Water - Hydrology

The "Hydrology" section addresses matters relating to the physical hydrology of GSL, including lake water level, inflows, flooding and diversions. The information collected during the scoping process highlighted three general areas of interest and concern with regard to the hydrology of the lake: lake level, including both low water levels and flooding potential; inflows to the lake, including flow quantities and locations; and diking and causeways in the lake, which affect currents and in-lake water conditions. Dikes and causeways have significant impacts on lake hydrology and water chemistry. The most significant resource impacts of dikes and causeways are more directly related to water chemistry than to other factors.

Based on the information gathered during scoping and the resource inventory, the planning team identified five major conditions and trends for the hydrology of the lake which are relevant to future management:

- **Continued reduction in inflows is anticipated. Studies of the lake hydrology indicate that 100,000 acre-feet of additional depletions per year would lower the average lake level approximately one foot.**

- **The statutory requirement to define the flood plain and develop strategies to deal with a fluctuating lake level needs to be addressed.**

- **The WDPP can presently be used for mitigation of flood impacts when the south arm lake level reaches 4208 by pumping north arm brines. The WDPP stands ready to be utilized for mitigation, but administrative barriers to its operation, external to DNR, now exist.**

- **Locomotive Springs is being impacted by decreasing water flows. This issue would require that DNR develop strategies to mitigate and remediate this inter-state situation.**

- **DNR is interested in establishing a policy regarding inter-island diking and freshwater embayments.**

Changes to Inflows

GSL is a remnant of Pleistocene Lake Bonneville, and occupies the lowest point in a 22,000 square mile drainage basin. The lake is a terminal lake with no outlet. This closed basin is formed by the drainages of the Bear, Weber and Jordan Rivers, plus drainage areas northwest and southwest of the lake (Exhibit 2). The average annual inflow to the lake, for the years from 1851 to 1996, has been approximately 3,684,500 acre-feet. Inflows originate from gaged or correlated stream flows (2,382,500 acre-feet); estimated un-gaged surface water (191,500 acre-feet); estimated un-gaged groundwater (107,500 acre-feet); and precipitation directly onto the lake surface (1,003,000 acre-feet) according to DWRe Great Salt Lake Simulation Model (1974a) (Exhibit 3). The average total annual evaporation equals average annual inflow, although inflow exceeds evaporation during cooler, wetter weather cycles, and evaporation exceeds inflow during hotter, dryer cycles. All water which is diverted from the lake (except the WDPP) is utilized for mineral extraction by evaporation and is included in the annual evaporation.

At the average water elevation of 4200 (above sea level), GSL has a surface area of 1,500 square miles, making it the fourth largest terminal lake in the world. GSL is hypersaline, with average total dissolved salt concentrations in its various arms ranging from about 8 percent to more than 26 percent. The average depth of the lake is approximately 14 feet, so that small changes in lake level either expose or inundate large areas of lake shoreline. For example, at a lake elevation of 4200 (above sea level), the lake's waters cover 1,079,259 acres. At 4204, lake waters inundate a total of approximately 1,223,000 acres. Seasonal and long-term fluctuations in lake level produce dramatic changes in the lake's shoreline. These fluctuations are an integral part of the lake ecosystem. Pumping from the lake would reduce peak elevations with minimal changes to natural lake level fluctuations.

The physical configuration of the lake and its high salinity create a "buffering" effect on the rate of evaporation of the lake. In general terms, as the lake rises, it increases significantly in surface area and declines in salinity. These factors contribute to an increase in annual lake water evaporation, and tend to slow the rise of lake level. Conversely, when the lake level drops, the surface area diminishes and the salinity increases, reducing the total annual evaporation. The lake, therefore, has a natural mechanism to prevent drying up and has a tendency to slow its own rate of rise. It has been suggested that a one-time removal of water from the lake, while noticeable at the time of removal, will eventually "heal" itself through this buffering effect, returning to pre-removal elevations. Long-term increases in diversions will, however, produce long-term changes in lake level.

Water Development Impacts on Lake Level

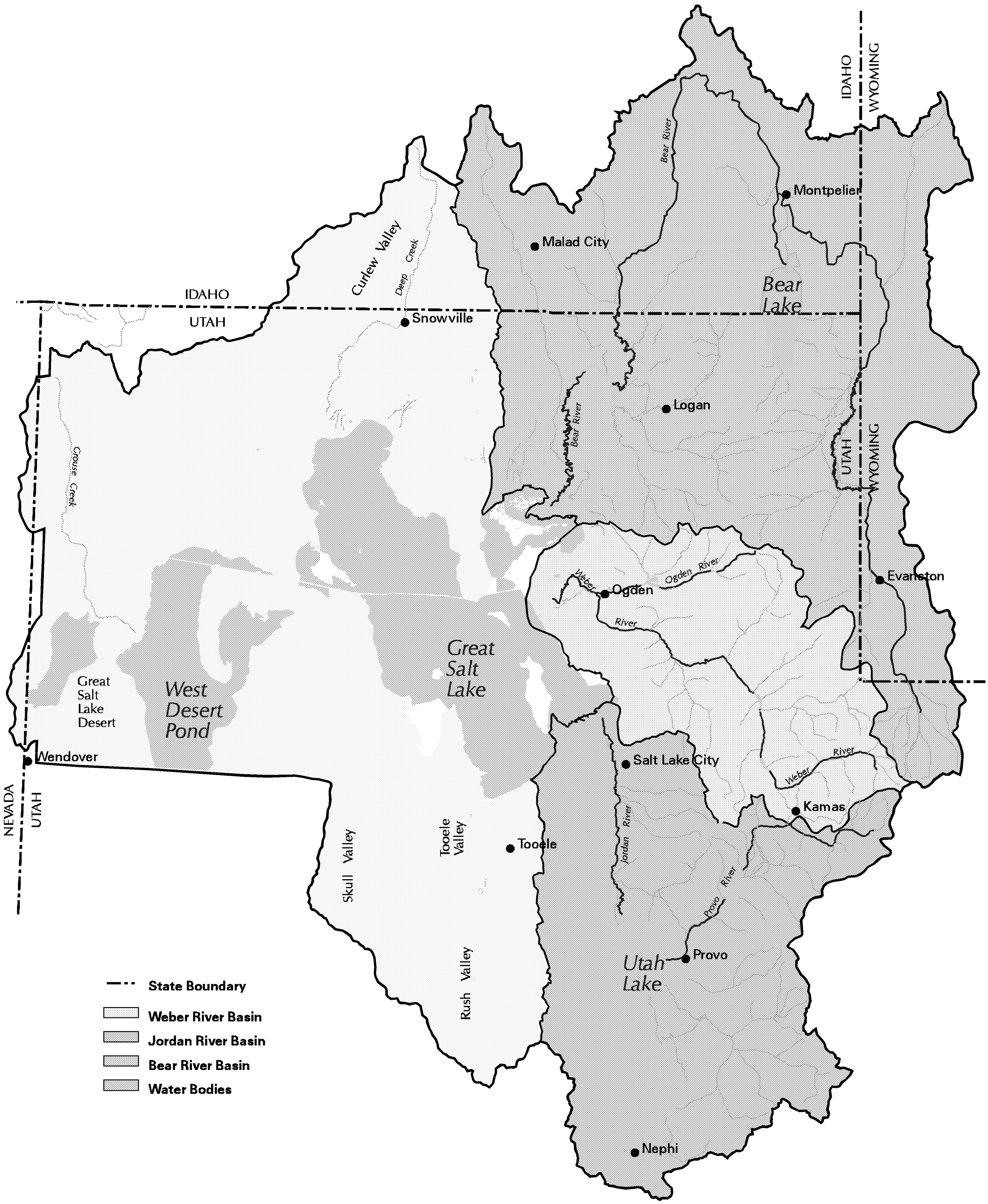
Over the last 20 to 30 years, studies have attempted to define the effects of water development and other human-caused water use on lake level. The studies indicate that with 100,000 acre-feet of annual depletion in the basin, the average level of the lake would be approximately one foot lower. The effect of this depletion on the lake elevation is greatest at low lake levels. The diversion of 100,000 acre-feet does not result in the depletion of 100,000 acre-feet if part of the diverted water returns to the lake. Water diverted for agricultural uses and for municipal (including drinking water) and industrial uses (M&I) is not entirely depleted, and significant quantities, approximately 60-70 percent (Jordan Valley Water Conservancy District, 2000a) are returned to the system as return flows. Also an average increase of 100,000 acre-feet of inflow per year to the lake would raise the average lake level by approximately one foot.

These studies have also shown that the lake would be approximately five feet higher without any human-caused depletions.

It is expected that depletions to the inflow of GSL from historical sources will continue through water development

Exhibit 2 - Great Salt Lake Drainage Basin

Plotted March 29, 2000



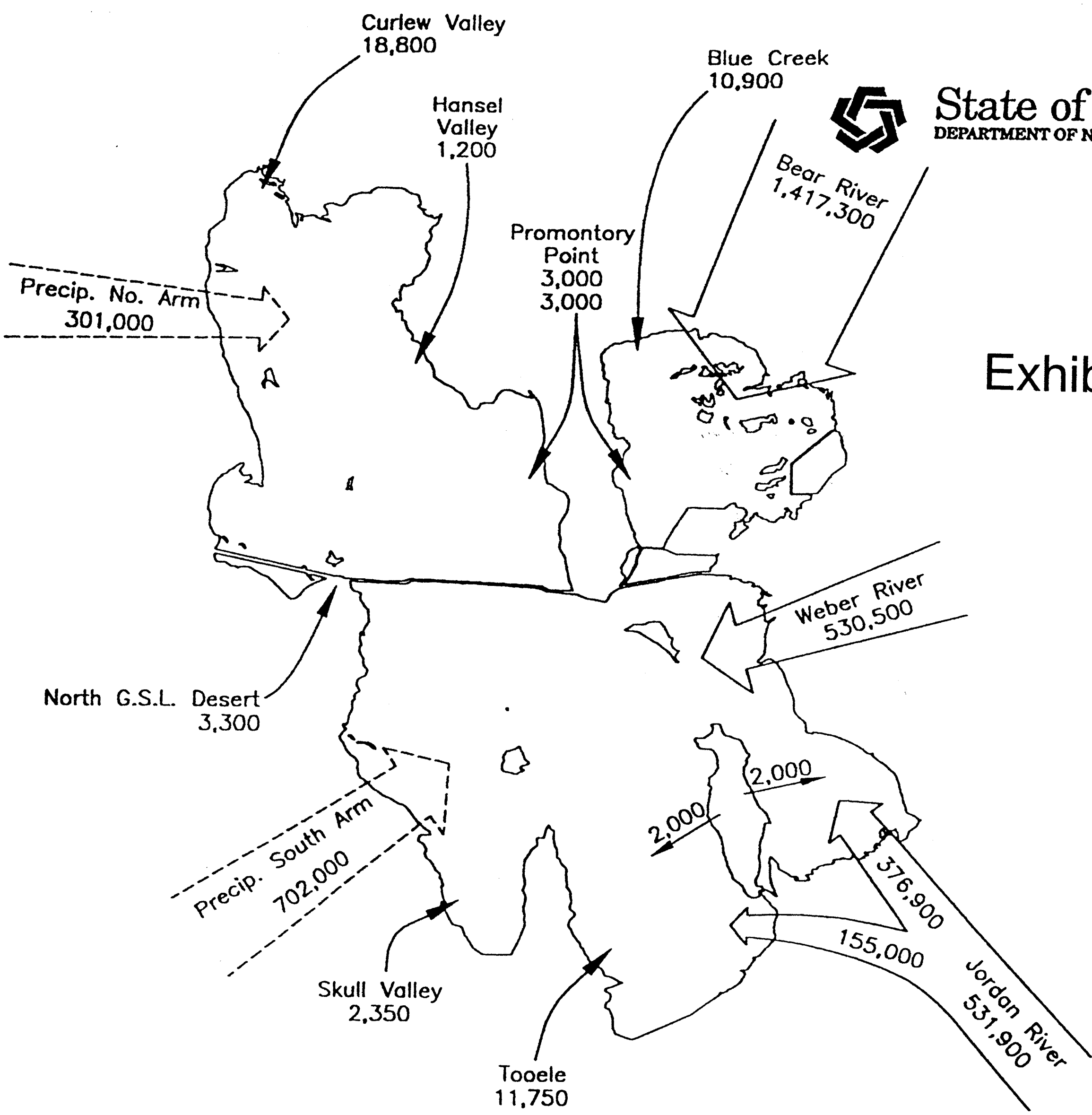
SOURCE:
This map was produced by Daniel Smith from the Utah Division of Oil, Gas and Mining
Information on this map was compiled by the Utah Department of Natural Resources and the Utah Automated Geographic Reference Center.
Official and detailed information is only available through DNR and AGRC.

0 10 20 30 40 50 mi
0 100,000 250,000 ft
0 10 40 70 k

Scale 1:825000 (verify scale)

State of Utah
Department of Natural Resources

Exhibit 3



River Basin	Inflow Gaged	Ungaged	Ground Water	Total	%
Bear River	1,417,300	79,500	64,000	1,560,800	42
Weber River	482,400	26,600	21,500	530,500	14
Jordan River	482,800	27,100	22,000	531,900	14
Other		58,300 *		58,300	2
Subtotal	2,382,500	191,500	107,500	2,681,500	
Precipitation				1,003,000	27
Total				3,684,500	

* Includes Surface & Subsurface Flow

Source: Division of Water Resources – Great Salt Lake Simulation Model 1851–1996

Great Salt Lake Water Supply

on tributaries to the lake and other human-caused water uses. In the Jordan and Weber Basins, which have been highly developed by Weber Basin Water Conservancy District and Central Utah Water Conservancy District projects, it is expected that already diverted and developed water will be converted from agricultural uses to meet M&I demands, rather than large, new water projects being developed. M&I uses tend to consume similar quantities of water per acre as do agricultural uses. Another mitigating factor may be the importation of Uinta Basin water to the GSL Basin. The total estimated flow from the Uinta Basin, including the completion of the CUP, will be approximately 195,000 acre-feet per year (af/yr). Currently, approximately 95,000 af/yr enter the GSL Basin from the Uinta Basin. This inflow reduces human impact on lowering GSL.

In the Bear River Basin, it is expected that major new water diversions and developments will occur. Alternatives for development of water resources in the GSL drainage area have been documented in the Utah State Water Plans. These plans guide management and development of water resources in the GSL drainage basin, but are not for the purposes of managing inflow, level or surface area of GSL. These plans are available from DWRe.

Changes in Water Diversions from Great Salt Lake

Administration of Water Rights and Diversions

The diversion of water from GSL is governed by the same Utah water appropriation laws and regulations as the diversion of water from streams, springs or wells. Under Utah law, all waters of the state are the property of the public (Utah Code 73-1-1). A water right secures to an individual or entity the right to divert the water and place it to a recognized beneficial use. All water rights in the state are administered by the State Engineer with the assistance of DWRi staff.

Currently, Utah water law requires that water be distributed according to the priority date of the underlying water right. During dry periods, water rights for domestic use and public supply can be taken ahead of rights for other uses when the priority dates of the involved rights are equal. Any change to this arrangement will require legislative action (Utah Code 73-3-21).

A water right is acquired by filing an application with the State Engineer and receiving approval. If the application is approved, the applicant generally has three years to develop the project, place the water to beneficial use and submit proof of the beneficial use to the State Engineer. Extensions of time for filing proof can be requested. An unapproved water right is considered to be the personal property of the applicant. When the application has been approved it becomes real property. Once proof of beneficial use is submitted defining the quantity of water developed and the water uses, the State Engineer issues a Certificate of Appropriation which the applicant files with the local county recorder. At this point, the water right is said to be perfected.

For an application to be approved for development, the following conditions must exist: (1) there must be unappropriated water in the proposed source; (2) the proposed use must not interfere with existing rights or interfere with a more beneficial use of the water; (3) the proposed development must be physically and economically feasible and not detrimental to public welfare; (4) the applicant must have the financial ability to complete the proposed works; and (5) the application must be filed in good faith and not for speculation or monopoly 73-3-8 (Utah Code Annotated, 1953). If there is reason to believe that an application will interfere with a more beneficial use, unreasonably effect public recreation or the natural stream environment or will prove detrimental to public welfare, the State Engineer will withhold approval.

There is an additional requirement of the law which is important. To maintain a water right, the water must be diverted, or physically removed, from its natural source. The only exception to this rule is approved in-stream flow rights, which must be held by either DWR or DPR.

There are several reasons a water right may be terminated. An unperfected water right may be terminated by the State Engineer, (1) at the applicant's request, (2) if the applicant fails to meet the criteria for appropriation or the conditions of approval, or (3) the applicant fails to develop the project in the time allotted. Once a water right is perfected there are two reasons it may be terminated. The water right holder can file a statement of abandonment and forfeiture with the State Engineer and the local county recorder, or the courts may terminate the water right as part of a civil or criminal proceeding.

Tributary Water Rights

Except for the Bear River drainage, the West Desert and the lake itself, all surface waters of the GSL Basin are considered to be fully appropriated, except during high water years. On the Bear River, appropriations are still allowed, but there are factors which may restrict the amounts available. At present, the Board of Water Resources, by statute, is considering various alternatives for the development of Bear River water for use in various locations along the Wasatch Front. Development of the Bear River is subject to the limitations of the Bear River Compact.

Ground Water Rights

The Jordan River system, the Weber River drainage, and Tooele Valley are closed to new appropriations of ground water except for the shallow water table aquifers of Salt Lake Valley, Tooele Valley, and the Weber Delta. Groundwater is still available in the Bear River drainages and the west desert. In the Weber Delta and Bountiful sub-area, ground water from the deeper aquifers is still available for single-family domestic uses where no public water system exists. The Weber Delta is open to municipal appropriations on a case-by-case basis where an immediate need can be demonstrated.

For administrative purposes, the State Engineer has divided the GSL drainage basin into sub-basins. Each sub-basin has its own set of policies governing the appropriation and management of its water. GSL is open to appropriation. However, the siting of diversion facilities is dependent upon the applicant securing the proper easements and/or permits from the responsible regulatory agencies and landowner (Appendix F, Exhibit 1).

There are currently 11 perfected water rights to divert water from the lake, all owned by companies or individuals in the mineral extraction industry (Exhibit 4, locations of mineral extraction operations). The earliest priority date of these rights is 1940; the latest is 1986. Under these rights, if used to their fullest, it is possible for the rights holders to divert 362,306 af/yr. Due to economic limitations, climatic conditions and the available evaporative surface, only 95,000 to 180,000 af/yr is currently diverted. The vast majority of this water is evaporated, while very small amounts return to the lake through pond leakage and flushing.

There are six water rights applications which have been approved for development, one of which is non-consumptive. These rights, all owned by mineral extractors, represent a possible diversion of 444,562 af/yr for mineral extraction. The earliest priority date of these rights is 1962; the latest is 1993. Like the perfected rights, the majority of the water diverted under these applications would be consumed by evaporation.

There are 11 applications which have not been approved for development. Ten of these applications are owned by mineral extractors and one is owned by a quasi-governmental agency to provide cooling water for a proposed nuclear power plant. These applications represent a potential additional diversion of 657,565 af/yr, the great majority of which is for mineral extraction. The earliest priority date is 1964; the latest is 1995. The State Engineer has on file four unapproved applications which do not divert water from the lake, but which would have a large impact on it. All call for the diking of Farmington Bay and its use as a freshwater reservoir.

Under existing approved rights, an additional 627,000 to 712,000 acre-feet of brine per year could be diverted from GSL and consumed by evaporation. However, unless this diverted water is evaporated in ponds constructed outside the lake area, thereby increasing the effective surface area of the lake, such additional diversions should have no measurable effect on average lake level. Although this quantity is approximately 25 percent of the total annual inflow to the lake from all sources, the primary limiting factor on greatly increased water diversions from the lake under existing rights and applications is the amount of new land available and suitable for evaporation ponds. The possibility that all the water approved under existing applications will be diverted and consumed at some time in the near future is unlikely. It is, however, likely that existing mineral extraction operations will seek to expand their evaporation ponds and brine diversions.

Global and Regional Climatic Change

GSL and it's watershed respond to global and regional climatic variability (precipitation, cloud cover, temperature and wind patterns). Understanding the relationship between lake and watershed hydrology and global climatic processes is important to understand changes in lake volume, salinity, and ecosystems behavior. (SRC, 1999c)

Many studies have focused on the relationship between lake volume, watershed processes and global climatic behavior. See Mann et al. (1995), Lall and Mann (1995), Moon and Lall (1996), Abarbanel et al. (1996), Lall et al. (1996) and Sangoyomi et al. (1996). (SRC, 1999c)

Flood Plain

DFFSL's statutory mandate is to define the lake's flood plain and the legislative policy is to maintain the lake's flood plain as a hazard zone. DNR considers the flood plain to extend to 4217. This is based on recent high lake level of roughly 4212, plus three feet for wind tide and two feet for wave action.

DNR has no regulatory authority over land it does not own in the flood plain. The regulatory framework is provided by local government planning and zoning, FEMA and U.S. Army Corps of Engineers (COE). DNR satisfies the legislative mandate and policy by defining the flood plain for planning purposes as lands below 4217 and discouraging development below that level. FEMA has mapped the flood plain to determine when flood insurance is required. Adherence to FEMA's demarcation is required if local communities want to participate in the National Flood Insurance Program. COE regulates placement of fill material in wetlands. If a wetland lies within the flood plain as determined by COE, an additional criterion is added to the permit decision-making process. Agencies do not always agree on the extent of the flood plain.

Flooding and the Operation of West Desert Pumping Project

Lake Level Fluctuations and Flooding

The historic hydrograph of GSL in Exhibit 5 is based on measurement at a series of lake gages since 1875 and on estimates of the lake level for the period prior to 1875. These estimates are based largely on interviews with stockmen who moved livestock to and from Antelope and Stansbury Islands from 1847 to 1875. The annual variations shown for this early period are the average of those measured since 1875. Although the major features of the pre-1875 hydrograph are real, the details are uncertain. For the period since 1875 a small but significant uncertainty exists in the elevation of the various gages used, and thus an uncertainty of several tenths of a foot exists in the absolute elevation of the lake level shown on the hydrograph for certain periods. Any analysis of the hydrograph should consider the uncertainties in the data upon which it is based.

GSL has historically (defined as the period from 1847 to the present), experienced wide cyclic fluctuations of its surface elevation. Since 1851, the total annual inflow (surface, ground water and precipitation directly on the lake surface) to the lake has ranged from approximately 1.1 to 9.0 million acre-feet. This wide range of inflow and changes in evaporation has caused the surface elevation to fluctuate within a 20 foot range. Historically, the surface elevation of the lake reached a high of 4211.5 in 1873 and a low of 4191.35 in 1963 (Exhibit 5). A new record high elevation of 4211.85 in (USGS Provisional Lake Level Records) the south arm was reached in 1986 and matched again in 1987.

From 1933 to 1983, the average elevation of the lake was 4196.77 (above mean sea level), with a maximum of 4202.25 and a standard deviation of 2.58 feet. During the 100-year period prior to 1983, the lake's average elevation was 4198.29 with a high of 4207 and a standard deviation of 3.60 feet. During the period 1983 to 1987, however, the lake rapidly rose 12.2 feet from 4199.65 to 4211.85 feet, causing extensive flooding. The result was millions of dollars in damages and many millions more spent for mitigation and protection from future damage.

Because GSL is a terminal lake in a closed basin, the surface level of the lake changes continuously. Short-term changes occur in an annual cycle of dry, hot summers and wet, cool winters. Long-term climatic changes occur with overlapping periods of about 20 to 120 years, and perhaps longer. The annual high-lake level, which normally occurs between May and July, is caused by spring-summer runoff. The annual low-lake level occurs in October or November at the end of the hot summer evaporation season. The average annual (pre-1983) fluctuation of the south arm of the lake, between high and low, was about 1.48 feet; the north arm fluctuation averaged 0.99 feet. The difference between the magnitude of the south and north arm fluctuations is due mainly to the flow-restrictive influence of the northern railroad causeway (formerly the Southern Pacific Railroad [SPRR] Causeway) and the lack of tributary inflow to the north arm. The highest recorded annual rise of the south arm, 5.05 feet, occurred in 1983. This exceptional rise in lake level was due to high snow pack and above-normal spring precipitation.

Because of the broad, shallow nature of GSL, its surface area expands rapidly as its elevation increases. Elevations 4200 and approximately 4212 represent a common average lake level and the historical high-lake elevation, respectively. Between these two elevations, the area of the lake increases more than 46 percent from about 1,079,259 to 1,572,000 acres. Within this range, the potential of flooding exists. Above-normal annual fluctuations, such as those experienced during 1983 and 1984, result in extensive flooding.

The low lying plain surrounding GSL is particularly susceptible to flooding and other related hazards. Regarding the flood plain, Lowe (1990a and 1990b) states the following: "Using the best available historical and scientific data on GSL, government policy-makers and lake experts have recommended that a beneficial development strategy should exist for lake-shore areas up to 4217 feet in elevation" (DCEM, 1985). This strategy establishes a Beneficial Development Area (BDA) along the shore of GSL between 4191.4 (the lake's historical low level in 1963) and 4217. The strategy recommends that, within the elevation interval between 4191.4 and 4217, development take place in a manner that will encourage the maximum use of the land for the people of Utah while avoiding unnecessary disaster losses. Pursuant to this strategy, (1) UGS would provide technical information and maps showing geologic hazards; (2) city-county surveyors would provide a BDA line which is at the 4217 elevation contour to the planning, zoning and permitting agencies of applicable city, county and state agencies.

The naturally occurring water level fluctuations of GSL are termed “flooding” when the level of the lake begins to adversely affect structures and developments which are located within the flood plain. However flooding is a natural process and is mostly beneficial to species adapted to this dynamic environment. The impact of flooding is greatest around the shores of the south arm of the lake where the majority of the recreational, industrial, wildlife management and transportation facilities have been built. To minimize the impact of flooding, the present and past elevations of the lake and its anticipated short- and long-term fluctuation (rises and falls) should serve as guides to determine “safe” construction areas. This should also identify areas which may be subjected to inundation, wind tides, ice damage or shallow ground water problems.

Long-term lake fluctuations result from a net gain or loss in lake elevation over a specified period of time. For example, between 1873 and 1963, the elevation of the lake fluctuated downward more than 20 feet, from 4212 to the historic low of 4191 feet. It then moved upward, while fluctuating within a 20-foot range, to the historic measured high of nearly 4212 in 1986.

For planning purposes, it is important to know the maximum movement that might be expected during a given period of time. Based on historic estimated and measured lake levels, it is estimated that during six-year blocks of time from 1847 through 1982, the maximum measured one-year upward fluctuation is about six feet. A notable exception to this was seen during 1983-84 when the level of the lake increased by nearly 12 feet during a five-year block. When the trend is downward, the maximum one-year downward fluctuation is about 2.5 feet.

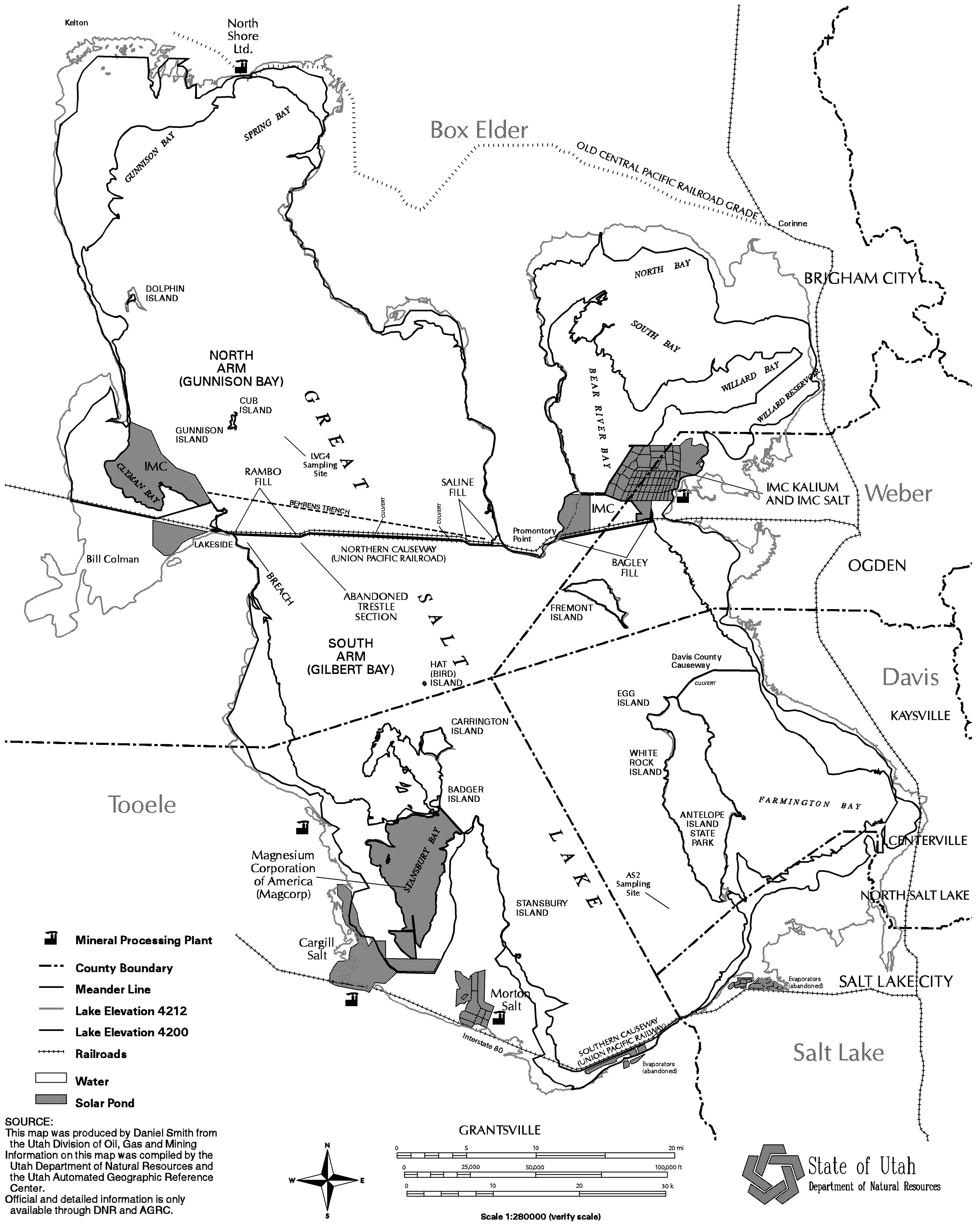
In addition to the historic record of lake level fluctuations, an extensive geologic record of prehistoric fluctuations is preserved as shorelines and other geomorphic evidence in the sediments underlying the lakebed and in the lagoons around the lake shore. This prehistoric record reveals that GSL has risen twice above the 4220 level in the last 10,000 years and numerous times to elevations between 4212 and 4217. The rises above the 4220 level are exceptional. They result from significant departures from what is considered normal climate for the Great Basin in non-glacial times. The rises to the 4217 level occur with climate that is "normal” for the region. They result from a series of years with precipitation above average, but normal for the region. An initial high lake level coupled with consecutive years of above average precipitation will result in a high lake level.

Great Salt Lake Planning Zones

The 1995 GSL CMP adopted seven four-foot elevation zones as a tool to aid in the planing process. These zones are shown in the following table (Table 1). Many of the exhibits used in this report show these zones along the elevation axis. Salinity ranges given in these zones are taken from the “Salinity

Exhibit 4 - Great Salt Lake Mineral Industries

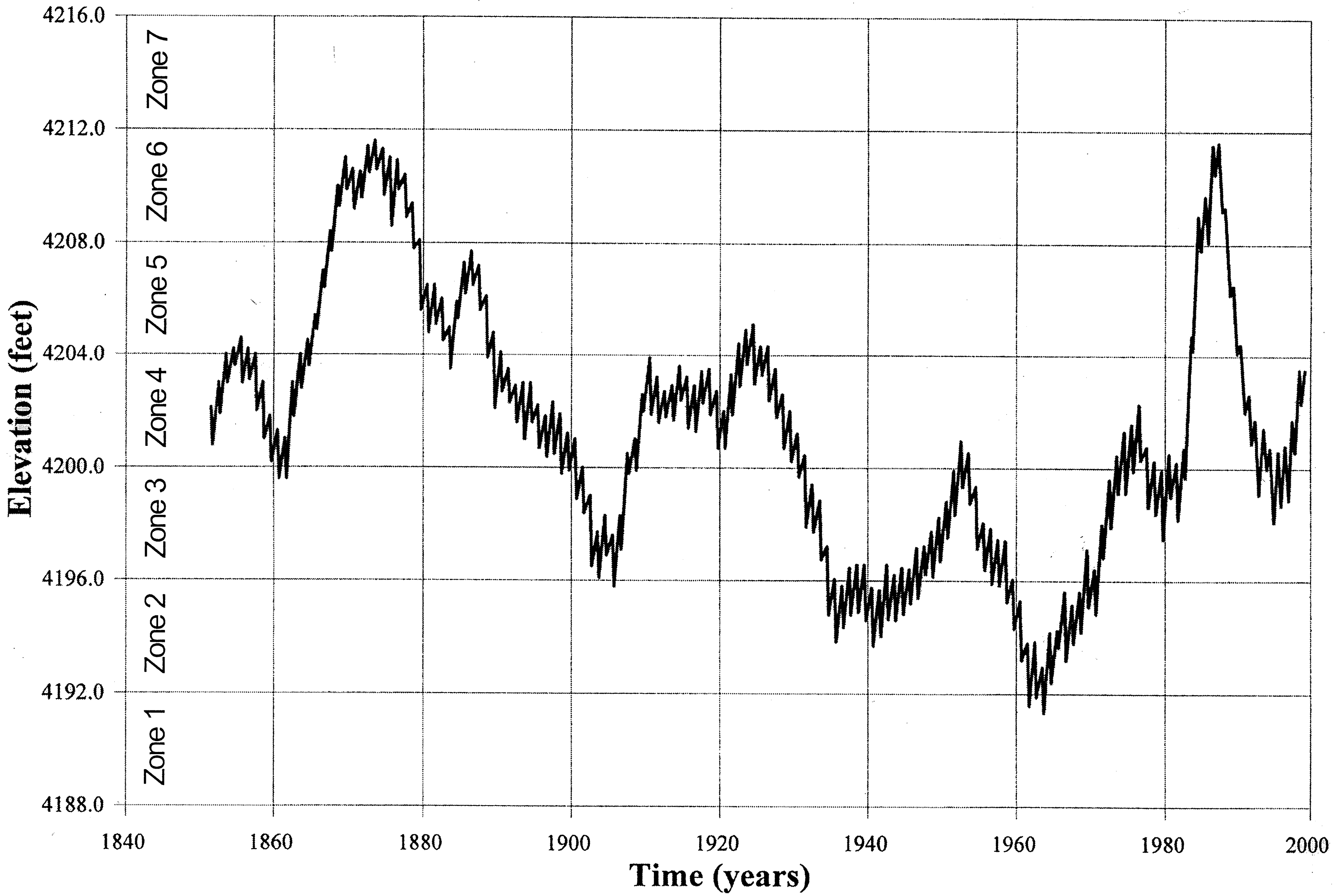
Plotted March 29, 2000



SOURCE:
This map was produced by Daniel Smith from the Utah Division of Oil, Gas and Mining
Information on this map was compiled by the Utah Department of Natural Resources and the Utah Automated Geographic Reference Center.
Official and detailed information is only available through DNR and AGRC.

Exhibit 5

HISTORICAL GREAT SALT LAKE HYDROGRAPH



vs South Arm Elevation - Breach at 4198 with Culverts" (Figure 7 in Appendix G for different management options).

Great Salt Lake Planning Zones

Zones	Elevation	Area Acres	Change in Area Acres	Volume Acre-feet	Probability* Percent
	4188	535,056		6,768,670	
1			66,805		1.4
	4192	601,861		9,030,560	
	4192	601,861		9,030,560	
2			171,103		7.6
	4196	772,964		11,749,730	
	4196	772,964		11,749,730	
3			306,295		23.0
	4200	1,079,259		15,370,180	
	4200	1,079,259		15,370,180	
4			143,741		33.0
	4204	1,223,000		20,040,700	
	4204	1,223,000		20,040,700	
5			187,000		24.0
	4208	1,410,000		25,074,700	
	4208	1,410,000		25,074,700	
6			162,000		8.3
	4212	1,572,000		30,669,000	
	4212	1,572,000		30,669,000	
7			656,000		1.7
	4216+	2,228,000		38,671,000	

Table 1 Great Salt Lake Planning Zones - *Log normal probability of annual peak lake elevations. The probability of the historical data indicates the percent of time the lake elevation would be in each zone.

Each agency having responsibilities on the lake should develop their planning and management activities for each of the seven four-foot zones. The information could be assembled by zone to provide plans and management options for a full range of lake levels. A general description of each zone is given below.

Zone 1. Elevation 4188-4192. The probability analysis indicates the lake would be in this zone about 1.4 percent of the time. Historically the lake was in this zone during the low levels in 1961, 1962 and 1963. While in this zone, the lake would be characterized with an average surface area and volume of 564,200 acres and 7,868,300 acre-feet, respectively. Access to the lake would be extremely limited for recreational and industrial purposes. A vast mudflat would be exposed around the lake. Managed wildlife areas around the lake may continue to operate, but other wildlife habitat may be severely impacted in this zone. These low lake levels and high salinity may either help or hurt mineral industries, depending on their location and salts they are harvesting. The salinity of the lake would be at saturation in the north arm. The south arm would vary from about 7 percent salt by weight to about 9 percent. Vast amounts of salts would precipitate and collect on the bottom of the north arm.

Zone 2. Elevation 4192-4196. The lake probability analysis indicates this would be in this zone 7.6 percent of the time. Historically, the lake was in this zone briefly in 1902, and from 1934 to 1946 (except 1937 to 1939 and 1943 to 1945, when the highs exceeded 4206), and from 1960 to 1968. While in this zone, the lake would be characterized with an average surface area and volume of 677,900 acres and 10,301,100 acre-feet, respectively. Access to the lake would still be difficult for recreational and industrial purposes because of extended mudflat areas and low lake elevations. The salinity of the lake would range from 9 to 10.5 percent salt by weight in the south arm but would be at saturation in the north arm. Large amounts of salts would be precipitated in the north arm of the lake while in this zone.

Zone 3. Elevation 4196-4200. The probability analysis indicates the lake would be in this zone about 23 percent of the time. Historically, the lake was in this zone from 1902 to 1906, from 1932 to 1939, from 1942 to 1951, from 1954 to 1959 and from 1969 to 1972. While in this zone, the lake would be characterized with an average surface area and volume of 890,000 acres and 13,422,000 acre-feet, respectively. Access to the lake should range from a problem at the lower part of the zone to a more normal nature in the rest of the zone. The salinity of the lake would range from about 10.5 to 12.5 percent salt by weight in the south arm and still be at saturation in the north arm. Salts would still precipitate in the north arm of the lake.

Zone 4. Elevation 4200-4204. The probability analysis indicates the lake would be in this zone about 33 percent of the time. The 1851 to 1994 average (south arm) level of the lake is 4201.3. Historically, the lake was in this zone from 1851 to 1853, from 1858 to 1863, from 1891 to 1901, from 1907 to 1921, from 1927 to 1931, from 1952 to 1953, from 1973 to 1982, and from 1991 to 1994. While in this zone, the lake would be characterized with an average surface area and volume of 1,175,000 acres and 17,641,000 acre-feet, respectively. Access to the lake would be good in the lower part of the zone but may start to be a problem in the upper part of the zone due to the high nature of the lake. Recreation, wildlife and other activities/facilities that operate close to the lake have experienced some flooding/damage in this zone. The salinity of the lake would range from about 11 to 12.5 percent salt by weight in the south arm and 21 to 28 percent salt by weight in the north arm.

Zone 5. Elevation 4204-4208. The probability analysis indicates the lake would be in this zone about 25 percent of the time. Historically, the lake was in this zone from 1863 to 1866, from 1880 to 1890, from 1922 to 1926, 1983, and from 1989 to 1990. While in this zone, the lake would be characterized with an average surface area and volume of 1,330,000 acres and 22,541,900 acre-feet respectively. This zone should also be characterized as the zone where major flooding and damages to facilities begins. This damage/flooding will occur to recreation facilities, wildlife areas (flooding of managed marshlands) and the Davis County Causeway (elevation of crest is 4208.75). Major transportation facilities (interstates and railroads), mineral industries and sewage treatment facilities that were generally protected above the 4208 during the 1983-87 flooding should remain protected to at least 4208. The salinity of the lake would range from about 9 to 11 percent salt by weight in the south arm and 16 to 21 percent salt by weight in the north arm.

Zone 6. Elevation 4208-4212. The probability analysis indicates the lake would be in this zone about 8.3 percent of the time. Historically, the lake was in this zone from 1867 to 1879 and from 1984 to 1988. The average surface area and volume are 1,490,000 acres and 27,607,300 acre-feet, respectively. This zone can be characterized as the major flood zone of the lake. Many facilities near the lake were damaged/wiped out during the 1984-88 period. It would be expected that many of the facilities around the lake that were protected during the 1983 to 1987 period would remain protected if the lake again rose to near 4212. It should also be expected that the facilities in this zone that were rebuilt after the lake lowered would be damaged/wiped out again. The salinity of the lake would range from about 8 to 9 percent salt by weight in the south arm to about 12.5 to 16 percent salt by weight in the north arm.

Zone 7. Elevation 4212-4216+. The probability analysis indicates the lake would be in this zone about 1.7 percent of the time. Historically, the lake has never been in the zone, although it reached a peak of 4211.6 in 1873 and a peak of 4211.85 in 1986 and again in 1987. Were the lake to reach the average elevation of this zone, the 1,900,000 acre surface area and 34,670,000 acre-feet volume would be over twice the average extent and size of the lake. Based on the flooding that occurred in 1986 and 1987, the two railroad causeways, Interstate 80 (I-80) along the southern part of the lake would be flooded by the time the lake reached 4213-4214. Also, as was happening in 1987, major flooding would be occurring in residential areas near Rose Park and places along the east of the lake, such as Plain City and Corinne. Protection to sewage treatment plants along the east shore area may also fail at these elevations. Although zones about elevation 4216 are not discussed, it goes without saying that major damages would continue to occur if the lake continued to rise. One area, Salt Lake City International Airport (SLCIA), needs to be noted. Studies during the 1983-87 period indicated the airport facilities are well protected and could continue to operate with elevations above 4216 (perhaps up to 4220) without major interruption to its operations. The salinity of the lake (assuming northern railroad causeway remained in place) would range 3 to 4 percent in the south arm and 13 to 15 percent in the north arm.

Current Status of Predicting Lake Levels

During the early 1980s when the lake rose to an elevation of 4211.85, there was a great deal of interest in predicting future levels of GSL. Although some of these forecasts, with hindsight, seemed to show some promise, there was a general consensus by researchers and climatologists, at the time, that predictions could not be made with any degree of assurance. Some researchers who made forecasts in the 1980s still believe they are able to make reasonably good short-term future forecasts of the GSL level. However, there still remains a general scepticism by researchers and climatologists that these forecasts can be made with any assurance.

Since 1990, one new forecasting model has been developed at the Utah State University Utah Water Research Laboratory (UWRL). This model is still being "fine-tuned" but has shown a reasonable good reliance to forecast short-term levels of GSL. Recent forecasts made using the water lab's model have matched the lake levels for 1998 and 1999. The model forecasts a rising lake level for at least another four years. If this or other models prove to be reliable in forecasting short-term future lake levels, they will be valuable tools for use with the GSL CMP.

Flooding Impacts

Flooding in the recent past has caused enormous financial damage and has required expensive mitigation. The lake flooding episode of 1983-87 is estimated to have caused over $240 million (1985 dollars) in damages. Had the lake level continued to rise and halt the operation of the northern and southern railroad causeways and I-80, it is estimated that the state could have suffered from $500 million to $1 billion (1985 dollars) in direct and consequential damages. Development and placement of structures in hazardous or flood-prone areas are the major causes of these high damage figures.

Most dikes on the lake are used and maintained for a particular purpose. Maintenance would ensure that these dikes would be able to withstand high lake levels (1980s).

Flooding of Interstate 80 and Other Access Roads

I-80 near GSL was adversely affected during the flooding period of 1983-87. Several sections had to be raised as much as eight feet, to an elevation of 4214, to make the freeway useable. The cost to do this work was approximately $20 million.

UDOT subsequently installed concrete pavement (final surface) from Burmester to the Tooele Interchange, replaced the bridge and modified Black Rock Interchange, all of which were completed in 1992. This section of I-80 is not expected to need attention, other than routine maintenance, until around 2002. Because of this construction, I-80 would not be flooded as long as the lake level does not rise above 4211.

The Davis County Causeway to Antelope Island was a state highway at the time of the severe flooding of the 1980s and was inundated. This highway was transferred to Davis County on May 17, 1991, was subsequently raised two feet, to 4208.75, and was paved during 1992. Use of the Davis County Causeway is adversely affected by lake levels of approximately 4204 and higher.

Flooding Impacts on the Southern Railroad Causeway

The southern railroad causeway (Union Pacific Railroad Causeway), located at the southern end of GSL, is a major rail line to the West Coast. It presently serves many chemical industries in this region and provides daily passenger service via Amtrak as part of an east/west rail corridor. In 1983, the rising lake began to effect the railroad track structure. Union Pacific raised the track in this area to protect it from the rising water. The elevation (top of the rail) through most of this area is 4221.0 feet, with the sub-grade (top of the embankment) at 4218.5 feet.

Flooding Impacts on the Northern Railroad Causeway

In 1906 Southern Pacific Transportation Company (SPTC) constructed the Rambo Fill, a wooden trestle and the Saline Fill between Lakeside and Promontory Point, to shorten the time required to go north around the lake. In 1959, SPTC completed the replacement of the original wooden trestle across the lake with a rock-fill and earthen causeway (Exhibit 4). The causeway was designed and constructed to have a minimum freeboard (vertical distance from maximum water level in the lake to the top of the causeway slope protection) of 10 feet. The slope protection design was based on the COE *Shore Protection Manual,* and was provided by utilizing very large one to three ton stones placed on a 1.5 to 1 slope. The thickness of the large stone layer was five feet. The causeway began to settle soon after construction and settles an average of two to four inches per year. Several areas of the causeway have experienced more settlement than the average, up to a half foot per year with a total settlement of up to 17 feet.

GSL is subject to sudden and violent storms, with winds over 70 mph. The winds generate waves that can reach eight feet in height and have 20 percent more energy than the ocean due to the higher density of lake waters. The height, length and period of wind-generated waves are determined by wind speed. The calculated "design wave," which is the average of the highest one-third of all waves, is 7.2 feet for the northern railroad causeway. High winds and waves can occur year round. However, most of the damaging wind and waves occur from the north, from April to July, and from the south, from July to August.

Prior to completion of the northern railroad causeway, the surface elevation throughout the lake was uniform. After completion of the causeway, however, an elevation difference began to develop between the two arms of the lake, with the south arm being higher. This elevation difference is due to two factors; the majority of the tributary inflow enters the south arm of the lake and the causeway restricts the movement of water from the south to the north arm of the lake.

From 1959 to 1982 the freeboard varied from 8 to 17 feet. During periods of the higher water elevations and low freeboard, the slope protection had some isolated areas that eroded and required repair. In January 1983, the average elevation of the crest of the causeway fill areas crossing the lake was 4209 to 4210 with some isolated areas as low as 4207. There were approximately 30 miles of fills crossing the lake and 60 miles of exposed slopes. By 1987, the fills crossing the expanding lake increased to 60 miles with over 105 miles of slopes to protect. The decision was made to utilize surplus and scrap box cars to create a "boxcar sea wall" on the north side of the causeway, which allowed the tracks and fill to be raised from about 4206 to 4217.

During the flood years, the causeway began to slough-off, settle and subside into the lake. It experienced five to six feet of subsidence along much of its length due to the weight of additional fill material. By spring 1984, very large inflows of freshwater into the south arm of the lake and restriction of flows to the north through the causeway fill, plus plugged causeway culverts, created a head differential of water levels. The higher elevation in the south arm added greatly to flooding problems on the south and east shores of the lake. The state constructed a 300-foot opening (breach) in the causeway, just off the west shore near Lakeside, to allow the rising waters to flow more freely into the north arm, thus reducing the large head differential and flood damage. The plugged causeway culverts and extremely high inflow created a head differential of water levels of nearly 3.5 feet between the north and south arms. The breach lowered the head differential between the lake arms to less than one foot.

Flooding Impacts on Recreation

Due to record high water of the early 1980s, millions of dollars of recreation facilities and user opportunities were lost. Antelope Island was isolated, marinas were forced to close and the southern sandy beaches were inundated by the waters of the lake. Recreation facilities on the lake generally begin to experience damage and interference with operations at lake levels of approximately 4205 and higher.

Flooding Impacts on Wildlife and Wetland Structures

Most WMAs around the lake were constructed in the 1930s to 1940s when lake level was relatively stable at 4198 above sea level. At these levels, annual production of waterfowl approached three-quarters of a million birds, with non-game production numbering in the multi-millions. Total bird use of the marshes on the lake exceeded 100 million use-days annually and recreationists would expend one-half million days each year afield. Marshes were managed for mean water depths of about 18 inches.

During the flood years of the 1980s, nearly 300,000 of the 400,000 acres of marsh around the lake were inundated or devegetated due to salt water intrusion. Damages to state-owned property, dikes, water control structures, parking facilities, fences, signs and gates were estimated at over $30 million. Similar damage occurred on the federal Bear River Migratory Bird Refuge (BRMBR).

During the floods, production of ducks and geese dropped by 80 percent and fall swan use decreased over 90 percent. Total bird use in marshes decreased nearly 90 percent and public use all but disappeared.

As the water depth increases, thousands of acres of brackish and freshwater marshes, as well as upland habitats, are flooded. This forces birds, particularly nesting species, to move to higher ground. In many areas around the lake, the upland buffer is no longer available because of human development. Either natural or anthropogenic flooding events could result in large population reductions of breeding birds, though there would again be some differences between long-term local events and short-term broad-scale events.

Although potentially damaging to structures in WMAs, fluctuations in lake water levels can be beneficial to wildlife. Periodic flooding and drying events keep wetlands in early successional stages and increase their productivity. Flooding impacts begin at lake elevation of 4198. Most lake-shore freshwater wetlands have been inundated with salt water when lake elevations exceed 4208.

The bulk of dike maintenance expenditures occurs in the lake level range 4200-4205. Regardless of which WDPP policy is implemented, dikes sustain the same amount of damage for that range. The current strategy for WMAs at this lake level range is to accept the rising lake and repair dikes after the lake recedes. It is very expensive to flood-proof dikes above 4205 and managers recognize the benefits associated with periodic flooding.

Flooding Impacts on Investor-Owned Public Utilities

Unless flooding is so severe as to enter established commercial and residential developments, damages to the telephone and gas utilities (US West and Questar [formerly Mountain Fuel], respectively) are minimal, even at lake elevations above 4208. Much more vulnerable to flooding are Pacificorp's (formerly Utah Power & Light) power lines. Much of the damage that occurred west of Bountiful and Centerville was caused by wind-blown ice which was able to reach the transmission lines due to high lake level. Utah Power & Light constructed a dike between the power lines and the open water to prevent ice damage to the power lines.

The anticipated loss at 4210 is $1.3 million (1993 dollars), adversely affecting several high-voltage transmission lines between SLCIA and Kaysville, two near Saltair, three more near Timpie Springs, a substation in Centerville and numerous service distribution lines. Damage costs would escalate to an expected level of $19.5 million (1993 dollars) if the lake level reached 4212. The construction of the third commercial runway at SLCIA required relocation of several major power transmission lines closer to the lake, which could make the damage estimates greater.

West Desert Pumping Project

Although the name West Desert Pumping Project implies a pumping project, it is actually a project which operates by expanding the surface area available to evaporate the flow into GSL by approximately 23 percent at 4208 lake level. The increased evaporation slows lake level increases and accelerates lake level declines during periods of pump operation.

The WDPP consists of a 10-mile access road along the former SPTC railroad causeway, a pumping station, two canals, trestles, dikes, a 37-mile natural gas pipeline and the West Pond in the desert west of the Newfoundland Mountains (Exhibit 6). The West Pond has a surface area of 320,000 acres, approximately 508 square miles, and a volume of 800,000 acre-feet at an elevation of 4216.5. Three large pumps lift up to 3,000 cubic feet per second of water from the north arm of the lake to a 4.1-mile outlet canal. The canal begins at 4224 (above sea level) and discharges water into the West Pond. The project is designed to pump approximately two million acre-feet of water a year into the West Pond to evaporate up to 825,000 net acre-feet of water each year.

A 24.4 mile dike with a maximum height of six feet retains the southwest portion of the evaporation pond and prevents water from the project from flooding I-80 and the famous Bonneville Speedway. A second dike 8.1 miles long with a maximum height of seven feet extends southeast from the southern tip of the Newfoundland Mountains and is used to contain the water and restrict the surface flooding of the U.S. Air Force (USAF) military range. A weir in the dike is used to regulate the pond's surface level between 4215 and 4217 and the return of concentrated brine to the lake. Return flow through the military range was not confined and flowed over the natural topography in an expansive path on its return to the lake.

Pumping started on April 10, 1987 and continued until June 30, 1989. During this period an estimated 2.73 million acre-feet of brines were pumped from the lake. The pumping was started too late to have a significant impact on the maximum lake level in 1987; however, the pumping project was successful in increasing the rate of decline of the lake and lowering the level of the lake some 15 inches. After pumping had ceased, the lake level continued to drop an additional two feet through the end of 1989. Precipitation dropped to average levels or below. The lake level continued to drop an additional four feet through the end of 1993.

Operating Consequences and Constraints

The design of the WDPP was modified prior to construction. The original design called for brine to be pumped from the fresher south arm of GSL. The final modification reduced the cost of the project and sped construction by pumping brine from the north arm. The use of more concentrated north arm brine reduced the evaporation potential of the project and resulted in more salt being left in the West Pond.

Part of the reason why 12 percent of the lake's salt was deposited in the west desert was the intentional continuation of pumping into the summer months (to provide feed stock to Magcorp's Knolls evaporation ponds). Had pumping been stopped in March or April of 1989 at the end of a planned cycle, or continued through the winter of 1990 to complete yet another full cycle, the salt loss to the west desert would have been greatly reduced.

In 1994, U.S. Geological Survey (USGS) published a report entitled "Salt Budget of the West Pond, Utah, April 1987 to June 1989." The report summarized the salt budget as follows:

"During operation of the West Desert pumping project, April 10, 1987, to June 30, 1989, data were collected as part of a monitoring program to evaluate the effects of pumping brine from GSL into West Pond in northern Utah. The removal of brine from GSL was part of an effort to lower the level of GSL when the water level was at a high in 1986. These data were used to prepare a salt budget that indicates about 695 million tons of salt or about 14.2 percent of salt contained in GSL was pumped into West Pond. Of the 695 million tons of salt pumped into West Pond, 315 million tons (45 percent) were dissolved in the pond, 71 million tons (10.2 percent) formed a salt crust at the bottom of the pond, 10 million tons (1.4 percent) infiltrated the subsurface areas inundated by storage in the pond, 88 million tons (12.7 percent) were withdrawn by Magnesium Corporation of American (Magcorp), and 123 million tons (17.7 percent) discharged from the pond through the Newfoundland Weir. About 88 million tons (13 percent) of the salt pumped from the lake could not be accounted for in the salt budget. About 94 million tons of salt (1.9 percent of the total salt in GSL) flowed back to Great Salt Lake."

Therefore at the end of pumping operations, approximately 484 million tons of salts were either in the pond or infiltrated into the subsurface. Another 211 million tons were withdrawn by Magcorp or discharged over the Newfoundland Weir. About 94 million tons of the 211 million tons had returned to the lake. Therefore approximately 600 million tons (as of 1989) had been pumped but not returned to the lake. Efforts are underway to estimate how much additional salt has returned to the lake since 1989.

It is presently believed that some portion of the precipitated salt, approximating 180 million tons, has been redissolved by rainfall and removed from the pond by either Magcorp or by flow over the weir. Much of this has not, however, returned to the lake. This removal of salt has had an impact on the overall salinity of the lake.

In its present configuration, the WDPP is capable of operating only at south arm lake levels of 4208 or higher (The WDPP operation is referenced to south arm lake elevation). The current configuration of the WDPP will allow the pumping of only north arm brines. Pumping the denser north arm brines reduces the efficiency of evaporation, in that less water can be extracted from the brines before salts begin to precipitate in the West Pond. Operation of the WDPP should begin in the early spring as the lake begins its seasonal rise and continue through the summer evaporation season. Pumping should continue through the fall and into the winter to redissolve the salts left during the summer and return them to the lake.

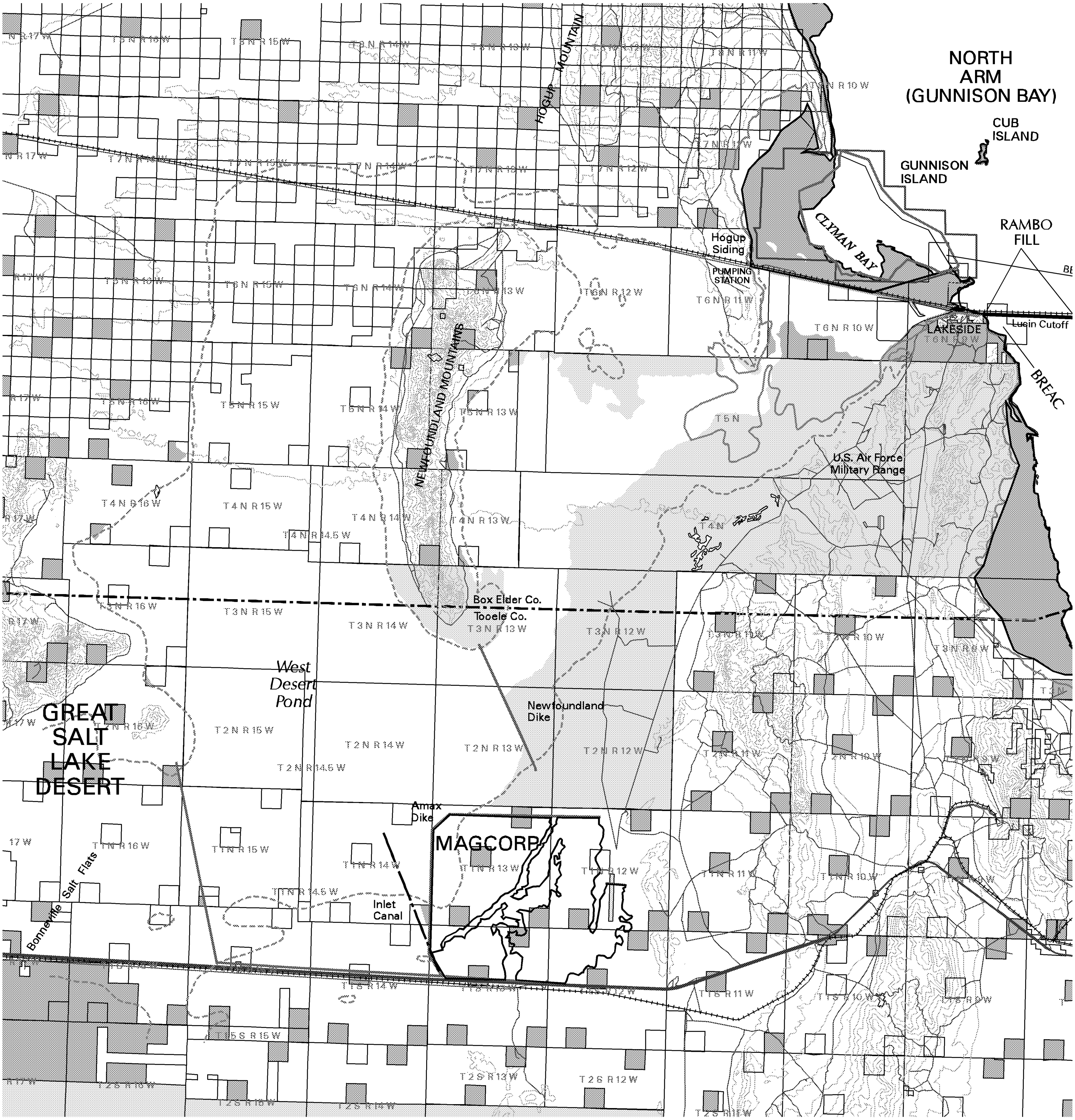
The relationship between lake levels, the pumping of brine from the north and south arms, and the build-up of salts in the West Pond are presented in Exhibit 7. The upper, more densely stippled shading shows the upper and lower limits of salt precipitation for north arm brines at varying lake level elevations. The lower, less densely stippled shading shows the same limits for south arm brines. Exhibit 7 shows that the WDPP could operate without precipitation of salts in the West Pond if operation is commenced only at lake elevations of 4210 (above sea level) and higher. With the current configuration of the inlet canal and West Pond, the WDPP can only be operated at lake levels above 4208, with feed brine pumped from the north arm of the lake. Unless the West Pond is significantly reduced in size, which would significantly reduce the effectiveness of the system, operation of the WDPP in its current configuration will result in precipitation of additional salts in the West Pond.

Administrative and Legal Considerations

As part of the WDPP, various rights-of-way, permits and memoranda of understanding (MOU) were executed among the State of Utah, BLM, USAF and COE. Several of these were long-term agreements to operate the WDPP, such as the right-of-way issued by BLM. Others were short term, temporary permission arising out of the emergency nature of the project. USAF never granted official approval for the use of the range in operation of the WDPP, but instead issued a letter of approval for temporary operation for the duration of the flooding emergency. In recent discussions, USAF notified the state that an environmental baseline study would

Exhibit 6 - West Desert Pumping Project

Plotted March 29, 2000



County Boundary	Major Roads	State Trust Lands	Intermittent Water
Meander Line	Minor Roads	State Wildlife Reserves and Management Areas	
Township & Range Grid	Railroads	Bureau of Land Management	
Lake Elevation 4212	Mineral Lease Boundary	Department of Defense	
Lake Elevation 4200	Dikes	Water	
Lake Elevation 4217	Pump Canal		

SOURCE:
This map was produced by Daniel Smith from the Utah Division of Oil, Gas and Mining
Information on this map was compiled by the Utah Department of Natural Resources and the Utah Automated Geographic Reference Center.
Official and detailed information is only available through DNR and AGRC.

0 5 10 20 mi
0 25,000 50,000 100,000 ft
0 10 20 30 k

Scale 1:220000 (verify scale)

State of Utah
Department of Natural Resources

State of Utah
DEPARTMENT OF NATURAL RESOURCES

Exhibit 7

West Desert Pumping Project with pumping rate vs. South Arm Elevation vs. Salinity.

LEGEND / NOTES:

(1) Max. weir elev./salt buildup boundary (4216.57 weir elev.)

(2) Min. weir elev./salt buildup boundary (4215.00 weir elev.)

(3) Operating system above max., line allows for maximum pond size with no salt buildup in pond.

(4) Operating system below max. line requires a reduction in pond size (resulting in loss of evap.) to not build up salts. Determination of the weir height can best be done using a computer model of the ponds.

(5) Lowest limit (lowest level of weir setting) at which the system can be operated with no salt build up. System can be operated below min. line but not without salt build up.

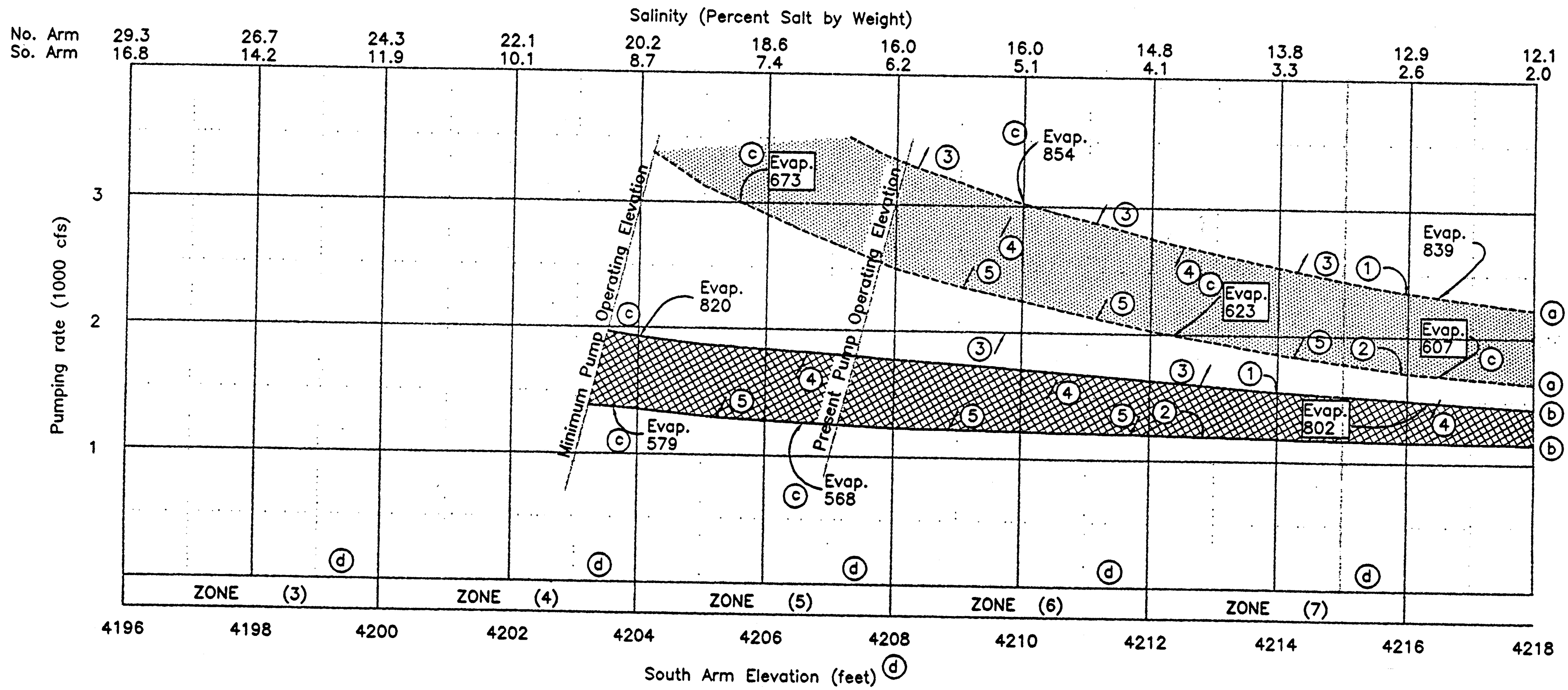
(a) ----- North Arm Brines

(b) —— South Arm Brines

(c) Pond evaporation in 1,000 Acre Feet.

(d) All elevations are referenced to South Arm Datum. A 0.9' amount was added to the North Arm gage reading (0.2' for gage correction and 0.7' for level difference), to adjust North Arm data to the South Arm Datum.

Source: Utah Division of Water Resources.



be required, and perhaps an update of the original project EIS, before Hill Air Force Base (HAFB) would grant permission to flood parts of the Utah Test and Training Range. HAFB has also indicated that a proposal to utilize the WDPP will require the state to address several HAFB concerns. Use of the WDPP raises several safety concerns such as the impact of the West Pond on fog levels and increased bird use, both of which affect flight safety. Presence of the West Pond will also affect planning for flying missions, operation of target complexes and conducting environmental clean-up activities. All of these concerns would have to be addressed before USAF would allow operation of the WDPP to resume. HAFB also indicated that a proposal to utilize the WDPP for lake levels below 4208 may make it more difficult to obtain USAF approval to pump GSL water into the West Desert.

COE has also raised a concern over the impacts the pumping project may have had on the ecology of GSL, (removal of salts from the lake). COE issued a Section 404 permit for construction of much of the WDPP, which also covers operations. COE has indicated that a resumption of pumping or a change in the use or protocols of the WDPP would likely trigger an evaluation of the state's performance under the permit in light of these concerns.

Locomotive Springs

The most critical issue facing Locomotive Springs is maintaining freshwater flow. From 1993 to 1997 DWRi has collected hydrologic data regarding the groundwater system in Curlew Valley. A report entitled *Hydrologic Data for Curlew Valley, Utah* (Atkin, 1998) was recently published containing this data. DWR cooperated with this data collection and installed and operated several gaging stations at Locomotive Springs.

The groundwater system in Curlew Valley is the source of water for Locomotive Springs. The basin is in both Idaho and Utah. The Utah portion of the valley has been closed to new groundwater applications, except single-family domestic wells, since 1976. However, it is reported that Idaho is still approving new applications. In addition, the data indicated that most of the water for Locomotive Springs comes from the Holbrook-Snowville Flow System. Most of the groundwater withdrawals from this flow system are in Idaho. Due to decreased hydrostatic pressure in this aquifer, the potential for salt water intrusion is another concern.

The State Engineer held a public meeting on March 3, 1999 in Snowville to discuss the current groundwater conditions in the valley. The data shows that the discharge from Locomotive Springs has dropped considerably during the last 40 years. The solution to this matter is complex and potentially very controversial—it will most likely take considerable effort to resolve.

Inter-Island Diking and Freshwater Embayment Proposals

Over the past hundred years, the state has received several significant proposals for major inter-island diking projects to create large freshwater embayments in GSL. The projects which have made a water right filing with the State Engineer are as follows:

Table 2. Water Rights Filings

Owner	Priority Date	Amount	Common Name
DWRe	March 31, 1971	1,510,000 af	
Glenn R. Maughan	May 5, 1989	5,000,000 af	Lake Maughan (Wasatch)
Davis County	January 6, 1993	800,000 af	Davis Lake
Western Water	March 31, 1999	450,000 af	Bonneville Reservoir

Lake Wasatch (1990), Lake Davis (1993) and Lake Bonneville (1996) are a few examples of recent proposals to create freshwater impoundments.

Sponsors of these projects listed the following potential benefits:

- Provide and enhance recreational and tourism opportunities—boating, fishing and water sports
- Provide year-round water storage to supply increasing municipal and irrigational demands
- Provide opportunities for economic development (industrial and residential) around these impoundments
- Protect wildlife and upgrade existing habitat (freshwater system)
- Provide transportation and utility corridors across these dikes
- Provide flood protection to facilities, industries, causeways and other areas bordering the lake
- Improve aesthetics, quality of life and enhance lifestyles
- Improve economy and provide additional revenue

"These proposals have been the subject of repeated, detailed and scientific studies. The studies have uniformly found the proposals unworkable for a variety of reasons . . . " (DFFSL, 1996). In 1996, the Utah Sovereign Lands Advisory Council along with Governor Michael Leavitt replied to the Bonneville proposal by stating that "The Bonneville Bay proposal could dramatically affect certain sovereign lands and would be similar to other concepts the state has repeatedly studied and rejected." In 1990, the Great Salt Lake Development Authority, as defined in Utah Code Ann. Section 17A-2-1603(9), rejected the Wasatch Lake proposal by stating that it "does not appear to be economically or environmentally feasible."

Some of the reasons that these proposals have been rejected are listed below:

- Did not appear to be economically or environmentally feasible
- Loss or damage to existing wetlands
- Impact on wetlands and other wildlife habitat
- Cost of diking, pumping and transportation facilities
- During flood events, it would require larger pump system
- Salinity problems
- Earthquake safety and dike stability concerns
- Studies showed the proposals could not provide water with quality adequate for agriculture or M&I uses

- Potential dam safety issue
  Water quality concerns—unacceptable for even irrigational purposes, recreation and residential waterfront uses and would require constant monitoring
  Possible offensive odors
  Fisheries may not be able to persist
  Water right concerns
  Water depth too shallow for recreational activities

Proposed locations for freshwater embayments would also conflict with sovereign land which the state legislature has authorized to be set side for wildlife purposes (23-21-5)(Appendix F, Exhibit 2).

There are no active proposals being considered at this time. However, establishing a DNR policy regarding how to address intra-lake proposals in the future would be advantageous since this issue arises nearly every three years. Small freshwater embayments may not possess some of these identified consequences.