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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Federal Center, Denver, Colorado 80225

HYDRAULIC TESTING OF THE OJO ALAMO SANDSTONE
IN HOLE GB-3, PROJECT GASBUGGY,
RIO ARriba COUNTY, NEW MEXICO

(Gasbuggy-5)
1971

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By

J. E. Weir, Jr.

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ABSTRACT

Hydraulic tests were made August 24 to September 2, 1969, in the Ojo Alamo Sandstone of Cretaceous age in hole GB-3, drilled about 20 months after the Gasbuggy explosion. The tests were made to determine whether increases in fracture permeability occurred as a result of the Gasbuggy experiment to stimulate gas production from a low yield reservoir by a nuclear explosion. The lower part of the formation, 3,564 to 3,686 feet below ground level, had a transmissivity (T) of 1.56 gallons per day per foot. Comparing this value with the value for T (2.64 gallons per day per foot), determined before the explosion for virtually the same stratigraphic interval in hole GB-1 in February 1967, suggests either that the Gasbuggy experiment fractured none of the lower Ojo Alamo Sandstone at hole GB-3 or that fracturing was insufficient to manifest itself through a permeability increase.

A water sample from hole GB-3, as compared to a sample collected prior to the explosion from the same interval in hole GB-1, indicates a slight increase in radioactivity following the Gasbuggy experiment.

INTRODUCTION

The U.S. Geological Survey participated in the investigation following the Gasbuggy experiment in all tests involving the hydrologic evaluation of the project. Other prime participants are the U.S. Atomic Energy Commission, El Paso Natural Gas Co., Lawrence Radiation Laboratory, and U.S. Bureau of Mines.

The Gasbuggy experiment, part of the U.S. Atomic Energy Commission's Plowshare program, was designed to stimulate gas production from low-yield reservoir rocks. The Gasbuggy explosion was detonated December 10, 1967. The Gasbuggy site is 55 miles east of Farmington, New Mexico, in the Chosa Mesa-Pictured Cliffs Field operated by the El Paso Natural Gas Co.

The Gasbuggy nuclear device was detonated in hole GB-E at a depth of 4,240 ft, 40 ft below the base of the 300-foot thick Pictured Cliffs Sandstone--the gas reservoir rock. The top of the resultant rubble chimney extended upward to about 3,900 ft, a point very near the contact between the Pictured Cliffs Sandstone and the coal unit at the base of the Fruitland Sandstone (Atkinson and Ward, 1970, p. 722-731). The bottom of the Ojo Alamo Sandstone is about 300 ft above the top of the Gasbuggy chimney, with an intervening shale zone about 200 ft thick.

Hole GB-3 was drilled 250 ft northwest of ground zero (fig. 1) to investigate the effects of the Gasbuggy nuclear explosion on the underground environment. Hole GB-3 was begun in mid-August 1969, about 20 months after the explosion, at a location 1,430 ft north of the south line and 1,636 ft east of the west line of section 36, T. 29 N., R. 4 W. The hole was completed in late September to a depth of 4,809 ft. Hydraulic tests were made or were attempted in the interval 3,481 to 3,699 ft below the kelly bushing, which was 13 ft above ground level.

The principal purpose of hydraulic tests in the Ojo Alamo Sandstone was to determine whether the permeability was increased by explosion-induced fracturing in this water-bearing unit. The tests were to have been duplicates, insofar as practical, of tests made on hole GB-1 prior to the nuclear explosion. A comparison of test results should show whether permeability was increased in the vicinity of holes GB-1 and GB-3. Interpretation of hydraulic-testing data presented in this report was done by the same method that was used in interpreting the data from tests of GB-1 (Koopman and Ballance, 1968).

During the hydraulic tests, August 24 to September 2, 1969, attempts were made to swab water from below an hydraulically inflatable packer emplaced to isolate specific intervals of the borehole (fig. 2). The packer was attached to 4½-inch drill stem.

Figure 1.-- Location of Gasbuggy Site and the drill holes at the site.

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Figure 2.--Hydrogeologic correlation of holes GB-3 and GB-1.

A string of $2\frac{3}{8}$ -inch tubing run inside the drill stem to depths below the packer was used for pushing the knock-out plug from the production-type packer and for swabbing.

Swabbing test 1 was made after the hole depth reached 3,575 ft. A single packer was placed near the top of the Ojo Alamo Sandstone to test the interval from 3,481 to 3,575 ft. Free hydraulic communication around the packer (packer bypass) clearly began after 28 minutes of swabbing. Some bypass may have occurred before that time (fig. 3), as demonstrated by pressure recorded downhole and by water conductance readings (table 1) far lower than 9,000 micromhos per centimeter, which is typical for water from the Ojo Alamo. Swabbing test 1 failed to yield any reliable data so the hole was deepened to 3,699 ft preparatory to swabbing test 2.

Swabbing test 2 of the interval 3,576 to 3,699 ft, made on August 29, 1969, was also unsuccessful. Packer bypass began after 90 minutes of swabbing; but intermittently the bypass was sealed, or partly sealed (fig. 3), until swabbing was discontinued after 5.5 hours (table 2). The bypass was probably due to channeling of the borehole around the packer. Most of the swabbed fluid was drilling fluid bypassing the packer; however, because formation water intermixed with the fluid, the relative conductance of the mixture rose to 4,900 micromhos per centimeter after about 3 hours of swabbing.

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Figure 3.--Fluid-head pressure changes during swabbing tests 1 and 2 of hole GB-3, August 24-25, and 29, 1969, respectively.

Table 1.--Data from swabbing test 1, hole GB-3, August 24-25, 1969^{1/}

Swab run	Clock time (m.d.t.)	Approximate depth to top of fluid (feet)	Swab depth (feet)	Cumulative volume of fluid swabbed to tank (gallons)	Downhole pressure (psig)		Temperature (°C at land surface)	Relative conductance (μmhos per cm at surface temp)	pH	Remarks
					High	Low				
1	2153		600		1,512	1,406				Began swabbing.
2	2157		900		1,453	1,352	25.0	1,500	8.0	
3	2205		1,500		1,393	1,246				
4	2213		1,700		1,361	1,232				
5	2221	700	2,000		1,321	1,080	27.0	1,570	8.4	
6	2230	1,000	2,200		1,432	1,246				
7	2243	1,200	2,500		1,351	1,191				
8	2256	1,200	2,800		1,287	1,098	26.0	3,050	9.2	
9	2308	1,200	2,900		1,350	1,191				Changed swab cups.
10	2328		2,900		1,361	1,224				
11	2348	850	2,700		1,344	1,222	26.5	4,100	9.6	
12	0004	950	2,500		1,373	1,230				
13	0027	1,000	2,500		1,371	1,247	29.0	4,300	9.8	
14	0048	1,050	2,500		1,382	1,238				Began measuring volume of fluid in tank.
15	0102	1,050	2,500	82.3	1,405	1,273				
16	0126	1,050	2,500	235.3	1,340	1,227	28.0	4,200	9.8	
17	0147	750	1,800	412.3	1,332	1,229				Changed swab cups.
18	0307	800	2,500	441.7	1,409	1,259				
19	0327	800	2,500	614.3	1,420	1,239	25.0	3,900	9.8	
20	0343	800	2,500	840.3	1,387	1,280				
21	0358	900	2,500	1,057.8	1,342	1,268				Changed swab cups.
22	0428	900	2,500	1,240.8	1,369	1,208				
23	0452	1,000	2,500	1,605.8	1,396	1,201				
24	0512	1,050	2,500	1,893.8	1,381	1,250				
25	0530	1,075	2,500	2,100.8	1,363	1,221	27.0	4,200	9.8	
26	0548	1,100	2,500	2,312.8	1,312	1,152				
27	0606	1,100	2,500	2,489.4	1,298	1,146				
28	0624	1,100	2,500	2,659.9	1,225	1,085				
29	0657		2,000±	2,823.9	1,320	1,240				
2/30	0709				1,486	1,412				
2/30	0724				1,436	1,226				Maximum temperature recorded below packer 42°C (108°F).

^{1/} Packer was positioned to test the interval 3,481 to 3,575 ft--depth of the hole during testing. All depth measurements referred to the kelly bushing 13 ft above ground level.

^{2/} Shallow runs made while down-rigging swabbing unit.

Table 2.--Data from swabbing test 2, hole GB-3, August 29, 1969^{1/}

Swab run	Clock time (m.d.t.)	Approximate depth to top of fluid (feet)	Swab depth (feet)	Cumulative volume of fluid swabbed to tank (gallons)	Downhole pressure (psig)		Temperature (°C at land surface)	Relative conductance (μmhos per cm at surface temp)	pH	Remarks
					High	Low				
1	1418		1,200		1,536	1,350				Swabbed to waste during first 9 runs.
2	1427	300	1,400		1,377	1,243				
3	1436	350	1,500		1,268	1,151				
4	1446	400	1,600		1,181	1,040				
5	1456	450	1,700		1,092	959				
6	1508	500	1,750		1,009	890	28.0	2,200	6.8	Changed swab cups.
7	1524	550	1,750		937	848				
8	1537	650	2,100		893	778				
9	1548	750	2,100		843	749				
										Began discharge to tank.
10	1601	800	2,200	29.4	1,081	950	28.0	2,200	7.0	Changed swab cups.
11	1615	900	2,300	96.5	1,004	853				
12	1630	900	2,300	272.5	928	800				
13	1645	950	2,300	502.5	914	785				
14	1700	1,000	2,300	649.5	927	760	30.5	2,900	7.4	
15	1725	1,050	2,400	737.7	1,194	1,023				Swab descending very slowly. Lost 30 barrels of mud in annulus.
16	1740	1,050	2,400	914.1	1,156	1,013				
17	1756	700	2,400	1,119.9	1,246	1,095				
18	1813	800	2,400	1,355.1	1,144	977	26.0	4,900	8.6	
19	1837	800	2,400	1,443.3	1,029	884	26.5	4,400	8.8	
20	1851	900	2,400	1,560.9	957	834	27.0	4,500	9.0	Maximum temperature recorded below packer 46.5°C (116°F).
21	1904	900	2,400	1,678.5	1,206	1,029				
22	1919	800	2,400	1,767.7	1,157	1,000				
23	1934	700	2,400	1,913.7	1,225	1,027				
24	1950	500	1,200	2,001.9	1,365	1,225				

^{1/} Packer was positioned to test the interval 3,472 to 3,647 ft--depth of the hole during testing. All depths referred to the kelly bushing 13 ft above ground level.

Swabbing test 3 of the interval 3,577 to 3,699 ft was run September 1, 1969 (table 3). Although the packer was seated only 1 foot below its position during test 2, no bypass occurred; and the lower part of the Ojo Alamo Sandstone^{1/} was successfully tested by the swabbing method (fig. 4). Drilling mud was removed from the tools and the open hole below the packer during the first 15 of 29 swab runs. Swabbing time totaled 6 hours.

Water-level recovery measurements (table 4) were made for 590 minutes after the swabbing period ended (fig. 5). To expedite recovery and determine a static head, about 100 gallons of water was then injected into the tubing; fluid decline was measured for 100 minutes or 730 minutes after swabbing ended.

DISCUSSION OF RESULTS OF HYDRAULIC TESTS

A static head of 1,065.5 ft below ground level for the lower part of the Ojo Alamo Sandstone was determined by extrapolation of the recovery trend after swabbing and also partly by extrapolation of a declining trend after injecting. The static level determined in this manner is probably accurate within a few tens of feet and saved several hours of rig time.

^{1/}Because the Kirtland Shale has such a low permeability the 51 ft included in the tested interval should have no noticeable effect on testing the lower Ojo Alamo Sandstone.

Table 3.--Data from swabbing test 3, hole GB-3 September 1, 1969^{1/}

Swab run	Clock time (m.d.t.)	Approximate depth to top of fluid (feet)	Swab depth (feet)	Cumulative volume of fluid swabbed to tank (gallons)	Downhole pressure ^{2/} (psig)		Temperature (°C at land surface)	Relative conductance (μmhos per cm at surface temp)	pH	Remarks
					High	Low				
1	1431		1,200		1,561	1,424				
2	1439	300	1,500		1,462	1,336				
3	1453	400	1,800		1,367	1,194				
4	1504	550	1,900		1,235	1,080				
5	1515	700	2,000		1,124	993	26.5	1,050	7.7	
6	1535	900	2,100		1,053	916				Changed swab cups.
7	1546	1,000	2,200		963	844				
8	1600	1,100	2,200		904	801	26.5	1,150	7.8	
9	1613	1,200	2,400		872	750				
10	1628	1,300	2,500		832	701	28.5	1,700	7.7	
11	1638	1,500	2,600		783	655				Changed swab cups.
12	1650	1,500	2,600		740	611	29.6	4,190	7.2	
13	1715	1,600	2,700		740	590				About 1,100 gallons swabbed to here.
14	1730	1,650	2,700	111.72	678	534				Began measuring volume of fluid in tank.
15	1745	1,650	2,700	264.60	616	496	29.0	9,000	7.0	
16	1800	1,700	2,700	405.72	584	467				
17	1815	1,750	2,700	540.96	564	468	27.5	8,200	7.0	
18	1830		2,700	658.56	569	468				
19	1848	1,800	2,700	746.76	551	451				
20	1858	1,800	2,700	858.48	546	442				
21	1908	1,800	2,700	964.32	541	432				
22	1920	1,800	2,700	1,046.64	530	432	29.5	9,200	7.0	
23	1930	1,800	2,700	1,117.20	530	432				
24	1941	1,800	2,700	1,187.76	530	432				
25	1952	1,800	2,700	1,275.96	530	432				
26	2002		2,700	1,334.76	530	432				
27	2013	1,800	2,700	1,422.96	530	432				
28	2023		2,700	1,487.64	530	432				
29	2034		2,700	1,540.54	544	449	28.5	9,600	6.8	Maximum temperature recorded below packer 51°C (124°F).

^{1/} Packer set at 3,577 ft and tested interval 3,577 ft to bottom of hole at 3,699 ft. All depths referred to the kelly bushing 13 ft above ground level.

^{2/} Recording pressure gage set at a depth of about 3,581 ft below the kelly bushing.

DOWNHOLE PRESSURE, IN POUNDS PER SQUARE INCH

12

Figure 4.--Fluid-head pressure changes during swabbing test 3 of hole GB-3, September 1-2, 1969.

Table 4.--Data from recovery after swabbing test 3, hole GB-3
September 1-2, 1969

Clock time (m.d.t.)	Elapsed time (minutes)		Depth to fluid level ^{1/} (feet)
	Since swabbing began	Since swabbing stopped	
<u>September 1, 1969</u>			
2152	441	78	1,912.7
2204	453	90	1,846.5
2206	455	92	1,837.3
2209	458	95	1,820.9
2213	462	99	1,804.5
2221	470	107	1,771.7
2229	478	115	1,738.8
2238	487	124	1,705.0
2248	497	134	1,673.2
2258	507	144	1,640.4
2309	518	155	1,607.6
2321	530	167	1,574.8
2334	543	180	1,542.0
2348	557	194	1,509.2
<u>September 2, 1969</u>			
0005	574	211	1,476.4
0023	592	229	1,442.65
0043	612	249	1,410.8
0108	637	274	1,378.0
0137	666	303	1,345.1
0213	702	339	1,312.3
0300	749	386	1,278.5
0400	809	446	1,245.87
0500	869	506	1,221.45
0550	919	556	1,206.60
0624	953	590	1,197.99
0637 to 0647	Injected approximately 100 gallons of water into tubing.		
0701	990	627	1,082.68
0704	993	630	1,084.03
0707	996	633	1,085.37
0710	999	636	1,086.19
0713	1,002	639	1,087.57
0716	1,005	642	1,089.00
0719	1,008	645	1,090.22
0724	1,013	650	1,091.90
0731	1,020	657	1,094.26
0738	1,027	664	1,096.26
0743	1,032	669	1,097.60
0753	1,042	679	1,100.72
0804	1,053	690	1,104.13
0824	1,073	710	1,108.36
0844	1,093	730	1,111.84
0930 to 0950 - Collected water samples. Forced formation water out of drill stem by injecting mud into 2-3/8-inch tubing inserted to 3,577 ft inside 4-1/2-inch drill stem to which packer was attached.			

^{1/} All depths of water-level recovery and injection decline are referred to top of 2-3/8-inch tubing, which is 14.5 ft above ground level.

Figure 5.--Graphic analysis of water-level recovery in hole GB-3 after swabbing test 3, September 2, 1969.

The recovery data were used in the following formula for determining transmissivity (T):

$$T \text{ in gallons per day per foot (gpd per ft)} = \frac{264 Q}{s} \log_{10} t/t'$$

where

s = residual drawdown or depth to water in feet

t = time in any unit since swabbing began

t' = time in any conforming unit since swabbing stopped

Q = discharge rate in gallons per minute (gpm).

During the span of one log cycle on the data plot, $\log_{10} t/t'$ becomes one and s equals Δs or the change in s and the formula becomes:

$$T = \frac{264 Q}{\Delta s}$$

The relative specific capacity (RSC) also was determined from recovery data for swabbing test 3. The formula used is identical to that used for the analyses of tests in hole GB-1 prior to the explosion:

$$RSC = \frac{Q}{(h' - h)}$$

where

Q = typically the average volumetric rate of fluid-level rise in the tools during a 1-minute time span; however, average swabbing rate was used in analyzing hole GB-1 data and is likewise used herein

h = static water level of the interval tested in feet referred
to a convenient datum

h' = average water level during the time interval used for
determining Q referred to the same datum as h .

For the lower 67 ft of Ojo Alamo Sandstone in hole GB-3, the
following computations were made (fig. 5):

$$\begin{aligned} T &= \frac{264 Q}{\Delta s} \\ &= \frac{264 (8.2)}{1,365} \\ &= 1.56 \text{ gpd per ft or } 0.086 \text{ Darcy foot} \end{aligned}$$

The relative specific capacity as determined from data for
swabbing test 3 was:

$$RSC = \frac{8.2}{(1,910 - 1,080)} = 0.0098 \text{ gpm per ft of drawdown.}$$

Swabbing test 2 during the initial 90 minutes had a tight seal
for the packer seat and showed an even pressure decline in this
period. A plot of pressure decline may be analyzed similarly to
the method described above, except that drawdown is plotted instead
of residual drawdown and head change, Δh , is used instead of Δs .
Also, actual pressures are plotted on the arithmetic scale of the
semilogarithmic graph (fig. 3), and these are converted to feet of
water in calculating T . The T calculated for this test is 1.71 gpd
per ft.

A similar plot for the swabbing period of test 3 indicates a T of 1.25 gpd per ft (fig. 4). All of these determinations are for virtually the same interval. The recovery data are expected to yield the most accurate value for T (1.56 gpd per ft) (fig. 5). The determination of T from the drawdown data does show substantiating evidence that permeability is unchanged in the Ojo Alamo Sandstone as a result of nuclear explosion.

Field measurements of relative conductance of the water circulated from the Ojo Alamo Sandstone were 10,000 micromhos per centimeter at 24°C. The water sampled was dark green and highly turbid; it had a very salty taste.

QUALITY OF THE WATER

Water samples were collected after swabbing test 3, in hole GB-3, for chemical and radiochemical analyses and for tritium determinations (table 4). Results of the chemical analyses show that water from the lower Ojo Alamo Sandstone is sodium sulfate type (table 5). The specific conductance of the water is 9,050 micromhos per centimeter at 25°C--typical for water from the Ojo Alamo Sandstone (Koopman and Ballance, 1967, p. 10). A comparison of this chemical analysis to the one for water from the same interval in drill hole GB-1 (specific conductance of 7,450 micromhos) indicates that the sample from hole GB-3 is more representative of formation water.

Table 5.--Chemical analyses of water from the lower part of the
Ojo Alamo Sandstone, drill holes GB-3 and GB-1,
Gasbuggy Site, New Mexico

(Analyses by U.S. Geological Survey. Constituents in
milligrams per liter unless otherwise noted.)

Chemical components	GB-3 9-2-69 ^{1/}	GB-1 2-26-67 ^{2/}
Silica (SiO ₂)	26	16
Aluminum (Al)	.40	.02
Iron (Fe)	.18	.69
Manganese (Mn)	.26	.08
Calcium (Ca)	310	242
Magnesium (Mg)	17	14
Strontium (Sr)	6.7	5.3
Sodium (Na)	2,400	1,880
Potassium (K)	12	12
Lithium (Li)	.33	.28
Copper (Cu)	.02	.01
Selenium (Se)	.013	<.01
Zinc (Zn)	.02	.01
Bicarbonate (HCO ₃)	23	86
Carbonate (CO ₃)	0	0
Sulfate (SO ₄)	5,290	3,630
Chloride (Cl)	260	221
Fluoride (F)	.7	1.4
Nitrate (NO ₃)	.1	.0
Phosphate (PO ₄)	<.01	.00
Boron (B)	.34	.25
Dissolved solids		
Res. on evap. at 180°C	8,560	6,880
Calculated	8,330	6,060
Hardness as CaCO ₃		
Total	852	668
Non-carbonate	833	598
Specific conductance		
(μmhos/cm at 25°C)	9,050	7,450
pH	5.9	6.9

Analysts: O. J. Feist, Jr., and G. F. Scarbro

^{1/} Sample from interval 3,577 to 3,699 ft below the kelly bushing.

^{2/} Sample from interval 3,575 to 3,696 ft below the kelly bushing.

Samples from hole GB-1 were collected prior to the Gasbuggy nuclear experiment, whereas samples from hole GB-3 were collected after the experiment. Comparison of results of radiochemical analysis for sample suites obtained before the explosion (hole GB-1) and afterward (hole GB-3) indicates a slight increase in the radioactivity of the water (table 6). Gross beta increased from 4.0 to 37 picocuries per liter and gross alpha increased from 1.5 to 110 micrograms per liter. Tritium concentration was below the detection level by liquid scintillation counting methods used on both samples.

Pre-explosion background values of radioactivity apparently are too low because samples from hole GB-1 were composed of almost one-fourth drilling water, based on concentrations of chemical constituents. However, this amount of dilution would account for only a small part of the indicated increase in beta and alpha radioactivity shown by analyses of samples.

CONCLUSIONS

The transmissivity (T) of the lower Ojo Alamo Sandstone was determined to be 1.56 gpd per ft (0.086 Darcy foot). For virtually the same interval tested in hole GB-1 the value of T was 2.64 gpd per ft (0.144 Darcy foot), about twice the value determined in hole GB-3. This comparison indicates that the rock in the lower

Table 6.--Radiochemical analyses of water from the lower part of the
Ojo Alamo Sandstone, drill holes GB-3 and GB-1,
Gasbuggy Site, New Mexico

(Analyses by U.S. Geological Survey)

Radiochemical analyses	Hole GB-3 ^{1/}		Hole GB-1 ^{2/}	
	Concen- tration	Date analyzed	Concen- tration	Date analyzed
Gross beta (as $\text{Sr}^{90}\text{-Y}^{90}$, pc/l) ^{3/}	37	1-29-70	4.0	5-18-67
Gross alpha as Uranium equivalent ($\mu\text{grams/l}$) ^{4/}	110	1-29-70	1.5	5-18-67
Tritium, tritium units	<200	10-14-69	<350	4-24-67

Analysts: Radiochemical - P. K. Roscio and R. S. Dewar

Tritium - Not designated

1/ Sample from interval 3,577 to 3,699 ft below the kelly bushing,
September 2, 1969.

2/ Sample from interval 3,575 to 3,696 ft below the kelly bushing,
February 26, 1967.

3/ Gross beta data can be reported in many ways; $\text{Sr}^{90}\text{-Y}^{90}$ equivalent
and Cs^{137} equivalent are most commonly used. The difference is
only in which isotope is used for calibration. $\text{Sr}^{90}\text{-Y}^{90}$ is used
as a gross beta standard by the U.S. Geological Survey for data
here reported.

4/ Natural uranyl acetate has been used as an alpha standard since
1957. The term "natural uranium" is defined in the Code of
Federal Regulations 10 CFR 150.20.5c as 3,000 kg (kilograms)
natural U $\equiv$ 1 Ci (curie) natural U $\equiv$ $(3.7 \times 10^{10}$ disintegrations
per second $\text{U}^{238}) + (3.7 \times 10^{10}$ disintegrations per second $\text{U}^{234})$
+ $(9 \times 10^8$ disintegrations per second $\text{U}^{235})$.

Ojo Alamo Sandstone was not fractured in the vicinity of hole GB-3 by the Gasbuggy explosion; or, fracturing was not sufficiently strong to be manifested as a permeability increase.

Apparent slight increases in gross beta and gross alpha radioactivity in a water sample from hole GB-3 as compared to a sample from hole GB-1, collected prior to the explosion, indicates a slight increase in radioactivity of water in the lower part of the Ojo Alamo Sandstone following the Gasbuggy explosion. However, background values of radioactivity for samples from hole GB-1 may be too low because samples were composed of almost one-fourth drilling water.

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