

Waste Isolation Pilot Plant  
Compliance Certification Application  
**Reference 694**

Wilmot, R.D., and Galson, D.A. 1996.  
Human-Initiated Brine Density Changes. Summary Memo of Record for NS17 and  
NS18. SWCF-A 1.1.6.3:PA:QA:TSK;NS-17, NS-18. Sandia National Laboratories,  
Albuquerque, NM WPO 39424.

WFO 39424

INFORMATION ONLY

# HUMAN-INITIATED BRINE DENSITY CHANGES

## Qualitative screening arguments for Side Efforts NS-17, NS-18

For Review

R.D. Wilmot, Galson Sciences Ltd  
D.A. Galson, Galson Sciences Ltd

A.L.C.  
D.A. Galson

b) 7/96

D.R. Anderson

22 May 1996

### Recommended Screening Decision

Changes in brine density resulting from historical, current and near-future human-initiated EPs outside the controlled area have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Changes in brine density resulting from future drilling inside and outside the controlled area have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Changes in brine density resulting from future human-initiated EPs other than drilling have been eliminated from performance assessment calculations on regulatory grounds.

### Screening Issue

The evaluation of compliance with 40 CFR 191 requires the consideration of human-initiated events and processes (EPs). A distinction is made between historical and current events and processes that are taking place or have recently taken place outside the controlled area, events and processes initiated outside the controlled area in the near future (prior to closure of the WIPP), and those that might be initiated in the future either within or outside the controlled area.

The observational data obtained as part of the WIPP site characterization reflect any changes that human activities may have had up to the time of submission of the Compliance Certification Application (CCA). Thus, the effects of historical and current human-initiated events and processes are an inherent part of performance assessment calculations. Human activities initiated outside the controlled area in the near future could potentially influence the performance of the disposal system and require consideration if they are expected to occur based on leases and plans existing at the time of submission of the CCA. The EPA has provided criteria relating to future human activities in 40 CFR §194.32(a) that limit the scope of consideration of future human actions in performance assessments to mining and drilling. Compliance assessments need consider only the effects of historical, current and near-future human activities on the performance of the disposal system.

Both mining and drilling in the vicinity of the WIPP may cause changes in fluid density in units above the Salado. Potash mining, and the associated processing, could cause local increases in brine densities in the Culebra. Oil and gas exploration and production boreholes that penetrate pressurized brine pockets in the Castile could give rise to brine flow to the Rustler through degraded casing. Similarly, disposal of oil/gas production byproducts could alter fluid densities should leaks develop in the borehole casing. There are no near-future or future human actions that are likely to reduce brine densities; operations such as waterflooding use fluids derived from the target reservoir, or fluids with a similar composition, to avoid scaling and other reactions. The effects of leakage from waterflood boreholes would be similar, therefore, to leakage from disposal wells.

Denser fluids have a tendency to sink relative to less dense fluids and, if the hydrogeological unit concerned has a dip, there will be a tendency for the dense fluid to travel in the downdip direction. If this direction is the same as the direction of the groundwater pressure gradient, there would be an increase in flow velocity, and conversely, if the downdip direction is opposed to the direction of the groundwater pressure gradient, there would be a decrease in flow velocity. In general terms, taking account of density-related flow will cause a rotation of the flow vector towards the downdip direction that is dependent on the density contrast and the dip (see Davies (1989) and Appendix 1 for further details).

### **Basis for Recommended Screening Decision**

#### *Historical, Current and Near-Future Human-Initiated EPs*

Historical and current human-initiated events and processes taking place outside the controlled area have changed fluid densities within the Culebra (Davies, 1989 p. 43), as demonstrated by the areas of higher densities around boreholes WIPP-27 and WIPP-29 (Figure NS-17.1). Transient groundwater flow calculations (Davies, 1989, pp. 77-81) show that brine density variations to the west of the WIPP site caused by historical and current potash processing operations will not persist, because the rate of groundwater flow in this area is fast enough to flush the high density groundwaters to the Pecos River. These calculations also show that accounting for the existing brine density variations in the region east of the WIPP site, where hydraulic conductivities are low, would have little effect on the direction or rate of groundwater flow. Changes in fluid densities from historical and current human-initiated EPs can therefore be excluded from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Compliance assessments and performance assessments need to consider the effects of any potash mining that takes place in the near-future outside the controlled area, in addition to the effects of drilling and other activities that could lead to changes in brine density in the Culebra. The distribution of existing leases and potash grades suggests that near-future mining will take place to the north, west, and south of the controlled area (Westinghouse, 1996). Consistent with the

guidance in the Supplementary Information to 40 CFR Part 194 concerning the consideration of future mining, the direct effect of this near-future potash mining is assumed to be an increase in the transmissivity of the Culebra above the mined region. Groundwater modeling that accounts for mining shows a change in the fluid pressure distribution, and a consequent shift of flow directions, in the Culebra within the controlled area, towards the west (Wallace, 1996). A localized increase in fluid density in the Culebra, in the mined region or elsewhere outside the controlled area, resulting from intersection of a pressurized brine pocket in the Castile or other drilling-related activities, would rotate the flow vector towards the downdip direction - towards the east. A comparison of the relative magnitudes of the freshwater head gradient and the gravitational gradient shows, however, that the density effect is of low consequence to the performance of the disposal system (see Appendix 1).

Changes in brine density from historical, current and near-future human-initiated EPs outside the controlled area have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

#### *Future Human-Initiated EPs*

The EPA has provided criteria relating to future human activities in 40 CFR §194.32(a) that limit the scope of consideration of future human actions in performance assessments to mining and drilling. The EPA provides additional criteria concerning the type of future mining that should be considered in 40 CFR §194.32(b), which limits assessments to a consideration of "... changes in the hydraulic conductivity of the hydrogeologic units of the disposal system from excavation mining for natural resources." The effects of changes in brine density resulting from future mining can therefore be eliminated from performance assessment calculations on regulatory grounds.

The type of future human activity that need be considered in performance assessments is limited further by 40 CFR §194.33(d), which states that "... performance assessments need not analyze the effects of techniques used for resource recovery subsequent to the drilling of the borehole" and by 40 CFR §194.33(b)(1), which states that "(i)adventent and intermittent intrusion by drilling for resources ... is the most severe human intrusion scenario." The effects of brine density changes arising from future post-drilling activities such as waterflooding can therefore be eliminated from performance assessment calculations on regulatory grounds.

Future inadvertent intrusion could intercept a pressurized brine pocket in the Castile, and brines could be injected into the Culebra with a consequent localized increase in fluid density. The effect of such a localized increase in fluid density would be to increase any gravity-driven component of groundwater flow. If the downdip direction, along which the gravity-driven component would be directed, is different to the direction of the groundwater pressure gradient, there would be a rotation of the flow vector towards the downdip direction (see Davies (1989) and Side Effort NS-19 for further details).

The groundwater modeling presented by Davies (1989) indicates that an intrusion borehole that intersects the excavation and a pressurized brine pocket, and causes a localized increase in fluid density in the Culebra above the waste panels, would rotate the flow vector slightly towards the east. The magnitude of this effect would be small, however, in comparison to the effects of the head gradient (Appendix 1), and such a localized increase in density would not divert radionuclides into the high-transmissivity zone within the Culebra.

Over the 10,000-year period of regulatory concern, the EPA requires the DOE to assume that a large number of boreholes will be drilled within and around the controlled area. If sufficient of these boreholes intersect pressurized brine pockets and connect with the Culebra, density changes in the Culebra may become widespread. Geophysical measurements and borehole records indicate that the most probable locations for pressurized brine in the Castile, and hence for higher densities in the Culebra, are to the south and north of the waste panels (Earth Technology Corp., 1988; SNL, 1992).

Gravity effects related to increase in density of Culebra groundwaters south of the waste panels will be small in comparison to freshwater head gradients (see Appendix 1). The calculations undertaken by Davies (1989) show that a density increase in the northern part of the controlled area could rotate the flow vector and hence affect flow in the region of the waste panels. These calculations did not, however, consider any effects of mining and were based on a very flat pressure gradient in this region. Accounting for potash mining, following the methodology suggested by the EPA, results in a rotation of the freshwater head gradient towards the west<sup>1</sup>. Density-related gravity effects would oppose this gradient, and increase travel times to the western boundary of the controlled area. Although locally significant, these effects would not affect flow south of the waste panels or divert radionuclides into the high-transmissivity zone within the Culebra.

In summary, then, brine density changes brought about through future drilling will be of low consequence to the performance of the disposal system.

---

<sup>1</sup> The effects of changes in brine density resulting from future mining have been eliminated from performance assessment calculations on regulatory grounds, but the hydrogeological effects of potash mining need to be accounted for in the analysis of the effects of intrusion into a pressurized brine reservoir in the Castile. The distribution of existing leases and potash grades suggests that near-future mining will take place to the north, west, and south of the controlled area, and that future mining may extend from this region into the eastern part of the controlled area, but not to the area directly above the waste panels. Consistent with 40 CFR §194.32(b), the direct effect of potash mining is assumed to be an increase in the transmissivity of the Culebra above the mined region. Groundwater modeling that accounts for mining shows a change in the fluid pressure distribution, and a consequent shift of flow directions within the Culebra towards the west and away from the high-transmissivity zone within the Culebra. Some re-direction of flow inside the controlled area is calculated to take place as a result of near-future mining outside the controlled area. Future mining inside the controlled area results in a more pronounced re-direction of flows towards the west (Wallace, 1996).

## References

Davies, P.B., 1989. Variable-density ground-water flow and paleohydrology in the Waste Isolation Pilot Plant (WIPP) region, southeastern New Mexico. U.S. Geological Survey, Open File Report 88-490.

Earth Technology Corp., 1988. *Final Report for Time Domain Electromagnetic (TDEM) Surveys at the WIPP Site*. SAND87-7144. Albuquerque, NM: Sandia National Laboratories.

Sandia National Laboratories. 1992. *Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992*. SAND92-0700, Vols. 1-5. Sandia National Laboratories, WIPP Performance Assessment Division, Albuquerque, NM.

Wallace, M.G., 1996. Subsidence associated with mining inside or outside the controlled area. Summary Memo of Record NS-11. Errata SWCF-A 1.1.6.3:PA:QA:TSK:NS-11.

Westinghouse Electric Corporation, 1996. Future mining events in the performance assessment. Memo from B. A. Howard to M. Marietta, SNL, February 29, 1996.

---

## Appendix 1

Groundwater flow may be influenced by a density gradient as well as by the gradient of fluid pressure. If fluid density is constant across the region of concern, flow can be assumed to be horizontal, and pressure gradients can be represented by equivalent freshwater heads. If, however, there is spatial variability in fluid density, the density-related component of flow will be in the down-dip direction, which may be in a different direction to the pressure gradient.

Flow in an isotropic medium (Darcy's Law) is governed by the gradient of fluid pressure and a gravitational term.

$$\bar{v} = -\frac{k}{\mu}[\nabla p - \rho \bar{g}]$$

Where:

$\bar{v}$	=	Darcy velocity vector	(m s <sup>-1</sup> )
$k$	=	intrinsic permeability	(m <sup>2</sup> )
$\mu$	=	fluid viscosity	(pa s)
$\nabla p$	=	gradient of fluid pressure	(pa m <sup>-1</sup> )
$\rho$	=	fluid density	(kg m <sup>-3</sup> )
$\bar{g}$	=	gravitational acceleration vector	(m s <sup>-2</sup> )

The relationship between the gravity-driven flow component and the pressure-driven component can be shown by expressing the velocity vector in terms of a freshwater head gradient and a density-related elevation gradient:

$$\bar{v} = -K \left[ \nabla H_f + \frac{\Delta \rho}{\rho_f} \nabla E \right]$$

where:

$K$	=	hydraulic conductivity	$(m^2 s^{-1})$
$\nabla H_f$	=	gradient of freshwater head	$(-)$
$\Delta \rho$	=	difference between actual fluid density and reference fluid density	$(kg m^{-3})$
$\rho_f$	=	density of freshwater	$(kg m^{-3})$
$\nabla E$	=	gradient of elevation	$(-)$

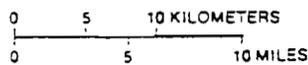
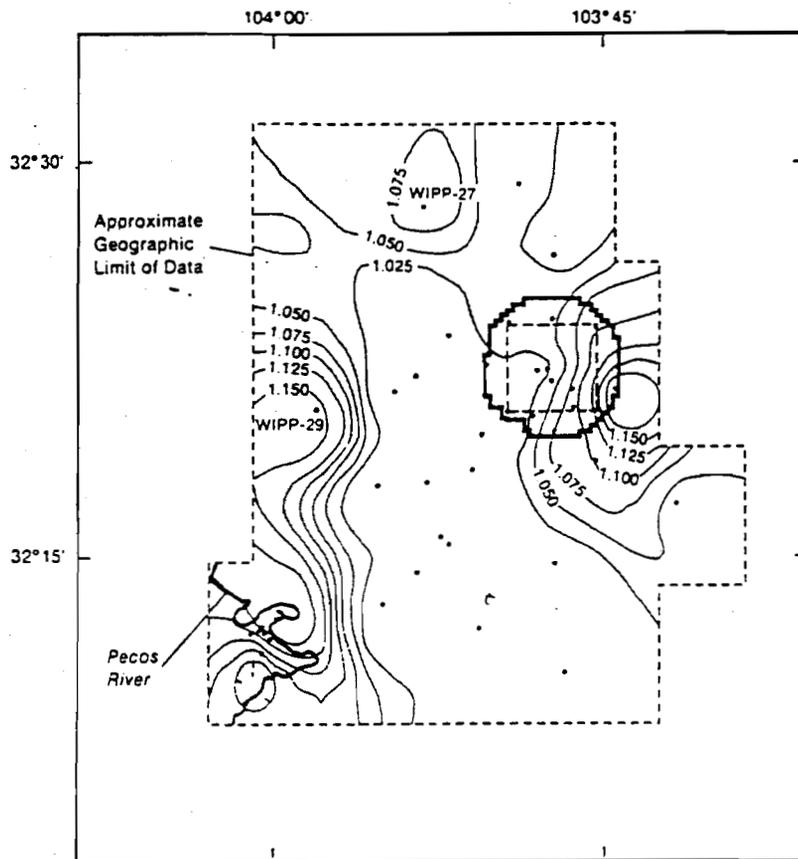
Davies (1989) defined a driving force ratio (DFR) to assess the potential significance of the density gradient:

$$DFR = \frac{\Delta \rho |\nabla E|}{\rho_f |\nabla H_f|}$$

and concluded that a DFR of 0.5 can be considered an approximate threshold at which density-related gravity effects may become significant (Davies, 1989, p. 28).

The density of Castile brines is assumed to be  $1215 \text{ kg/m}^3$  (SNL, 1992), and Culebra brines in the vicinity of the high-transmissivity zone have densities ranging from  $1050$  to  $1100 \text{ kg/m}^3$  (Davies, 1989, p. 32). The dip of the Culebra in the vicinity of the WIPP is about  $0.44^\circ$  or  $8 \text{ m/km}$  (SNL, 1992). According to Wallace (1996), freshwater head gradients in the Culebra between the waste panels and the southwestern and western boundaries of the accessible environment range from  $4 \text{ m/km}$  to  $7 \text{ m/km}$ , with only small changes in gradient arising from the calculated effects of near-future and future mining. These values lead to a DFR of between  $0.13$  and  $0.38$ .

These values of the DFR show that, in the region of the high-transmissivity zone, density-related gravity effects caused by an injection of Castile brine are not significant. Human-initiated brine density changes can, therefore, be eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.



EXPLANATION

- WIPP ZONE IV BOUNDARY
- WIPP SITE BOUNDARY
- 1.025— LINE OF EQUAL FLUID DENSITY--interval 0.025 gram per cubic centimeter
- WELL OR TEST HOLE

Figure NS-17.1 Distribution of approximate fluid density in the Culebra Dolomite Member of the Rustler Formation (Davies, 1989, p. 46)

## HUMAN-INITIATED BRINE DENSITY CHANGES

### Qualitative screening arguments for Side Efforts NS-17, NS-18

R.D. Wilmot, Galson Sciences Ltd

D.A. Galson, Galson Sciences Ltd

*DA Galson*

5 July 1996

#### Recommended Screening Decision

Changes in brine density resulting from historical, current and near-future human-initiated EPs outside the controlled area have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Changes in brine density resulting from future drilling inside and outside the controlled area have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Changes in brine density resulting from future human-initiated EPs other than drilling have been eliminated from performance assessment calculations on regulatory grounds.

#### Screening Issue

The evaluation of compliance with 40 CFR 191 requires the consideration of human-initiated events and processes (EPs). A distinction is made between historical and current events and processes that are taking place or have recently taken place outside the controlled area, events and processes initiated outside the controlled area in the near future (prior to closure of the WIPP), and those that might be initiated in the future either within or outside the controlled area.

The observational data obtained as part of the WIPP site characterization reflect any changes that human activities may have had up to the time of submission of the Compliance Certification Application (CCA). Thus, the effects of historical and current human-initiated events and processes are an inherent part of performance assessment calculations. Human activities initiated outside the controlled area in the near future could potentially influence the performance of the disposal system and require consideration if they are expected to occur based on leases and plans existing at the time of submission of the CCA. The EPA has provided criteria relating to future human activities in 40 CFR §194.32(a) that limit the scope of consideration of future human actions in performance assessments to mining and drilling. Compliance assessments need consider only the effects of historical, current and near-future human activities on the performance of the disposal system.

Both mining and drilling in the vicinity of the WIPP may cause changes in fluid density in units above the Salado. Potash mining, and the associated processing, could cause local increases in brine densities in the Culebra. Oil and gas exploration and production boreholes that penetrate pressurized brine pockets in the Castle could give rise to brine flow to the Rustler through degraded casing. Similarly, disposal of oil/gas production byproducts could alter fluid densities should leaks develop in the borehole casing. There are no near-future or future human actions that are likely to reduce brine densities; operations such as waterflooding use fluids derived from the target reservoir, or fluids with a similar composition, to avoid scaling and other reactions. The effects of leakage from waterflood boreholes would be similar, therefore, to leakage from disposal wells.

Denser fluids have a tendency to sink relative to less dense fluids and, if the hydrogeological unit concerned has a dip, there will be a tendency for the dense fluid to travel in the downdip direction. If this direction is the same as the direction of the groundwater pressure gradient, there would be an increase in flow velocity, and conversely, if the downdip direction is opposed to the direction of the groundwater pressure gradient, there would be a decrease in flow velocity. In general terms, taking account of density-related flow will cause a rotation of the flow vector towards the downdip direction that is dependent on the density contrast and the dip (see Davies (1989) and Appendix 1 for further details).

### Basis for Recommended Screening Decision

#### *Historical, Current and Near-Future Human-Initiated EPs*

Historical and current human-initiated events and processes taking place outside the controlled area have changed fluid densities within the Culebra (Davies, 1989, p. 43), as demonstrated by the areas of higher densities around boreholes WIPP-27 and WIPP-29 (Figure NS-17.1). Transient groundwater flow calculations (Davies, 1989, pp. 77-81) show that brine density variations to the west of the WIPP site caused by historical and current potash processing operations will not persist, because the rate of groundwater flow in this area is fast enough to flush the high density groundwaters to the Pecos River. These calculations also show that accounting for the existing brine density variations in the region east of the WIPP site, where hydraulic conductivities are low, would have little effect on the direction or rate of groundwater flow. Changes in fluid densities from historical and current human-initiated EPs can therefore be excluded from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Compliance assessments and performance assessments need to consider the effects of any potash mining that takes place in the near future outside the controlled area, in addition to the effects of drilling and other activities that could lead to changes in brine density in the Culebra. The distribution of existing leases and potash grades suggests that near-future mining will take place to the north, west, and south of the controlled area (Westinghouse, 1996). Consistent with the

guidance in the Supplementary Information to 40 CFR Part 194 concerning the consideration of future mining, the direct effect of this near-future potash mining is assumed to be an increase in the transmissivity of the Culobra above the mined region. Groundwater modeling that accounts for mining shows a change in the fluid pressure distribution, and a consequent shift of flow directions, in the Culobra within the controlled area, towards the west (Wallace, 1996). A localized increase in fluid density in the Culobra, in the mined region or elsewhere outside the controlled area, resulting from intersection of a pressurized brine pocket in the Castile or other drilling-related activities, would rotate the flow vector towards the downdip direction - towards the east. A comparison of the relative magnitudes of the freshwater head gradient and the gravitational gradient shows, however, that the density effect is of low consequence to the performance of the disposal system (see Appendix 1).

Changes in brine density from historical, current and near-future human-initiated EPs outside the controlled area have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

#### *Future Human-Initiated EPs*

The EPA has provided criteria relating to future human activities in 40 CFR §194.32(a) that limit the scope of consideration of future human actions in performance assessments to mining and drilling. The EPA provides additional criteria concerning the type of future mining that should be considered in 40 CFR §194.32(b), which limits assessments to a consideration of "... changes in the hydraulic conductivity of the hydrogeologic units of the disposal system from excavation mining for natural resources." The effects of changes in brine density resulting from future mining can therefore be eliminated from performance assessment calculations on regulatory grounds.

The type of future human activity that need be considered in performance assessments is limited further by 40 CFR §194.33(d), which states that "... performance assessments need not analyze the effects of techniques used for resource recovery subsequent to the drilling of the borehole" and by 40 CFR §194.33(b)(1), which states that "(i)adventent and intermittent intrusion by drilling for resources .... is the most severe human intrusion scenario." The effects of brine density changes arising from future post-drilling activities such as waterflooding can therefore be eliminated from performance assessment calculations on regulatory grounds.

Future inadvertent intrusion could intercept a pressurized brine pocket in the Castile, and brines could be injected into the Culobra with a consequent localized increase in fluid density. The effect of such a localized increase in fluid density would be to increase any gravity-driven component of groundwater flow. If the downdip direction, along which the gravity-driven component would be directed, is different to the direction of the groundwater pressure gradient, there would be a rotation of the flow vector towards the downdip direction (see Davies (1989) and Side Effort NS-19 for further details).

The groundwater modeling presented by Davies (1989) indicates that an intrusion borehole that intersects the excavation and a pressurized brine pocket, and causes a localized increase in fluid density in the Culebra above the waste panels, would rotate the flow vector slightly towards the east. The magnitude of this effect would be small, however, in comparison to the effects of the head gradient (Appendix 1), and such a localized increase in density would not divert radionuclides into the high-transmissivity zone within the Culebra.

Over the 10,000-year period of regulatory concern, the EPA requires the DOE to assume that a large number of boreholes will be drilled within and around the controlled area. If sufficient of these boreholes intersect pressurized brine pockets and connect with the Culebra, density changes in the Culebra may become widespread. Geophysical measurements and borehole records indicate that, within the controlled area, the most probable locations for pressurized brine in the Castile, and hence for higher densities in the Culebra, are to the south and north of the waste panels (Earth Technology Corp., 1988; SNL, 1992-1993; Powers et al., 1996). Recent geostatistical studies suggest that fewer than 10% of deep boreholes drilled within the area underlain by the waste panels are likely to intersect pressurized brine in the Castile, and that the probability increases significantly within the controlled area around WIPP 12 (Powers et al., 1996).

Gravity effects related to increase in density of Culebra groundwaters south of the waste panels will be small in comparison to freshwater head gradients (see Appendix 1). The calculations undertaken by Davies (1989) show that a density increase in the northern part of the controlled area could rotate the flow vector and hence affect flow in the region of the waste panels. These calculations did not, however, consider any effects of mining and were based on a very flat pressure gradient in this region. Accounting for potash mining, following the methodology suggested by the EPA, results in a rotation of the freshwater head gradient towards the west<sup>1</sup>. Density-related gravity effects would oppose this gradient, and increase travel times to the western boundary of the controlled area. Although locally significant, these effects would not affect flow south of the waste panels or divert radionuclides into the high-transmissivity zone within the Culebra.

<sup>1</sup> The effects of changes in brine density resulting from future mining have been eliminated from performance assessment calculations on regulatory grounds, but the hydrogeological effects of potash mining need to be accounted for in the analysis of the effects of intrusion into a pressurized brine reservoir in the Castile. The distribution of existing leases and potash grades suggests that near-future mining will take place to the north, west, and south of the controlled area, and that future mining may extend from this region into the eastern part of the controlled area, but not to the area directly above the waste panels. Consistent with 40 CFR §194.32(b), the direct effect of potash mining is assumed to be an increase in the transmissivity of the Culebra above the mined region. Groundwater modeling that accounts for mining shows a change in the fluid pressure distribution, and a consequent shift of flow directions within the Culebra towards the west and away from the high-transmissivity zone within the Culebra. Some re-direction of flow inside the controlled area is calculated to take place as a result of near-future mining outside the controlled area. Future mining inside the controlled area results in a more pronounced re-direction of flows towards the west (Wallace, 1996).

In summary, then, brine density changes brought about through future drilling will be of low consequence to the performance of the disposal system.

## References

Davics, P.B., 1989. Variable-density ground-water flow and paleohydrology in the Waste Isolation Pilot Plant (WIPP) region, southeastern New Mexico. Open File Report 88-490. Albuquerque, NM: U.S. Geological Survey.

Earth Technology Corp., 1988. *Final Report for Time Domain Electromagnetic (TDEM) Surveys at the WIPP Site*. SAND87-7144. Albuquerque, NM: Sandia National Laboratories.

Powers, D.W., Sigda, J.M., and Holt, R.M. Probability of intercepting a pressurized brine reservoir under the WIPP. Draft memo to M. Chu, SNL, June 18, 1996.

Sandia National Laboratories, 1992-1993. *Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992*. SAND92-0700, Vols. 1-5. Albuquerque, NM: Sandia National Laboratories, WIPP Performance Assessment Division.

Wallace, M.G., 1996. Subsidence associated with mining inside or outside the controlled area. Summary Memo of Record NS-11. Errata SWCF-A 1.1.6.3:PA:QA:TSK:NS-11.

Westinghouse Electric Corporation, 1996. Future mining events in the performance assessment. Memo from B. A. Howard to M. Marietta, SNL, April 3, 1996.

## Appendix 1

Groundwater flow may be influenced by a density gradient as well as by the gradient of fluid pressure. If fluid density is constant across the region of concern, flow can be assumed to be horizontal, and pressure gradients can be represented by equivalent freshwater heads. If, however, there is spatial variability in fluid density, the density-related component of flow will be in the down-dip direction, which may be in a different direction to the pressure gradient.

Flow in an isotropic medium (Darcy's Law) is governed by the gradient of fluid pressure and a gravitational term.

$$\bar{v} = -\frac{k}{\mu} [\nabla p - \rho \bar{g}]$$

Where:

$\bar{v}$	=	Darcy velocity vector	(m s <sup>-1</sup> )
$k$	=	intrinsic permeability	(m <sup>2</sup> )
$\mu$	=	fluid viscosity	(pa s)
$\nabla p$	=	gradient of fluid pressure	(pa m <sup>-1</sup> )
$\rho$	=	fluid density	(kg m <sup>-3</sup> )
$\bar{g}$	=	gravitational acceleration vector	(m s <sup>-2</sup> )

The relationship between the gravity-driven flow component and the pressure-driven component can be shown by expressing the velocity vector in terms of a freshwater head gradient and a density-related elevation gradient:

$$\bar{v} = -K \left[ \nabla H_f + \frac{\Delta \rho}{\rho_f} \nabla E \right]$$

where:

$K$	=	hydraulic conductivity	(m s <sup>-1</sup> )
$\nabla H_f$	=	gradient of freshwater head	(-)
$\Delta \rho$	=	difference between actual fluid density and reference fluid density	(kg m <sup>-3</sup> )
$\rho_f$	=	density of freshwater	(kg m <sup>-3</sup> )
$\nabla E$	=	gradient of elevation	(-)

Davies (1989) defined a driving force ratio (DFR) to assess the potential significance of the density gradient:

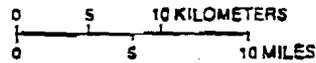
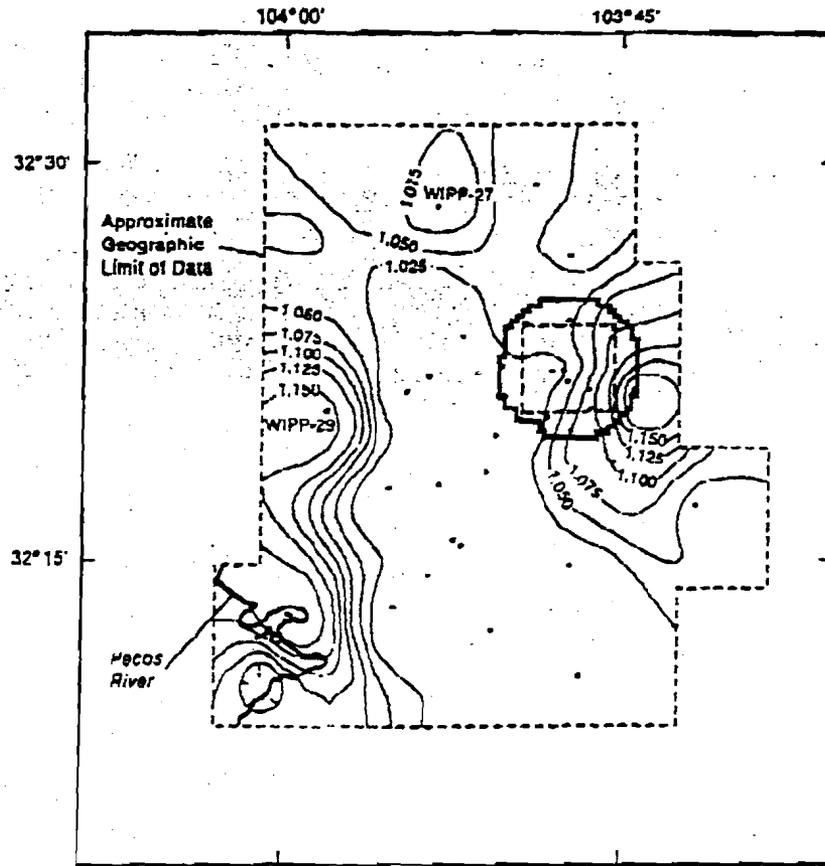
$$DFR = \frac{\Delta \rho |\nabla E|}{\rho_f |\nabla H_f|}$$

and concluded that a DFR of 0.5 can be considered an approximate threshold at which density-related gravity effects may become significant (Davies, 1989, p. 28).

The density of Castile brines is assumed to be  $1215 \text{ kg/m}^3$  (SNL, 1992-1993), and Culebra brines in the vicinity of the high transmissivity zone have densities ranging from 1050 to  $1100 \text{ kg/m}^3$  (Davies, 1989, p. 32). The dip of the Culebra in the vicinity of the WIPP is about  $0.44^\circ$  or  $8 \text{ m/km}$  (SNL, 1992-1993). According to Wallace (1996), freshwater head gradients in the Culebra between the waste panels and the southwestern and western boundaries of the accessible environment range from  $4 \text{ m/km}$  to  $7 \text{ m/km}$ , with only small changes in gradient arising from the calculated effects of near-future and future mining. These values lead to a DFR of between 0.13 and 0.38.

These values of the DFR show that, in the region of the high transmissivity zone, density-related gravity effects caused by an injection of Castile brine are not significant. Human-initiated brine density changes can, therefore, be eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Figure NS-17.1 Distribution of approximate fluid density in the Culebra Dolomite Member of the Rustler Formation (Davies, 1989, p. 46)



EXPLANATION

- WIPP ZONE IV BOUNDARY
- - - WIPP SITE BOUNDARY
- 1.025 — LINE OF EQUAL FLUID DENSITY—Interval 0.025 gram per cubic centimeter
- WELL OR TEST HOLE

### FEP Technical Review Sheet

FEP Title: Human Initiated Brine Density Changes

FEP ID: NS-17, NS-18

Documents Reviewed: Qualitative Screening Argument for Side Efforts NS 17 and NS-18

Reviewer Instructions

Check "Yes" for each item reviewed and found acceptable.

Check "No" for each item reviewed which requires further work. For NO answers, provide comments.

#### I. Technical Review

For Computational Approach

1. Are the calculations applicable, correct, and adequate?

YES

NO

NA (for reasoned argument FEPs)

For Reasoned Argument Approach

1. Are the arguments applicable, relevant, and adequate?

YES

NO

For Both Computational and Reasoned Argument Approaches

2. Are the screening recommendations derived from the calculations or reasoned arguments applicable, correct, and adequate?

YES

NO

3. Is the record package documenting the screening effort, complete?

YES

NO

4. Are candidate parameter, called out in the screening recommendations and listed in Part A of Conceptual Model/Parameter Reconciliation Form, appropriate to the FEP screening issue.

YES

NO

NA

5. Does the record packages contain sufficient information for an independent person with equivalent technical background to understand the work, evaluate the technical quality of the work, continue unfinished work, and/or reproduce the work and its primary results.

YES

NO

#### II. Approval Signatures

Signatures on this document indicate that all comments have been resolved.

Signature of technical reviewer(s) and lead staff member indicates that the package reviewed was complete, accurate, and acceptable.

Technical Reviewer(s) (attach pages as needed)

Name (Print) Wendell Dilworth Signature Wendell Dilworth Date 7/10/96

Lead Staff Approval  
Lead Staff

Name (Print) Daniel A. Galson Signature Daniel A. Galson Date 10 July-96

Signature of department manager indicates that the individuals who signed as preparers and reviewers were qualified to perform their tasks, and that the department manager approved of the work product.

Department Manager

Name (Print) M. E. Fewell Signature M. E. Fewell Date 7/11/96  
for D.R. Anderson

08/07 '96 16:15  
 001572 770650  
 GALSON SCIENCES + + + SNT  
 002/012

WASTE ISOLATION PILOT PLANT Sandia National Laboratories	<h2 style="margin:0;">Document Review and Comment</h2> <p>Form Number: 430      Effective: 7/31/95</p>	Procedure: <u>QAP 6-3</u> Revision: <u>1</u> Page <u>1</u> of <u>1</u>
---	--	--

This form may be used for test plans, procedures, reports, design packages, abstracts, and Technical Operating Procedures

Title: Human-Initiated Brine Density Changes (Side Efforts NS-17 and NS-18)

Pre-Publication       Post-Publication

Reviewer's Comments			Author/Designer's Response			Reviewer's Response		
Item No.	Ref. Loc.	Mandatory F	Comment	Accept	Reject	Reasoning	Accept	Reject
1			I agree with the logic and approach taken to eliminate NS-17 and NS-18 from the P.A. modeling	✓				
2	Pg 4, P2		Has the recent study by Dennis Powers on Brine Reservoir encounter statistics been considered in the statements about brine reservoir locations. Are the comments about probable encounters to the south still within site boundary?	✓		Reference made in the work of Powers et al.  The probable encounters to the south are within the site boundary based on geophys. data.		

Reviewed By: <u>Wendell Dukat</u> Response Prepared By: <u>D.A. Galson</u> <small>Author/Designer Name</small>	Date: <u>6/13/96</u> Date: <u>7/5/96</u>	Response Concurrence: <u>Wendell Dukat</u> <small>Reviewer Name</small> Date: <u>7-9-96</u> To Be Completed on First Page Only
--	---	--