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submitted to

Nevada Site Office
National Nuclear Security Administration
U.S. Department of Energy
Las Vegas, Nevada

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ABSTRACT

Well EPNG 10-36 began as a gas production well in the San Juan Basin of northwestern New Mexico. In 1967, the Gasbuggy underground nuclear test was conducted nearby as part of an effort to study nuclear stimulation of low-permeability reservoirs. The proximity of EPNG 10-36 to the nuclear test required it to be plugged prior to the nuclear test. Re-entry into the well after the test was not possible due to the original producing horizon in the Pictured Cliffs Formation, so the well was completed as a groundwater monitoring well in the Ojo Alamo Formation.

The well was sampled annually as part of the Long-term Hydrologic Monitoring Program (LTHMP), operated by the U.S. Environmental Protection Agency for the U.S. Department of Energy. In the mid 1980s, low levels of tritium began to be detected in the well. Subsequent investigation revealed the tritium to be located high in the water column, in water too dilute to be from the Ojo Alamo. Several casing integrity logs were run and finally a pressure test in 2002 confirmed that the casing was likely to be compromised. Water from the well was purged and hydrochemical logging and sampling was performed after the water level recovered. The results of the logging and sampling confirm that the casing in EPNG 10-36 is compromised. The region of water inflow is identified as limited to between the depths of 1,850 and 1,880 ft below land surface. The water entering the wellbore at that horizon has a lower salinity than that from the Ojo Alamo and was mixed with the Ojo Alamo groundwater during recovery following purging. This low-salinity water is also associated with the low levels of tritium.

Issues not resolved by the purging and subsequent field work are the original source of the tritium entering between 1,850 and 1,880 ft (whether from an aquifer at that horizon, or from wellbore storage of water injected in the well) and discrepancies between LTHMP monitoring results and these results in regard to the location of tritium in the wellbore.

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ACRONYMS

bgs	below ground surface
BLM	U.S. Bureau of Land Management
DRI	Desert Research Institute
DOE/NV	U.S. Department of Energy, Nevada Operations Office
EPA	U.S. Environmental Protection Agency
EC	electrical conductivity
mg/L	milligrams per liter
pCi/L	picoCuries per liter

INTRODUCTION

Well EPNG 10-36 is a long-term groundwater monitoring well located near the Gasbuggy underground nuclear test in northern New Mexico. Analytical results collected during annual monitoring began indicating erratic, low levels of tritium in the well in 1984. This prompted a series of investigations of both the source of the tritium and the condition of the well casing. The most recent of these investigations was conducted under the Site Characterization Work Plan for Gasbuggy, New Mexico (DOE, 2001) and is reported here. Decisions regarding plugging and abandoning well EPNG 10-36 will be made in the near future. For this reason, additional information regarding the well's history and previous investigations is included. English units of measurement are used for consistency with the drilling logs for Gasbuggy. To convert English to metric, multiply by 0.3048 m.

PHYSICAL AND GEOLOGIC SETTING

The Gasbuggy site is located in northern New Mexico, between Farmington and Chama, in the Carson National Forest (Figure 1). The site is accessible from state highway 64 via a well-maintained dirt road. From highway 64, the route to the site travels in a generally southerly direction through the Jicarilla Indian Reservation for approximately 11.5 km, then turns west-northwest approximately 1.8 km into the Carson National Forest.

Gasbuggy was detonated in the San Juan Basin, a large structural basin composed of more than 11,000 ft of Paleozoic and Tertiary sedimentary rocks (Stone *et al.,* 1983) (Figure 2). The detonation occurred in the Lewis Shale Formation at a depth of 4,240 ft below ground surface (bgs). The test was designed to fracture the Pictured Cliffs Formation, a gas reservoir directly overlying the Lewis Shale. The Pictured Cliffs is one of the San Juan Basin's major gas reservoirs; however, in the part of the basin where Gasbuggy was conducted, the Pictured Cliffs is a low-productivity, sparsely developed reservoir with a thickness of about 300 ft.

Below the Pictured Cliffs are over 1,500 ft of Lewis Formation shale. Overlying the Pictured Cliffs is the 100-ft thick Fruitland Formation, comprised of sandstone, shale, and siltstone, which are overlain by the Kirtland Shale. Above these formations is the Ojo Alamo Sandstone, the only water-bearing unit of concern to the nuclear test. The Ojo Alamo is a fine- to medium-grained, clayey sandstone containing minor shale beds (Mercer, 1967). The bottom of the Ojo Alamo is approximately 600 ft above the detonation point. The top of the Ojo Alamo is approximately 3,465 ft bgs, and the potentiometric surface is approximately 985 ft bgs. The recharge area for the Ojo Alamo is probably in the southeastern portion of the basin, with flow westward or northwestward toward the San Juan River (Sokol, 1970) (Figure 3). The Nacimiento and San Jose formations top-out the section.

GASBUGGY TEST HISTORY

The Gasbuggy test was part of the Plowshare Program, investigating peaceful uses for nuclear detonations. The test was designed to investigate the feasibility of using nuclear explosives to increase the natural gas production of low-permeability reservoirs. Pre-test investigations involved collecting formation data from two exploratory boreholes, GB-1 and GB-2. The test was then conducted in hole GB-E. It was a 29-kiloton device detonated at a depth of 4,240 ft bgs on December 10, 1967 (DOE, 2000). The blast created a cavity with a radius of 80 to 88 ft, into which overlying rock collapsed, creating a chimney with a height of

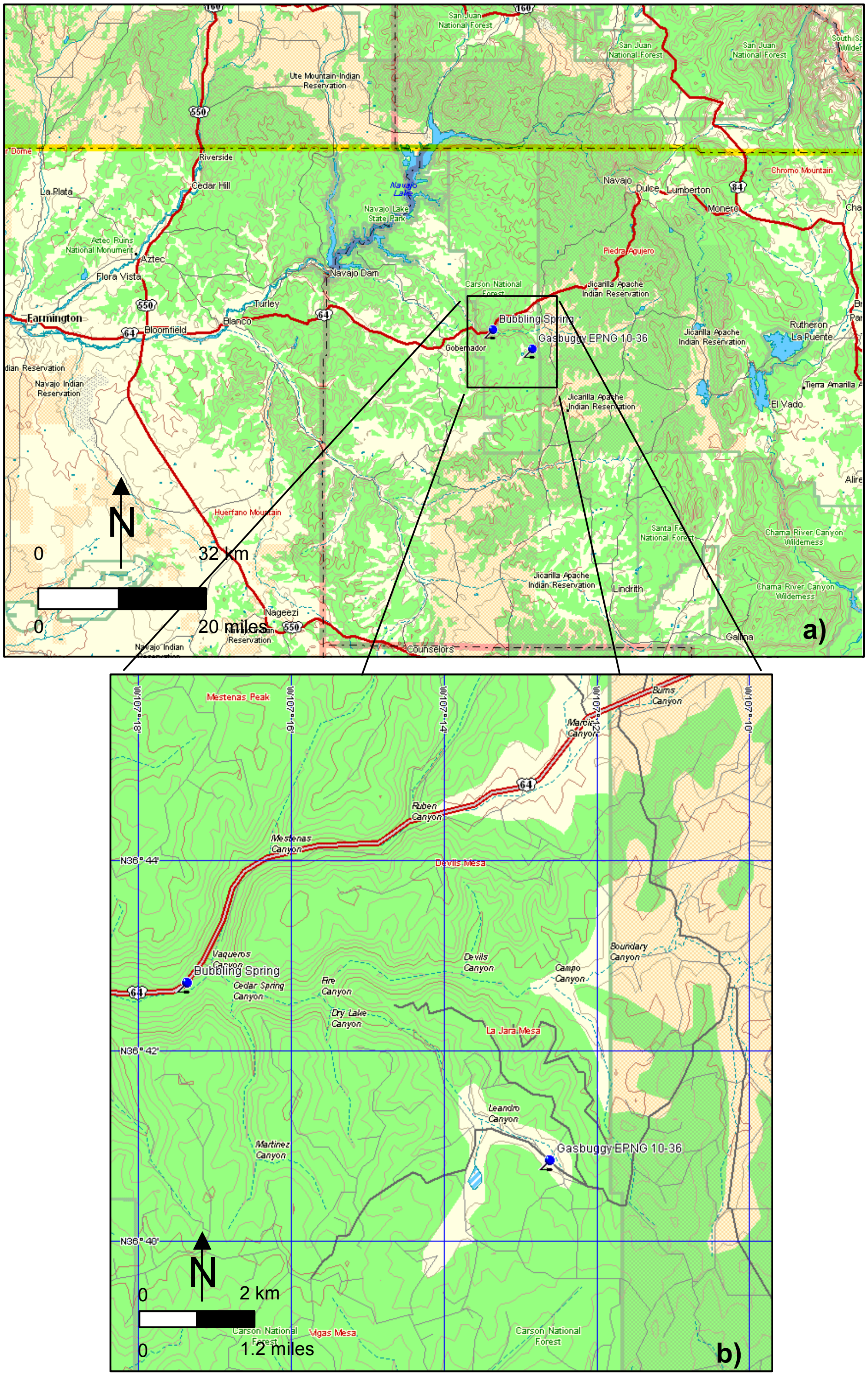

Figure 1. a) Generalized location map of the Gasbuggy site in Northern New Mexico, between Farmington and Chama, New Mexico. b) Location map of EPNG 10-36 within the Carson National Forest.

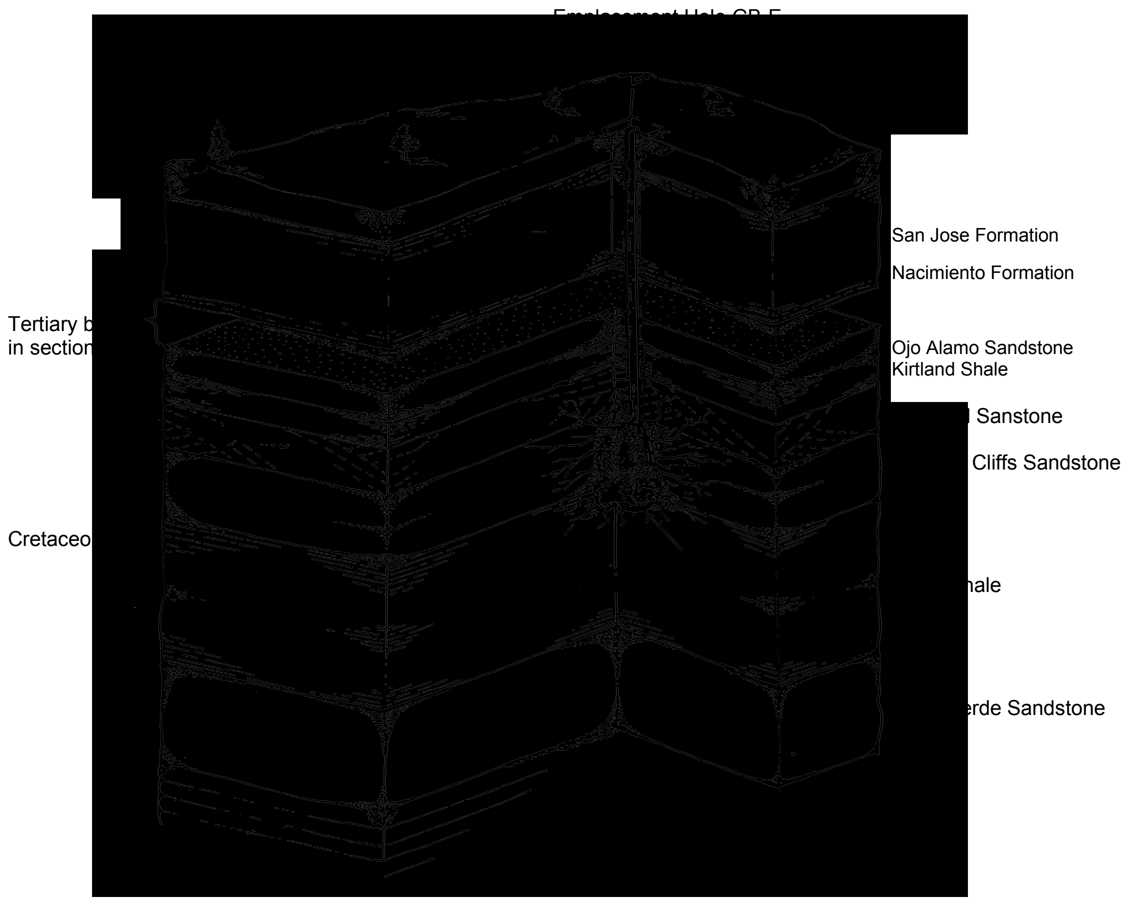

Figure 2. Generalized geologic cross section at the Gasbuggy emplacement hole (DOE, 1986).

approximately 333 ft. The chimney was accessed for gas production testing by re-entering the previously plugged GB-E emplacement hole, which was then renamed GB-ER. Hole GB-3 was drilled after the test to investigate post-test conditions. All four of these wells were plugged and abandoned in 1978 when the site underwent restoration and cleanup, after production testing ended. Well EPNG 10-36 was also to be used for post-test production testing, but was recompleted as a long-term hydrologic monitoring well.

HISTORY OF WELL EPNG 10-36

The well began as a wildcat gas well known as San Juan 29-4 Unit 10. It was spudded by Summit Drilling Company on July 6, 1956, and completed on August 19, 1956. The land surface elevation is 7,184 ft. Rotary and cable drilling was used to a total drilled depth of 4,210 ft. Three formation tops are noted: the Fruitland Formation at 3,734 ft, the Pictured Cliffs at 3,896 ft, and the Lewis Shale at 4,188 ft. Seventy feet of pay section was identified, topping at 3,901 ft. The well began production in 1957 and was in continuous production into 1966. Cumulative gas produced from the well totaled 81,854 million cubic feet.

From October 13 to 17, 1967, the well was prepared for the Gasbuggy test. The bottom of the hole was plugged with sand from 4,170 to 3,337 ft, with a bridge plug set above. This was done with the intention of preserving the producing perforated interval for production after the

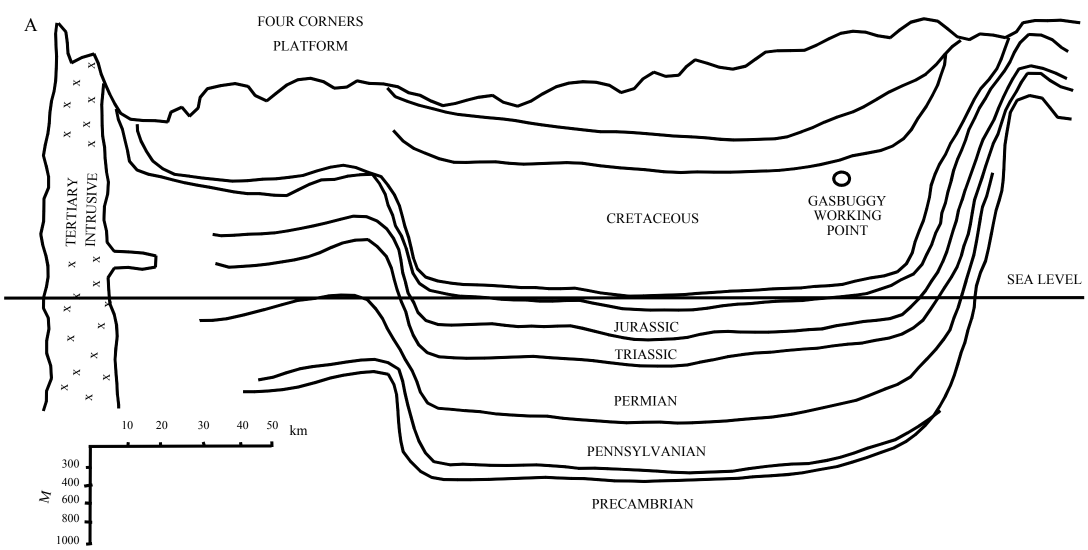

Figure 3. Generalized geologic cross section of northern New Mexico, showing the Gasbuggy working point (Sokol, 1970).

Gasbuggy test. The remainder of the borehole was filled with cement and mud, inside the 5-1/2" casing and in the annular space. On October 7, 1968, post-Gasbuggy re-entry work began on San Juan 29-4 Unit 10. On October 9, drilling encountered an obstruction at 3,616 ft that behaved like debris in the well, damaging drill bits. An impression block was run in the well and showed perimeter roughness with no impression in the center. It was concluded that the metal was the casing itself that had apparently sheared as a result of motion from the Gasbuggy test. The well was perforated at 3,571 to 3,587 ft and 3,591 to 3,611 ft with the intention to create a groundwater monitoring well in the Ojo Alamo Sandstone. This "monitoring" was likely geared originally toward measuring hydraulic responses during production testing, as there were concerns about the source of an unexpectedly large volume of water being produced with the gas. Production tubing was left in the hole and also perforated.

In 1978, the U.S. Department of Energy purchased the well for $10 from El Paso Natural Gas Company. From this point on, the well is referred to more commonly as EPNG 10-36. The well is a regular sampling location for the Long-term Hydrologic Monitoring Program performed by the U.S. Environmental Protection Agency (EPA) (DOE, 1986).

In 1994, the production tubing was removed from the well to allow a larger-diameter logging tool access to test casing integrity. The well configuration after the tubing was removed is shown in Figure 4.

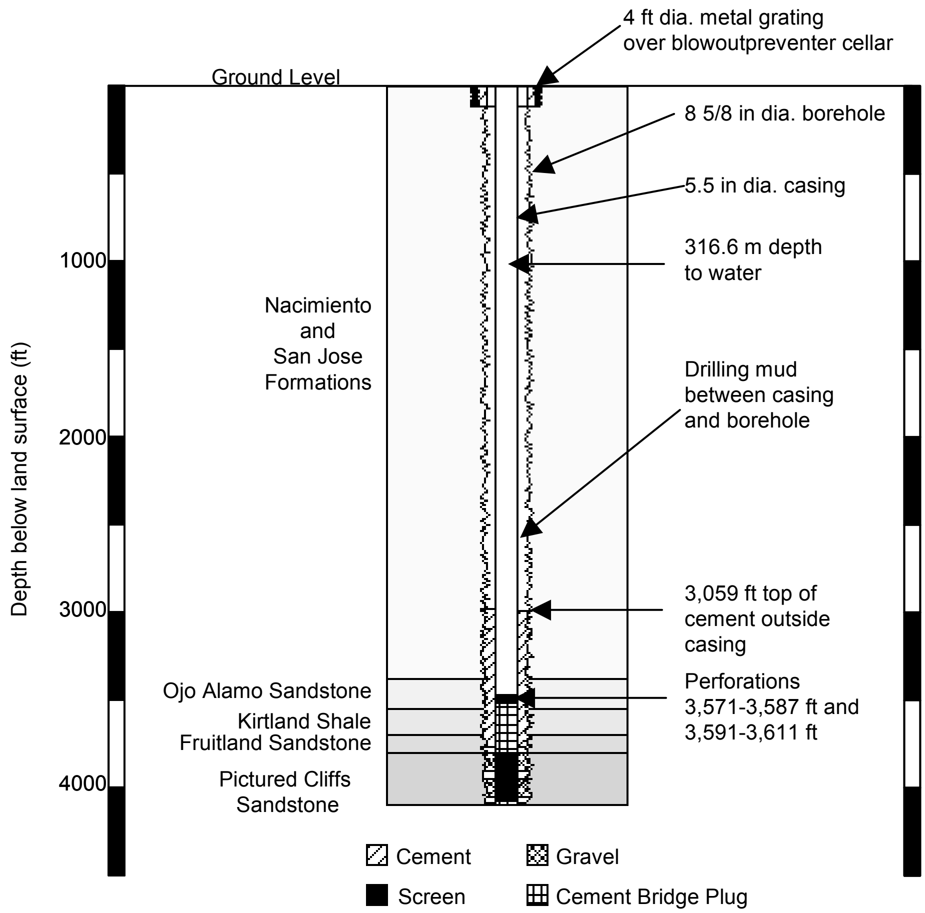

Figure 4. Current well configuration of EPNG 10-36. A blowout preventer is still present below ground level in a shallow cellar, covered with a metal grating.

RECORD OF MONITORING RESULTS FROM EPNG 10-36

Monitoring of well EPNG 10-36 by the EPA under the Long-term Hydrologic Monitoring Program did not detect radionuclides until low, but above background, tritium concentrations began appearing in 1984 (Figure 5). Sampling by EPA also detected Cs-137 at concentrations up to 16 pCi/L between 1990 and 1994, although none was detected in 1992, or since 1994. It is recorded in EPA's sampling notes that a sample collected from the well in June 1988 was accidentally contaminated. This appears to be related to using the same downhole equipment to sample at Gasbuggy immediately after sampling a well with very high radionuclide concentrations at the Gnome site. The Gnome site was routinely sampled prior to Gasbuggy during this time period.

Once the small-diameter production tubing was removed from the well in 1994, the monitoring results were investigated. Hydrochemical and flowmeter logging were performed, and groundwater samples were collected from multiple discrete depths (Chapman *et al*., 1996). Most significantly, no tritium was detected in the lower part of the well adjacent to the perforations, despite the fact that the tubing removal caused water inflow to the well as it recovered.

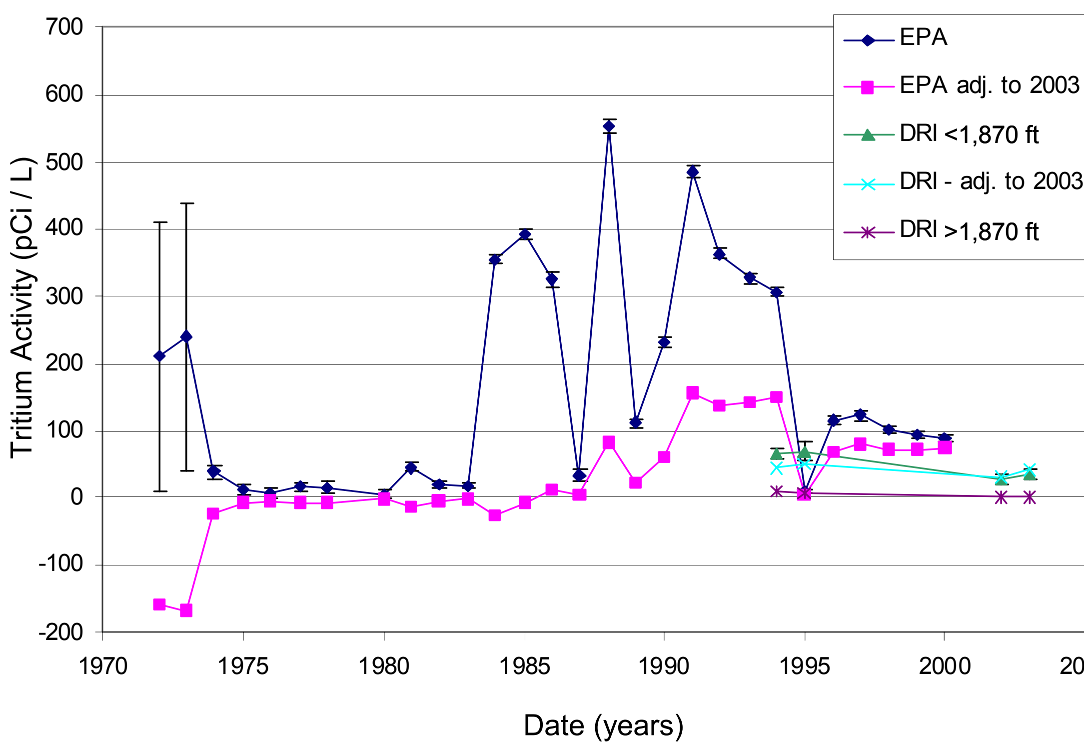

Figure 5. Well EPNG 10-36, tritium activity versus time. Selected results from the EPA Long-term Hydrologic Monitoring Program are shown as well as those data normalized for decay to the year 2003, for comparison purposes. Results from Desert Research Institute (DRI) are grouped as samples less than 1,870 ft below land surface and samples greater than 1,870 ft deep. DRI-averaged samples from less than 1,870 ft are stable over adjusted time (approx. 41 pCi/L) and samples greater than 1,870 ft were all below analytical detection limits (< 3 pCi/L).

The hydrochemical logging identified a chemically stratified water column. The lower portion of the well contains water that chemically resembles that recorded for the Ojo Alamo Sandstone in well GB-1 (Mercer, 1970), (though the pH and alkalinity have been altered by cementing operations), and has no detectable radionuclides. The upper portion of the well contained a lower salinity water with an enriched stable isotope composition indicative of evaporation in a surface pond. Within this zone, tritium is detected at concentrations between 100 and 150 pCi/L.

WELL INTEGRITY TESTING

The removal of the production tubing in 1994 was precipitated by a request from the U.S. Bureau of Land Management (BLM) for DOE to test the integrity of EPNG 10-36. Well integrity testing is routinely performed in oil and gas fields to ensure that the brines commonly associated with petroleum reservoirs do not contaminant potable aquifers through deteriorating casing.

In September 1994, an evaluation was performed to test the casing integrity and cement bond between the casing and the formation. A cement bond log showed no cement from the water table at 944 ft to a depth of 3,114 ft, poor quality cement or poor bonding from 3,114 to 3,248 ft, and good cement from 3,248 to 3,604 ft. An ultrasonic imaging log was then performed and confirmed the top of cement at 3,251 ft with good cement and bonding to the bottom of the well. Interpretation of this log appeared problematic given that it was interpreted as showing good cement and bonding from 914 to 1,064 ft and from 1,344 to 1,448 ft, where there is no record of cement work nor does it show up on the cement bond log. Additional interpretations of the ultrasonic imaging log concluded that the casing is badly corroded from 1,362 to 1,678 ft and from 2,128 to 3,112 ft, that probable holes occur sporadically between 1,360 to 1,801 ft, and that holes in the casing are common from 2,022 to 2,390 ft, 3,050 to 3,155 ft, and 3,359 to 3,590 ft. However, substantial uncertainty should be associated with those interpretations given the misinterpretation of cement higher in the annular space.

In September 1999, a cement bond log and acoustic televiewer log were performed. These logs were sent to the BLM without interpretation and no interpretation was received from the BLM.

In September 2002, a hydrostatic pressure test was performed. A bridge plug was set at 3,550 ft below land surface, the casing was loaded with 960 gallons of water, and was pressurized to 500 psig; the test failed to hold the pressure with less than 50 psig decrease within 30 minutes. Attempts were made to tighten fittings, to draw air out of the annulus and to tighten the rams in the blowout preventer; the well still failed the test. Approximately 2,510 gallons of water were swabbed from the well; the calculated total volume of the well is 3,682 gallons.

FIELD INVESTIGATION FY 2003

Fall 2002

Brad Lyles and David Gillespie of DRI performed well logging and sampling on November 15-17, 2002; DRI was accompanied by Jim Coburn of IT Corporation-Albuquerque and Bill Wilborn of DOE/Nevada Operations Office (DOE/NV). The site conditions were generally good, soils were frozen with the soil surface thawing to produce muddy conditions by afternoon, no precipitation was observed, and temperatures ranged from about -10 to 5^{o}C.

Desert Research Institute was prepared to perform a video survey of the unsaturated casing left by the swabbing activity, but found the water level had recovered to 987 ft (bgs), within 43 ft of the pre-purged water level. Prior experience has shown that attempting video surveys below the water level in wells of this type often produce unsatisfactory results; therefore, the video survey was not performed.

Water chemistry samples were collected on November 15, 2002, from four depths via a discrete sampler in six-liter volumes from each depth. Water samples were analyzed for major cations and anions, and stable isotopes of hydrogen, oxygen, and carbon. Field and laboratory measurements of pH and EC were also made for each sample. The results of these analyses are listed in Table 1; the results from previous water samples are also listed for comparison purposes. Stable isotope samples from the upper portion of the well now have a similar isotopic signature as the samples collected previously from deeper in the well (Figure 6), no longer exhibiting an evaporated signature indicative of surface exposure. However, distinct chemical differences remain between the water higher and lower in the borehole.

A chemistry log was performed on November 16, 2002, after the water samples were collected; therefore, the chemistry log results are slightly smeared, due to the repeated trips into the well with the sampling equipment. The static water level was 990.5 ft and the total depth was 3,604 ft. Chemical stratification was observed in the well at the same depth that it was observed in similar surveys conducted in 1994 and 1995 (Figure 7). Electrical conductivity (EC uS/cm-25^{o}C) ranged from 5,000 to 6,000 near the upper portion of the water column to nearly 12,000 in the lower portion of the well, with an abrupt change in EC at 1,787 ft. The temperature ranges from 19.0 to 44.5^{o}C, with a few small changes in gradient, but generally showed a gradual increase with increasing depth. The pH profile was generally higher near the top of the well and lower at the bottom, similar to previous logs, with a sharp decrease centered around 1,880 ft and a broad increasing trend both above and below that depth.

Four tritium samples were collected. The sample collected at the bottom of the well at the perforations to the Ojo Alamo contained no tritium above the detection limit of 3 pCi/L. The sample from a depth of 1,900 ft also contained no detectable tritium. The two samples collected in the upper portion of the chemically stratified water column did contain low amounts of tritium: 30 ± 8 pCi/L at 1,180 ft, and 25 ± 9 at 1,600 ft.

Spring 2003

Brad Lyles and David Gillespie of DRI performed well logging and sampling on June 11 through 13, 2003. During the site visit, climatic conditions were very good, temperatures ranged from about 10 to 30^{o}C, and no precipitation was observed. While on location, they were visited by U.S. Forest Service personnel performing horse studies and by Bruce Martin of the State of New Mexico, Energy, Minerals and Natural Resources Department.

A chemistry log was performed prior to water sample collection, on June 11, 2003. The static water level was 952.29 ft and the total depth was 3,605.5 ft bgs. Chemical stratification was at the same depth as was previously observed. Electrical conductivity (EC uS/cm-25^{o}C) ranged from 6,000 near the upper portion of the water column to 12,000 in the lower portion of the well, with an abrupt change in EC at 1,764 ft (Figure 7). The temperature ranged from 19.0 to 43.0^{o}C, with a few small changes in gradient, but generally showed a gradual increase with increasing depth. Equipment malfunctions precluded the measurement of pH during this survey.

Water samples were collected from nine depths via a discrete sampler in six-liter volumes from each depth. Sampling locations were selected to help better define the tritium found in the November samples, as well as confirm the absence of tritium at the Ojo Alamo. As found in all

Table 1. Chemical and isotopic analyses of groundwater samples from the Gasbuggy site. All units are in mg/L unless otherwise noted.

Date	Depth (ft)	Depth (m)	pH	EC (µS/cm)	Ca	Mg	Na	K	Cl	SO_4	HCO_3	CO_3	OH	NO_3	SIO_2	$\delta^{18}O$ (‰)	δD (‰)	Tritium (pCi/L)	$\delta^{13}C$ (‰)
5/19/1995	950	289.5	12.2	4,060	44.7	<0.1	482	172	89.1	585		49.7	186	<0.01	3.8	-2.3	-34	128±9	
11/15/2002	1,180	359.6	10.13	5,720	137	0.06	1,370	61.6	176	3,030		24.1	24.1	<0.01	0.38	-9.1	-70.35	30±8	-23.2
6/11/2003	1,180	359.6																20±5	
5/19/1995	1,181	360.0	12.2	4,470	46.7	<0.1	498	164	88.4	628		47.7	197	<0.01	4.1	-1.8	-34	107±14	
5/19/1995	1,410	429.7	12.2	4,490	49.7	<0.1	494	164	84.8	598		47.8	199	<0.01	4.2	-1.8	-32	138±11	
5/21/1995	1,600	487.7	12.2	4,740	62.8	<0.1	547	151	82.5	740		57.2	195	<0.01	4.4	-2	-32	119±10	
11/15/2002	1,600	487.7	7.34	4,830	122	3.08	1,140	51	193	2,480	35.6			<0.01	0.38	-9.55	-72.7	25±9	-22.3
6/11/2003	1,600	487.7																22±8	
5/30/1994	1,700	518.1	12.1	4,670	69.5	<0.1	520	154	66.5	670		54.7	215	0.18	4	-2.3	-32	121±8	
6/11/2003	1,700	518.1																24±9	
6/11/2003	1,740	530.3																27±6	
6/11/2003	1,780	542.5																14±6	
6/11/2003	1,820	554.7																6±7	
6/12/2003	1,860	566.9																134±12	
5/21/1995	1,900	579.1	11.5	10,200	352	<0.1	2,200	65.4	313	5,160		34.1	49	<0.01	15.4	-9.5	-68	14±9	
11/15/2002	1,900	579.1	6.77	9,720	336	0.59	2,260	39.6	283	5,110	35.3			<0.01	0.35	-10.16	-71.8	<3	-17.6
6/12/2003	1,900	579.1																<3	
5/30/1994	2,100	640.0	11.3	10,200	382	<0.1	2,220	56.7	261	5,520		23.8	47.9	0.13	18.8	-9.9	-68	12±9	
5/27/1994	3,060	932.6	11.2	10,200	382	<0.1	2,240	54.7	263	5,460		25.1	34.2	0.13	18.6	-9.8	-69	<10	
5/27/1994	3,556	1,083.8	10.1	9,760	406	0.54	2,150	67.6	266	5,390		23.6	4.8	0.22	18.5	-9.9	-68	<10	
5/20/1995	3,556	1,083.8	10.4	9,870	376	<0.1	2,160	73.4	315	5,350		29.4	5.4	<0.01	20.8	-9.7	-73	<10	
5/28/1994	3,585	1,092.7	10.3	9,760	406	0.99	2,180	69	263	5,380		24.2	7.0	0.18	18.3	-9.7	-68	<10	
5/20/1995	3,585	1,092.7	10.5	9,880	389	<0.1	2,160	72.2	328	5,380		40.2	2.9	<0.01	21.3	-9.7	-69	<10	
11/15/2002	3,585	1,092.7	9.36	10,900	418	14.7	2,500	26.3	280	5,450	355	32.9	32.9	<0.01	27.1	-10.21	-70.83	<3	26
6/12/2003	3,585	1,092.7																<3	
5/28/1994	3,605	1,098.8	10.2	9,830	414	1.78	2,170	80.7	263	5,430		25.4	6.0	0.13	22.7	-9.9	-68	<10	

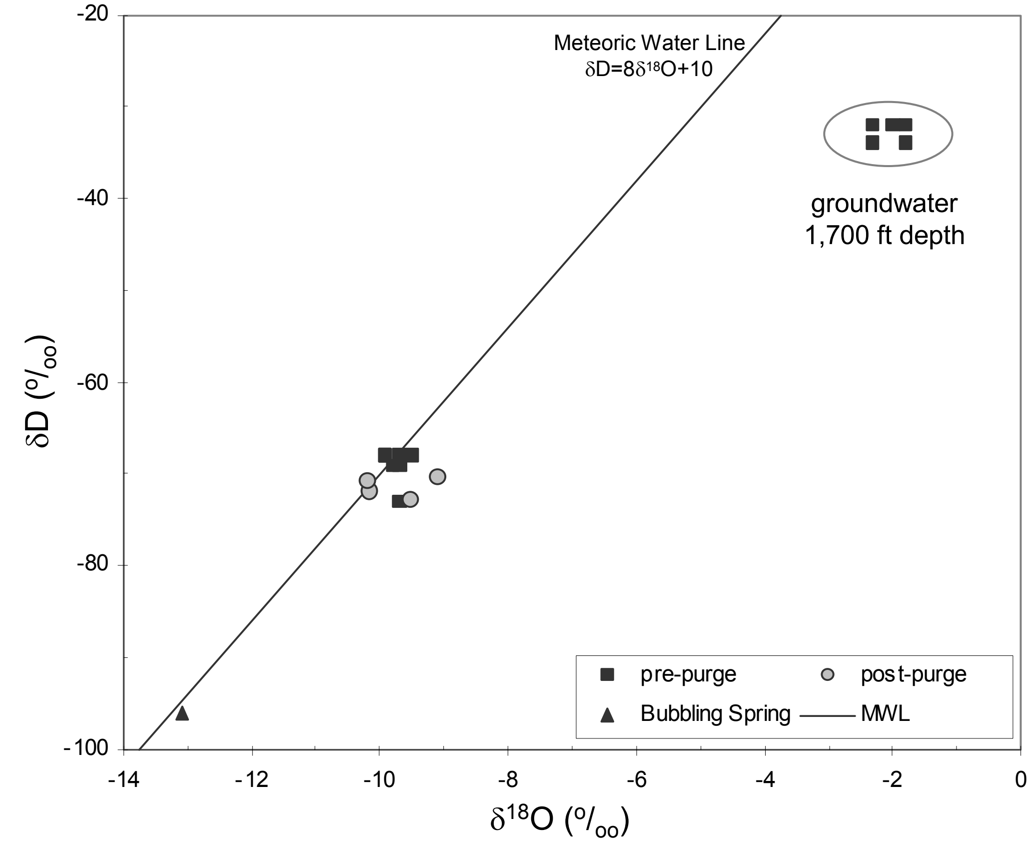

Figure 6. Stable isotope samples from EPNG 10-36 and Bubbling Spring. Groundwater samples from less than 1,700 ft depth, prior to purging, group together on an evaporative enrichment line. After purging in 2002, all zones in the well have the same signature. Bubbling Spring falls on the meteoric water line, but is unrelated to the well samples.

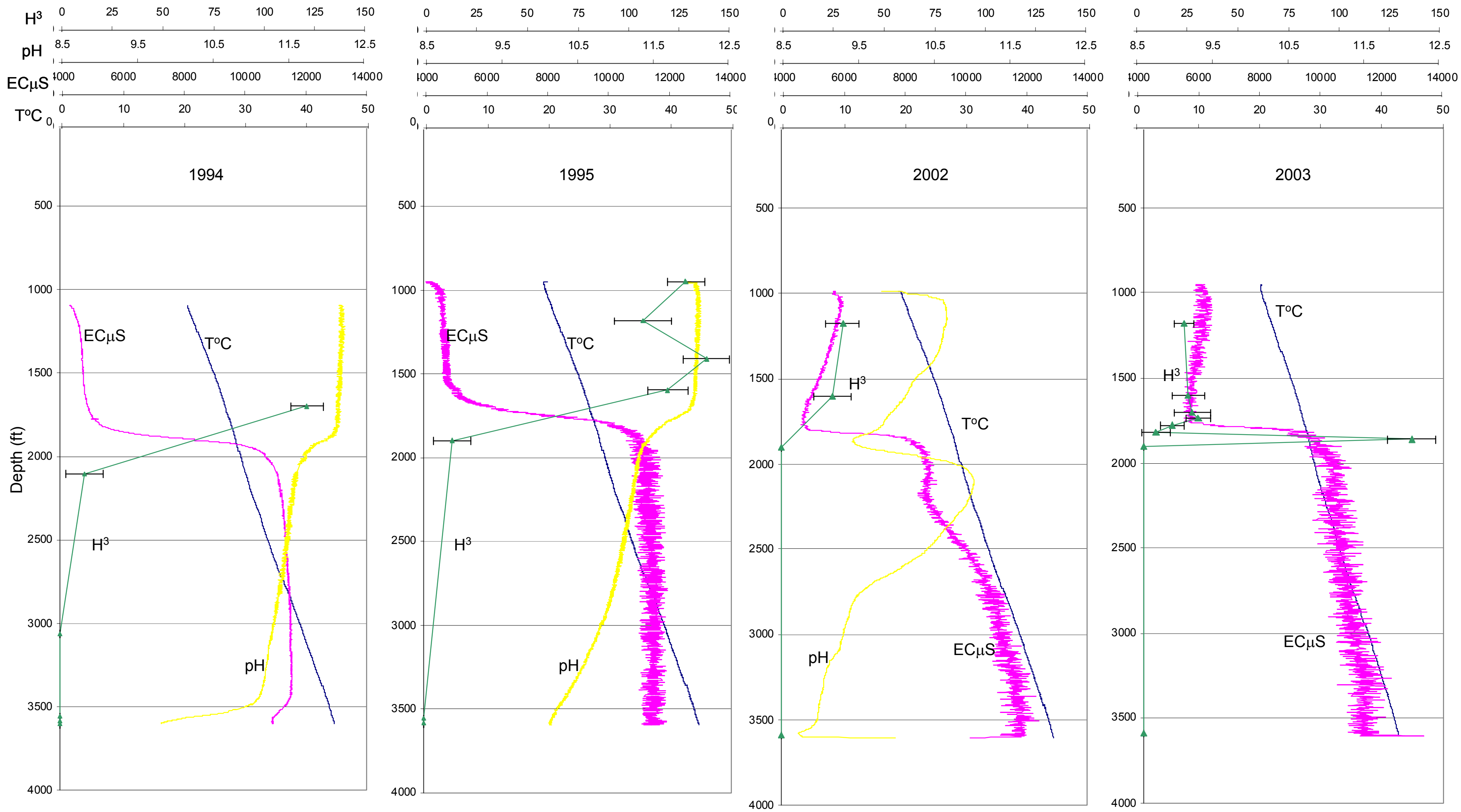

Figure 7. EPNG 10-36 well logging results from 1994, 1995, 2002, and 2003. Temperature (ºC), EC (μS/cm-25ºC) and pH are from chemistry logs and tritium (pCi/L) is from depth discrete samples. No tritium has been observed greater than 1,969 ft below land surface.

previous samples, no tritium above the detection limit of 3 pCi/L was measured in the samples from 3,585 and 1,900 ft. At 1,860 ft, the highest tritium concentration of 134 ± 12 pCi/L was observed. The sampling location at 1,860 ft was selected based on the sharp trend of the November 2002 pH log toward more representative pH values at that depth. Immediately above that, at 1,820 ft, only 6 ± 7 pCi/L was measured. Samples from 1,780, 1,740, 1,700, 1,600, and 1,180 ft varied between 14 ± 6 and 27 ± 6 pCi/L. Tritium activities are presented in Table 1 and shown graphically in Figure 7 versus depth for comparison with chemistry logging results.

INTERPRETATIONS

Data Interpretations Regarding Casing Integrity

The results of the water chemistry analyses and hydrochemical logs strongly indicate that the casing of EPNG 10-36 is compromised. What the data show is that water atypical of that in the Ojo Alamo Sandstone is entering the well. As the only designed perforations are at the Ojo Alamo horizon, it must be concluded that the other water type is entering through breaks in the casing.

The presence of the two water types was known in 1994 and confirmed in 1995. At that point, however, there were at least two possible sources for the non-Ojo Alamo water: it could be coming through breaks in the casing, or it could have been injected into the well from the surface. The purging of EPNG 10-36 in 2003 allowed the injection pathway to be ruled out because the chemical stratification recurred during well recovery.

The exact location(s) of the casing holes cannot be determined but can be inferred from the logging results. Based on the electrical conductivity logs, Ojo Alamo groundwater fills the casing undiluted from the bottom of the hole to a depth near 1,850 ft. Above this point is a mixing zone, with the lower-salinity water becoming dominant above a depth of 1,800 ft. The pH log demonstrates a sharp shift toward natural groundwater values (discussed in the following paragraph) in the region of 1,820 to 1,900 ft, centered on 1,880 ft. The hydrochemical logging results together suggest a lower salinity, lower pH water inflow occurring somewhere in the interval between 1,800 and 1,900 ft, focused on the zone between 1,850 and 1,880 ft below ground surface.

The pH log in November 2002 suggests that 1,850 to 1,880 ft may be the only section of significant water inflow through compromised casing. Water in EPNG 10-36 was characterized by extremely high pH values in 1994 and 1995, related to cementing operations in the well when it was plugged before the nuclear test. The pH log after the well was purged clearly shows more representative groundwater pH values at the bottom perforations, associated with water entering from the Ojo Alamo, but it also shows lower pH values centered in a zone at 1,880 ft with increasing values above that point to the water table. This suggests formation water entering the wellbore at the bottom perforations, and also around 1,880 ft, coinciding with the dramatic decrease in salinity. No other hydrochemical variations occur to indicate any other inflow zones.

Data Interpretations Regarding Tritium Monitoring

The occurrence of tritium in EPNG 10-36 is associated with the water entering the casing breaks. No tritium was detected in the water characteristic of the Ojo Alamo. The peak tritium value is in a relatively limited zone in the vicinity of 1,860 ft. The sample collected at 1,860 ft has the highest tritium measured in 2003 (134 ± 12 pCi/L), whereas tritium was below detection at 1,900 ft and insignificant at 1,820 ft (6 ± 7 pCi/L).

The low levels of tritium detected above 1,860 ft, which are all below 30 pCi/L, are likely to originate near 1,860 ft but to have experienced dilution. Though the water salinity is much lower in the upper portion of the borehole, the proportions of major ions are virtually identical to those found in the Ojo Alamo groundwater (Figures 8 and 9). This indicates that as the Ojo Alamo groundwater filled the borehole following the purging, it was diluted by fresh water inflowing around 1,860 ft. This inflow did not contribute enough dissolved ions to alter the hydrochemical facies, though the overall salinity was reduced. The tritium concentrations observed above 1,800 ft can then be attributed to mixing between the tritium-rich, low-salinity inflow around 1,860 ft with the tritium-free, saline water filling the borehole from the bottom perforations.

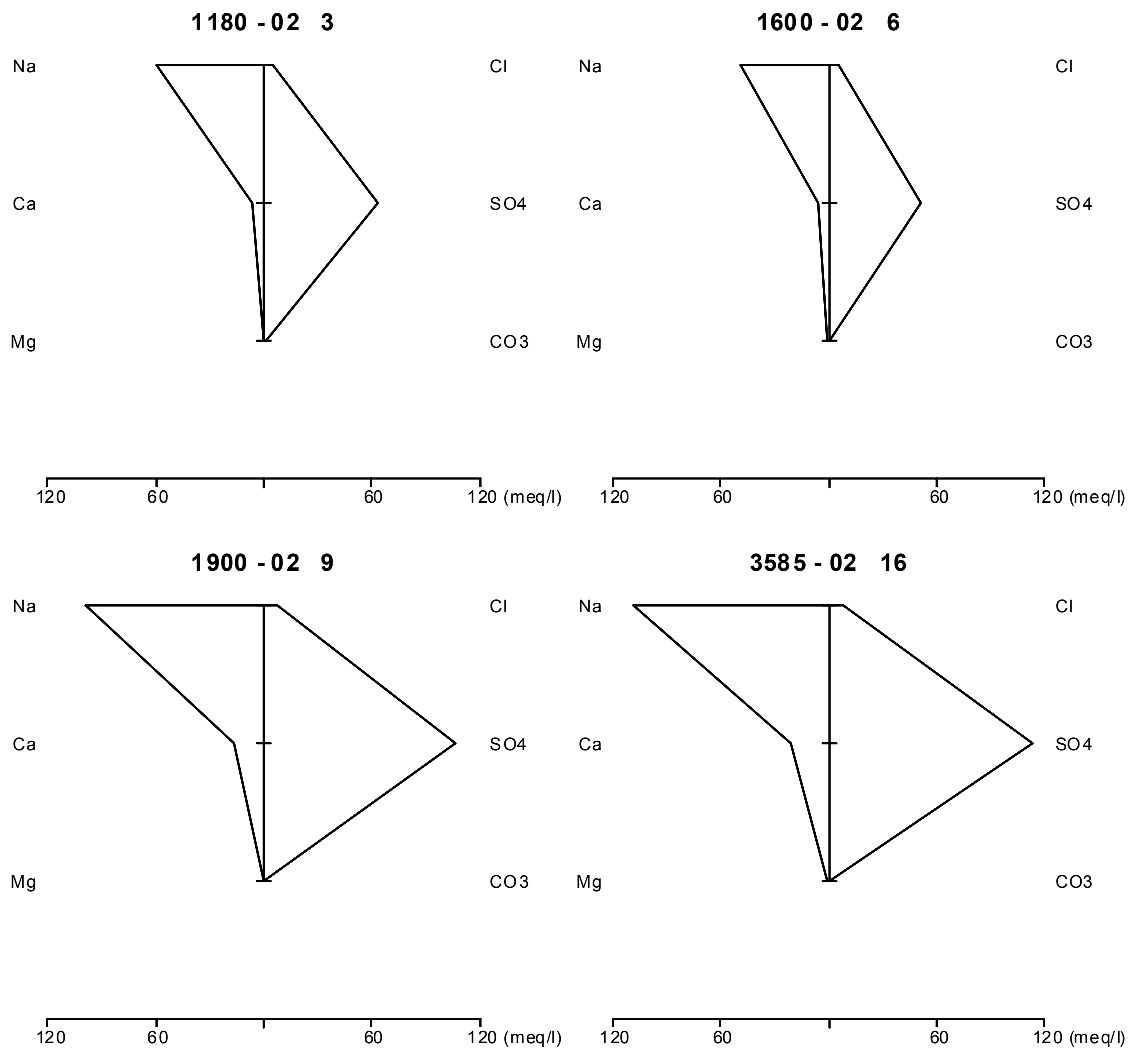

Figure 8. Stiff diagrams displaying the ionic composition of water samples collected in November 2002 from the EPNG 10-36 borehole. The first number above each diagram represents the depth in feet of the sample. The concentration of ions is much higher in the samples from 1,900 and 3,585 ft below land surface than the more shallow samples.

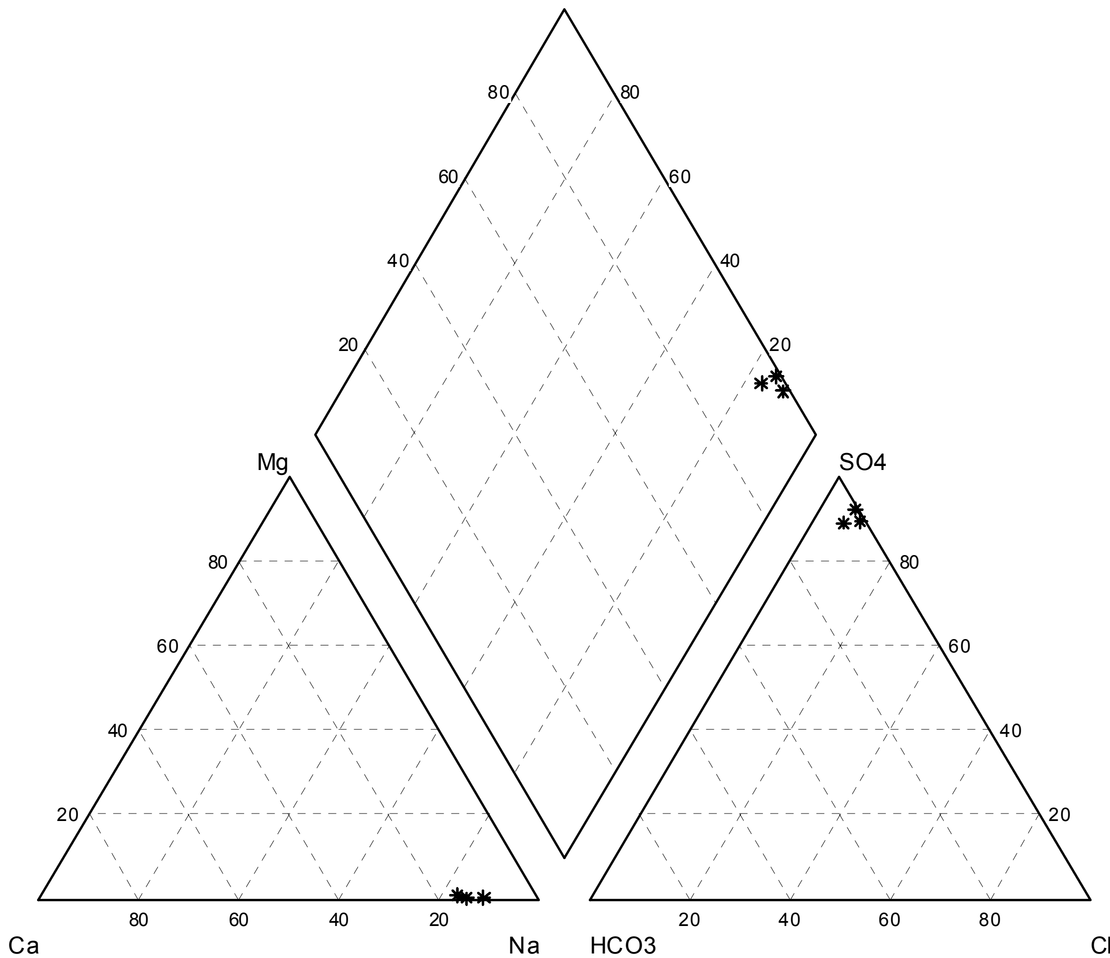

Figure 9. Piper diagram displaying the hydrochemical facies of the groundwater samples collected in November 2002. All of the samples have very similar cation and anion ratios.

Based on the chloride concentrations measured in the water samples collected at 3,585 and 1,180 ft in November 2002, and assuming a chloride content of 50 mg/L for the fresher inflow, the sample from 1,180 ft represented about 55 percent water originating from the Ojo Alamo and about 45 percent of the freshwater inflow. If a starting chloride concentration of zero is assumed for the inflow, the percentages shift to 63 percent from the Ojo Alamo and 37 percent for the inflow. Applying those percentages to the tritium measurements at 1,180 ft (30 ± 8 and 20 ± 5 pCi/L in November 2002 and June 2003) leads to a starting tritium concentration for the fresh water of 40 to 80 pCi/L. Comparing this estimate to the value measured at 1,860 ft in June 2003 (134 ± 12pCi/L) indicates that though the mixing percentages may be somewhat in error, it is unlikely that the tritium concentration entering the borehole is substantially higher than that measured at 1,860 ft.

The salinity of the water in the upper part of the borehole is substantially higher following the purging than measured in samples from 1994 and 1995. Similarly, the tritium concentrations measured in the upper portion of the borehole are lower following the purging than in 1994 and

1995, when they tended between 100 and 150 pCi/L. These features again relate the tritium to the low-salinity water and suggest there was less mixing with Ojo Alamo groundwater in the upper part of the borehole prior to the purging. Using the chloride concentrations from 1,180 and 3,585 ft in 1995, the percentage of Ojo Alamo groundwater at 1,180 ft in 1995 is estimated between 27 and 37%, as compared to the 55 to 63 percent estimated above for conditions in 2002 post-purging.

Stable isotope samples support a larger non-Ojo Alamo component to the upper well water prior to purging. The isotopic content of the upper groundwater in 1994 and 1995 was enriched in the heavy isotopes of hydrogen and oxygen and resembled water that had undergone evaporation in a surface pond or lake. The stable isotopic composition of the 2002 samples is essentially identical throughout the water column and coincident with that measured for the Ojo Alamo. This indicates that either very little water is actually mixing in through the casing break around 1,860 ft, or that it was recharged under similar climatic conditions as the groundwater in the Ojo Alamo.

CONCLUSIONS

The hydrologic logging and sampling strongly indicates that the casing in well EPNG 10-36 is compromised. Only one region of water inflow was identified and appears to be in a limited region between 1,850 and 1,880 ft below land surface.

Low levels of tritium are entering well EPNG 10-36 along with low-salinity water through the casing break. No tritium is associated with the Ojo Alamo groundwater at the casing perforations, nor is tritium encountered in any groundwater with the chemical character of unmixed Ojo Alamo water. The lower-salinity water in the upper portion of the wellbore appears to be a mix of Ojo Alamo groundwater diluted by some low-ionic-strength groundwater. This lower-salinity water also contains low levels of tritium as a result of mixing with the inflow around 1,860 ft.

Unresolved Issues

Issue #1: The source of the tritium entering the wellbore at 1,860 ft has not been determined. There remain two possibilities: 1) it was introduced into the wellbore at some time in the past, perhaps inadvertently during recompletion operations, and diffused into the annular region through the casing break at 1,860 ft, and after the purging, it is now bleeding back out into the wellbore from the annular space, or 2) there is tritium in the Tertiary-age aquifer encountered at the casing break (as there is mud outside the casing, the contributing horizon may not coincide directly with the inflow location). There is nothing in the record of Gasbuggy operations that supports either scenario, though the increase in percentage of Ojo Alamo groundwater following the purging is consistent with a limited source for the mixing water, such as annular space storage.

Issue #2: There remains a discrepancy between the Long-term Hydrologic Monitoring Program monitoring results and the tritium analyses of the discrete samples collected by DRI. In particular, the DRI samples have never detected tritium above background at the bottom of the well, neither prior to nor after the well purging. The monitoring program samples continue to record low levels of tritium in the one sample collected close to the bottom of the well.

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