

**EVALUATION OF
POTENTIAL WATER-RESOURCE IMPACTS
FROM BLM PROPOSED
RESOURCE MANAGEMENT PLAN AMENDMENT
FOR FEDERAL FLUID MINERALS LEASING
AND DEVELOPMENT IN THE SALT BASIN, NEW MEXICO**

prepared by

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OVERVIEW

In January 2004, the Bureau of Land Management issued its *Proposed Resource Management Plan Amendment and Final Environmental Impact Statement for Federal Fluid Mineral Leasing and Development in Sierra and Otero Counties* (BLM, 2003), a document which outlines the terms and conditions under which oil and gas exploration and production activity may take place in southern New Mexico, including the ecologically sensitive Otero Mesa.

In short, our analysis finds that the proposed BLM plan does not assure that the public water supply will be protected from oil and gas exploration and production. The BLM plan puts in place no special provisions for protection of ground-water resources, which is to say the public water supply. This is despite the vulnerability of the aquifer under the Otero Mesa, which can be inferred from fracture mapping, the direction of ground-water flow, and the proximity of water supply wells to the BLM land proposed for oil and gas developments.

Specific findings, including the BLM plan's flaws, existence of other water contamination cases in New Mexico and the potential for contaminant migration, are outlined below.

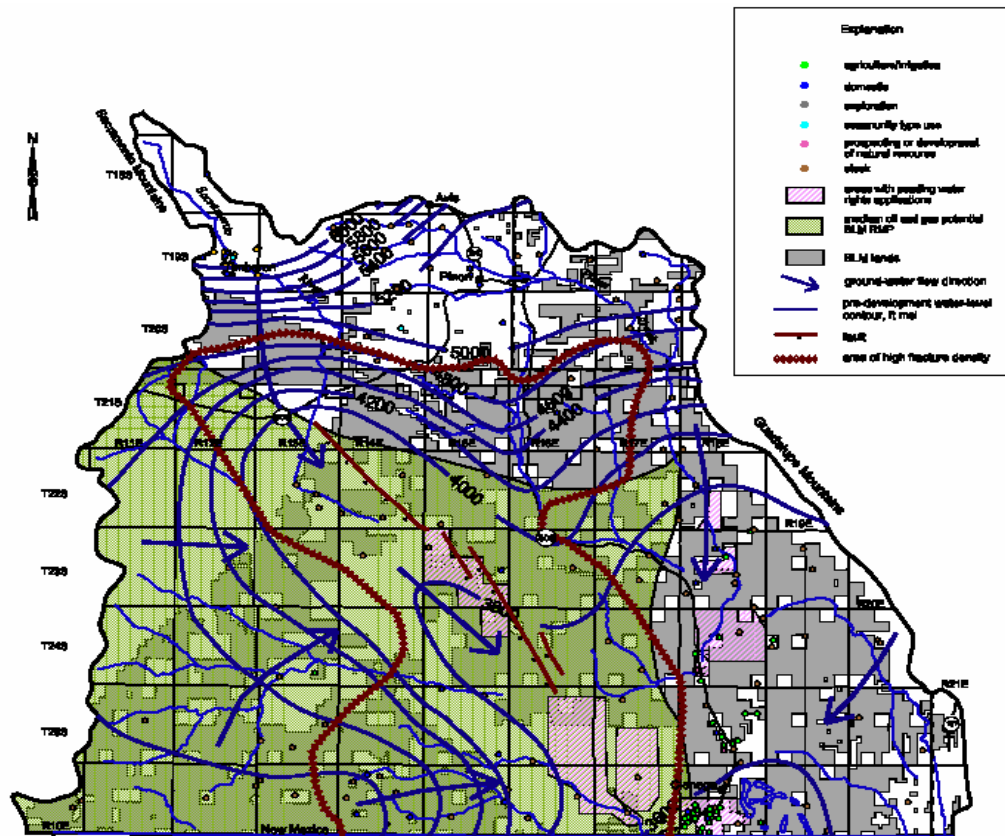
Key BLM Plan Flaws

- The proposed plan leaves approximately 70 percent of the public land open with standard lease terms and conditions and no special provisions for protection of ground-water resources (public water supply). Proposed activities may include oil and gas exploration and development, with the potential for injection wells to dispose waste. Proposed activities and protection of identified water resources (public water reserves) would be regulated under standard lease terms and conditions (BLM, 2003).
- Depth to water in the central part of the basin is around 200 ft, and many of the wells that produce from shallow perched ground water may have depth to water less than 100 ft (see well data in Appendix A). The BLM RMP and EIS does not include the shallow depth to water data in the analysis of water-resource impacts.
- The possibility of injection wells should be omitted from the RMP given the widespread distribution of fresh "public ground water beneath the Salt Basin, and the fractured nature of the aquifer(s)."

Vulnerability of Water Supply Beneath Otero Mesa

The vulnerability of the aquifer beneath the Otero Mesa can be inferred from fracture mapping performed by Mayer (1995), the direction of ground-water flow, and the proximity of water supply wells to the BLM land proposed for oil and gas development (shown on the attached map). In many areas there are existing or proposed water supply wells in the same area as BLM land proposed for oil and gas development.

The areas of highest vulnerability for contamination of the regional aquifer beneath Otero Mesa are in the areas where the fracture density is highest in the central part of the Salt Basin (see map below).



Examples of Water-quality Impacts from Oil and Gas Development in New Mexico

Water-quality impacts from oil and gas drilling have occurred, on a regional scale, in the San Juan Basin, Lea County in southeastern New Mexico, and in the artesian aquifer along the Pecos River Valley. Some examples are described as follows.

- The New Mexico Oil Conservation Division (OCD) and the BLM are involved in energy development within the San Juan Basin. Oil and gas production there are sources of contamination by Polycyclic Aromatic Hydrocarbons (PAH), a growing water quality concern for threatened and endangered fish in the San Juan River.
- The aquifer that supplies the City of Artesia’s water supply wells was impacted with manganese and sulfur compounds by oil and gas drilling. This contamination has limited the areas and well depth for future water -supply wells.

- The City of Jal in southeastern New Mexico had a well field that was impacted by brine water and organic compounds from oil and gas drilling operations in the mid 1970's. The well field was abandoned, and a new well field was developed to the west away from the oil and gas drilling activity.

Type of Contaminants Associated With Oil and Gas Development

Types of contaminants from oil and gas development sites in Texas are well documented, and typically include petroleum hydrocarbons and dissolved solids, such as Brine (Cl, TDS), Chromium, Chloride, Condensate, Crude Oil, Hydrochloric acid, Hydrocarbons, Sodium Chloride, Natural Gas, Natural Gas liquid, Oil, Salt Water, and Total dissolved solids (TNRCC SFR-20, April 1995).

Potential for Contaminant Migration in Salt Basin

The aquifer beneath Otero Mesa (Salt Basin) is composed of carbonate rocks of the Permian-age Bone Springs Victorio Peak Formation. This rock unit has been tectonically altered by the Otero Break; a region of numerous faults and fractures. These faults and fractures relay ground water recharge from the Sacramento Mountains to the Dell City area, where extensive ground water development has occurred.

In addition to being fractured by the Otero Break, the Bone Springs Victorio Peak aquifer has been characterized as a "karst" aquifer containing solution-cavities and caverns. There are two flow regimes that occur in karst settings, which are:

1. Pipe Flow – fluids completely fill the solution cavities and channels and the fluid movement may be described as non-turbulent pipe flow.
2. Open-Channel Flow – fluid movement occurs as subterranean streams through modest to large solution cavities and caverns (Gorelick and Others, 1993)

Either flow regime results in a tracer velocity greater than that observed in porous media such as sand and gravel.

There are no known case studies of contaminant migration for the Bones Springs Victorio Peak aquifer, although case studies and other information on the comparable Edwards Aquifer in central Texas may suggest possible examples of contaminant migration beneath Otero Mesa. Tracer velocities of 30 ft/day have been calculated for the Edwards Aquifer by Maclay and Small (1986), but the actual tracer velocity in the Bone Springs Victorio Peak aquifer would depend on the quantity of recharge and discharge driving the flow.

In summary, water supply beneath Otero Mesa is potentially vulnerable to contamination by the BLM proposed oil and gas development because of the proximity of existing and proposed water supply wells, the porous nature of the regional aquifer and the absence of any special water protection provisions in the BLM plan.

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- Figure 3. Hydrogeologic cross-section, A-A', Salt Basin.
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- Figure 5. Predevelopment ground-water elevation contours and direction of ground-water flow for the study area.
- Figure 6. Aerial photograph mosaic from September 21, 1996 of southeastern Otero Mesa, showing system of northwest-trending lineaments.
- Figure 7. Map of Salt Basin, southern New Mexico, showing existing wells and locations of pending water-rights applications.

APPENDICES

(follow illustrations)

- Appendix A. List of water -supply wells in the Salt Basin
- Appendix B. Selected pages and figures from Mayer, 1995
- Appendix C. Selected parts of the Regional and State Water Plans

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1.0 INTRODUCTION

John Shomaker & Associates, Inc. (JSAI) was contracted by the Otero Mesa Coalition to provide a technical opinion on the U.S. Department of Interior Bureau of Land Management (BLM) proposed resource management plan for the Otero Mesa area. The BLM document is titled *Proposed Resource Management Plan Amendment and Final Environmental Impact Statement for Federal Fluid Mineral Leasing and Development in Sierra and Otero Counties* (BLM, 2003).

The primary area of concern and review is the Otero Mesa and surrounding area within the Salt basin, New Mexico (Fig. 1). As stated in the Resource Management Plan (RMP), some of the criteria in developing the plan included (but was not limited to) the following:

1. Provide for the protection of water resources
2. Maintain public health and safety
3. Consider social and economic effects

1.1 BLM Proposed Plan

According to the proposed plan, the majority of public land in the Salt Basin part of Otero County would remain open to fluid mineral leasing. The BLM (public land) in the Salt Basin is shown on Figure 1, and comprises more than 70 percent of the basin (approximately 850,000 acres). The proposed plan leaves approximately 70 percent of the public land open with standard lease terms and conditions and no special provisions for protection of ground-water resources (public water supply). Proposed activities may include oil and gas exploration and development, with the potential for injection wells to dispose waste. Proposed activities and protection of identified water resources (public water reserves) would be regulated under standard lease terms and conditions (BLM, 2003).

1.2 Objective and Purpose

The objective and purpose of this report is to address the following issues:

- Identify water resources underlying Otero Mesa that the BLM has not recognized or adequately addressed
- Identify areas of the aquifer that could potentially be impacted from surface disturbances (i.e., recharge zones)
- Identify activities and methods related to oil and gas exploration and development that could affect the existing aquifer(s)

2.0 DESCRIPTION OF REGIONAL AQUIFER (S)

The Salt basin is a large, internally drained basin covering about 5,900 square miles, of which 4,000 square miles are in Texas and the remaining 1,900 square miles are located just across the state line in New Mexico (Bjorklund, 1957). The water in the Salt Basin originating in New Mexico flows toward Texas. The portion of the Salt Basin in New Mexico includes Crow Flats and Otero Mesa. The Crow Flats portion of the basin drains to a series of alkali flats or playas to the south, just above the state line (Bjorklund, 1957). Irrigation with ground water has occurred in the Salt Basin near the New Mexico-Texas border, an extension of the agricultural area referred to as the Hudspeth County Underground Water District No. 1 (HCUWD#1) in Dell City, Texas.

Major watersheds within the New Mexico portion of the Salt Basin include the Sacramento River, Piñon Creek, and Shiloh Draw (Fig. 1). The Sacramento River drains the southern end of the Sacramento Mountains, where elevations of the upper watershed range from 8,000 ft to 9,500 ft.

Depth to water in the central part of the basin is around 200 ft, and many of the wells have depth to water less than 100 ft (see well data in Appendix A).

2.1 Structure and Framework

The Salt Basin is an extensional basin that widens to the south and is bordered on the east by the Guadalupe and Brokeoff Mountains and on the west by the Hueco Mountains and Otero Mesa. The Salt Basin is a block-faulted graben bounded by faults that extends 260 miles from the Sacramento River south into Texas (Fig. 1). The Crow Flat area is at lower

elevation than the surrounding mesas, plateaus, and mountains, and is the site of the salt flats where ground-water discharges and evaporates.

Faults and associated folds on the eastern side of the basin represent the eastern extent of the Rio Grande Rift portion of the Basin and Range physiographic province. A good description of the hydrogeologic setting for the Salt Basin can be referenced from TWDB/NMWRI (1997).

Ground-water flow in the limestone rocks of the Salt Basin is largely controlled by regional fracture systems (Mayer and Sharp, 1998). The most significant regional fracture system in the Salt Basin area is referred to as the Otero Break, trending from the Sacramento River to Dell City, Texas.

The Otero Break structural feature “graben” formed in late Paleozoic time along a northwest fault zone from right-lateral shear and extensional forces (Mayer, 1995). This fault zone was reactivated during the development of Basin and Range extension (Salt Basin), and extensively fractured the Permian-age carbonate rocks (Yeso Fm., San Andres Fm., etc) that occupy the majority of the Salt Basin and Otero Mesa area (Fig. 2).

2.2 Geologic Units

A summary of the geologic units found in the study area is presented as Table 1, and shown on Figures 2 through 4. Tertiary igneous intrusions of both andesitic and basaltic composition are present in the Cornudas Mountains and Dell City area (Dietrich et al. 1995). Quaternary-age basin fill in the form of alluvium and piedmont deposits, as well Santa Fe Group sediments, can be more than 500 ft thick, but in most places range from 25 to 300 ft thick (Bjorklund, 1957).

The principal bedrock aquifer units in the New Mexico portion of the Salt Basin are the San Andres Limestone, Yeso Formation, and Abo (Hueco) Formation, which together make up the bulk of the water bearing strata. In the Dell City area, the carbonate rock aquifer is referred to as the Victorio Peak-Bone Spring. Older formations (pre-Permian-age rocks), such as the Fusselman Dolomite, are water bearing and may possibly contain a viable public water supply.

Table 1. Summary of geologic units for the Salt Basin

age	symbol	stratigraphic unit	thickness, ft	description
Quaternary	Qal	alluvium	200 - 500	basin fill - unconsolidated clay, silt, sands, and gravels
	Qts	Upper Santa Fe Group	500 - 2000	basin fill - silts, sands, and gravels
Tertiary	Ti	intrusives	10 - 100	igneous intrusives - dikes and sills
Permian	P	Permian undivided	2000 - 5000	shale, limestone, mudstone, gypsum
	Psa/ Pvp	San Andres/ Victorio Peak	200 - 1000	limestone
	Pbs	Bone Spring	900 - 1,700	limestone
	Py	Yeso Formation	1200 - 1800	interbedded limestones and shales
	Pa/ Ph	Abo/ Hueco Formations	200 - 500	mudstones and conglomerates
	Pb	Bursum Formation	400 - 600	interbedded siltstones, sandstones, shales and conglomerates
Pennsylvanian	IPh	Holder Formation	500 - 900	interbedded limestones and conglomerates
		Gobbler Formation	1200 - 1600	sandstones and conglomerates
Mississippian	M	Lake Valley Formation	350 - 450	interbedded limestones and shales
Devonian	D	Percha Shale	40 - 80	black noncalcareous shale
Silurian	Sf	Fusselman Dolomite	20 - 100	massive dolomite with chert
Ordovician	Om	Montoya Formation	190 - 225	massive dolomite
Cambrian	Ce	El Paso Formation	350 - 450	dolomitic sandstone
		Bliss Sandstone	100 - 150	quartz sandstone
Precambrian	pC	granite	--	granites and granodiorites

Figure 2 is a map showing the distribution of major geologic units that make up the aquifer(s) in the study area. On Figure 2, the basin-fill deposits (Qal) refer to alluvium and Upper Santa Fe Group listed in Table 1; other Permian-age rocks are equivalent to Permian undivided. Cretaceous rocks refer to the Cox Sandstone and other overlying and underlying rocks of similar age.

The upper sequence of Permian-age rocks, Yeso, San Andres, Bone Spring, and Victorio Peak Formations, were deposited in a shallow sea environment behind the reef margin of the Delaware Basin. These carbonate rocks typically become more permeable

toward the reef margin (Capitan reef in the Guadalupe Mountains), which would suggest increasing permeability to the southeast in the New Mexico portion of the Salt Basin. The lower member of the San Andres Formation grades to the southeast toward the Permian reef facies into the Victorio Peak Formation (Black, 1975). Therefore, the Victorio Peak is equivalent, in time of deposition, to the upper Yeso and lower San Andres. Cross-sections showing the relationship of major geologic units from west to east, across the New Mexico portion of the Salt Basin, are provided as Figures 3 and 4.

The San Andres Limestone and Yeso Formation cover most of the upper portion of the Salt Basin (Fig. 2). The San Andres Formation is composed of limestone, with sandstone at the base of the formation. The Yeso consists of sandstone, limestone, dolomite, siltstone, shale, and evaporites (Pray, 1961). The Yeso Formation is approximately 1,000 ft thick in the southern Sacramento Mountains (Kelly, 1971). Many of the springs in the southern Sacramento Mountains discharge from the contact between the San Andres and Yeso Formations. Most wells that yield water from the Yeso Formation are completed in the upper 500 ft of the formation in fractured limestone and dolomite where the permeability has been enhanced by solution. In the Timberon area, wells drilled into the lower Yeso Formation are typically low yielding (<5 gpm) as compared with wells in the upper Yeso, which produce more than 100 gpm.

The Bone Spring-Victorio Peak aquifer extends from Crow Flat in an arc to the south around the edge of the Permian-age Delaware Basin. The Bone Spring-Victorio Peak aquifer is present under most of the east part of the Diablo Plateau (Fig. 2). High-yield irrigation wells that produce from the Bone Spring-Victorio Peak aquifer commonly intercept fractures that have been opened by the percolation of ground water from overlying alluvium (Scalapino, 1950; Bjorklund, 1957). Scalapino (1950) reported that approximately 50 percent of the wells drilled are high-yield (> 1,000 gpm) and the other half are low-yielding (< 500 gpm).

Rocks older than Permian include (1) Pennsylvanian- and Mississippian-age limestone and shale, (2) shale, dolomite, and sandstone of Devonian-, Silurian-, Ordovician-, and Cambrian-age, and (3) Precambrian-age granite and metamorphic rocks (see Table 1).

Exploration drilling has indicated biogenic gas is associated with the Pennsylvanian- and Mississippian-age organic shale, which is formed by decomposition of organic matter by fresh water microbes.

The Silurian-age Fusselman Dolomite has been reported by the oil and gas exploration industry as having “fresh” water in the Otero Mesa and Diablo Plateau areas. The Fusselman Dolomite is generally found at depths greater than 2,000 ft below land surface (Black, 1975; Pearson, 1980; Harder, 1982).

2.3 Recharge

Due to the absence of perennial streams in the basin center, ground-water recharge is mainly infiltration of precipitation from melting snowpack and during flash flooding of ephemeral channels (Bjorklund, 1957). Most of the water for recharge originates from the higher elevations of the Sacramento River and Piñon Creek watersheds. The total annual average yield of these watersheds is approximately 35,000 ac-ft/yr (Table 2). The area of these watersheds is approximately 20-percent of the total area for the New Mexico portion of the Salt Basin.

Table 2. Watersheds in the Salt Basin, and summary of watershed data and estimated yield

name	mean annual precipitation, in./yr	mean elevation, ft amsl	area, mi ²	estimated watershed yield, ac-ft/yr
Sacramento River	22.8	7,795	135	17,580
Piñon Creek	20.0	7,100	99	8,872
small un-named watersheds and mountain front on Otero Mesa and Cornudas and Brokeoff Mountains	17.2	6,500	124	8,626
Salt Basin total			358	35,078

in./yr inches per year
mi² square miles

ft amsl feet above mean sea level
ac-ft/yr acre-feet per year

The watershed yield analysis was performed by evaluating monthly precipitation and potential evaporation data collected from weather stations in the region (Livingston Associates and John Shomaker & Associates, Inc., 2001).

The watershed yield analysis indicates that aerial recharge does not occur below an elevation of 5,860 ft, although below an elevation of 5,860 ft recharge from storm-water runoff occurs along arroyos and highly fractured rock where infiltration rates are high. Total watershed yield calculated for the Salt Basin area is 35,000 ac-ft/yr (Table 2), with approximately one-half originating from the Sacramento River Watershed.

Due to the fractured conditions of the rocks, all of the 35,000 ac -ft/yr plus storm-water runoff infiltrates into the ground-water system and can be considered as recharge.

Mayer (1995) estimated a total average annual rate of recharge at 58,000 ac -ft/yr for the Salt Basin, which included part of the Diablo Plateau in Texas.

2.4 Direction of Ground-Water Flow

Ground-water elevation contour maps for only parts of the study area have been developed by Ashworth (1995), Mayer (1995), and TWDB/NMWRRI (1997). The water-level contour maps from Ashworth (1995) and TWDB/NMWRRI (1997) are limited to the Dell City area and are representative of near present pumping conditions. The water-level contouring by Mayer (1995) was limited to a few data points in New Mexico, and implied a relatively flat hydraulic gradient throughout the study area.

The ground-water elevation contour map shown as Figure 5 was constructed from data from existing reports, the Texas Water Development Board (TWDB) database, and the New Mexico Office of the State Engineer (NMOSE) WATERS database. There are several areas where water-level data are absent, and extrapolation between data points 10 to 20 miles apart was made. Additional data are needed for Otero Mesa, Diablo Plateau, and the northern fringes of Otero Break to have a more accurate ground-water elevation contour map of the study area.

Regional ground-water flow is from the northern Salt Basin, Otero Mesa, and Diablo Plateau toward the Salt Flats near Dell City (Fig. 5). Ground-water elevation contours along the northern watershed boundary of the Salt Basin, between Timberon and Piñon, indicate ground-water flow from the Peñasco Basin to the Salt Basin.

The direction of ground-water flow from Otero Mesa and the Sacramento watershed area is toward the highly fractured region referred to as Otero Break. The fractured rocks of Otero Break have very high permeability and, as a result, effectively transport water to the

Dell City area and Salt Flats. Figure 6 is an aerial photograph of a portion of the Otero Break area (T23S, R16E), showing the visibility and northwest orientation of the regional fracture system.

Ground-water flows radially away from the Cornudas Mountains, presumably as a result of recharge there. Mayer (1995) suggested the water levels in the Cornudas Mountains indicate a perched water table, but data from nearby deep wells still show radial flow from the Cornudas Mountains.

2.5 Current and Historic Use

The primary uses of ground water in the New Mexico portion of the Salt Basin have been for domestic supply, stock watering, and irrigation. Irrigation has primarily been in the Crow Flat area. Bjorklund (1957) reported 3,000 acres of irrigated land from 17 wells in 1956, all in the Crow Flats area with most of it near the New Mexico-Texas state line.

Stock wells are scattered throughout the Salt Basin, and several of them are converted oil and gas exploration wells. A list of well data from the NMOSE WATERS database is provided in Appendix A. Existing wells are shown on the map provided as Figure 7.

Timberon Water & Sanitation District has approximately 1,500 ac-ft/yr of surface-water rights associated with Carriza Spring, tributary to the Sacramento River. Table 3 summarizes the declared water rights in the Salt Basin.

Table 3. Summary of declared water rights in Salt Underground Water Basin, New Mexico

use	declared water rights, ac-ft/yr
domestic	80
stock	566
municipal	1,499
irrigation*	47,595
total	49,740

* Hunt Development Corp. has declared 35,290 ac-ft/yr for irrigation of 3,600 acres ac-ft/yr acre-feet per year

The majority of pumping from the Salt Basin occurs in the Dell City area, in Texas. Ashworth (1995) and Scalapino (1950) have summarized the acre-feet pumped for the HCUWD#1 (Dell City area), as listed in Table 4. Irrigation in the Dell City area began in 1947, and approximately 26,000 acres are currently irrigated for growing alfalfa, cotton, and chile. The HCUWD#1 claims 36,000 acres can potentially be irrigated, which would require about 180,000 ac-ft/yr of pumping at the current application rate of about 5 acre-feet per acre. Wilson and Lucero (1997) estimated a total pumping for irrigation in the New Mexico side of the Salt Basin at 10,171 ac-ft/yr in 1995.

Table 4. Summary of historic pumping for irrigation in the Dell City area

year	acre-feet pumped
1948 ^a	7,500
1949 ^a	18,000
1958 ^b	67,000
1964 ^b	91,500
1974 ^b	132,700
1979 ^b	144,600
1984 ^b	102,000
1989 ^b	94,700
1994 ^c	100,000
1999 ^c	100,000

^a from Scalapino (1950)

^b from Ashworth (1995)

^c from HCUWD#1

2.6 Future Use

Recognizing the importance of the public ground-water reserve, the New Mexico State Engineer declared the Salt Underground Basin in September 13, 2000. After the basin was declared, several applications have been filed to further develop the water resources in Crow Flat and Otero Break (Fig. 7).

The Tularosa-Salt Basin Regional Water Plan was adopted by the New Mexico Interstate Stream Commission in May 2002, which defines the water resources of the Salt Basin and outlines current and future use. Even though the Salt Basin is sparsely populated and remote, the vast water supply in the Salt Basin is an important alternative resource for the future of New Mexico. Alternatives include development and importation to areas of need, as well as, preservation for use beyond the 40-year planning horizon.

The State Water Plan for New Mexico (selected pages in Appendix C) contains the following discussion on the Salt Basin and associated water resources:

- The availability of safe and adequate drinking water supplies for all New Mexicans is of paramount importance to the health and safety of the State's citizens (pg 6).
- Little development of the Salt Basin has occurred in New Mexico, but pressure to develop this resource is growing (appendix A, A-36)
- Steps must be taken to ensure that water from the basin is preserved to meet growing demands in southern New Mexico (appendix A, A-37)

3.0 DEFICIENCIES IN BLM RMP AND EIS

3.1 Identification of Water Resources and Potential Impacts

The BLM RMP and EIS did not review and include key publications on the water resources for the impact assessment (see references Section 5.0, and Appendix B).

- The majority of the Salt Basin is underlain by limestone (carbonate) rock that is fractured, and considered a regional aquifer (Mayer, 1995; Mayer and Sharp, 1998). Detailed description of this regional aquifer can be obtained from the references provided in Appendix B.
- The shallow alluvial aquifer is localized to arroyo and stream channels where recharge occurs. The alluvial aquifer is used for domestic and stock purposes. Depth to water is shallow in the alluvial aquifer rendering it susceptible to contamination from surface disturbances.
- There are potentially significant fresh water resources above and below the target formations for oil and gas development.
- The full extent of the water resources in the Salt Basin has not been defined.

3.2 Characterization of Aquifer(s) and Sensitivity to Management Alternatives

The BLM RMP and EIS did not identify the regional fractured carbonate rock aquifer beneath the Salt Basin and its susceptibility to surface disturbances related to oil and gas development.

- The regional aquifer is similar to the Edwards Aquifer in Texas, where the recharge zone is sensitive to contamination and requires controlled surface use for protection.
- The majority of the Salt Basin has fractured Permian-age carbonate rocks exposed at the surface, which is part of the regional aquifer. The fracture density has been quantified by Mayer and Sharp (1998), in which fracture density can be as high as 15,800 ft per square mile; in some cases fractures are no more than one meter apart (see discussion and photographic documentation by Mayer (1995) in Appendix B). Fractures are exposed at the land surface and potentially provide pathways for contaminant migration to the regional aquifer.
- The hydraulic conductivity for the Otero Break area is estimated to average 100 ft/d, and the hydraulic gradient estimated from Figure 5 is 0.002 ft/ft. Using Darcy's Law to calculate the tracer velocity, an average value of 20 ft/d was calculated for the fractured part of the aquifer at Otero Break (assuming an effective porosity of 0.01). Within a particular fracture, the tracer velocity may be several orders of magnitude greater. This indicates how rapid contaminants could travel once introduced into the aquifer.

3.3 Ground-Water Protection Measures

Additional ground-water protection measures need to be implemented to insure protection of water resources in the Salt Basin.

- The possibility of injection wells should be omitted from the RMP given the widespread distribution of fresh "public ground water beneath the Salt Basin, and the fractured nature of the aquifer(s)."
- The fracture density study performed by Mayer (1995) could provide guidance for determining areas of the aquifer susceptible to contamination from surface disturbances. It is likely a more detailed fracture evaluation will need to be undertaken before land management decisions are made.

3.4 Economic and Ranking Evaluation of Resources

The BLM RMP and EIS should review existing water plans for the Salt Basin and incorporate those into resource evaluation and protection of water resources identified for future use. (excerpts from the State Water Plan can be referenced in Appendix C).

- The value of the water resources and fluid mineral resources should be evaluated, and appropriate methods should be used to rank resources based on impacts, value, and sustainability.

4.0 CONCLUSIONS AND FINDINGS

1. The proposed plan leaves approximately 70 percent of the public land open with standard lease terms and conditions and no special provisions for protection of ground-water resources (public water supply). Proposed activities may include oil and gas exploration and development, with the potential for injection wells to dispose waste. Proposed activities and protection of identified water resources (public water reserves) would be regulated under standard lease terms and conditions (BLM, 2003).
2. Depth to water in the central part of the basin is around 200 ft, and many of the wells that produce from shallow perched ground water may have depth to water less than 100 ft (see well data in Appendix A). The BLM RMP and EIS does not include the shallow depth to water data in the analysis of water-resource impacts.
3. The majority of the Salt Basin is underlain by limestone (carbonate) rock that is fractured, and considered as a regional aquifer (Mayer, 1995; Mayer and Sharp, 1998).
4. The regional aquifer is similar to the Edwards Aquifer in Texas, where the recharge zone is sensitive to contamination and requires controlled surface use for protection.

5. The Silurian-age Fusselman Dolomite has been reported by the oil and gas exploration industry as having “fresh” water in the Otero Mesa and Diablo Plateau areas. The Fusselman Dolomite is generally found at depths greater than 2,000 ft below land surface (Black, 1975; Pearson, 1980; Harder, 1982).
6. The possibility of injection wells should be omitted from the RMP given the widespread distribution of fresh “public ground water beneath the Salt Basin, and the fractured nature of the aquifer(s).”

5.0 REFERENCES

- Ashworth, J. B., 1995, Ground-water resources of the Bone Spring – Victorio Peak Aquifer in the Dell Valley area, Texas: Texas Water Development Board Report 344, 42 p.
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ILLUSTRATIONS

APPENDICES

Appendix A.

List of Water-Supply Wells in the Salt Basin

Appendix B.

Selected Pages and Figures from Mayer, 1995

Appendix C.

Selected Parts of the Regional and State Water Plans

John Shomaker presented at American Ground Water Trust conference in Albuquerque. Welcome to JSAI! We have been providing Professional Hydrogeologic Services in New Mexico, the Western United States, and abroad for 45 years. I've really enjoyed working with you over the years...We have come to depend on you as our "collective memory" when it comes to subsurface issues, and personally I hope that you'll be around for a long time in the future. On behalf of the Water Division; please accept our sincerest gratitude for your extraordinary technical, planning and financial su