RAINWATER RECHARGE AT THE WIPP SITE

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The Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, is intended for the permanent disposal of radioactive waste from nuclear weapons production. The WIPP site was selected in 1974. It is now 1997, and the Department of Energy (DOE) still does not know where the groundwater aquifers are recharged. This, at a minimum, must be understood, or DOE's site characterization has no credibility (EEG-32, 1985; Anderson, 1994; Konikow, 1995; EEG-61, 1996; SEIS, 1996, Appendix H).

DOE's failure to grasp the fundamentals of WIPP site hydrology stems not from a lack of evidence, but from an unwillingness to face the truth: (1) the WIPP site is in karst; (2) the Dewey Lake Redbeds and the Rustler Formation are recharged by rainwater, and (3) groundwater flow at WIPP is three-dimensional.

The controversy over karst at the WIPP site dates to a paper by Larry Barrows entitled: "WIPP Geohydrology -- The Implications of Karst" (Barrows, 1982; reprinted in EEG-32, 1985, Appendix A). Barrows cites as evidence of karst geomorphology: (1) ample precipitation; (2) lack of surface runoff; (3) disappearing arroyos; (4) sink holes; and (5) underground caverns.

The WIPP site is located in one of the largest karstlands in the world. The Pecos River valley is famous for Santa Rosa Sinks, Bottomless Lakes, and Carlsbad Caverns. Within one mile of the northwest corner of the WIPP site is Nash Draw, a huge depression in the land surface, up to 18 miles long and 10 miles wide. Nash Draw was formed by the coalescence of thousands of sink holes caused by the abrupt collapse or gradual subsidence of overlying rocks into underground caverns beneath them.

Nash Draw is bounded on the east by Livingston Ridge, which is actually a rim, a 100-foot escarpment capped by Mescalero caliche. Livingston Ridge is not a geomorphic divide; it does not represent the eastern edge of karst conditions. It is the eastern extent of widespread collapse of surficial rocks into the voids caused by dissolution of evaporite rocks in the subsurface. Karst exists east of Livingston Ridge, but the karst landforms are not as widespread or as well developed as in Nash Draw.

The WIPP site has almost no surface runoff. This is not due to inadequate precipitation. Rainfall averages 14 inches per year, and 20 inches per year is not uncommon. Rather, the WIPP site is covered with windblown sand in the form of deflation basins and partially stabilized dunes. These sands are transmissive enough to allow infiltration of even the largest storms. "Instead of running off, the precipitation collects in small topographic depressions and rapidly soaks into the ground. The absence of surface runoff is characteristic of a karstland." (Barrows, 1982)

Most of the depressions are windblown. But some of the larger ones are sink holes, exemplified by WIPP-33 and WIPP-14, located 1.1 mile and 3.4 miles east of Nash Draw, respectively. WIPP-33 is a collapse sink with a disappearing arroyo, underlain by five caverns: one in Dewey Lake siltstone, two in Forty-Niner gypsum, and two in Magenta dolomite. WIPP-14 is a solution-subsidence doline which has held water in the geologic past; now the Culebra dolomite is underlain by 70 feet of mud with gypsum and anhydrite fragments, here interpreted as cave sediments. The cavernous zones at WIPP-33 and WIPP-14 are direct evidence of karst. These zones can be correlated stratigraphically with washouts and loss of core in seventeen other WIPP boreholes and in the WIPP ventilation shaft. The question is not whether karst exists at the WIPP site, but whether karst hydrology is active today.

The Rustler Formation is the most transmissive aquifer and the principal karst horizon at the WIPP site. If karst hydrology is active today, then the Rustler must be recharged by rainwater. A likely process, according to Barrows (1982), is downward infiltration of fresh water through feeders in the overlying Dewey Lake Redbeds to karst channels in the Rustler Formation. Conversely, if karst hydrology is <u>not</u> active today, then the Rustler Formation must not be recharged by rainwater. This would require a continuous impermeable layer, acting as a barrier to rainwater infiltration, somewhere in the stratigraphic column above the Rustler Formation. Bachman (1985) argued that Mescalero caliche forms such a barrier, preventing infiltration and recharge of the Dewey Lake Redbeds and the Rustler Formation.

Caliche is a layer of calcium carbonate that forms in desert soils at the depth of soil water penetration. Where soil cover is thin, the caliche horizon may become plugged and indurated, forming a “hardpan” resistant to erosion and impervious to rainwater. But where soil cover is thick, infiltrating soil water may migrate along the caliche surface until it finds a fracture that allows downward drainage, or a hole where a plant root has penetrated the caliche; or it may collect in a small depression in the caliche surface and begin to dissolve a new hole in the caliche. In the southwestern part of the WIPP site (SW/4 sec 30, T 22 S, R 31 E), where Mescalero caliche is in direct contact with the Dewey Lake Redbeds, trench exposures revealed fifteen solution pipes, 1 to 14 feet in diameter, right through the caliche. Here the Dewey Lake Redbeds are recharged directly by rainwater. These trenches were located in a karst valley, a broad swale one mile long, ten feet deep, trending east-west, and narrowing from 900 feet in the east to 200 feet in the west, where thick groves of mesquite bushes are impenetrable. Other smaller topographic depressions, visible in the WIPP site air photos, shown on USGS topographic maps, lead directly to the deepest fluvial incisions in Livingston Ridge. The air photos reveal ephemeral or near-surface drainage courses expressed at the land surface as vegetation in dendritic patterns.

The Gatuna Formation, consisting of light reddish-brown, poorly consolidated sandstone, is alluvial fill material deposited in ancient sinks and topographic lows by westward-flowing streams. It was exposed in trenches on the slopes of WIPP-33, below the caliche escarpment. The Gatuna sandstone is commonly fractured, jointed, and broken into blocks. As soil water dissolves the carbonate cement, these openings become enlarged by solution, forming solution pans or tinajitas, and solution grooves or slots. The Gatuna is not a barrier to rainwater infiltration.

The Santa Rosa Formation consists of pale orange, coarse-grained sandstone, cemented by dolomite, interbedded with conglomerate lenses containing dolomite, chert, and quartz pebbles. The Santa Rosa has been eroded from the western part of the WIPP site; to the east, where it remains, it protects the underlying Dewey Lake Redbeds from erosion. At WIPP-14, the Santa Rosa was exposed in trenches beneath a leached and degraded caliche profile. The Santa Rosa exhibited carbonate-filled fractures, direct evidence of rainwater infiltration. The Santa Rosa retards, but does not prevent, rainwater recharge to the underlying Dewey Lake Redbeds.

Water has been encountered in the Dewey Lake Redbeds in eleven test wells inside or within one mile of the WIPP site. All are listed in Table 1. According to the neutron log for H-3b4, a down-hole camera recorded "water streaming from fracture." The water level was 466.85 feet below the surface. Water was also observed in the Dewey Lake Redbeds in the air intake shaft near the center of the WIPP site (EEG-61, 1996, p. 2-6), at WIPP-33 (SAND 80-2011, p. 11), and in three private wells within 2.5 miles of the WIPP site (Ranch, Barn, and Unger). All are shown in Figure 1.

Table 1 reveals a strong correlation between encounters of water in the Dewey Lake Redbeds and absence of the overlying Santa Rosa sandstone. At least nine of the thirteen test wells where the Santa Rosa is <u>not</u> present produced water in the Dewey Lake Redbeds. It is not certain that the other four (H-6, P-14, WQSP-5, and Cabin Baby) did not produce water in the Dewey Lake Redbeds, because the actual neutron logs for these test wells are unavailable. However, the "abridged drill-hole histories" for P-13 (located 224 feet from the H-6 hydropad) and P-14 do not report water in the Dewey Lake Redbeds. Only two of the twenty test wells where the Santa Rosa is present produced water in the Dewey Lake Redbeds. At these test wells (H-11 and H-16) the Santa Rosa is only 54 feet and 15 feet thick, respectively. This is further evidence that the Santa Rosa retards, but does not prevent, rainwater recharge to the underlying Dewey Lake Redbeds.

Figure 2 graphically displays the relationship between the western edge of the Santa Rosa sandstone and the locations of wells that produce water in the Dewey Lake Redbeds. Simply stated, the recharge area for the Dewey Lake Redbeds is everywhere that the Santa Rosa is not present.

TABLE 1: THICKNESS OF SANTA ROSA SANDSTOEN, MEASURED IN FEET, CORRELATED WITH ENCOUNTERS OF WATER IN DEWEY LAKE REDBEDS, AT WIPP TEST WELLS

test well	Santa Rosa	water in Dewey Lake
H-1	N.P.	*
H-2	N.P.	*
H-3	N.P.	*
H-4	N.P.	*
H-5	217	
H-6	N.P.	?
H-11	54	*
H-14	N.P.	*
H-15	126	
H-16	15	*
H-17	34	
H-18	12	
P-14	N.P.	?
P-15	N.P.	*
P-17	N.P.	*
P-18	78	
WIPP-12	138	
WIPP-13	53	
WIPP-18	129	
WIPP-19	82	
WIPP-21	34	
WIPP-22	68	
DOE-1	87	
DOE-2	120	
ERDA-9	9	
Cabin Baby	N.P.	?
WQSP-1		
WQSP-2		
WQSP-3		
WQSP-4		
WQSP-5	N.P.	?
WQSP-6	N.P.	*
WQSP-6a	N.P.	*

Note: WQSP-6 and WQSP-6a are shown as one well in Figures 5 and 6.

Sources: DOE/CAO 1996-2184, pp. 2-131, USDW-25; SAND 88-0157, p. 81; SAND 80-2011, pp. 8, 11, 15, C-3; and EEG-61, p. 2-6.

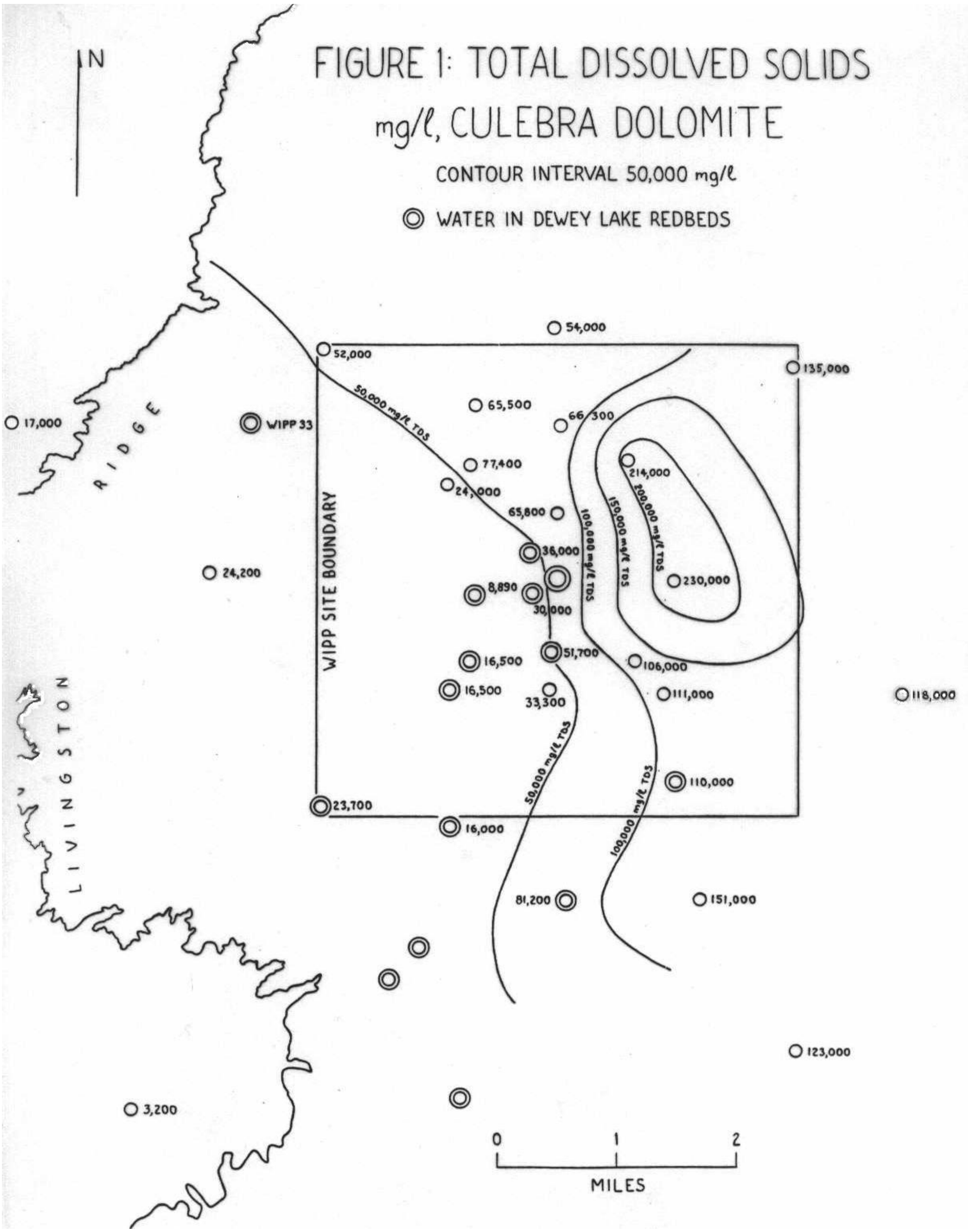

FIGURE 1: TOTAL DISSOLVED SOLIDS mg/ℓ, CULEBRA DOLOMITE

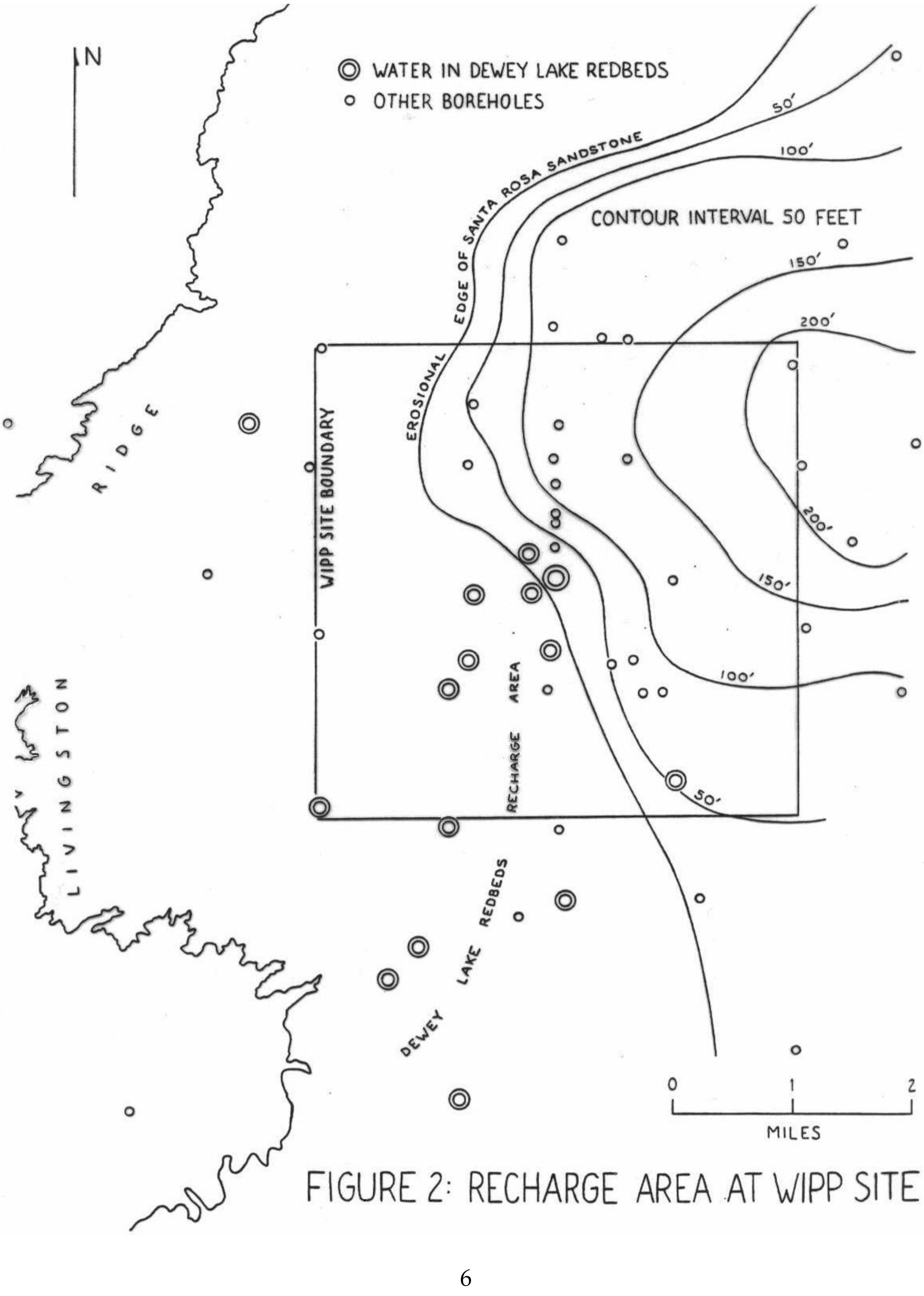

FIGURE 2: RECHARGE AREA AT WIPP SITE

The water in the Dewey Lake Redbeds is potable. Environmental Protection Agency (EPA) criteria for drinking water are twofold: (1) less than 10,000 milligrams per liter (mg/l) total dissolved solids (TDS); and (2) more than 5 gallons per minute (gpm) of water produced by the well. Water quality data for the Dewey Lake Redbeds are given in Table 2. Five private wells within eight miles of the WIPP site produce water of potable quality in the Dewey Lake Redbeds, but the quantity has never been measured. Three WIPP test wells produce water in sufficient quantity from the Dewey Lake Redbeds, but the quality has never been tested. At seven WIPP test wells, (and also at WIPP-33), water produced by the Dewey Lake Redbeds has never been tested for quality or quantity. At only one test well, WQSP-6a, has both the quality and quantity of water from the Dewey Lake Redbeds been tested, and it was found to meet both criteria for drinking water (3,920 to 4,238 mg/l TDS, 12 gpm). DOE claims (DOE/CAO 1996-2184, Appendix USDW, Table USDW-4) that test well WQSP-6a is not subject to EPA standards (40 CFR 191, Subpart C) because WQSP-6a is located on-site -- one mile southwest of the center of the WIPP site, 0.3 miles southwest of the waste emplacement panels (DOE/CAO 1996-2184, Figure 3-9). DOE says it is "possible" that other test wells are subject to EPA drinking water standards (DOE/CAO 1996-2184, Appendix USDW, Table USDW-4). DOE does not know because DOE has not done the necessary testing. P-17 is 3908 feet outside the WIPP site. WIPP-33 is 2854 feet outside the WIPP site. H-4c is 446 feet outside the WIPP site. All the private wells are outside the WIPP site. Until these wells are properly tested, it cannot be claimed that the Dewey Lake aquifer does not qualify as an underground source of drinking water under 40 CFR 191, Subpart C. Absence of evidence is not evidence of absence.

Directly underlying the Dewey Lake Redbeds is the Rustler Formation. In WIPP boreholes, outside of Nash Draw, the Rustler ranges in thickness from 276 feet at WIPP-33, a collapse sink, to 462 feet at P-18, considered to be a complete Rustler section. The Rustler is divided into five members, here described in descending order: (1) the Forty-Niner member consists of 48 to 78 feet of broken and slumped gypsum with a bed of massive siltstone near the base; (2) the Magenta dolomite, 19 to 28 feet thick, is a highly fractured aquifer; (3) the Tamarisk member consists of 80 to 179 feet of anhydrite or gypsum with clay seams; (4) the Culebra dolomite, 21 to 31 feet thick, also highly fractured, is the most transmissive unit of the Rustler aquifers; and (5) the lower unnamed member consists of 72 to 150 feet of siltstone and very fine-grained sandstone, with interbedded gypsum or anhydrite.

The Culebra and Magenta dolomite members are persistent marker beds and reliable aquifers. In forty-one WIPP test wells, the Culebra was always saturated; the Magenta was dry at H-7 and WIPP-26, and absent at WIPP-29, all in Nash Draw (Mercer, 1983, Table 8). But water is sometimes found in the other members of the Rustler, even near the center of the WIPP site. Water was observed seeping into the WIPP ventilation shaft from a zone of solution residue in the Forty-Niner member, 17.7 to 30.2 feet above the Magenta; test well H-1 yielded as much water in the Tamarisk member as in the Culebra or Magenta; and test

TABLE 2: WATER IN THE DEWEY LAKE REDBEDS, GALLONS PER MINUTE, TOTAL DISSOLVED SOLIDS

well	gpm	TDS (mg/l)	date
H-1	not tested	not tested	
H-2	not tested	not tested	
H-3	not tested	not tested	
H-14	not tested	not tested	
H-16	not tested	not tested	
P-15	not tested	not tested	
P-17	not tested	not tested	
WIPP-33	not tested	not tested	
P-9	25	not tested	
H-4c	12-25	not tested	
H-11	25-30	not tested	
WQSP-6	25-30	not tested	
WQSP-6a	12	4,238	07/13/95
		3,920	03/28/96
Barn Well	not tested	670	11/04/87
		720	04/20/88
		630	07/27/89
		650	06/21/90
Ranch Well	not tested	3,300	06/18/86
		3,200	12/20/87
		2,900	04/20/88
		2,800	07/27/89
		3,000	06/20/90
Twin Wells	not tested	400	01/30/86
		390	08/03/88
		400	10/20/89
		410	05/30/90
Fairview Well	not tested	3,400	11/16/87
		3,300	07/06/88
Unger Well	not tested	3,300	11/18/87
		3,200	07/06/88

Notes: WIPP-33 encountered 7.0-foot cavity in Dewey Lake Redbeds; fluid level during logging was 274 feet below land surface.

Criteria for drinking water: < 10,000 mg/l TDS and > 5 gpm.

Sources: DOE/CAO 1996-2184, pp. 2-131, USDW-25; SAND 88-0157, p. 81; SAND 80-2011, pp. 8, 11, 15, C-3; EEG-61, p. 2-6; and USGS Open-file Report 78-592.

well H-3 yielded as much water in the lower unnamed member as in the Culebra or Magenta (EEG-32, 1985, pp. 37, 39). Potash test holes P-4, P-12, P-13 and P-17 hit water in the lower unnamed member.

Karst features have been observed in Dewey Lake siltstone, Forty-Niner gypsum, Magenta dolomite, Tamarisk anhydrite, and Culebra dolomite. Lost circulation of drilling fluid has been reported in the Dewey Lake Redbeds at H-7c, P-1, DOE-2, WIPP-25 and WIPP-33; in Forty-Niner gypsum at H-1 and WIPP-33; and in Magenta dolomite at WIPP-33. Four boreholes clustered near the center of the WIPP site have encountered washouts or loss of core in Tamarisk anhydrite (H-1, H-2, H-3 and ERDA-9). Five cavernous zones were encountered in Culebra dolomite at H-7c. Just three miles from the WIPP site in Nash Draw, at the Gnome Site turnoff, a surface exposure of Forty-Niner gypsum features a striking display of grikes, tunnels, caves, and collapse sinks; at least one of the caves is large enough to enter. These caves supply fresh water to deeper Rustler aquifers.

Thus it is shown that rainwater recharge to the Rustler Formation is possible, that no impermeable barrier exists above the Culebra dolomite. The question is whether or not rainwater recharge is actually occurring. This question can be answered by looking at the geochemistry of groundwater in the Culebra dolomite.

Total dissolved solids (TDS) in Culebra groundwater has been measured in 38 WIPP test wells [Table 3]. In some cases there have been multiple samplings at the same test well; in these cases the lowest measured values are presented in Table 3, as they are the most likely to represent mixing of groundwater with fresh water, and the least likely to represent contamination by brine from nearby injection wells. Table 3 reveals that TDS in Culebra groundwater in WIPP test wells vary by nearly two orders of magnitude, from 239,000 mg/l at WIPP-29 to 2,710 mg/l at H-8. When the wells are plotted on a map [Figure 1], it is shown that even within the WIPP site, TDS in Culebra groundwater vary by a factor of 25 -- from 230,000 mg/l at H-15 to 8,890 mg/l at H-2b. These two test wells are less than 8,750 feet (1.66 miles) apart.

Figure 1 shows contour lines of TDS at a contour interval of 50,000 mg/l. The contour lines display a zone of high TDS in the northeastern part of the WIPP site, where the Santa Rosa sandstone is present, with TDS steadily decreasing to the southwest, where the Santa Rosa is absent. This is consistent with the interpretation that Culebra groundwater becomes mixed with increasing amounts of fresh water as it approaches Nash Draw, because the hydrologic regime is increasingly karstic.

A similar observation was made by Chapman (EEG-39, 1988). She concluded (p. 35) that "the only plausible mechanism" for an order of magnitude decrease in TDS as Culebra groundwater moves along its flow path "is the influx of a large quantity of low TDS water. As no fresh-water aquifers are located in the WIPP area, the source of the fresh water must be surface water recharge."

TABLE 3: LOWEST RELIABLE MEASUREMENTS,
TOTAL DISSOLVED SOLIDS, CULEBRA DOLOMITE

well	TDS (mg/l)
H-1	30,000
H-2	8,890
H-3	51,700
H-4	16,000
H-5	135,000
H-6	52,000
H-7	3,200
H-8	2,710
H-9	3,040
H-10	66,000
H-11	110,000
H-12	123,000
H-14	16,500
H-15	230,000
H-16	36,000
H-17	151,000
H-18	24,000
P-14	24,200
P-15	23,700
P-17	81,200
P-18	118,000
WIPP-13	65,500
WIPP-19	65,800
WIPP-25	17,000
WIPP-26	16,000
WIPP-27	126,000
WIPP-28	56,000
WIPP-29	239,000
WIPP-30	109,000
DOE-1	111,000
DOE-2	54,000
Engle	3,000
WQSP-1	77,400
WQSP-2	66,300
WQSP-3	214,000
WQSP-4	106,000
WQSP-5	33,300
WQSP-6	16,500

Sources: Mercer, 1983 (USGS-WRI 83-4016, Table 8); Ramey, 1985 (EEG-31); Chapman, 1988 (EEG-39); Lappin et al., 1989 (SAND 89-0462, Table 3-12); DOE/CAO 1996-2184, Appendix USDW, Table USDW-2; Annual Site Environmental Reports, 1992-1995.

Test wells known to have produced water in the Dewey Lake Redbeds are depicted as bull's eyes in Figure 1. At ten of these wells, TDS in the Culebra dolomite were measured; and in seven of these, the lowest measurement was 36,000 mg/l or less (H-16 was measured only once). According to Ramey (EEG-31, 1985): "Waters with greater than 35,000 mg/l of total dissolved solids are classified as brines." Thus, Culebra water in the recharge area, where the Santa Rosa is absent, is fresh enough not to be classified as brine. In fact, Culebra water at H-2b is potable (8,890 mg/l TDS). H-2b is on-site. DOE has tested the quality, but not the quantity, of Culebra water at H-2b. Five private wells within ten miles of the WIPP site produce water of potable quality in the Culebra dolomite, but the quantity has never been measured. Three test wells outside the WIPP site – H-7b1, H-8b and H-9b – produce water of sufficient quality and quantity (less than 10,000 mg/l TDS and more than 5 gpm) to meet EPA criteria and establish the Culebra as an underground source of drinking water under 40 CFR 191, Subpart C. Test well H-7b1 is located only 2.9 miles from the WIPP site, in Nash Draw, along a potential groundwater flow path from the WIPP site to the accessible environment. Water quality data for the Culebra dolomite are given in Table 4. Thirteen wells which produced potable water are shown in Figure 3.

Conclusions:

1. Karst landforms exist at the WIPP site, and karst hydrology is active at the WIPP site today.

2. Rainwater infiltrates through solution pipes in Mescalero caliche, solution features in Gatuna sandstone, and fractures in Dewey Lake Redbeds.

3. Cavernous zones have been found, in WIPP boreholes, in Dewey Lake siltstone and in every member of the Rustler Formation – in Forty-Niner gypsum, Magenta dolomite, Tamarisk anhydrite, Culebra dolomite, and mudstone of the lower unnamed member.

4. Water has been found at the WIPP site in the Dewey Lake Redbeds and in every member of the Rustler Formation.

5. The Dewey Lake Redbeds and the Culebra dolomite contain potable water at and near the WIPP site, which can only be explained by rainwater recharge.

6. The recharge area for the Dewey Lake Redbeds and the Rustler Formation is at and near the WIPP site, everywhere that the Santa Rosa sandstone is not present.

7. Groundwater flow in the Rustler Formation is three-dimensional.

TABLE 4: POTABLE WATER IN CULEBRA DOLOMITE

well	TDS (mg/l)	date	gpm
H-2b	8,890	02/22/77	not tested
H-7b1	3,400	03/27/86	5-6
	3,500	02/25/87	
	3,400	04/25/88	
	3,500	05/19/89	
	3,500	11/09/90	
H-8b	3,100	01/22/86	6
	3,100	02/11/87	
	2,900	06/08/88	
H-9b	3,300	11/14/85	9.6-10.5
	3,300	01/28/87	
	3,100	06/21/88	
	3,300	01/19/90	
Engle	3,450	03/04/85	not tested
	4,000	12/08/87	
	3,600	01/31/90	
Poker Trap	2,200	07/07/88	not tested
Mobley Well	3,800	04/14/88	not tested
USGS-1	2,100	04/12/88	not tested
	4,000	07/07/88	
James Brothers	3,940	04/30/50	not tested

Criteria for drinking water: < 10,000 mg/l TDS and > 5 gpm.
Source: DOE/CAO 1996-2184, Appendix USDW, pp. 19, 20, 22.

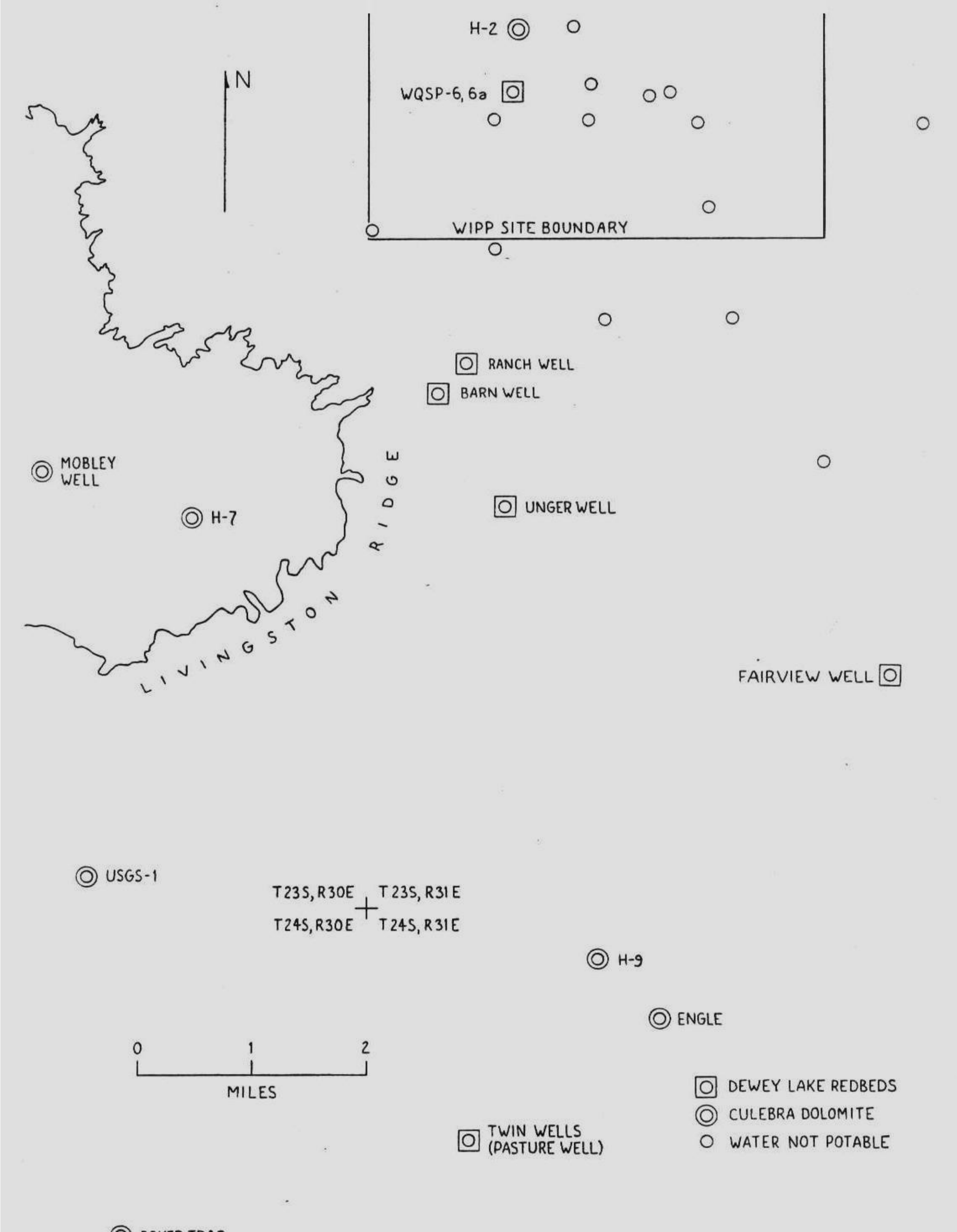

FIGURE 3: POTABLE WATER NEAR WIPP SITE
(less than 10,000 mg/l TDS)