20
6-1-83 W.B.
SANDIA REPORT

SAND82-2922 • Unlimited Release • UC-70

Printed April 1983

5/5 Dr. 145-8
3

IA566

Waste Isolation Pilot Plant (WIPP) Site Gravity Survey and Interpretation

SAND--82-2922

DE83 012382

Lawrence J. Barrows, Sue-Ellen Shaffer,
Warren B. Miller, John D. Fett

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-76DP00789

MASTER

DO NOT MICROFILM
THIS PAGE

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

NOTICE: This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government, any agency thereof or any of their contractors or subcontractors. The views and opinions expressed herein do not necessarily state or reflect those of the United States Government, any agency thereof or any of their contractors or subcontractors.

Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes
Printed copy: A06
Microfiche copy: A01

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Waste Isolation Pilot Plant (WIPP) Site Gravity Survey and Interpretation

Lawrence J. Barrows
Ground Motion and Seismic Division 7111
Sue-Ellen Shaffer and Warren B. Miller
Earth Sciences Division 9731
Sandia National Laboratories
Albuquerque, NM 87185

John D. Fett
Earth Science and Engineering, Inc.
Austin, TX 78759

POSSIBLE REPRODUCIBILITY

Abstract

A portion of the WIPP site has been extensively surveyed with high-precision gravity. The main survey (in T22S, R31E) covered a rectangular area 2 by 4-1/3 mi encompassing all of WIPP site Zone II and part of the disturbed zone to the north of the site. Stations were at 293-ft intervals along 13 north-south lines 880 ft apart. The data are considered accurate to within a few hundredths of a milligal.

Long-wavelength gravity anomalies correlate well with seismic time structures on horizons below the Castile Formation. Both the gravity anomalies and the seismic time structures are interpreted as resulting from related density and velocity variations within the Ochoan Series. Shorter wavelength negative gravity anomalies are interpreted as resulting from bulk density alteration in the vicinity of karst conduits.

The WIPP gravity survey was unable to resolve low-amplitude, long-wavelength anomalies that should result from the geologic structures within the disturbed zone. It did indicate the degree and character of karst development within the surveyed area.

NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE.

It has been reproduced from the best available copy to permit the broadest possible availability.

Acknowledgment

Appreciation is extended to the Sandia National Laboratories Applicon Graphics Personnel, Dept. 9761, for preparing appropriate base maps and to Carmen de Souza for patiently typing and retyping the manuscript. D. J. Borns and C. A. Searls reviewed the report and offered many helpful suggestions. The interpretation is that of the authors and is not necessarily agreed to by the reviewers.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Contents

1.	Introduction	7
1.1	Purpose and Scope of WIPP	7
1.2	Geologic Setting	9
1.2.1	Stratigraphy	9
1.2.2	Structure	15
1.2.3	Karst	19
1.3	The Gravity Surveys	25
1.3.1	Background and Original Objectives	25
1.3.2	Survey Locations	27
1.3.3	Data Reduction	27
2.	Data	30
2.1	Main Site Survey	30
2.2	The WIPP 14 Anomaly	43
2.3	Reconnaissance Profiles	43
2.3.1	The WIPP 33 Area	44
2.3.2	Bell Lake Sink	51
3.	Interpretation	54
3.1	Broad Features	54
3.2	Negative Anomalies	57
3.2.1	The WIPP 14 Anomaly	57
3.2.2	Seismic Line 77X2	59
3.2.3	The WIPP 33 Anomaly	63
4.	Summary	65
	References	66
	APPENDIX A — Gravity Data From the Main Site Survey and Detailed Grid in the Southeast Corner of Section 28	67
	APPENDIX B — Gravity Data Over the WIPP 14 Anomaly	91
	APPENDIX C — Gravity Data Along Reconnaissance Profiles Near WIPP 33	99
	APPENDIX D — Gravity Data Over Bell Lake Sink	105

Figures

1.1-1	Conceptual drawing of an operational repository	7
1.1-2	WIPP site zonation	8
1.2.1-1	Major regional structures	10
1.2.1-2	Local stratigraphic section	11
1.2.1-3	Densilog of the Castile Formation at borehole AEC 8	11
1.2.1-4	Isopach of the Dewey Lake Red Beds	12
1.2.1-5	Isopach of the Dockum Group	13
1.2.1-6	Isopach of the Gatuna Formation	14
1.2.2-1	Location of seismic lines used to construct the seismic time-structure and isochron maps	15
1.2.2-2	Seismic time-structure of a strong seismic horizon near the Anhydrite II member of the Castile Formation	16
1.2.2-3	Seismic time-structure of a seismic horizon near the top of the Cherry Canyon Formation	17
1.2.2-4	Seismic isochron map of the two-way travel time between the mid-Castile and Cherry Canyon seismic horizons	18
1.2.2-5	Boreholes to the north of the WIPP site that penetrate the Castile Formation	20

Contents (Cont)

1.2.2-6 Borehole correlation for the Salado and Castile Formations along the solid line on Figure 1.2.2-5	21
1.2.2-7 Bore correlation for the Salado and Castile Formations along the dashed line on Figure 1.2.2-5	22
1.2.2-8 Structure contours on the top of the Salado Formation	23
1.2.3-1 Isopach of the Rustler Formation	24
1.3.1-1 Gravimeter and operator	26
1.3.1-2 Surveyor with Hewlett-Packard model 3820A laser rangefinder/theodolite	26
1.3.2-1 Topographic map of the Nash Draw Quadrangle	28
2.1-1 Gravity station location and identification	31
2.1-2 Simple Bouguer gravity profiles for the main site survey	32
2.1-3 Main site survey—simple Bouguer gravity (posted data and rigorous contours) (in pocket)	
2.1-4 Simple Bouguer gravity—main site survey (generalized)	43
2.2-1 Detailed survey over the WIPP 14 anomaly	45
2.2-2 Simple Bouguer gravity at the WIPP 14 anomaly	46
2.2-3 A gravity profile across the WIPP 14 anomaly	46
2.3.1-1 Gravity station identification and locations for reconnaissance profiles in the WIPP 33 area	47
2.3.1-2 Gravity profiles, the WIPP 33 area	48
2.3.1-3 Fence diagram of the WIPP 33 reconnaissance profiles	50
2.3.2-1 Topographic map of the Bell Lake Quadrangle	52
2.3.2-2 Gravity station locations and identification	53
2.3.2-3 Gravity profiles, Bell Lake Sink	53
2.3.2-4 Gravity profiles at different Bouguer slab densities, Bell Lake Sink	54
3.1-1 North-south profile showing gravity, shallow geologic structure, deep seismic time-structure	55
3.1-2 Empirical curves relating rock density to acoustic velocity	55
3.1-3 A comparison of interval velocities calculated from uphole velocity surveys at boreholes WIPP 13 and WIPP 34	56
3.2.1-1 A comparison of densilogs from boreholes WIPP 14 and WIPP 34	58
3.2.1-2 A comparison of gamma logs of the Rustler Formation at boreholes WIPP 14 and WIPP 34	58
3.2.2-1 Simple Bouguer gravity along survey line G	60
3.2.2-2 Seismic line 77X2, shotpoints 58-105 and the coincident gravity anomaly from gravity survey line G	61
3.2.2-3 A model of the gravity anomaly on line G	62
3.2.3-1 Observed and modeled gravity along the pipeline trail crossing the WIPP 33 anomaly ...	64
3.2.3-2 Density model related to the profile on Figure 3.2.3-1 and the corresponding geologic interpretation	64

Tables

1.2.2-1 Seismic reflection field parameters	16
1.3.3-1 Gravity survey base stations	30
3.2.2-1 Measured velocities and calculated WIPP 11 depth-time tie	62

Waste Isolation Pilot Plant (WIPP) Site Gravity Survey and Interpretation

1. Introduction

1.1 Purpose and Scope of WIPP

The Waste Isolation Pilot Plant (WIPP) is a Department of Energy (DOE) research and development facility for demonstrating the safe disposal of defense-generated transuranic radioactive wastes. The program includes construction of an underground test facility within thick salt deposits in southeastern New Mexico. After successful completion of testing, the facility may be converted into a mined repository for disposal of the actual wastes. Figure 1.1-1 is a conceptual drawing of an operational repository.

The WIPP site is located in the semi-arid Pecos Valley section of the southern Great Plains physiographic province. The site area was initially divided into four concentric zones. The innermost Zone I is for surface facilities and access shafts. Zone II is for underground facilities, although not all of this area may ultimately be developed. Zone III is an administrative buffer where underground mining and through-going boreholes are prohibited. In Zone IV

Figure 1.1-1. Conceptual drawing of an operational repository

these were allowed, but were subject to control and regulation by the DOE. Figure 1.1-2 shows the original site zonation and the local system of township and

range. During preparation of this report, Zone IV was deleted from the WIPP. It is still included in the figures and discussion herein.

Figure 1.1-2. WIPP site zonation

The gravity survey is part of an ongoing effort to establish the geologic characteristics of the WIPP site. This report contains the gravity data and their interpretation. It assumes that the reader is familiar with general geologic principles and with techniques of geophysical investigation. The local geology is described sufficiently to support the gravity interpretation. For further information on the geology, see Powers et al (1978).

No attempt has been made in this report to assess the implications of the gravity data and their interpretation upon the suitability of the site. Such assessment requires careful consideration of this material along with many other factors.

1.2 Geologic Setting

1.2.1 Stratigraphy

The Delaware Basin is a broad, oval-shaped, asymmetric sedimentary trough in southeastern New Mexico and west Texas. It was structurally initiated in the early Pennsylvanian, underwent minor adjustment in the late Pennsylvanian and early Permian, and then subsided regionally through the late Permian. Basin subsidence ceased in the early Triassic. The subsequent environment is one of general structural stability, epirogenic uplift and subsidence accompanied by widespread deposition and erosion, and no clear geologic record over long intervals of time. Figure 1.2.1-1 shows the regional setting of the basin and the location of the WIPP site within it.

During the late Permian, a carbonate reef or bank grew up around the periphery of the slowly subsiding basin. Deposition within the basin was initially fine-grained clastics and subsidiary carbonates of the Delaware Mountain Group. The depositional environment changed to a partially restricted basin, and a thick section of evaporites was deposited. The underground facilities are being constructed within these evaporites. The evaporites, plus an overlying siltstone formation, make up the Ochoan Series. Figure 1.2.1-2 is the local stratigraphic section.

For purposes of this report, the top of the Delaware Mountain Group directly underlying the Ochoan Series can be regarded as "basement." Near the WIPP site this surface now forms a generally smooth east-dipping homocline (Borns et al, 1983). Structures on this surface indicated by oil and gas wells in the basin are generally simple and of low amplitude. The WIPP seismic sections indicate that simple geologic structure continues through the Delaware Mountain Group and the underlying Bone Spring Formation (Borns et al, 1983).

The Castile Formation is the oldest of the Ochoan Series. At the WIPP site, this formation consists of three massive anhydrite units separated by two massive halite units. In ascending order, the units are informally identified as Anhydrite I, Halite I, Anhydrite II, Halite II, and Anhydrite III. These units are indicated on Figure 1.2.1-2.

The basal unit, Anhydrite I, consists of laminated anhydrite and bituminous calcite. Halite I is nearly pure halite. Anhydrite II is distinctly laminated layers of anhydrite and calcite. The individual laminae of this member have been correlated between wells 113 km apart (Kirkland and Anderson, 1970) and have been interpreted as seasonal varves (e.g., Anderson et al, 1972). The next unit, Halite II, consists of nearly pure halite beds up to about 30 ft thick interlayered with five to seven thinner beds of anhydrite. The uppermost Anhydrite III is a generally massive anhydrite with some color layering of various shades of gray.

There is a distinct density contrast between the massive anhydrite and massive halite units. Figure 1.2.1-3 is the densilog of the Castile Formation in borehole AEC 8. The density contrast between the anhydrite and halite units was important in planning the WIPP gravity survey as described later in this report. It may also be important in formation of structures within the Castile Formation. This structural relation is discussed at length in Borns et al (1983, Appendix A).

The Salado Formation is the second of three evaporite formations in the Ochoan Series. The formation is primarily halite interlayered with laterally continuous beds of anhydrite and polyhalite. It is divided into a lower unnamed member, the middle McNutt Potash Zone, and an informal upper member. The McNutt Potash Zone locally contains economic potash minerals, mainly sylvite and langbeinite, and is the ore zone supporting the local potash industry.

At the WIPP site the Salado is conformably overlain by the Rustler Formation. This formation has been divided into five members largely on the basis of two conspicuous dolomite horizons. From bottom to top the members are: an unnamed lower member, the Culebra Dolomite, the Tamarisk Member, the Magenta Dolomite, and the Forty-Niner Member. The formation has been extensively altered by dissolution or karstification. In unleached areas the formation composition is: 43% rock salt and other halides; 30% anhydrite, polyhalite, gypsum, and other sulfates; 17% clastics; and 10% dolomite, limestone, and magnesite.

Figure 1.2.1-1. Major regional structures

Figure 1.2.1-2. Local stratigraphic section

More detailed lithology, the interrelation among deposition facies, and subsequent dissolution are discussed by Jones in Powers et al (1978, pp 4-39). The progressive dissolution of these evaporites is important to the gravity interpretation and is discussed in Section 1.2.3.

The Rustler Formation is conformably overlain by a sequence of terrigenous reddish-orange micaceous siltstones and sandstones called the Dewey Lake Red Beds. The unit is ~500 ft thick in the eastern half of the WIPP site, where it is protected by the overlying Dockum Group. It thins rapidly to the west where it is exposed and has been partially removed by erosion. Figure 1.2.1-4 is an isopach of this formation. The Dewey Lake Red Beds are gypsiferous with gypsum cement, secondary gypsum crystals, and numerous selenite veins. Density variations within this formation were found to contribute to the gravity anomalies (this report, Section 3.2).

Figure 1.2.1-3. Densilog of the Castile Formation at borehole AEC 8

Figure 1.2.1-4. Isopach of the Dewey Lake Red Beds

The rest of the stratigraphic section is thin and largely incomplete. The Dewey Lake Red Beds are unconformably overlain by undifferentiated rocks of the upper Triassic Dockum Group. These deposits are fine- to coarse-grained, cross-stratified, muddy, micaceous sandstones. They vary from 250 ft thick in the extreme eastern part of WIPP site, Zone IV, to zero along an erosional truncation through the middle of

the site. Thin discontinuous patches of the Pleistocene Gatuna Formation make up the next identified formation at the site. Figures 1.2.1-5 and 1.2.1-6 are isopach maps of the Dockum Group and the Gatuna Formation, respectively. Presumably the Cretaceous system and the late Tertiary Ogallala Formation were deposited, but they were later removed by erosion.

Figure 1.2.1-5. Isopach of the Dockum Group

Figure 1.2.1-6. Isopach of the Gatuna Formation

1.2.2 Structure

Mapping of geologic structures was the primary motivation for the WIPP gravity survey. It was thought that the gravity data would help establish the form and extent of structures in the northern part of the site and help ensure that additional undetected structures are not present in the rest of the site. During the survey it was found that the gravity field is dominated by effects of lateral density variations within fairly flat-lying strata. The structures were found to be an inconsequential part of the interpretation. They are reviewed here because of their role in planning the gravity survey and because they form the structural framework of the area.

As previously noted, the Delaware Mountain Group near the WIPP site forms a simple east-dipping homocline. This dip is ~ 100 ft/mi; it was formed during the Plio-Pleistocene tilting of the Delaware Basin and surrounding areas (Borns et al, 1983).

The WIPP site has been extensively explored with the seismic reflection technique. Figure 1.2.2-1 shows line locations of the seismic sections used to construct the following time structure and isochron maps. Additional redundant lines and lines gathered earlier with petroleum exploration field parameters were checked for consistency with the interpretation but were not worked into the maps.

Figure 1.2.2-1. Location of seismic lines used to construct the seismic time-structure and isochron maps

The field parameters for the lines on Figure 1.2.2-1 are given in Table 1.2.2-1. Further information on the seismic surveys is available in Bell and Murphy and Assoc., Inc. (1979) and in Hern et al (1979). The lines have good resolution from the top of the Castile Formation through the Delaware Mountain Group. Seismic events from shallower and deeper horizons are considered too unreliable to map. Figures 1.2.2-2 and 1.2.2-3 are time-structure maps on events near the Anhydrite II member of the Castile Formation and near the top of the Cherry Canyon Formation in the middle of the Delaware Mountain Group. Figure 1.2.2-4 is an isochron map on the interval between these horizons. These maps show the seismic features of interest on and near the WIPP site. Both the maps and structures are discussed in further detail in Borns et al, 1983.

Table 1.2.2-1. Seismic reflection field parameters (77X and 78GG surveys)

	Description
Source	<ul style="list-style-type: none"> • 3 or 4 vibrators stepped over 220 ft • 12-s, 25- to 100-Hz
Receiver	<ul style="list-style-type: none"> • 36 geophones per receiver in a 6-arm fan • 24 receivers • 1650-440-0-440-1650 split spread • 2-ms sample rate
Processing	<ul style="list-style-type: none"> • 12-fold CDP stack

Figure 1.2.2-2. Seismic time-structure of a strong seismic horizon near the Anhydrite II member of the Castile Formation

Figure 1.2.2-3. Seismic time-structure of a seismic horizon near the top of the Cherry Canyon Formation

Figure 1.2.2-4. Seismic isochron map of the two-way travel time between the mid-Castile and Cherry Canyon seismic horizons

The seismic time-structure maps on the mid-Castile and Cherry Canyon reflections indicate smooth continuous structure over most of the WIPP site. There is an arcuate fault to the southeast of Zone III and a possibly faulted syncline (graben?) in the southwest. Neither of these features indicates much displacement (5 to 10 ms @ 14000 ft/s = 70 to 140 ft).

The largest feature of interest is the disturbed zone (DZ) in the northern part of the site. In the DZ, the seismic sections indicate a blocky, discontinuous structure in the Castile Formation with abrupt offsets or changes in dip between units (faults?). The seismic character or wiggle shape changes, indicating variations in thickness and/or acoustic properties. The map on the mid-Castile event shows increased dips and faults around the periphery of the DZ and an unmapped area of complex structure in the middle. The seismic data in this unmapped area are valid, but the geologic structures are too complex to map with these data. The map on the Cherry Canyon event is continuous through the DZ. The seismic isochron map indicates thickness variations within members of the Castile Formation.

The seismic indications of complex geologic structure in the northern part of the site have been verified with boreholes. Figure 1.2.2-5 shows locations of boreholes that penetrate the Castile Formation. Figures 1.2.2-6 and 1.2.2-7 are borehole correlations along the lines indicated on Figure 1.2.2-5. On the borehole correlations, the Cowden Anhydrite marker bed in the lower part of the Salado Formation is used to separate two methods of log correlation. Above the Cowden Anhydrite, the horizons are convenient markers on the logs. Below the Cowden, the dark intervals are primarily anhydrite and the light intervals are halite.

Structural deformation is intense within the Castile Formation. There are vertical displacements of hundreds of feet and thickness variations of hundreds of percent. In AEC 7 there are four massive anhydrites; in POGO Fed. 1 there are two (the latter may be a depositional pinchout of Halite II along the basin margin). In ERDA 6 the uppermost anhydrite was identified from core as Anhydrite II, and Anhydrite III may be missing (Anderson, 1976).

The complex deformation within the Castile Formation does not extend through the overlying Salado Formation. Figure 1.2.2-8 is a structure contour map of the top of the Salado Formation prepared from borehole control. There is a broad gentle syncline in the area of the DZ, but no indication of deformation as complex as that in the underlying Castile Formation. At this stratigraphic level there are sufficient boreholes to reliably define the structure.

1.2.3 Karst

Evaporite and carbonate rocks dissolve, or corrode, when they contact chemically undersaturated water. Karst refers to a distinctive surface morphology and groundwater hydrology resulting from such dissolution. Karst surface morphology is characterized by collapse sinks, alluvial dolines, caves, grikes, and various domes and mounds. The hydrology is characterized by sinking streams, swallow holes, the absence of surface runoff, an integrated arterial system of sub-surface conduits, and a few large irregular springs. The general principles of karst morphology are discussed by M. Sweeting (1973), and karst hydrology is discussed by A. Bogli (1980).

A large area of southeastern New Mexico and west Texas, including the Delaware Basin, is underlain by soluble carbonates and evaporites. Much of this material has been removed by dissolution, and the area is recognized as one of the karstlands of the United States (Davies and LeGrand, 1972; LeGrand et al, 1976). Regional karst is described by G. O. Bachman (1980) in his report on the geology and Cenozoic history of the Pecos Region, and by Powers et al (1978).

The regional dissolution history is complex. The stratigraphic sequence above the Permian is discontinuous, presumably indicating periods of uplift, erosion, and dissolution. Even intervals of active deposition, such as during Gatuna time, may be accompanied by groundwater dissolution and collapse of the new deposits into solution cavities. Despite the complexity, the present episode of dissolution can be related to development of the Pecos drainage system and the associated demise of Ogallala deposition (King, 1948, p 152). The Ogallala was deposited as complex overlapping alluvial fans shed from the uplifted Rocky Mountains to the west. During the Pleistocene, the Pecos River extended to the north by headward erosion and captured the easterly flowing Ogallala streams. Subsequent excavation of the Pecos River basin is a combined result of normal fluvial erosion and the dissolution of halite, gypsum, and limestone (Morgan, 1941). The west-sloping topography at the site, Nash Draw to the west, and San Simon Swale to the east are all products of the present geomorphic cycle.

The easterly structural tilt of the Delaware Basin, along with incising of the Pecos Drainage, has exposed progressively older formations to the west. The Castile Formation outcrops along the west side of the basin near White City and farther south into the gypsum plains of west Texas. The area of outcrop has a series of elongated east-west troughs and ridges that Olive

(1957) attributed to the collapse of solution conduits initially developed along east-trending joints. Farther east the Salado Formation discontinuously outcrops as scattered patches of insoluble residuum. In the subsurface the thickness of Salado salt varies from zero near US Route 285 to ~1900 ft 20 mi to the east

(Bachman, 1980, Figure 8). Part of the thinning may be depositional or caused by an earlier dissolution episode, but the correlation between thinning, surface topography, and present course of the Pecos River implies that much of the thinning is caused by the present system.

Figure 1.2.2-5. Boreholes to the north of the WIPP site that penetrate the Castile Formation

Figure 1.2.2-6. Borehole correlation for the Salado and Castile Formations along the solid line on Figure 1.2.2-5

Figure 1.2.2-7. Bore correlation for the Salado and Castile Formations along the dashed line on Figure 1.2.2-5

Figure 1.2.2-8. Structure contours on the top of the Salado Formation

The Rustler Formation outcrops in scattered areas of Nash Draw. In outcrop, it is generally gypsum with interbedded dolomite and reddish-brown clayey insoluble residues. The gypsum supports the openings of caves and swallow holes, some of which are large enough to enter. In the subsurface, dissolution has formed a complex of tunnels and caves. Many of the cavities have filled with alluvium washed in from the surface, and many have collapsed, forming complex breccias. The surface exhibits collapse sinks, grikes, and vanishing arroyos.

At the WIPP site, the Rustler Formation is overlain by the Dewey Lake Red Beds. It is here an example of an interstratal phreatic karst. Figure 1.2.3-1 is a borehole-controlled isopach of the Rustler

Formation. The formation thins from 450 ft in the southeast corner of WIPP site Zone IV to 300 ft along the western side. Isopach thinning is accompanied by the downward progression of surfaces defined by borehole encounters with the uppermost halite, the uppermost anhydrite, and the deepest gypsum. These relations are reasonably attributed to dissolution by groundwater infiltrating from above (e.g., Powers et al, 1978, pp 6-38; Snyder in Borns et al, 1983). The occurrence of anhydrite stratigraphically above dissolution residues implies that the infiltration is areally discontinuous. As noted previously, farther to the west the Rustler is both closer to the surface and progressively more dissolved.

Figure 1.2.3-1. Isopach of the Rustler Formation

The detailed lithologic character of the Rustler is considerably more complex than suggested by the WIPP site isopach map. Ferrall and Gibbons (1980) documented a study of this formation based on core photographs, core inspection, borehole logs, and brief field trips. Their report is summarized here at length because it describes the geologic variations responsible for at least some of the observed gravity anomalies.

The Rustler Formation was never a simple homogeneous rock unit. It was deposited as silty evaporites, silts, and lime muds during the final irregular stages of the Permian evaporite basin. Pseudomorphic gypsum rosettes suggest that the calcium sulfate was initially deposited as gypsum and later dehydrated to anhydrite. The lime mud was diagenetically altered to dolomite. Both these processes and the normal compaction of clastic sediments affect the physical volume of the deposit.

Ferrall and Gibbons described core from WIPP 19 and then contrasted it with cored intervals of other holes. The lithologies identified include anhydrite, gypsum, halite, dolomite, siltstone, and solution residues. The solution residues are layers of generally unstructured clay or silt, lacking original bedding, and often containing breccia clasts. Fractures, in some cases breccia, occur in adjacent units and are attributed to collapse into dissolution voids. Also, since the solution residues represent former paths of migrating groundwater, they have acted as centers for the hydration of anhydrite to gypsum in adjacent units.

At WIPP 19 Ferrall and Gibbons identified one solution residue at the top of the Salado Formation, three in the unnamed lower member, one at the base of the Tamarisk Member, and one within the Forty-Niner Member. A generally similar sequence of solution residues was identified in other holes, but their

degree of development, cementation, and exact stratigraphic position varied.

The residue at the base of the Rustler was interpreted as representing the leached top of the Salado Formation. The next two are adjacent to a halite layer within the lower member. At WIPP 19, these are cemented by halite and are not extensively leached. However, in the other holes studied (WIPP 25, 26, 30), this halite layer has been removed by solution, and a single dissolution residue is present. The third residue in the lower member is at the base of the Culebra Dolomite.

At WIPP 19, 15 ft of solution residue in the Tamarisk Member immediately overlies the Culebra Dolomite. The lower foot of this particular residue is layered, and Ferrall and Gibbons (1980) suggest it may have been deposited in the bottom of a solution cavity. In other holes, the residue in the Tamarisk Member varies between 6 and 18 ft in thickness and is separated from the Culebra Dolomite by up to 22 ft of gypsum. The Forty-Niner Member residue in WIPP 19 is 10 ft thick. The calcium sulfate is gypsified out to a few feet of both the top and bottom of this residue.

In addition to the solution residues, Ferrall and Gibbons identified leached zones in the lower member and in the Forty-Niner Member in which bedding plane breaks resulted from solution activity of groundwater traveling along the laminae.

Karst, or groundwater alteration of the Rustler Formation, is important to the gravity interpretation, but its effect on rock densities is not necessarily simple. Dissolution may decrease the bulk density of the formation if the voids remain open or are filled with less dense material. Alternately, it may increase the bulk density if removal of a low-density evaporite (e.g., halite) is compensated for by compaction of the formation.

The removal of calcium sulfate can be even more complex. In unaltered areas, calcium sulfate in the Rustler occurs as anhydrite (density 2.9 to 3.0 g/cc). During dissolution, the anhydrite is normally hydrated to gypsum (density 2.2 to 2.6 g/cc) with up to a 38% increase in volume. In at least some instances the increased volume is compensated for by removed material. In other instances, the volume increase causes significant distortion in the rock. These mechanical effects are discussed by Ferrall and Gibbons (1980, Section 2.3.1).

1.3 The Gravity Surveys

1.3.1 Background and Original Objectives

The gravity method is based on the measurement and interpretation of small variations in the earth's gravity field. These variations (or anomalies) result from lateral variations in the subsurface distribution of mass or rock density. In a layered sequence of sedimentary rocks, the lateral density variations normally, but not always, result from structural displacement of strata of differing density. Examples would be a high-angle fault that juxtaposes a heavy anhydrite layer against a lighter halite, or a piercement diapir in which the less dense halite is rising through a more dense overburden.

The gravity data can be used to detect subsurface density structures and to place constraints on the allowable interpretations of those structures. By itself, the detailed shape of a gravity anomaly can be used to establish the maximum depth to the top of the causative density structure and the minimum amount of missing, or excess, mass in the structure. Used in conjunction with other forms of data (such as seismic sections, boreholes, regional geology, and magnetics), gravity can help establish the most likely form of the structures, infer lithologies, and extend the interpretation into areas of deficient information. The gravity technique is a very useful and relatively inexpensive exploration tool. However, its application requires careful consideration of all available data.

During a gravity survey, measurements are made with a sensitive gravimeter at discrete locations or stations. Figure 1.3.1-1 shows the gravimeter and operator at one of the WIPP survey stations. The instrument is a LaCoste and Romberg model D geodetic meter.

Because gravity is sensitive to both elevation and geographic latitude, station surveying is as important as the actual gravity metering. Surveying generally requires more than half the total field effort. Figure 1.3.1-2 shows the operator adjusting the Hewlett-Packard 3820A laser rangefinder/theodolite used for the survey.

To locate stations, the surveyor sets up the rangefinder/theodolite on a topographic high with a reasonable field of view along the survey line. The rodwoman

paced off the approximate distance and then was walked to within a couple of inches of the correct location by the surveyor. The station was leveled with a garden trowel, and a foot-square board was embedded in the sand. The survey rod was then centered on the board and the station elevation recorded. When the station was subsequently metered, the gravimeter baseplate was centered on the board. The operator could tell from the sand packed around its edges whether the board had been inadvertently moved during the interim.

Figure 1.3.1-1. Gravimeter and operator

Figure 1.3.1-2. Surveyor with Hewlett-Packard model 3820A laser rangefinder/theodolite

Gravity data are expressed in milligals, where a gal is an acceleration of 1 cm/s/s. The WIPP high-precision survey approached a relative accuracy of ± 0.02 mgal, or about 2×10^{-8} of the earth's total field (980 cm/s^2).

The WIPP survey was originally planned to resolve anomalies originating within the DZ and to help assure that additional structures are not present at the site. Models of representative DZ structures produced anomalies of a few tenths of a milligal, with double half-widths of 2 km. (The double half-width is the distance between points at one-half the maximum amplitude of the anomaly and is a measure of the spatial wavelength.) It was felt that the relatively simple geologic structure of strata above and below the Castile Formation would allow spatial wavelength discrimination of the DZ anomalies.

The WIPP project had previously purchased use of a regional gravity survey of the northern Delaware Basin from Exploration Surveys, Inc. of Dallas, Texas. These data are proprietary and cannot be released. The regional survey had stations at quarter-mile intervals along a grid of lines ~ 1 mi apart. The map indicated gravity anomalies in the vicinity of the DZ, but neither the station spacing nor data accuracy are sufficient to resolve the shape of the anomalies. It provided definition of the regional gradient associated with the Delaware Basin and demonstrated a strong correlation between the longer wavelength anomalies and the seismic time structure maps prepared from the WIPP Vibroseis surveys.

As the WIPP gravity data became available, the density structure of the site was found to differ substantially from that anticipated. Instead of gravity anomalies originating within DZ structures of the Castile Formation, the field is dominated by effects of lateral density variations within shallower and relatively flat-lying strata.

These results are consistent with those reported from gravity surveys in other karstlands. Colley (1963) discussed the gravity effect of air- and water-filled cavities of differing dimensions and depths below the surface. This paper includes examples of sharp negative anomalies of $\sim 1/2$ to 1 mgal delineated during detailed gravity surveys in Iraq. The region is part of an anhydrite karstland noted for its topographic depressions. The gravity anomalies are attributed to solution caverns and the related hydration of anhydrite to gypsum.

In a more recent paper, Omnes (1977) discussed the fairly extensive use of microgravity to detect subsurface cavities in karstlands. Examples are given of sharp negative anomalies of a few tenths of a milligal that were found, by drilling, to be associated with

either cavities or low-density fill in local sinks. In their surveys, the measured anomalies were always at least several times larger than the anomalies calculated on the basis of the geometrical dimensions of the cavities. This phenomenon is attributed by Omnes to stress relief, jointing, and dissolution induced by the existence of a cavity.

1.3.2 Survey Locations

The initial plan was to survey a rectangular area 2 by 5 mi covering all of WIPP site Zone II, and 6 sq mi of the DZ to the north. Stations were located on a uniform square grid because spatial filtering would be used to resolve low-amplitude, long-wavelength anomalies originating within the Castile Formation.

As the survey progressed and data became available, modifications were made to the original field plan. First the station spacing was changed from a grid 1/6 by 1/6 mi square to 13 north-south lines spaced 1/6 mi apart with stations at 1/18-mi intervals. This change was made because the entire lines would have to be surveyed and walked either way, and because the work associated with the additional stations was not great. The additional stations were later found necessary to resolve the gravity anomalies. A second change was to delete the northern 2/3 mi from the survey area. This northern area was covered with steep sand dunes, and both surveying and data reduction (terrain corrections) would be excessively difficult. The area actually surveyed, and additional detailed surveys, are indicated on Figure 1.3.2-1.

Two small areas were surveyed in fine detail before the main portion of the WIPP site was surveyed. The purpose of these two detail surveys was to establish the short-wavelength character of the gravity field to assure the adequacy of planned station spacing. One of the detailed areas was in the southeast corner of Section 21, R31E, T22S. This area has a fairly uniform smoothly dipping field and is not of further concern. The second detailed area was centered over a closed topographic depression along the east-west line between Sections 9 and 16. This area has one of the most distinctive short-wavelength negative anomalies at the site. Borehole WIPP 14 was drilled to investigate the anomaly; it is subsequently referred to as "the WIPP 14 Anomaly."

The main WIPP survey indicated two positive elliptical gravity anomalies in the southeast quarter of Section 28. These anomalies were near the southern ends of survey lines L and M on the flanks of a topographic hill. There was no reasonable geologic interpretation of the anomalies. The area was detailed later with a close spaced grid of gravity stations. Also, alternate lines of the close spaced grid were surveyed

with a hand-held total-intensity magnetometer. The new data showed that the gravity anomalies were not as extensive as originally interpreted, and that the magnetic field was relatively flat. Some inconsistencies were also noted between the two surveys. In an effort to resolve the inconsistencies, we rechecked the station elevations. The new elevation survey showed that the anomalies were caused by two sequential erroneous instrument setups on the original survey. The area is now known to have almost flat gravity and magnetic fields.

Two additional projects were undertaken during the gravity survey. These were a network of reconnaissance profiles over and around borehole WIPP 33, and two Reconnaissance profiles over Bell Lake Sink in R33E, T24S. These additional surveys were to explore the relation between the gravity anomalies and karstification. The location of the WIPP 33 profiles are indicated on Figure 1.3.2-1 and the Bell Lake Sink profiles on Figure 2.3.2-1.

1.3.3 Data Reduction

The force of gravity at the surface of the earth depends on solar and lunar tides, on latitude, and on elevation. These effects are comparable to, or larger than, the effect of subsurface density structures. Thus the gravity measurements must be corrected before they can be interpreted. The corrections require additional data. Latitude and elevation are from the surveying. Tides are calculated from the position of the sun and the moon at the time of the meter reading. In addition, the meter readings are corrected for instrument drift prorated over the time between base station readings. The corrections were made by the contractor and are tabulated in the contractor's report.

The Bouguer correction accounts for the attraction of a flat-layered slab of material between the station and sealevel. The value of the Bouguer correction depends on average density beneath the station (which is in general unknown). Fortunately, gravity interpretation depends on the relative gravity between stations in the survey area and is independent of any constant offset in the data. The Bouguer slab density of interest is then the average density over the elevation range of the topography in the survey area. For the WIPP survey the contractor calculated gravity for a family of Bouguer slab densities between 1.7 and 2.67 g/cc. Inspection of the gravity profiles over the topographic hill in the southeast corner of Section 28 indicated that the slab density ranges from 2.1 to 2.5 g/cc; 2.3 g/cc was selected for making the Bouguer slab corrections. The data set used in the following interpretation was reduced with a Bouguer slab density of 2.3 g/cc.

Figure 1.3.2-1. Topographic map of the Nash Draw Quadrangle

Topography near a station affects the gravity. Nearby hills or ridges exert an upward pull, and the missing mass of valleys results in less downward attraction. In areas of steep topography, the net effect can be large and is compensated for with a terrain correction calculated from topographic maps. At the WIPP site, terrain features include sand dunes, shallow topographic depressions, and the hill in the southeast corner of Section 28. The local terrain is closely controlled through a set of detailed topographic contour maps prepared by Bohannon Huston Inc. for Bechtel International (1 in. = 100 ft, 2-ft contour interval). These maps were inspected to select six sites showing the greatest topography. The terrain corrections of these sites were calculated with the high-precision methods described in Hammer (1982). The largest value was 0.041 mgal (top of hill in the southeast corner of Section 28). Terrain corrections for the gravity survey should not exceed this and are generally less than 0.02 mgal.

Considering the relatively large size of the gravity anomalies (several tenths of a milligal), detailed terrain corrections were not justified for the WIPP gravity survey. (The local terrain introduces an uncertainty of several hundredths of milligal into the gravity data.)

The strongest component of the gravity field in the area of the WIPP site is the regional gradient associated with the Delaware Basin. This regional gradient is partially due to the thick sediments within the basin. According to Djeddi (1979), it is also partially due to density variations between basement rocks within the Central Basin Platform and those on the eastern periphery of the basin. For large-scale structural studies, the gravity anomaly of the Delaware Basin is the "signal." For detailed study of a small area within the basin, it is another form of noise that must be removed before the data are interpreted. The gravity effect of the Delaware Basin is clearly shown on the proprietary regional survey. These data were used to determine a plane regional gradient that was subtracted from the WIPP survey gravity data. The WIPP site survey, the detailed areas, and the WIPP 33 reconnaissance profiles were reduced with a regional gradient of 1.28 mgal/mi, increasing N34°E. The Bell Lake Sink reconnaissance profiles were reduced with a regional gradient of 1.32 mgal/mi, increasing N56°E.

It is also necessary to consider subjective data editing. Gravity surveying requires the very careful, repetitive setup, adjustment, and reading of sensitive instruments, often under less than optimal field conditions. Gages, meters, and clocks, must be read and recorded in field notebooks. These data are transcribed and entered onto computer cards, processed along with supporting information, and finally printed out as a gravity value. The gravity values are again transcribed, filtered, and plotted. Even in the best of conditions, some errors are bound to creep into the data set.

Editing consisted of the following:

- Single-station anomalies that were obviously discordant with respect to the rest of a line were deleted.
- Stations occupied more than once were averaged.
- Some sets of readings were adjusted as a block so that their end points tie the adjacent sets.
- Some questionable areas were resurveyed and the newer data used.

All editing is identified on the data tables in the appendices to this report.

Three semipermanent base stations were established during the WIPP survey. Each semipermanent base is a small square pad of poured concrete, level on top, with three notches for the legs of the gravimeter base plate. They are located near (1) borehole WIPP 12 at the northern edge of WIPP site Zone II, (2) borehole P-4 in the southeast corner of Section 28, and (3) borehole P-12 along the road to H6 (the WIPP 33 reconnaissance profiles). Three additional temporary base stations were established on station survey boards near the two initial detail surveys and at Bell Lake Sink. Base station data are in Table 1.3.3-1.

The base near borehole WIPP 12 is tied to the eastern end of the front porch of the Chamber of Commerce Visitors Center in downtown Carlsbad. This location is near and at the same elevation as a prime gravity base station of the world gravity network (inside the building and not readily accessible). Reference code numbers of the prime base are ACIC 0431-3 and IGB 11924B. The 1970 value of prime base of 979,203.120 mgal was assumed for the corner of the porch.

All other WIPP survey base stations were tied to the one near borehole WIPP 12.

Table 1.3.3-1. Gravity survey base stations

Base No.	I. D. No.	Gravity (Mgal)	Location/Elevation	Description
1 (prime)		979,203.120	N 32° 25.06' W 104° 13.70' 3112 ft	Carlsbad Chamber of commerce Visitors Center East end of porch
2 (semipermanent)	CB 99	979,171.221	N 32° 23.064' W 103° 47.309' 3471.18 ft	Near borehole WIPP 12 Northwest of the SE corner of Sec 17 0.87 ft below benchmark Z347
3 (temporary)	M 18	979,168.224	N 32° 22.116' W 103° 46.402' 3483.60 ft	Near detailed survey in SE corner of Sec 21 293.33 ft due south of NE corner of Sec 28
4 (temporary)	J 55	979,175.252	N 32° 23.898' W 103° 46.916' 3437.82 ft	Near WIPP 14 detailed survey Middle of line between Sec 9 and 16
5 (semipermanent)	CB 97	979,176.040	N 32° 23.0681' W 103° 49.5295' 3373.71 ft	Area of the WIPP 33 reconnaissance profiles Near borehole P-12 along N-S road to H6
6 (temporary)	BL 50	979,150.831	N 32° 14.3583' W 103° 34.0932' 3583.00 ft	Bell Lake Sink Station #BL 50
4 (new) (semipermanent)	CB 98	979,168.242	N 32° 21.3212' W 103° 46.7006' 3443.11 ft	Near borehole P-4 In detailed survey in SE corner of Sec 28

2. Data

2.1 Main Site Survey

The main site survey had stations at 1/18-mi intervals along 13 north-south lines spaced 1/6 mi apart. From west to east the lines are identified as A through M; from south to north the stations are numbered 1 through 79. Figure 2.1-1 shows the station locations. Also shown on Figure 2.1-1 are stations of a detailed grid in the southeast corner of the site. This detailed grid covers the southeast quarter of Section 28 plus an additional 1/6 mi to the south and east. Within the detailed area, stations are on a 1/18-mi square grid.

The data for the main site survey and for the detailed area in the southeast corner are here handled as profiles along the north-south survey lines. Appendix A gives for each line:

- station number
- elevation
- Bouguer gravity
- Bouguer gravity less regional

- Bouguer gravity less regional and parabolic trend
- editing

Figure 2.1-2 are north-south profiles of the simple Bouguer gravity. These data have been reduced with the linear regional trend discussed in Section 1.3.3 and with the parabolic trend indicated on the figures. The linear trend is related to the structure of the Delaware Basin. The parabolic trend correlates well with a seismic time-structure anticline on reflection horizons below the Castile Formation. In Section 3.1, these broad features are interpreted as resulting from related lateral variations in seismic velocity and bulk density in the Ochoan Series.

Figure 2.1-3 (in pocket) is a contour map of the Bouguer gravity less regional and parabolic trend. On this map the contours are constrained to rigorously honor the posted data. Figure 2.1-4 is a generalized contour map of the same data, except the contours are within ± 0.025 mgal of the data. This map shows the location and general form of significant anomalies detected by the survey. The original data points should be used for calculations (e.g., minimum missing mass, max depth to top of body) or for modeling.

Figure 2.1-1. Gravity station location and identification

(a)

(b)

Figure 2.1-2. Simple Bouguer gravity profiles for the main site survey

(c)

(d)

(e)

(f)

Figure 2.1-2. (Cont)

(g)

(h)

Figure 2.1-2. (Cont)

(i)

(j)

Figure 2.1-2. (Cont)

Figure 2.1-2. (Cont)

Figure 2.1-2. (Cont)

(c)

(p)

Figure 2.1-2. (Cont)

(q)

(r)

Figure 2.1-2. (Cont)

(s)

(t)

Figure 2.1-2. (Cont)

Figure 2.1-2. (Concluded)

Figure 2.1-4. Simple Bouguer Gravity
 Less Linear Regional & Parabolic Trend
 Slab Density 2.3 g/c³
 0.05-Milligal Contour Interval
 Contours Within ± 0.025 mg

2.2 The WIPP 14 Anomaly

The WIPP 14 anomaly is on one of the two small areas surveyed in detail before conducting the main site survey. The survey grid was centered on a small closed topographic depression midway along the line between Sections 9 and 16. This depression is evident on stereographic viewing of areal photos and is one of several noted in Griswold (1977, p 13) and in Powers et al (1978, p 4.7). The depression is generally round, ~700 ft across, and 10 ft deep.

The detailed survey covered a rectangular area 7/54 by 12/54 mi with stations on a square grid 1/54 mi apart (a rectangle ~680 by 1170 ft with 100-ft station spacing). Three lines had a 1/108-mi (~50-ft) station spacing, and two of these lines extended beyond the rectangular area. Figure 1.3.2-1 shows the general location of the detailed survey. Figure 2.2-1 shows the grid configuration and station identification.

These data were corrected for the same linear regional as those of the main site survey, but were not corrected for the larger scale parabolic trend. Appendix B lists station identification, elevation, simple Bouguer gravity, and simple Bouguer gravity less the linear regional. Figure 2.2-2 is a contour map of the regional-corrected Bouguer gravity. Included on this map are gravity values from surrounding stations of the main site survey, the locations of boreholes WIPP 34 and WIPP 14, and the outline of the closed topographic depression (3434- and 3430-ft elevation contours). Also included is the line of profile A-A'.

The gravity along profile A-A' is plotted on Figure 2.2-3 and was used as a representative two-dimensional cross section of the anomaly. The double half-width is 450 ft and, following Nettleton (1976, p 192), the top of the causative density structure must be at or above 225 ft. The minimum missing mass was calculated by the method described in Telford et al (1976, p 85) to be 470 tons per linear foot along the length of the anomaly. Also shown on Figure 2.2-3 are the family of horizontal cylinders of varying densities and radii that give the modeled gravity anomaly. These are included to show only the approximate scale of possible density structures and are not intended to indicate an interpretation.

2.3 Reconnaissance Profiles

2.3.1 The WIPP 33 Area

The shape of the negative gravity anomalies found during the main site survey requires the top of the causative density structures to be within a few hundred feet of the surface. Depth-structure maps of formations above the Salado indicate relatively flat-lying strata (Borns et al, 1983). The isopach variations (Figures 1.2.1-4, -5, -6, 1.2.3-1) do not correlate with the anomalies. The implication is that anomalies originate from lateral density variations within flat-lying strata. The correlation of a closed topographic depression (alluvial doline) with the negative gravity anomaly at borehole WIPP 14 suggests that the anomalies may be related to karst processes.

The reconnaissance profiles were surveyed to investigate the relation between karst and the negative gravity anomalies. Borehole WIPP 33 is an important element in the subsequent interpretation. It was drilled in a closed topographic depression. The stratigraphic profile was normal, but there were slightly over 20 ft of cavities in the Forty-Niner and Magenta Dolomite Members of the Rustler Formation (SNLA and USGS, February 1981).

One of the survey lines of the proprietary regional gravity survey was along the pipeline right-of-way crossing the depression. This survey indicated the presence of a negative anomaly at borehole WIPP 33; however, the station spacing was too coarse to resolve the shape of the anomaly.

The reconnaissance profiles consisted of a network of intersecting lines with gravity stations at 200-ft intervals. Whenever possible, the lines were along roads and pipelines. Figure 1.3.2-1 shows the line locations, and Figure 2.3.1-1 shows the station locations and line identification.

Appendix C lists station number, location, elevation, simple Bouguer gravity (no terrain correction), value of the linear regional, and simple Bouguer gravity less the linear regional. Corrections are for data transcribed incorrectly from the field notebooks. Figure 2.3.1-2 shows the gravity along each of the lines. These profiles indicate a 0.6-mgal negative anomaly at WIPP 33 with a double half-width of 900 ft. The anomaly appears to continue to the northeast, but becomes more spread out and less intense. Finally, Figure 2.3.1-3 is a fence diagram of the anomalous gravity.

Figure 2.2-1. Detailed survey over the WIPP 14 anomaly

Figure 2.2-2. Simple Bouguer gravity at the WIPP 14 anomaly

Figure 2.2-3. A gravity profile across the WIPP 14 anomaly

N-S Road to H6

(a)

Pipeline Road

(b)

Figure 2.3.1-2. Gravity profiles, the WIPP 33 area

Pipeline Trail

(c)

E-W Road to WIPP 33

(d)

Figure 2.3.1-2. (Cont)

WIPP 33 Area - Short Profiles

Figure 2.3.1-2. (Concluded)

Figure 2.3.1-3. Fence diagram of the WIPP 33 reconnaissance profiles

2.3.2 Bell Lake Sink

A second set of reconnaissance profiles was surveyed over Bell Lake Sink in the northern part of T24S, R33E. Bell Lake Sink is a broad, closed topographic depression. It is nearly circular, about 2 mi across and 50 ft deep. The floor has irregular topography with multiple playas, quartz sand and gypsum sand dunes, and smaller scale alluvial dolines. The surface geology was mapped in detail and discussed by Widdicombe (1980). She interpreted the sink as a late-Wisconsin, solution-subsidence, collapse feature. The dissolved stratigraphic horizon has not been identified.

The reconnaissance profiles consisted of two parallel east-west lines 1/4 mi apart interconnected by three tie lines. Stations were at 220-ft intervals. Figure 2.3.2-1 shows the line locations over the sink, and Figure 2.3.2-2 shows the station locations. Appendix D lists the stations, elevations, simple Bouguer gravity, and simple Bouguer gravity less a linear regional. Figure 2.3.2-3 shows the two east-west profiles.

At Bell Lake Sink, the topography is sufficient to make the shape of the gravity anomaly dependent on the density used to make the Bouguer slab correction. Figure 2.3.2-4 shows the simple Bouguer gravity along the northern profile corresponding to the indicated slab densities. Anomalous gravity persists throughout the range of densities. At lower densities (1.7 to 1.9 g/cc), there is a broad low associated with the entire

sink and shorter-wavelength low-amplitude anomalies within the sink. At higher densities (2.1 to 2.5 g/cc) the broad gravity anomaly is equivocal, and the shorter-wavelength anomalies have larger amplitudes.

Stations 45 thru 49 and Stations 58 thru 62 of this profile cross small topographic ridges. These segments show distinct negative anomalies in gravity calculated with slab densities > 1.9 g/cc. However, the anomalies vanish if the gravity is calculated with a slab density of 1.7 g/cc. These particular ridges may be composed of low-density material (gypsum clay?) and may be unrelated to significant subsurface structures.

With the above noted exceptions, the gravity profiles still indicate complex subsurface density structures. These may be complex geologic structures, varying fill on an irregular collapse surface, or lateral density variations within relatively flat-lying strata.

If Bell Lake Sink is further investigated, it is recommended that additional gravity data be gathered and multiple boreholes be used to investigate the various gravity features. The subsurface complexity indicated by the reconnaissance profiles makes it probable that a single hole will not adequately characterize the sink.

NOTE: At the WIPP site, gravity anomalies are generally uncorrelated with topography. Where they do correlate (e.g., boreholes WIPP 14 and WIPP 33), the elevation variations are too small to account for the amplitudes of the anomalies.

Figure 2.3.2-1. Topographic map of the Bell Lake Quadrangle

Figure 2.3.2-2. Gravity station locations and identification

Figure 2.3.2-3. Gravity profiles, Bell Lake Sink

Figure 2.3.2-4. Gravity profiles at different Bouguer slab densities, Bell Lake Sink

3. Interpretation

3.1 Broad Features

There is an excellent correlation between the seismic time structure of strata below the Castile Formation and long-wavelength anomalies on the filtered regional gravity map. In areas outside the DZ, this correlation holds for horizons in the Castile Formation. The correlation is such that 10 ms of seismic two-way time corresponds to 0.2 mgal of anomalous gravity. The features are 1 to 3 mi across. The filtered regional gravity map is part of the proprietary data that cannot be released.

The east-west trending gravity high that transects the area of the main WIPP site gravity survey is one of these broad anomalies. Figure 3.1-1 is a north-south profile across this anomaly that shows: gravity (line G); shallow geologic structure (from borehole control); and seismic time structure on the Cherry Canyon Formation (seismic line 77X2). The correlation between the gravity profile and seismic time structure is excellent. There is no correlation with the shallow geologic structure.

There are two possible interpretations of the long-wavelength gravity anomalies and associated seismic time structures. First, the time structures could simply be caused by geologic depth structures. A density increase with stratigraphic depth of 0.22 g/cc^3 would be sufficient to cause the corresponding gravity anomalies:

$$10 \text{ ms} = 70 \text{ ft at } 14,000 \text{ ft/s}$$

$$0.2 \text{ mgal} = 70 \text{ ft slab at } 0.22 \text{ g/cc}^3$$

The density increase could occur across a particular folded stratigraphic horizon, or it could be gradational throughout the entire section involved in the structure. Both types of density increases are not unusual (Nettleton, 1976, p 259).

The second possibility is that the seismic time structures result from lateral velocity variations within the strata overlying undeformed reflecting horizons. The higher-velocity material overlying seismic pullups should have higher density that, in turn, would cause positive gravity anomalies. This form of density/velocity relation is shown on Figure 3.1-2 adapted from an empirical curve from Nettleton (1976, p 252). The curve is developed from large amounts of broadly scattered data points and should not be used to rigorously relate specific velocities and densities. This is particularly true for evaporites. The curve does show that, in general, higher-velocity rocks tend to have higher densities.

Several indications suggest that the velocity time structures are caused by lateral velocity variations and not geologic depth structures. First, the regional borehole data is discordant with the seismic time structure. Two petroleum exploration wells, Cotton Baby (T22S, R31E, Section 34) and Cabin Baby (T23S, R31E, Section 5), indicate *east* dip in the Delaware Mountain Group consistent with an east-dipping homocline. The seismic time structure indicates an anticlinal nose at Cotton Baby and *west* dip between the holes. Both the borehole and seismic data appear reliable.

Second, the magnitude of lateral velocity variations indicated by uphole velocity surveys is sufficient to account for the seismic time structures. Figure 3.1-3 compares uphole velocity data from boreholes WIPP 13 and WIPP 34. The velocity difference for the Dewey Lake and Rustler Formations accounts for 48 ms of seismic time structure.

Additional uphole velocity surveys and petrophysical studies are needed to clarify this phenomenon. The present data are sufficient to conclude that significant lateral velocity variations do exist. The borehole depths *suggest* that this is the origin of the seismic time structures.

Figure 3.1-1. North-south profile showing gravity, shallow geologic structure, deep seismic time-structure

Figure 3.1-2. Empirical curves relating rock density to acoustic velocity

Figure 3.1-3. A comparison of interval velocities calculated from uphole velocity surveys at boreholes WIPP 13 and WIPP 34

A simple second-order parabolic trend was used to separate the short-wavelength anomalies from the broad gravity high. Two-dimensional spatial filters, higher-order surfaces, or perhaps a model based on the seismic time structure could have been used to accomplish the separation. However, both the short- and long-wavelength anomalies apparently result from lateral density variations. There is no physical reason to believe broad gradational density variations do not exist in the shallow formations, and no physical reason to believe that part of the short-wavelength

anomalies should not originate in the Salado and Castile Formations. The double half-width rule indicates only the maximum depth to the *top* of the causative density structure and implies nothing about the total depth to the base. In lieu of a causative distinction between the long- and short-wavelength anomalies, the more sophisticated filtering techniques are not justified. Note that the filtered gravity field- (Figures 2.1-2 and 2.1-3) is undetermined by both a linear and a second-order trend.

3.2 Negative Anomalies

3.2.1 The WIPP 14 Anomaly

The negative gravity anomalies are the most distinctive and unanticipated feature of the gravity field. These anomalies were first detected on the detailed grid surveyed over the closed topographic depression midway along the line between Sections 9 and 16 (later drilled as WIPP 14). They were later found to extend in an east-west direction across the northern part of the survey area. Reconsideration of data from a coarsely spaced, poorly documented survey at the "old site" (Gera, 1974) showed their presence east of our survey area; the reconnaissance profiles around WIPP 33 show their presence to the west.

The interpretation of the negative anomalies involves consideration of shallow geologic structure, densilogs, velocity surveys, seismic profiles, surface topography, and regional and local geology. Different portions of the anomalies are interpreted with various logs from various holes. This was done because not all holes were logged with the same tools and not all logs were usable. The interpretation may seem piecemeal, but it is mutually consistent. The negative anomalies are here interpreted as caused by rock density decrease, solution/removal, and gypsum hydration in the vicinity of karst conduits. Interpretation begins with comparison of WIPP 14/WIPP 34 density logs. These densilogs indicate sufficient mass deficiency in the Dewey Lake and Rustler Formations to account for the negative gravity anomaly at WIPP 14. Next, the negative anomaly is modeled at its intersection with seismic line 77X2. The seismic line indicates a seismic time syncline coincident with the negative gravity anomaly. Both the seismic time syncline and the negative anomaly are explained by lateral velocity and inferred density variations comparable to those observed in uphole velocity surveys. Finally, the negative gravity anomaly and alluvial doline at WIPP 33 are related to the solution cavities encountered in that hole.

The data from the WIPP 14 anomaly are in Section 2.2 of this report. This anomaly is 0.4 mgal deep and trends WNW-ESE. It has a double half-width of 450 ft, and the top to the causative density structure should be at or above half this value (225 ft). The minimum missing mass is 470 tons per linear foot along the trend of the anomaly. These parameters are established by the gravity data and must be satisfied by any acceptable interpretation.

Borehole WIPP 14 was drilled to establish the geologic origin of the gravity anomaly. The hole was drilled to a total depth of 999 ft and penetrated 49 ft

into the Salado Formation. Tops of stratigraphic horizons were at or near where projected from neighboring holes, and there were no stratigraphic or structural anomalies. The upper 97 ft of sediments was poorly indurated. However, comparison of densilogs between WIPP 14 (USGS log) and WIPP 34 (1200 ft to the west) shows that this shallow material cannot account for most of the gravity anomaly.

Figure 3.2.1-1 is a comparison of compensated densilogs from WIPP 14 and WIPP 34 from 300 to 800 ft. The difference between logs was integrated over this interval and found equivalent to a mass deficiency of 1 ton (1955 lb)/ft² at WIPP 14. The log-indicated mass deficiency begins at 300 ft. There are possible contributions to the gravity anomaly by the upper 97 ft of poorly indurated sediments, and the borehole may well have missed the uppermost density deficiency in the Dewey Lake Formation. Therefore, the borehole observations are considered consistent with the calculated maximum depth to the top of the density structure of 225 ft. The mass deficiency at WIPP 14 (1 ton/ft²) is also consistent with minimum missing mass calculated from the gravity data (470 tons per linear foot). The total width of the anomaly is 800 to 1000 ft, and the low density material would reasonably occupy about the central 500 ft of this distance.

Particularly notable on Figure 3.2.1-1 are density variations in the Rustler Formation. These variations are here interpreted as caused by hydration of anhydrite to gypsum. This interpretation is consistent with the lithologic descriptions given in the basic data reports for boreholes WIPP 14 and WIPP 34 (SNLA and USGS, August 1982 and November 1981, respectively). The well-developed mass deficiency indicated by an asterisk on Figure 3.2.1-1 immediately overlies the Magenta Dolomite member of the Rustler. At WIPP 14 this interval is described as 9.5 ft of gypsum and 10 ft of gypsiferous anhydrite. At WIPP 34 it is described as 3.8 ft of gypsum, 4.3 ft of gypsiferous anhydrite, and 9.5 ft of anhydrite (broken by 1.1 ft of no core).

Figure 3.2.1-2 compares the gamma logs of the Rustler Formation at WIPP 14 and WIPP 34. The total thickness of the formation is nearly constant, and the individual layers are all present although their thicknesses vary. From the Rustler Formation isopach map (Figure 1.2.3-1), the area of WIPP 14 and WIPP 34 had 125 to 150 ft of the formation removed by solution. The hydration of anhydrite to gypsum involves up to 38% increase in volume (Ferrall and Gibbons, 1980, p 39). The implication is that solution/removal is *locally* compensated for by gypsum hydration. Perhaps this, along with mechanical strength of the overlying Dewey Lake Formation, largely prevents

development of more complex solution/collapse structures within the Rustler Formation.

Figure 3.2.1-1. A comparison of densilogs from boreholes WIPP 14 and WIPP 34

Figure 3.2.1-2. A comparison of gamma logs of the Rustler Formation at boreholes WIPP 14 and WIPP 34

Depositional facies variations and buried stream channels were considered as possible causes of the WIPP 14 gravity anomaly. Both of these interpretations are inconsistent with the observations and are considered highly unlikely.

“Facies” refers to those aspects of the lithology that are attributable to lateral variations in the depositional environment. The Dewey Lake and Rustler Formations were deposited over tens of thousands of square miles in a broad basin that extended over the Capitan Reef and Central Basin Platform (Snider, 1966, Figure 34). C. L. Jones (1954, p 110) notes that some of the halite in the Rustler Formation thins reefward and pinches out in the shelf area. He also notes that the two dolomite members and several siltstone and sandstone layers form remarkably persistent stratigraphic markers. The implication of the areal extent and the lateral persistence is that, while

some gradational north-south variations may be attributable to depositional facies, the east-west thinning (Figures 1.2.1-4 and 1.2.3-1) cannot. In particular, there is nothing in the depositional environment that suggests abrupt lateral variations over distances of several hundred feet.

When the WIPP 14 gravity anomaly was first detected, a buried stream channel was one of the hypotheses considered to explain it. A model of such a channel had a density contrast of 0.3 g/cc and a maximum thickness of 150 ft. A shallower channel would require a greater density contrast; a lesser density contrast would require a deeper channel. Both the 0.3 g/cc density contrast and the 150-ft thickness are larger than reasonably anticipated at this location. The lithologic character of such a feature should have been clearly discernible in the core.

When WIPP 14 was drilled, neither stratigraphic facies variations nor buried stream channels were identified in the core. Rather, the gravity anomaly was found to be reasonably attributed to diffuse density reductions in the Dewey Lake and Rustler Formations. The relation between these density reductions and the closed topographic depression will become clearer after considering the other elements in the interpretation.

3.2.2 Seismic Line 77X2

The negative gravity anomaly at WIPP 14 continues to the west-northwest across the WIPP site survey area. In the middle of this area it intersects north-south seismic line 77X2. (Field and processing parameters are given in Hern et al, 1979.) This seismic line shows a time-structure syncline in shallow events near the Rustler Formation. Both the seismic time syncline and the gravity low are here interpreted as due to a common region of altered rock properties.

Figure 3.2.2-1 shows the simple Bouguer gravity along survey line G. The negative anomaly and an assumed regional are indicated. Figure 3.2.2-2 shows coincident seismic line 77X2 (shotpoints 58-105) along with seismic horizons from borehole WIPP 11 and the gravity anomaly. The negative gravity anomaly corresponds with a 35-ms seismic time syncline near the Rustler Formation. The gravity anomaly here has an amplitude of -0.55 mgal and a double half-width of 420 m (1400 ft).

Borehole WIPP 11 lacks an uphole velocity survey necessary to rigorously convert horizon depths to seismic times. An approximate tie (Figure 3.2.2-2) was made with measured velocities from WIPP 34 for rocks above the Salado Formation and from WIPP 13

for rocks below the Rustler Formation. This combination was used because WIPP 13 is in a negative gravity anomaly, while both WIPP 11 and WIPP 34 are in a normal field. WIPP 13 is the closest hole with measured velocities for the Salado Formation and for the anhydrite and halite members of the Castile Formation.

If the seismic time syncline of 35 ms results from lateral velocity variations in the 662 ft of strata above the Rustler Formation, then the velocity variation might be 7734 ft/s to 6420 ft/s.

$$\begin{aligned} 662 \text{ ft at } 6420 \text{ ft/s} &= 206 \text{ ms} \\ -662 \text{ ft at } 7734 \text{ ft/s} &= \frac{171 \text{ ms}}{35 \text{ ms}} \end{aligned}$$

The high velocity (7734 ft/s) was measured at WIPP 34. The low velocity (6420 ft/s) compares reasonably with the 6549 ft/s measured at WIPP 13. Figure 3.1-3 compares the velocities measured at these two holes. Table 3.2.2-1 lists the measured velocities and the calculated seismic travel times at borehole WIPP 11.

The lateral velocity variation implies a lateral density variation (Figure 3.1-2). For a velocity variation of 7734 to 6420 ft/s, a reasonable density contrast is 0.12 g/cc . Figure 3.2.2-3 is a model of the gravity anomaly using this density contrast and a maximum thickness of 200 m (656 ft). The details needed to fit the model exactly to the gravity observations are well within the uncertainty in the control.

A first-order approximation of the seismic effect caused by this density structure is made with the following assumptions:

1. The density contrast of -0.12 g/cc is associated with a velocity contrast of 6420/7734 ft/s.
2. Vertical ray paths to the top of the Rustler Formation are from coincident source/receivers at the surface.

This approximate seismic effect is shown by the dark line on Figure 3.2.2-2.

A better seismic model would include the effects of ray bending at the sloping interface of the anomalous structure. Another, probably more important, correction is the effects of the actual vibrator/receiver array. Note that the total width of the modeled body is 550 m (1804 ft) and the survey used a 1650-440-0-440-1650 split-spread configuration (processed as a 12-fold common-depth-point (CDP) stack). Note also that the signal was muted so that shallow events are from only the inner receivers; the deeper events are from all receivers.

WIPP Gravity Survey - Line 'G'.

Figure 3.2.2-1. Simple Bouguer gravity along survey line G

Figure 3.2.2-2. Seismic line 77X2, shotpoints 58-105 and the coincident gravity anomaly from gravity survey line G

Line 'G' Anomaly - Model and Observations.

Figure 3.2.2-3. A model of the gravity anomaly on line G

Table 3.2.2-1. Measured velocities and calculated WIPP 11 depth-time tie

Horizon Top	WIPP 34 (G.L. 3433')			WIPP 13 (G.L. 3405')			WIPP 11 (G.L. 3426')			
	depth	time	velocity	depth	time	velocity	depth	assumed velocity	time	seismic 2-way time (datum corrected to 3200 2.5.1 @ 6000 ft/s)
Surface	-	-	7,734	-	-	6,549	-	7,734	-	-.0753
Rustler F.	652	.0843	12,570	518	.0791	11,474	662	12,570	.0856	.0959
Salado F.	965	.1092		845	.1076	14,426	943	14,426	.1080	.1407
Anhydrite III				2,957	.2540	19,266	2,330	19,266	.2041	.3329
Halite II				3,508	.2826	15,600	2,411	15,600	.2083	.3413
Anhydrite II				3,625	.2901	18,958	3,377	18,958	.2702	.4651
Halite I				3,716	.2949	14,921	3,499	14,921	.2767	.4781
Anhydrite I				3,810	.3012	16,428	3,549	16,428	.2800	.4847
t.d.				3,856	.3040		3,567		.2811	.4869

The seismic and gravity models show that the observed seismic and gravity anomalies might originate from a common lateral velocity/density variation. The possibility of a structural syncline at this location cannot be ruled out, but appears unlikely considering the existing borehole control.

3.2.3 The WIPP 33 Anomaly

The relation between negative gravity anomalies and karst conduits is clarified at borehole WIPP 33 (SNLA and USGS, February 1981). This hole was drilled in Section 13, R31E, T22S to determine the nature of a closed topographic depression. The hole encountered:

	Thickness (ft)
Surficial deposits (mostly sand)	44
Dewey Lake Formation	357
Rustler Formation	276
Salado Formation	163
Total Depth	840

Depths to stratigraphic markers were as projected from surrounding holes. At this location all of the halite has been dissolved from the Rustler Formation (Figure 1.2.3-1) and halite dissolution is affecting the top of the Salado Formation. Nearly all anhydrite in the Rustler Formation has converted to gypsum, and some of the gypsum has been removed by dissolution.

Particularly significant are four cavities totaling slightly over 20 ft in the Magenta Dolomite and Forty-Niner Members of the Rustler. These cavities resulted in lost circulation of drilling fluid and are here interpreted as karst conduits.

The closed topographic depression at this location is floored by loose sand and low brush. One of the few small arroyos in the site area drains into the depression from the southeast. Clumps of matted leaves and

debris indicate occasional flooding of depression. There is no evaporite crust as would be expected in an undrained playa.

The depression is interpreted as an alluvial doline. Following M. Sweeting (1973) or Bogli (1980), alluvial dolines are karst features formed when surficial material washes into cavities and conduits in the underlying corrodable rocks.

A negative anomaly at WIPP 33 was indicated on the regional gravity survey. A network of reconnaissance profiles was surveyed over the WIPP 33 area to verify the anomaly and to establish its form. Data from this survey are in Section 2.3.1 of this report. These data indicate a 0.6-mgal negative anomaly with a double half-width of 900 ft. There is no reason to distinguish this negative anomaly from those detected on the main WIPP site survey; all are assumed to have a common origin.

The anomaly at WIPP 33 was modeled along the profile of the pipeline trail. Figure 3.2.3-1 shows the observed gravity (less an arbitrary linear regional) and the modeled gravity. The modeled gravity is from the infinitely long polygonal bodies at the top of Figure 3.2.3-2. The geologic interpretation is at the bottom of that figure. The interpretation involves:

	Density Contrast (g/c ³)
Loose fill	0.3
Mass deficiency in the Dewey Lake Formation	0.12
Gypsification in the Rustler Formation	0.4
A solution conduit	1.3

Considering the lack of additional control and uncertainties in both the two-dimensional approximation and topographic corrections, different models could be proposed. This one incorporates all recognized sources for the short-wavelength negative anomalies.

Figure 3.2.3-1. Observed and modeled gravity along the pipeline trail crossing the WIPP 33 anomaly

Figure 3.2.3-2. Density model related to the profile on Figure 3.2.3-1 and the corresponding geologic interpretation

4. Summary

The WIPP gravity survey demonstrates both the utility and limitations of microgravity in a karst terrain. We were unable to resolve the low-amplitude long-wavelength anomalies that should originate in the Castile Formation geologic structures. We did map short-wave length anomalies that may reveal the style and extent of karst development in the Dewey Lake and Rustler Formations. The implications of this karst to the WIPP geohydrology are being carefully assessed (Barrows, 1982).

The nature of the broader gravity and related seismic features is equivocal. The present data suggest that they result from lateral density and velocity variations within fairly flat-lying strata. Additional uphole velocity surveys and petrophysical studies would help clarify this phenomenon.

Bell Lake Sink has a complex subsurface density structure. If further studies are done on this feature, it is recommended that microgravity be used to select multiple drilling sites.

References

- R.Y. Anderson, *Correlation and Structural Relationships of the Castile Salado Evaporite Sequence in ERDA 6, AEC 7 and AEC 8 Boreholes, Eddy and Lea Counties, New Mexico* (Albuquerque, NM: University of New Mexico, 1976).
- R. Y. Anderson, W. E. Dean, Jr., D. W. Kirkland, and H.I. Snider, "Permian Castile Varved Evaporite Sequence West Texas and New Mexico," *GSA Bull*, 83:59-86 (1972).
- G. O. Bachman, *Regional Geology and Cenozoic History of the Pecos Region, Southeastern New Mexico*, USGS, Open-File Report 80-1099 (1980).
- L. Barrows, SNLA, "WIPP Geohydrology—the Implications of Karst," Memo to W. D. Weart of SNLA, May 20, 1982.
- Bell and Murphy and Assoc., Inc. of Dallas, TX, *Geophysical Investigation of the Waste Isolation Pilot Plant*, Report for USDOE (1979).
- A. Bogli, *Karst Hydrology and Physical Speleology* (Berlin: Springer-Verlag, 1980).
- D. J. Borns, L. J. Barrows, D. W. Powers, and R. P. Snyder, *Deformation of Evaporites Near the WIPP Site*, SAND82-1069 (Albuquerque, NM: Sandia National Laboratories, 1983).
- G. C. Colley, "The Detection of Caves by Gravity Measurements," *Geophys Prospecting*, XI:273-284 (1963).
- W. E. Davies, and H. E. LeGrand, "Karst of the United States," in M. Herak and V.T. Stringfield, ed, *Important Karst Regions of the Northern Hemisphere* (Amsterdam: Elsevier, 1972).
- R. Djeddi, "An Integrated Geophysical and Geological Study of the Deep Structure and Tectonics of the Permian Basin of West Texas and Southeastern New Mexico," (MS Thesis, University of Texas at El Paso, 1979).
- C. C. Ferrall and J.F. Gibbons, *Core Study of the Rustler Formation Over the WIPP Site*, SAND79-7110 (Albuquerque, NM: Sandia National Laboratories, 1980).
- F. Gera, *On the Origin of the Small Hills in Nash Draw and Clayton Basin, Southeastern New Mexico*, Rpt 74-2-29 (Oak Ridge, TN: Oak Ridge National Laboratory, 1974).
- G. B. Griswold, *Site Selection and Evaluation Studies of the Waste Isolation Pilot Plant, Los Medanos, Eddy County, NM*, SAND77-0946 (Albuquerque, NM: Sandia Laboratories, 1977).
- S. I. Hammer, "Critique of Terrain Corrections for Gravity Stations," *Geophysics*, 47:839 (1982).
- J. L. Hern, D. W. Powers, and L. J. Barrows, *Seismic Reflection Data Report, Waste Isolation Pilot Plant (WIPP) Site*, SAND79-0264, Vol 1 and 2 (Albuquerque, NM: Sandia Laboratories, 1979).
- C. L. Jones, "The Occurrence and Distribution of Potassium Minerals in Southeastern New Mexico," in *NM Geol Soc Guidebook, 5th Field Conf*, pp 107-112 (1954).
- H. E. LeGrand, V. T. Stringfield, and P. E. LaMoreaux, "Hydrologic Features of United States Karst Regions," in V. Yevjevich, ed, *Karst Hydrology and Water Resources, Proceedings of US-Yugoslavian Symposium* (Fort Collins, CO: Water Resources Publications, 1976).
- P. B. King, *Geology of the Southern Guadalupe Mountains, Texas*, USGS Prof Paper 215 (1948).
- D. W. Kirkland and R.Y. Anderson, "Microfolding in the Castile and Todilto Evaporites, Texas and New Mexico," *GSA Bull*, 81:3259-3282 (1970).
- A. M. Morgan, "Solution-Phenomena in the Pecos Basin of New Mexico," *Trans of Am Geophys Union*, p 27-35 (1941).
- L. L. Nettleton, *Gravity and Magnetism in Oil Prospecting* (New York: McGraw-Hill, 1976).
- W. W. Olive, "Solution-Subsidence Troughs, Castile Formation of the Gypsum Plain, Texas and New Mexico," *GSA Bull*, 68:351-358 (1957).
- G. Omnes, "High Accuracy Gravity Applied to the Detection of Karstic Cavities," in J. S. Tolson and F. L. Doyle, ed, *Proc of the Twelfth International Congress on Karst Hydrology, Sept. 21-27, 1975* (Huntsville, AL: UAH Press, 1977).
- D. W. Powers et al, *Geological Characterization Report, Waste Isolation Pilot Plant Site, Southeastern New Mexico*, SAND79-1596 (Albuquerque, NM: Sandia Laboratories, 1978).
- Sandia National Laboratories and US Geological Survey, *Basic Data Report for Drillhole WIPP 33*, SAND80-2011 (Albuquerque, NM: Sandia National Laboratories, February 1981).
- Sandia National Laboratories and US Geological Survey, *Basic Data Report for Drillhole WIPP 34*, SAND81-2643 (Albuquerque, NM: Sandia National Laboratories, November 1981).
- Sandia National Laboratories and D'Appolonia Consulting Engineers, *Basic Data Report for Drillhole WIPP 14*, SAND82-1783 (Albuquerque, NM: Sandia National Laboratories, August 1982).
- H. I. Snider, "Stratigraphy and Associated Tectonics of the Upper Permian Castile-Salado-Rustler Evaporite Complex, Delaware Basin, West Texas and Southeast New Mexico," (PhD diss, University of New Mexico, 1966).
- M. M. Sweeting, *Karst Landforms* (New York: Columbia University Press, 1973).
- W. M. Telford et al, *Applied Geophysics* (Cambridge: Cambridge University Press, 1976).
- R. Widdicombe, "Quaternary Surficial Features in the Delaware Basin, Eddy and Lea Counties, New Mexico" (MS Thesis, University of New Mexico, 1980).

APPENDIX A

**Gravity Data From the Main Site Survey and
Detailed Grid in the Southeast Corner
of Section 28**

LINE A

STATION NUMER	ELEVATION (FEET)	SIMPLE BOUGUER GRAVITY (MILLIGALS AT 2.3 GM/CC)		
		RAW	- LINEAR REGIONAL	-PARABOLIC TREND
1	3341.85	-136.036	-.036	-.076
2	3342.49	-135.956	-.015	-.093
3	3345.39	-135.921	-.039	-.154
4	3348.72	-135.879	-.055	-.207
5	3348.18	-135.768	-.003	-.191
6	3348.52	-135.684	.022	-.200
7	3349.76	-135.632	.015	-.240
8	3347.70	-135.550	.038	-.250
9	3347.68	-135.487	.042	-.277
10	3347.31	-135.382	.089	-.261
11	3354.60	-135.301	.111	-.269
12	3360.42	-135.193	.160	-.248
13	3367.95	-135.104	.190	-.245
14	3369.30	-134.955	.280	-.182
15	3370.57	-134.852	.325	-.163
16	3374.78	-134.757	.361	-.151
17	3379.45	-134.669	.390	-.146
18	3380.40	-134.522	.478	-.080
19	3385.44	-134.446	.495	-.084
20	3384.34	-134.308	.574	-.026
21	3383.15	-134.172	.652	.032
22	3389.08	-134.058	.707	.069
23	3391.20	-133.934	.772	.116
24	3392.46	-133.801	.846	.174
25	3402.49	-133.733	.855	.168
26	3406.91	-133.646	.883	.181
27	3409.88	-133.560	.911	.195
28	3406.27	-133.427	.985	.257
29	3404.63	-133.378	.975	.236
30	3407.88	-133.349	.945	.195
31	3407.73	-133.299	.936	.177
32	3409.71	-133.180	.997	.229
33	3409.62	-133.126	.992	.216
34	3407.44	-133.076	.983	.201
35	3402.90	-133.018	.982	.195
36	3398.97	-132.937	1.004	.212
37	3399.93	-132.930	.952	.157
38	3403.30	-132.967	.857	.059
39	3401.98	-132.930	.835	.035
40	3397.86	-132.799	.907	.107
41	3395.20	-132.776	.871	.072
42	3393.90	-132.663	.925	.127
43	3394.74	-132.600	.930	.134
44	3393.00	-132.563	.908	.116
45	3391.25	-132.542	.870	.082
46	3388.56	-132.484	.869	.087
47	3393.17	-132.465	.829	.054
48	3395.12	-132.442	.793	.025
49	3386.89	-132.270	.907	.147
50	3382.09	-132.189	.929	.179
51	3381.80	-132.110	.949	.209
52	3378.60	-132.092	.908	.180
53	3376.75	-132.069	.872	.157
54	3377.66	-132.121	.762	.060
55	3379.50	-132.199	.625	-.063
56	3380.06	-132.186	.575	-.093
57	3375.24	-132.074	.632	-.023
58	3379.13	-132.023	.624	-.014
59	3377.21	-131.976	.612	-.007
60	3376.14	-131.941	.589	-.011
61	3380.73	-131.930	.541	-.039
62	3383.92	-131.978	.434	-.124
63	3383.25	-131.961	.392	-.143
64	3381.98	-131.885	.409	-.103
65	3384.88	-131.849	.387	-.101
66	3381.81	-131.818	.359	-.103
67	3381.35	-131.915	.203	-.233
68	3383.13	-132.037	.022	-.386
69	3384.44	-132.085	-.085	-.464
70	3387.72	-132.071	-.130	-.480
71	3387.19	-132.054	-.171	-.491
72	3386.07	-131.925	-.101	-.389
73	3384.97	-131.815	-.050	-.306
74	3381.31	-131.712	-.006	-.228
75	3383.05	-131.620	.027	-.160
76	3382.22	-131.539	.050	-.102
77	3381.69	-131.455	.075	-.041
78	3380.44	-131.359	.112	.034
79	3381.78	-131.317	.095	.056

EDITING

average of 2 readings

adjusted 0.034 milligals
to tie adjacent blocks

average of 2 readings

average of 2 readings

LINE B

STATION NUMBER	ELEVATION (FEET)	SIMPLE BOUGUER GRAVITY (MILLIGALS AT 2.3 GM/CC)			EDITING
		RAW	- LINEAR REGIONAL	-PARABOLIC TREND	
1	3347.59	-135.997	-.117	-.157	
2	3347.47	-135.906	-.085	-.163	
3	3347.40	-135.846	-.084	-.199	
4	3351.51	-135.769	-.065	-.217	
5	3354.05	-135.696	-.051	-.239	
6	3355.47	-135.621	-.035	-.257	
7	3357.63	-135.520	.007	-.248	
8	3361.12	-135.449	.019	-.269	
9	3361.36	-135.334	.075	-.244	
10	3365.97	-135.262	.089	-.261	
11	3361.75	-135.095	.157	-.183	
12	3363.48	-135.011	.222	-.186	
13	3371.61	-134.952	.222	-.213	
14	3374.88	-134.882	.233	-.229	
15	3373.15	-134.789	.268	-.220	
16	3373.97	-134.689	.309	-.203	
17	3381.58	-134.567	.372	-.164	
18	3379.51	-134.413	.467	-.091	
19	3380.12	-134.325	.496	-.083	average of 2 readings
20	3386.22	-134.192	.570	-.030	
21	3384.99	-134.049	.655	.035	
22	3387.18	-133.900	.745	.107	
23	3391.88	-133.771	.815	.159	
24	3397.63	-133.692	.835	.163	
25	3402.87	-133.590	.878	.191	
26	3407.51	-133.486	.923	.221	
27	3411.54	-133.419	.932	.216	
28	3414.96	-133.385	.907	.179	
29	3409.50	-133.250	.983	.244	
30	3415.05	-133.281	.893	.143	average of 2 readings
31	3410.79	-133.203	.912	.153	
32	3413.51	-133.150	.907	.139	
33	3415.50	-133.084	.914	.138	
34	3414.71	-133.066	.873	.091	
35	3413.67	-133.086	.794	.007	
36	3412.01	-133.065	.756	-.036	average of 2 readings
37	3412.60	-132.990	.772	-.023	
38	3412.55	-132.876	.828	.030	
39	3411.34	-132.787	.858	.058	
40	3407.35	-132.731	.855	.055	
41	3402.72	-132.613	.914	.115	
42	3406.84	-132.629	.839	.041	
43	3400.12	-132.580	.830	.034	
44	3399.87	-132.603	.748	-.044	
45	3401.96	-132.611	.681	-.107	
46	3393.95	-132.528	.705	-.077	
47	3395.92	-132.472	.702	-.073	
48	3392.46	-132.344	.771	.003	
49	3393.55	-132.239	.818	.058	
50	3395.98	-132.167	.831	.081	
51	3389.30	-131.998	.941	.201	
52	3388.81	-131.909	.971	.243	
53	3388.35	-131.841	.988	.265	
54	3385.45	-131.822	.941	.239	
55	3383.51	-131.834	.870	.182	average of 2 readings
56	3383.49	-131.787	.858	.186	
57	3383.71	-131.748	.838	.183	
58	3385.01	-131.766	.761	.123	
59	3384.76	-131.713	.755	.136	
60	3387.16	-131.791	.619	.019	
61	3387.13	-131.796	.555	-.025	
62	3382.74	-131.803	.489	-.069	
63	3388.68	-131.891	.342	-.193	
64	3396.18	-131.969	.205	-.307	
65	3387.47	-131.912	.204	-.284	
66	3388.47	-132.004	.053	-.409	
67	3385.95	-132.022	-.024	-.460	
68	3387.53	-132.042	-.103	-.511	
69	3388.20	-132.077	-.197	-.576	
70	3399.50	-132.021	-.200	-.550	
71	3402.46	-132.008	-.245	-.565	
72	3394.46	-131.889	-.185	-.473	
73	3392.34	-131.815	-.170	-.426	
74	3388.15	-131.605	-.019	-.241	
75	3385.84	-131.477	.050	-.137	
76	3388.11	-131.413	.055	-.097	
77	3388.61	-131.332	.078	-.038	
78	3388.84	-131.271	.080	.002	
79	3391.21	-131.229	.063	.024	

LINE C

STATION NUMER	ELEVATION (FEET)	SIMPLE BOUGUER (GRAVITY MILLIGALS AT 2.3 GM/CC)		
		RAW	- LINEAR REGIONAL	-PARABOLIC TREND
1	3354.80	-135.923	-.163	-.203
2	3353.20	-135.858	-.157	-.235
3	3359.09	-135.813	-.171	-.286
4	3359.40	-135.735	-.151	-.303
5	3359.04	-135.638	-.113	-.301
6	3362.48	-135.557	-.091	-.313
7	3362.31	-135.457	-.050	-.305
8	3365.02	-135.363	-.015	-.303
9	3368.87	-135.246	.043	-.276
10	3376.12	-135.193	.038	-.312
11	3373.47	-135.029	.143	-.237
12	3376.27	-134.965	.148	-.260
13	3379.76	-134.863	.191	-.244
14	3383.36	-134.783	.212	-.250
15	3375.06	-134.631	.306	-.182
16	3375.79	-134.550	.328	-.184
17	3377.77	-134.427	.392	-.144
18	3388.61	-134.361	.399	-.159
19	3384.57	-134.212	.489	-.090
20	3386.20	-134.107	.535	-.065
21	3394.46	-134.048	.536	-.084
22	3389.55	-133.877	.648	.010
23	3391.84	-133.754	.712	.056
24	3399.08	-133.647	.760	.088
25	3408.44	#####	####	####
26	3408.77	-133.485	.804	.102
27	3405.35	-133.377	.854	.138
28	3408.72	-133.318	.854	.126
29	3413.21	-133.257	.856	.117
30	3415.79	-133.201	.853	.103
31	3410.59	-133.089	.906	.147
32	3408.82	-133.021	.916	.148
33	3407.80	-132.966	.912	.136
34	3407.50	-132.941	.878	.096
35	3412.47	-132.874	.886	.099
36	3417.83	-132.818	.883	.091
37	3418.56	-132.766	.876	.081
38	3419.29	-132.714	.870	.072
39	3418.49	-132.694	.831	.031
40	3411.06	-132.604	.862	.062
41	3409.98	-132.565	.842	.043
42	3406.65	-132.537	.811	.013
43	3408.44	-132.346	.944	.148
44	3408.38	-132.362	.869	.077
45	3404.54	-132.568	.604	-.184
46	3403.13	-132.483	.630	-.152
47	3400.66	-132.390	.664	-.111
48	3396.90	-132.257	.738	-.030
49	3392.42	-132.155	.782	.022
50	3392.05	-131.987	.891	.141
51	3397.39	-131.889	.930	.190
52	3397.02	-131.811	.949	.221
53	3395.02	-131.747	.954	.239
54	3393.68	-131.694	.949	.247
55	3394.36	-131.627	.957	.269
56	3397.16	-131.627	.898	.226
57	3392.37	-131.623	.843	.188
58	3398.08	-131.787	.620	-.018
59	3395.40	-131.755	.593	-.026
60	3393.62	-131.722	.568	-.032
61	3398.49	-131.796	.435	-.145
62	3394.69	-131.716	.456	-.102
63	3393.04	-131.746	.367	-.168
64	3391.17	-131.779	.275	-.237
65	3394.13	-131.779	.217	-.271
66	3393.73	-131.815	.122	-.340
67	3393.18	-131.815	.063	-.373
68	3393.36	-131.858	-.039	-.447
69	3393.38	-131.881	-.121	-.500
70	3394.96	-131.705	-.004	-.354
71	3398.00	-131.602	.041	-.279
72	3396.04	-131.661	-.077	-.365
73	3392.78	-131.661	-.136	-.392
74	3388.33	-131.547	-.081	-.303
75	3389.57	-131.400	.007	-.180
76	3393.91	-131.326	.022	-.130
77	3394.15	-131.247	.043	-.073
78	3393.42	-131.179	.052	-.026
79	3400.32	-131.146	.026	-.013

EDITING

average of 2 readings

bad data point

average of 2 readings

average of 2 readings

average of 2 readings

LINE D

SIMPLE BOUGLER (GRAVITY
MILLIGALS AT 2.3 GM/CC)

EDITING

STATION NUMBER	ELEVATION (FEET)	RAW	- LINEAR REGIONAL	-PARABOLIC TREND
1	3361.07	-135.882	-.242	-.282
2	3362.84	-135.809	-.228	-.306
3	3364.71	-135.694	-.172	-.287
4	3365.21	-135.626	-.162	-.314
5	3363.83	-135.512	-.107	-.295
6	3368.48	-135.475	-.129	-.351
7	3368.80	-135.409	-.122	-.377
8	3367.05	-135.295	-.067	-.355
9	3370.74	-135.201	-.032	-.351
10	3371.88	-135.086	.025	-.325
11	3377.25	-135.001	.051	-.329
12	3383.24	-134.946	.047	-.361
13	3382.11	-134.798	.136	-.299
14	3382.03	-134.695	.180	-.282
15	3382.28	-134.586	.231	-.257
16	3385.27	-134.481	.277	-.235
17	3386.11	-134.332	.367	-.169
18	3387.49	-134.200	.440	-.118
19	3389.94	-134.087	.494	-.085
20	3389.10	-133.973	.549	-.051
21	3395.83	-133.900	.564	-.056
22	3396.59	-133.757	.648	.010
23	3396.24	-133.634	.712	.056
24	3404.60	-133.599	.688	.016
25	3405.81	-133.493	.735	.048
26	3402.91	-133.375	.754	.092
27	3410.18	-133.280	.831	.115
28	3411.40	-133.237	.815	.087
29	3413.51	-133.151	.842	.103
30	3414.25	-132.949	.985	.235
31	3415.89	-132.867	1.008	.249
32	3417.77	-132.797	1.020	.252
33	3420.18	-132.750	1.008	.232
34	3420.49	-132.682	1.017	.235
35	3421.63	-132.631	1.009	.222
36	3422.96	-132.520	1.061	.269
37	3428.30	-132.514	1.008	.213
38	3427.51	-132.455	1.009	.211
39	3427.08	-132.441	.964	.164
40	3428.94	-132.371	.975	.175
41	3423.08	-132.311	.976	.177
42	3419.61	-132.301	.927	.129
43	3413.27	-132.246	.924	.128
44	3413.38	-132.235	.876	.084
45	3412.17	-132.239	.813	.025
46	3411.19	-132.197	.756	.014
47	3409.22	-132.110	.824	.049
48	3406.48	-131.985	.890	.122
49	3405.02	-131.893	.924	.164
50	3403.13	-131.776	.982	.232
51	3408.68	-131.706	.993	.253
52	3406.58	-131.637	1.003	.275
53	3404.35	-131.697	.884	.169
54	3409.58	-131.824	.699	-.003
55	3404.45	-131.683	.781	.093
56	3400.56	-131.593	.812	.140
57	3401.35	-131.526	.820	.165
58	3398.89	-131.388	.899	.261
59	3398.58	-131.507	.721	.102
60	3397.95	-131.582	.588	-.012
61	3398.53	-131.562	.549	-.031
62	3398.73	-131.601	.451	-.107
63	3399.72	-131.572	.421	-.114
64	3398.75	-131.603	.331	-.181
65	3399.81	-131.696	.180	-.308
66	3400.16	-131.749	.068	-.394
67	3401.50	-131.791	-.033	-.469
68	3403.76	-131.794	-.095	-.503
69	3400.04	-131.744	-.104	-.483
70	3400.90	-131.685	-.104	-.454
71	3404.31	-131.587	-.064	-.384
72	3402.13	-131.554	-.090	-.378
73	3405.74	-131.591	-.186	-.442
74	3396.44	-131.386	-.040	-.262
75	3395.70	-131.269	.018	-.169
76	3397.71	-131.147	.081	-.071
77	3395.06	-131.028	.142	.026
78	3399.51	-130.981	.130	.052
79	3402.14	-130.911	.141	.102

average of 2 readings

average of 2 readings

average of 2 readings

average of 2 readings

LINE E

SIMPLE BOUGUER GRAVITY
(MILLIGALS AT 2.3 GM/CC)

EDITING

STATION NUMER	ELEVATION (FEET)	RAW	- LINEAR REGIONAL	-PARABOLIC TRENC
1	3366.87	-135.820	-.300	-.340
2	3365.53	-135.725	-.264	-.342
3	3373.19	-135.694	-.292	-.407
4	3370.19	-135.583	-.239	-.391
5	3370.84	-135.517	-.232	-.428
6	3373.07	-135.434	-.208	-.430
7	3374.10	-135.327	-.160	-.415
8	3373.13	-135.229	-.121	-.409
9	3376.62	-135.144	-.095	-.414
10	3378.03	-135.057	-.066	-.416
11	3385.54	-135.001	-.069	-.449
12	3387.26	#####	#####	#####
13	3387.95	-134.748	.066	-.369
14	3389.89	-134.645	.110	-.352
15	3390.88	-134.514	.183	-.305
16	3392.55	-134.413	.225	-.287
17	3392.53	-134.290	.289	-.247
18	3395.20	-134.185	.335	-.223
19	3397.18	-134.041	.420	-.159
20	3398.28	-133.930	.472	-.128
21	3400.22	-133.854	.490	-.130
22	3401.48	-133.785	.500	-.138
23	3408.19	-133.713	.513	-.143
24	3406.75	-133.587	.588	-.092
25	3414.78	-133.554	.554	-.133
26	3416.49	-133.447	.602	-.100
27	3417.80	-133.370	.621	-.095
28	3423.14	-133.267	.665	-.063
29	3426.56	-133.144	.729	-.010
30	3427.56	-132.976	.838	.088
31	3431.50	-132.871	.884	.125
32	3434.28	-132.753	.944	.176
33	3435.04	-132.666	.972	.196
34	3432.94	-132.559	1.020	.238
35	3434.44	-132.517	1.003	.216
36	3438.91	-132.404	1.057	.265
37	3448.50	-132.363	1.039	.244
38	3448.18	-132.363	.981	.183
39	3450.22	-132.175	1.110	.310
40	3448.23	-132.121	1.105	.305
41	3443.77	-132.051	1.116	.317
42	3435.70	-131.990	1.118	.328
43	3432.13	-132.015	1.035	.239
44	3429.70	-131.926	1.065	.273
45	3425.22	-132.120	.812	.024
46	3422.95	-132.127	.746	-.036
47	3423.88	-132.090	.724	-.051
48	3423.20	-131.961	.794	.026
49	3424.88	-131.946	.751	-.009
50	3422.41	-131.732	.906	.156
51	3418.28	-131.480	1.099	.359
52	3420.38	-131.524	.996	.268
53	3414.58	-131.498	.963	.248
54	3413.18	-131.454	.949	.247
55	3413.31	-131.602	.742	.054
56	3407.03	-131.577	.708	.036
57	3405.50	-131.579	.647	-.008
58	3405.67	-131.503	.664	.026
59	3405.15	-131.491	.617	-.002
60	3404.43	-131.453	.597	-.003
61	3402.37	-131.454	.537	-.043
62	3401.66	-131.472	.460	-.098
63	3400.98	-131.540	.333	-.202
64	3400.89	-131.582	.232	-.280
65	3402.22	-131.606	.150	-.338
66	3401.90	-131.533	.164	-.298
67	3402.60	-131.536	.102	-.334
68	3405.48	-131.500	.079	-.329
69	3407.12	-131.500	.020	-.359
70	3406.96	-131.562	-.101	-.451
71	3409.54	-131.585	-.182	-.502
72	3412.10	-131.492	-.148	-.436
73	3415.50	-131.393	-.188	-.364
74	3404.10	-131.129	.097	-.125
75	3404.58	-131.052	.115	-.072
76	3404.02	-130.940	.168	.016
77	3404.89	-130.908	.142	.026
78	3405.40	-130.864	.127	.049
79	3406.65	-130.788	.144	.105

bad data
2 readings - one was bad

average of 2 readings

average of 2 readings

average of 2 readings

average of 2 readings

LINE F

STATION ELEVATION SIMPLE BOUGUER GRAVITY
NUMEER (FEET) (MILLIGALS AT 2.2 GM/CC)

EDITING

		RAW	- LINEAR REGIONAL	-PARABOLIC TREND
1	3370.98	-135.645	-.245	-.285
2	3377.82	-135.565	-.224	-.302
3	3375.71	-135.483	-.201	-.316
4	3376.22	-135.441	-.217	-.369
5	3376.16	-135.362	-.197	-.385
6	3378.99	-135.320	-.214	-.436
7	3378.82	-135.235	-.188	-.443
8	3380.38	-135.151	-.163	-.451
9	3386.68	-135.056	-.127	-.446
10	3388.98	-134.942	-.071	-.421
11	3393.75	-134.852	-.040	-.420
12	3396.54	-134.719	.034	-.374
13	3395.02	-134.610	.084	-.351
14	3396.41	-134.540	.095	-.367
15	3394.34	-134.438	.139	-.349
16	3395.80	-134.349	.169	-.343
17	3400.76	-134.212	.247	-.289
18	3402.62	-134.107	.293	-.265
19	3402.31	-133.991	.350	-.229
20	3404.40	-133.910	.372	-.228
21	3405.77	-133.839	.385	-.235
22	3405.30	-133.708	.457	-.181
23	3411.68	-133.704	.402	-.254
24	3413.02	-133.617	.430	-.242
25	3418.04	-133.564	.424	-.263
26	3420.47	-133.498	.431	-.271
27	3422.70	-133.413	.458	-.258
28	3423.74	-133.249	.563	-.165
29	3427.15	-133.129	.624	-.115
30	3430.50	-132.942	.752	.002
31	3436.16	-132.766	.869	.110
32	3439.82	-132.567	1.010	.242
33	3445.67	-132.461	1.057	.281
34	3451.18	-132.405	1.054	.272
35	3448.43	-132.271	1.129	.342
36	3454.01	-132.253	1.088	.296
37	3459.37	-132.185	1.097	.302
38	3461.99	-132.118	1.106	.308
39	3456.36	-132.022	1.143	.343
40	3451.09	133.133	1.119	.320
41	3447.51	-131.928	1.107	.309
42	3444.45	-131.881	1.084	.288
43	3443.02	-131.846	1.097	.305
44	3438.26	-131.774	1.002	.214
45	3437.60	-132.083	.670	-.112
46	3438.84	-132.076	.618	-.157
48	3439.03	-131.763	.872	.104
49	3435.27	-131.689	.888	.128
50	3431.26	-131.631	.887	.137
51	3433.67	-131.735	.724	-.016
52	3421.49	-131.585	.815	.087
53	3428.55	-131.709	.632	-.083
54	3418.90	-131.657	.626	-.076
55	3417.60	-131.612	.612	-.076
56	3414.10	-131.572	.583	-.079
57	3414.05	-131.524	.582	-.073
58	3408.34	-131.432	.615	-.023
59	3408.52	-131.244	.744	.125
60	3408.47	-131.058	.872	.272
61	3409.12	-131.111	.760	.180
62	3407.83	-131.088	.724	.166
63	3408.42	-131.236	.517	-.018
64	3408.21	-131.326	.368	-.144
65	3408.43	-131.291	.345	-.143
66	3409.32	-131.278	.299	-.163
67	3412.56	-131.245	.273	-.163
68	3411.74	-131.318	.141	-.267
69	3411.01	-131.421	-.021	-.400
70	3412.70	-131.388	-.047	-.397
71	3409.37	-131.191	.092	-.228
72	3416.88	-130.962	.262	-.026
73	3414.38	-130.936	.229	-.027
74	3419.50	-130.956	.150	-.072
75	3420.01	-130.892	.155	-.032
76	3425.92	-130.915	.073	-.079
77	3426.10	-130.916	.014	-.102
78	3422.34	-130.839	.032	-.046
79	3421.11	-130.749	.063	.024

average of 2 readings

average of 2 readings

bad data
2 readings - on was bad

average of 2 readings

average of 2 readings

LINE G

SIMPLE BOUGUER GRAVITY
STATION ELEVATION (MILLIGALS AT 2.3 GM/CC)
NUMER (FEET)

EDITING

		RAW	- LINEAR REGIONAL	-PARABOLIC TREND
1	3384.55	-135.427	-.147	-.186
2	3392.69	-135.378	-.157	-.235
3	3388.24	-135.311	-.149	-.264
4	3387.22	-135.226	-.122	-.274
5	3388.89	-135.144	-.099	-.287
6	3387.25	-135.091	-.105	-.327
7	3389.96	-134.968	-.041	-.296
8	3392.26	-134.897	-.029	-.317
9	3400.05	-134.898	-.089	-.408
10	3397.17	-134.795	-.044	-.394
11	3402.74	-134.760	-.068	-.448
12	3402.45	-134.619	.014	-.394
13	3401.84	-134.510	.064	-.371
14	3398.93	-134.374	.141	-.321
15	3400.73	-134.244	.213	-.275
16	3403.82	-134.140	.258	-.254
17	3405.01	-134.037	.302	-.234
18	3405.30	-133.970	.310	-.248
19	3408.02	-133.980	.241	-.338
20	3410.59	-133.886	.276	-.324
21	3410.42	-133.809	.295	-.325
22	3412.66	-133.740	.305	-.333
23	3413.20	-133.626	.360	-.296
24	3416.90	-133.553	.374	-.298
25	3419.32	-133.435	.433	-.254
26	3420.15	-133.352	.457	-.245
27	3422.00	-133.319	.432	-.284
28	3426.61	-133.237	.455	-.273
29	3432.92	-133.129	.504	-.235
30	3437.39	-132.904	.670	-.080
31	3441.93	-132.704	.811	.052
32	3448.47	-132.614	.843	.075
33	3453.22	-132.501	.897	.121
34	3457.19	-132.412	.927	.145
35	3464.20	-132.346	.934	.147
36	3471.96	-132.231	.990	.198
37	3474.50	-132.210	.952	.157
38	3471.09	-132.158	.946	.148
39	3464.75	-132.054	.991	.191
40	3461.35	-131.988	.958	.198
41	3459.24	-131.921	1.006	.207
42	3461.24	-131.892	.976	.178
43	3457.53	-131.838	.972	.176
44	3455.06	-131.790	.961	.169
45	3451.50	-131.750	.942	.154
46	3452.24	-131.798	.835	.053
47	3450.17	-131.739	.835	.060
48	3445.77	-131.644	.871	.103
49	3443.69	-131.575	.882	.122
50	3440.10	-131.496	.902	.152
51	3437.99	-131.415	.924	.184
52	3431.66	-131.374	.906	.178
53	3434.16	-131.379	.842	.127
54	3427.33	-131.302	.861	.159
55	3425.56	-131.250	.854	.166
56	3422.53	-131.165	.880	.208
57	3418.92	-131.048	.938	.283
58	3416.27	-130.980	.947	.309
59	3420.76	-130.953	.915	.296
60	3417.60	-130.880	.930	.330
61	3419.13	-130.862	.889	.309
62	3419.47	-130.832	.860	.302
63	3418.79	-130.831	.802	.267
64	3416.57	-130.862	.712	.200
65	3420.10	-130.947	.569	.081
66	3419.48	-131.079	.378	-.084
67	3421.68	-131.248	.150	-.286
68	3420.69	-131.283	.056	-.352
69	3419.30	-131.274	.006	-.373
70	3419.45	-131.115	.106	-.244
71	3420.49	-130.834	.329	.009
72	3419.23	-130.664	.440	.152
73	3420.78	-130.655	.390	.134
74	3423.64	-130.640	.346	.124
75	3428.38	-130.627	.300	.113
76	3423.85	-130.621	.247	.095
77	3429.71	-130.628	.182	.066
78	3423.75	-130.532	.219	.141
79	3419.16	-130.479	.213	.174

resurveyed & new data used
average of 2 readings

average of 2 readings

2 readings straddling mud pit

average of 2 readings

average of 2 readings

average of 2 readings

resurveyed and new data used

LINE H

STATION		ELEVATION		SIMPLE BOUGUER (GRAVITY MILLIGALS AT 2.3 GM/CC)			
NUMBER		(FEET)		RAW	- LINEAR REGIONAL	-PARABOLIC TREND	EDITING
1	3409.07	-135.350			-.190	-.230	
2	3408.43	-135.221			-.120	-.198	
3	3405.89	-135.108			-.066	-.181	
4	3407.98	-134.990			-.006	-.158	
5	3409.72	-134.926			-.001	-.189	
6	3402.30	-134.775			.091	-.131	
7	3403.77	-134.727			.080	-.175	
8	3403.24	-134.686			.062	-.226	
9	3405.18	-134.625			.064	-.255	
10	3407.51	-134.609			.022	-.328	
11	3403.14	-134.489			.083	-.297	
12	3401.12	-134.397			.116	-.292	
13	3408.26	-134.315			.139	-.296	
14	3408.03	-134.201			.194	-.268	
15	3407.86	-134.117			.220	-.268	
16	3409.29	-134.057			.221	-.291	
17	3410.45	-133.984			.235	-.301	
18	3412.18	-133.909			.251	-.307	
19	3414.92	-133.846			.255	-.324	
20	3415.22	-133.800			.242	-.358	
21	3415.28	-133.757			.227	-.393	
22	3416.28	-133.684			.241	-.397	
23	3419.23	-133.565			.301	-.355	
24	3421.59	-133.436			.371	-.301	
25	3422.22	-133.402			.346	-.341	
26	3423.56	-133.368			.321	-.381	
27	3426.40	-133.270			.361	-.355	
28	3427.04	-133.164			.408	-.320	
29	3432.20	-133.083			.430	-.309	
30	3436.62	-132.929			.525	-.225	
31	3440.64	-132.853			.542	-.217	
32	3447.38	-132.656			.681	-.087	
33	3453.12	-132.529			.749	-.027	
34	3460.86	-132.451			.768	-.014	
35	3467.59	-132.384			.776	-.011	
36	3469.65	-132.308			.793	.001	
37	3471.38	-132.234			.808	.013	
38	3470.04	-132.139			.845	.047	
39	3467.92	-132.058			.867	.067	
40	3468.09	-132.003			.863	.063	
41	3469.64	-131.983			.824	.025	
42	3467.71	-131.901			.847	.049	
43	3469.08	-131.867			.823	.027	
44	3467.51	-131.795			.836	.044	
45	3465.07	-131.744			.828	.040	
46	3463.55	-131.712			.801	.019	
47	3462.98	-131.667			.787	.012	
48	3461.72	-131.622			.773	.005	
49	3458.87	-131.579			.758	-.002	
50	3449.80	-131.526			.752	.002	
51	3444.16	-131.481			.738	-.002	
52	3439.65	-131.441			.719	-.009	
53	3433.80	-131.346			.755	.040	
54	3430.78	-131.273			.770	.068	
55	3429.63	-131.232			.752	.064	
56	3427.07	-131.197			.728	.056	
57	3427.55	-131.111			.755	.100	
58	3425.20	-131.052			.755	.117	
59	3426.46	-131.012			.736	.117	
60	3424.19	-130.986			.704	.104	
61	3423.48	-130.981			.650	.078	
62	3424.81	-131.010			.562	.004	
63	3424.94	-130.988			.525	-.010	
64	3425.65	-131.025			.429	-.083	
65	3425.79	-131.002			.394	-.094	
66	3424.20	-131.078			.259	-.203	
67	3424.24	-131.100			.178	-.258	
68	3425.47	-130.938			.281	-.127	
69	3427.73	-130.924			.236	-.143	
70	3428.33	-131.025			.076	-.274	
71	3425.18	-131.050			-.007	-.327	
72	3427.74	-131.028			-.044	-.332	
73	3428.70	-131.018			-.093	-.349	
74	3431.32	-130.979			-.113	-.335	
75	3429.28	-130.901			-.094	-.281	
76	3429.90	-130.827			-.079	-.231	
77	3430.99	-130.735			-.045	-.161	
78	3433.47	-130.645			-.014	-.092	
79	3434.09	-130.530			.042	.003	

average of 2 readings

resurveyed and averaged
" and new data used
" and averaged

average of 2 readings

average of 2 readings

average of 2 readings

LINE I

STATION ELEVATION SIMPLE BOUGUER GRAVITY
NUMBER (FEET) (MILLIGALS AT 2.3 GM/CC)

EDITING

		RAW	- LINEAR REGIONAL	-PARABOLIC TREND
1	3408.06	-135.003	.037	-.002
2	3406.35	-134.910	.071	-.007
3	3405.40	-134.826	.096	-.019
4	3407.46	-134.760	.104	-.048
5	3410.58	-134.717	.088	-.100
6	3418.38	-134.713	.033	-.189
7	3410.36	-134.610	.077	-.178
8	3417.40	-134.571	.057	-.231
9	3415.09	-134.437	.132	-.187
10	3410.42	-134.339	.172	-.178
11	3413.23	-134.275	.177	-.203
12	3414.08	-134.248	.145	-.263
13	3416.72	-134.200	.134	-.301
14	3418.19	-134.125	.150	-.312
15	3424.07	-134.069	.148	-.340
16	3420.38	-133.973	.185	-.327
17	3424.60	-133.922	.177	-.359
18	3424.00	-133.857	.183	-.375
19	3424.08	-133.795	.166	-.393
20	3425.72	-133.683	.239	-.361
21	3425.69	-133.593	.271	-.349
22	3426.50	-133.460	.345	-.293
23	3427.36	-133.333	.413	-.243
24	3430.44	-133.223	.464	-.208
25	3432.74	-133.075	.553	-.134
26	3432.51	-133.029	.540	-.162
27	3430.86	-132.960	.551	-.165
28	3429.70	-132.892	.560	-.168
29	3435.80	-132.834	.559	-.180
30	3439.12	-132.759	.575	-.175
31	3441.88	-132.648	.627	-.132
32	3447.44	-132.579	.638	-.130
33	3453.40	-132.508	.650	-.126
34	3459.34	-132.418	.681	-.101
35	3463.03	-132.278	.762	-.025
36	3469.54	-132.227	.754	-.038
37	3471.74	-132.158	.764	-.031
38	3472.59	-132.060	.804	.006
39	3470.07	-131.983	.822	.022
40	3471.57	-131.969	.777	-.023
41	3472.15	-131.901	.786	-.013
42	3472.27	-131.842	.786	-.012
43	3470.54	-131.816	.754	-.042
44	3470.23	-131.829	.682	-.110
45	3466.03	-131.765	.687	-.101
46	3463.39	-131.753	.640	-.142
47	3461.15	-131.751	.583	-.192
48	3455.16	-131.695	.580	-.188
49	3451.21	-131.654	.563	-.197
50	3444.93	-131.611	.547	-.203
51	3443.55	-131.570	.529	-.211
52	3442.86	-131.506	.534	-.194
53	3437.29	-131.409	.572	-.143
54	3433.64	-131.421	.502	-.200
55	3431.50	-131.489	.375	-.313
56	3430.28	-131.381	.424	-.248
57	3429.84	-131.340	.406	-.249
58	3427.84	-131.176	.511	-.127
59	3426.87	-131.173	.455	-.164
60	3428.24	-131.167	.403	-.197
61	3427.09	-131.140	.371	-.209
62	3426.90	-130.947	.505	-.053
63	3432.59	-130.920	.473	-.062
64	3428.53	-130.941	.353	-.119
65	3430.47	-130.829	.447	-.041
66	3429.54	-130.798	.419	-.043
67	3431.95	-130.828	.330	-.106
68	3431.98	-130.820	.279	-.129
69	3435.59	-130.945	.095	-.284
70	3432.22	-130.936	.045	-.305
71	3436.11	-130.896	.027	-.293
72	3437.53	-130.833	.031	-.257
73	3437.83	-130.731	.074	-.182
74	3439.09	-130.720	.026	-.196
75	3439.04	-130.740	-.053	-.240
76	3439.59	-130.698	-.070	-.222
77	3438.33	-130.645	-.075	-.191
78	3440.16	-130.662	-.151	-.229
79	3439.34	-130.551	-.099	-.138

average of 2 readings

average of 2 readings

average of 2 readings

average of 2 readings

LINE J

SIMPLE BOUGUER GRAVITY
STATION ELEVATION (MILLIGALS AT 2.3 GM/CC)
NUMEER (FEET) RAW

EDITING

			- LINEAR REGIONAL	-PARABOLIC TREND
97	3410.54	-135.230	-.134	-.052
98	3411.06	-135.106	-.068	-.028
99	3416.30	-134.986	-.007	-.007
1	3417.92	-134.891	.029	-.011
2	3417.84	-134.819	.042	-.036
3	3419.58	-134.749	.053	-.062
4	3416.81	-134.631	.113	-.039
5	3415.91	-134.600	.085	-.103
6	3420.07	-134.546	.080	-.142
7	3420.73	-134.437	.130	-.125
8	3419.47	-134.318	.190	-.098
9	3420.87	-134.247	.202	-.117
10	3421.68	-134.169	.222	-.128
11	3422.83	-134.067	.265	-.115
12	3426.45	-134.140	.133	-.275
13	3426.31	-134.073	.141	-.294
14	3429.15	-133.996	.159	-.303
15	3430.48	-133.959	.138	-.350
16	3432.43	-133.886	.152	-.360
17	3433.64	-133.786	.193	-.343
18	3433.01	-133.674	.246	-.312
19	3434.24	-133.608	.253	-.326
20	3435.66	-133.602	.200	-.400
21	3436.24	-133.494	.250	-.370
22	3439.16	-133.391	.294	-.344
23	3441.46	-133.315	.311	-.345
24	3446.50	-133.141	.426	-.246
25	3447.26	-133.070	.438	-.249
26	3450.04	-132.978	.471	-.231
27	3448.71	-132.867	.524	-.192
28	3446.79	-132.835	.497	-.231
29	3444.33	-132.720	.553	-.186
30	3446.41	-132.670	.544	-.206
31	3446.53	-132.592	.563	-.196
32	3451.94	-132.540	.557	-.211
33	3454.63	-132.430	.608	-.168
34	3458.73	-132.375	.604	-.178
35	3465.74	-132.296	.624	-.163
36	3472.40	-132.187	.674	-.118
37	3477.77	-132.039	.763	-.032
38	3477.95	-131.951	.793	-.005
39	3476.43	-131.903	.782	-.018
40	3473.04	-131.866	.760	-.040
41	3468.59	-131.860	.707	-.092
42	3462.92	-131.830	.678	-.120
43	3459.42	-131.860	.590	-.206
44	3460.71	-131.780	.611	-.181
45	3454.72	-131.804	.528	-.260
46	3453.41	-131.820	.453	-.329
47	3451.46	-131.803	.411	-.364
48	3447.64	-131.807	.348	-.420
49	3447.59	-131.759	.338	-.422
50	3444.98	-131.664	.374	-.376
51	3442.29	-131.604	.375	-.365
52	3439.68	-131.527	.393	-.335
53	3436.23	-131.484	.377	-.338
54	3439.35	-131.448	.355	-.347
55	3437.82	-131.456	.288	-.400
56	3436.90	-131.509	.176	-.496
57	3433.28	-131.520	.106	-.549
58	3432.74	-131.487	.080	-.558
59	3435.05	-131.387	.121	-.498
60	3432.86	-131.108	.342	-.258
61	3430.69	-130.920	.471	-.109
62	3433.17	-130.802	.530	-.028
63	3434.88	-130.748	.525	-.010
64	3435.87	-130.759	.455	-.057
65	3439.22	-130.791	.365	-.123
66	3440.97	-130.836	.261	-.201
67	3436.92	-130.839	.199	-.237
68	3438.21	-130.822	.157	-.251
69	3438.74	-130.910	.010	-.369
70	3439.36	-130.895	-.034	-.384
71	3439.75	-130.836	-.033	-.353
72	3440.33	-130.689	.055	-.233
73	3444.19	-130.545	.140	-.116
74	3446.29	-130.391	.235	-.013
75	3448.84	-130.385	.182	-.005
76	3447.12	-130.419	.089	-.063
77	3446.83	-130.438	.012	-.104
78	3453.23	-130.527	-.136	-.214
79	3449.03	-130.473	-.141	-.180

resurveyed and
new data used

average of 2 readings

average of 2 readings

average of 2 readings

average of 2 readings

average of 2 readings

LINE JK

STATION ELEVATION SIMPLE BOUGUER GRAVITY
 NUPEER (FEET) (MILLIGALS AT 2.3 GM/CC)

		RAW	- LINEAR REGIONAL	-PARABOLIC TREND
--	--	-----	----------------------	---------------------

EDITING

96	3411.17	-135.230	-.115	.010
97	3411.50	-135.127	-.071	.011
98	3415.93	-134.997	.001	.041
99	3420.00	-134.912	.027	.027
1	3421.65	-134.784	.096	.056
2	3423.27	-134.765	.056	-.022
3	3422.91	-134.671	.091	-.024
4	3425.41	-134.599	.105	-.047
5	3422.07	-134.539	.106	-.082
6	3426.20	-134.528	.058	-.164
7	3424.16	-134.381	.146	-.109
8	3424.81	-134.302	.166	-.122
9	3426.12	-134.210	.199	-.120
10	3425.09	-134.125	.226	-.124

LINE KJ

		SIMPLE BOUGUER GRAVITY (MILLIGALS AT 2.3 GM/CC)			
STATION NUMER	ELEVATION (FEET)	RAW	- LINEAR REGIONAL	-PARABOLIC TREND	EDITING
97	3413.12	-134.989	.027	.109	
98	3419.93	-134.965	-.007	.033	
99	3424.93	-134.831	.062	.068	
1	3431.79	-134.750	.090	.050	
2	3430.36	-134.682	.099	.021	
6	3437.66	#####	###	###	
7	3430.89	#####	###	###	
8	3428.27	#####	###	###	
9	3430.30	#####	###	###	
10	3432.85	#####	###	###	
8	3431.01	-134.228	.200	-.088	
9	3432.98	-134.107	.262	-.057	
10	3433.71	-134.062	.249	-.101	

↑ bad data
↓

LINE K		SIMPLE BOUGUER GRAVITY				
STATION	ELEVATION	(MILLIGALS AT 2.3 GM/CC)				
NUMER	(FEET)	RAW	- LINEAR	-PARABOLIC	EDITING	
			REGIONAL	TRENC		
95	3418.52	-135.114	-.020	.148		
96	3419.10	-135.061	-.026	.099		
97	3422.54	-134.983	-.007	.075		
98	3426.74	-134.851	.067	.107		
99	3430.97	-134.725	.134	.134		
1	3438.32	-134.715	.065	.045		
2	3436.08	-134.645	.096	.018		
3	3438.51	-134.575	.107	-.008		
4	3436.37	-134.496	.128	-.024		
5	3435.13	-134.480	.085	-.103		
6	3436.40	-134.397	.109	-.113		
7	3434.76	-134.320	.127	-.128		
8	3438.38	-134.191	.157	-.091		
9	3439.53	-134.090	.239	-.080		
10	3441.78	-134.034	.237	-.113		
11	3441.36	-133.928	.284	-.096		
12	3442.21	-133.809	.344	-.064		
13	3443.60	-133.750	.344	-.091		
14	3444.22	-133.700	.335	-.127		
15	3446.57	-133.629	.348	-.140		
16	3445.27	-133.498	.420	-.092		
17	3445.07	-133.444	.415	-.121		
18	3446.62	-133.373	.427	-.131		
19	3446.05	-133.355	.386	-.193		
20	3448.09	-133.329	.353	-.247		
21	3446.96	-133.258	.366	-.254		
22	3450.23	-133.244	.321	-.317		
23	3450.64	-133.117	.389	-.267		
24	3453.00	-133.002	.445	-.227		
25	3458.81	-132.938	.450	-.237		
26	3460.69	-132.844	.485	-.217		
27	3463.18	-132.759	.512	-.204		
28	3465.15	-132.674	.538	-.190		
29	3461.70	-132.625	.528	-.211		
30	3458.65	-132.516	.578	-.172		
31	3461.10	-132.450	.585	-.174		
32	3462.48	-132.352	.625	-.143		
33	3464.23	-132.240	.678	-.098		
34	3465.54	-132.192	.667	-.115		
35	3468.04	-132.135	.665	-.122		
36	3469.95	-132.058	.683	-.109		
37	3472.54	-131.949	.733	-.062		
38	3474.53	-131.892	.732	-.066		
39	3472.26	-131.838	.727	-.073		
40	3469.81	-131.822	.684	-.116		
41	3471.50	-131.820	.627	-.172		
42	3464.03	-131.740	.648	-.158		
43	3462.78	-131.690	.640	-.156		
44	3457.42	-131.626	.645	-.147		
45	3455.36	-131.621	.591	-.197		
46	3453.54	-131.618	.535	-.247		
47	3447.64	-131.557	.537	-.238		
48	3446.23	-131.553	.482	-.286		
49	3447.95	-131.573	.404	-.356		
50	3446.82	-131.560	.358	-.392		
51	3440.41	-131.471	.388	-.352		
52	3441.33	-131.434	.366	-.362		
53	3441.51	-131.493	.248	-.467		
54	3439.55	-131.786	-.103	-.805		
55	3436.98	-131.641	-.017	-.705		
56	3436.28	-131.266	.299	-.373		
57	3437.26	-131.221	.285	-.370		
58	3438.59	-131.266	.181	-.457		
59	3435.26	-131.099	.289	-.330		
60	3438.37	-130.965	.365	-.235		
61	3435.01	-130.857	.414	-.166		
62	3443.63	-130.802	.410	-.148		
63	3444.32	-130.774	.379	-.156		
64	3442.13	-130.716	.378	-.134		
65	3443.45	-130.680	.356	-.132		
66	3447.66	-130.697	.280	-.182		
67	3446.84	-130.722	.196	-.240		
68	3444.58	-130.844	.015	-.393		
69	3447.85	-130.901	-.101	-.480		
70	3449.79	-130.883	-.142	-.492		
71	3452.67	-130.853	-.170	-.490		

resurveyed and
new data used

average of 2 readings

average of 2 readings

average of 2 readings

resurveyed and
new data used

average of 2 readings

average of 2 readings

average of 2 readings

average of 2 readings

72	3455.99	-130.776	-.152	-.440
73	3453.94	-130.596	-.031	-.287
74	3451.98	-130.321	.165	-.037
75	3452.73	-130.153	.294	.107
76	3455.85	-130.168	.220	.068
77	3454.30	-130.334	-.004	-.120
78	3457.58	-130.410	-.139	-.217
79	3453.62	-130.329	-.117	-.156

average of 2 readings

LINE KL

STATION NUMBER	ELEVATION (FEET)	SIMPLE BOUGUER GRAVITY (MILLIGALS AT 2.3 GM/CC)		
		RAW	- LINEAR REGIONAL	-PARABOLIC TREND

EDITING

97	3430.37	-134.948	-.012	.070
98	3432.30	-134.850	.028	.068
99	3438.14	-134.772	.047	.047
1	3440.58	-134.664	.096	.056
2	3443.28	-134.626	.075	-.003
3	3445.57	-134.527	.115	-.000
4	3441.50	-134.515	.069	-.083
5	3440.81	-134.441	.084	-.104
6	3440.54	-134.314	.152	-.070
7	3441.05	-134.273	.134	-.121
8	3444.67	-134.145	.203	-.085
9	3448.82	-134.075	.214	-.105
10	3448.06	-133.967	.264	-.086

LINE LK

STATION ELEVATION SIMPLE BOUGUER GRAVITY
 NUMBER (FEET) (MILLIGALS AT 2.3 GM/CC)

RAW - LINEAR -PARABOLIC
 REGIONAL TREND

EDITING

97	3432.64	-134.871	.025	.107
98	3436.10	-134.777	.061	.101
99	3440.40	-134.620	.159	.159
1	3447.53	-134.602	.118	.078
2	3449.76	-134.518	.143	.065
3	3452.92	-134.474	.128	.013
4	3449.38	-134.441	.103	-.049
5	3448.51	-134.373	.112	-.076
6	3447.73	-134.231	.195	-.027
7	3447.96	-134.183	.184	-.071
8	3450.56	-134.088	.220	-.068
9	3453.77	-134.032	.217	-.102
10	3454.86	-133.939	.252	-.098

average of 2 close stations

average of 2 close stations

LINE L STATION NUMBER	ELEVATION (FEET)	SIMPLE BOUGUER GRAVITY (MILLIGALS AT 2.3 GM/CC)				EDITING
		RAW	- LINEAR REGIONAL	-PARABOLIC TREND		
97	3437.99	-134.757	.099	.181	↑ resurveyed and new data used	
98	3443.01	-134.700	.098	.138		
99	3449.90	-134.635	.104	.104		
1	3454.00	-134.538	.092	.052		
2	3457.76	-134.502	.119	.041		
3	3459.06	-134.463	.099	-.016		
4	3457.01	-134.419	.085	-.067		
5	3455.56	-134.352	.093	-.095		
6	3453.02	-134.211	.175	-.047		
7	3454.80	-134.077	.250	-.005		
8	3457.97	-133.982	.286	-.002	↓	
9	3461.44	-133.935	.274	-.045		
10	3465.13	-133.865	.286	-.064		
11	3469.32	-133.752	.340	-.040		
12	3465.69	-133.679	.354	-.054		
13	3462.03	-133.610	.364	-.071		
14	3461.38	-133.566	.349	-.113		
15	3458.51	-133.463	.394	-.094		
16	3460.75	-133.373	.425	-.087		
17	3459.91	-133.287	.452	-.084		
18	3461.47	-133.239	.441	-.117	average of 2 stations	
19	3465.08	-133.200	.421	-.158		
20	3464.78	-133.139	.423	-.177		
21	3462.96	-133.075	.429	-.191		
22	3463.01	-133.036	.409	-.229		
23	3464.55	-132.964	.422	-.234		
24	3465.73	-132.837	.490	-.182		
25	3470.21	-132.771	.497	-.190		
26	3472.73	-132.669	.540	-.162		
27	3475.94	-132.572	.579	-.137		
28	3474.09	-132.459	.633	-.095	average of 2 stations	
29	3472.11	-132.369	.664	-.075		
30	3473.43	-132.317	.657	-.093		
31	3475.98	-132.238	.677	-.082		
32	3479.91	-132.135	.722	-.046		
33	3481.97	-132.084	.714	-.062		
34	3481.39	-132.019	.720	-.062		
35	3482.66	-131.983	.697	-.090		
36	3480.39	-131.885	.736	-.056		
37	3481.82	-131.838	.724	-.071	average of 2 stations	
38	3476.16	-131.759	.745	-.053		
39	3479.20	-131.772	.673	-.127		
40	3475.64	-131.714	.672	-.128		
41	3475.29	-131.681	.646	-.153		
42	3474.82	-131.651	.617	-.181		
43	3474.56	-131.627	.583	-.213		
44	3468.11	-131.561	.590	-.202		
45	3460.18	-131.532	.560	-.228		
46	3454.99	-131.487	.546	-.236	average of 2 stations	
47	3450.33	-131.447	.527	-.248		
48	3447.50	-131.404	.511	-.257		
49	3447.17	-131.394	.463	-.297		
50	3446.33	-131.416	.382	-.368		
51	3447.26	-131.399	.340	-.400		
52	3444.82	-131.345	.335	-.393		
53	3447.33	-131.484	.137	-.578		
54	3446.64	-131.628	-.065	-.767		
55	3446.87	-131.621	-.117	-.805	average of 2 stations	
56	3446.28	-131.244	.201	-.471		
57	3441.14	-131.042	.344	-.311		
58	3435.38	-130.893	.434	-.204		
59	3438.75	-130.821	.447	-.172		
60	3441.59	-130.751	.459	-.141		
61	3443.08	-130.692	.459	-.121		
62	3448.09	-130.700	.392	-.166		
63	3452.40	-130.676	.357	-.178		
64	3451.36	-130.621	.353	-.159	average of 2 stations	
65	3449.97	-130.543	.373	-.115		
66	3451.63	-130.563	.294	-.168		
67	3454.92	-130.585	.213	-.223		
68	3455.90	-130.571	.168	-.240		
69	3452.73	-130.543	.137	-.242		
70	3457.13	-130.627	-.006	-.356		
71	3459.31	-130.779	-.216	-.536		
72	3461.21	-130.752	-.248	-.536		
73	3466.42	-130.678	-.233	-.489	average of 2 stations	
74	3458.37	-130.490	-.104	-.326		
75	3460.40	-130.203	.124	-.063		
76	3458.58	-130.012	.256	.104		
77	3459.42	-129.986	.224	.108		
78	3454.64	-129.925	.226	.148		
79	3456.87	-129.936	.156	.117		

LINE LM

SIMPLE BOUGUER GRAVITY
(MILLIGALS AT 2.3 GM/CC)

STATION NUMER	ELEVATION (FEET)	RAW	- LINEAR REGIONAL	-PARABOLIC TREND
------------------	---------------------	-----	----------------------	---------------------

EDITING

(these are close-spaced stations)

971	3447.66	-134.788	.028	.110
972	3450.25	-134.786	.011	.079
973	3448.91	-134.723	.054	.108
2	3451.29	#####	#####	#####
982	3453.07	-134.691	.047	.074
983	3454.30	-134.652	.066	.080
991	3456.52	-134.650	.049	.049
992	3457.86	-134.613	.066	.053
993	3459.11	-134.586	.074	.047
11	3461.64	-134.579	.061	.021
12	3465.52	-134.531	.089	.037
13	3468.07	-134.503	.098	.032
21	3467.11	-134.470	.111	.033
22	3466.24	-134.425	.137	.046
23	3463.38	-134.376	.166	.063
31	3463.37	-134.414	.108	-.007
32	3460.63	-134.382	.121	-.007
33	3460.68	-134.378	.105	-.035
41	3464.14	-134.360	.103	-.048
42	3463.21	-134.313	.131	-.033
43	3463.98	-134.310	.114	-.061
51	3463.90	-134.276	.129	-.059
52	3463.35	-134.245	.140	-.059
53	3463.04	-134.176	.189	-.021
61	3462.01	-134.145	.201	-.021
62	3463.74	-134.124	.202	-.031
63	3463.91	-134.088	.219	-.026
71	3464.46	-134.086	.201	-.054
72	3465.06	-134.040	.227	-.039
73	3465.33	-133.990	.258	-.019
81	3467.29	-134.011	.217	-.071
82	3466.52	-133.962	.247	-.052
83	3468.28	-133.919	.270	-.039
91	3469.70	-133.888	.281	-.038
92	3473.42	-133.856	.294	-.036
93	3474.55	-133.825	.305	-.035
101	3475.46	-133.803	.307	-.042

bad data

LINE ML

STATION ELEVATION SIMPLE BOUGUER GRAVITY
 NUPEER (FEET) (MILLIGALS AT 2.3 GM/CC)

		RAW	- LINEAR REGIONAL	-PARABOLIC TREND
--	--	-----	----------------------	---------------------

EDITING

97	3452.48	-134.698	.078	.160
98	3460.06	-134.626	.092	.132
99	3466.28	-134.582	.077	.077
1	3474.28	-134.514	.086	.046
2	3471.22	-134.465	.076	-.002
3	3465.25	-134.351	.131	.016
4	3470.56	-134.277	.147	-.005
5	3475.64	-134.223	.142	-.046
6	3474.21	-134.107	.199	-.023
7	3477.17	-134.046	.201	-.054
8	3480.02	-133.944	.244	-.044
9	3479.36	-133.852	.277	-.042
10	3479.69	-133.778	.293	-.057

LINE STATION NUMBER	M ELEVATION (FEET)	SIMPLE BOUGUER GRAVITY (MILLIGALS AT 2.3 GM/CC) RAW	- LINEAR REGIONAL	-PARABOLIC TREND	EDITING
97	3457.82	-134.697	.039	.121	
98	3463.88	-134.586	.092	.132	
99	3477.65	-134.548	.071	.071	
1	3482.17	-134.510	.050	.010	
2	3477.34	-134.421	.080	.002	
3	3467.32	-134.356	.086	-.029	
4	3469.32	-134.254	.130	-.022	
5	3471.42	-134.153	.172	-.016	
6	3474.98	-134.059	.207	-.015	
7	3476.36	-134.007	.200	-.055	
8	3477.64	-133.910	.238	-.050	
9	3476.24	-133.809	.280	-.039	
10	3479.46	-133.669	.362	.012	
11	3480.56	-133.594	.378	-.002	
12	3479.14	-133.498	.415	.007	
13	3481.48	-133.429	.425	-.010	
14	3482.26	-133.370	.425	-.037	
18	3483.05	#####	####	####	
16	3480.48	-133.215	.463	-.049	
17	3481.27	-133.149	.470	-.066	
18	3483.60	-133.089	.471	-.087	
19	3483.42	-133.014	.487	-.092	
20	3482.47	-132.956	.486	-.114	
21	3480.40	-132.844	.540	-.080	
22	3479.95	-132.799	.526	-.112	
23	3480.19	-132.714	.552	-.104	
24	3482.54	-132.633	.574	-.098	
25	3483.06	-132.523	.625	-.062	
26	3486.27	-132.462	.627	-.075	
27	3485.92	-132.345	.686	-.030	
28	3486.48	-132.279	.693	-.035	
29	3486.68	-132.204	.709	-.030	
30	3489.10	-132.129	.725	-.025	
31	3492.20	-132.037	.758	-.001	
32	3493.41	-131.960	.777	.009	
33	3495.42	-131.880	.798	.022	
34	3497.55	-131.835	.784	.002	
35	3495.20	-131.777	.783	-.004	
36	3490.42	-131.757	.744	-.048	
37	3484.67	-131.716	.726	-.069	
38	3481.23	-131.671	.713	-.085	
39	3483.62	-131.636	.689	-.111	
40	3490.63	-131.645	.621	-.179	
41	3494.57	-131.633	.574	-.225	
42	3485.77	-131.599	.549	-.249	
43	3479.50	-131.532	.558	-.238	
44	3472.50	-131.478	.553	-.239	
45	3468.07	-131.449	.523	-.265	
46	3463.02	-131.369	.544	-.238	
47	3457.28	-131.332	.522	-.253	
48	3455.75	-131.313	.482	-.286	
49	3451.93	-131.267	.470	-.290	
50	3451.32	-131.203	.475	-.275	
51	3450.96	-131.136	.483	-.257	
52	3449.11	-131.109	.451	-.277	
53	3449.82	-131.191	.310	-.405	
54	3451.61	-131.442	.001	-.701	
55	3450.74	-131.454	-.070	-.758	
56	3448.67	-131.306	.019	-.653	
57	3449.06	-130.948	.318	-.337	
58	3447.60	-130.806	.401	-.237	
59	3449.31	-130.729	.419	-.200	
60	3453.89	-130.705	.385	-.215	
61	3455.50	-130.696	.335	-.245	
62	3455.80	-130.663	.309	-.249	
63	3460.08	-130.604	.309	-.226	
64	3462.00	-130.570	.284	-.228	
65	3459.66	-130.454	.342	-.146	
66	3459.64	-130.434	.303	-.159	
67	3462.36	-130.390	.288	-.148	
68	3463.93	-130.359	.260	-.148	
69	3467.42	-130.353	.207	-.172	
70	3466.99	-130.365	.136	-.214	
71	3470.90	-130.604	-.161	-.481	
72	3472.66	-130.654	-.270	-.558	
73	3469.88	-130.523	-.198	-.454	
74	3470.10	-130.385	-.119	-.361	
75	3470.42	-130.048	.159	-.028	
76	3471.26	-129.924	.224	.072	
77	3473.94	-129.983	.107	-.009	
78	3470.46	-129.986	.045	-.033	
79	3470.99	-130.002	-.030	-.069	

resurveyed and
new data used

bad data

average of 2 readings
average of 2 readings

average of 2 readings

average of 2 readings

average of 2 readings

LINE MN

STATION ELEVATION SIMPLE BOUGUER GRAVITY
 NUMEER (FEET) (MILLIGALS AT 2.3 GM/CC)

		RAW	- LINEAR REGIONAL	-PARABOLIC TRENC
--	--	-----	----------------------	---------------------

EDITING

97	3467.05	-134.691	.005	.087
98	3472.02	-134.528	.110	.150
99	3482.87	-134.484	.095	.095
1	3476.24	-134.408	.112	.072
2	3474.28	-134.340	.121	.043
3	3469.79	-134.295	.107	-.008
4	3468.91	-134.214	.130	-.022
5	3471.05	-134.082	.203	.015
6	3474.32	-133.989	.237	.015
7	3476.23	-133.941	.226	-.029
8	3478.24	-133.893	.215	-.073
9	3475.42	-133.771	.278	-.041
10	3478.23	-133.727	.264	-.086

LINE NM

STATION NUMBER	ELEVATION (FEET)	SIMPLE BOUGUER GRAVITY (MILLIGALS AT 2.3 GM/CC)		
		RAW	- LINEAR REGIONAL	-PARABOLIC TREND
97	3466.44	-134.585	.071	.153
98	3471.03	-134.495	.103	.143
99	3472.82	-134.433	.106	.106
1	3471.02	-134.388	.092	.052
2	3471.12	-134.346	.075	-.003
3	3468.50	-134.272	.090	-.025
4	3467.12	-134.202	.102	-.050
5	3470.88	-134.102	.143	-.045
6	3473.17	-133.951	.235	.013
7	3475.04	-133.914	.213	-.042
8	3475.34	-133.855	.213	-.075
9	3472.17	-133.761	.248	-.071
10	3475.67	-133.717	.234	-.116

EDITING

LINE N

STATION ELEVATION SIMPLE BOUGUER GRAVITY
 NUMEER (FEET) (MILLIGALS AT 2.3 GM/CC)

		RAW	- LINEAR REGIONAL	-PARABOLIC TREND
--	--	-----	----------------------	---------------------

EDITING

97	3460.22	-134.644	-.028	.054
98	3460.53	-134.499	.059	.099
99	3460.40	-134.409	.090	.090
1	3463.10	-134.387	.053	.013
2	3462.36	-134.238	.143	.065
3	3465.40	-134.226	.096	-.019
4	3463.26	-134.149	.115	-.037
5	3466.28	-133.986	.219	.031
6	3469.00	-133.896	.250	.028
7	3470.44	-133.855	.232	-.023
8	3472.71	-133.803	.225	-.063
9	3472.67	-133.694	.275	-.044
10	3473.21	-133.621	.290	-.060

APPENDIX B

Gravity Data Over the WIPP 14 Anomaly

Station Number	Elevation (feet)	Simple Bouguer Gravity		Editing
		Raw	-Linear Regional	
XA 1	3440	-131.465	0.357	
2	3439	.451	.361	
3	3439	.454	.348	
4	3438	.440	.352	
5	3436	.437	.345	
6	3436	.422	.351	
7	3438	.448	.315	
8	3438	.461	.292	
9	3440	.495	.248	
10	3440	.461	.272	
11	3437	.434	.290	
12	3435	.428	.286	
13	3433	.439	.265	
14	3432	.465	.229	
15	3432	.527	.157	
16	3434	.617	.058	
17	3436	.654	.011	
18	3437	.664	-.009	
19	3436	.648	-.003	
20	3436	.644	-.009	
21	3435	.624	.001	
22	3435	.621	-.005	
23	3434	.556	.050	
24	3434	.537	.059	
25	3435	.534	.052	
XC 1	3440	-131.470	0.333	
3	3440	.450	.339	
5	3440	.466	.303	
7	3436	.439	.310	
9	3436	.477	.253	
11	3433	.443	.267	
13	3430	.486	.205	
15	3430	.589	.082	

Station Number	Elevation (feet)	Simple Bouguer Gravity		Editing
		Raw	-Linear Regional	
17	3435	.668	-.017	
19	3437	.657	-.025	
21	3435	.594	.018	
23	3437	.473	.120	
25	3436	.478	.095	
XE 1	3441	-131.462	0.333	
3	3442	.481	.294	
5	3436	.445	.311	
7	3433	.463	.273	
9	3431	.516	.200	
11	3428	.570	.127	
13	3427	.606	.071	
15	3428	.651	.007	
17	3432	.636	.002	
19	3438	.636	-.018	
21	3436	.550	.049	
23	3436	.449	.130	
25	3435	.376	.184	
XG54	3438	-131.450	0.381	
53	-	-	-	No data this station
52	3441	.312	.499	
51	3441	.459	.342	
50	3442	.459	.332	
1	3440	.495	.287	
2	3438	.463	.309	
3	3437	.460	.302	
4	3436	.464	.288	
5	3436	.487	.255	
6	3434	.495	.238	
7	3434	.563	.160	
8	3431	.584	.129	
9	3430	.611	.092	

Station Number	Elevation (feet)	Simple Bouguer Gravity		Editing
		Raw	-Linear Regional	
10	3428	.649	.044	
11	3428	.650	.034	
12	3427	.669	.005	
13	3427	.666	-.002	
14	3427	.673	-.019	
15	3427	.668	-.024	
16	3428	.633	.002	
17	3431	.625	.000	
18	3437	.629	-.014	
19	3439	.599	.006	
20	3439	.544	.051	
XG21	3438	.474	.111	
22	3435	.398	.178	
23	3436	.357	.209	
24	3436	.322	.234	
25	3435	.301	.245	
26	3435	.293	.243	
27	3435	.300	.227	
28	3435	.310	.207	
29	3434	.312	.195	
30	3436	.363	.135	
XI 1	3441	-131.477	0.305	
3	3438	.505	.257	
5	3437	.581	.161	
7	3434	.651	.072	
9	3431	.682	.021	
11	3429	.679	.005	
13	3428	.694	-.030	
15	3427	.628	.016	
17	3432	.574	.051	
19	3437	.505	.100	
21	3438	.367	.218	

Station Number	Elevation (feet)	Simple Bouguer Gravity		Editing
		Raw	-Linear Regional	
23	3436	.287	.279	
25	3436	.269	.277	
XK 1	3440	-131.511	0.257	
3	3440	.615	.134	
5	3438	.700	.029	
7	3437	.745	-.036	
9	3434	.757	-.067	
11	3431	.717	-.047	
13	3431	.665	-.014	
15	3431	.569	.062	
17	3433	.469	.142	
19	3437	.366	.226	
21	3438	.291	.281	
23	3437	.252	.301	
25	3436	.250	.283	
XM 1	3439	-131.576	0.179	
3	3440	.717	.018	
5	3439	.781	-.065	
7	3439	.820	-.124	
9	3438	.802	-.126	
11	3434	.722	-.065	
13	3433	.548	.089	
15	3434	.429	.189	
17	3435	.324	.274	
19	3437	.255	.323	
21	3437	.255	.304	
23	3438	.417	.122	
25	3435	.382	.138	
XO 1	3438	-131.545	0.197	
3	3439	.676	.046	
5	3440	.755	-.053	
7	3439	.796	-.113	

Station Number	Elevation (feet)	Simple Bouguer Gravity		Editing
		Raw	-Linear Regional	
9	3438	-	-	anomalous point
11	3437	.689	-.045	
13	3438	.509	.115	
15	3437	.353	.251	
17	3436	.282	.303	
19	3436	.226	.339	
21	3436	.201	.344	
23	3438	.217	.309	
25	3438	.253	.253	
XX 8	3435	-131.353	0.431	
XX 7	3434	.345	.432	
XX 6	3435	.353	.417	
XX 5	3438	.394	.370	
XX 4	3437	.387	.370	
XX 3	3438	.414	.336	
J 55	3438	.441	.303	
XX 2	3438	.438	.299	
XX 1	3439	.447	.283	
XAl1	3437	.434	.290	
XB11	3436	.446	.271	
XC11	3433	.443	.267	
XD11	3430	.490	.214	
XE11	3428	.570	.127	
XF11	3428	.614	.076	
XG11	3428	.650	.034	
XH11	3428	.702	-.025	
XI11	3429	.679	-.009	
XJ11	3431	.734	-.070	
XK11	3431	.717	-.060	
XL11	3435	.745	-.095	
XM11	3434	.722	-.078	
XN11	3435	.711	-.074	
XO11	3437	.689	-.059	

Station Number	Elevation (feet)	Simple Bouguer Gravity			Editing
		Raw	-Linear	Regional	
K 55	3437	-131.647		-.023	
Q 11	3437	.633		-.016	
R 11	3438	.622		-.012	
S 11	3439	.617		-.013	
T 11	3439	.591		.006	
U 11	3439	.575		.015	
V 11	3440	.580		.004	
W 11	3441	.572		.005	
X 11	3441	.573		-.003	
Y 11	3441	.596		-.032	
Z 11	3441	.619		-.062

APPENDIX C

**Gravity Data Along Reconnaissance Profiles Near
WIPP 33**

STATION ID	LATITUDE N 32 DEG (min)	LONGITUDE W 103 DEG (min)	ELEVATION (ft)	GRAVITY (ms)	REGIONAL (ms)	REDUCED GRAVITY (ms)
----	-----	-----	-----	-----	-----	-----
C100	22.7209	49.517	3387.22	-133.859	-134.335	0.476
C101	22.7538	49.517	3385.90	-133.814	-134.294	0.480
C102	22.7866	49.517	3384.07	-133.793	-134.254	0.461
C103	22.8195	49.517	3383.23	-133.789	-134.214	0.425
C104	22.8524	49.517	3382.29	-133.776	-134.174	0.398
C105	22.8854	49.517	3381.33	-133.787	-134.134	0.347
C106	22.9182	49.517	3379.35	-133.776	-134.094	0.318
C107	22.9511	49.517	3378.32	-133.704	-134.053	0.349
C108	22.9840	49.517	3377.34	-133.688	-134.013	0.325
C109	23.0169	49.517	3376.14	-133.693	-133.973	0.280
C110	23.0498	49.517	3375.02	-133.660	-133.933	0.273
C111	23.0827	49.517	3372.09	-133.593	-133.893	0.300
C112	23.1155	49.517	3370.37	-133.574	-133.853	0.279
C113	23.1485	49.517	3369.02	-133.539	-133.812	0.273
C114	23.1814	49.517	3368.17	-133.493	-133.772	0.279
C115	23.2143	49.517	3365.88	-133.465	-133.732	0.267
C116	23.2473	49.517	3366.11	-133.465	-133.692	0.227
C117	23.2801	49.517	3364.40	-133.521	-133.652	0.131
C118	23.3130	49.517	3363.80	-133.551	-133.611	0.060
C119	23.3459	49.517	3364.31	-133.590	-133.571	-0.019
C120	23.3788	49.517	3364.66	-133.605	-133.531	-0.074
C121	23.4117	49.517	3359.23	-133.576	-133.491	-0.085
C122	23.4446	49.517	3353.76	-133.557	-133.451	-0.106
C123	23.4775	49.517	3351.79	-133.554	-133.410	-0.144
C124	23.5104	49.517	3349.96	-133.550	-133.370	-0.180
C125	23.5433	49.517	3349.94	-133.544	-133.330	-0.214
C126	23.5762	49.517	3348.91	-133.491	-133.290	-0.201
C127	23.6091	49.517	3347.06	-133.464	-133.250	-0.214
C128	23.6420	49.517	3345.86	-133.463	-133.210	-0.253
C129	23.6748	49.517	3345.67	-133.435	-133.169	-0.266
C130	23.7077	49.517	3346.80	-133.421	-133.129	-0.292
C131	23.7406	49.517	3348.58	-133.430	-133.089	-0.341
C132	23.7735	49.517	3345.14	-133.388	-133.049	-0.339
C133	23.8064	49.517	3341.60	-133.326	-133.009	-0.317
C134	23.8393	49.517	3342.10	-133.263	-132.969	-0.294
C135	23.8722	49.517	3341.77	-133.205	-132.928	-0.277
C136	23.9051	49.517	3343.98	-133.186	-132.888	-0.298
C201	23.9051	49.478	3345.33	-133.116	-132.885	-0.231
C202	23.9051	49.439	3346.76	-133.152	-132.883	-0.269
C203	23.9051	49.400	3347.88	-133.116	-132.880	-0.236
C204	23.9051	49.361	3350.15	-133.198	-132.877	-0.321
C205	23.9051	49.322	3335.04	-133.276	-132.874	-0.402
C206	23.9051	49.283	3352.62	-133.178	-132.872	-0.306
C207	23.9051	49.244	3351.34	-133.124	-132.869	-0.255
C208	23.9051	49.205	3339.16	-133.147	-132.866	-0.256
C211	23.9051	49.556	3339.80	-133.182	-132.891	-0.291
C212	23.9051	49.595	3337.68	-133.230	-132.894	-0.336
C213	23.9051	49.634	3335.19	-133.284	-132.896	-0.388
C214	23.9051	49.673	3336.70	-133.366	-132.899	-0.467
C215	23.9051	49.712	3336.18	-133.424	-132.902	-0.522

STATION ID	LATITUDE N 32 DEG (min)	LONGITUDE W 103 DEG (min)	ELEVATION (ft)	GRAVITY (ms)	REGIONAL (ms)	REDUCED GRAVITY (ms)
----	-----	-----	-----	-----	-----	-----
C216	23.9051	49.751	3335.15	-133.433	-132.905	-0.528
C217	23.9051	49.790	3335.17	-133.437	-132.907	-0.530
C218	23.9051	49.829	3332.94	-133.422	-132.910	-0.512
C219	23.9051	49.867	3332.47	-133.379	-132.913	-0.466
C221	23.0169	49.556	3376.82	-133.729	-133.976	0.247
C222	23.0169	49.595	3377.30	-133.734	-133.979	0.245
C223	23.0169	49.634	3377.08	-133.746	-133.981	0.235
C224	23.0169	49.673	3374.98	-133.763	-133.984	0.221
C225	23.0169	49.712	3374.30	-133.825	-133.987	0.162
C226	23.0169	49.751	3375.01	-133.880	-133.989	0.109
C227	23.0169	49.790	3375.87	-133.857	-133.992	0.135
C228	23.0169	49.828	3378.20	-133.904	-133.995	0.091
C229	23.0169	49.965	3376.36	-133.829	-134.004	0.175
C231	23.9380	49.439	3345.40	-133.136	-132.842	-0.294
C232	23.9709	49.439	3344.79	-133.141	-132.802	-0.339
C233	24.0037	49.439	3344.98	-133.120	-132.762	-0.358
C234	24.0367	49.439	3344.07	-133.063	-132.722	-0.341
C235	24.0696	49.439	3342.87	-132.983	-132.682	-0.301
C236	24.1025	49.439	3344.21	-132.951	-132.642	-0.309
C237	24.1354	49.439	3345.41	-132.945	-132.601	-0.344
C238	24.1682	49.439	3344.77	-132.866	-132.561	-0.305
C239	24.2013	49.439	3343.81	-132.784	-132.521	-0.263
C240	24.2430	49.439	3346.30	-132.821	-132.470	-0.351
C241	23.8722	49.439	3347.22	-133.134	-132.923	-0.211
C242	23.8393	49.439	3346.76	-133.172	-132.963	-0.209
C243	23.8064	49.439	3353.46	-133.288	-133.003	-0.285
C244	23.8393	49.361	3349.33	-133.177	-132.958	-0.219
C250	22.5703	50.026	3375.78	-134.358	-134.554	0.196
C251	22.6331	50.049	3367.21	-134.225	-134.479	0.254
C252	22.6646	50.061	3364.76	-134.183	-134.441	0.258
C253	22.6960	50.072	3368.63	-134.244	-134.404	0.160
C254	22.7275	50.084	3365.95	-134.143	-134.366	0.223
C255	22.7588	50.095	3366.27	-134.105	-134.329	0.224
C256	22.7902	50.107	3366.16	-134.078	-134.291	0.213
C257	22.8217	50.118	3362.54	-134.049	-134.254	0.205
C261	23.4110	49.826	3341.49	-134.172	-133.513	-0.659
C262	23.4439	49.826	3341.28	-134.270	-133.473	-0.797
C263	23.4768	49.826	3337.68	-134.275	-133.433	-0.842
C264	23.5155	49.826	3337.42	-134.160	-133.386	-0.774
C271	23.3452	49.826	3346.19	-133.945	-133.594	-0.351
C272	23.3123	49.826	3350.47	-133.878	-133.634	-0.244
C273	23.2794	49.826	3355.50	-133.828	-133.674	-0.154
C274	23.2465	49.826	3357.40	-133.780	-133.714	-0.066
C275	23.2136	49.826	3360.95	-133.769	-133.754	-0.015
C301	23.3499	49.555	3360.90	-133.634	-133.569	-0.065
C302	23.3540	49.594	3357.11	-133.649	-133.567	-0.082
C303	23.3580	49.633	3351.77	-133.691	-133.565	-0.126
C304	23.3620	49.671	3350.02	-133.761	-133.562	-0.199
C305	23.3661	49.710	3348.03	-133.829	-133.560	-0.269
C306	23.3701	49.749	3344.07	-133.896	-133.558	-0.338

STATION ID	LATITUDE N 32 DEG (min)	LONGITUDE W 103 DEG (min)	ELEVATION (ft)	GRAVITY (ms)	REGIONAL (ms)	REDUCED GRAVITY (ms)
-----	-----	-----	-----	-----	-----	-----
C307	23.3741	49.788	3342.12	-133.982	-133.556	-0.426
C308	23.3781	49.826	3340.26	-134.026	-133.553	-0.473
C310	23.3821	49.865	3338.66	-134.104	-133.551	-0.553
C311	23.3862	49.903	3335.92	-134.122	-133.549	-0.573
C312	23.3902	49.942	3335.51	-134.138	-133.547	-0.591
C313	23.3942	49.981	3335.83	-134.227	-133.545	-0.682
C314	23.3962	50.000	3332.48	-134.275	-133.544	-0.731
C315	23.3982	50.019	3327.20	-134.330	-133.542	-0.788
C316	23.4002	50.039	3323.19	-134.392	-133.541	-0.851
C317	23.4023	50.058	3323.28	-134.391	-133.540	-0.851
C318	23.4043	50.077	3326.98	-134.402	-133.539	-0.863
C319	23.4063	50.097	3332.99	-134.288	-133.538	-0.750
C320	23.4083	50.116	3332.88	-134.216	-133.537	-0.679
C321	23.4103	50.135	3334.12	-134.156	-133.536	-0.620
C322	23.4144	50.174	3334.29	-134.108	-133.534	-0.574
C323	23.4184	50.213	3335.53	-134.061	-133.531	-0.530
C324	23.4224	50.251	3339.22	-134.018	-133.529	-0.489
C325	23.4264	50.290	3339.95	-133.957	-133.527	-0.430
C326	23.4305	50.329	3341.18	-133.987	-133.525	-0.462
C327	23.4345	50.367	3340.81	-133.990	-133.522	-0.468
C328	23.4385	50.406	3343.18	-133.989	-133.520	-0.469
C329	23.4446	50.444	3340.34	-133.966	-133.516	-0.451
C331	23.3419	49.478	3367.91	-133.547	-133.573	0.026
C332	23.3378	49.439	3372.95	-133.511	-133.576	0.065
C333	23.3338	49.401	3375.98	-133.454	-133.578	0.124
C334	23.3298	49.362	3374.40	-133.333	-133.580	0.247
C335	23.3257	49.323	3374.00	-133.266	-133.582	0.316
C336	23.3217	49.285	3374.74	-133.184	-133.585	0.401
C337	23.3176	49.246	3377.20	-133.176	-133.587	0.411
C338	23.3136	49.207	3377.02	-133.130	-133.589	0.459
C401	22.8828	48.958	3397.83	-133.425	-134.098	0.673
C402	22.8731	48.996	3397.40	-133.438	-134.112	0.674
C403	22.8634	49.033	3399.11	-133.495	-134.127	0.632
C404	22.8537	49.070	3397.34	-133.521	-134.141	0.620
C405	22.8440	49.107	3395.87	-133.545	-134.156	0.611
C406	22.8343	49.145	3394.87	-133.589	-134.170	0.581
C407	22.8246	49.182	3394.11	-133.642	-134.185	0.543
C408	22.8194	49.219	3393.41	-133.689	-134.193	0.504
C409	22.8053	49.256	3392.62	-133.704	-134.213	0.509
C410	22.7956	49.294	3392.07	-133.738	-134.228	0.490
C411	22.7859	49.331	3391.57	-133.735	-134.242	0.507
C412	22.7762	49.368	3389.77	-133.776	-134.257	0.481
C413	22.7665	49.405	3388.32	-133.812	-134.271	0.459
C414	22.7568	49.442	3386.42	-133.811	-134.286	0.475
C415	22.7471	49.480	3386.22	-133.805	-134.300	0.495
C416	22.7374	49.517	3387.31	-133.830	-134.314	0.484
C417	22.7277	49.554	3386.52	-133.836	-134.329	0.493
C418	22.7180	49.591	3387.36	-133.884	-134.343	0.459
C419	22.7083	49.628	3386.64	-133.934	-134.358	0.424
C420	22.6986	49.666	3383.44	-133.959	-134.372	0.413

STATION ID	LATITUDE N 32 DEG (min)	LONGITUDE W 103 DEG (min)	ELEVATION (ft)	GRAVITY (ms)	REGIONAL (ms)	REDUCED GRAVITY (ms)
-----	-----	-----	-----	-----	-----	-----
C421	22.6889	49.703	3382.86	-134.014	-134.387	0.373
C422	22.6792	49.740	3383.07	-134.048	-134.401	0.353
C423	22.6695	49.777	3384.64	-134.075	-134.416	0.341
C424	22.6598	49.814	3379.01	-134.069	-134.430	0.361
C425	22.6501	49.852	3377.58	-134.111	-134.445	0.334
C426	22.6406	49.889	3374.14	-134.155	-134.459	0.304
C427	22.6307	49.926	3371.58	-134.167	-134.473	0.306
C428	22.6210	49.963	3369.54	-133.165	-134.488	0.323
C429	22.6113	50.001	3368.05	-133.230	-134.502	0.272
C430	22.6017	50.038	3371.21	-134.298	-134.517	0.219
C431	22.5920	50.075	3372.40	-134.325	-134.531	0.206
C432	22.5823	50.112	3375.94	-134.376	-134.546	0.170
C433	22.5729	50.149	3380.58	-134.479	-134.560	0.081
C434	22.5629	50.187	3382.94	-134.507	-134.575	0.068
C435	22.5532	50.224	3384.78	-134.525	-134.589	0.064
C436	22.5435	50.261	3385.32	-134.633	-134.603	-0.030
C437	22.5338	50.298	3383.64	-134.777	-134.618	-0.159
C438	22.5241	50.336	3380.14	-134.974	-134.632	-0.342
C439	22.5144	50.373	3377.59	-134.913	-134.647	-0.266
C440	22.5047	50.410	3373.43	-134.874	-134.661	-0.213
C441	22.4950	50.447	3370.53	-134.871	-134.676	-0.195
C442	22.4853	50.484	3369.48	-134.953	-134.690	-0.263
C443	22.4756	50.522	3369.50	-135.006	-134.705	-0.301
C444	22.4659	50.559	3365.08	-135.094	-134.719	-0.375
C445	22.4562	50.596	3363.18	-135.229	-134.733	-0.496
C446	22.4466	50.633	3359.77	-135.295	-134.748	-0.547
C447	22.4369	50.671	3357.23	-135.370	-134.762	-0.608
C448	22.4272	50.708	3356.31	-135.463	-134.777	-0.686
C449	22.4175	50.745	3354.50	-135.504	-134.791	-0.713
C501	22.5095	49.729	3396.12	-134.220	-134.608	0.388
C502	22.5409	49.741	3392.63	-134.171	-134.570	0.399
C503	22.5724	49.752	3389.22	-134.138	-134.533	0.395
C504	22.6038	49.764	3387.07	-134.118	-134.495	0.377
C505	22.6353	49.775	3386.67	-134.109	-134.457	0.348
C506	22.6667	49.787	3384.93	-134.053	-134.420	0.367
C507	22.6981	49.798	3384.39	-134.001	-134.382	0.381
C508	22.7296	49.810	3385.58	-133.966	-134.345	0.379
C509	22.7610	49.821	3387.66	-133.955	-134.307	0.352
C510	22.7925	49.833	3387.78	-133.957	-134.269	0.312
C511	22.8239	49.844	3386.08	-133.949	-134.232	0.283
C512	22.8553	49.855	3385.09	-133.922	-134.194	0.272
C513	22.8867	49.867	3382.77	-133.942	-134.157	0.215
C514	22.9181	49.878	3381.12	-133.924	-134.119	0.195
C515	22.9496	49.890	3379.56	-133.915	-134.081	0.166
C516	22.9810	49.901	3376.94	-133.913	-134.044	0.131
C517	23.0125	49.913	3374.95	-133.907	-134.006	0.099
C518	23.0439	49.924	3373.79	-133.880	-133.969	0.089
C519	23.0753	49.936	3369.95	-133.825	-133.903	0.078
C520	23.1068	49.947	3365.86	-133.829	-133.865	0.036
C521	23.1382	49.959	3363.98	-133.848	-133.828	-0.020

STATION ID	LATITUDE N 32 DEG (min)	LONGITUDE W 103 DEG (min)	ELEVATION (ft)	GRAVITY (ms)	REGIONAL (ms)	REDUCED GRAVITY (ms)
-----	-----	-----	-----	-----	-----	-----
C522	23.1696	49.570	3363.21	-133.822	-133.790	-0.032
C523	23.2010	49.982	3361.17	-133.854	-133.781	-0.073
C524	23.2325	49.993	3355.98	-133.855	-133.743	-0.112
C525	23.2640	50.005	3357.93	-133.900	-133.705	-0.195
C526	23.2954	50.016	3355.84	-133.958	-133.668	-0.290
C527	23.3111	50.022	3350.66	-134.000	-133.649	-0.351
C528	23.3268	50.028	3340.76	-134.095	-133.630	-0.465
C529	23.3426	50.033	3332.36	-134.182	-133.611	-0.571
C530	23.3583	50.039	3326.32	-134.305	-133.593	-0.712
C531	23.3740	50.045	3324.77	-134.425	-133.574	-0.851
C532	23.3897	50.051	3323.33	-134.377	-133.555	-0.822
C533	23.4054	50.056	3323.74	-134.374	-133.536	-0.838
C534	23.4211	50.062	3327.80	-134.341	-133.517	-0.824
C535	23.4368	50.068	3328.05	-134.305	-133.499	-0.806
C536	23.4525	50.074	3328.01	-134.222	-133.480	-0.742
C537	23.4683	50.079	3328.59	-134.166	-133.461	-0.705
C538	23.4840	50.085	3328.87	-134.108	-133.442	-0.666
C539	23.5154	50.097	3328.38	-134.007	-133.405	-0.602
C540	23.5468	50.108	3329.08	-133.914	-133.367	-0.547
C541	23.5783	50.120	3328.94	-133.872	-133.330	-0.542
C542	23.6097	50.131	3328.20	-133.867	-133.292	-0.575
C543	23.6412	50.143	3327.53	-133.809	-133.254	-0.555
C544	23.6726	50.154	3325.63	-133.776	-133.217	-0.559
C545	23.7040	50.165	3324.00	-133.703	-133.179	-0.524
C546	23.7355	50.177	3324.84	-133.676	-133.141	-0.535
C547	23.7669	50.189	3327.64	-133.645	-133.104	-0.511

APPENDIX D

Gravity Data Over Bell Lake Sink

Station Number	Elevation (ft.a.s.l.)	Bouguer Gravity (mg)	Gravity Less		Notes
			Regional (mg)		
29	3635	-134.595	-0.197		
30	3636	.537	-0.181		
31	3636	.515	-0.200		
32	3635	.502	-0.229		
33	3620	.383	-0.152		
34	3610	.282	-0.092		
35	3604	.232	-0.084		
36	3597	.199	-0.093		
37	3588	.100	-0.035		
38	3590	.154	-0.131		
39	3586	.115	-0.134		
40	3574	-133.967	-0.027		
41	3572	.917	-0.019		
42	3573	.871	-0.015		
43	3570	.786	+0.029		
44	3569	.736	+0.037		
45	3572	.693	+0.038		
46	3586	.725	-0.036		
47	3598	.813	-0.165		
48	3593	.700	-0.094		
49	3586	.609	-0.044		
50	3583	.523	0		section line regional = Bouguer Gravity
51	3579	.471	+0.010		
52	3574	.405	+0.035		
53	3571	.385	+0.013		
54	3568	.333	+0.023		
55	3568	.274	+0.041		

Station Number	Elevation (ft.a.s.l.)	Bouguer Gravity (mg)	Gravity Less		Notes
			Regional (mg)		
56	3571	-133.237	+0.036		
57	3580	.230	+0.001		
58	3587	.245	-0.056		
59	3589	.238	-0.090		
60	3596	.266	-0.150		
61	3599	.249	-0.184		
62	3598	.212	-0.189		
63	3590	.079	-0.098		
64	3588	.035	-0.095		
65	3589	-132.986	-0.088		
66	3591	.929	-0.073		
67	3594	.879	-0.064		
68	3597	.847	-0.074		
69	3597	.752	-0.021		
70	3600	.681	+0.009		
71	3602	.599	+0.049		
72	3605	.537	+0.069		
73	3607	.480	+0.085		
74	3608	.470	+0.053		section line
75	3610	.443	+0.039		
76	3612	.412	+0.028		
77	3612	.362	+0.036		
78	3613	.297	+0.059		
79	3613	.254	+0.061		
80	3612	.194	+0.079		
81	3611	.141	+0.091		
82	3611	.091	+0.099		
83	3614	.047	+0.101		

Station Number	Elevation (ft.a.s.l.)	Bouguer Gravity (mg)	Gravity Less		Notes
			Regional (mg)		
131	3623	-134.714	-0.217		
132	3624	.703	-0.248		
133	3624	.618	-0.204		
134	3623	.579	-0.207		
135	3622	.527	-0.197		
136	3609	.430	-0.141		
137	3597	.371	-0.124		
138	3581	.282	-0.077		
139	3568	.207	-0.043		
140	3565	.158	-0.036		
141	3564	.093	-0.013		
142	3564	.033	+0.006		
143	3568	.001	-0.004		
144	3576	.018	-0.063		
145	3580	-133.957	-0.043		
146	3587	.969	-0.097		
147	3592	.958	-0.128		
148	3596	.935	-0.146		
149	3592	.821	-0.074		
150	3591	.788	-0.082		section line
151	3591	.726	-0.062		
152	3591	.694	-0.072		
153	3590	.645	-0.064		
154	3593	.607	-0.068		
155	3588	.520	-0.023		
156	3594	.558	-0.102		
157	3586	.424	-0.010		
158	3587	.356	+0.016		
159	3593	.340	-0.009		
160	3601	.361	-0.072		

Station Number	Elevation (ft.a.s.l.)	Bouguer Gravity (mg)	Gravity Less		Notes
			Regional (mg)		
161	3602	-133.309	-0.062		
162	3593	.205	+0.001		
163	3592	.157	+0.007		
164	3593	.106	+0.016		
165	3593	.096	-0.015		
166	3592	.051	-0.012		
167	3590	-132.961	+0.036		
168	3588	.935	+0.021		
169	3587	.869	+0.045		
170	3588	.823	+0.049		
171	3597	.799	+0.032		
172	3604	.799	-0.010		
173	3604	.692	+0.055		
174	3599	.630	+0.076		section line
175	3600	.573	+0.091		
176	3603	.566	+0.056		
177	3609	.548	+0.033		
178	3607	.449	+0.090		
179	3605	.402	+0.095		
180	3606	.351	+0.105		
181	3609	.299	+0.115		
182	3610	.272	+0.100		
183	3611	.242	+0.089		
201	3590	-133.586			
202	3593	.664			
203	3594	.695			
204	3592	.722			
205	3592	.757			

Station Number	Elevation (ft.a.s.l.)	Bouguer Gravity (mg)	Gravity Less Regional (mg)	Notes
206	3609	-132.503		
207	3606	.505		
208	3603	.548		
209	3601	.568		
210	3600	.603		
211	3601	-133.237		
212	3602	.268		
213	3598	.222		
214	3594	.131		
215	3592	.130		

DISTRIBUTION:

US Department of Energy, Headquarters (3)
Office of Nuclear Waste Management
Washington, DC 20545
Attn: L. Harmon, Program Manager (WIPP)
W. Ballard, Director,
Division of Waste Isolation (2)

US Department of Energy, Headquarters
Office of Defense Waste & By-Products
Washington, DC 20545
Attn: G. Oertel, Director (NE-320)

US Department of Energy (3)
Albuquerque Operations
PO Box 5400
Albuquerque, NM 87115
Attn: J. M. McGough, Mgr, WIPP Project Office (2)
D. Jackson, Director, Public Affairs Division

US Department of Energy
Carlsbad WIPP Project Office
Room 113, Federal Building
Carlsbad, NM 88220

US Department of Energy
c/o Battelle Office of Nuclear Waste Isolation
505 King Ave
Columbus, OH 43201
Attn: J. O. Neff

Battelle Memorial Institute
Office of Nuclear Waste Isolation
505 King Ave
Columbus, OH 43201
Attn: S. Goldsmith, Mgr, ONWI Library

Battelle Memorial Institute
Project Management Division
505 King Ave
Columbus, OH 43201
Attn: N. Carter, General Manager

Bechtel National, Inc. (2)
Fifty Beale St
PO Box 3965
San Francisco, CA 94119
Attn: D. L. Ledbetter
D. Roberts

D'Appolonia Consulting Engineers (10)
2340 Alamo, SE
Albuquerque, NM 87106
Attn: D. Shukla

Westinghouse Electric Corporation (3)
PO Box 40039
Albuquerque, NM 87196
Attn: R. K. Brown
R. Jones (TSC)
C&C File, c/o G. Wilkenson

Vanderbilt University
Department of Environmental and
Water Resources Engineering
Nashville, TN 37235
Attn: F. L. Parker, Chairman

Stanford University
Department of Geology
Stanford, CA 94305
Attn: K. B. Krauskopf, Vice Chairman

Karl P. Cohen, Consultant
928 N California Ave
Palo Alto, CA 94303

University of California at Berkeley
Dept of Material Sciences and Engineering
Hearst Mining Building, #320
Berkeley, CA 94720
Attn: N. G. W. Cook

Fred M. Ernsberger
250 Old Mill Road
Pittsburgh, PA 15238

Pennsylvania State University
Department of Hydrogeology
University Park, PA 16802
Attn: R. R. Parizek

D'Arcy A. Shock
233 Virginia
Ponca City, OK 74601

John Fett (20)
11102 Township Cove
Austin, TX 78759

DISTRIBUTION: (Cont)

Florida State University
Department of Oceanography
Tallahassee, FL 32306
Attn: J. W. Winchester

John T. Holloway
Senior Staff Officer
2101 Constitution Ave, NW
Washington, DC 20418

WIPP Public Reading Room
Atomic Museum, KAFB East
Albuquerque, NM 87185
Attn: G. Schreiner

WIPP Public Reading Room
Carlsbad Municipal Library
101 S. Hallagueno St
Carlsbad, NM 88220
Attn: L. Hubbard, Head Librarian

Thomas Brannigan Library
106 W Hadley St
Las Cruces, NM 88001
Attn: D. Dresp, Head Librarian

Roswell Public Library
301 N Pennsylvania Ave
Roswell, NM 88201
Attn: N. Langston

Hobbs Public Library
509 N Ship St
Hobbs, NM 88248
Attn: M. Lewis, Librarian

State of New Mexico (2)
Environmental Evaluation Group
320 Marcy St
PO Box 968
Santa Fe, NM 87503
Attn: R. H. Neill, Director

NM Department of Energy & Minerals (2)
PO Box 2770
Santa Fe, NM 87501
Attn: L. Kehoe, Secretary
K. LaPlante, Librarian

New Mexico State Geologist
PO Box 2860
Santa Fe, NM 87501
Attn: E. C. Arnold

New Mexico State Library
PO Box 1629
Santa Fe, NM 87503
Attn: I. Vollenhofer

New Mexico Tech
Martin Speer Memorial Library
Campus St
Socorro, NM 87801

University of New Mexico
Zimmerman Library
Albuquerque, NM 87131
Attn: Z. Vivian

USGS, Water Resources Division (2)
505 Marquette, NW
Western Bank Bldg, #720
Albuquerque, NM 87102
Attn: J. W. Mercer

USGS, Conservation Division
PO Box 1857
Roswell, NM 88201
Attn: W. Melton

USGS, Special Projects Branch (2)
Federal Center, Bldg 25
Denver, CO 80225
Attn: R. P. Snyder

NM Bureau of Mines and Mineral Resources (2)
Socorro, NM 87801
Attn: F. E. Kottlowski, Director

Klaus Kuhn
Gesellschaft fuer Strahlen-und
Umweltforschung MBH Muenchen
Institut fuer Tieflagerung
Berliner Strasse 2
3392 Clausthal-Zellerfeld
FEDERAL REPUBLIC OF GERMANY

DISTRIBUTION: (Cont)

Klaus Eckart Maass
Hahn-Meitner-Institut fuer Kernforschung
Glienicke Strasse 100
1000 Berlin 39
FEDERAL REPUBLIC OF GERMANY

Michael Langer
Bundesanstalt fuer Geowissenschaften
und Rohstoffe
Postfach 510 153
3000 Hannover 51
FEDERAL REPUBLIC OF GERMANY

Helmut Rothemeyer
Physikalisch-Technische
Bundesanstalt
Bundesallee 100
3300 Braunschweig
FEDERAL REPUBLIC OF GERMANY

Rolf-Peter Randl
Bundesministerium fuer Forschung
und Technologie
Postfach 200 706
5300 Bonn 2
FEDERAL REPUBLIC OF GERMANY

Fenix & Scisson, Inc.
3170 W Sahara Avenue
Spanish Oaks D-12
Las Vegas, NV 89102
Attn: J. A. Cross

Gayle Pawloski, L-222
Geologist CSDP
Lawrence Livermore Laboratory
Livermore, CA 94550

US Nuclear Regulatory Commission (3)
Division of Waste Management
Mail Stop 69755
Washington, DC 20555
Attn: J. Martin
M. Bell
H. Miller

Michigan Technological University
Center of Waste Management Programs
Department of Social Sciences
Houghton, MI 49931
Attn: G. L. Downey

University of Texas at El Paso
Department of Geological Sciences
El Paso, TX 79968
Attn: D. W. Powers

7111 J. R. Banister
7111 L. J. Barrows (10)
7133 R. D. Statler
7135 P. D. Seward
9700 E. H. Beckner
9730 W. D. Weart
9731 A. R. Lappin
9731 D. J. Borns
9731 D. D. Gonzalez
9731 S. J. Lambert
9731 K. L. Robinson
9731 S. E. Shaffer
9731 C. L. Stein
9732 Sandia WIPP Central Files (12)
8214 M. A. Pound
3141 L. J. Erickson (5)
3151 W. L. Garner (3)
3154-3 C. H. Dalin (25)
For DOE/TIC (Unlimited Release)