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Subject: ***Consideration of TDEM Data for PBRINE Parameter Including Replacement Panels***

The probability of encountering brine below repository waste panels is an important factor in WIPP PA calculations and is implemented via the PBRINE parameter. The current PBRINE parameter distribution was derived by the EPA based on geophysical data taken via soundings above the layout for the current 10 waste panels. With a proposed 19-panel layout being the basis for upcoming PA calculations and a lack of data covering all 19 panels, we investigate here the appropriateness of using the current PBRINE distribution beyond its original intent. Based on the available data, a regional trend in observed brine occurrences, and the EPA model used to derive the current PBRINE distribution, our conclusion is that the current PBRINE distribution is adequate for a 12-panel representation and likely adequate for a 19-panel representation.

## Introduction

WIPP PA calculations account for the potential for inadvertent intrusions into the repository to intersect pressurized brine by using a probability factor represented by the GLOBAL:PBRINE (hereafter PBRINE) parameter. PBRINE is a sampled parameter in PA calculations and the parameter distribution used for the CRA-2019 PA was derived by the EPA (2017) based on Time Domain Electronic Magnetic (TDEM) geophysical sounding data (The Earth Technology Corporation 1987). The data was used in a model to estimate the probability of encountering pressurized brine in the Castile formation below the 10 repository waste panels.

A new, 19-panel layout has been proposed for the WIPP repository (Sjomeling 2019) consisting of the original 10 panels, two replacement panels, and seven additional panels. Upcoming PA calculations will be based on waste being distributed over the 19-panel layout (Hansen et al. 2023, Brunell 2023). Here we discuss the appropriateness of using the EPA-derived PBRINE distribution for PA calculations in which the planned panel layout extends beyond the 10 panels used to derive that distribution.

## Documented Observations of Castile Brine Encounters

Directly calculating a probability of encountering brine within the repository footprint is not possible due to not being able to drill extensively within the land withdrawal boundary (LWB). Drilling inside the LWB has only taken place three times with brine encountered for one of those intrusions. However,

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drilling for hydrocarbon wells is common in the Delaware Basin near the LWB. Castile brine encounters in the Delaware Basin are relatively rare (Figure 1). Documented brine encounters are typically to the east of the LWB and rarely to the west of the LWB.

The PBRINE distribution used in the CRA-2014 PA was based on a statistical approach to the observed occurrences of brine encounters near the WIPP (Kirchner et al. 2012). That distribution relied on the overall frequency of brine encounters for its justification, but not the location of the encounters relative to waste panels. For the purposes here, we are interested in information that helps assess whether there is a regional trend in the frequency of brine encounters in order to estimate whether it would be more or less likely to encounter brine below panels to the west of the current 10 panels (i.e., in the direction of the replacement and additional panels). Based on the observation that the frequency of brine encounters is much greater to the east of the LWB, there is a strong suggestion that the probability of encountering brine below additional panels toward the west would decrease. However, this estimation is not based on local geologic or hydrologic information beyond reported instances of encountering brine in drilling.

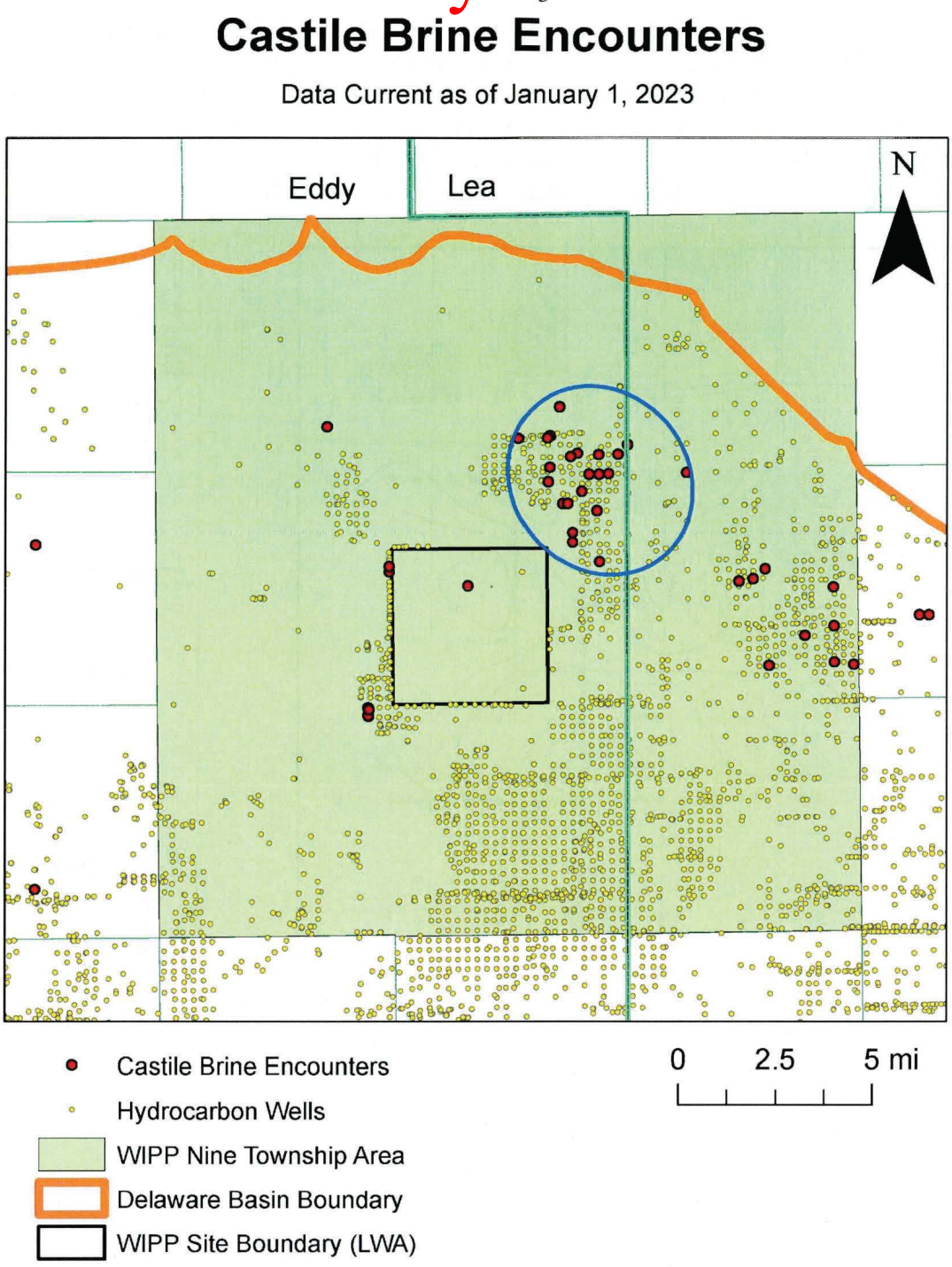



*Figure 1. Map of brine pocket encounters as of January 1, 2023 on or near the WIPP site with area of highest density highlighted (reproduced from LaClair (2023)).*

## Interpretation of TDEM data for PBRINE (EPA 2017)

The 1987 TDEM survey consisted of 38 soundings at the WIPP site. Most of the soundings (35) were arranged in a grid (250 m between points) while three were off of the grid (Figure 2). The 10 waste panels were bounded by a subset of the 35 TDEM points in the rectangular grid (Figure 3) with additional columns of TDEM grid points to the east and west of those points used in the EPA assessment of PBRINE.

The EPA's 2017 technical support document (TSD) for the CRA-2014 provides a detailed description of their process for determining a PBRINE distribution (EPA 2017). The TDEM sounding data were used to identify zones of high electrical conductivity (HCZs) below the 10-panel WIPP repository layout in the Castile formation. The HCZs were interpreted to be indicative of the presence of pressurized brine.

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The depths to the HCZs were subsequently used in part to construct a "TDEM block model." The block model was used to derive probability distributions for PBRINE for each of the 10 panels which were then combined to produce a single PBRINE distribution. Figure 2 shows the original TDEM data (depths to HCZ) and the array of sounding points. Figure 3 shows an overlay of the current 10 waste panels over a part of the TDEM array area. The location of the ERDA-9 borehole was used by the EPA to align TDEM sounding locations with waste panel locations (EPA 2017).

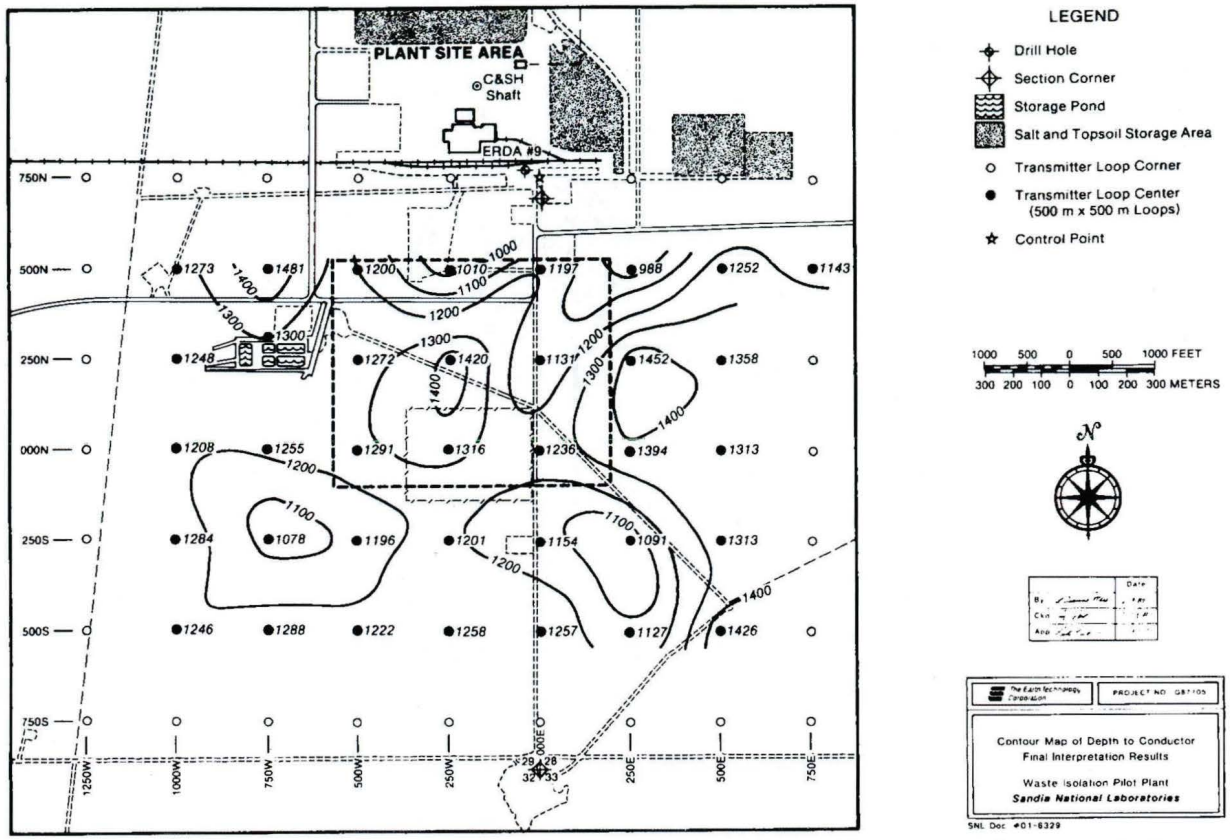



*Figure 2. TDEM array showing depths (in meters) at the sounding locations and waste panel area—dotted rectangle (reproduced from The Earth Technology Corporation (1987), Figure 1-1).*

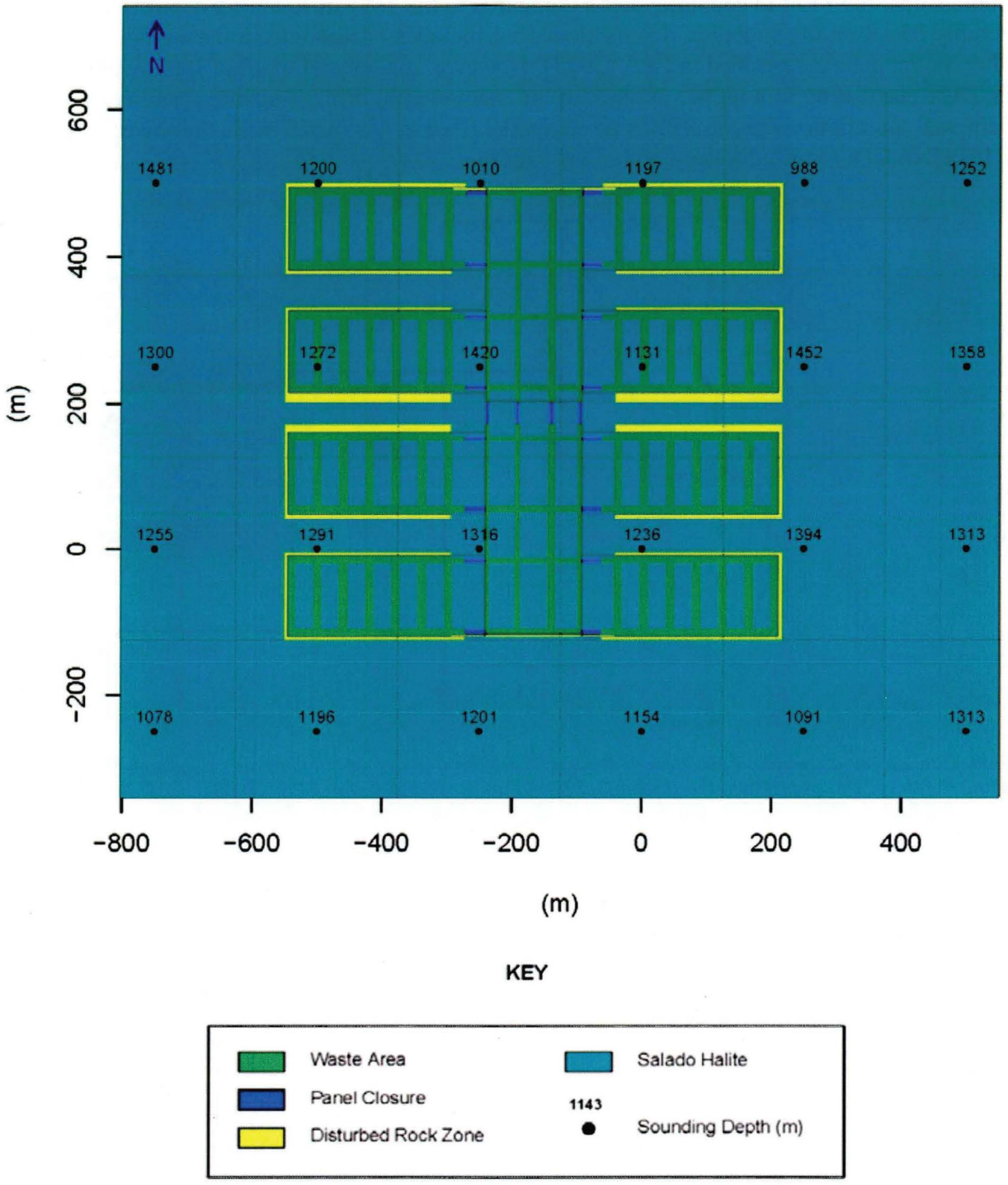



*Figure 3. Locations of TDEM soundings near the waste panels relative to the projected locations of the underlying waste panels (reproduced from EPA (2017), Figure 12). The estimated depth in meters to the first high electrical conductivity zone (HCZ) is shown for each sounding.*

## The EPA's PBRINE Calculation—Probability on a Panel Basis

The results of the EPA's analysis of the TDEM data using the block model included individual cumulative distribution functions (CDFs) for each of the 10 waste panels (Figure 4) (EPA 2017). They categorized the panels into three groups based on relative values of PBRINE: "high" (Panels 1 and 8), "low" (Panels 5, 6,7, and 9), and "mid" (Panels 2, 3, 4, and 10). The CDFs were derived by assessing 1000 simulated intrusions into each panel for whether they encountered brine or not (Figure 5). When the TDEM sounding value was generally at a shallower depth (i.e., lower number), the probability of encountering brine was higher. In the example shown in Figure 5 for Panel 2, there are more brine

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encounters near the 1131 m sounding depth compared to the 1452 m sounding depth. The block model is not simply based on the sounding depths alone, but includes uncertainty in the sounding depths as well as other model details described in EPA (2017). However, the general trend of shallower sounding depth to the HCZ correlating to a higher probability of encountering brine is apparent and consistent with the fundamental assumptions in the EPA's block model. Panels associated with shallower sounding depths have PBRINE CDFs shifted toward higher probabilities.

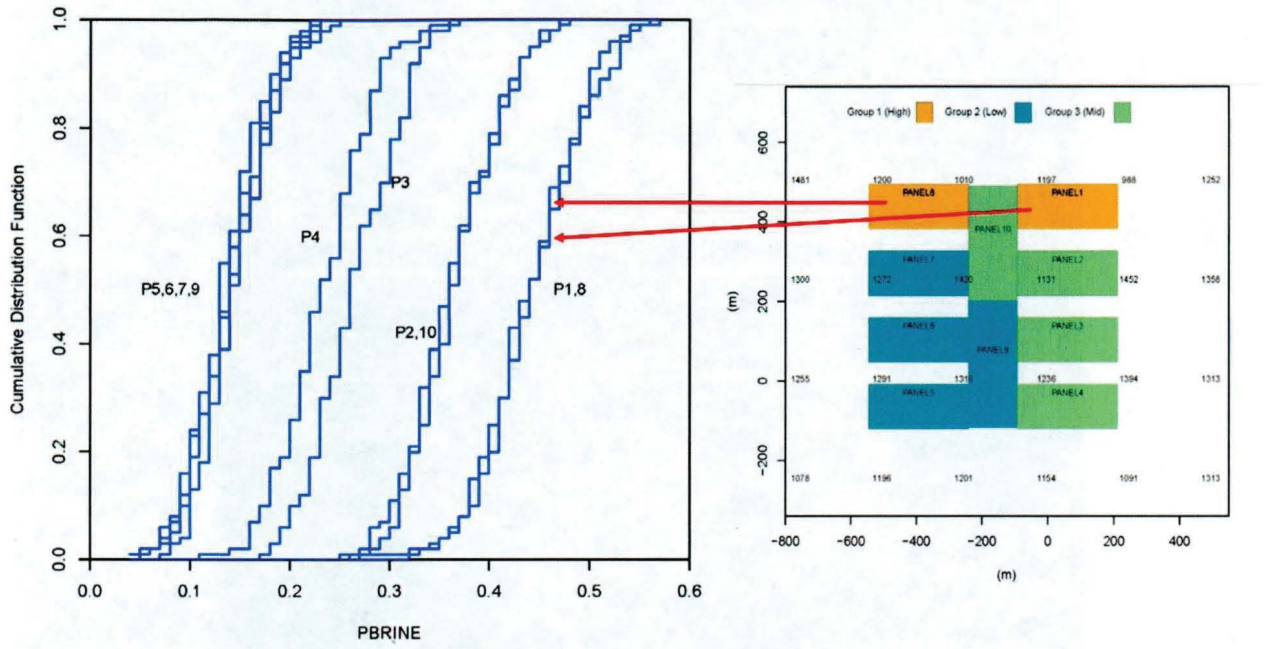



*Figure 4. Cumulative distribution functions (CDFs) of PBRINE by waste panel (left) and 10-panel layout with TDEM sounding depths (right) (reproduced and modified from Figures 4 and C-4 in EPA (2017)).*

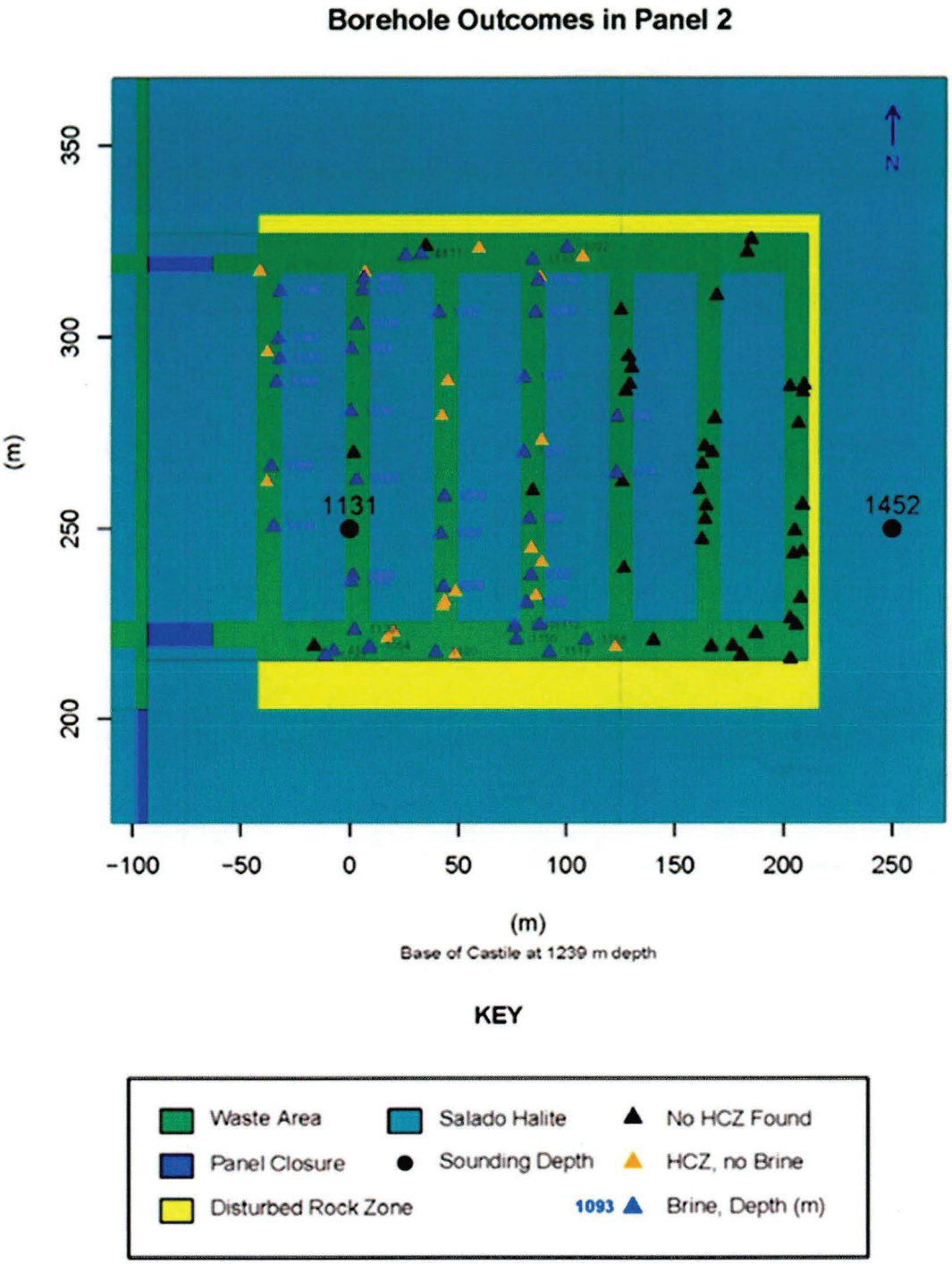



*Figure 5. Simulated borehole outcomes (i.e., brine found or not found) in Panel 2, based on EPA model (reproduced from Figure C-7 in EPA (2017)).*

## Updated Panel Layout Including Replacement Panels 11 and 12

An updated repository layout that includes 19 waste panels has been proposed (Figure 6) (Sjomeling 2019). The layout includes the 10 original panels (Panels 1-10), two replacement panels (Panels 11 and 12), and seven additional panels (Panels 13-19). The 1987 TDEM data used to construct the current PBRINE distribution included 20 data points bounding the original 10 panels, but also includes additional points extending far enough West to bound most of Panels 11 and 12. By considering the complete set of TDEM data, we are able to make inferences about how the current PBRINE distribution may be modified if contributions from Panels 11 and 12 were added to the contributions from Panels 1-10. TDEM data points were added to Figure 6 and Figure 7 by anchoring the data point in Room 6 of

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Panel 7 (consistent with overlay used in the EPA model in Figure 3) and using the 250 m separation between adjacent data points based on the TDEM survey.

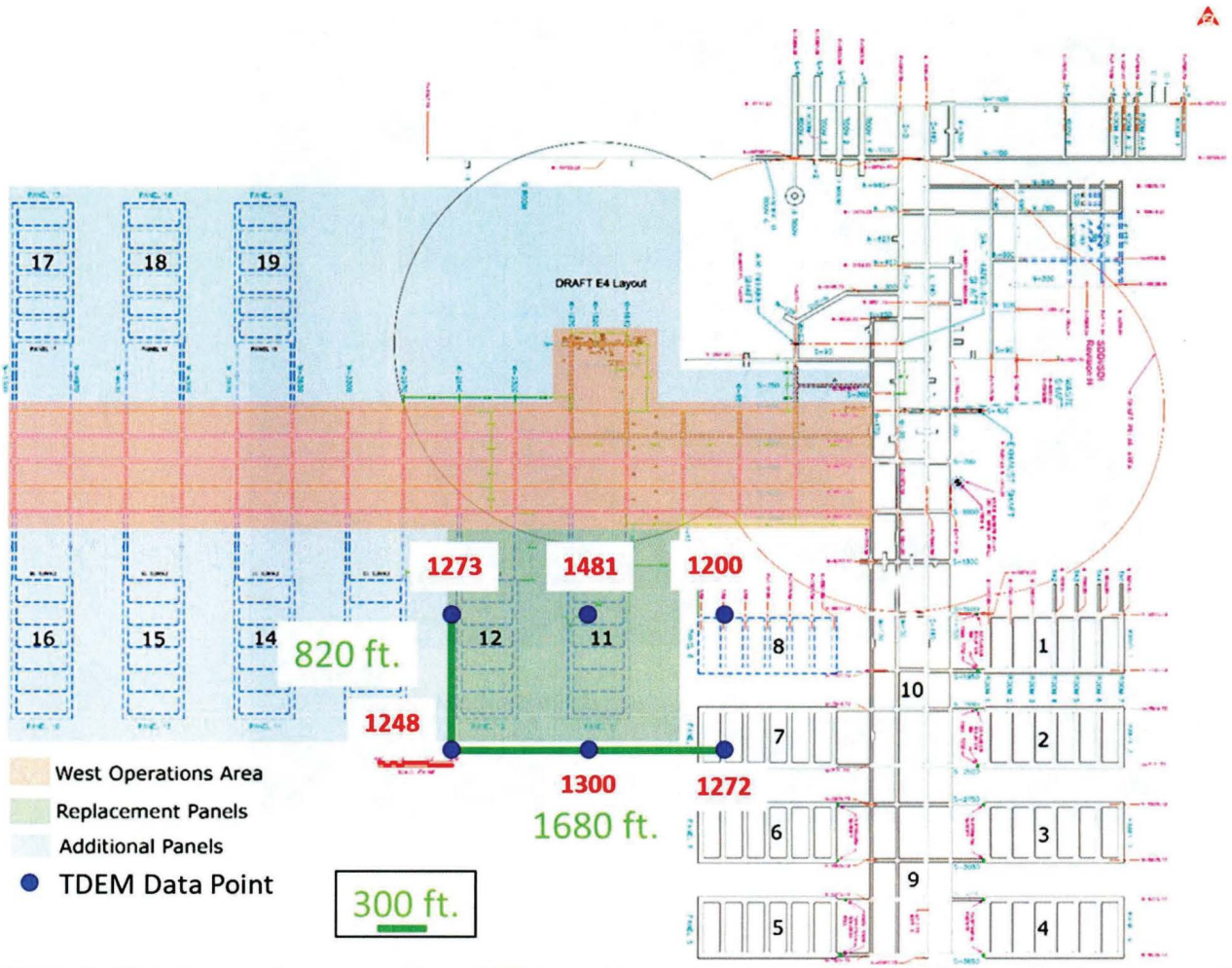



*Figure 6. Nineteen-panel representation of WIPP panel layout overlain with six TDEM sounding locations and depths (in m) (reproduced and modified from Sjomeling (2019)).*

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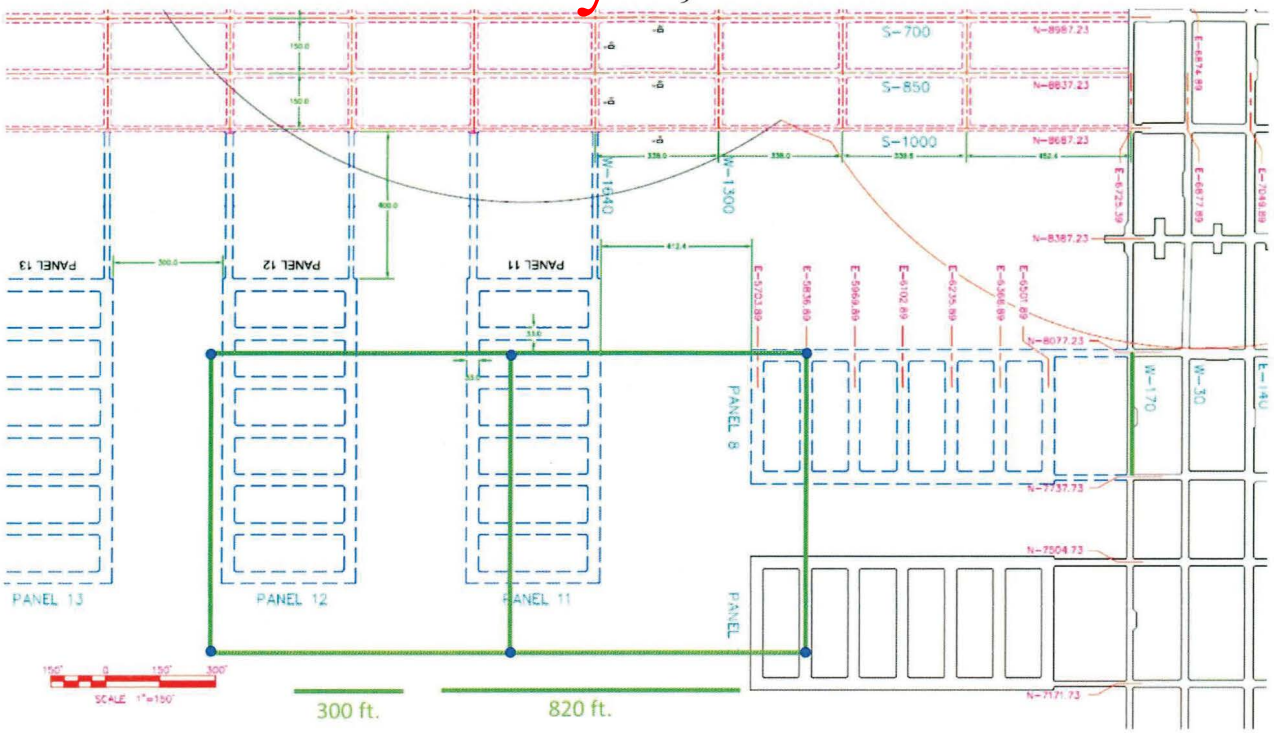




*Figure 7. Nineteen-panel representation of WIPP panel layout (zoom in on area near Panels 11 and 12) overlain with six northwesternmost TDEM sounding locations and depths (in m) (reproduced and modified from Sjomeling (2019)).*

## Interpolation of TDEM Data Across Panels 11 and 12

The limited number of TDEM sounding locations sets the resolution of our understanding of the locations of low and high probabilities of encountering brine beneath the waste panels. To give some sense of where depths to the first HCZ may be in the regions between sounding locations, a two-dimensional "heat map" was created based on linear interpolation of the TDEM sounding depths (i.e., depths to HCZ) between the TDEM sounding locations (Figure 8). The map shows shallower HCZ depths, which correlate with higher PBRINE values, in lighter yellow colors and deeper HCZ depths, which correlate with lower PBRINE values, in darker purple colors. In deriving this map, we do not consider the uncertainty in the sounding depth data. Figure 9 shows the same heat map with an overlay of the waste panels from the 19-panel design.

As shown in Figure 9, shallower depths (i.e., lighter colors) are associated with Panel 1, 2, 8, and 10. This is consistent with the relatively high probability PBRINE CDFs shown for these panels in Figure 4. For the replacement panels (Panels 11 and 12), the heat map shows relatively darker colors, indicating that the lower values of PBRINE would be associated with these panels if the EPA model were to be run on the replacement panels. As a result, the lower values of the replacement panels would decrease the overall PBRINE distribution toward lower probabilities.[1] Lower values of PBRINE are associated with lower direct brine releases (DBRs) and spallings releases, the most significant contributors to overall releases in PA. Thus, incorporating contributions to PBRINE from Panels 11 and 12, based on the observations of the heat map in Figure 9, would result in lower releases compared to using the current PBRINE distribution. One limitation here is that these conclusions are based on only a few data points; however, they are the only data currently available to estimate brine encounter probability under the waste area. The regional trend noted above in the section titled "Documented Observations of Castile Brine Encounters" supports the conclusion that there is a lower probability of encountering pressurized brine below waste panels towards the West.

[1] Note that a single value of PBRINE is chosen from the overall distribution for each realization (i.e., vector) of PA runs, such that each simulated intrusion will intersect pressurized brine with the same probability factor, independently of which panel is intersected.

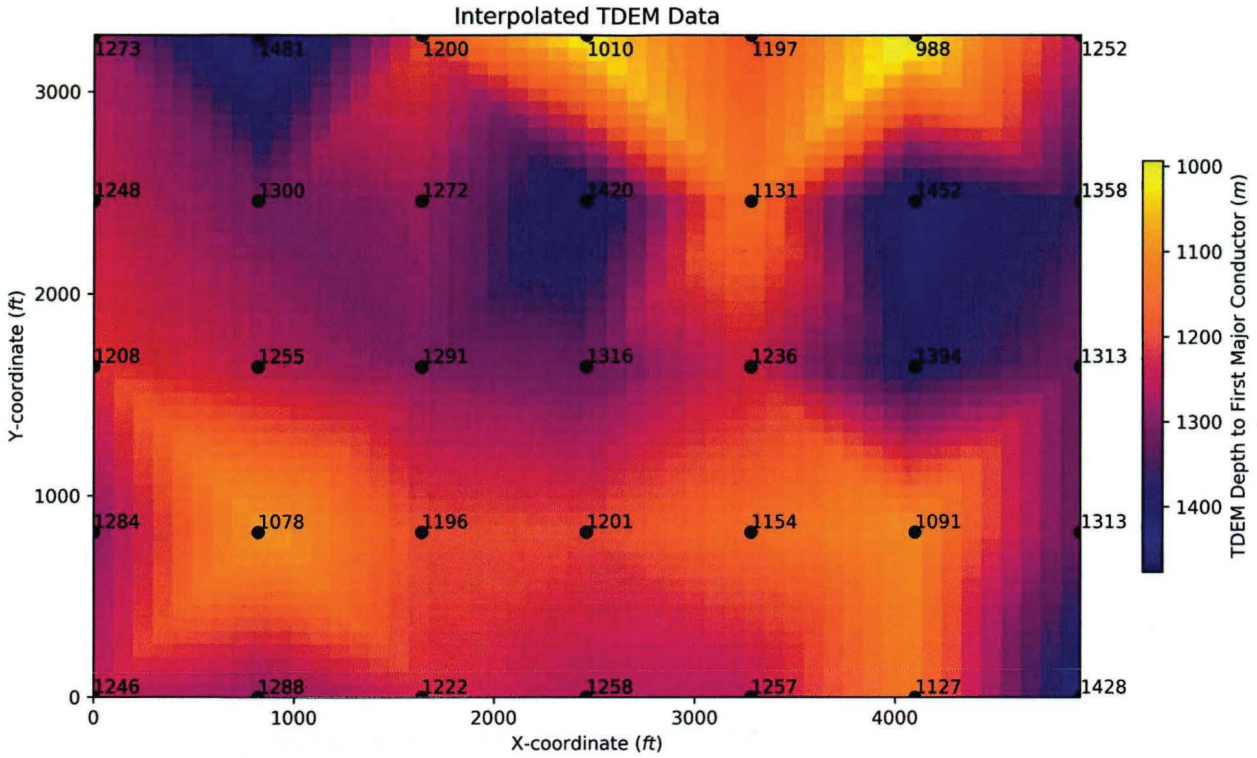



*Figure 8. Heat map of TDEM depths to first major conductor (linear interpolation between TDEM data points).*

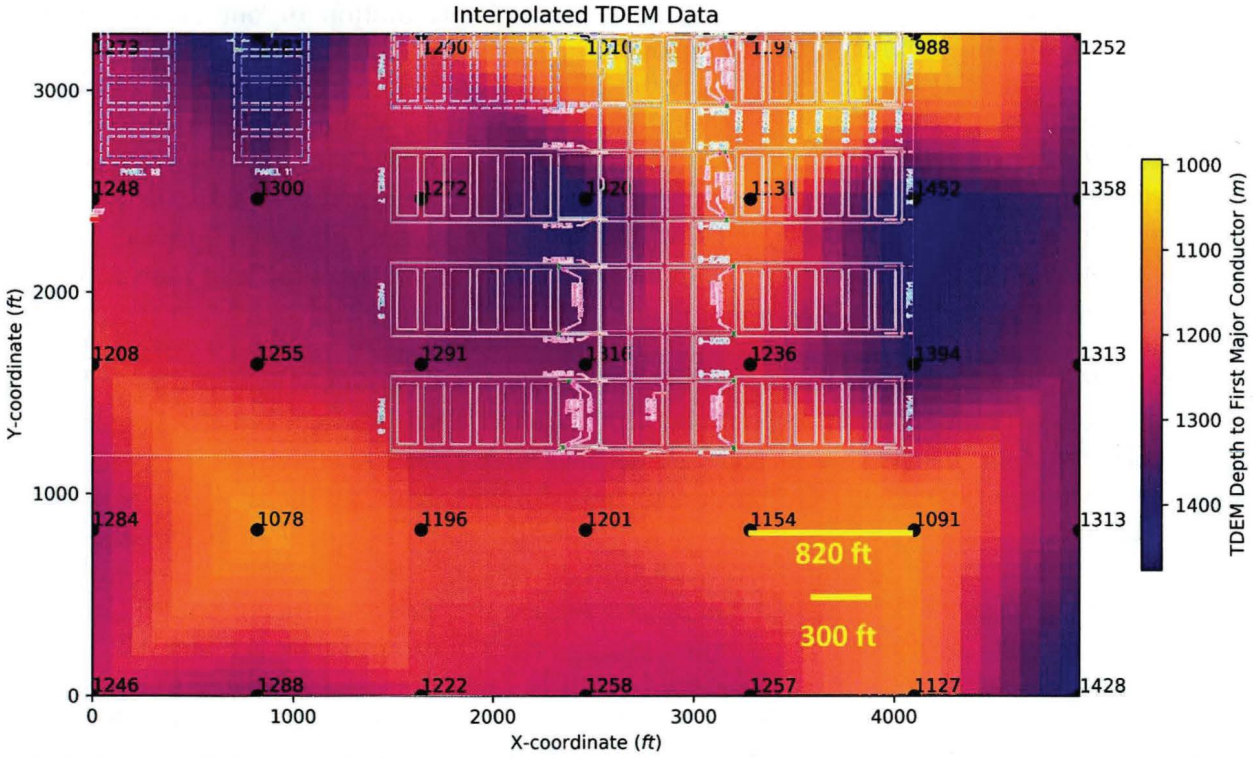



*Figure 9. Heat map of TDEM depths to first major conductor (linear interpolation between TDEM data points) with portion of 19-panel representation overlain.*

## Estimation of TDEM Sounding Depth on a Panel Basis

As a complement to the above analysis based on interpolation of colors in the TDEM depths heat map, we also consider here an estimation of an average TDEM sounding depth on a panel basis. We compare those values across all panels to confirm the relative position of Panels 11 and 12 among the existing 10

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panels with respect to contributions to an overall PBRINE distribution. First, we choose TDEM sounding locations to represent the panel area bounds for each panel. In this analysis, the bounds for a given panel are based on two to six TDEM sounding locations (Table 1). The average TDEM sounding depth is then calculated for each panel based on the sounding locations chosen to represent it. The average sounding depths are plotted in Figure 10. The following section describes the correlation of average sounding depths to estimates of PBRINE.

*Table 1. Estimated Average Sounding Depth on a Panel Basis*

| Panel Number | Bounding Sounding Depths (m) | | | | | | Estimated Average Sounding Depth (m) | Approx. PBRINE value at CDF = 0.5 |
|---|---|---|---|---|---|---|---|---|
| | D1 | D2 | D3 | D4 | D5 | D6 | | |
| 1 | 1197 | 988 | 1131 | 1452 | | | 1192 | 0.45 |
| 2 | 1131 | 1452 | | | | | 1292 | 0.35 |
| 3 | 1131 | 1452 | 1236 | 1394 | | | 1303 | 0.25 |
| 4 | 1236 | 1394 | 1154 | 1091 | | | 1219 | 0.22 |
| 5 | 1196 | 1201 | 1291 | 1316 | | | 1251 | 0.15 |
| 6 | 1291 | 1316 | 1272 | 1420 | | | 1325 | 0.15 |
| 7 | 1272 | 1420 | | | | | 1346 | 0.15 |
| 8 | 1272 | 1420 | 1200 | 1010 | | | 1226 | 0.45 |
| 9 | 1201 | 1154 | 1316 | 1236 | 1420 | 1131 | 1243 | 0.15 |
| 10 | 1420 | 1131 | 1010 | 1197 | | | 1190 | 0.35 |
| 11 | 1200 | 1272 | 1300 | 1481 | | | 1313 | 0.20 |
| 12 | 1300 | 1481 | 1248 | 1273 | | | 1326 | 0.18 |

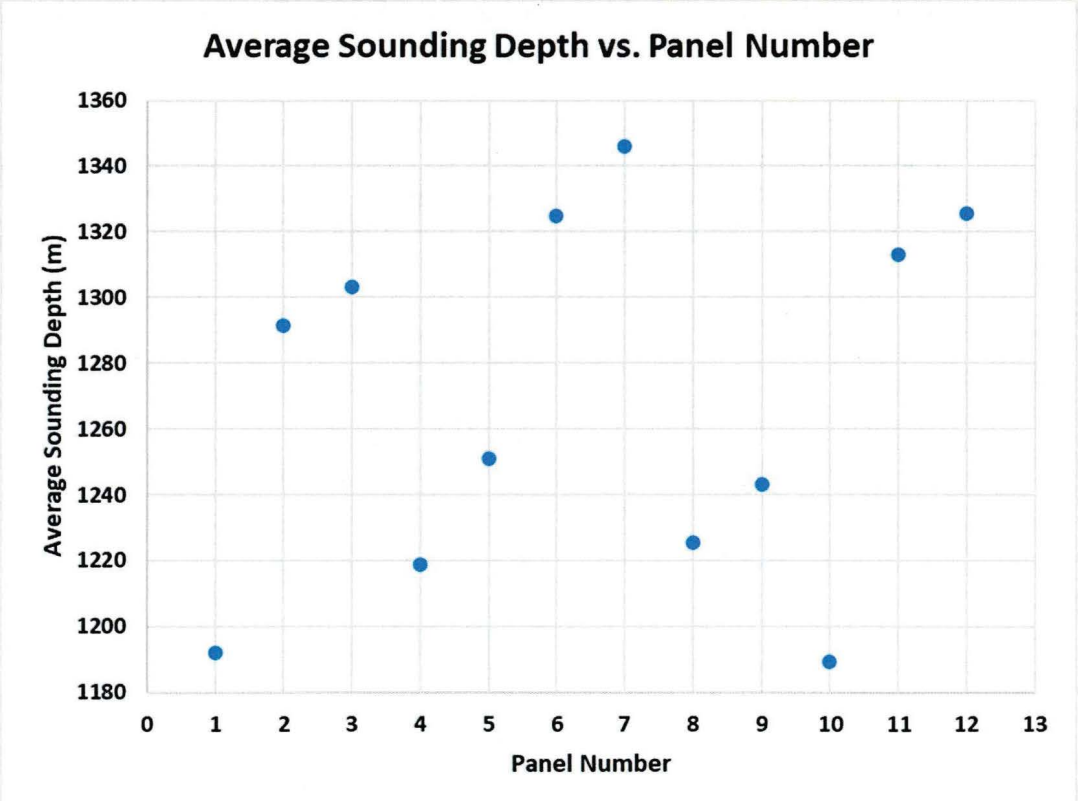



*Figure 10. Estimated average sounding depth for Panels 1-12, based on sounding depths in and around each panel.*

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## Estimation of PBRINE on a Panel Basis via Estimated Sounding Depth

To estimate a contribution to the overall PBRINE distribution for each panel, the median probability was identified for each panel. Figure 11 shows how the median PBRINE value was taken for Panels 1-10 based on the PBRINE value at which the CDF is equal to 0.5. The values are tabulated in Table 1 in the previous section.

In Figure 12, the median PBRINE values are plotted against average sounding depth from the previous section. The overall correlation is for PBRINE to decrease as sounding depth increases, although a linear fit shows a low $R^2$ value of 0.33. The trend is in agreement with the fundamental assumptions of the EPA model; i.e., that shallower depths to the HCZ are indicative of higher probabilities of encountering pressurized brine.

Also plotted on Figure 12 are points representing Panels 11 and 12 (points P11 and P12). They are plotted based on the average sounding depths calculated above and the assumption that they land on the linear fit to the points representing the other 10 panels. The shaded rectangles represent the three categories of panels identified by the EPA in Figure 4 above based on relative values of PBRINE: "high" in orange (Panels 1 and 8), "low" in blue (Panels 5, 6, 7, and 9), and "mid" in green (Panels 2, 3, 4, and 10).

The average sounding depths calculated for Panels 11 and 12 put these panels above all of the "high" and "mid" panels, which correlates them to PBRINE probabilities below those for the six panels in those two groups. Based on the linear fit, Panels 11 and 12 would be expected to have median PBRINE values between 0.15 and 0.2. With the low $R^2$ value of the linear fit, there is still considerable uncertainty for this correlation. Note that Panels 5 and 9 (points P5 and P9) belong to the "low" grouping, yet have average sounding depths lower than Panels 11 and 12, meaning higher values of PBRINE would be expected based on the overall correlation. If Panels 11 and 12 had average sounding depths as shallow as these two "low" panels, the linear fit would predict median PBRINE values in the range 0.25-0.3 and Panels 11 and 12 would be classified into the "mid" group.

Nonetheless, based on the average sounding depths calculated here, Panels 11 and 12 are predicted to be on the low end of contributors to the overall PBRINE distribution. The linear fit approach gives evidence that if contributions from Panels 11 and 12 were made to the overall PBRINE distribution, the overall distribution would likely skew lower, such that the current distribution leads to higher releases calculated in WIPP PA.

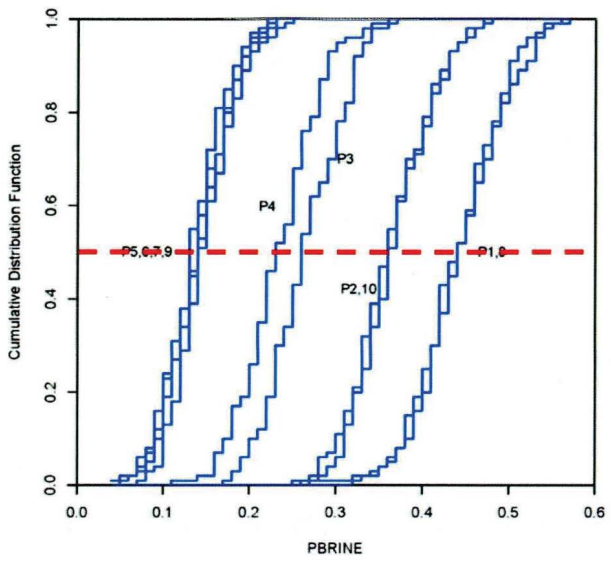



*Figure 11. Cumulative distribution functions (CDFs) of PBRINE by waste with median value (CDF=0.5) highlighted (reproduced and modified from Figure 4 in EPA (2017)).*

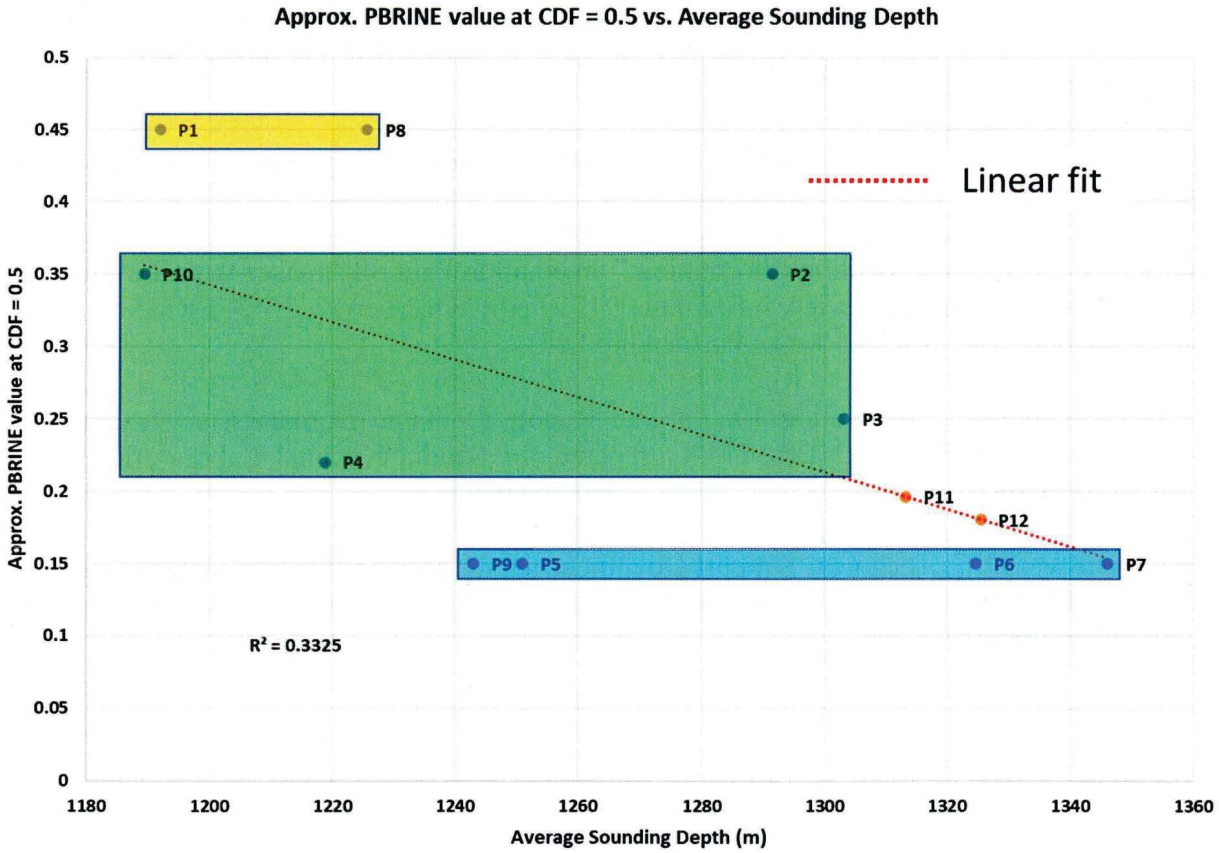



*Figure 12. EPA-generated median PBRINE value plotted versus estimated averaged sounding depth (calculated herein) for each panel along with a linear fit. Shaded areas correspond to panel groups identified by the EPA in Figure 4.*

## Conclusions

Three approaches have been undertaken to judge the appropriateness of using the EPA-derived PBRINE distribution for PA calculations in which the planned panel layout extends beyond the 10 panels used to derive that distribution. First, observations of Castile brine encounters near the WIPP site indicate that

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pressurized brine is less likely to be found toward the West; this indicates that Panels 11-19 would more likely have lower values of PBRINE than Panels 1-10. Second, observations of a 2D "heat map" of TDEM sounding depths show deeper HCZ depths in the areas near Panels 11 and 12; this indicates that Panels 11 and 12 would more likely have values of PBRINE on the lower side of the current PBRINE distribution. Third, an estimate of PBRINE was calculated for Panels 11 and 12 based on an assumed linear relationship between average sounding depth in the area around a panel and the median value of PBRINE calculated by the EPA for each panel; the results indicate that Panels 11 and 12 would more likely have values of PBRINE on the lower side of the current PBRINE distribution. In conclusion, we have determined that the current PBRINE distribution is adequate for a 12-panel representation and likely adequate for a 19-panel representation.

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