IMC Chemicals

IMC Chemicals Inc.
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June 3, 2002

Kai Dunn, Ph. D.
California Regional Water Quality
Control Board, Lahontan Region
15428 Civic Drive, Suite 100
Victorville, CA 92392-2359

Re: ACL Order No. R6V-2002-0025 Item 3.H., Hydrologic Study Final Report

Dear Dr. Dunn:

California Regional Water Control Board's Administrative Civil Liability Order No. R6V-2002-0025, Item 3.H. requires IMC Chemicals (IMCC) to submit the final report on implementation of the "Workplan for Evaluating Hydrologic Resources within the Searles Valley Hydrologic Basin." The hydrologic study was completed in accordance with the work plan. On March 15, 2002, Kennedy/Jenks Consultants submitted a report on behalf of IMCC entitled "Evaluating Hydrological Resources Within the Searles Valley Hydrologic Basin."

Because the March 15, 2002, Kennedy/Jenks report "Evaluating Hydrological Resources Within the Searles Valley Hydrologic Basin" satisfies the requirement for a final report on the hydrologic study, IMCC considers ACL Item 3.H. closed.

Please call me at (760) 372-2118 if you have any questions regarding this matter.

Sincerely,

Denise Kirchner

Kennedy/Jenks Consultants

Engineers & Scientists

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15 March 2002

Ms. Cindi Mitton
Senior Water Control Resource Engineer
California Regional Water Quality Control Board – Lahontan Region
15428 Civic Drive
Victorville, CA 92392

Subject: Evaluating Hydrological Resources Within The Searles Valley Hydrologic Basin
IMC Chemicals Inc.
Trona, San Bernardino County, California
K/J Project Number 004013.13

Dear Ms. Mitton:

In accordance with a request from the Regional Water Quality Control Board – Lahontan Region (Board) as an action item from the 11 April 2001 meeting between the Board staff and IMCC, and the Board's "Concurrence With Proposed Work Plan...." Dated 17 May 2001, Kennedy/Jenks Consultants hereby transmits the subject Report on behalf of IMC Chemicals Inc. This report was requested by the Board to produce data that may support IMCC's request for site-specific designations for beneficial uses for Searles Dry Lake.

Should you have any questions regarding this Work Plan, please contact Larry Trowsdale of IMCC at (760) 372-2042 or Bruce Thomas at (949) 261-1577.

Very truly yours,

KENNEDY/JENKS CONSULTANTS

R. Bruce Thomas, P.E.
Project Manager

Enclosures

cc: Mr. Charles Hungerford, Heller Ehrman (w/ attachments)
Ms. Darlene Ruiz, Hunter-Ruiz (w/ attachments)
Mr. Larry Trowsdale, IMCC (12 copies w/ attachments)

IMC Chemicals Inc.

EVALUATING HYDROLOGIC RESOURCES WITHIN THE SEARLES VALLEY HYDROLOGIC BASIN

submitted to:

California Regional Water Quality Control Board
Lahontan Region

March 2002

on behalf of:

IMC Chemicals Inc.
13200 Main St.
P.O. Box 367
Trona, CA 93592

prepared by:

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1 Introduction

This Report has been prepared by Kennedy/Jenks Consultants (Kennedy/Jenks) of Irvine, California, on behalf of IMC Chemicals (IMCC) in response to a request from the Regional Water Quality Control Board-Lahontan Region (LRWQCB), as an action item from the 11 April 2001 meeting and the LRWQCB's concurrence letter dated 17 May 20001. The report provides hydrologic background and data to support IMCC's request for a change in site-specific designation for Searles Dry Lake in the Beneficial Use Plan. For the purposes of discussion, the area for which the change in site-specific designation is requested is referred to as the Searles Dry Lake Brine Area. The approximate limit of the proposed Searles Dry Lake Brine Area is shown in Figure 1.

1.1 SITE DESCRIPTION

The IMCC Trona, Argus, and Westend Plants are located near the City of Trona, San Bernardino County, California within T25S, R43E, MDB&M in the Searles Valley Hydrologic Area (Figure 1). IMCC manufactures soda ash and boron chemicals from minerals and chemicals extracted from the saline mineral body below Searles Valley. Searles Valley is located within California's Mojave Desert and contains a rich source of diversified minerals and chemicals that are used in the production of IMCC products.

1.2 BACKGROUND

IMCC currently owns and operates the Trona, Argus and Westend Plants. The plants have operated since the early 1900's under several prior ownerships. Most recently, in 1998 IMC Global purchased the plants from North American Chemical Company and renamed the company IMC Chemical. North American Chemical Company had taken ownership from Kerr-McGee Chemical Company in 1990. The Trona facility is a brine processing facility that produces various boron products from influent brine. At the Trona facility, influent brine is contacted with a solvent (similar to kerosene) and mixed with a proprietary organic extractant in a liquid-liquid extraction system to form boric acid. The partially depleted brine effluent is then treated to remove residual hydrocarbon compounds and discharged to the Percolation Pond. At the Argus facility, the partially depleted brine effluent, after beneficiation to produce soda ash, is returned to the surface (Percolation Pond via the Dredge Pond) and subsurface (via direct re-injection) of Searles Lake.

Brackish water resources are present in and produced from the alluvial aquifers at locations between the saline deposits and the adjacent mountain ranges. Three well fields provide about three-quarters of the non-brine water used in the basin: Valley Wells on the north, the Golf Course well in the former Argus Well Field on the west, and the Brackish Well Field on the south. The remaining water resources are imported from wells located in Indian Wells Valley to the west. Prior to importing this water, mining operations in the valley used spring water collected from numerous springs that issue from bedrock in the Argus Range north and west of Trona.

1.3 GENERAL SITE GEOLOGIC SETTING

Searles Lake is the third lake in a chain of many large pluvial lakes that were developed during the Quaternary Period, in the Basin and Range area of eastern California. Searles Lake was formed by the overflow of China Lake and was host to a sequence of large ephemeral lakes for much of the last 3.2 million years (M.Y). Searles Lake was also the final destination for Owens River water for most of the Quaternary. Searles Lake occasionally drained to the east, into the Panamint Valley, where Panamint Lake was formed as a consequence of Searles Lake overflowing (Smith and Street-Perrott, 1983).

Searles Lake is located between two dominant physiographic features, the Argus Range to the west and the Slate Range to the east. The Garlock Fault is located about 15 miles south of the site and is the dominant tectonic feature in the vicinity of the site. The general stratigraphy in the vicinity of the site consists of evaporites, flood plain and marsh saline deposits, and gravel derived from the erosion of older alluvial fan deposits. Sediments found below the Searles Lake lakebed consist of silts and clays where the former lake was deepest; calcareous sand and silt found along the flanks of the basin; gravel, sand and tufa deposits near the margins of the lake; and evaporite salt layers that were deposited as lake levels declined (Smith and Street-Perrott, 1983). Low lying portions of the Searles Dry Lake lakebed are subject to ephemeral inundation during periods of high precipitation or rising groundwater.

1.4 PURPOSE AND OBJECTIVES

The purpose of the hydrologic resources investigation is to provide the Board with background hydrogeologic information in support of IMCC's request for a change in the site-specific designation in the Beneficial Use Plan. The investigation is qualitative and semi-quantitative in nature and relies largely on historical information collected by others. Data new to this investigation include the limited analytical testing of groundwater from six Argus Range springs.

1.5 SOURCES OF HYDROGEOLOGIC DATA

Several sources of hydrogeologic information were available during the preparation of this hydrogeologic investigation including:

1) References obtained from the Searles Valley Historical Society.

2) Previously published reports, most prominently a hydrogeologic investigation of Searles Valley by Errol L. Montgomery & Associates, Inc. (Montgomery).

3) IMCC files and discussions with IMCC personnel. In particular, Kennedy/Jenks had several extended discussions with James Fairchild and Michael Lovejoy. Michael Lovejoy is currently a consultant to and was formerly an employee of IMCC.

4) Spring water quality data from the United States Navy, China Lake Naval Weapons Center.

5) Spring water quality data for selected Argus Range springs collected as part of the current investigation.

The hydrogeologic setting of Searles Valley is described by Montgomery in a report titled "Hydrogeologic Conditions, Searles Lake Area, Inyo and San Bernardino Counties California" (Montgomery, 1989). This report was prepared for Kerr-McGee Chemical Corporation and summarizes the well and spring data for the Searles Valley available at the time the report was prepared. The hydrogeologic conceptual model described in this report is based on the hydrogeologic conditions described in Montgomery (1989). The original report contains important tabular summaries of brine, well, and spring data that were available at the time the report was prepared.

1.6 REPORT ORGANIZATION

This report has been organized into seven sections:

- Section 1, presented above, provides a brief description of the IMCC facility and the project background.
- Section 2 describes the hydrogeologic setting of Searles Valley.
- Section 3 describes the occurrence and movement of groundwater.
- Section 4 describes the occurrence of springs and the quality of spring water as documented by previous sampling programs and a limited spring sampling event performed for this evaluation.
- Section 5 summarizes the result of the recently conducted ephemeral waters evaluation and compares these brines to the spring sampling results.
- Section 6 provides a discussion of Searles Valley hydrology as it pertains to the objectives of the investigation.
- References are provided in Section 7.

2 Hydrogeologic Setting

2.1 BASIN DESCRIPTION

Searles Valley (Figure 2) is a north-trending structural valley that is bound by the Argus Range on the west and north and by the Slate Range on the north and east. Maximum elevations in the Argus and Slate ranges are 6,562 and 5,578 feet above mean sea level (msl), respectively. The Garlock Fault is generally recognized as the southern limit of the groundwater basin, however topographically, the surface water drainage area of the valley continues south of the Garlock fault. The area of the Searles Valley drainage basin as shown in Figure 2 is estimated to be about 693 square miles.

Searles Dry Lake occupies the central portion of the valley and is described by Montgomery (1989) as a salt-encrusted playa that occupies about 41 square miles in the lowest part of Searles Valley. Searles Dry Lake is at and below an elevation of approximately 1,625 feet msl. The minimum elevation is about 1,621 feet msl.

Recognized sub-basins of Searles Valley Hydrologic Unit include:

- **Teagle Wash**, the southwestern extension of the basin that extends about 20 miles southwest of the Pinnacles. The wash is flanked on the north and west by the Spangler Hills and the south by the Lava Mountains and is occupied by broad alluvial fans that slope northeastward toward the lakebed.
- **Salt Wells Valley** is a narrow, eastward sloping basin west of Searles Valley through which State Route 178 (Trona Road) passes. Salt Wells Valley is connected to Searles Valley through Poison Canyon. Surface drainage from China Lake to Searles Lake during the Quaternary Period passed through this valley.

Regional topographic relationships of Searles Valley with the adjacent valleys are illustrated in the topographic contours shown in Figure 2. Searles Valley is flanked by Indian Wells Valley to the west with a minimum valley floor elevation of about 2,165 feet msl and Panamint Valley on the northeast with valley floor elevations that range from 1050 to 1730 feet msl.

2.2 HISTORICAL REFERENCES TO WATER IN SEARLES VALLEY

A review by IMCC of materials in the collection of the Searles Valley Historical Society identified three books that make references to the occurrence of water in Searles Valley as described by the first pioneers to enter Searles Valley. A summary of these references as they pertain to water resources in the Searles Valley and Panamint Valley areas (including numerous quotes) is included in Appendix B.

The cited quotations clearly document the presence and temporal variability of fresh water springs in the Slate and Argus ranges during late 1849 and early 1850. The quotations also document how the pioneers attempted to reach the lake near the center of Searles Valley only to find that: "When we reached the water we found it to be of a wine color, and so strongly alkaline as to feel slippery to the touch, and under our feet." Two other quotations note that the lake contained both salt and borax. These early pioneers recognized that surface water on the

floor of Searles Valley was not potable. One quotation suggests that one week after a rainstorm, pioneers found the water on the valley floor was "... bitter brine instead of sweet water."

2.3 HYDROGEOLOGIC UNITS

Montgomery (1989) recognizes three primary hydrogeologic units in Searles Valley:

1) Alluvial Deposits
2) Saline Deposits
3) Bedrock Complex

Each of these units and important subdivisions of these units are described in the paragraphs that follow. The lateral extent of the saline deposits is illustrated in Figure 2. The bedrock complex is exposed in the adjacent ranges, generally above an elevation of 2,500 feet msl. The alluvial deposits are present between the bedrock complex and the saline deposits. The vertical and lateral relationships among these hydrologic units are illustrated in cross section in Figure 3 and discussed in the following sections.

2.3.1 Alluvial Deposits

Alluvial deposits (Figure 3) are loosely to moderately lithified clay, silt, sand, gravel, and boulders that were derived from the adjacent mountain ranges and overlie the bedrock complex. Near the basin margins the alluvial deposits consist chiefly of sand, gravel, and boulders. Toward the center of the basin, the coarse-grained facies grades laterally into finer grained facies which contain abundant silt and clay beds. The alluvial deposits are generally thin where they approach the ranges and thicker in the central portion of the basin. Montgomery (1989) reports that alluvial deposits encountered in wells north of Searles Dry Lake were as thick as 1,280 feet and southwest of the lake the thickness of alluvium encountered in two wells was 655 to 830 feet. Geophysical investigations (Mabey, 1956 and 1963) suggest that the alluvial deposits are thickest toward the east side of the valley and may be several thousand feet thick a few miles north of the Garlock fault. A seismic investigation performed by the United States Navy (USN) Geothermal Project office in 1994 along the USN corridor across Searles Valley reportedly indicates depths to bedrock in excess of 7,000 feet (Lovejoy, personal communication 2001).

Where saturated, alluvial deposits may yield small quantities of water of various salinity classes to wells. Four well fields are known to produce or have produced water from the alluvial deposits. From north to south these well fields are: Valley Wells, Argus, Westend and South Brackish well fields (Figure2). The production of groundwater from alluvial wells is described in Section 3.

2.3.2 Saline Deposits.

The saline deposits (Figure 3) are a sequence of interbedded mud and soluble evaporite strata of lacustrine origin that grade laterally into the surrounding alluvial deposits. Evaporite strata pinch out and a mud facies occurs around the periphery of the saline deposits. This mud facies interfingers with adjacent alluvial deposits. Where saturated, saline deposits may yield large

quantities of brine to wells. Montgomery (1989) identified three important subdivision of the saline deposits:

a) The Upper/Lower Salt deposits are separated from each other by the Parting Mud and separated from deeper saline deposits by the Bottom Mud.

b) The Mixed Layer as defined by Montgomery (1989) is the thick sequence of saline deposits below the Bottom Mud that is comprised of at least nine recognizable layers, each containing various proportions of evaporite strata and fine grained sediments that are referred to as mud. The term Mixed Layer is more narrowly defined by IMCC to include saline deposits to a maximum depth of about 400 feet below ground surface (bgs) that are capable of being solution mined. This upper portion of the Mixed Layer is referred to in this report as the "Mixed Layer." The Mixed Layer below the practical limit of solution mining is referred to as the deep Mixed Layer.

c) The transition zone is an area on the periphery of the saline deposits in which the saline and alluvial deposits interfinger.

The total thickness of the saline deposits may exceed 2,275 feet. Where present, the Upper/Lower Salt deposits are about 100 feet thick. The thickness of the Bottom Mud is about 100 feet. The Mixed Layer and deep Mixed Layer comprises the remainder of the saline deposits.

The Upper/Lower Salt deposits and the Mixed Layer production zone are the primary units from which minerals are extracted. Wells that penetrate into various portions of the saline deposits are used to extract process brine and inject partially spent brine effluent.

Because the primary focus of the current investigation is the occurrence and quality of water outside of the saline deposits, a detailed discussion of groundwater conditions in the saline deposits is not provided in this report. The hydraulic relationships between the saline deposits and the surrounding alluvial deposits are discussed in Section 3.

2.3.3 Bedrock Complex

The bedrock complex is exposed in the ranges that flank Searles Valley (Figure 2) and underlies the alluvial deposits. In the Argus Range to the west, bedrock consists primarily of moderately fractured granitic rocks. In the Slate Range to the east, bedrock is more heterogeneous and consists of granitic igneous, metamorphic, volcanic, and sedimentary rocks (Montgomery, 1989).

Montgomery (1989) reports that two wells in the southwestern portion of the valley are drilled into and have yielded some water from the bedrock complex. However, the primary evidence of the occurrence of water in the bedrock complex is a series of springs located in the Argus Range (Figure 2). Fewer springs are known to occur in the Slate Range. Springs in both the Argus and Slate ranges typically occur hundreds of feet above the alluvial deposits and are located miles from active mining operations. Additional information regarding the occurrence and water quality of springs that flow from the bedrock complex is provided in Section 4.

Springs in the Argus Range cluster in locations that are generally north of the Wilson Canyon fault (Figure 2). South of the fault, elevations of the range are generally lower and springs are

generally absent. The area between the Wilson Canyon fault on the north and Poison Canyon on the south may be more heavily fractured and therefore permit some inter-connecting saline underflow from Indian Wells Valley to Searles Valley through the bedrock complex (Mike Lovejoy, personal communication, 2001). Evidence for this underflow includes the availability of water formerly pumped from wells in the Argus and Westend well fields, and the presence of seeps at the base of the Argus Range between Trona and Westend. The Pinnacles tufa deposits are evidence of ancient groundwater flow through bedrock south of Poison Canyon during the Quaternary Period. The volume of underflow from Indian Wells Valley to Searles Valley that may currently be occurring in this area is unknown.

3 Occurrence and Movement of Groundwater

3.1 GROUNDWATER FLOW SYSTEMS

Montgomery (1989) recognized two "independent" groundwater systems in Searles Valley:

1) The Upper/Lower Salt system and

2) A combination of the alluvial deposits and the Mixed Layer saline deposits.

The bedrock complex is not recognized by Montgomery (1989) as a separate flow system because there is little known about the occurrence and movement of water in the bedrock complex.

The suggestion that the Upper/Lower Salt system is independent of the alluvial/Mixed-Layer system is based on the presence of a thick Bottom Mud and lateral changes in the salt facies to mud facies that effectively isolate the salt layers from the surrounding alluvial deposits and the underlying Mixed Layer. These muds have low hydraulic conductivity. However, leaky well casings, improperly abandoned wells, and collapse features associated with solution mining are potential hydraulic pathways through which groundwater flow can occur in the muds. IMCC personnel cite boron and potassium chloride enrichment of Mix-Layer brines as evidence that brine moves from the Upper/Lower Salt into the Mixed Layer (Fairchild, personal communication).

Grouping the alluvial deposits and the Mixed Layer suggests that the deposits may have aquitard interconnections. Montgomery (1989) recognizes that few wells are drilled into the areas that these deposits interfinger and that little is known about the interrelationship of these units.

3.1.1 The Upper/Lower Salt System

The movement of brine within the Upper/Lower Salt system can reasonably be assumed to be driven by production activities that occur within the Searles Dry Lake Brine Area. The following paragraphs describe the general relationship between the Upper/Lower Salt system and the deeper alluvial deposit/ Mixed Layer system.

IMCC reports that away from production and injection well fields, hydraulic heads in the alluvial/Mixed Layer system are generally an inch lower than those in the Upper/Lower Salt system. Given the low hydraulic conductivity of the Bottom Mud that separate these units, and brine densities in the Upper/Lower Salt system that are 0.03 gm/cm greater than the Mixed Layer brines, the small vertical differential in head would create the potential for downward migration at very slow velocities.

Production activities in the Mixed Layer below the Upper/Lower Salt could induce vertical gradients and therefore flow. Local changes in vertical hydraulic head can exist where brine effluents are injected into or where brine is produced from the Mixed Layer. Injection wells induce an upward hydraulic gradient and the potential for upward brine migration. Conversely, Mixed-Layer production wells induce downward hydraulic gradients and the potential for downward brine migration. IMCC reports that the largest production/injection induced vertical

gradients occur in newly developed areas and decline as an injection/production area matures. Thus, the increased potential for brine migration that may be induced by mining is transitory and unlikely to result in brine migration from the Upper/Lower Salt system across the Bottom Mud and into the Mixed Layer.

3.1.2 Alluvial Deposit/Mixed Layer System

Although combined as a single unit, different processes affect the movement of brine and brackish water in the alluvial deposits and Mixed Layer.

3.1.2.1 Mixed Layer Flow

Within the upper 200 feet of the Mixed Layer, injection and production of brine alter the hydraulic head and therefore alter brine movements in the vicinity of the injection/production cells. Typically, these flow cells are created by parallel lines of injection and production wells spaced up to 3,000 feet apart. Wells are typically spaced along these lines at 500-foot intervals and the lines of wells may be up to 7,000 feet long (Personal communications, Mike Lovejoy). These local flow systems occur within the Searles Dry Lake Brine Area and would appear to have little or no direct affect outside this area. Indirectly however, the mining process results in a net 20 to 40 percent loss of brine to the Percolation Pond where water is lost by evaporation (Personal communications, Mike Lovejoy). This process lowers brine levels in the Mixed Layer, increasing the horizontal gradient toward the Mixed-Layer saline deposits, and increasing the potential for flow from the transition zone and adjacent alluvial deposits toward the mixed-layer saline deposits. Given local changes in hydraulic gradient that occur because of injection/production and the large area over which this recharge process operates, the changes in horizontal gradients induced by this process are likely to be difficult to measure.

3.1.2.2 Alluvial Deposit Flow

Away from brackish water production areas, very few water level measurements are available for the alluvial aquifer and therefore groundwater movements are inferred based on:

1) The hydraulic heads caused by the elevation of the adjacent ranges relative to the valley

2) The tendency for groundwater recharge to occur during periods of rainfall in coarse alluvial deposits closer to the range where ephemeral stream channels pass from bedrock to alluvium

3) The possibility of underflow from Indian Wells Valley into Searles Valley through the Argus Range south of the Wilson Canyon fault.

4) The apparent lack of a surface water and groundwater discharge areas from the valley.

Together, these conditions suggest that natural flow directions in the alluvial deposits are from the ranges toward the saline deposits at the valley bottom. Superimposed on these natural flow directions are the radial flow patterns caused by pumping from the brackish aquifer.

Montgomery (1989) drew "groundwater level contours" using fluid elevation data collected in 1988 from wells completed in both the alluvial deposits and the Mixed Layer of the saline deposits. The contours provide an approximation of groundwater flow directions in the alluvial/Mixed Layer system, but are limited by significant variations in the specific gravity of the

brine that have not been corrected for. If applied, corrections for specific gravity would have the affect of raising the water-table elevations and flattening the hydraulic gradients into the center of the valley.

Groundwater level contours prepared by Montgomery (1989) illustrate the expected relationships and flow directions. Water levels are lowered in the vicinity of well fields that draw from the alluvial deposits including: Valley Wells, Argus Wells, Westend Field and South Brackish Wells. Between Mixed Layer injection and production wells, hydraulic gradients are relatively flat and generally slope toward the production wells. Montgomery (1989) suggests that the Wilson Canyon Fault might be a barrier to groundwater migration and cites differences in the specific gravity of groundwater on either side of the fault as evidence of the barrier.

Groundwater elevation contours based on March 2000 water-level measurements in the alluvial deposits are shown in Figure 2. While similar to the 1988 contours, the March 2000 contours illustrate the general decline of water levels in the South Brackish pumping wells by as much as 200 feet since 1988 and more generally in this area by 70 to 80 feet.

3.2 WATER BALANCE CONSIDERATIONS

Figure 4 is a schematic cross section illustrating the movement of water in Searles Valley. This schematic identifies the primary inputs, outputs and transfers of water within the basin. The following sections briefly describe water gains, water transfers and water losses that are significant to hydrogeologic resources in the Searles Valley.

3.2.1 Water Gains

Known and suspected water gains in the Searles Valley include:

- Direct precipitation,
- Underflow/seepage into the basin from Indian Wells Valley through the Argus Range, and
- Imported water from Indian Wells Valley

Searles Valley is located in the Basin and Range geomorphic province of eastern California, immediately north of the Mojave Dessert and in the rain shadow of the Sierra Nevada. National Oceanic and Atmospheric Administration (NOAA) precipitation records for a recording station at Trona for the period 1931 to 1997 document an average rainfall of 4.24 inches per year. The maximum annual precipitation recorded during this period was 9.01 inches during 1941 (Figure 5). During the period of record for the Trona station, less than one inch of precipitation was recorded during 1947, 1953, 1985, and 1989. Typically, seventy two percent of the annual precipitation occurs in the months of November through March (Figure 6). Assuming the average annual rainfall of 4.24 inches per year and a drainage basin area of 693 square miles, precipitation inputs about 170,000 acre-feet of water per year. The percentage of rainfall that infiltrates and recharges the groundwater system within the valley is unknown.

As described in Section 2, there is evidence of underflow through the Argus Range into Searles Valley. The quantity of this underflow may be significant, but has not been estimated with certainty.

Water is imported into Searles Valley from Indian Wells Valley by pipeline. Figure 7 illustrates that water was typically imported into Searles Valley from Indian Wells Valley at rates of 1,500 to 1,700 gpm during the period of 1990 to mid 2000. During the period of April 2000 to March 2001, the quantity of the imported water was 2,363 acre-feet.

3.2.2 Intra-Basin Water Transfers

Known intra-basin water transfers that have indirect affects on the water balance include:

- Discharges from Argus and Slate Range Springs
- Brackish water pumped from wells in the South Brackish and Valley Wells well fields and from the Golf Course well
- Brine production, injection in the saline deposits and discharge to brine effluent ponds.

Argus Range springs within the Searles Valley Drainage basin were previously used by salt production facilities as a water supply. Montgomery (1989) reports that the flow accumulated from these springs fluctuated between 75 and 300 gpm. Assuming that the springs tapped for the water supply represent about fifty percent of the spring discharge in the Argus Range, total spring flow may range from 200 to 1,000 acre-feet per year.

Figures 8 and 9 illustrate the monthly rates of pumping that have occurred from all wells in the South Brackish and Valley Wells well fields during the period of 1990 through mid 2000. Production from the South Brackish well field has generally been at rates of 3,500 to 4,700 gpm. Monthly production from the Valley Wells well field has generally been at rates of 2,000 to 2,700 gpm. During the period of April 2000 to March 2001, water pumped from the Valley Wells well fields and the Argus well was estimated to be 4,580 acre-feet. From the South Brackish well field, during the same period, production of brackish water was estimated to be 6,326 acre-feet. An estimated 600 to 800 gallons per minute of water is produced from the Golf Course well located west of Trona (Fairchild, personal communication). Most of this water is combined with production or process brine effluents and either injected or diverted to the Dredge and Percolation ponds.

Salt production operations include:

- Pumping of brine from the Upper/Lower Salt and from the Mixed Layer
- Injection of process brine effluent into the Mixed Layer
- Return of brine effluent to the Dredge and Percolation ponds
- Percolation of brine effluent into the Upper/Lower Salt and loss of water from the ponds by evaporation.

The estimated quantities of brine and water that were involved in these transfers during the period of April 2000 to March 2001 are illustrated in Figure 4.

3.2.3 Water Losses

Known water loses from the valley are by:

- Basin-wide evaporation
- Brine influent solar pond at the Westend Plant
- Brine effluent pond evaporation.

Montgomery (1989) reports that the potential evaporation rate for fresh water in the Searles Valley is estimated to be 84 inches per year. Because fresh water is not available at the surface of the valley for evaporation during the entire year, the total annual water loss through freshwater evaporation is unknown. Shallow soil moisture that accumulates during wet periods and a high percentage of water discharged by springs are likely lost by evaporation.

Montgomery (1989) reports that the evaporation rate for bines (e.g., Dredge and Percolation ponds) near saturation is 41.5 inches per year. Because brine effluent ponds are present at the site, this rate can be achieved over the surface of the ponds. Thus, the total annual water loss through brine effluent evaporation is largely dependant on the size the brine effluent ponds. The total annual water loss from evaporation on the brine effluent ponds is estimated to range from 1,000 to 6,000 acre-feet per year.

Given that ephemeral waters are brine (Kennedy/Jenks, 2001), the brine evaporation rate also applies to ephemeral waters, when present. The total annual loss of water by evaporation of ephemeral waters is highly seasonal and has not been estimated.

3.2.4 Water Balance Summary

A comprehensive understanding of the water balance for Searles Valley is impeded by significant uncertainties in:

- The net volume of infiltration from precipitation. The uncertainty is primarily the result of the large difference between precipitation and evaporation. Annual precipitation of 4.24 inches per year could, on average, input 170,000 acre-feet of fresh water per year into the basin. The evaporation potential for fresh water (84 inches per year) and brine (41.5 inches per year) could remove more than 10 times the volume input by precipitation.

- The volume of underflow through the Argus Range. A good estimate of the volume of groundwater that enters Searles Valley from the adjacent Indian Wells Valley is not available.

Although the details of water transfers within the basin are complicated by injection and production activities, the net affect of these transfers increases the potential for evaporation of water from the brine effluent.

A conservative estimate of water losses by evaporation from the surface of the brine effluent ponds is 1,000 to 6,000 acre-feet per year, depending on pond area. Mass balance calculations by IMCC for the period of April 2000 to March 2001 suggest that about 9,400 acre-ft of water evaporated from the ponds. Annual evaporation from ephemeral ponds increases the total evaporative loss by variable and undetermined amount.

A comparison of water levels in the brackish aquifer during 1988 (Montgomery, 1989) and water levels for March 2000 (Figure 2) suggest that declines have occurred under the influence of: 1) long-term pumping and 2) seepage of brackish water in alluvial deposits into the Mixed Layer of the saline deposits. The long-term, water-level decline in the brackish aquifer suggests that basin-wide water losses exceed basin-wide gains.

4 Springs and Spring Water Quality

4.1 OCCURRENCE OF SPRINGS IN SEARLES VALLEY

Despite the low annual precipitation received by Searles Valley and the surrounding area, springs are known to exist. The distribution of the springs in the Searles Valley drainage basin is highly variable and is primarily from the bedrock complex. Discharges from the springs are generally low and subject to season variations. The locations of springs that were identified by IMCC from personal knowledge and from USGS and BLM maps are shown in Figure 2.

A large cluster of springs is located in the Argus Range north of Wilson Canyon. Twenty six of these Argus Range springs are located in the Searles Valley drainage basin and thirteen are located in the adjacent Indian Wells Valley drainage basin. All of the Argus Range springs north of Wilson Canyon are located above 2000 feet msl, many are above 2,500 feet msl and a few are above 4,000 feet msl. A series of the springs within the Searles Valley drainage basin were previously tapped by Searles Valley mining operations for water supply. This water system was referred to as the Mountain Water System and yielded a total flow of 75 to 300 gpm (Montgomery, 1989).

In the Argus Range south of Wilson Canyon, three springs have been identified including a spring in Poison Canyon that discharges poor quality water that is unlike any of the other spring water in the area. Springs south of Wilson Canyon are located at elevations of 1,900 to 2,000 feet msl. Estimates of yield are not available for these Argus Range springs.

Four springs are known in the Slate Range, three in the Searles Valley drainage basin and the fourth in the adjacent Panamint Valley drainage basin. The Slate Range springs within the Searles Valley drainage basin appear to be located at elevations between 2,100 and 3,100 feet msl. Estimates of yield are not available for the Slate Range springs.

One spring is known to exist in the southward extension of the Slate Range, south of the Garlock Fault. This spring appears to be located at an elevation between 3,000 and 3,500 feet msl. Information regarding the yield of this spring is not available.

4.2 WATER QUALITY DATA FOR SEARLES VALLEY SPRINGS

Analytical data for springs in the Argus and Slate ranges are available from four separate sampling events:

1) Sampling reported by Montgomery (1989) for twelve springs (Table 1).

2) Sampling performed by the United States Navy in October/November 1993 at 32 area springs. Analytical results for nine of these springs are considered pertinent to the investigation and are summarized in Table 2.

3) Sampling performed by the United States Navy in October 1996 at 19 springs. Analytical results for eleven of these springs are considered pertinent to the investigation and are summarized in Table 3.

4) Samples collected for the current investigation in June 2001 at six springs, including a sample from Poison Canyon Spring. Analytical results for these six springs are summarized in Table 4.

The June 2001 spring sampling event is described in Section 4.2.1. A discussion of the available spring water analytical results for the Argus Range is provided in Section 4.2.2

On 22 June 2001, representatives of Kennedy/Jenks and IMCC visited six accessible springs located in the Argus Range. These springs included:

- Great Falls
- Bainter
- Indian Joe
- Wilson Canyon
- Christmas Tree
- Poison Canyon

Great Falls is named Austin Spring and Wilson Canyon Spring is not shown on the Trona West USGS Topographic quadrangle. The locations of these and other area springs are shown in Figure 2.

With the exception of Poison Canyon Spring, these springs are located north of the Wilson Canyon fault. Poison Canyon Spring is located in Poison Canyon between Salt Wells Valley and Searles Valley. The GPS coordinates of the springs were obtained during reconnaissance visits made by IMCC the week prior to sampling.

The rate of discharge from these springs varies with annual rainfall and season. At the time of the visits, discharges were estimated to be considerably less than one gallon per minute (gpm). Where the actual spring location was not accessible, water was collected from pools or streamlets that issued from the spring.

During the visit, temperature, pH, and specific conductance were measured in the field using a Hydac model 910 meter. At the request of LRWQCB, samples were collected in appropriate sample containers for the analysis of:

- Major cations: Calcium, Magnesium, Potassium, and Sodium
- Major anions: Alkalinity, Chloride, Nitrate as NO^3 , Sulfate, and Sulfide
- Metals: Arsenic, Boron, Selenium, and Tungsten
- Specific Conductance and
- Total Dissolved Solids

The results of these analyses are summarized in Table 4. Laboratory reports for these analyses are included in Appendix A. Pictures of the spring sampling locations taken the week prior to sampling are included in Appendix B.

4.3 ARGUS RANGE SPRING WATER QUALITY

The scope and analytical testing for the four sampling events (Tables 1 through 4) described above are different, but after examining the data, Kennedy/Jenks notes the following regarding the springs in the Argus Range, exclusive of Poison Canyon Spring samples:

1) The reported concentrations of total dissolved solids in the spring-water samples ranged from 192 to 1010 milligrams per liter (mg/l).

2) Boron was detected in all of the spring-water samples at concentrations that ranged from 0.08 to 1.02 mg/l.

3) Arsenic was detected in two of the spring-water samples at a concentration of 0.003 mg/l.

4) Nitrate was detected in 29 samples at concentrations that ranged from 0.3 to 40 mg/l as nitrogen.

The quality of water collected from Poison Canyon Spring is distinctly different than all of the other spring water samples and is characterized by:

1) A TDS concentration of 49,640 mg/l that classifies the water as a brine.

2) A combined sodium plus chloride concentration of 31,610 mg/l

3) Sulfate concentration of 4,810 mg/l

4) Elevated concentrations of arsenic (884 mg/l), boron (219 mg/l), selenium (108 mg/l) and tungsten (582 mg/l). The maximum contaminant levels for drinking water are exceeded for arsenic (0.01 mg/l) and for selenium (0.05).

Water from the natural-occurring Poison Canyon Spring flows eastward into Searles Valley south of the Westend Plant.

4.4 SLATE RANGE SPRING WATER QUALITY

Four spring-water analyses are available for springs in the Slate Range; two each from the 1993 and 1996 Navy sampling events (Table 2 and 3). These sample results suggest that spring waters on the western slope of the Slate Range are different from spring water in the Argus Range. Water from Amity Spring contained less than 1,000 mg/l TDS and contains low concentrations of sodium (61 mg/l), chloride (75 mg/l) and boron (0.3 mg/l) similar to the Argus Range Springs. The following observations are made regarding Layton, Dust Bowl, and New York springs in the Slate Range:

1) Total dissolved solids (TDS) range from 1,130 to 3,990 mg/l and much of the increase in comparison to Argus Range springs can be attributed to increased concentrations of sodium, chloride, and sulfate.

2) Boron was present in these spring water samples at concentrations that range from 2.7 to 9.8 mg/l.

3) Arsenic was not reported in any of the spring water samples.

5 Comparison to Ephemeral-Water/Brine Effluent Quality

Kennedy/Jenks (2001) reports the results of an investigation to characterize the quality of water that ponded on the surface of Searles Dry Lake after the 2000-2001 period of precipitation that was significantly wetter than in recent years. Referred to as ephemeral water, the temporarily ponded water occurs as the water levels beneath the lakebed rise. Process ponds cover approximately 1,200 acres of the Searles Dry Lake lakebed including the 1,100-acre Percolation Pond. During March of 2001 ephemeral ponding covered an additional 2,000 to 2,500 acres of the lakebed. Depths of the ephemeral ponds ranged from less than one to nineteen inches deep.

Kennedy/Jenks (2001) summarizes the results of two rounds of sampling and testing of the ephemeral waters collected on the dry lakebed as well as solution mining process brine effluents collected from three process ponds (i.e., Dredge, Percolation, and Westend Ponds). The results of these analyses are summarized in Table 5. The locations of these ponds and the general locations of the ephemeral waters are shown in Figure 2.

A comparison of the ephemeral waters to the process brine effluent indicates that both are brines. The TDS concentrations for five Ephemeral Ponds (3, 10, 14, 32, and 52) were shown to be higher than the concentrations found in the process brine effluent. An additional comparison between the ephemeral ponds and the Dredge and Percolation Ponds also showed this to be the case for arsenic, boron, selenium, and tungsten.

The chemistry of spring waters that flow in the Argus and Slate ranges are distinctly different from the chemistry of both the process brine effluent and the ephemeral water of Searles Valley. In general, the TDS content of Argus Range spring water is three orders of magnitude less than the TDS concentrations measured for effluent brines and ephemeral waters. Similar differences are noted for sodium, potassium, chloride, and sulfate concentrations.

With few exceptions, spring water from the Argus Range contains detectable concentrations of boron and occasionally an individual spring may contain detectable arsenic, barium, cadmium, lithium, or selenium. However, these trace metals are absent from most of the springs. Brine effluent and ephemeral waters contain arsenic, boron selenium and tungsten at concentrations that are as much as four orders of magnitude higher than the detection limit for the spring water samples.

6 Discussion and Conclusions

Regarding the movement of water in the hydrogeologic units:

- The Upper/Lower Salt zone appears to be separated from the Mixed Layer by a thick, low-permeability Bottom Mud that limits the movement of brine between the layers. The Upper/Lower Salt zone appears to be recharged by infiltration from brine effluent ponded on the lakebed. Movements within this zone are highly dependent on brine production activities that are beyond the scope of this report.

- The injection of 20-40 percent less brine effluent to the Mixed Layer than is produced from this zone suggests that a general lowering of brine levels in the Mixed Layer production zone might induce hydraulic gradients toward the Mixed Layer from 1) the overlying Upper/Lower Salt and 2) , the transition zone into the saline deposits. These effects essentially increase the natural tendency of water to move toward the low point of the basin that lies within the Searles Dry Lake Brine Area. Movements within this zone are dependent on brine effluent production and injection activities that are beyond the scope of this report.

- There is limited evidence that groundwater may be moving from Indian Wells Valley through the Argus Range into Searles Valley in the area south of the Wilson Canyon fault. The primary evidence of this flow appears to be the continued production of water from the well referred to as the "Golf Coarse" Well in the Argus Well field and the presence of seeps at the base of the Argus Range between Trona and Westend.

- Long-term declining water levels in the alluvial deposits can be attributed to pumping at the Valley Wells and South Brackish well fields and suggest that production from these fields is exceeding the average annual recharge to the Searles Valley. These pumping centers induce radial flow toward the producing wells. Drawdown in the South Brackish Well Field could eventually draw water from the transition zone adjacent to the saline deposits at the south end of the saline deposits.

Regarding the quality of water within Searles Valley:

- Water quality varies over a wide range of salinity within the Searles Valley, suggesting different origins and histories for these waters.

- Springs in the Argus and Slate ranges occur well above the dry lakebed and are fresh to slightly saline. They are distinctly different from the production brines within the saline deposits, the brine effluent, and ephemeral waters (also brine) that are seasonally present on the lakebed.

- There is limited evidence that Slate Range springs have higher TDS and classify as slightly to moderately saline in comparison to the fresh water springs in the Argus Range. The higher TDS of springs in the Slate Range may be caused by the presence of more sedimentary and fewer igneous rocks in the Slate Range. Alternatively, the higher TDS may be explained by the presence of salt-laden dust blown into the Slate Range off the Searles Dry Lake lakebed by predominately westerly winds.

- The quality of the water in Poison Canyon Spring is distinctly different from both the Argus Range springs and the Searles Dry Lake brines. Water from Poison Canyon Spring has the highest concentrations of arsenic, selenium and tungsten measured in any brine or water sample. However, the TDS and salinity of Poison Canyon Spring are less than those of the brines. Poison Canyon Spring appears to be seepage from Salt Wells Valley that flows into Searles Valley.

This evaluation of the hydrologic resources supports IMCC's request for a change in site-specific designation in the Beneficial Use Plan by:

- Providing an overview of the Searles Valley hydrogeologic system in which the proposed Searles Dry Lake Brine Area is located.
- Illustrating the relative isolation of the brine body from the surrounding brackish aquifer by virtue of the
    - Brine body's location at the low point of the valley and
    - Presence of thick, low-permeability strata within the valley that inhibit the movement of brine out of the saline deposits (Upper/Lower Salt and Mixed Layer) and into the brackish alluvial aquifer.
- Identifying that net the loss of brine produced from the brine zones by evaporation of water from the ponds should tend to enhance water movements toward, rather than away from, the brine body.
- Demonstrating that the quality of water in the Argus and Slate Range springs is distinctly different than the brine that is characteristic of the Searles Dry Lake Brine Area.

7 References

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