The Karst and Related Issues at the Waste Isolation Pilot Plant

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Introduction

This paper addresses the karst and other related issues raised in a press release entitled, "WIPP at 10: Geologically Unstable," which was issued by Citizens for Alternatives to Radioactive Waste Dumping (CARD) on March 25, 2009. The press release distorts and misrepresents the statements in the 2008 Culebra Peer Review Panel report (Burgess, et al., 2008), including incorrectly ascribing to it a part of a statement that was made in a very different context by another peer review panel in 1996. The "Critique" by R.H. Phillips attached to the press release freely lifts text from Burgess, et al. (2008) out of context and improperly uses it to advance the CARD's criticism of the integrity of the WIPP site. In this manner, Phillips reiterates several assertions that have been thoroughly reviewed and discredited by the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA) and independent scientists for the past 25 years. Because of the long history of these assertions, this paper first provides a history of addressing the karst issue by DOE, EPA, and many independent scientists and other groups. Specific issues raised in the CARD's March 25 press release are discussed at the end of this paper.

What is Karst?

The EPA has described "karst" as it relates to the WIPP as follows:

> Karst is a type of topography in which there are numerous sinkholes and large voids, such as caves. Karst is caused when soluble rock dissolves. Karst may form when rainwater reacts with carbon dioxide from the air, forms carbonic acid, and seeps through the soil into the subsurface rock. Soluble rock includes limestone and evaporite rocks, such as halite (salt) and gypsum. If substantial and abundant karst features were present at WIPP, they could increase the speed at which releases of radionuclides travel away from the repository through the subsurface to the accessible environment. (EPA, 2006a, p. 18015)

A History of the Karst Issue at the WIPP

In May 1982, Dr. Larry Barrows, who was then a geophysicist working on the WIPP project with Sandia National Laboratories (SNL), prepared a manuscript titled, "WIPP Geohydrology – The Implications of Karst" (Barrows, 1982). In it, Barrows argued that the results of the gravity surveys conducted over the WIPP site indicated "…density and (acoustic velocity) alterations in the vicinity of karst channels." He made other arguments to support his contention that karst type conditions may exist in the Rustler Formation in the immediate vicinity of the WIPP site and this may make this Formation an unreliable barrier to the migration of contaminated water. These arguments were: the thinning of the

Rustler Formation from east to west over the WIPP site, existence of closed topographic depressions over the WIPP site, cavities found in borehole WIPP-33 (see Fig. 1), and a lack of surface runoff at the WIPP site. Details of Barrows' gravity data interpretation were published in Barrows et al. (1983) and Barrows and Fett (1985).

The State of New Mexico's Environmental Evaluation Group (EEG) undertook an investigation and analysis of the karst phenomenon at the WIPP site and invited Harry LeGrand, a U. S. Geological Survey (USGS) specialist in karst hydrology who was recommended by Larry Barrows, to participate in that analysis. As a part of this effort, Barrows was invited to suggest specific field evidence in support of his hypothesis and was given the opportunity to guide a field trip specifically designed by him to present his evidence to a group of DOE and independent scientists. The report, EEG-32, contains the results of this investigation and analysis and includes the Barrows' manuscript, the field trip notes, LeGrand's reports, and Barrows' review of LeGrand's reports (Chaturvedi and Channell, 1985).

In his letter reports to EEG, Harry LeGrand (in Chaturvedi and Channell, 1985) focused on the extent of Nash Draw type karst processes to the east of Nash Draw toward the WIPP site. He concluded that the WIPP site ("Upland East" in his words) was an area of low permeability of the Culebra and the Magenta dolomite water-bearing beds in the Rustler Formation and that it was "essentially isolated from sufficient circulating water for dissolution to occur." He was unsure about the extent to which the area between the WIPP site and Nash Draw ("Upland West"), where no halite beds in the Rustler were found, was affected by Nash Draw type karst processes, and recommended more field studies in this area.

Chaturvedi and Channell (1985) analyzed the impact of karst on the potential release of radionuclides from the WIPP repository and recommended several specific studies to address the question of karst in addition to the extensive site characterization investigations that were being conducted by DOE at that time. In 1985, George Bachman of the U. S. Geological Survey (Bachman, 1985), who had already conducted thorough investigations of karst in the large area surrounding the WIPP site for many years, reexamined the surface features at and around the WIPP and concluded that there was no evidence for active karst within the WIPP site. Chaturvedi and Rehfeldt (1984) provided a discussion of the status of shallow and deep dissolution issues at the WIPP site and recommended studies to resolve them.

In 1987, Richard Phillips published a thesis (Phillips, 1987) in which he argued that the Mescalero Caliche layer under the surface at the WIPP site is discontinuous and allows surface water to infiltrate to deeper layers, particularly to the water-bearing layers in the Rustler Formation. He also cited several topographic depressions at the WIPP site, and streams flowing to some of them, as evidence of karst sinks. There are a number of difficulties with this proposition, including the existence of several hundred feet of insoluble sandstones and siltstones (which do not form karst) of the Santa Rosa and Dewey Lake Redbeds Formations between the gaps in the Mescalero Caliche layer and the water bearing zones in the Rustler Formation.

After reviewing a number of hydrogeological reports published by DOE between 1982 and 1990, Chaturvedi (1990) wrote a brief status paper on the question of karst and stated that while karst processes exist in the Nash Draw depression west of the WIPP site, there is no evidence of karst east of the WIPP-33 depression located 3 miles northwest of the center of the WIPP repository (see Fig. 1). Among the reports available at that time were Beauheim (1986), Beauheim (1987a), Beauheim (1987b) and Beauheim (1989), which contained the results of multi-well tests. Later, Beauheim and Ruskauff (1998) presented the results of all the multi-well tests conducted at WIPP before the certification application.

Chaturvedi (1990) noted: "Observations of drawdowns of water levels in wells separated miles apart, as a result of continuous pumping from selected wells, yield a picture of predictable permeabilities. These tests show no interception by channels of much faster flow of water. While the Karst specialists would argue that solution channels may exist and not be seen in the multi-well flow tests data, the existence of a large amount of clearly interpretable data does reduce the likelihood of such occurrence to a minimum." This paper is included in EPA's WIPP docket A-93-02 at II-D-102.

In its Compliance Certification Application (CCA) (DOE, 1996), DOE argued that the karst feature nearest the WIPP site is located at WIPP-33, but within the site boundary there are no known surficial or underground features caused by dissolution or karst. For performance assessment (PA), DOE assumed a steady-state flow field in the Culebra aquifer in the Rustler Formation and developed 100 different geostatistically based transmissivity fields, each of which is consistent with available head and transmissivity data. The PA did not assume any karst channels or conduits within the WIPP site.

In its certification decision (EPA, 1998), EPA agreed with DOE's position and stated:

> "The EPA concludes that dissolution has occurred in the WIPP area outside of the WIPP site, as evidenced by karst features like Nash Draw. It is possible that dissolution has occurred at the WIPP site sometime in the distant past (i.e., millions of years ago for strata-bound features) associated with a geologic setting other than currently present at WIPP; however, dissolution in the Culebra is not an ongoing process at the WIPP site. Thus EPA finds that DOE modeling (which assumes no karst within the WIPP site boundary) is consistent with existing borehole data and other geologic information." (EPA, 1998, p. 27374)

Following the 1998 certification decision, several groups challenged EPA's decision in the United States Court of Appeals for the District of Columbia Circuit (No. 98-1322). One of the issues in this lawsuit was EPA's conclusions regarding karst at the WIPP site. The petitioners argued that EPA denied and ignored evidence of karst features at WIPP, and failed to address public comments regarding karst. On June 28, 1999, the U.S. Court of Appeals upheld all aspects of EPA's 1998 certification decision, including EPA's conclusion that karst is not a feature that will likely impact the containment capabilities of the WIPP.

The arguments in favor of the existence of karst at the WIPP site continued to be advanced after EPA certification of WIPP and the U.S. Court of Appeals upholding EPA's decision. Snow (1998, 2002) argued that the Rustler Formation overlying and down-gradient of the WIPP repository will not provide the claimed geologic containment because karst conduits are present that will facilitate rapid, ephemeral flow. In a comprehensive report (Hill, 1999) on the subject of karst at the WIPP site submitted to SNL, Carol Hill presented in detail many of the arguments previously made by the proponents of the existence of karst features and processes at the WIPP site. In 2003, she summarized her thoughts on the subject in a publication of the Oklahoma Geological Survey (Hill, 2003).

In the first required five-year compliance recertification application (CRA-2004) submitted to EPA in 2004, DOE (2004) revisited the issue of karst and provided detailed arguments against the proposition that active karst processes may exist at the WIPP site. During EPA's review of CRA-2004, commenters again raised questions regarding the potential formation of karst in the Culebra or Magenta and whether preferential groundwater pathways could exist or develop that could affect groundwater transport of radionuclides from the repository.

In its recertification decision, EPA (2006a) gave the issue of karst sufficient importance to devote an entire Technical Support Document (TSD) to this issue (EPA, 2006b). This TSD analyzed the arguments related to the karst issue and evaluated the Hill (1999 and 2003) and Snow (1998 and 2002) conceptual models in detail. The EPA concluded:

> "After careful review of the available information, EPA concludes that dissolution may have occurred in the immediate vicinity of WIPP-33. There is, however, no evidence, that dissolution is pervasive, wide spread, or has led to connected groundwater pathways, such as "underground rivers" as noted by the stakeholders. From the perspective of performance assessment, this lack of interconnection between localized dissolution features will render any effects on travel times insignificant. If, in fact, point recharge is occurring, the effects have already been taken into account in hydraulic gradients measured in the Culebra and used in the WIPP performance assessment calculations….Our review reaffirms our original certification decision that karst processes are not active at the WIPP site, and that karst processes will not affect containment of radionuclides at the WIPP site now or during the regulatory time period for 10,000 years." (EPA, 2006b, Executive Summary)

In its recertification decision (EPA, 2006a, p. 18015), EPA also requested that DOE/SNL conduct a separate analysis of the potential for karst and address some general and specific issues raised by stakeholders. In response, DOE conducted yet another comprehensive review of all claims and information pertaining to karst in the WIPP vicinity. The major issues reviewed in the resulting DOE/SNL report (Lorenz, 2006a) were: insoluble residues, negative gravity anomalies, specific well results, water in the exhaust shaft, and recharge and discharge issues. This report reaffirmed the previous analysis demonstrating that pervasive karst processes have been active outside the WIPP

site but not directly at WIPP. Another technical paper, Lorenz (2006b), summarizes the essential points of the DOE/SNL report.

The Appendix HYDRO-2009 (DOE, 2009), submitted by DOE to EPA as a part of the second recertification application (CRA-2009), describes additional karst studies performed during the period 2003-2007 to evaluate the potential for karst at the WIPP site, and to increase the understanding of karst in Nash Draw. These additional studies further confirm that the Nash Draw type karst processes are not active at the WIPP site.

The CARD's March 25 Press Release

The CARD press release and the attached "Critique" by Phillips (2009) misrepresent the Culebra Peer Review report (Burgess et al., 2008) by incorrectly ascribing statements to it that are not in it and by quoting, out of context, introductory sentences or parts of sentences from it. The following is an evaluation of the main points/assertions in the press release and Phillips (2009) paper, in the order in which they appear in the press release and the paper.

The 2008 Peer Review Panel Judgment on the Culebra Conceptual Model

Referring to the peer review by Burgess et al. (2008), the CARD press release states: "The report from the Peer Review Panel, *Culebra Hydrogeology Conceptual Model Peer Review*, concludes that the DOE's conceptual model of the Culebra member which lies above the repository has 'failed to correlate the detailed hydrogeology of the Culebra with its tested hydrologic character' (page 8, pa. 1)."

There is no such statement on page 8 of Burgess et al. (2008). However, the following statement appears on page 1 of Burgess et al. (2008), in which the reference "that panel" is to a 1996 (Wilson et al., 1996a) peer review panel:

> "The original conceptual model for Culebra hydrogeology developed for the CCA was found to be 'inadequate, but of no consequence' by the Conceptual Models Peer Panel constituted to review it (and other conceptual models). That Panel found that the conceptual model 'failed to correlate the detailed hydrogeology of the Culebra with its tested hydrologic character' but that adequate data existed from hydraulic testing to develop a numerical model." (Burgess et al., 2008, p. 1)

With respect to the validity of the current conceptual model, Burgess et al. (2008) concluded: "The Panel believes that the conclusions in the RCHCM *(Revised Culebra Hydrogeology Conceptual Model)* from the integration of geology and hydrology are valid, and can be used to develop T-fields for incorporation in the PA."

Rainwater Recharge Reaching the Culebra Dolomite

Phillips (2009) states "Rainwater recharge does reach the Culebra dolomite" and cites the data presented by Rick Beauheim to the peer review panel in support of his contention. The statement is correct for parts of the Nash Draw, but not for the WIPP site. The observation of several Culebra wells responding to major precipitation events has been documented by Hillesheim et al. (2006) and Hillesheim et al. (2007). Wells in the Nash Draw, i.e., WIPP-25 and WIPP-26, have been observed to respond to major rainfall events quickly, because the Culebra is unconfined and close to the surface in Nash Draw. Once the head in the Culebra is increased in Nash Draw, a pressure transient propagates through the confined Culebra under Livingston Ridge and across the WIPP site over the following days to months, decreasing in magnitude as it propagates farther away from Nash Draw. (Hillesheim et al., 2007)

Chaturvedi and Channell (1985) argued, based on the observation of similar heads in the Culebra and the Magenta at well H-6, that the Culebra and the Magenta are not confined at the northwest corner of the WIPP site and thus "have hydraulically merged almost two miles east of the Livingston Ridge" (p. 42). This argument was repeated by Snow (1998) and by Hill (1999). Phillips (2009) uses the same argument to propose, "The recently obtained data reveal that the Culebra and Magenta hydraulic heads are nearly equal at test wells WIPP-30, DOE-2 and H-18, confirming that the Culebra is unconfined three miles east of Nash Draw." The fallacy in this argument has been pointed out by Lorenz (2006b) as follows:

> "The plane of the Magenta potentiometric head slopes down to the west and therefore must cross the southward-sloping Culebra regional trend somewhere. The crossover line is not a physical intersection; it is a line on a map where the two potentiometric surfaces would intersect." (Lorenz, 2006a, p. 77)

The southern Nash Draw as a possible source of recharge to the Culebra is a relatively recent understanding and is still being refined. There is no evidence of such recharge at the WIPP site. The Culebra is a confined aquifer under the WIPP site, there are 600 to 800 ft of rock above it, including at least 160 ft of unsaturated rock, none of the suspected depressions have been shown to be sink holes, and multi-well tests establish the hydrologic properties of the Culebra without any indication of karst channels.

To argue in favor of his contention that "rainwater recharge to the Rustler is occurring at the WIPP site," Phillips uses a statement from the 2008 peer review panel report (Burgess et al., 2008): "Water level observations in the Culebra show short term fluctuations that have been correlated with precipitation events." In fact, the complete statement of the peer review panel, quoted below, is contradictory to Phillips' assertion:

> "Water level observations in the Culebra show short term fluctuations that have been correlated with precipitation events. While these responses indicate continuity for the transmission of pressure transients, they do not necessarily

> signify significant hydraulic interconnection and leakage/recharge." (Burgess et al., 2008, sec. 5.2, p. 19)

Halite Dissolution vs. Facies Change in the Rustler

Phillips (2009) cites (on page 5) "twenty-one authors of fifteen scientific reports" to argue that the pattern of progressive absence of halite from the Rustler from east to west is due to post-depositional dissolution of halite. The list of proponents of this idea in the 1970s and 1980s is in fact much longer and includes several SNL and USGS scientists who published on this subject at that time. However, the validity of a scientific argument is not determined on the basis of numbers of publications, but on the most logical interpretation of data and the most robust hypothesis. A hypothesis evolves or is rejected as more data become available.

Chaturvedi and Channell (1985) provided detailed arguments in favor of the concept of Rustler halite dissolution under the WIPP site and cited several SNL and USGS reports, most notably Snyder (1983) and Snyder (1985). Chaturvedi and Channell (1985) also noted, however, that Powers and Holt (1984) and Holt and Powers (1984) had expressed doubts about this concept on the basis of detailed mapping in the WIPP Waste Handling Shaft where they did not find any post-depositional dissolution features, and concluded: "In as much as this statement (*of Holt and Powers, 1984*) is based only on the mapping of one shaft, it requires no further discussion unless the results of detailed sedimentological studies of rock cores from several wells, now under way, point to the depositional mode for the absence of salt in Rustler as a more logical explanation." (Chaturvedi and Channell, 1985, p. 47)

Results of detailed sedimentological studies of rock cores from several wells and WIPP shafts are now available. In fact, a large number of reports and publications in respected peer-reviewed journals reporting the results of detailed and careful work, have strongly established the Rustler depositional environment that caused the simultaneous deposition of halite and muddy deposits side by side. These studies have also shown that the interpretation of halite dissolution causing the thinning of the Rustler Formation from east to west across the WIPP site is in error. Although Dennis Powers and Robert M. Holt have performed most of this work, there are no publications in scientific journals challenging the credibility of Powers' and Holt's interpretations contained in Holt and Powers (1986), Holt and Powers (1988), Holt and Powers (1990), Powers and Holt (1990), Powers and Holt (2000), Powers et al. (2003) and Powers et al. (2006).

Lorenz (2006a) has best summarized the interpreted depositional environment for the Rustler and why the old interpretation of post-deposition dissolution is not valid, as follows:

> "Rustler halites were deposited in shallow depressions ("pans") on this depositional surface at the same time that muddy deposits were accumulating at the margins of the pans, and this lateral facies equivalency, a well documented and founding principle of stratigraphy, caused most of the sedimentary patterns

that are mistakenly cited as evidence for post-depositional dissolution and removal of halite from the thinner parts of the Rustler Formation in the vicinity of the WIPP site. The larger extents of the dolomite layers are not evidence for the original extents of the halite layers since the dolomites were deposited in much deeper waters that were not affected by the low-relief topography of the depositional surface. It would be impossible to obtain the observed thicknesses of muddy and silty deposits that have been called "residues" by dissolving the limited available volume of muddy and silty halite. Moreover, the silty and muddy beds do not contain evidence of other in-soluble remnants that are common in the thicker halite beds." (Lorenz, 2006a, p. 88)

Peer Review Panel's Review of Karst

Phillips (2009) criticizes the Burgess et al. (2008) Panel for not reviewing "the extensive body of karst at the WIPP by Larry Barrows and others." While the Panel was constituted to review the conceptual model for the Culebra, it did review the issue of karst as a part of the conceptual model and had access at least to Lorenz (2006a) and Hill (1999), which are the latest comprehensive review reports on karst and contain all the previous ideas and arguments. The Panel comments on karst include both the subjects of WIPP-33 and Barrows' gravity survey interpretations.

The 2008 Culebra peer review report (Burgess, et al., 2008) states the following on the karst issue:

> "Lorenz (2006) and Powers (Culebra Conceptual Peer Review Meeting, August 11, 2008) convincingly argued that no unequivocal karst features exist at the WIPP Site. Some of the points made by Lorenz (2006) and summarized by Powers are:
>
> - There have been no observed cavernous porosity or tool drops in the Culebra at WIPP or in wells more than a few hundred meters east of the upper Salado dissolution line.
> - Cores, logs, and shafts do not show cavernous porosity that has been filled.
> - Hydraulic testing of WIPP holes away from Nash Draw shows no evidence of intersecting such cavernous porosity.
> - There are no open fractures in the lower part of the Rustler in WIPP shafts to carry water.
> - Broad gravity anomalies at the surface are not a response to small open conduits or caves at depths of hundreds of feet.

- WIPP-33 encountered cavernous porosity in the Magenta and higher units; this location has a surface depression, and it also has a shallow gravity anomaly. It is 0.5 mi. west of WIPP, near Nash Draw.

- WIPP-14 encountered neither cavernous porosity nor mud-filled porosity in the Rustler. Cuttings reported as "mud, mud, mud" below Culebra are through an interval with normal lithology, including anhydrite, based on geophysical logs.

These and other arguments made by Lorenz (2006) and Powers (2008) have convinced the Panel that significant karst features are not present at the WIPP site." (Burgess, et al., 2008, section 5.1, p. 18)

Culebra Water Level Rise

Phillips (2009) quotes passages from the Panel report and the SNL presentations and ends this section (p. 7) with a prediction that "the hydraulic gradient will continue to increase as the water levels continue to rise, thereby facilitating groundwater flow toward Nash Draw." The fact is that if the water level rises in all the wells uniformly, there would be no effect on the gradient. Differences in the magnitude of increase in water levels in wells would determine the changes in the gradient. There is no evidence to suggest that the flow is now, or will be in the future, toward Nash Draw.

Culebra as a Confined and Most Transmissive Aquifer at the WIPP Site

Phillips (2009) claims (on pages 7 and 8) that the Culebra: (1) may or may not be the most transmissive groundwater pathway, because the Dewey Lake Redbeds and the Magenta have yielded higher transmissivity values from tests in some wells, (2) is not a confined aquifer because there are five zones in the Rustler Formation "with open fractures and solution channels providing preferential pathways for groundwater transport," and (3) the Dewey Lake and the Santa Rosa perched water zones are part of the Culebra groundwater system.

The facts are thus: (1) The Culebra is the most pervasive highest transmissivity water-bearing zone overlying the repository at the WIPP site, even though some other zones may locally be more transmissive. (2) The three non-dolomite members of the Rustler Formation consist of anhydrite/gypsum and claystone beds having extremely low transmissivity, and have never been shown to have fractures or solution channels capable of transmitting water. The Culebra hydraulic head reaches above the top of the Rustler Formation and is distinctly different from that of the other Rustler members; therefore, the Culebra is a confined aquifer. (3) There is no evidence that the Dewey Lake and Santa Rosa water is connected to the Culebra water anywhere at the WIPP site. Wherever water has been detected in the Dewey Lake or Santa Rosa on the WIPP site, its level has been significantly different from that of Culebra water.

Culebra T values

Phillips (2009) makes several claims under this heading on pages 8 and 9. They are discussed below in the order in which they appear in the paper.

WIPP-29: Phillips claims that WIPP-29, located in the southern part of Nash Draw, should have been included in the WIPP groundwater flow model.

WIPP-29 was not included in the model because it is believed to be separated from the Culebra flow system at the WIPP site by a groundwater divide. Head and geochemical data suggest that water flowing through the Culebra across the WIPP site does not move westward across Nash Draw to Laguna Grande de la Sal, but instead flows to the south towards the Balmorhea-Loving Trough. Even if flow were towards Laguna Grande de la Sal, it would not affect the calculations of flow across the regulatory boundary, which is the WIPP site boundary.

Exclusion of T values: Phillips claims that by excluding T values from multi-well tests, SNL was "able to manipulate its model to produce the desired groundwater travel time." The T values to which Phillips refers come from reports on three large-scale ("multipad") pumping tests by Beauheim (1987a, 1987b, 1989). Each of those reports contains cautionary remarks about how those T values are to be understood, such as the following:

> "Several assumptions are implicit in the use of the line-source solution to simulate observation-well responses. One assumption is that the aquifer is areally homogeneous. This means that water is contributed to the pumping well equally from all directions. In a nonhomogeneous aquifer, less permeable regions will contribute less water, and more permeable regions will contribute more water. In a nonhomogeneous aquifer with smoothly and monotonically varying properties, this will cause more drawdown in the more permeable regions than would result from pumping at the same rate in a homogeneous system and less drawdown in the less permeable regions.
>
> As a result, estimates of the transmissivity between the pumping well and an observation well in a more permeable region will be too low, and estimates of the transmissivity between the pumping well and an observation well in a less permeable region will be too high. In a more complex, nonhomogeneous aquifer with an irregular distribution of properties, responses are more difficult to predict and could result in estimated hydraulic properties that are either too high or too low. Thus, the solution obtained from a single test in a nonhomogeneous aquifer is in no sense a unique description of the average hydraulic properties between any two points.
>
> Numerical rather than analytical modeling is required to define the distribution of hydraulic properties that will best simulate the responses observed when a number of wells in a nonhomogeneous system are pumped concurrently or in succession. In this report, the transmissivity and storativity values derived by using an analytical approach are termed the "apparent" values." (Beauheim, 1987b, p. 41-42)

As stated by Beauheim (1987a, 1987b, 1989), the "apparent" T values do not reflect the actual T at an observation well and are not suitable for direct use in a groundwater flow model. Instead, the model is calibrated to the measured observation-well drawdown responses to determine what the T distribution in the area of a pumping test is.

Geochemistry: Phillips (2009) claims that dissolved sodium chloride in Culebra water across the WIPP site is evidence of westward flow toward Nash Draw. In fact, the Culebra flow model does have a westward component of flow from the halite margins lying to the east. However, the dominant flow component on the WIPP site is from north to south. Furthermore, halite is present in the Los Medaños Member of the Rustler below the Culebra over the entire WIPP site except for the northwest corner, and halite is present in all the non-dolomite members of the Rustler north of the WIPP site. Hence, primarily westward flow is not needed to explain the occurrence of dissolved sodium chloride in the Culebra.

Conclusion

A review of the CARD press release and the critique by Phillips (2009) does not reveal any new issues which have not already been addressed by DOE and EPA. The 2008 peer review of the refined Culebra conceptual model was fairly and openly conducted to continue to improve our understanding of the geology and hydrology of the WIPP site. There is nothing in the material presented to the peer review panel or in the report of the peer review panel (Burgess et al., 2008) that casts doubt about the integrity of the WIPP site or its ability to contain transuranic waste for 10,000 years or more.

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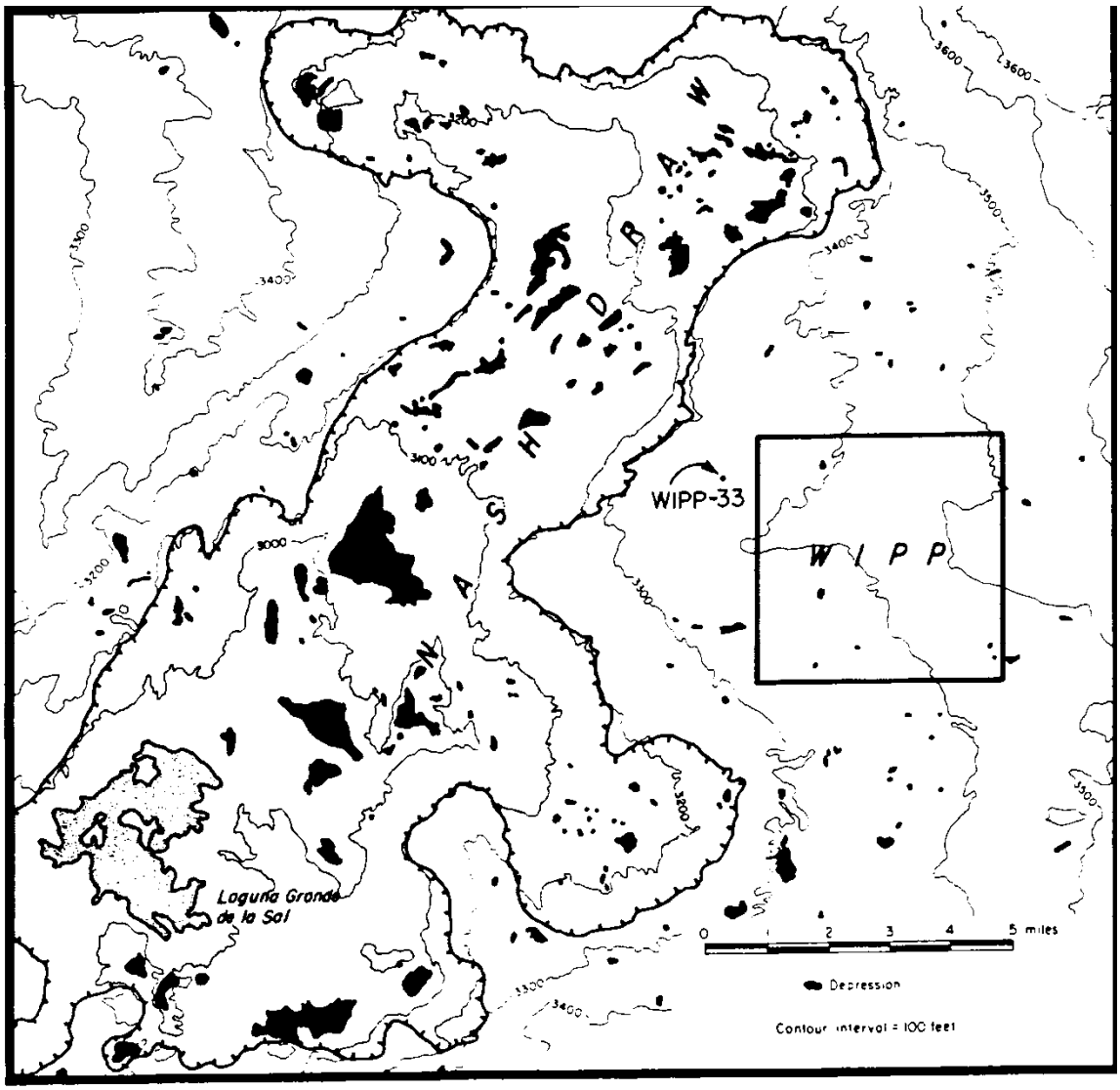

Closed topographic depressions at and near the WIPP site, based on USGS Nash Draw Quadrangle, 15 minute series. (Fig. 5 of Chaturvedi and Channell, 1985)

Figure 1: Location of WIPP-33 in relation to WIPP site and Nash Draw