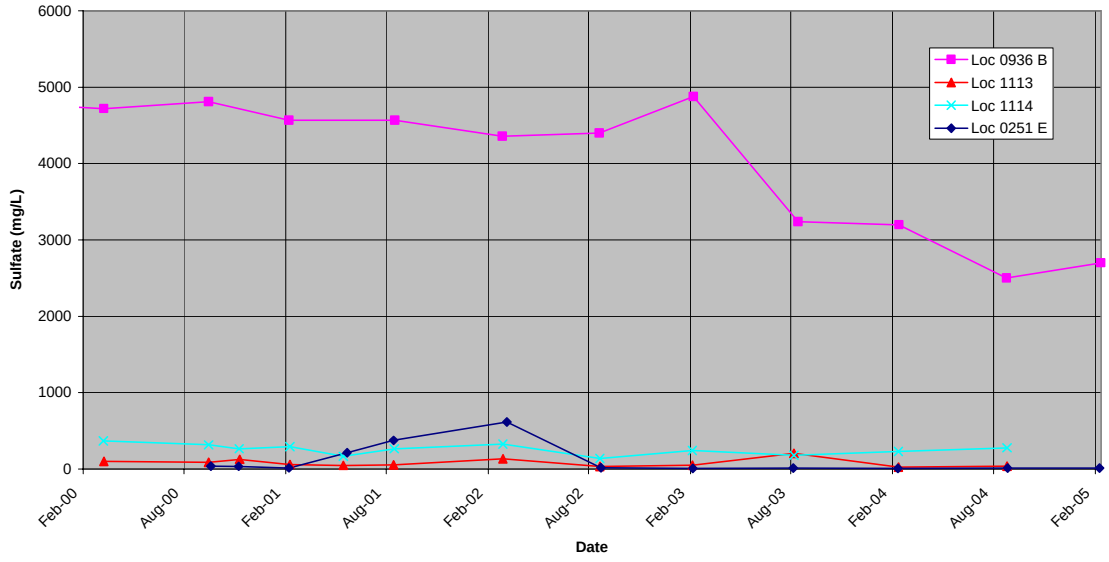


Figure 6. Sulfate Concentrations in Ground Water at Well Group 936/251/1113/1114

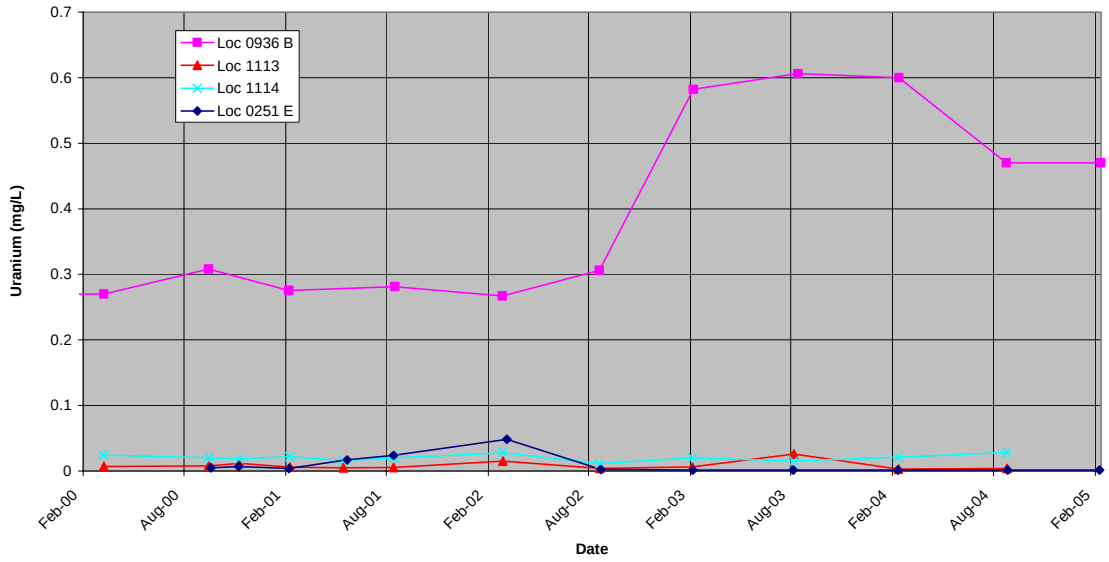


Figure 7. Uranium Concentrations in Ground Water at Well Group 936/251/1113/11145

2.3.2 Extraction Well Rebound Effect

During periods of non-pumping (hours to days) contaminant concentrations at many extraction wells are observed to increase significantly above those during "steady state" pumping, often approaching concentrations in nearby shallow monitor wells (DOE 2004). Once pumping resumes, this rebound effect is short-lived, generally less than one day. Concentration rebounding at the site may be due in part to water table recovery during the rest period within shallow, more-highly contaminated parts of the aquifer. During subsequent pumping, concentrations in an extraction well would then decrease as the shallow zone is again presumably dewatered and ground water capture expands into less contaminated deeper regions of the aquifer.

2.4 Ground Water Capture Zone

The existing ground water extraction system (i.e., before installation of the newest extraction wells in 2004) captures the bulk of the contaminant plume in lateral extent and probably the full vertical extent, as determined by analysis of water level drawdowns, flow direction analysis, and contaminant distribution (DOE 2005). The contaminated region of the aquifer not currently captured is south of the existing extraction system and extends to the escarpment separating the middle and lower terraces. New extraction wells 1125 through 1133 target Horizons A and B in this area. Existing evidence suggests that the existing capture zone likely extends beyond the limits of contamination to the east and west of the well field comprised of wells 1101 through 1125. Similarly, it appears that the vertical extent of the vast bulk of contamination does not extend below Horizon D. Significant water level drawdowns produced by the extraction system to several hundred feet or more beneath the base of the extraction wells in Horizon E likely indicate capture well below the depth of contamination.

3.0 Aquifer Isolation Tests

Packer isolation tests were conducted at wells 1101 and 1107 during March 9 to 11, 2004, and again from June 15 to 17, 2004 at wells 1101 and 1106, in an attempt to profile vertical contaminant distribution in the aquifer. Table 2 lists relevant information of the conditions of each test; field data for the tests are contained in Appendix B.

Table 2. Packer Test Information

Well	Date	Test	Packer Depth (ft)	Duration (min)	Pumping rate (gpm)	Bore Volumes Removed	Maximum Drawdown (ft)[a]	Water Level Horizon
1101	3/9/04	1	216	63	0.55	0.1	7.5	
		2	186	90	5.8	1.7	9	
		3	156	90	5.4	1.6	9.5	
		4		60	4.6	0.9	9	
	3/10/04	5	126	90	5.7	1.7	9	
1107	3/11/04	1	218	30	1.8	0.2	29	
		2	188	100	1.9	0.7	27	
		3	158	90	1.5	0.5	24	
		4	128	105	1.2	0.4	18	
1101	6/15/04	1	194	130	upper: 3.8 & 5.5 lower: 4	4.2	20	
		2	162	90	upper: 5.7 lower: 3.5	3	21	
1106	6/17/04	1	191	90	upper: 2.5 & 1.8 lower: 2.5, 2.2, 1.7	1.3	40	
		2	191	80	upper: 1.3, 0.8 lower: 1.2, 0.7	0.6	17	
		3	161	60	upper: 0.7 lower: 0.7	0.3	1-2	
		4	131	90	upper: 0.7 lower: 0.7	0.5	1-2	

[a]Drawdown produced by packer test, excludes prior residual drawdown.

3.1 March 2004 Packer Tests

The 10-ft tool assembly for the March 2004 tests consisted of a single 3-ft inflatable packer, the dedicated well pump for ground water extraction above the packer, a bladder pump with intake below the packer, and pressure transducers above and below the packer. After inserting this tool string to near the base of the well and inflating the packer, ground water extraction began while the bladder pump operated at a much lower rate for sample collection. The discharge of both pumps was monitored continuously for pH, electrical conductivity, and temperature, and samples were collected periodically for on-site analysis of chloride, nitrate, sulfate, and uranium. Following a brief period of field parameter stability and sample collection, pumping was discontinued, the packer deflated, and the assembly raised 30 ft. This process was repeated several times per well to the top of the screen. Test rationale assumed that by maintaining upward flow from below the packer, a pronounced increase in contaminant concentrations at the lower pump would identify the base of contamination in the adjacent formation.

3.1.1 Well 1101

Five tests at four depth intervals were conducted at well 1101 (Table 2). Test 1 was completed in 1 hour at a flow rate of about 0.5 gpm. About one-tenth of the calculated bore volume (300 gallons, casing plus filter pack) was extracted during Test 1. The duration of each remaining test except Test 4 (1 hour) was 1.5 hours at flows ranging from 4.5 to 5.5 gpm, resulting in the extraction of about 1 to 1.7 bore volumes per test. Test 4 was a continuation of Test 3 but with air injected below the packer in attempt to bridge the filter pack. The tests at well 1101 produced about 10 ft of drawdown. This drawdown, when combined with the 40 ft of residual drawdown before the tests started, placed the water level in well 1101 at about the top of Horizon C.

Figure 8 shows the measured concentrations of nitrate, sulfate, and uranium above and below the packer throughout the tests. Test order is from deepest (Test 1, top of packer at 215 ft) to shallowest (Test 5, packer at 125 ft), left to right in the figure. In Test 1, respective analyte (nitrate, sulfate, uranium) concentrations are initially greater above the packer then below despite the perturbations of first pulling the extraction pump from the well and then inserting the tool string to depth. By the end of Test 1 higher concentrations were measured below the packer. Given the short separation distance of pump intakes (10 ft), this initial test may indicate a heterogeneous water composition within the well at the start of the test. Due to limited purging, Test 1 samples likely represent pre-test compositions within the borehole rather than water quality in the adjacent formation.

Higher initial concentrations above the packer may again indicate a non-uniform water composition in the well at the start of Test 2. At its conclusion, concentrations above and below the packer are nearly identical and similar to those at the end of Test 1. Initial concentrations above and below the packer for Test 3 are only slightly greater than those at the end of Test 2. During Tests 3 and 4, gradually decreasing concentrations above the packer accompany increasing concentrations below. By the design criteria of these tests, this signifies the base of contamination at about 155 ft (base of Horizon C) at well 1101. This result cannot be confirmed or disputed by the conflicting evidence at nearest monitoring wells: contaminant levels at well 275 (upper Horizon D) far exceed remediation goals, but are consistent with background levels at well 276 (lower Horizon C). Air injection (Test 4) had no noticeable effect.

Test 5 did not maintain the high contaminant concentrations detected in Test 4. Instead, concentrations above and below the packer stabilized at similar values. This occurred because the test interval was at the top of the water column and so essentially all flow in the well bore and casing was upward, resulting in the same composite water at both the upper and lower pumps by the end of the test. This final composition is common to that occurring at the end of Tests 1 and 2 in the upper and lower pumps, and to those measured at the upper pump during each test. This is because during each test, the interval above the packer was open to the entire the well bore with minimal flow restriction or isolation by the packer. Test 5 best exemplifies this condition: the 0.6-foot interval above the packer was not drawn down or dewatered during sustained pumping of about 5.5 gpm, equaling the full production capacity of the well.

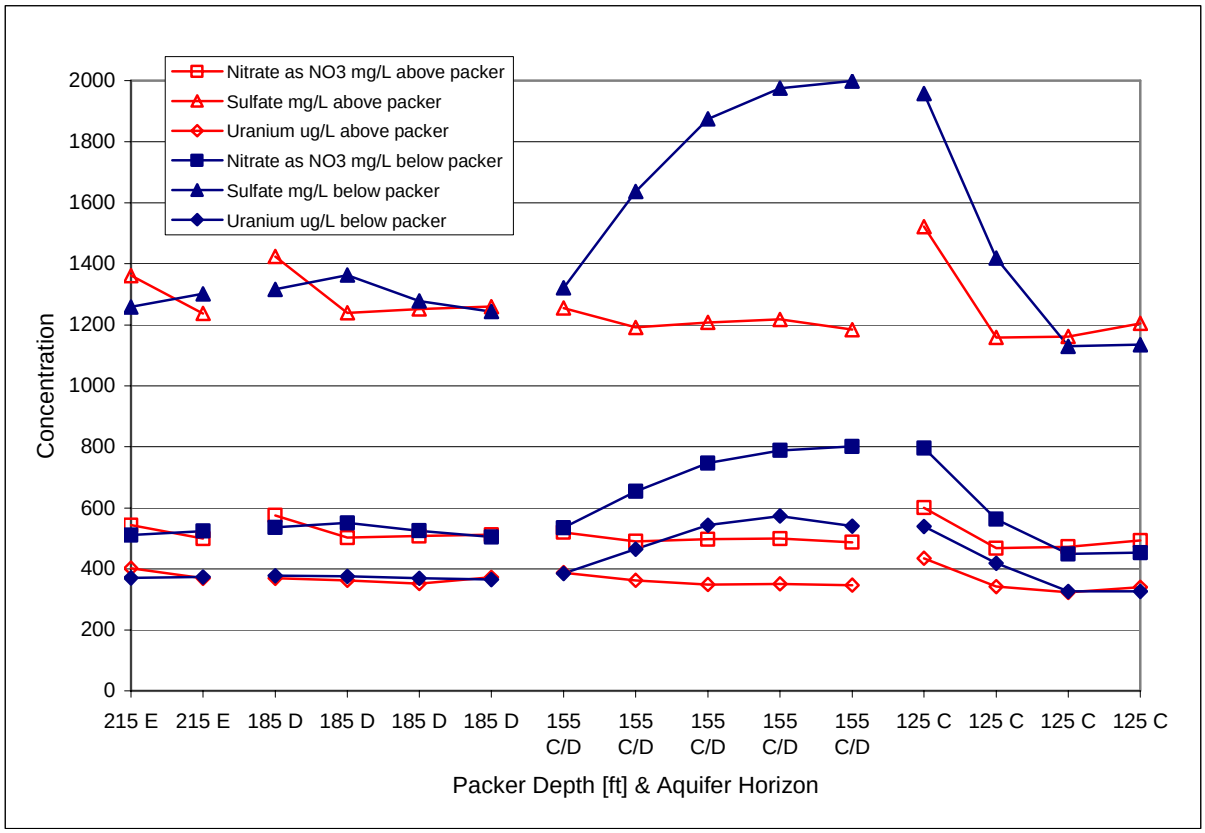


Figure 8. Well 1101 Packer Test Results for March 2004

3.1.2 Well 1107

Air injection was not a component of either test conducted at well 1107 because of no noticeable effect at well 1101. Well 1107 Test 1 was completed in one-half hour during which the initial flow rate of 8 gpm was later reduced to about 2 gpm. Total ground water extraction was about 0.2 bore volumes. Tests 2, 3, and 4 were between 90 and 105 minutes in duration. In Test 2, the initial flow rate of 2.8 gpm was reduced to 1.5 gpm. Total ground water extraction accounted for about 0.7 bore volumes. Pumping was steady at 1.6 and 1.2 gpm throughout Tests 3 and 4, respectively, each extracting about one-half of a bore volume. Maximum drawdown reached 30 ft during Tests 1 and 2, and 25 and 18 ft, respectively, during Test 3 and 4. Combined with 20 ft of pre-test residual drawdown, the varied pumping levels in well 1107 were in the upper half of Horizon C.

Figure 9 shows analyte concentrations above and below the packer for the well 1107 tests. Test order is from deepest (Test 1, packer at 218 ft) to shallowest (Test 4, packer at 128 ft). In Test 1, initial concentrations of the respective contaminants are distinct above and below the packer but by the end are almost identical. As with Test 1 at well 1101, the results probably do not represent water quality outside of the well bore because of low purge volume. Test 2 initial concentrations match those at the end of Test 1. As the test proceeded, upper concentrations steadily declined while those below the packer remained relatively stable. Throughout Test 3, concentrations above and below the packer were similar to those at the upper pump at the end of Test 2. Initially heterogeneous concentrations appear to converge on a common composition by the end of Test 4.

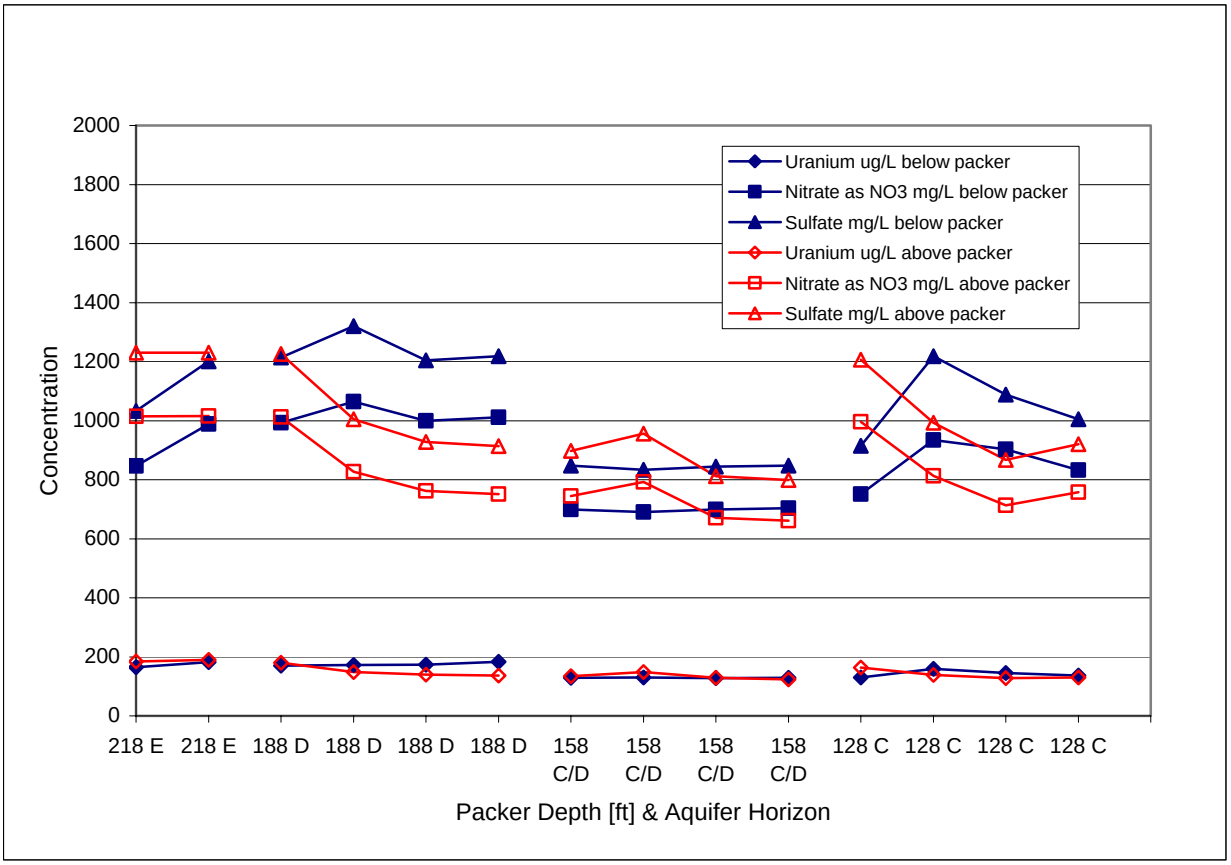


Figure 9. Well 1107 Packer Test Results for March 2004

Under the given test conditions (excluding Test 1), the middle test interval (Test 3, lower portion of Horizon C) apparently is less contaminated than those above and below, with no recognizable "base" of contamination. Discrete depth samples at adjacent monitor well 273, which is screened in Horizon D between 153 and 173 ft, identify only limited contamination at this location (185 mg/L nitrate as N, <250 mg/L sulfate, and 0.06 mg/L uranium). These concentrations are much lower than any observed in the well 1107 tests and attest to significant contamination in an overlying horizon. Such a contrast or transition of concentration in vertical profile is not recognized in the packer test results.

3.2 June 2004 Packer Tests

Packer tests were conducted again at well 1101 and at well 1106 on June 15 and 17, 2004, respectively, using a similar apparatus at that used in March 2004. However, condition of the June tests was to extract water from above and below the packer at approximately equal rates with submersible pumps to prevent possible flow stagnation in the sampling interval below the packer as may have resulted in the previous tests. Injection of buoyant glass spheres (11 to 17 micron diameter) below the packer during several tests attempted to seal the filter pack in the test interval.

3.2.1 Well 1101

Test 1 was conducted for 2 hours at a packer depth of 194 ft. The pumping rate above the packer varied between 3.8 and 5.5 gpm, while the lower pump maintained a rate of 4 gpm. Several bore volumes in total were extracted by the conclusion of the test, at which time concentrations above and below the packer were identical and unchanged from the initial condition (Figure 10).

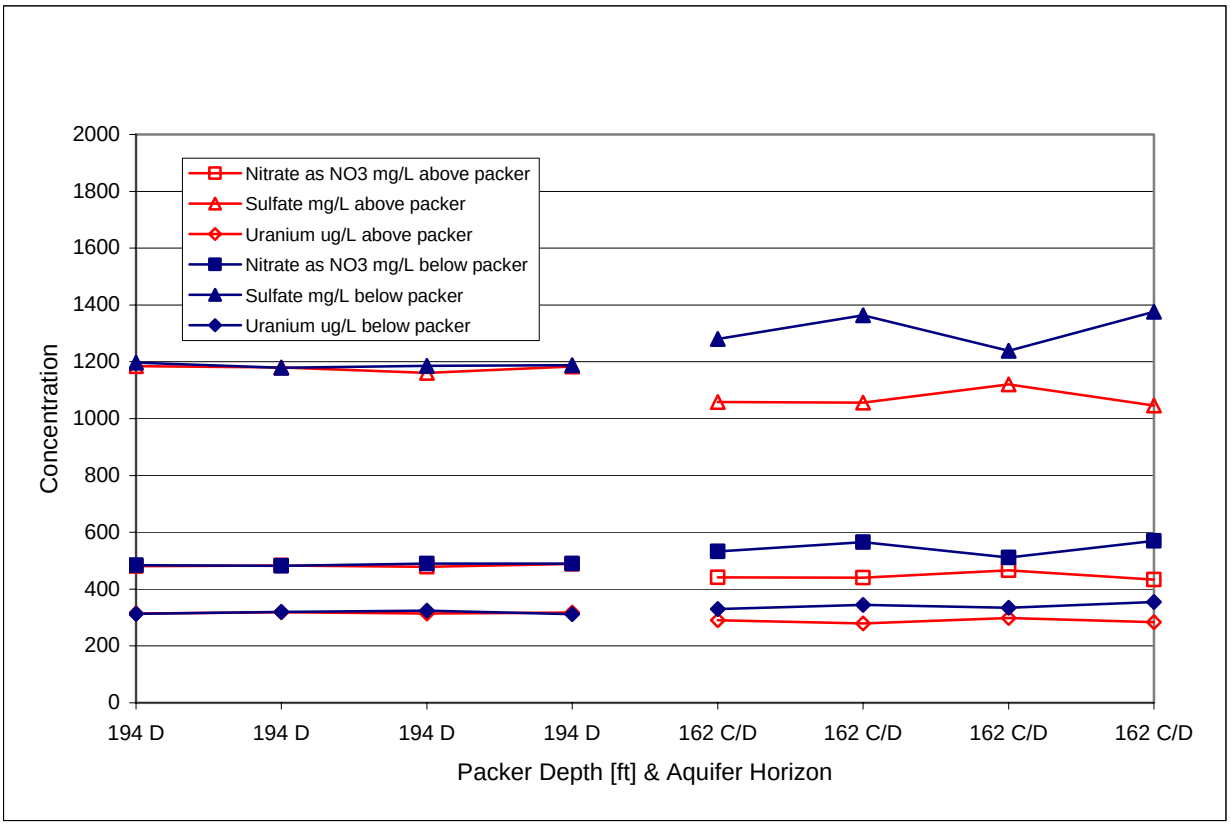


Figure 10. Well 1101 Packer Test Results for June 2004

With the packer raised 28 ft, Test 2 was conducted for 1.5 hours at pumping rates of 5.7 and 3.5 gpm, respectively, for the upper and lower pumps. Fifteen to 20 ft of drawdown resulted and about three bore volumes were extracted. Stable, distinct concentrations were maintained above and below the packer throughout this test. Based on this distinction, the interval above the packer at 162 ft apparently is less contaminated than below, a result vaguely consistent with Test 3, conducted at approximately the same depth, at well 1101 in March 2004.

An additional result of the tests conducted at well 1101 in June 2004 was the occurrence of air and glass spheres in the discharge from the upper pump after their injection below the packer.

3.2.2 Well 1106

Four tests at 3 depth intervals were conducted at well 1106 in June 2004. The top of the packer was at 191 ft for Tests 1 and 2, 162 ft for Test 3, and 131 ft for Test 4. The duration of Test 1 was 1.5 hrs. Pumping from above and below the packer was reduced from 2.5 gpm initially to

1.7 gpm later in the test, totaling 1.3 bore volumes of water extracted, and producing 60 ft drawdown, equivalent to a pumping level in the upper part of Horizon D. In Test 2, the upper and lower pump discharge was initially 1.2 gpm each, and later reduced to 0.7 gpm, reducing the drawdown in the extraction well by about 45 ft compared to Test 1. The volume of water extracted equaled about 0.6 bore volumes. Figure 11 illustrates slightly increasing concentrations during Tests 1 and 2 conducted at 191 ft.

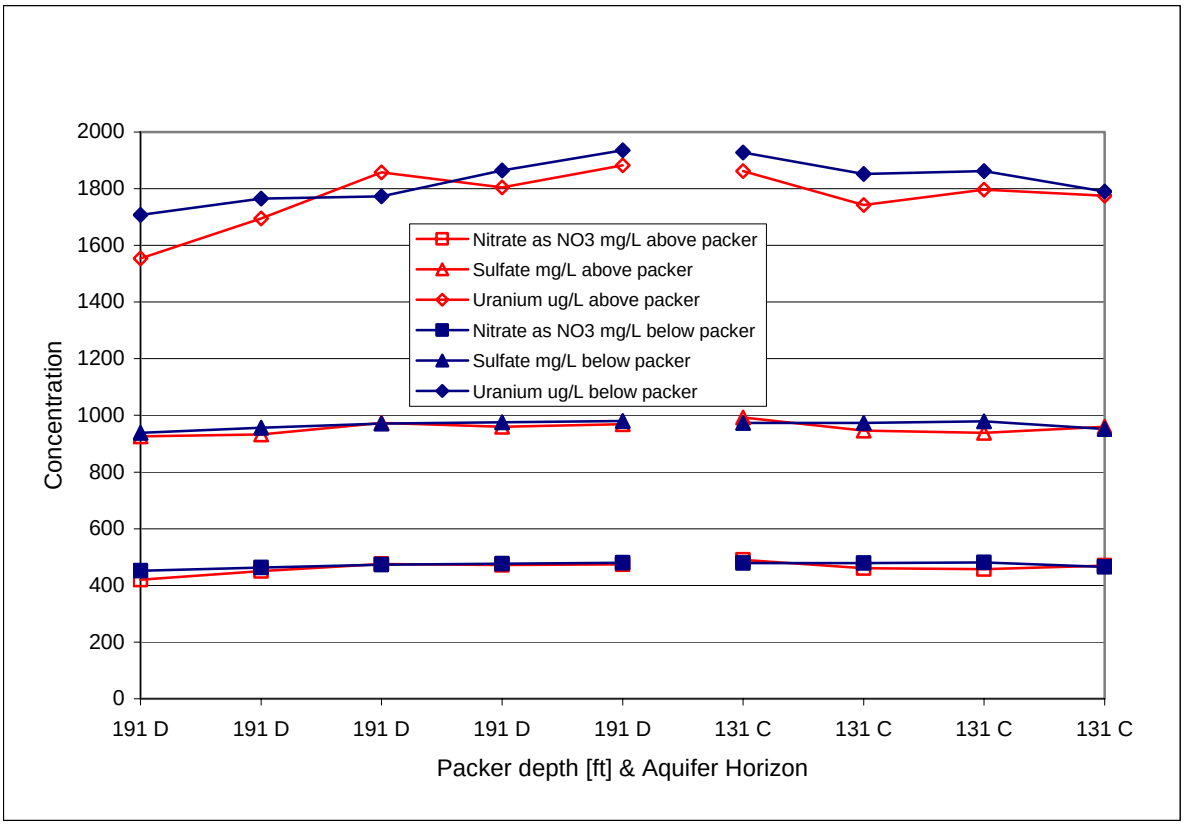


Figure 11. Well 1106 Packer Test Results for June 2004

In Tests 3 and 4, pumping rates were steady at 0.7 gpm above and below the packer, resulting in drawdown of only 1 to 2 ft. Each test extracted about one-half of a bore volume. Samples were not collected during Test 3. By the end of Test 4, concentrations had declined slightly to be only marginally greater than Test 1 starting values (Figure 11). Very similar and stable concentrations above and below the packer throughout each test conducted at well 1106 may indicate similar and homogeneous water composition in the intervals tested or thorough mixing in the region of the pump intakes of dissimilar waters. Air and glass spheres were also observed in the discharge from the upper pump after their injection below the packer during the tests conducted at this well.

3.3 Discussion of Packer Test Results

Results of the March and June 2004 packer tests are ambiguous in resolving the vertical distribution of contamination within the screened intervals of the test wells. Interpretation of test results is problematic for four reasons: (1) incomplete purging of the test interval (below the packer), particularly for several of the tests conducted at the deepest interval; (2) excessive drawdown, resulting in shallow ground water entering a well at an artificially low position relative to ambient or low-stress conditions; (3) non-steady pumping during and between tests at a given well that could result in transient contaminant input from different inflow zones; and (4) the water produced during a given test may simply originate from above the packer, whereas the sample below the packer is drawn from a zone of stagnant water (Figure 12) of unknown origin. This last reason questions the assumption of upward flow past the packer. Preferred flow past the packer could be a cause of stagnation in the lower zone. The air and glass spheres observed in the upper pump discharge attest to such a flow conduit, likely occurring as an annulus between packer and inner vertical rods of the well screen (Figure 13).

4.0 Technology Review

Several broad approaches are available to characterize contaminant profiles utilizing existing long-screened wells. These are (1) aquifer isolation methods, (2) geophysical and hydrophysical logging, and (3) discrete depth, multilevel sampling (Taylor 1990). These technologies are briefly reviewed for their potential application to the Tuba City site for future work in characterizing the vertical distribution of contamination.

4.1 Aquifer Isolation

Inflatable packers are routinely used to isolate specific depth intervals for various testing purposes. Without innovation, packers are best suited for open-hole conditions in stable formations and have limited value in isolating sections of screened wells because the gravel pack remains unaffected (Sukop 2000). Packers may be used singly or paired to straddle a specific interval.

Use of a temporary sealant, such as guar gel, to isolate portions of an aquifer has potential application to the Tuba City site. The sealant could be injected into the filter pack from the interval of a straddle packer. Presumably, the guar would also seal the annulus between packer and vee-wrap screen but the final disposition of the sealant would not be certain. Later injection of a specific enzyme decomposes the guar seal.

4.2 Downhole Logging

Radiometric logging to characterize uranium distribution was previously evaluated for the site and determined to be infeasible because dissolved uranium concentrations in the ground water are too low.

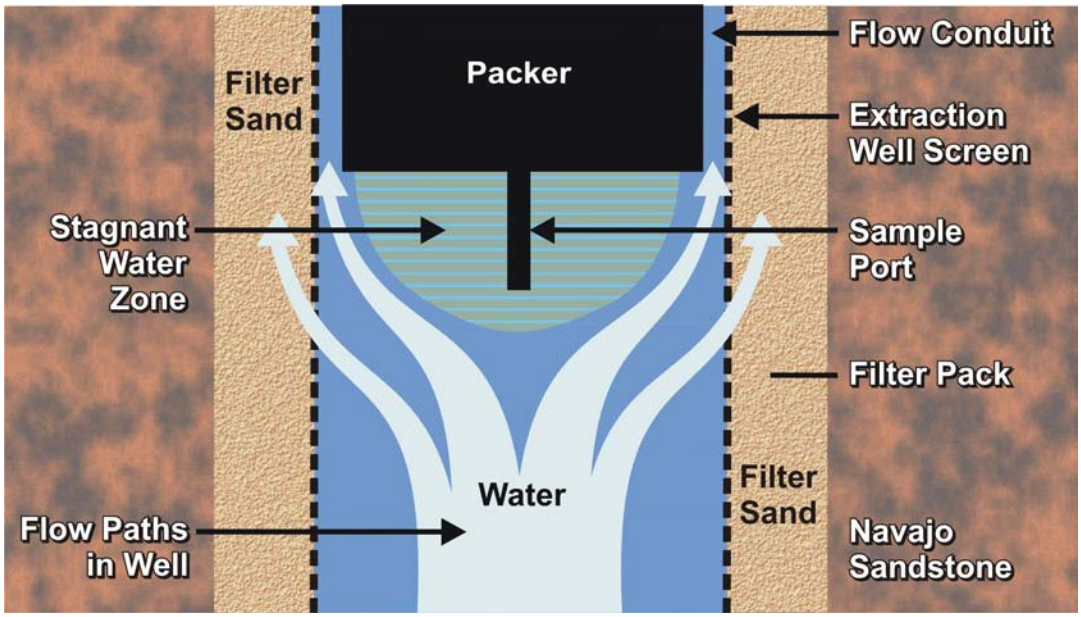


Figure 12. Hypothetical Stagnant Flow Zone Beneath Packer

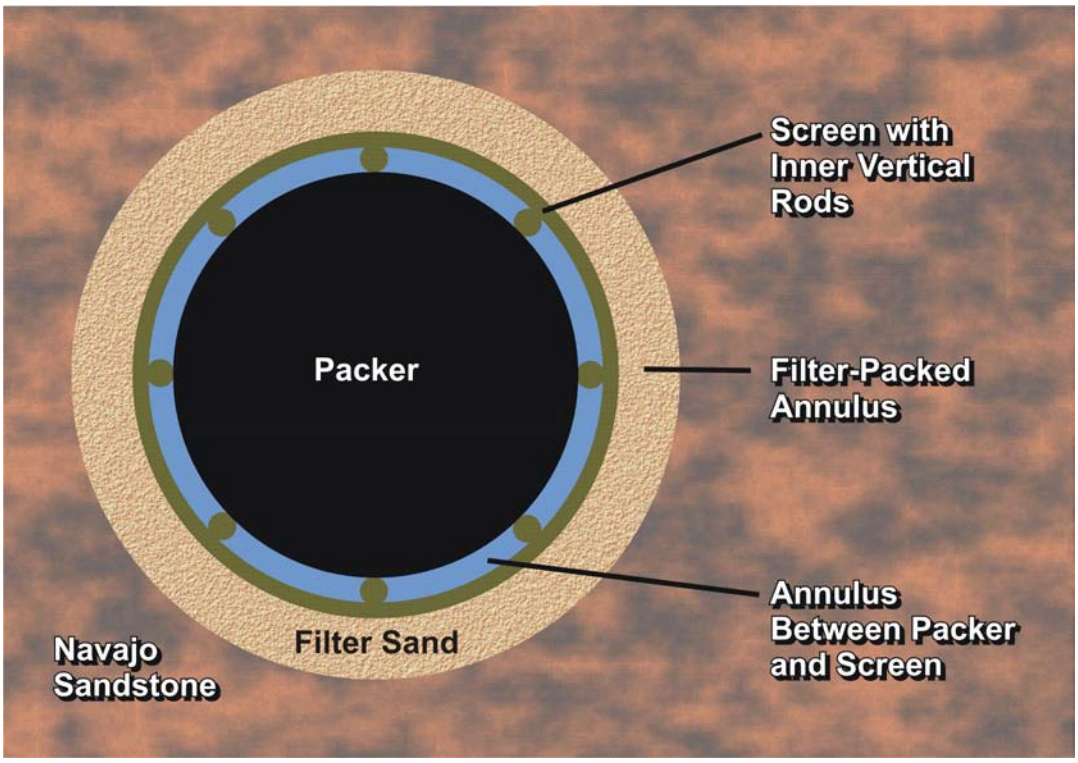


Figure 13. Cross-Section Schematic of Well Bore

Hydrophysical logging is a feasible technology that involves replacing the initial water in the well bore with distilled water and then recording electrical conductivity profiles over time as formation water enters the well and displaces the control water. Tests are conducted either under ambient or low stress conditions to identify inflow zones. Contamination is identified by the conductivity signature or by accompanying multilevel sampling. Hydrophysical logging was successfully employed previously at the site but for a different purpose.

The logging of vertical flow within the well under ambient or low flow conditions using heat pulse or electromagnetic induction is feasible. Impeller flow logging is feasible only at high flow rates. If conducted under pumping conditions, ground water extraction is steady and stationary from either top or bottom of the water column. The resulting flow log, in combination with accompanying discrete depth sampling, determines the position and quantity of inflow zones. By mass balance analysis, the composition of water from each inflow zone can be estimated.

4.3 Multilevel Sampling

Low flow purging and sampling at different depths under ambient flow conditions is not feasible because there is no assurance that the sample originates from formation adjacent to the sample collection intake. Additionally, strong vertical hydraulic gradients exist at the site over distances equivalent to the lengths of the extraction well screens; thus solute transport and mixing within the well bore is possible, which obscures the contaminant profile (Church 1996). This condition also limits passive, diffusion-type sampling methods. Multilevel sampling under mildly stressed, low-flow conditions is feasible if steady pumping is from the top of the water column and well bore purging is sufficient to remove the initial volume of water present in the well bore.

5.0 Summary and Conclusions

- Conditions under which the March and June 2004 packer tests were conducted lead to an ambiguous interpretation of the results.
- Evidence independent of the packer tests suggests that ground water contamination does not extend below the depth of the extraction wells.
- Contamination of Horizon D is much less extensive than in Horizons A and B.
- The extraction system captures the base of contamination.
- Vertical capture of uncontaminated ground water may be excessive at many extraction wells depending on the proportion of inflow from the various horizons, which is unknown.

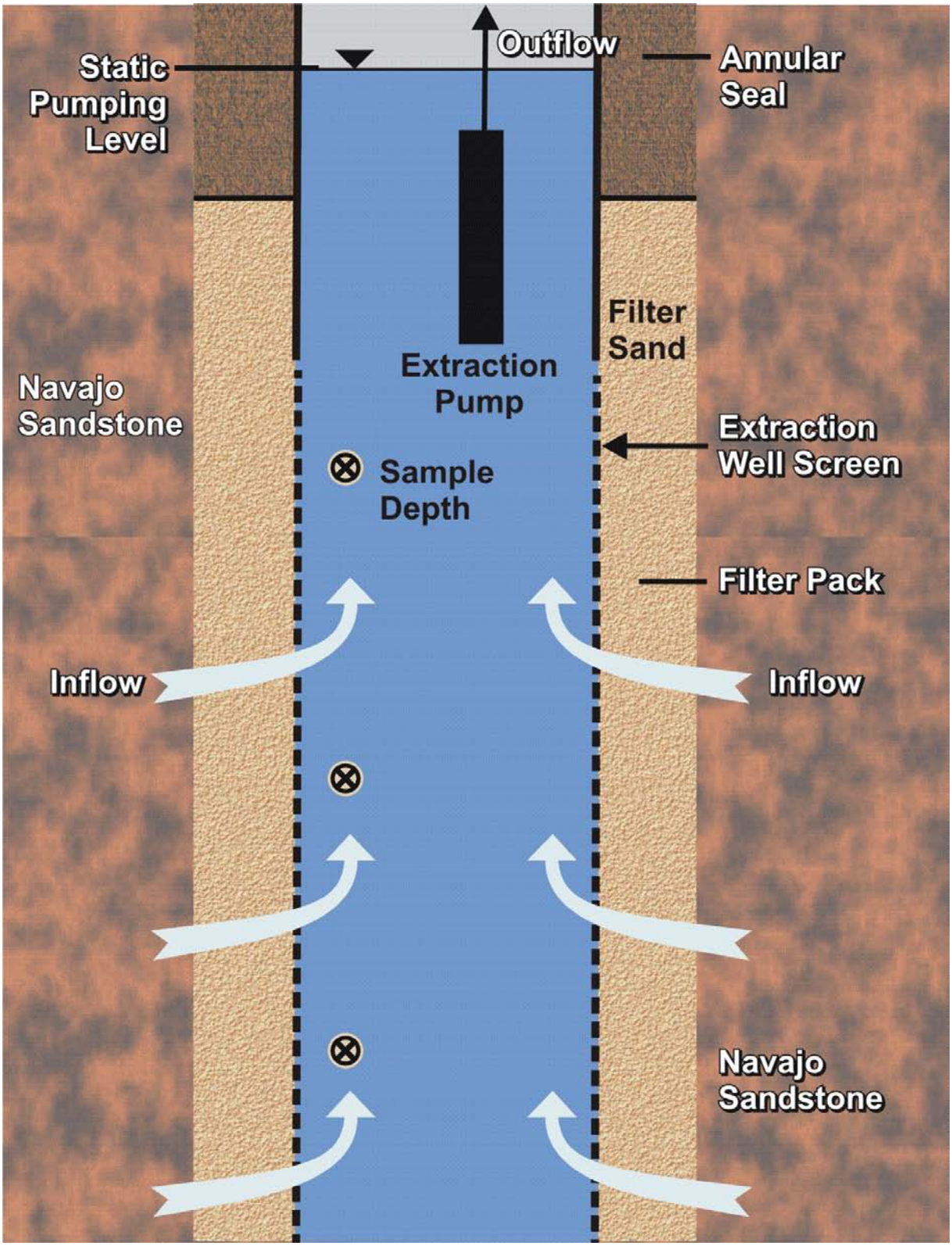


Figure 14. Conceptual Test Design

6.0 Recommendations

- Modifying the extraction wells based on the findings of this report is not recommended.
- Additional field tests to determine vertical flow and contamination profiles may justify extraction well modification on a well-by-well basis. Initial testing would occur at wells on the periphery of the extraction field that exhibit low concentrations of contaminants.
- Additional tests based on multilevel sampling and flow logging under low-flow pumping conditions are recommended. After full water level recovery in the extraction well, small-diameter bladder pumps placed at various depths (e.g., lower, middle, and upper portions of Horizon D) would monitor water quality as pumping occurred from the top or bottom of the water column. Raising the sample ports while maintaining the same flow would facilitate investigation of the upper portions of the screen interval. Flow logging of the entire depth interval would be performed either before or after sample collection. Figure 14 illustrates the conceptual test design.

7.0 References

U.S. Department of Energy (DOE) 2004. *Analysis of Contaminant Rebound in Ground Water on Extraction Wells at the Tuba City, Arizona, Site*, Environmental Sciences Laboratory, DOE−LM/GJ625−2004, ESL−RPT−2004−04, prepared for the U.S. Department of Energy Office of Legacy Management, Grand Junction, Colorado, April.

———, 2005. *Annual Performance Evaluation of Ground Water Remediation from March 2004 Through March 2005 at the Tuba City, Arizona, Disposal Site*, DOE−LM/GJ881−2005, prepared for the U.S. Department of Energy Office of Legacy Management, Grand Junction, Colorado, June.

Church, P.E. and G.E. Granato, 1996. "Bias in Ground-Water Data Caused by Well-Bore Flow in Long-Screen Wells," *Ground Water*, vol. 34, No. 2, March-April.

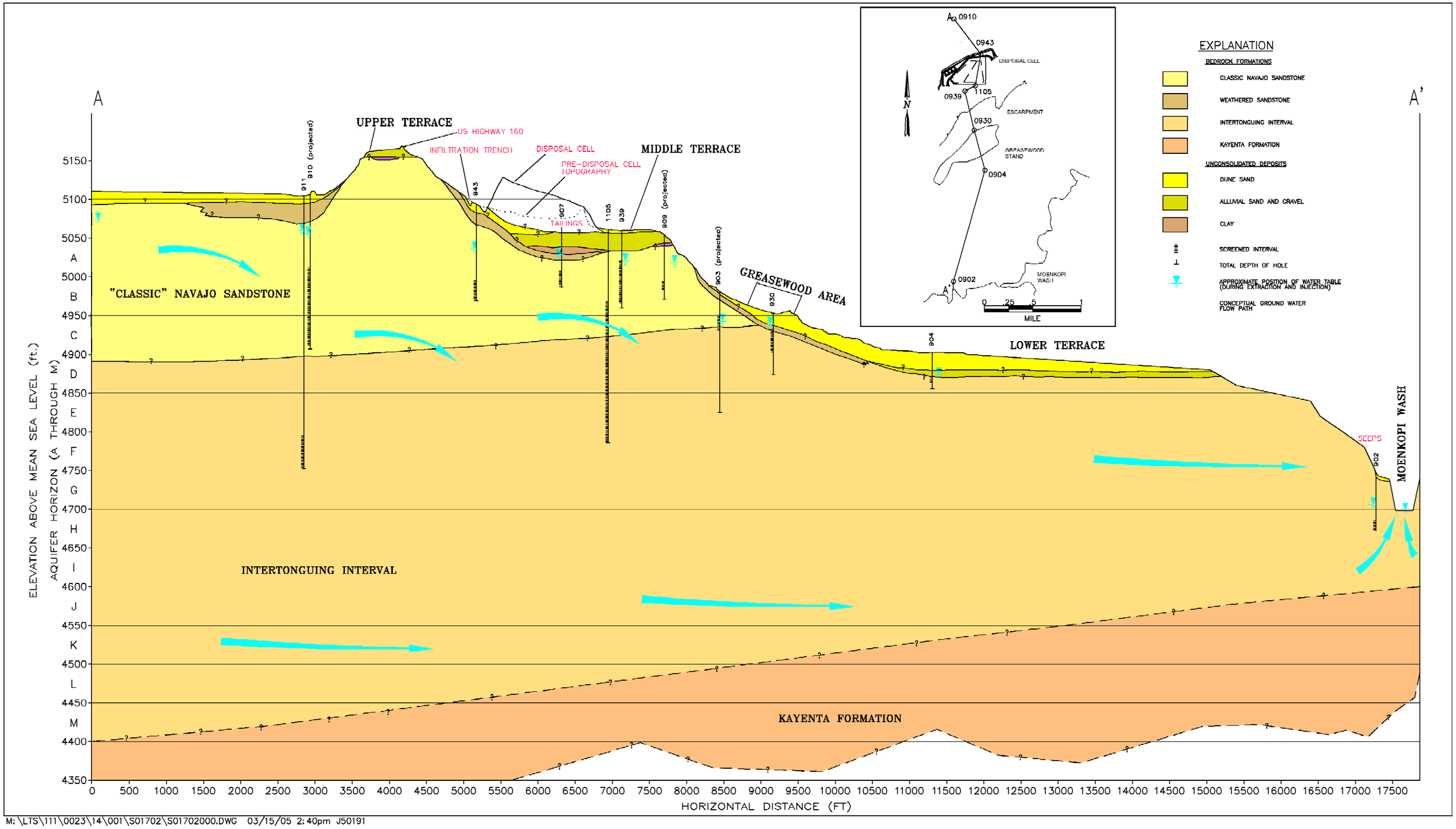
Sukop, M.C., 2000. "Estimation of Vertical Concentration Profiles from Existing Wells," *Ground Water*, vol. 38, No. 6, November-December, pp. 836-841.

Taylor, K., J. Hess, A. Mazzella, and J. Hayworth, 1990. "Comparisons of Three Methods to Determine the Vertical Stratification of Pore Fluids," *Ground Water Monitoring and Remediation*, vol. 10, No. 1, Winter.

End of current text

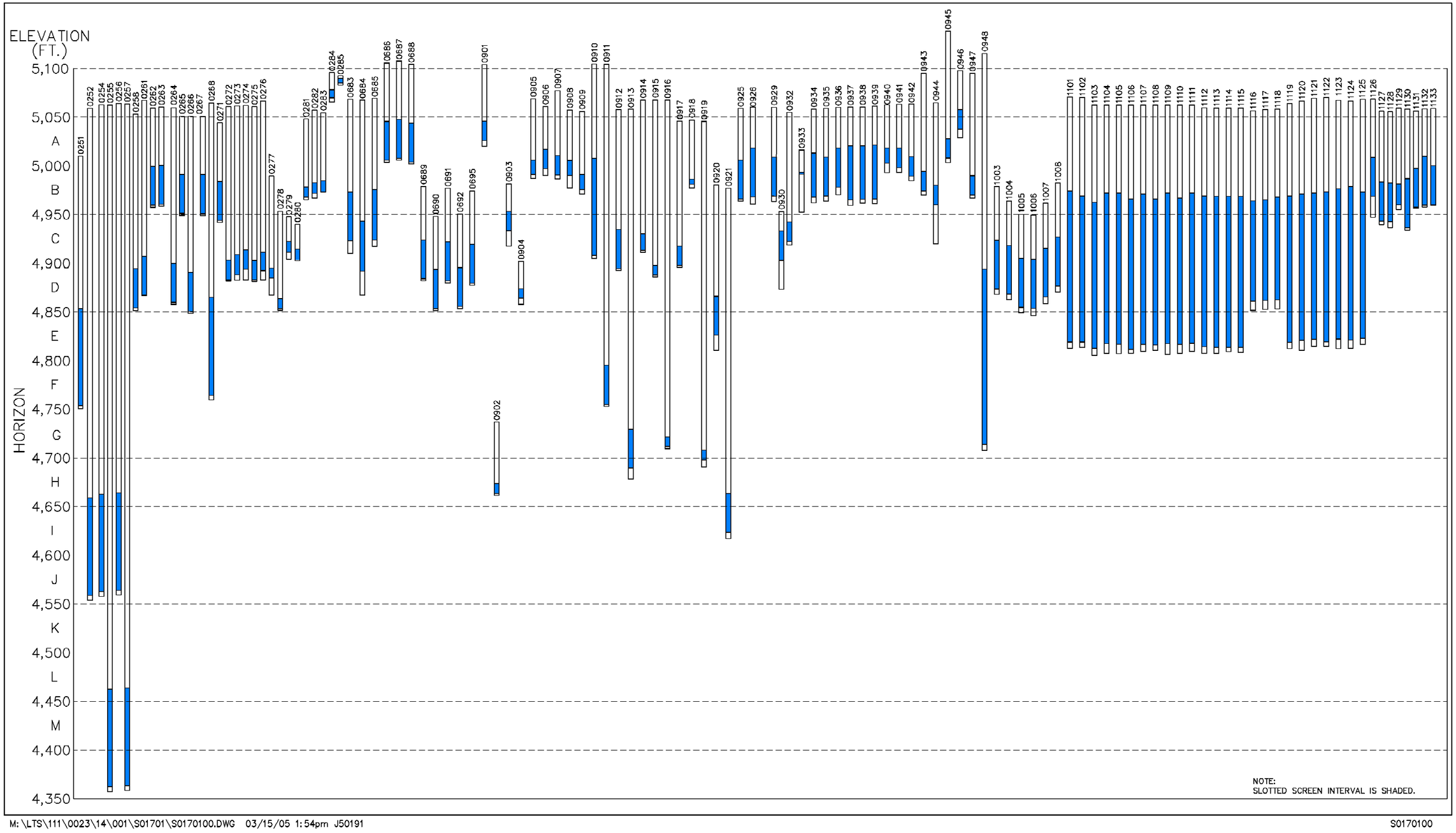
Appendix A

Additional Figures



M:\LTS\111\0023\14\001\S01702\S01702000.DWG 03/15/05 2:40pm J50191

Figure A–1.


ELEVATION
(FT.)
5,100
5,050
A
5,000
B
4,950
C
4,900
D
4,850
E
4,800
F
4,750
G
4,700
H
4,650
I
4,600
J
4,550
K
4,500
L
4,450
M
4,400
4,350
HORIZON
NOTE:
SLOTTED SCREEN INTERVAL IS SHADED.
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S0170100

Figure A–2.

Appendix B

Packer Test Field Data

Well 1101—March 2004
Well 1107—March 2004
Wells 1101 and 1106—June 2004

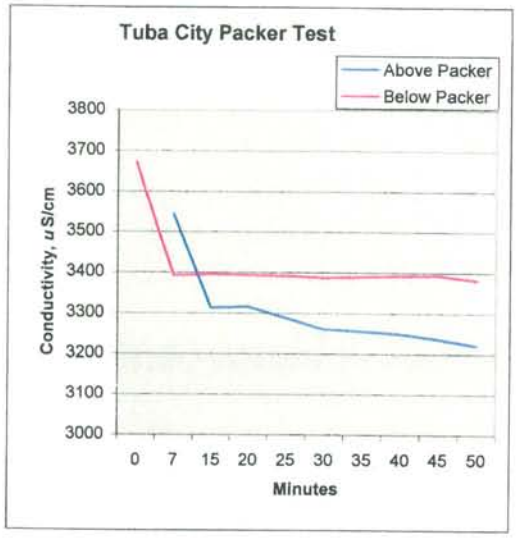
Well 1101—March 2004

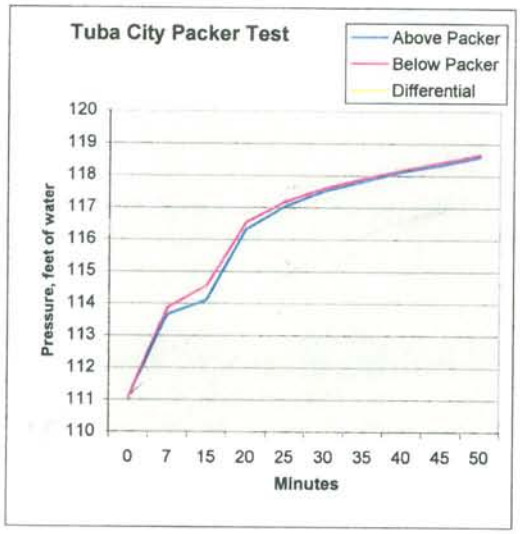
Tuba City Well 1101

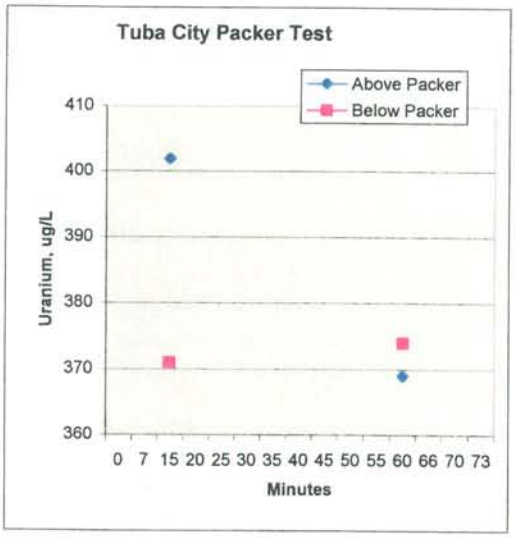
Date	Well	No	B/T	Time	Uranium	Chloride	Nitrate	Sulfate
3/9/2004	1101	1	B	9:55	371	81	511	1,259
3/9/2004	1101	1	T	9:55	402	85	544	1,361
3/9/2004	1101	1	B	10:40	374	83	524	1,302
3/9/2004	1101	1	T	10:40	369	80	500	1,237
3/9/2004	1101	2	B	13:35	378	85	536	1,316
3/9/2004	1101	2	T	13:35	370	89	575	1,424
3/9/2004	1101	2	B	14:05	376	87	551	1,363
3/9/2004	1101	2	T	14:05	362	81	503	1,240
3/9/2004	1101	2	B	14:35	369	82	525	1,278
3/9/2004	1101	2	T	14:35	352	81	508	1,252
3/9/2004	1101	2	B	15:00	365	81	505	1,244
3/9/2004	1101	2	T	15:00	373	82	512	1,260
3/9/2004	1101	3	B	15:50	385	86	535	1,321
3/9/2004	1101	3	T	15:50	388	79	520	1,255
3/9/2004	1101	3	B	16:15	465	109	654	1,637
3/9/2004	1101	3	T	16:15	362	77	490	1,191
3/9/2004	1101	3	B	16:45	543	129	747	1,875
3/9/2004	1101	3	T	16:45	349	78	497	1,208
3/9/2004	1101	3	B	17:15	573	137	788	1,975
3/9/2004	1101	3	T	17:15	351	78	499	1,218
3/9/2004	1101	4	B	18:30	540	139	801	1,999
3/9/2004	1101	4	T	18:30	347	77	487	1,184
3/10/2004	1101	5	B	9:05	539	134	796	1,958
3/10/2004	1101	5	T	9:05	435	90	601	1,522
3/10/2004	1101	5	B	9:35	419	86	563	1,419
3/10/2004	1101	5	T	9:35	342	76	468	1,159
3/10/2004	1101	5	B	10:05	327	75	449	1,130
3/10/2004	1101	5	T	10:05	323	76	473	1,162
3/10/2004	1101	5	B	10:35	327	75	453	1,135
3/10/2004	1101	5	T	10:35	340	78	493	1,205

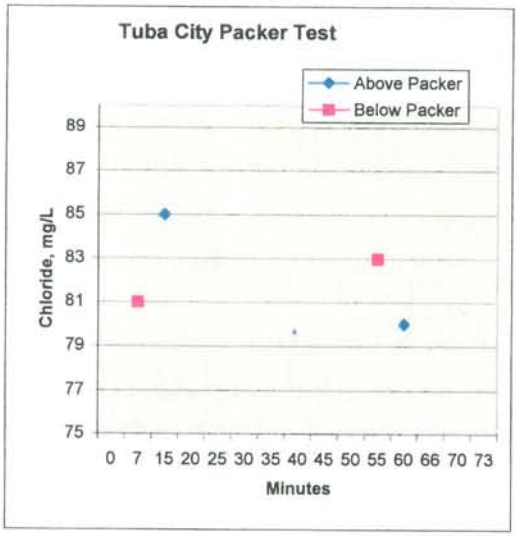
Tuba City Extraction Well Packer Test

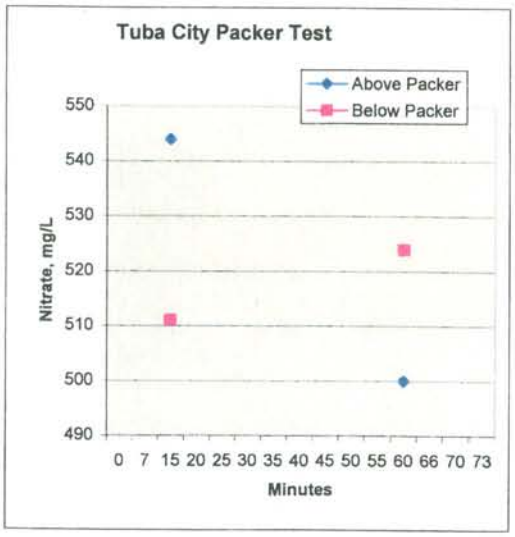
Date	03/09/04	Packer Depth	216.5 ft	Name	Jeff Price & Carl Jacobson
Well #	1101	Top of screen	100 ft		
		Above Packer Pressure with water at top of screen	ft		
Test #	1	Depth to water table	ft		

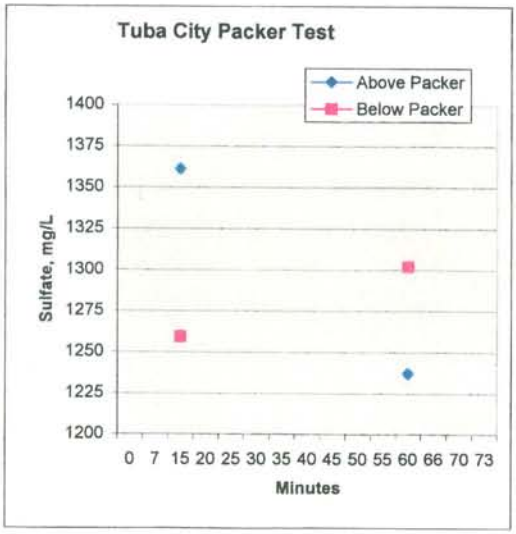






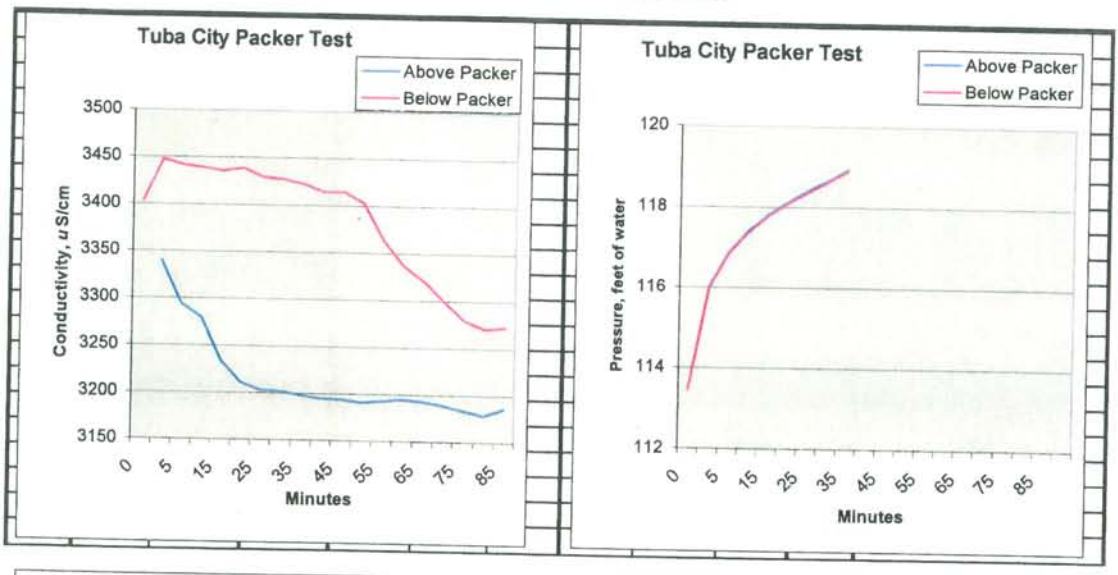


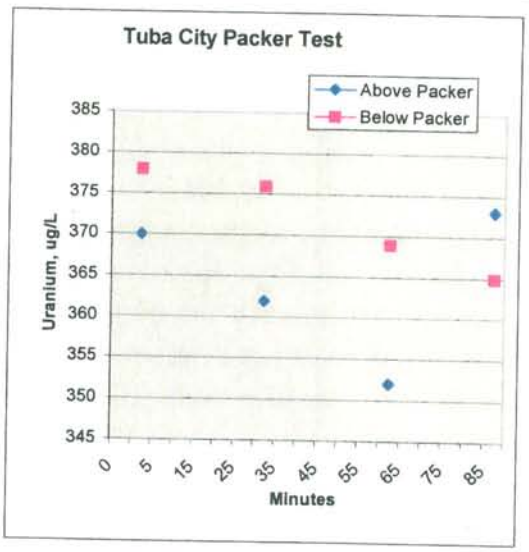


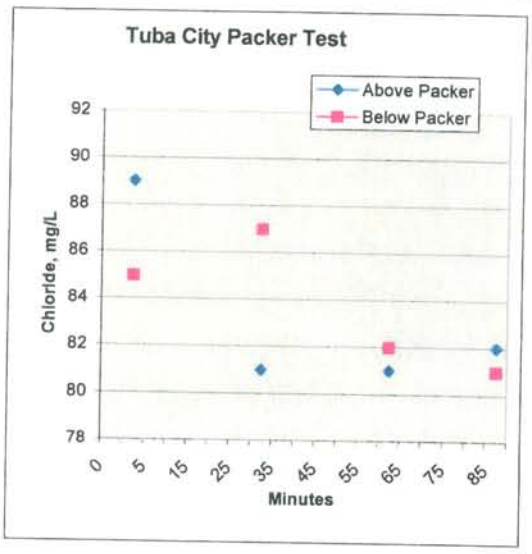


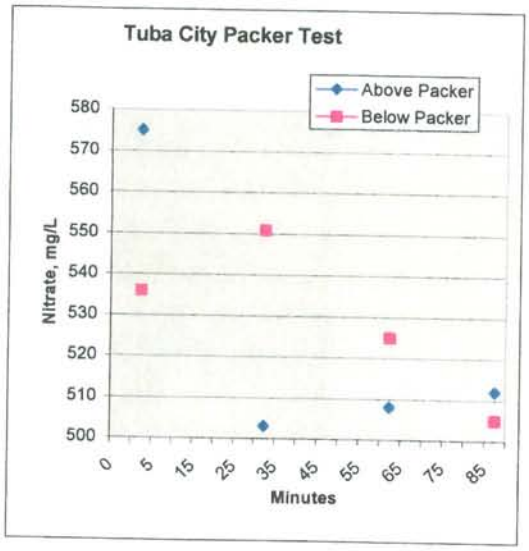
Tuba City Extraction Well Packer Test

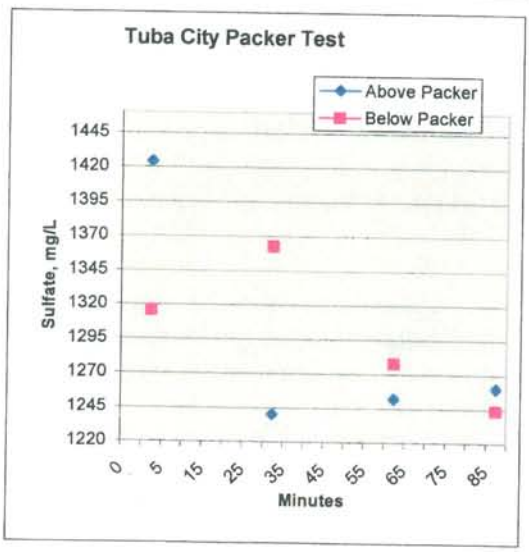
Date	03/09/04	Packer Depth	186.5 ft	Name	Jeff Price & Carl Jacobson
Well #	1101	Top of screen	100 ft		
Test #	2	Above Packer Pressure with water at top of screen	ft		
		Depth to water table	ft		





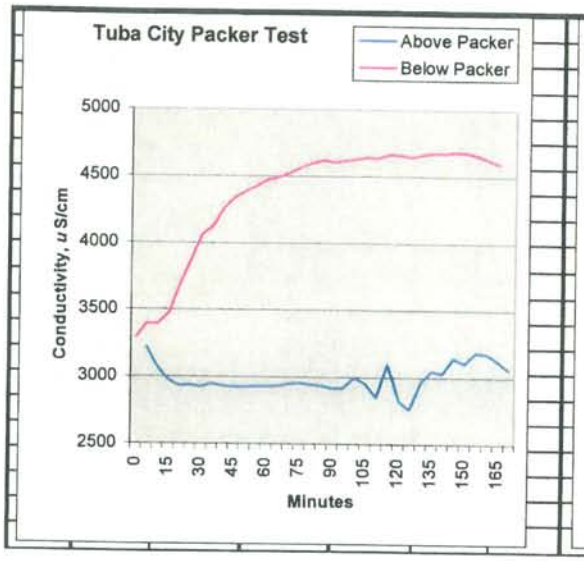


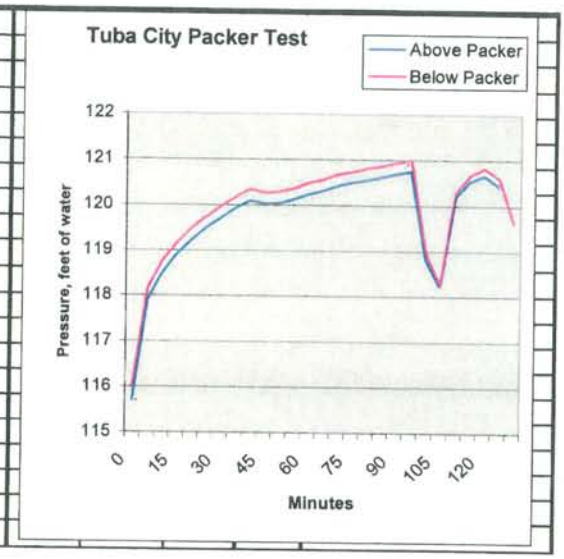


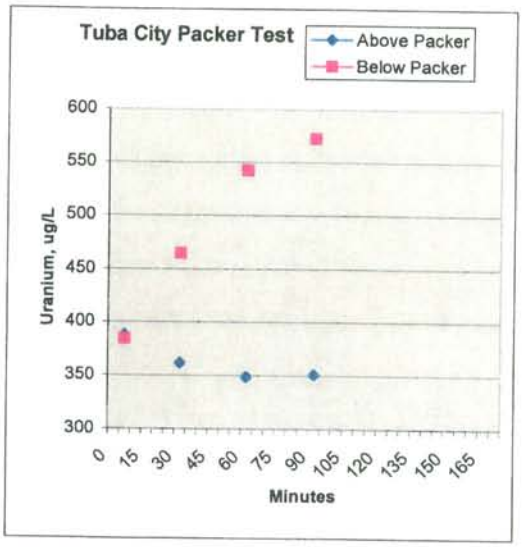


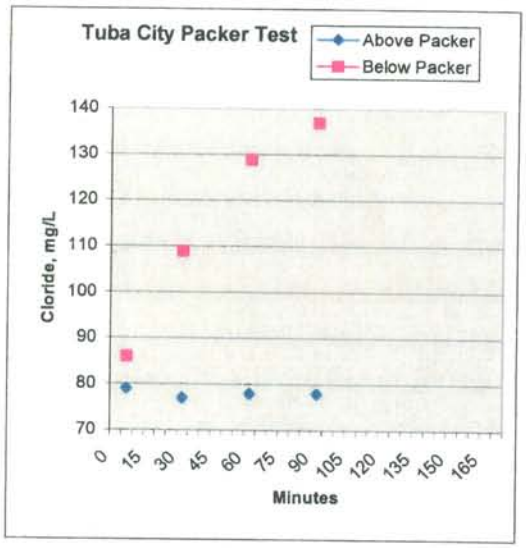
Tuba City Extraction Well Packer Test

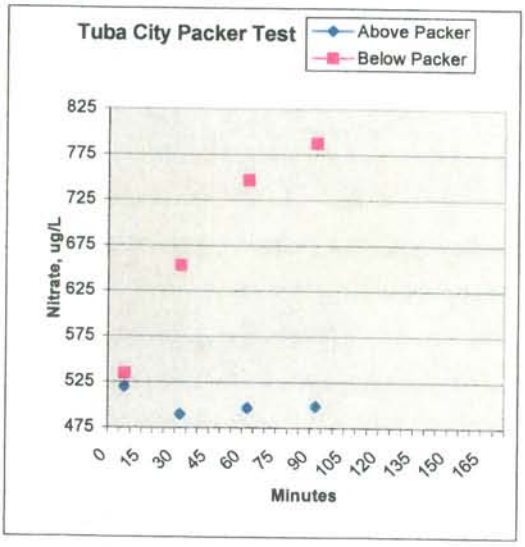
Date	03/09/04	Packer Depth	156.5 ft	Name	Jeff Price & Carl Jacobson
Well #	1101	Top of screen	100 ft		
Test #	3	Above Packer Pressure with water at top of screen	ft		
		Depth to water table	ft		

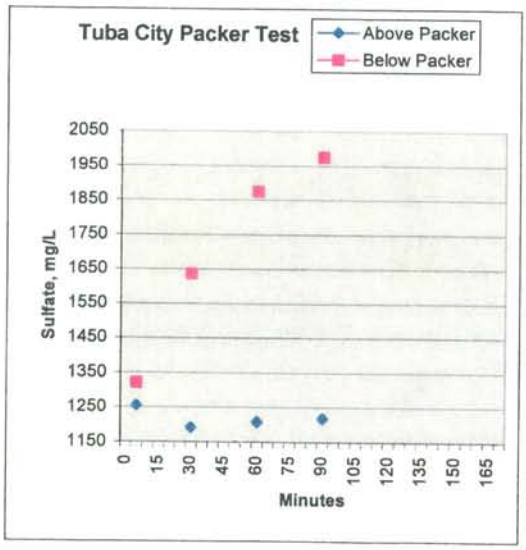












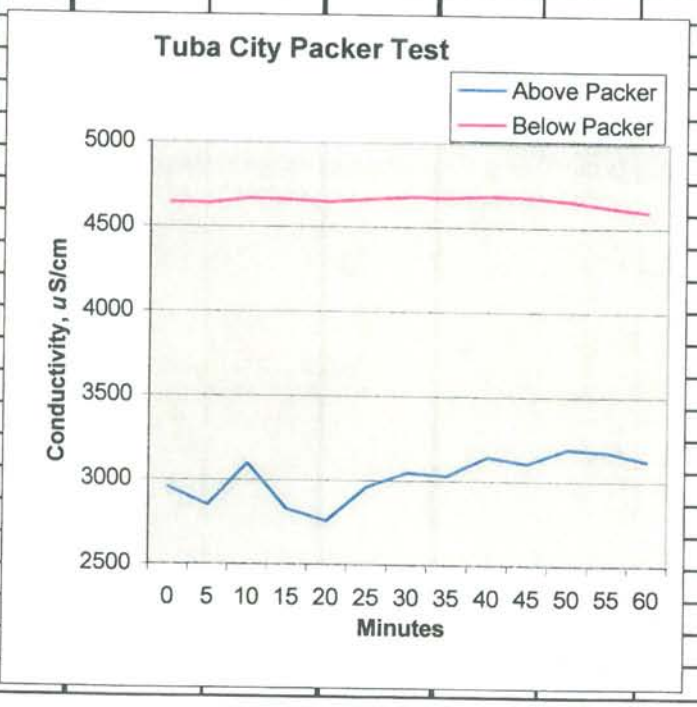
Tuba City Extraction Well Packer Test

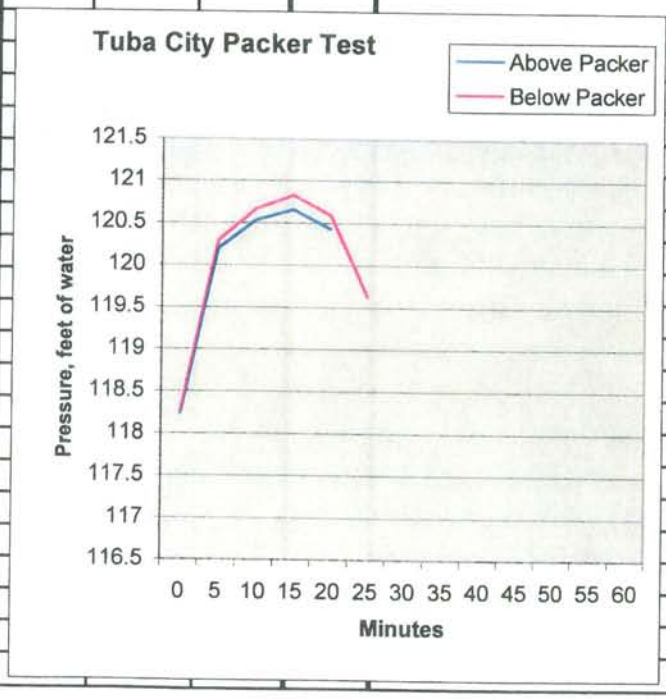
Date 03/09/04
Well # 1101
Test # 4

Packer Depth 156.5 ft
Top of screen 100 ft
Above Packer Pressure with water at top of screen ____ ft
Depth to water table ____ ft

Name Jeff Price & Carl Jacobson

Time	Well Pressure Above Packer ft	Well Pressure Below Packer ft	Flow Totalizer gallons	Extraction Pump Cond. u S/cm	Extraction Pump Temp F	Extraction Pump pH	Bladder Pump Cond. u S/cm	Bladder Pump Temp F	Bladder Pump pH	Air Press psi	Comment
17:30										10	
17:35	120.20			3034	16.78	6.99	4638	18.17	6.38	10	
17:40				2824	16.79	6.96	4666	18.12	6.39	15	
17:45				2758	16.79	6.95	4658	18.02	6.40	15	
17:50				2961	16.82	6.92	4646	17.92	6.40	17	
17:55				3042	16.81	6.92	4667	17.74	6.41	17	
18:00				3022	16.80	6.91	4676	17.67	6.40	17	
18:05				3091	16.73	6.91	4676	17.52	6.40	19	
18:10				3108	16.71	6.96	4683	17.07	6.40	20	
18:15				3175	16.71	6.98	4671	16.56	6.40	20	
18:20				3176	16.72	6.99	4834	15.99	6.40	18	
18:25				3095	16.76	7.00	4617	15.86	6.40	18	
18:30				3050	16.77	6.97	4578	15.67	6.41	16	Took sample



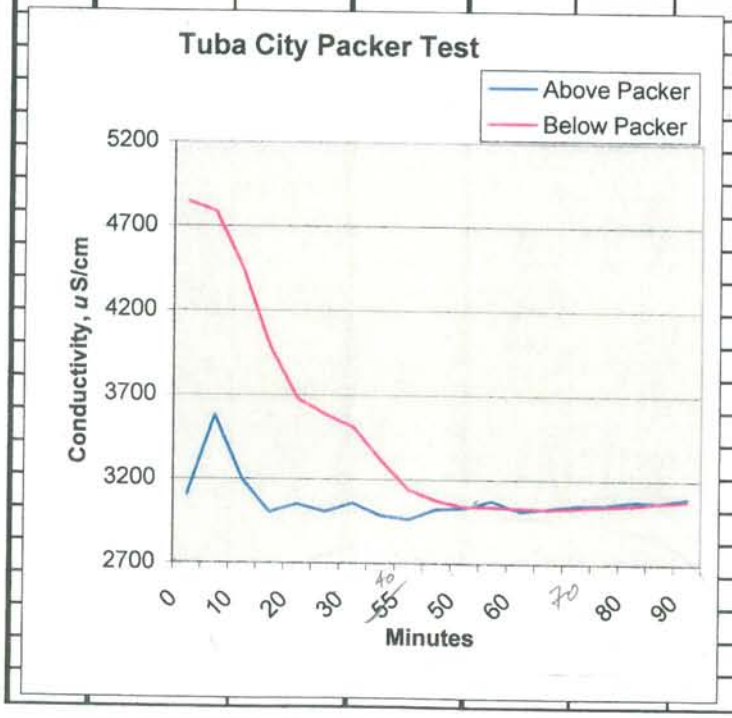


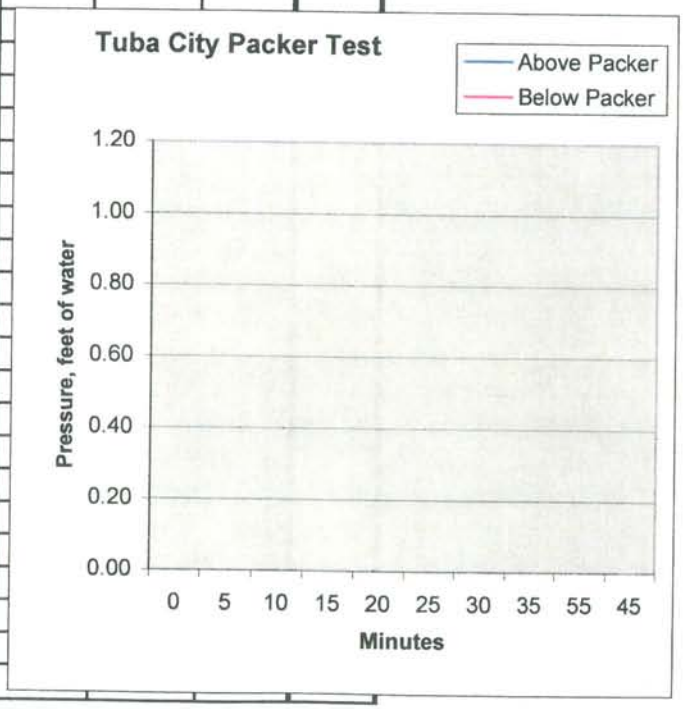
Tuba City Extraction Well Packer Test

Date	03/09/04	Packer Depth	126.5 ft	Name	
Well #	1101	Top of screen	100 ft		
Test #	5	Above Packer Pressure with water at top of screen	ft		
		Depth to water table	ft		

Time	Well Pressure Above Packer ft	Well Pressure Below Packer ft	Flow Totalizer gallons	Extraction Pump Cond. u S/cm	Extraction Pump Temp F	Extraction Pump pH	Bladder Pump Cond. u S/cm	Bladder Pump Temp F	Bladder Pump pH	Air Press psi
9:05				3103	15.72	7.75	4846	15.23	6.76	
9:10				3582	16.67	6.77	4788	15.90	6.69	
9:15				3200	16.56	6.10	4452	16.44	6.67	
9:20				3004	16.58	6.68	3983	16.73	6.69	
9:25				3054	16.78	6.70	3682	16.92	6.68	
9:30				3008	16.80	6.67	3585	17.39	6.64	
9:35				3060	16.82	6.72	3514	17.65	6.64	
9:40				2988	16.89	6.67	3316	18.38	6.68	
9:45				2965	16.87	6.68	3141	19.13	6.67	
9:50				3025	16.88	6.73	3077	19.81	6.69	
9:55				3030	16.93	6.84	3041	20.28	6.69	
10:00				3075	16.96	6.68	3040	20.83	6.67	
10:05				3014	16.97	6.67	3032	21.62	6.68	
10:10				3030	22.28	6.71	3028	16.97	6.67	
10:15				3051	16.98	6.68	3037	22.98	6.67	
10:20				3053	16.93	6.66	3047	23.55	6.67	
10:25				3074	17.02	6.65	3053	23.84		
10:30				3071	17.05	6.65	3069	24.47	6.69	
10:35				3096	17.06	6.66	3080	25.02	6.67	
9:47	-47.83	2720								
10:24	37.42	2930	5.61							
10:36	12.08	3007	6.37							

10° temp. increase
Specific conductance inc. w/ temp.





Tuba City Extraction Well Packer Test

Date 3/10/04 | Packer Depth 126.5 ft | Name JP & CJ

Well # 1101 | Top of screen ft

Test # 5 | Above Packer Pressure with water at top of screen ft

Depth to water table 109.83 ft

1101-5 T | 1101-5-13

Time	Well Pressure		Flow Totalizer gallons	Extraction Pump			Bladder Pump			Air Flow ?	Comment
	Above Packer ft	Below Packer ft		Cond. uS/cm	Temp F	pH	Cond. uS/cm	Temp F	pH		
9:05				3103	15.72	7.75	4846	15.23	6.76		Started bladder pump
9:10				3582	16.67	6.77	4789	15.90	6.69		Took sample
9:15				3200	16.56	6.16	4457	16.44	6.67		
9:20				3054	16.59	6.68	3993	16.73	6.69		WL 116.7
9:25				3054	16.79	6.70	3682	16.92	6.68		WL 117.15
9:30				3008	16.90	6.67	3595	17.39	6.64		
9:35				3060	16.82	6.72	3514	17.65	6.64		Took sample
9:40				2988	16.89	6.67	3316	18.38	6.68		
9:45		9:47:10	32720	2965	16.87	6.68	3141	19.13	6.67		
9:50				3025	16.80	6.73	3077	19.81	6.69		
9:55				3030	1643	6.94	3041	20.29	6.69		
10:00				3075	16.96	6.68	3040	20.83	6.67		WL 115.85
10:05				3014	16.97	6.67	3032	21.62	6.68		Took sample
10:10				3030	22.29	6.71	3028	16.97	6.67		
10:15		35		3051	16.98	6.68	3037	22.98	6.67		
10:20		10:38:50	32930	3053	16.93	666	3047	23.55	6.67		
10:25				3074	17.02	6.65	3053	23.84	23.86		
10:30				3071	17.05	6.65	3069	24.47	6.69		
10:35		10:36:40	33007	3096	17.06	6.66	3050	25.02	6.67		WL 120.05 Took sample

Tuba City Extraction Well Packer Test

Date 3/10/04
Well # 1101
Test # 6

Packer Depth 126.5 ft
Top of screen ____ ft
Above Packer Pressure with water at top of screen ____ ft
Depth to water table 109.88 ft

Name JP & CJ

Time	Well Pressure		Flow Totalizer gallons	Extraction Pump			Bladder Pump			Air Flow ?	Comment
	Above Packer ft	Below Packer ft		Cond. uS/cm	Temp F	pH	Cond. uS/cm	Temp F	pH		
10:35										0	at 120.05
											aborted test pump would not run with air

Tuba City Extraction Well Packer Test

Date 3/9/04 | Packer Depth 216'6" ft | Name CJ/JP

Well # 1101 | Top of screen ft

Test # 1-X | Above Packer Pressure with water at top of screen ft

Depth to water table 111.04 ft

Time	Well Pressure		Flow	Extraction Pump			Bladder Pump			Air	Comment
	Above Packer ft	Below Packer ft	Totalizer gallons	Cond. uS/cm	Temp °C	pH	Cond. uS/cm	Temp °C	pH	Flow ?	
1155			407030								
945							3902	16.02C	7.21		
952	111.64	111.64		3,5449	16.24	7.04	3424	16.36	651		Started pump 9:52
1000			407067	3313	17.38	6.85	3400	16.48	6.52		
1005			407086	3316	17.71	6.88	3396	16.66	6.55		
1010	117.18	117.03		3284	17.95	6.88	3390	16.81	6.64		≃ 4 gpm
1015				3261	17.81	6.87	3392	16.82	6.57		
1020			407095	3256	18.67	6.90	3394	16.94	6.53		
1025				3249	18.24	6.88	3385	17.30	6.57		
1030			407100	3237	18.81	6.89	3391	17.40	6.58		water depth 118.55'
1035				3221	19.17	6.85	3397	17.54	6.54		
1040				3221	19.09	6.90	3396	17.79	6.54		Sampled 10:45
1045				3213	19.45	6.90	3391	18.03	6.59		well bore = 290 l/ft
1050				3211	19.54	6.92	3373	1811	6.58		
1055				3210	19.19	6.91	3360	18.29	6.57		Power outage 10:59 shut down test and moved to test #2

Tuba City Extraction Well Packer Test

Date 3/9/04
Well # 1101-X2
Test # ~~1-b~~ 2

Packer Depth 186'4" ft
Top of screen ft
Above Packer Pressure with water at top of screen ft
Depth to water table ~~111.84~~ ft 111.10
1101-BD 1101-17

Name CS/SP

Time	Well Pressure Above Packer ft	Well Pressure Below Packer ft	Flow Totalizer gallons	Extraction Pump Cond. uS/cm	Extraction Pump Temp F/C	Extraction Pump pH	Bladder Pump Cond. uS/cm	Bladder Pump Temp F	Bladder Pump pH	Air Flow ?	Comment
~~1155~~											
1330			4731150	3352	7.09	16.63	3448	19.6	6.77		Bladder pump start 13:19
1335				3334	6.96	16.64	3443	19.24	6.70		Pump on @ 13:30
1340				3297	16.70	6.89	3443	19.16	6.66		Took sample
1345		1344→ 31730		3275	16.78	6.86	3432	19.14	6.62		
1350				3231	16.86	6.87	3432	19.37	6.59		Water level 117.6
1355				3211	16.82	6.86	3436	19.24	6.60		
400 ~~1360~~				3204	16.76	6.86	3430	19.04	6.59		WL = 118.3
1405				3202	16.74	6.86	3424	19.07	6.57		Took sample
1410			4731380	3198	16.74	6.86	~~3498~~ 3423	18.99	6.57		WL 118.95
1415				3195	16.90	6.86	3412	19.30	6.55		
1420				3192	16.91	6.86	3413	19.53	6.54		
1425				3191	16.91	6.87	3397	19.67	6.54		
1430				3194	16.90	6.87	3349	19.67	6.55		WL = 119.7
1435				3195	16.95	6.86	3324	19.67	6.55		Took sample
1440				3192	16.96	6.86	3318	19.65	6.55		WL = 120.1
1445				3187	16.89	6.86	3287	19.59	6.56		Adjusted valve to hold @ 120
1450				3185	16.95	6.86	3271	19.54	6.55		WL = 120.1
1455				3178	16.90	6.86	3282	19.51	6.54		
1500				3185	16.93	6.86	3266	19.45	6.54		Took sample WL = 120.3

Tuba City Extraction Well Packer Test

Date 3/9/04
Well # 1101
Test # 3

Packer Depth 156.45 ft
Top of screen ____ ft
Above Packer Pressure with water at top of screen ____ ft
Depth to water table ____ ft
1101-3B 1101-3T

Name JP & CJ

Time	Well Pressure Above Packer ft	Well Pressure Below Packer ft	Flow Totalizer gallons	Extraction Pump Cond. uS/cm	Extraction Pump Temp F C	Extraction Pump pH	Bladder Pump Cond. uS/cm	Bladder Pump Temp F	Bladder Pump pH	Air Flow ?	Comment
1545				3106	17.18	7.20	3412	21.43	6.54		Took sample
1550	5		31720	3057	16.74	7.18	3392	21.53	6.53		WL = 117.1
1555				2965	16.81	7.13	3393	21.38	6.52		WL = 118.5
1600				2933	16.77	7.10	3508	21.39	6.51		WL = 118.9
1605				2941	16.90	7.08	3740	21.25	6.48		WL = 119.2
1610				2925	16.87	7.07	3920	21.78	6.48		WL = 119.25
1615	30		31860	2947	16.86	7.05	4071	20.97	6.45		Took sample
1620				2933	16.84	7.05	4155	21.58	6.44		
1625		1627 →	31930	2923	16.93	7.02	4288	21.44	6.43		WL = 120.2
1630				2941	16.88	7.01	4338	21.62	6.41		WL = 120.0 reduced flow by half
1635				2929	16.89	6.99	4433	20.69	6.42		
1640				2926	16.88	6.99	4433	20.66	6.42		WL = 120.2
1645	60			2961	16.89	6.97	4472	20.40	6.41		Took sample
1650				2957	16.87	6.97	4509	20.60	6.41		
1654				2946	16.88	6.97	4536	20.73	6.40		
1700				2947	16.85	6.96	4568	20.88	6.40		
1705				2947	16.83	6.96	4602	20.42	6.39		WL = 120.6
1710		1712	32154	2915	16.81	6.96	4617	19.90	6.40		5.0 gpm
1715	90			2920	16.83	6.97	4608	19.67	6.39		Took sample

Tuba City Extraction Well Packer Test

Date 3/9/04
Well # 1101
Test # 4

Packer Depth 156.5 ft
Top of screen ____ ft
Above Packer Pressure with water at top of screen ____ ft
Depth to water table ____ ft

Name JP & CJ

Time	Well Pressure: Above Packer ft	Well Pressure: Below Packer ft	Flow Totalizer gallons	Extraction Pump: Cond. uS/cm	Extraction Pump: Temp F	Extraction Pump: pH	Bladder Pump: Cond. uS/cm	Bladder Pump: Temp F	Bladder Pump: pH	Pressure Air Flow psi	Comment
1730											started adding air
1735		5:37:30	32588	3034	16.78	6.99	4638	18.17	6.38	10	
1740		5:42:40	32944	2824	16.79	6.96	4666	18.12	6.39	10	120.2
1745				2758	16.79	6.95	4658	18.02	6.40	15	
1750		5:49:00	32314	2961	16.82	6.92	4646	17.92	6.40	17	
1755				3042	16.81	6.92	4667	17.74	6.41	17	
1800		18:01:20	33766	3022	16.80	6.91	4676	17.67	6.40	17	
1805				3091	16.73	6.91	4676	17.52	6.40	19	
1811				3109	16.71	6.96	4683	17.07	6.40	20	
1815				3175	16.71	6.98	4671	16.56	6.40	20	
1822				3176	16.72	6.99	4634	15.99	6.40	18	
1924				3095	16.76	7.00	4617	15.84	6.40	14	
1930				3050	16.77	6.97	4579	15.67	6.41	16	

Packer Test 3-9-04 Drill

	1	2	3	4	5	6	7 Li	8 NO_3	9 SO_4	10 Uranium	11	12	13
1	1101-1-	B	0955				81.0	511.3	1259.4	371.3			
2	1101-1-	T	0955				84.9	544.2	1360.5	402.1			
3	1101-1-	B	1040				82.5	524.2	1301.6	373.6			
4	1101-1-	T	1040				79.9	500.3	1237.2	368.8			
5	1101-2-	B	1335				84.9	535.5	1315.5	377.6			
6	1101-2-	T	1335				88.5	574.7	1423.9	370.0			
7	1101-2-	B	1405				86.5	550.8	1362.6	375.6			
8	1101-2-	T	1405				80.5	503.1	1239.6	361.9			
9	1101-2-	B	~~1510~~ for 1435				82.1	524.9	1278.3	368.9			
10	1101-2-	T	~~1500~~ for 1435				81.1	508.0	1252.1	352.1			
11	1101-2-	B	1500				80.7	505.3	1243.6	364.5			
12	1101-2-	T	1500				81.5	511.8	1259.5	373.4			
13	1101-3-	B	1550				85.9	534.6	1320.8	385.3			
14	1101-3-	T	1550				79.3	519.8	1255.2	387.8			
15	1101-3-	B	1615				109.1	653.8	1636.5	465.0			
16	1101-3-	T	1615				76.8	489.8	1191.1	362.0			
17	1101-3-	B	1645				129.0	747.0	1874.6	542.8			
18	1101-3-	T	1645				77.9	496.5	1207.8	348.5			
19	1101-3-	B	1715				137.4	788.3	1974.7	573.1			
20	1101-3-	T	1715				78.4	499.3	1217.9	351.4			
21	1101-4-	B	1830				139.0	800.7	1998.9	539.6			
22	1101-4-	T	1830				76.7	486.6	1183.6	346.5			
23													
24													
25													
26													
27													
28													
29													
30													
31													

Dacker Test 3-10-04 Jeri R

	1	2	3	8 Cl	9 NO_3	10 SO_4	11 Uranium
1	1101-5-B		0905	133.5	795.6	1957.8	538.7
2	1101-5-T		0905	89.6	601.2	1522.4	434.7
3	1101-5-B		0935	86.3	563.2	1419.3	419.1
4	1101-5-T		0935	75.5	468.3	1159.1	341.5
5	1101-5-B		1005	74.7	449.2	1130.4	3268
6	1101-5-T		1005	75.6	472.5	1161.9	323.3
7	1101-5-B		1035	74.9	452.8	1135.0	326.5
8	1101-5-T		1035	77.7	492.8	1204.8	340.2
9							
10							
11							
12							
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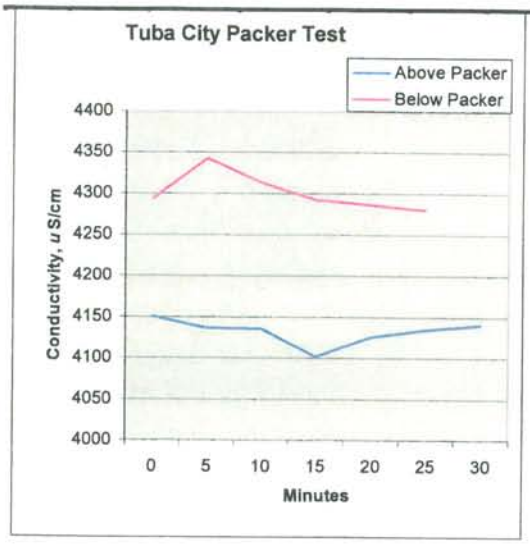
Well 1107—March 2004

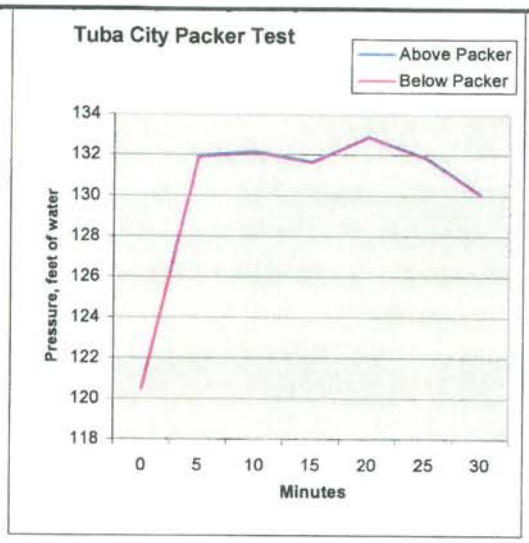
Tuba City Well 1107

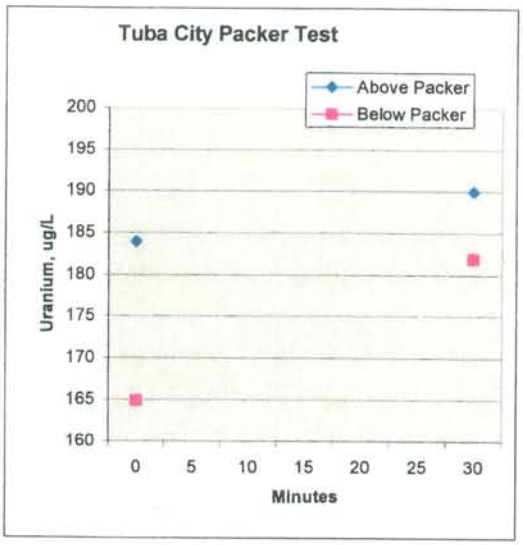
Date	Well	No	B/T	Time	Uranium	Chloride	Nitrate	Sulfate
3/11/2004	1107	1	B	7:35	165	104	847	1,033
3/11/2004	1107	1	T	7:35	184	113	1,015	1,230
3/11/2004	1107	1	B	8:05	182	111	989	1,201
3/11/2004	1107	1	T	8:05	190	112	1,016	1,230
3/11/2004	1107	2	B	9:10	170	112	993	1,214
3/11/2004	1107	2	T	9:10	180	113	1,013	1,226
3/11/2004	1107	2	B	9:45	172	119	1,065	1,320
3/11/2004	1107	2	T	9:45	148	98	827	1,005
3/11/2004	1107	2	B	10:15	173	111	999	1,204
3/11/2004	1107	2	T	10:15	140	92	762	928
3/11/2004	1107	2	B	10:45	183	112	1,011	1,218
3/11/2004	1107	2	T	10:45	137	90	751	914
3/11/2004	1107	3	B	11:40	129	86	699	848
3/11/2004	1107	3	T	11:40	134	90	745	898
3/11/2004	1107	3	B	12:10	130	85	690	834
3/11/2004	1107	3	T	12:10	148	93	792	956
3/11/2004	1107	3	B	12:40	128	85	699	844
3/11/2004	1107	3	T	12:40	129	83	671	812
3/11/2004	1107	3	B	13:10	129	86	703	848
3/11/2004	1107	3	T	13:10	124	82	661	799
3/11/2004	1107	4	B	15:15	130	89	751	915
3/11/2004	1107	4	T	15:15	164	112	996	1,206
3/11/2004	1107	4	B	15:45	159	103	934	1,128
3/11/2004	1107	4	T	15:45	139	96	813	993
3/11/2004	1107	4	B	16:15	145	101	903	1,088
3/11/2004	1107	4	T	16:15	128	87	713	867
3/11/2004	1107	4	B	16:45	137	95	832	1,005
3/11/2004	1107	4	T	16:45	130	90	758	920

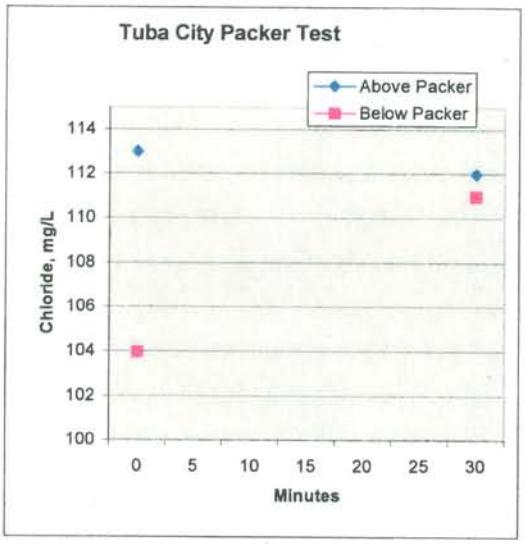
Tuba City Extraction Well Packer Test

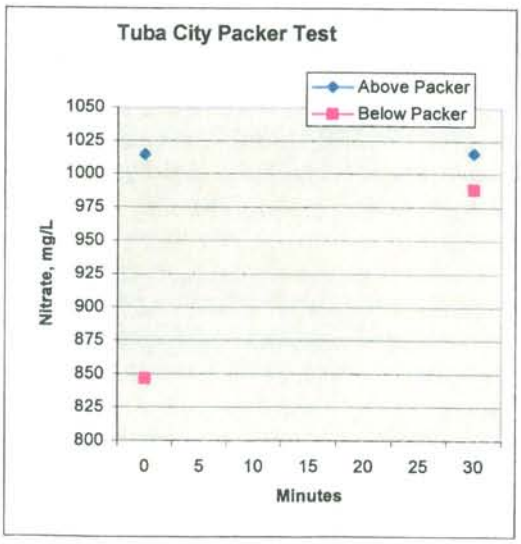
Date	03/11/04	Packer Depth	218 ft	Name	Jeff Price & Carl Jacobson
Well #	1107	Top of screen	100 ft		
		Above Packer Pressure with water at top of screen	ft		
Test #	1	Depth to water table	ft		

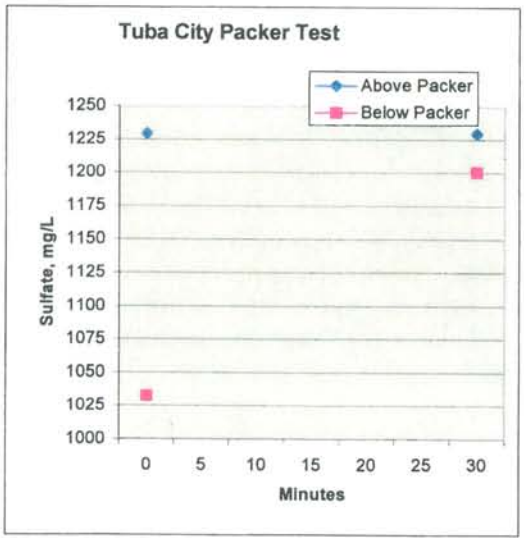






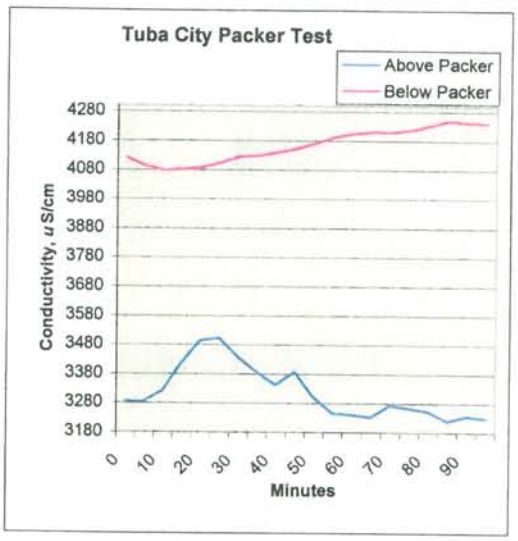


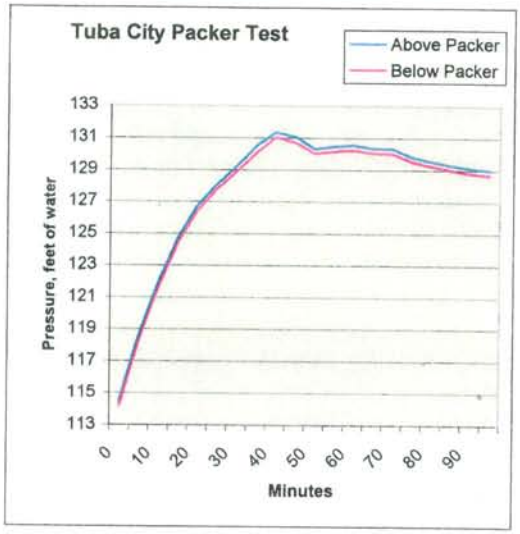


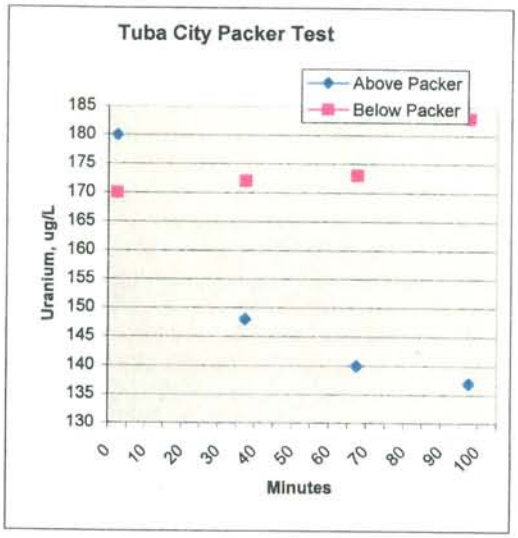


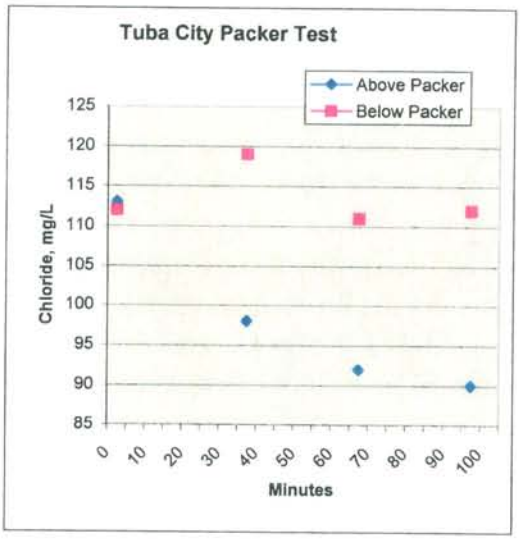
Tuba City Extraction Well Packer Test

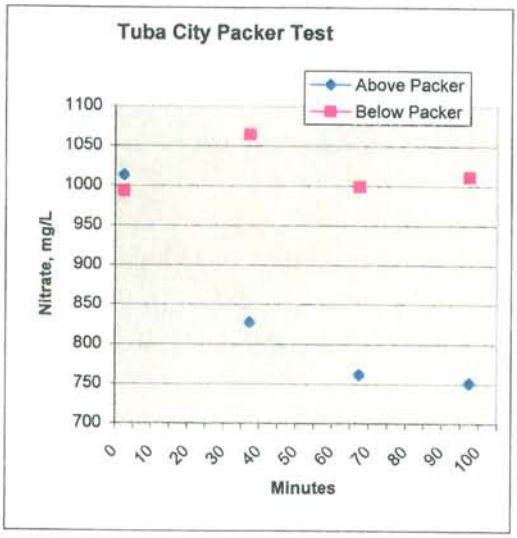
Date	03/11/04	Packer Depth	188 ft	Name	Jeff Price & Carl Jacobson
Well #	1107	Top of screen	100 ft		
Test #	2	Above Packer Pressure with water at top of screen	ft		
		Depth to water table	107.0 ft		

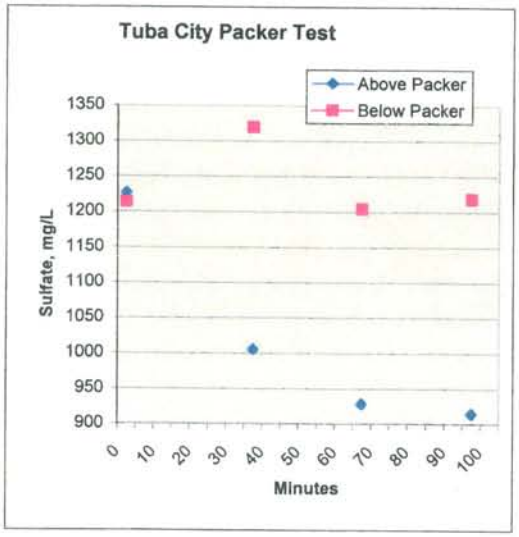






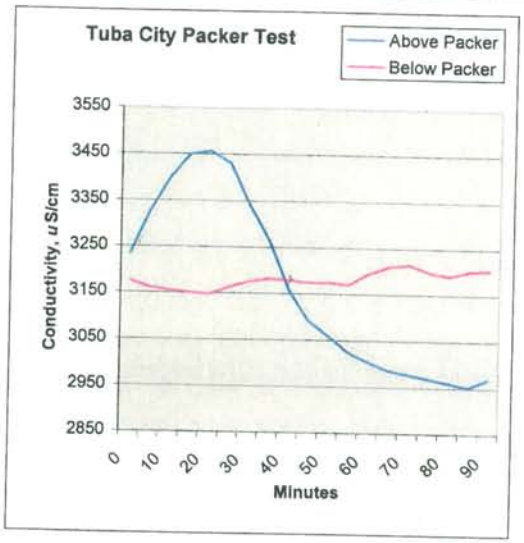


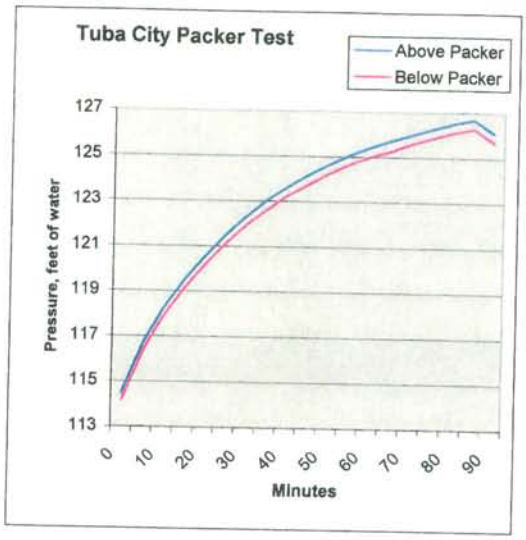


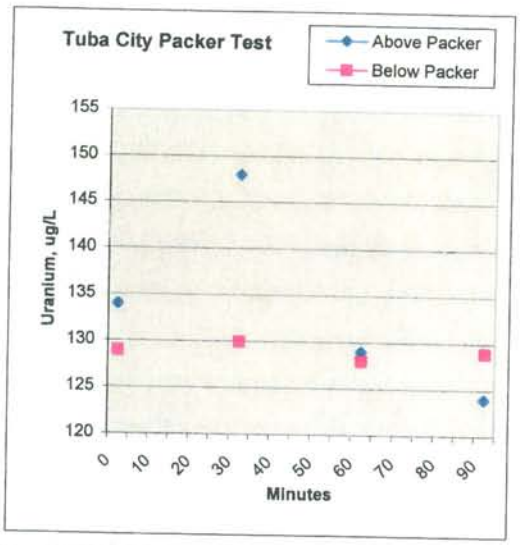


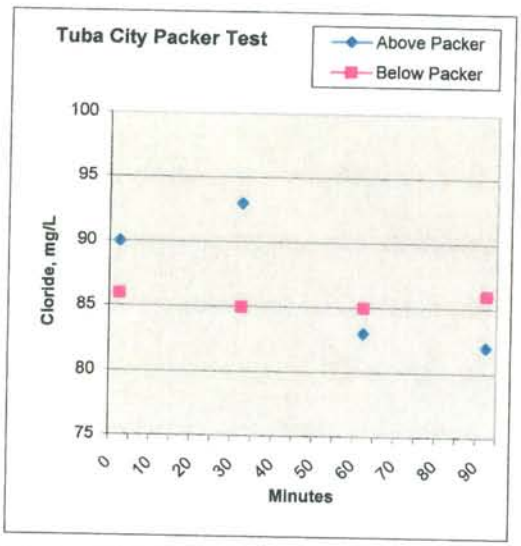
Tuba City Extraction Well Packer Test

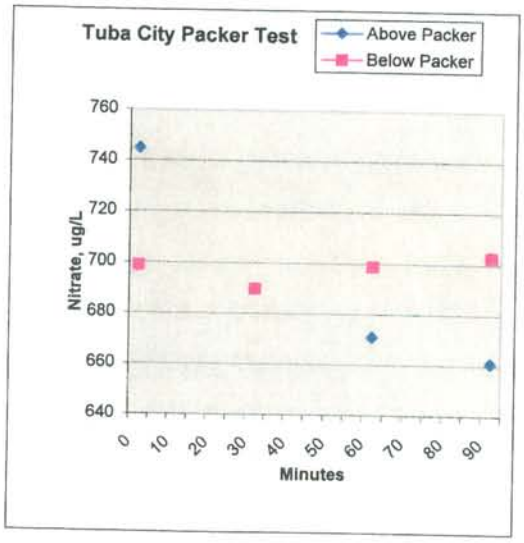
Date	03/09/04	Packer Depth	158 ft	Name	Jeff Price & Ben Zahne
Well #	1107	Top of screen	100 ft		
Test #	3	Above Packer Pressure with water at top of screen	ft		
		Depth to water table	111.0 ft		

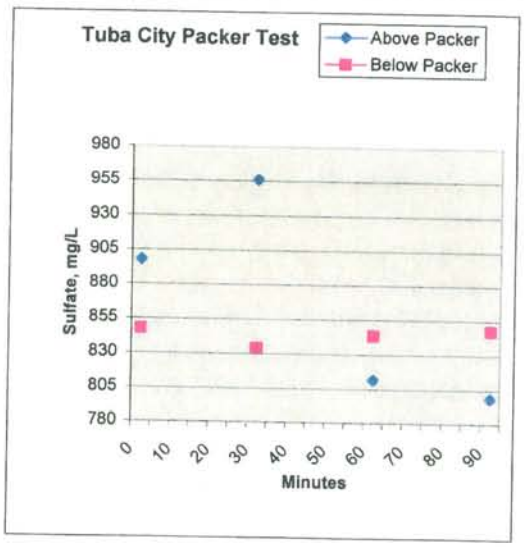






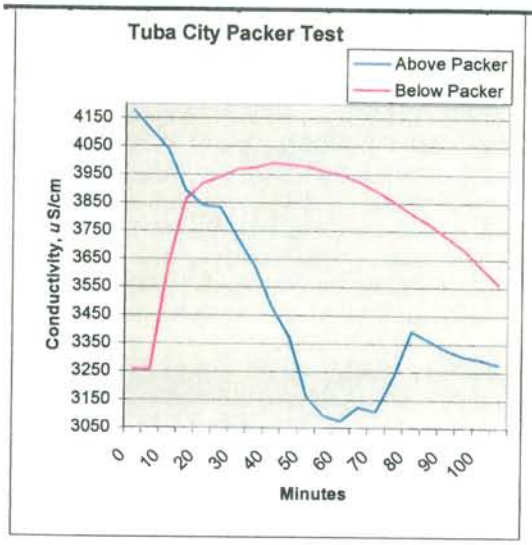


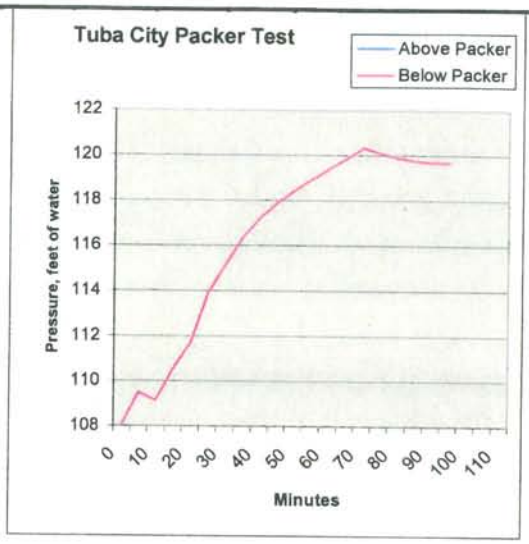


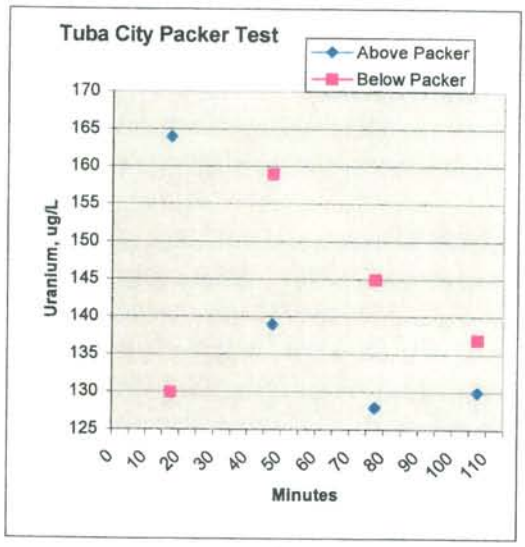


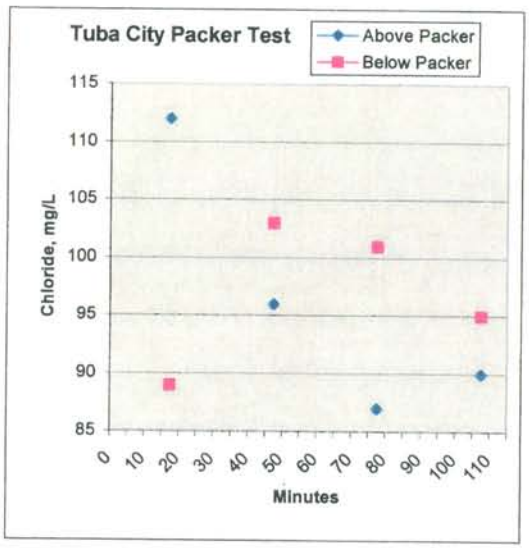
Tuba City Extraction Well Packer Test

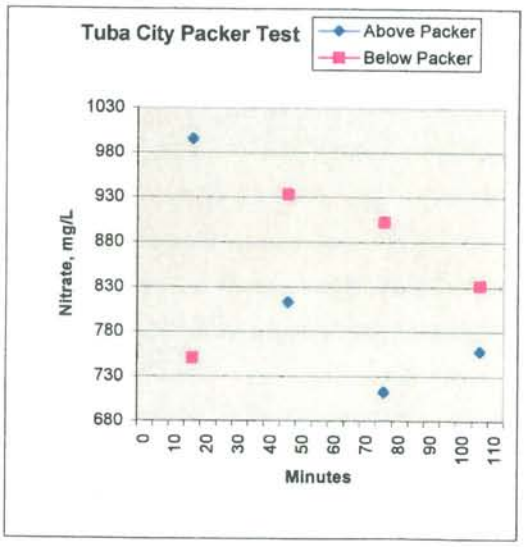
Date	03/11/04	Packer Depth	128 ft	Name	Jeff Price & Ben Zahne
Well #	1107	Top of screen	100 ft		
Test #	2 4	Above Packer Pressure with water at top of screen	ft		
		Depth to water table	104.5 ft		

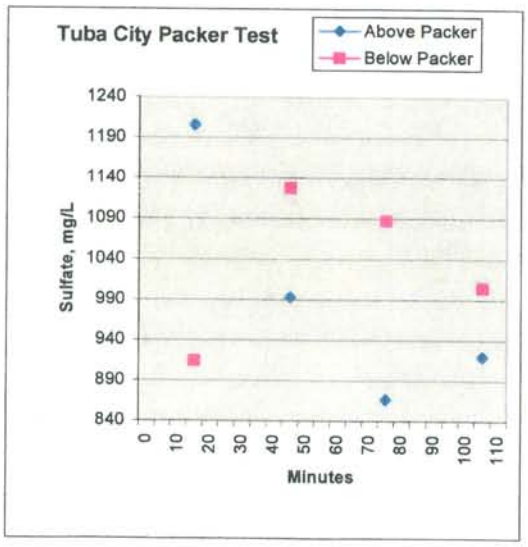












Tuba City Extraction Well Packer Test

Date 3/11/04
Well # 1107
Test # 1107-1-~~B~~

Packer Depth 218 ft
Top of screen ____ ft
Above Packer Pressure with water at top of screen ____ ft
Depth to water table 101.38 ft

Name JP

Start Test : 0730

1107-1-~~B~~T

1107-1-~~*~~B

Time	Well Pressure: Above Packer ft	Well Pressure: Below Packer ft	Flow Totalizer gallons	Extraction Pump: Cond. uS/cm	Extraction Pump: Temp ~~F~~C	Extraction Pump: pH	Bladder Pump: Cond. uS/cm	Bladder Pump: Temp ~~F~~C	Bladder Pump: pH	Air Flow ?	Comment
0735	(Sample)		61080	4150	16.3	6.47	3988	14.3	6.61	✓	DTW = 120.5
0740			61120	4137	16.5	6.47	4295	14.6	6.54		= 132 Reduced Fl
0745			—	4131	16.5	6.48	4332	14.9	6.49		= 132 Rat
0750			61135	4097	16.7	6.48	4312	15.0	6.47		= 131.5 Flow↑
0755			61146	4143	16.8	6.49	4298	15.3	6.47		= 133 Flow↓
0900		61156	~~6156~~	4147	16.9	6.49	4284	15.4	6.46		= 131.9
0805	(Sample)		61165	4137	17.0	6.47	4282	15.4	6.47	6	= 131.3

Tuba City Extraction Well Packer Test

Date 3/11/04
Well # 1107
Test # 1107-2

Packer Depth 188 ft
Top of screen ____ ft
Above Packer Pressure with water at top of screen ____ ft
Depth to water table 107.0 ft

Name JP

(First readings are flip-flopped)

Start Test: 0905

1107-2-t
1107-2-b

Time	Well Pressure: Above Packer ft	Well Pressure: Below Packer ft	Flow Totalizer gallons	Extraction Pump: Cond. uS/cm	Extraction Pump: Temp °C	Extraction Pump: pH	Bladder Pump: Cond. uS/cm	Bladder Pump: Temp °C	Bladder Pump: pH	Air Flow ?	Comment
											1st Sample: 09:10 2 " : 09:45 3 " : 10:15 4 " : 10:45
0910	Sample		61177	4155	16.9	6.48	3713	17.1	6.68	/	Start: 61165 gal. WL 114.
0915				*3276	17.2	6.60	4111	17.0	6.46		WL = 118.2
0920			61200	3275	17.3	6.58	4090	17.3	6.45		= 121.2
0925				3320	17.3	6.58	4080	17.5	6.45		= 123.1
0930			61220	3435	17.4	6.58	4088	17.5	6.44		= 126.0
0935				3501	17.5	6.58	4090	17.6	6.45		= 127.5 Flow ↓
0940			61240	3522	17.6	6.57	4105	17.9	6.44		= 129.8
0945	Sample		3450	~~3427~~	17.5	6.59	4124	17.9	6.45		
0950			61260	3473	17.7	6.58	4134	18.3	6.45		= 131.0
0955				3324	17.7	6.61	4142	18.5	6.45		= 131. Flow ↓
1000			61276	3355	17.9	6.63	4159	18.7	6.44		= 130
1005				3321	17.9	6.62	4172	18.8	6.44		= 130
1010			61290	3320	18.0	6.60	4192	19.0	6.45		= 130
1015	Sample			3258	18.1	6.62	4204	19.3	6.45		= 129.8
1020			61306	3277	18.2	6.64	4211	19.4	6.45		= 129.7
1025				3264	18.6	6.65	4207	19.6	6.45		= 129.3
1030			61320	3252	18.4	6.66	4223	19.6	6.45		= 129.0
1035				3252	18.4	6.66	4238	19.6	6.46		= 128.9
1040			61336	3240	18.5	6.66	4247	19.7	6.46		= 128.7
1045	Sample			3240	18.5	6.67	4241	19.9	6.46		= 128.5
1050			61352	3237	18.5	6.68	4242	19.8	6.46		= 128.5

Tuba City Extraction Well Packer Test

Date 3/11/04
Well # 1107
Test # 1107-3

Packer Depth 158 ft
Top of screen ft
Above Packer Pressure with water at top of screen ft
Depth to water table 111.0 ft

Name JP / BZ

Start Test - 11:35

1107-3-t

1107-3-b

Time	Well Pressure: Above Packer ft	Well Pressure: Below Packer ft	Flow Totalizer gallons	Extraction Pump: Cond. uS/cm	Extraction Pump: Temp °C	Extraction Pump: pH	Bladder Pump: Cond. uS/cm	Bladder Pump: Temp °C	Bladder Pump: pH	Air Flow ?	1= Sample: 1140 2 " - 1210 3 " - 1240 4 " - 1310 Comment
1140	Sample		61360	3253	18.0	6.74	3179	22.1	6.64	✓	WL = 114.3
1145				3328	18.4	6.71	3159	22.4	6.65		= 116.1
1150			61378	3422	18.4	6.72	3158	22.3	6.65		= 118.1
1155				3453	18.5	6.73	3149	22.6	6.65		= 119.1
1200			61390	3462	18.5	6.73	3151	22.9	6.65		= 120.2
1205				3433	18.5	6.73	3169	22.9	6.65		= 121.2
1210	Sample		61405	3334	18.5	6.77	3180	23.3	6.65		= 122.2
1215				3260	18.6	6.78	3181	23.2	6.65		= 122.7
1220			61420	3152	18.5	6.79	3180	23.5	6.65		= 123.4
1225				3102	18.4	6.80	3179	23.4	6.65		= 123.9
1230			61435	3061	18.3	6.80	3173	23.7	6.65		= 124.4
1235				3026	18.1	6.81	3166	23.8	6.65		= 124.9
1240	Sample		61450	3006	18.1	6.81	3195	23.7	6.65		= 125.2
1245				2985	18.1	6.81	3209	23.8	6.64		= 125.5
1250			61465	2978	18.1	6.83	3210	23.8	6.65		= 125.9
1255				2970	18.2	6.83	3197	23.8	6.65		= 126.1
1300			61480	2964	18.1	6.82	3200	24.0	6.64		= 126.3
1305				2968	18.1	6.83	3206	23.7	6.64		= 126.5
1310	Sample		61495	2968	18.1	6.80	3206	23.7	6.65		= 126.6

Tuba City Extraction Well Packer Test

Date 3/11/04 | Packer Depth 128 ft | Name BZ / JP

Well # 1107 | Top of screen ft

Above Packer Pressure with

Test # 1107-4 | water at top of screen ft

Depth to water table 104.5 ft

Start Test 1455 | 1107-4-t | 1107-4-b

1st Sample: ~~1505~~ ~~1510~~ 1515

2 – 1545

3 – 1615

4 – 1645

Time	Well Pressure: Above Packer ft	Well Pressure: Below Packer ft	Flow Totalizer gallons	Extraction Pump: Cond. uS/cm	Extraction Pump: Temp °C	Extraction Pump: pH	Bladder Pump: Cond. uS/cm	Bladder Pump: Temp °C	Bladder Pump: pH	Air Flow ?	Comment
1505			61501	4160	17.2	6.55	3256	26.0	6.73	/	WL = 107.9
1505				4164	17.7	6.49	3261	25.7	6.66	/	= 109.3
1510											Pump shut-off @
											1509 - back on @
											1511
1515	Sample		61509	4031	18.1	6.51	3667	25.0	6.55		
1520				3872	18.3	6.50	3901	24.7	6.49		
1525			61511	3840	18.6	6.51	3929	24.6	6.48		WL = 112.4
1530			61518	3837	19.0	6.51	3960	24.6	6.47		= 113.8
1535			61525	3721	18.5	6.54	3969	24.3	6.47		= 115.0
1540				3625	18.5	6.53	3975	24.2	6.46		= 116.3
1545	Sample		61539	3467	18.6	6.55	3991	24.0	6.47		= 117.1
1550				3375	18.7	6.55	3985	24.1	6.47		= 117.9
1555			61553	3148	18.6	6.56	3977	23.8	6.47		= 118.3
1600				3098	18.7	6.57	3961	23.6	6.47		= 118.8
1605			61567	3079	18.5	6.57	3952	23.4	6.47		= 119.3
1610				3130	18.5	6.56	3922	23.1	6.48		= 119.8
1615	Sample		61580	3109	18.6	6.56	3880	22.9	6.48		= 120.3 RATE ↓
1620				3296	18.6	6.55	3843	22.4	6.49		= 120.1
1625			61592	3392	18.6	6.53	3809	22.4	6.49		= 119.9
1630				3365	18.7	6.54	3775	22.3	6.49		= 119.7
1635			61603	3325	18.6	6.55	3724	21.9	6.50		= 119.7
1640				3319	18.6	6.55	3693	21.6	6.50		= 119.65
1645	Sample		61624	3290	18.7	6.54	3622	21.5	6.51		= 119.70

Inject 10 psi of air into well. Pump shut off 20 sec. later

* - lost communication with upper transducer; lost test; no upper trans.

1520 * - Flow meter has stopped working. 1524 - Surge flow rate; meter operable.

Wells 1101 and 1106—June 2004

Date	Well	No	B/T	Time	Uranium	Chloride	Nitrate	Sulfate
6/15/2004	1101	1		14:40	313.1	78.3	484.7	1196.6
6/15/2004	1101	1	T	14:40	313.9	78.9	481.1	1185.2
6/15/2004	1101	1		15:15	320.0	77.9	481.8	1178.8
6/15/2004	1101	1	T	15:15	318.8	77.9	482.6	1180.2
6/15/2004	1101	1		16:15	324.5	78.5	489.4	1185.5
6/15/2004	1101	1	T	16:15	314.4	77.1	478.6	1161.4
6/15/2004	1101	1		16:30	311.8	78.8	489.5	1188.1
6/15/2004	1101	1	T	16:30	317.8	78.8	489.0	1182.7
6/15/2004	1101	2		17:40	329.4	84.2	532.2	1279.9
6/15/2004	1101	2	T	17:40	290.5	70.4	440.6	1059.1
6/15/2004	1101	2		18:00	344.6	89.4	565.7	1363.8
6/15/2004	1101	2	T	18:00	279.4	70.1	440.0	1055.9
6/15/2004	1101	2		18:25	333.9	82.1	511.7	1239.2
6/15/2004	1101	2	T	18:25	298.0	74.0	466.3	1119.6
6/15/2004	1101	2		19:00	354.5	90.6	570.0	1375.8
6/15/2004	1101	2	T	19:00	284.6	69.9	433.2	1045.7
6/17/2004	1106	1		11:05	1708.3	69.2	452.2	938.5
6/17/2004	1106	1	T	11:05	1553.5	68.0	419.5	925.9
6/17/2004	1106	1		11:30	1764.9	74.0	463.1	957.3
6/17/2004	1106	1	T	11:30	1695.4	71.9	450.7	932.8
6/17/2004	1106	1		12:05	1772.5	74.6	472.6	970.5
6/17/2004	1106	1	T	12:05	1858.2	74.9	474.8	972.8
6/17/2004	1106	2		13:50	1863.9	75.0	477.1	975.6
6/17/2004	1106	2	T	13:50	1805.0	73.9	472.1	960.2
6/17/2004	1106	2		14:20	1941.2	74.8	480.3	979.5
6/17/2004	1106	2	T	14:20	1881.8	74.5	474.2	969.1
6/17/2004	1106	4		17:05	1928.2	75.4	478.9	973.0
6/17/2004	1106	4	T	17:05	1861.9	76.8	490.3	993.3
6/17/2004	1106	4		17:25	1852.2	75.0	478.7	973.4
6/17/2004	1106	4	T	17:25	1742.9	72.5	461.0	946.1
6/17/2004	1106	4		17:55	1862.1	74.8	480.8	979.2
6/17/2004	1106	4	T	17:55	1797.3	71.8	456.6	938.3
6/17/2004	1106	4		18:25	1790.3	72.7	464.9	952.1
6/17/2004	1106	4	T	18:25	1774.6	73.9	470.3	960.4

Tuba City Extraction Well Packer Test

Date 6/15/04 Packer Depth 193.5 ft Name Price - JGC06504

Well # 1101 Top of screen ____ ft

Above Packer Pressure with

Test # 1 water at top of screen ____ ft

Depth to water table ____ ft

Test FN = 1101-LT FN = 1101-1 (8774) @ 1420 Lower totalizer

Time	Well Pressure Above Packer ft	Well Pressure Below Packer ft	Flow Totalizer gallons	Upper Extraction Pump Cond. uS/cm	Upper Extraction Pump Temp F	Upper Extraction Pump pH	Lower Pump Cond. uS/cm	Lower Pump Temp F	Lower Pump pH	Air Flow	Comment
1421											Lower Pump - @ 700 Totalizer - 8000 RPM
											4.5 gpm
											7600 12:29:00
											upper pump 6.5 gpm - adjusted to 4.5 gpm
1400											115.4' Before pumping
1420											Started pumps 5820 gal upper @ 1420
1428											Started flowcells ~ 1425
1430				3362		6.50	3310		6.38		
1435				3342		6.48	3337		6.40		
1440				3319		6.48	3312		6.42		water level 127.5
1444				3311		6.50	3294		6.44		Samples Taken
1450				3309		6.5	3276		6.45		3.8 gpm upper, 4 gpm lower
1455				3307		6.51	3287		6.47		water level 129.7
1500				3314		6.50	3280		6.48		
1505				3322		6.51	3280		6.48		water level 130.7
1510				3318		6.51	3279		6.43		
1515				3309		6.52	3268		6.49		water level 131.3
1520				3296		6.52	3088		6.50		
1525				3290		6.53	3093		6.51		
1530				3213		6.54	3230		6.53		Air on @ 1527 waterlevel 132.15
1534				3262		6.57	3215		6.58		water level 132.20
1350				3297		6.53	3262		6.53		Air off @ 1340 132.66
1355				3303		6.54	3240		6.53		Air on @ 1350 31 psi 132.25
1605				3275		6.58	3214		6.59		Injected glass beads 1558 → 1603
1610				3296		6.62	3230		6.67		Bubbles in lower water line, None in 131.45
1615							3256		6.82		Samples taken upper
1620				3311		6.73	3210		6.77		Air off 1611 upper pump off 1614
1625				3296		6.62	3256		6.72		5.5 gpm upper pump on @ 1618 level 128.0
1630				3259		6.57	3231		6.65		1628 135.65 1620 level 133.75
1635				3313		6.54	3210		6.58		Samples taken
											Pumps off 135.8
											heads were on level probe at water level
											packer was pressurized

Tuba City Extraction Well Packer Test

Date 6/15/04
Well # 1101
Test # 2

Packer Depth 162.1 ft
Top of screen ____ ft
Above Packer Pressure with water at top of screen ____ ft
Depth to water table ____ ft

Name Jeff Price Carl Jacobson

Time	Well Pressure Above Packer ft	Well Pressure Below Packer ft	Flow Totalizer gallons	Upper Extraction Pump Cond. uS/cm	Upper Extraction Pump Temp F	Upper Extraction Pump pH	Lower Pump Cond. uS/cm	Lower Pump Temp F	Lower Pump pH	Air Flow	Comment
1730											1732 started pumps ~~1154~~ 120.55
											1732-6947 upper tubing
											9920 @ 1732:30
1735				3019		6.58	3732		6.44		17:37 → 130.0
1740				3075		6.57	3396		6.40		sampled 5.7 gpm upper 3.5 gpm lower
1745				3078		6.56	3529		6.46		132.27 ft @ 1746
1750				3078		6.56	3561		6.46		
1755				3078		6.57	3587		6.45		
1800				3057		6.57	3620		6.45		sampled Air on @ 1802 18:00 134.30'
1805				3198		6.59	3652		6.46		1806 132.1
1810				3204		6.66	3467		6.64		
1815				3187		6.73	3340		6.74		
1820				3173		6.76	3291		6.77		
1825				3173		6.77	3300		6.79		~~Sampled~~ 18:22 @ 130.4'
1830				3160		6.76	3292		6.80		Sample
1835				3160		6.75	3357		6.74		134.20' Added glass beads 1827 — 1829
1840				3139		6.75	3375		6.76		Air bubbles in lower pump line @ 1831
1845				3025		6.73	3320		6.77		18 psi, Air off 134.2 @ 1842 also upper pump 174
1850				2952		6.61	3523		6.59		
1855				2949		6.59	3583		6.49		
1900				2942		6.59	3586		6.48		Sample
											shut down 1900 @ 136.95

Tuba City Extraction Well Packer Test

Date 6/16/04
Well # 1103
Test # 3

Packer Depth 162.1 ft
Top of screen ____ ft
Above Packer Pressure with water at top of screen ____ ft
Depth to water table ____ ft

Name Price - Jacobson

Time	Well Pressure Above Packer ft	Well Pressure Below Packer ft	Flow Totalizer gallons	Upper Extraction Pump Cond. uS/cm	Upper Extraction Pump Temp F	Upper Extraction Pump pH	Lower Pump Cond. uS/cm	Lower Pump Temp F	Lower Pump pH	Air Flow	Comment
											Q27 H5O 115.6 water level
											Lower Totalizer 9622
											upper totalizer 7654
938											
940				3573		6.61	3367		6.49		Started pumps Lower Flow 3.5 upper Flow 6.0
945				3289		6.53	3443		6.47		
950				3175		6.55	3586		6.46		127.7' @ 947
955				3124		6.57	3542		6.45		Lower flow 6.3 gpm
900				3113		6.58	3551		6.56	24 psi	Air on @ 9:57
905				3103		6.58	3454		6.74		Bubble in lower pump line @ 9:04
910				3112		6.58	3386		6.84		125.4' @ 9:07
915				3173		6.57	3355		6.86		Lower Flow 6.8 gpm @ 9:09
920				3199		6.68	3346		6.85		126.2' @ 9:13
925				3171		6.85	3355		6.87		Glass beads added @ 9:17 → @ 22
930				3250		6.84				21 psi	130.2 ~~127.7~~ @ 9:25
											Lower pump shutdown on dry ~~sto~~ vane @ 9:30
											beads on level probe @ water line

Tuba City Extraction Well Packer Test

Date 6/16/04
Well # 1101
Test # 4

Packer Depth 131.9 ft
Top of screen ____ ft
Above Packer Pressure with water at top of screen ____ ft
Depth to water table ____ ft

Name Price Jacobson

Time	Well Pressure		Flow Totalizer gallons	Upper Extraction Pump			Lower Pump			Air Flow	Comment
	Above Packer ft	Below Packer ft		Cond. uS/cm	Temp F	pH	Cond. uS/cm	Temp F	pH		
											Upper Totalizer 6900.5 @ 9:48
											water level 118.6 @ 10:06
											Lower Totalizer 9806 @ 10:07
10:1?											-- Started upper pump

Tuba City Extraction Well Packer Test

Date 6/17/04
Well # 1106
Test # 1

Packer Depth 191.4 ft
Top of screen ____ ft
Above Packer Pressure with water at top of screen ____ ft
Depth to water table 85.25 ft
FN = 1106 - 1T

FN = 1106 - 1

Name BEN Z. JEFF P.

Time	Well Pressure Above Packer ft	Well Pressure Below Packer ft	Flow Totalizer gallons	Upper Extraction Pump Cond. uS/cm	Upper Extraction Pump Temp F	Upper Extraction Pump pH	Lower Pump Cond. uS/cm	Lower Pump Temp F	Lower Pump pH	Air Flow	Comment
1005											
1010				3206	17.4	6.62	3229	17.6	6.76		WL = 115' Flow Rate Lower = 3 1/2 gpm T = 6.2
1015											WL = 142' Stop test - need to slow pumps
1030	RE-START TEST										
1035				3114	17.5	6.67	3296	18.1	6.74		WL = 120' Q lower = 3 1/2 gpm Upper = 2 1/2 gpm
1050				2978	17.6	6.70	3190	18.2	6.75		WL = 146
1055				3005	17.7	6.71	~~3331~~	~~19.8~~	~~6.76~~		WL = 151
							3090	19.9	6.77		WL = 160.5 (Sample Valve was closed)
1100				2490	17.7	6.73	3110	18.8	6.77		
1105				2829	17.8	6.72	3010	18.8	6.77		WL = 163.3 Q lower = 2.2 gpm Q upper = 1.80
1110				3024	17.8	6.71	3050	19.2	6.77		WL = 167 (water Sample)
1115				3080	17.8	6.71	3100	19.2	6.77		WL = 170.6
1120				3091	17.8	6.72	3154	19.4	6.77		WL = 173.3
1125				3100	17.8	6.73	3190	19.3	6.77		WL = 175.3
1130				3052	18.6	6.74	3200	20.2	6.77		WL = 176.45 Restricted flow valve
1135				3029	19.0	6.75	3197	20.2	6.78		WL = 175.4 (water Sample)
1140				3055	19.1	6.75	3191	20.1	6.78		WL = 174.8
1145				3069	18.9	6.75	3171	19.7	6.78		WL = 174.7 Q lower = 1.7 Q upper = 1.37
1150				3084	18.9	6.75	3178	19.9	6.78		WL = 174.4
1155				3111	20.4	6.75	3195	20.7	6.78		WL = 174.3
1205				3164	21.3	6.75	3200	20.5	6.78		WL = 174.25
											WL = 174.45 (Water Sample)
	STOP TEST										
											Will allow the WL to recover some, reduce Q further, and do another test @ this depth.

Tuba City Extraction Well Packer Test

Date 6/17/04
Well # 1106
Test # 2

Packer Depth 191.4 ft
Top of screen ____ ft
Above Packer Pressure with water at top of screen ____ ft
Depth to water table ____ ft
FN = 1106-2T FN = 1106-2

Name Ben Z. Jeff P.

Time	Well Pressure Above Packer ft	Well Pressure Below Packer ft	Flow Totalizer gallons	Upper Extraction Pump Cond. uS/cm	Upper Extraction Pump Temp F	Upper Extraction Pump pH	Lower Pump Cond. uS/cm	Lower Pump Temp F	Lower Pump pH	Air Flow	Comment
1305	—	—	—	3237	22.9	6.73	3204	25.9	6.75		START TEST 12:55 WL = 119.60' → WL = 129.5'
1315				3207	23.9	6.71	3121	22.3	6.74		Q lower = 1.2 gpm Q upper = 1.3 gpm
1325											WL = 132.25'
1335				3118	23.2	6.72	3165	27.5	6.75		WL = 132.05 Q lower = 0.7 Q upper = 0.8 gpm
1345				3108	20.1	6.72	3106	27.6	6.74		WL = 130.75
1350				3111	20.0	6.71	3100	27.5	6.74		WL = 130.30
~~1355~~	1400			3107	19.6	6.71	3070	26.3	6.73		WL = 130.05 (Water Sample)
1405				3100	20.2	6.72	3070	26.6	6.73		WL = 129.70 Inject air @ 30 psi
1410				3109	20.1	6.71	3041	25.4	6.73		WL = 129.3
1415				3106	20.1	6.72	3035	24.8	6.73		WL = 126.6 Add glass beads,
1420				3115	19.9	6.73	3034	25.3	6.73		WL = 129.92
1425				3104	19.8	6.77	3027	25.5	6.75		WL = 129.85 (Water Sample)
											WL = 128.70
	STOP TEST										

Tuba City Extraction Well Packer Test

Date 6/17/04
Well # 1106
Test # 3

Packer Depth 161.4 ft
Top of screen ____ ft
Above Packer Pressure with water at top of screen ____ ft
Depth to water table ____ ft

Name Ben Z Jeff P.

FN = 1106-3T FN = 1106-3

Time	Well Pressure Above Packer ft	Well Pressure Below Packer ft	Flow Totalizer gallons	Upper Extraction Pump Cond. uS/cm	Upper Extraction Pump Temp °C	Upper Extraction Pump pH	Lower Pump Cond. uS/cm	Lower Pump Temp F	Lower Pump pH	Air Flow	Comment
1500											Start Test WL = 112.5
1510				3044	22.9	6.77	2969	24.4	6.82		WL = 114.45 Q = both pumps 0.7 gpm
1515				3022	23.6	6.79	2965	25.2	6.80		WL = 114.80
1520				3017	20.7	6.78	2960	25.4	6.80		WL = 115.25
1525				3006	20.8	6.78	2954	25.7	6.79		WL = 115.58
1530				2995	21.4	6.77	2954	25.5	6.79		WL = 115.72 Inject Air @ 30 w/ sand
1535				3003	21.1	6.77	2982	26.2	6.79		WL = 116.10
1540				2992	21.3	6.77	2950	25.5	6.78		WL = 116.10 ↓
1545				2995	21.4	6.76	2954	27.4	6.78		WL = 116.10 Stop Air
1550				2987	21.9	6.76	2966	28.1	6.79		WL = 116.15
1555				3002	22.9	6.76	2976	29.1	6.80		WL = 113.6 Add Air @ 30 psi
1600				3005	24.2	6.80	2984	24.3	6.87		WL = 112.9 Some air in lower pump discharge
1605				3003	25.8	6.83	2975	22.7	6.92		WL = 112.65
		STOP TEST									

No Water Samples taken - No change in field parameter values

Tuba City Extraction Well Packer Test

Date 6/17/04
Well # 1106
Test # 4

Packer Depth 131.4 ft
Top of screen ____ ft
Above Packer Pressure with water at top of screen ____ ft
Depth to water table ____ ft
FN = 1106-4T

Name J. PRICE
FN = 1106-4

Time	Well Pressure: Above Packer ft	Well Pressure: Below Packer ft	Flow Totalizer gallons	Upper Extraction Pump: Cond. uS/cm	Upper Extraction Pump: Temp F	Upper Extraction Pump: pH	Lower Pump: Cond. uS/cm	Lower Pump: Temp F	Lower Pump: pH	Air Flow	Comment
1640				—	—	—	—	—	—		WL = 104.8
1650				3033	20.9	6.84	2916	21.0	6.92		WL = 106.45 Q = 0.7 gpm both pumps
1655				2992	19.7	6.85	3050	31.0	7.00		
1700				2993	19.8	6.86	3006	32.0	7.19		
1705				3031	19.7	6.83	2964	23.4	7.09		WL = 111.1 Water Sample
1710				3035	19.7	6.81	2957	22.1	7.04		WL = 112.9
1715				3016	19.7	6.79	2944	23.2	7.00		WL = 114.0
1720				2991	19.8	6.77	2933	23.6	7.08		WL = 114.9
1725				2927	19.9	6.76	3007	23.3	6.99		WL = 115.4 Water Sample
~~1730~~	1735			2818	20.2	6.76	2958	24.0	6.92		WL = 115.25
1745				2807	20.4	6.75	2990	25.5	6.87		WL = 115.15
1755				2852	20.3	6.75	2940	23.7	6.83		WL = 115.1 Water Sample
1805				2890	20.6	6.75	2906	24.8	6.80		WL = 114.95
1815				2907	20.9	6.75	2870	25.6	6.78		WL = 114.90
1825				2912	20.7	6.75	2860	24.2	6.77		WL = 114.90 Water Sample

STOP TEST