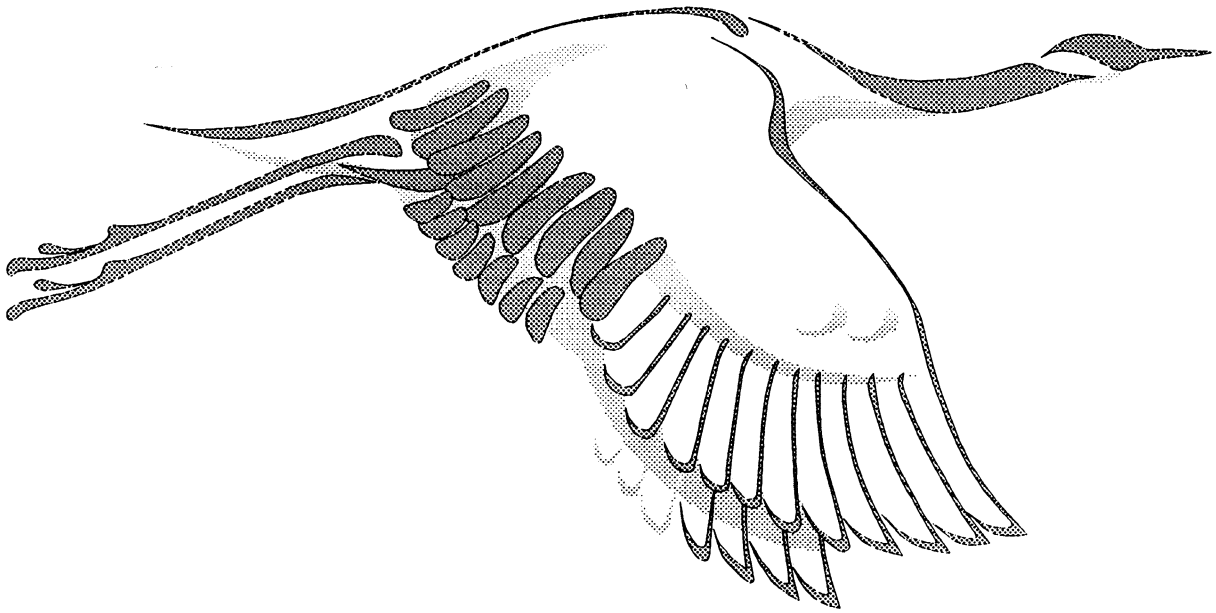
Great Salt Lake
Draft Comprehensive Management Plan



Prepared by the Great Salt Lake Planning Team
Utah Department of Natural Resources

November 3, 1999

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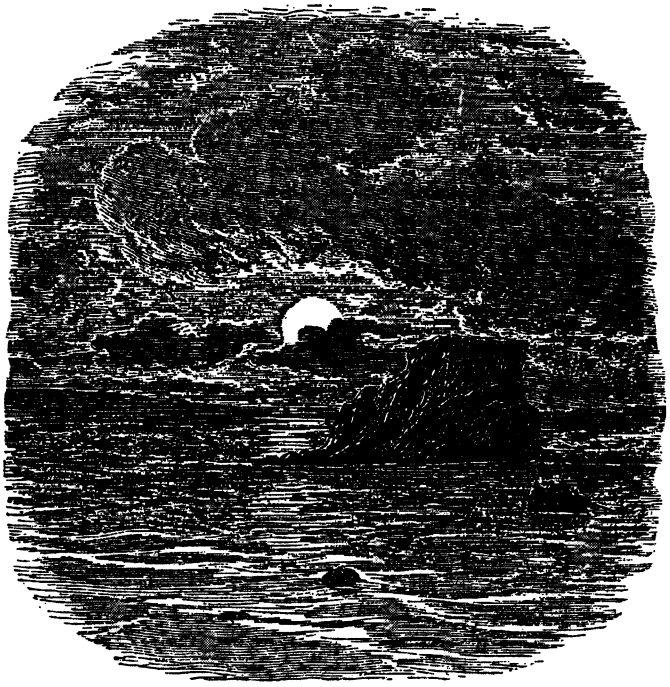

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Utah Department of Natural Resources

November 3, 1999

Great Salt Lake Planning Team

Name, Title and Division	Role on the Team
Arthur W. DuFault, State Forester/Director Division of Forestry, Fire and State Lands	Team Leader
Karl F. Kappe, Strategic Planner Division of Forestry, Fire and State Lands	Sovereign Lands, Minerals, Diking, Agriculture, Public Involvement, Planning Team Coordinator
Brenda L. Landureth, GSL Analyst/Administrative Assistant, Administration	Open Space, Critical Lands, Visual Resources, Water Quality, Air Quality, Ecosystem, Public Involvement, Planning Team Coordinator
Lloyd H. Austin, Chief Resource Inventories and Special Studies Section Division of Water Resources	Hydrology, Chemistry, Diking
Darin Bird, Special Assistant policy and Inter-Governmental Relations	Public Involvement
Martin B. Bushman, Assistant Attorney General	Legal Advisor
William C. Perschon, GSL Ecosystem Project Coordinator Division of Wildlife Resources	Biology
Ann Price, Administrative Assistant	Editor/Production
Bruce Ratzlaff, Natural Resource Analysis, Office of Energy and Resource Planning	Economic Team Coordinator, Economics, Recreation
William E. Schlotthauer, Hydrologic Engineer Division of Water Rights	Water Rights, Hydrology
Daniel K. Smith, Applications, Programmer, Analyst III	GIS Specialist
James K. Springer, Public Information Officer Division of Forestry, Fire and State Lands Division of Oil, Gas and Mining	Public Relations, Slide Presentation, Public Involvement, Media Relations
Garth C. Taylor, Antelope Island State Park Manager Division of Parks and Recreation	Recreation, Cultural Resources, Law Enforcement, Search and Rescue
Previous Planning Team Members	
James W. Carter, Director Division of Oil, Gas and Mining	Team Leader
Kimm M. Harty, Deputy Director Utah Geological Survey	Geologic Hazards, Chemistry, Transportation
Susan L. Jancart, Natural Resource Analyst Office of Energy and Resource Planning	Economics, Commercial, Industrial, Editing
Tim Smith, Antelope Island State Park Manager Southeast Regional Manager Division of Parks and Recreation	Recreation, Cultural Resources, Law Enforcement, Search and Rescue
Jeff Richards, Assistant Attorney Attorney General's Office	Legal Advisor

Department of Natural Resources Great Salt Lake Board of Directors
Kathleen Clarke, Executive Director
Sherman Hoskins, Deputy Director
Marty Ott, Deputy Director
Darin Bird, Special Assistant Policy and Inter-Governmental Relations
Art DuFault, State Forester/Director Division of Forestry, Fire and State Lands
Kimm Harty, Acting Director Utah Geological Survey
Robert L. Morgan, State Engineer/Director Division of Water Rights
John F. Kimball, Director Division of Wildlife Resources
Jeff Burks, Director Office of Energy and Resource Planning
Courtland Nelson, Director Division of Parks and Recreation
D. Larry Anderson, Director Division of Water Resources
Lowell Braxton, Director Division of Oil, Gas and Mining

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Introduction

Introduction

The Utah Department of Natural Resources (DNR) and the Utah Division of Forestry, Fire and State Lands (DFFSL) are jointly sponsoring the Great Salt Lake Planning Project to develop a coordinated natural resources management plan for the lands and resources of Great Salt Lake (GSL). Primary management responsibility for the lake's resources lies with DFFSL pursuant to Title 65A of the Utah Code, which governs management of all state lands. Specifically, Section 65A-10-8, *Great Salt Lake - Management Responsibilities of the Division*, requires the division to:

> "(1) Prepare and maintain a comprehensive plan for the lake which recognizes the following policies:
>
> (a) develop strategies to deal with a fluctuating lake level; (b) encourage development of the lake in a manner which will preserve the lake, encourage availability of brines to lake extraction industries, protect wildlife, and protect recreation facilities; (c) maintain the lake's flood plain as a hazard zone; (d) promote water quality management for the lake and its tributary streams; (e) promote the development of lake brines, minerals, chemicals, and petro-chemicals to aid the state's economy; (f) encourage the use of appropriate areas for the extraction of brines, minerals, chemicals, and petro-chemicals; (g) maintain the lake and the marshes as important to the waterfowl flyway system; (h) encourage the development of an integrated industrial complex; (i) promote and maintain recreation areas on and surrounding the lake; (j) encourage safe boating use of the lake; (k) maintain and protect state, federal, and private marshlands, rookeries, and wildlife refuges; (l) provide public access to the lake for recreation, hunting and fishing."

Section 65A-2-1 of the Utah Code provides; "The division [of Forestry, Fire and State Lands] shall administer state lands under comprehensive land management programs using multiple-use, sustained-yield principles." Briefly stated, the overarching management objectives of DFFSL and DNR are to protect and sustain the trust resources of, and to provide for reasonable beneficial uses of those resources, consistent with their long-term protection and conservation. This means that DFFSL will manage GSL and its resources under multiple-use sustained yield principles (Section 65A-2-1), implementing legislative policies (Section 65A-10-8) and accommodating public and private uses to the extent that those policies and uses do not compromise public trust obligations and sustainability is maintained. Any beneficial use of public trust resources is subsidiary to long-term conservation of resources.

Although primary lake planning and management responsibilities lie with DFFSL, the other divisions of DNR also have management responsibilities for resources on and around GSL. The Division of Wildlife Resources (DWR), for example, has plenary authority for managing wildlife in, on and around the lake. The Division of Parks and Recreation (DPR) manages Antelope Island State Park (AISP) and coordinates search and rescue and boating enforcement on the lake. The Division of Water Rights (DWRi) regulates the

diversion and use of lake and tributary waters. The Division of Water Resources (DWRe) conducts studies, investigations and plans for water use, and operates the West Desert Pumping Project (WDPP). DNR divisions also regulate mineral extraction activities, conduct hydrologic research and identify and map geologic hazards around the lake.

In order to more specifically articulate DNR's management objectives for the resources of GSL, and to reconcile the diverse mandates of the divisions of DNR, the Great Salt Lake Planning Project was initiated.

The purposes of the Great Salt Lake Planning Project are:

(1) To establish unifying DNR management objectives and policies for GSL trust resources,

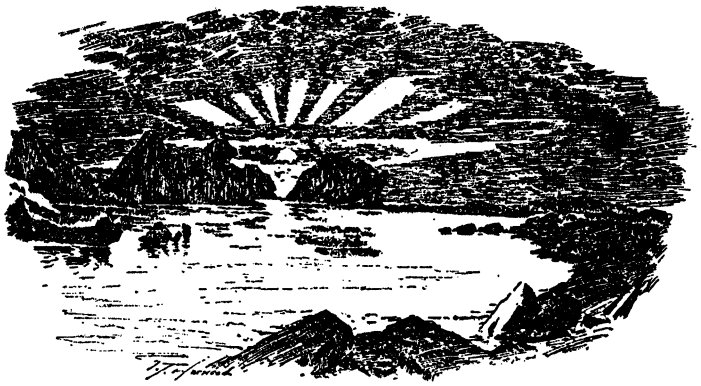
(2) To coordinate the management, planning and research activities of DNR divisions on GSL,

(3) To improve coordination among DNR divisions, establish a decision-making proposal review and appeal process, develop a sovereign land management plan for the lake that balances multiple-use and sustainability, resolves issues and improves management of the lake and its resources,

(4) To develop a sovereign lands and resources management plan, and

(5) To establish processes for plan implementation, monitoring, evaluation and amendment.

Statement of Current Conditions and Trends on Great Salt Lake



Statement of Current Conditions and Trends on Great Salt Lake

Overview

DNR has in place management programs for the resources of GSL. Those programs are designed to both conserve the lake's resources, and to make those resources available for beneficial uses. DNR's management of AISP and Farmington Bay Waterfowl Management Area (WMA), the regulation of commercial brine shrimping and sport hunting and the Mineral Leasing Plan (MLP) are examples of resource management programs currently in operation.

At the same time, factors exist which are affecting or have the potential to affect the lake, its resources and beneficial uses. Purposes of this planning process are to ensure that existing programs contribute optimally to DNR's management objectives for the lake and that emerging issues and demands are addressed in a coherent and comprehensive manner, consistent with overall management objectives.

The starting point for development of a comprehensive and consistent management plan is the assembly of relevant information and analyses into a resource inventory. Through a one year internal and external scoping project, the GSL Planning Team identified the resource inventory information it believes is relevant to the good management of GSL. The inventory information was assembled by resource and use category, and was evaluated to develop descriptions of the current conditions of the lake's resources, and to discern trends which should be taken into account in future management. Because the information available on GSL and its resources is encyclopedic in scope and volume, the team has digested and presented it in the context of the key issues and needs identified through internal and external scoping. This statement represents a baseline picture of the current conditions and trends of GSL and its resources.

The Statement of Current Conditions and Trends (SCCT) is organized by resource category and includes hydrology, chemistry, land, mineral, cultural, and biological trust resources for which DNR is responsible. The SCCT also includes ecosystem, recreation, tourism, air and water quality, commercial and industrial, open space and critical lands, and visual resource managements.

History of Planning and Management of the Great Salt Lake

Great Salt Lake Authority (1963)

In 1963, the Utah Legislature enacted House Bill No. 33 creating the Great Salt Lake Authority, and an advisory council to the authority (Laws of Utah 1963, Chapter 161). The authority was empowered to "coordinate multiple-use of [Great Salt Lake] property for such purposes as grazing, fish and game, mining and mineral removal, development and utilization of water and other natural resources, industrial, and

other uses in addition to recreational development, and adopt such reasonable rules and regulations as the authority may deem advisable to insure the accomplishment of the objectives and purposes of the act." The bill specified that both the state Department of Fish and Game and the state Land Board would retain the powers and jurisdiction conferred upon them, subject to such reasonable rules and regulations as the authority may make to ensure the accomplishment of the objectives of the act (Laws of 1963). The authority made little progress in discharging its duties and, in 1966, the Utah Supreme Court declared that the act creating the authority was unconstitutional as it failed to define the authority's geographical jurisdiction.

Re-establishment of the Authority (1967)

The legislature cured the jurisdictional defect in 1967 when it re-created the Great Salt Lake Authority (Laws of Utah 1967, Chapter 187). With legislation, the authority's geographical jurisdiction was defined, and included the mainland, peninsulas, islands and waters within the GSL meander line established by the U.S. Surveyor General.

The purpose of the re-created authority was to establish and coordinate programs for development of recreational areas and water conservation within GSL and its environs, and in conjunction to provide for: (1) the development of such area of Antelope Island as the authority may determine to be suitable and desirable for recreational usage, (2) testing the feasibility of the use of [Kennecott Copper] tailings in the development of GSL and its environs, and (3) the restoration and preservation of points of historical interest on Antelope Island.

A preliminary feasibility study for the recreational development of the north end of Antelope Island was prepared by Snedaker & Budd and Allred & Associates for the GSL Authority, and was submitted on June 26, 1964. In 1965, a document entitled, *A Preliminary Master Plan for the Development of Great Salt Lake Over a Period of the Next 75 Years* was prepared for the GSL Authority. This plan envisioned the use of surplus waters from the Bear River, Weber River and Jordan River drainage areas, and using Kennecott tailings material for the construction of dikes, highways and land reclamation within Farmington Bay.

Department of Natural Resources (1967)

After the creation of DNR in 1967, the GSL Authority was abolished, and functions of the authority were merged into DPR.

Division of the Great Salt Lake (1975)

The 1975 general session of the Utah Legislature enacted House Bill No. 23 which established a board and division within DNR to establish and coordinate programs for development of recreation areas, flood control, wildlife resources, industrial uses and conservation of GSL. The Division of Great Salt Lake (DGSL) was given the responsibility to determine the direction and implementation of all lake-related activities, working through existing DNR divisions. In addition, the division was given the following powers and duties:

(1) direct the preparation of and adopt a comprehensive plan for the lake in a manner which will assure the maximum interchange of information, ideas, and programs with affected state, federal and local agencies, private concerns, and the general public. Implement the provisions of the plan by utilizing the existing authority of the various state and local entities or agencies concerned. Weigh the policies and programs of agencies that affect the lake to ensure their compatibility with the adopted comprehensive plan. Revise and update the plan at periodic intervals. (2) employ assistants and advisors deemed necessary for the purposes of the act, (3) initiate studies of the lake and its related resources, (4) publish or authorize the publication of scientific information, (5) define the lake's flood plain, (6) qualify for, accept and administer loan payments, grants, gifts, loans or other funds for carrying out any functions under the act, (7) determine the need for and desirability of public works and utilities for the lake area, (8) cooperate with the state engineer and all upstream entities in considering the water relationship between the lake and its tributaries, and (9) perform all other acts reasonably necessary to carry out the purposes and provisions of the act (House Bill No. 23, 1975).

Comprehensive Management Plan (1976)

Under the directive of House Bill No. 23, DGSL began preparation of a *Comprehensive Management Plan* in July of 1975. The plan was developed through the inter-agency technical team which was established under the terms of the 1975 legislation. The inter-agency technical team was made up of representatives from various interests, public and private, and included representatives from several divisions of DNR, Utah Department of Transportation (UDOT), county commissioners of the five counties surrounding the lake and other representatives who served on the basic committees.

The *Comprehensive Management Plan* for GSL was intended to serve as a general statement for use and management of the lake. Goals and policies based on the concepts set forth in the legislation, and as adopted by the Great Salt Lake Board, served as a guide for preparation of the plan. The plan consists of six major sections: minerals, recreation, tourism, wildlife, hydrology, and transportation. The plan for each of the sections was developed after consideration of the interrelationships of plan sections and was not intended to be a detailed development plan for private agencies or for divisions of local, state or federal government.

Great Salt Lake Environs Report (1976)

The *Great Salt Lake Environs Report* was prepared in 1976 as a companion report to the *Comprehensive Management Plan*. The purpose of the report was to summarize and graphically portray the most current, accurate and reliable data available concerning land use ownership, soils, vegetation, human-made structures, access ways, freshwater and utilities lying between the water's edge on January 1, 1976, and the upper limits study line established at approximately 4212 feet.

Division of State Lands and Forestry (1979)

In 1979, DGSL was eliminated, and the staff functions for the management of GSL were transferred to DNR. Later, management was administratively delegated to the Division of State Lands and Forestry (DSLF), now known as DFFSL.

Great Salt Lake Contingency Plan (1983)

In 1982, the water level of GSL began a rapid rise which prompted DSLF to draft the *Great Salt Lake Contingency Plan*. This plan was designed to meet the legislative mandate for maintaining the water level of GSL below 4202 feet, and deals with background, analysis and recommendations for influencing both the high and low levels of GSL. The contingency plan states: "It is anticipated that lake levels will peak at approximately 4203 feet in 1983 with potential resultant damages of $20 to $30 million." Ironically, the lake peaked at approximately 4205 feet that year, and continued upward to nearly 4212 feet in 1987, with estimated capital damages exceeding $250 million (Bureau of Economic and Business Research, 1983). The causeway was breached in 1984 to lessen flooding impacts occurring in the south arm. The WDPP was built in 1986-87 and operated from April 1987-June 1989.

Great Salt Lake Advisory Council (1988)

In 1988, the Great Salt Lake Advisory Council (GSLAC) was created by legislative action to advise the Board of State Lands and Forestry through DSLF, which was designated as manager of the lake. The Great Salt Lake Technical Team (GSLTT) was given statutory authorization at the same time.

General Management Plan, Great Salt Lake (1988)

As GSL reached its historic high water level of 4211.85 feet in 1986 and again in 1987, a five-year *General Management Plan, Great Salt Lake* was prepared for GSLAC. The general management plan, and the "Beneficial Development Area" (BDA) concept developed by the Utah Division of Comprehensive Emergency Management, was a cooperative attempt to outline the best strategies available to avoid flood-related impacts to those utilizing the lake under its high-water and expected near-future conditions for a variety of purposes. Both the plan and the BDA concept were delivered to the five counties bordering the lake for adoption, and were adopted by the Federal Emergency Management Agency (FEMA).

Division of Sovereign Lands and Forestry (1994)

In 1994, management responsibilities for school and institutional trust lands were placed with the newly created School and Institutional Trust Lands Administration. The Board of State Lands and Forestry and the GSLAC were eliminated, and the Sovereign Lands Advisory Council (SLAC) was created to advise the newly-named DFFSL. DFFSL retained management responsibility for public trust lands and resources, and became able to devote more time to planning and management of these lands as public-trust lands, with a broader view of how

the lake's many trust resources are interrelated.

Great Salt Lake Comprehensive Management Plan (GSL CMP 1995)

Completed in 1995, the *Great Salt Lake Comprehensive Management Plan - Planning Process and Matrix* was prepared by the GSLTT for DFFSL and DNR. The goal of the plan was to, "... provide needed information and guidance in the form of recommendations to federal, state and local governments, and recommended legislation to the state legislature to facilitate and enhance management of GSL and its environs to assure protection of the unique ecosystem of the lake while promoting balanced multiple-resource uses."

As described in its goal statement, the 1995 plan includes analyses of lake management issues, and makes recommendations on those issues to local, state and federal government. Many of the recommendations have been acted upon by divisions of DNR, including development of the MLP by DFFSL. Notable exceptions include actions on WDPP and water quality standards. The fate of recommendations involving local government has not been fully analyzed or reported.

Mineral Leasing Plan (1996)

As an outgrowth of the 1995 plan, DFFSL announced the withdrawal of sovereign lands from minerals leasing as part of a comprehensive planning process for management of minerals on those lands. Included were GSL, Utah Lake and the Jordan River, and portions of Bear Lake, Bear River, Colorado River and Green River. To accomplish its planning and management mandates, DFFSL is creating mineral leasing plans for each area. The GSL MLP is the first of these plans to be completed. This document reviews the history of mineral ownership and leasing, inventories mineral resources and examines the existing conflicts among resources on the lake. The MLP zones the lake bed for mineral commodity production and specifies new mineral leasing procedures.

Current Department of Natural Resources Management Responsibilities

Division of Forestry, Fire and State Lands

DFFSL is "...the executive authority for the management of sovereign lands..." in Utah, including the sovereign lands of GSL. Title 65A of the Utah Code, entitled "State Lands", establishes the division and the Forestry, Fire and State Lands Advisory Council, and sets forth the powers and responsibilities of the division and council. Section 65A-10-8 establishes the division's responsibility to prepare and maintain a management plan for GSL under paragraph (1), and establishes other responsibilities for the lake as follows:

"(2) Employ personnel and purchase equipment and supplies which the legislature authorizes through appropriations for the purposes of this chapter.
(3) Initiate studies of the lake and its related resources.
(4) Publish scientific and technical information concerning the lake.
(5) Define the lake's floodplain.

(6) Qualify for, accept and administer grants, gifts, or other funds from the federal government and other sources, for carrying out any functions under this chapter.
(7) Determine the need for public works and utilities for the lake area.
(8) Implement the comprehensive plan through state and local entities or agencies.
(9) Coordinate the activities of the various divisions within the Department of Natural Resources with respect to the lake.
(10) Perform all other acts reasonably necessary to carry out the purposes and provisions of this chapter.
(11) Retain and encourage the continued activity of the Great Salt Lake Technical Team."

Division of Wildlife Resources

Title 23 of the Utah Code establishes DWR and the Wildlife Board and establishes their duties and powers. Section 23-14-1 provides, "The Division of Wildlife Resources is the wildlife authority for Utah, and is vested with the functions, powers, duties, rights and responsibilities provided in this title and other law." The section goes on to provide, "Subject to the broad policy making authority of the Wildlife Board, the Division of Wildlife Resources shall protect, propagate, manage, conserve, and distribute protected wildlife throughout the state."

The division manages wildlife areas on GSL, regulates hunting, manages all protected wildlife species and regulates the commercial harvest of brine shrimp from the lake. The legislature has authorized the division to utilize all or parts of 39 townships of sovereign lands on the lake for the "creation, operation, maintenance and management of wildlife management areas, fishing waters, and other recreational activities" (Section 23-21-5, Utah Code). Not all lands so authorized are now under management by the division for the authorized purposes.

Division of Parks and Recreation

Chapter 63-11 of the Utah Code establishes the division and the Board of Parks and Recreation, and sets forth their responsibilities. The division manages AISP, Willard Bay State Park and the Great Salt Lake Marina on the south shore of the lake.

DPR is also directly responsible for boating enforcement on GSL. DPR personnel also work closely with five county sheriff offices (Box Elder, Davis, Salt Lake, Tooele, Weber) to respond to search and rescue needs on the lake.

Division of Water Rights

DWRi regulates the appropriation and distribution of water in the State of Utah, pursuant to Title 73 of the Utah Code. The State Engineer, who is the director of DWRi, gives approval for the diversion and use of any water, regulates the alteration of natural streams and has the authority to regulate dams to protect public safety. All diversions from the lake for all purposes, including mineral extraction by evaporation, require the prior approval of the State Engineer. Any dam or dike placed in the lake requires consultation from the division.

Division of Oil, Gas and Mining

The Division of Oil, Gas and Mining (DOGM) is the regulatory agency for mineral exploration, development and reclamation on GSL, pursuant to Title 40 of the Utah Code. This regulatory role is conducted in close coordination with DFFSL.

Utah Geological Survey

The Utah Geological Survey (UGS), [a nonregulatory agency], is responsible for collecting, preserving, publishing and distributing reliable information on geology, brine and mineral resources and geologic hazards related to the state, including GSL. UGS is also responsible for assisting, advising and cooperating with state and local agencies and state educational institutions on all subjects related to geology.

Division of Water Resources

The mission of the Utah Board and DWRe is to direct the orderly and timely planning, conservation, development, protection and preservation of Utah's water resources used to meet the beneficial needs of Utah citizens. Although the division does not have direct regulatory responsibilities on GSL, it conducts studies, investigations and planning for water use, and is responsible for maintenance and operation of the WDPP.

Other State Agencies

Department of Environmental Quality (DEQ)

Division of Environmental Response and Remediation

Federal and state laws require prompt reporting of environmental incidents. Depending on the nature of the incident reports may be made to specific regulatory agencies, but in all cases the Division of Environmental Response and Remediation (DERR) may be contacted to forward the report to the appropriate agency. Follow-up activity often involves preparation of a written report summarizing the incident and remedial actions taken.

Division of Water Quality

The Utah Water Quality Board and the Division of Water Quality (DWQ) have the responsibility to maintain, protect and enhance the quality of surface and ground water resources. The board is charged with developing programs for prevention and abatement of water pollution. The board also is responsible for: establishing water quality standards throughout the state; enforcing technology-based, secondary treatment effluent standards or establishing and enforcing other more stringent discharge standards to meet in-stream standards; reviewing plans, specifications and other data relative to waste-water disposal systems; establishing and conducting a continuing planning process for control of water pollution.

DWQ's mission is to protect public health and all beneficial uses of water by maintaining and enhancing the chemical,

physical and biological integrity of Utah's waters. Objectives designed to achieve this mission are:

- Classify waters according to beneficial use and set water quality standards, including numeric and narrative criteria, to protect those uses;
- Achieve full compliance with treatment and water quality standards by ensuring the adequacy of planning, design, construction, and operation of municipal and industrial waste-water standards through appropriate technical assistance, regulation and enforcement;
- Develop and update pertinent regulations, policies, and strategies;
- Generate a comprehensive water quality data base;
- Conduct water quality management planning and continue to implement an effective statewide non-point source control program;
- Implement the ground water quality protection strategy.

Division of Air Quality

The Division of Air Quality (DAQ) facilitates Air Quality Board members as proactive participants in addressing air pollution issues and in shaping environmental policy. The following objectives support DAQ's mission:

- Involve others in the process; develop state implementation plans (SIP), issue permits, compliance and other public process activities.
- Partner with other in-state government agencies to develop and implement programs for the protection of air quality statewide and achieve and maintain acceptable air quality along the Wasatch Front.
- Maintain delegation of federal air quality programs by developing appropriate plans, programs, policies, procedures and rules.
- Influence state, regional and national policy through active involvement with the legislature and policy making organizations.
- Increase public awareness to educate the general public and businesses on emissions reduction.

State Ownership and Trust Responsibilities

Under English common law, the Crown held title to all lands underlying navigable waterways, subject to the Public Trust Doctrine. Following the American Revolution, title to such lands in the United States vested in the 13 original colonies. Under the Equal Footing Doctrine, fee title to those lands also vested in each state subsequently admitted to the Union, upon admission. Utah's public trust lands, known as "sovereign" lands, lie below the ordinary high water mark of navigable bodies.

The boundaries of sovereign lands are established by the location of the ordinary high water mark of a water body. For the ocean and most rivers and lakes, the ordinary high water mark is relatively constant, and can be identified reliably from year to year. Because rivers and streams establish many important boundaries and can move over time, the common law doctrine of reliction and accretion holds that slow, gradual movement of a river or stream course over time will result in relocation of the property boundary to follow the movement. Sudden changes in course, as

by flooding or other upset, will not result in the relocation of the property line.

In 1959, the Bureau of Land Management (BLM) challenged the state's claim to much of the shoreline of the lake, arguing that the declining lake level was resulting in the "reliction" of shore lands, and the relocation of the boundary between state and adjacent federal land, to BLM's advantage. In 1976, the U.S. Supreme Court determined that the state owns of all the lands, brines and other minerals within the bed and waters of the lake, and all shore lands located within the officially surveyed meander line.

The Surveyed Meander Line

The surveyed meander line is not, however, a constant elevation around the lake. The meander line was surveyed in segments between 1855 and 1966, during which time the water level of the lake fluctuated. Different segments of the line therefore lie at different elevations. The elevation of the meander line generally ranges between about 4202 and 4212 feet above mean sea level. In some locations the meander line runs across topographical features of higher elevation substantially inland of the shoreline. Regardless of its location relative to the water's edge and lake level, the officially surveyed meander is the adjudicated, fixed and limiting boundary between sovereign land and upland owners. (See Figure 1.)

The surveyed meander line is not usually identifiable on the ground without the aid of surveying or global positioning system equipment. To avoid trespass situations, DFFSL requires applicants to provide surveyed legal descriptions for leases and easements on GSL. Upland owners likewise should have the meander line located by survey whenever they need to know the location of the boundary between sovereign land and adjoining land.

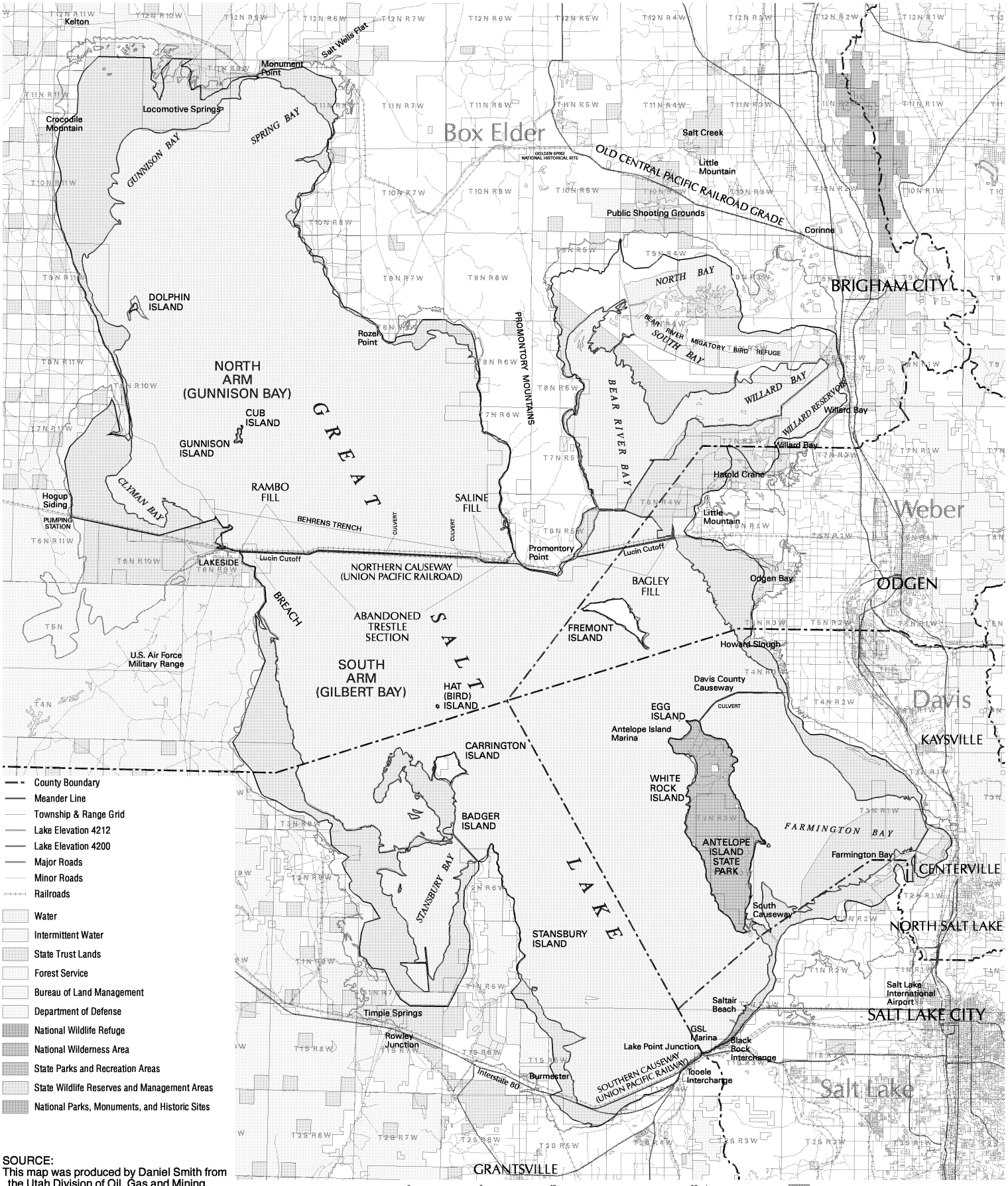
The Public Trust over Sovereign Lands

Under A.D. 6th Century Roman law, and perhaps earlier, the air, sea and running waters were common to all citizens and the separate property of none. All rivers and ports were public and the right of fishing was common to all. Any person was at liberty to use the seashore to the highest tide, to build a retreat on it, or to dry nets on it, so long as they did not interfere with the use of the sea or beach by others. Although the banks of a river could be privately owned, all persons had the right to bring vessels to the banks, to fasten them by ropes and to place any of their cargo there. The influence of Roman civil law carries forward through English common law to today's Public Trust Doctrine, which recognizes the special public interest in rivers, lakes, tidelands and waters. The Public Trust Doctrine "is founded upon the necessity of preserving to the public the use of navigable waters free from private interruption and encroachment" (Illinois Central R.R. Co. V. Illinois, 1892).

Sovereign lands are held in trust by the state for the benefit of the public. The "trust" is a real trust in the legal sense of the word. There is a clear and definite trust corpus (the lands, waters and living resources therein), clear beneficiaries (the public), elected and appointed state officials with fiduciary responsibilities in managing the trust corpus and a clear purpose for the trust. The Public Trust Doctrine establishes the right of the public to use and enjoy these trust waters, lands and resources for a wide

Figure 1 - Great Salt Lake Location Map

Plotted October 19, 1999



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.

variety of recognized public uses. The original purpose of the doctrine was to assure public access to navigable waters for commerce, navigation and fishing. That has evolved to include modern uses that the legislature has determined appropriate to multiple-use management of GSL (65A-10-8): preservation of the lake; availability of brines to lake extraction industries; wildlife protection; recreation protection; safe boating; availability of appropriate areas for extraction of brine, minerals, chemicals and petrochemicals to aid the state's economy; maintenance and protection of marshlands, rookeries and wildlife refuges and public access to the lake for recreation, hunting and fishing.

The Public Trust Doctrine has been, and will continue to be, flexible to accommodate changing demands for public trust resources. There is no particular hierarchy of uses, but when there are competing public benefits, the public trust requires that those benefits that best preserve the purpose of the public trust under the circumstances should be given a higher priority. The Utah Legislature has assigned responsibility for management of sovereign lands, including GSL, to DFFSL. As trustee, DFFSL must strive for an appropriate balance among compatible and competing uses specified in statute. It is desirable to maintain the option to adjust the allocation of public trust resources in response to changes in demand and changes in administrative and legislative policy.

Sale of sovereign lands is generally precluded by the constitutionally-imposed duty of the state to manage sovereign lands for the public. The general exception to this prohibition is if the disposition itself is in the furtherance of the public interest. The Utah Legislature has chosen to protect the public interest when sovereign land is sold or leased by requiring that "...the lease, contract of sale, or deed shall contain a provision that:

(a) these lands shall be open to the public for the purpose of hunting, trapping, and fishing upon them during the lawful season, except:

    (i) where the lands are situated in incorporated or unincorporated towns or cities: and

    (ii) when it is mutually agreed by the director of the Division of Forestry, Fire, and State Lands and the Wildlife Board that the lands may be leased or sold for exploration or development of minerals including oil and gas; and

(b) no charge may be made by the lessee, contractee, or grantee to any person who desires to go upon the land for the purpose of hunting, trapping, or fishing."

Even so, there are circumstances under which a lessee or grantee must be able to restrict public access to fully enjoy the rights granted under a lease, permit or sale. Examples include restrictions during mining operations, construction of improvements, harbor operations, military operations and access to personal property. The test of any disposition of an interest in sovereign land is that it must be done without any substantial impairment of the public interest in the lands and waters remaining. Once again, this involves a judgement call on the degree of impairment of the trust resource or the public's trust rights therein.

Notes:

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 has 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 feet 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 the 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. (See Figure 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. (See Figure 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 feet 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 feet above sea level, the lake's waters cover 1,079,259 acres. At 4204 feet, 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 but allow natural fluctuations to continue.

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

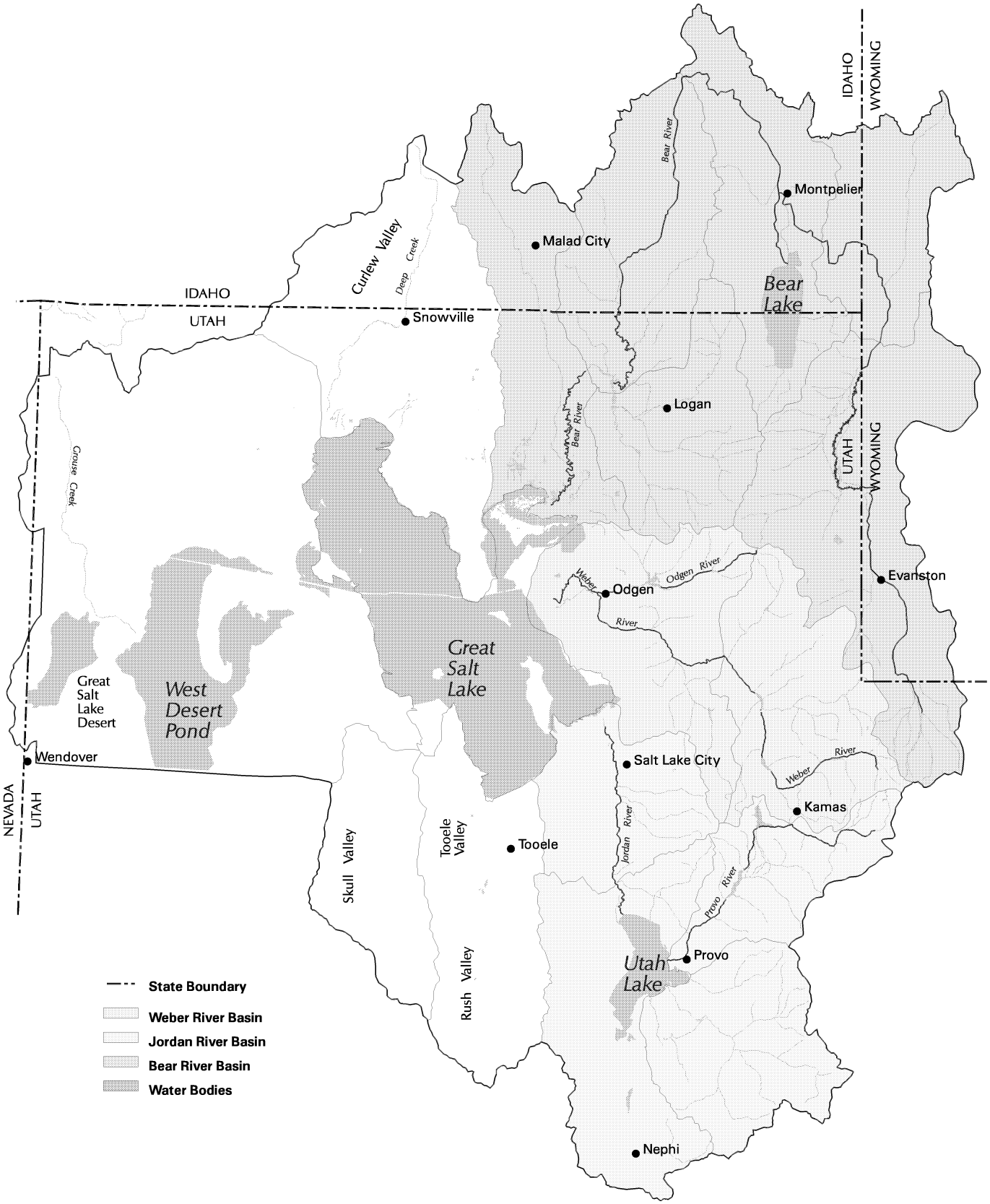
Over the last 20 to 30 years, studies have attempted to define the effects of water development and other human-caused water use on lake level. The studies indicate that 100,000 acre-feet of annual depletion in the basin, the average level of the lake would be approximately one foot lower. The effect 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 and industrial uses (M&I) is not entirely depleted, and significant quantities 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 on tributaries to the lake and other human-caused water uses. In the Jordan and Weber Basins, which have been

Figure 2 - Great Salt Lake Drainage Basin

Plotted November 04, 1999



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.

N W E S

0 10 20 30 40 50 mi
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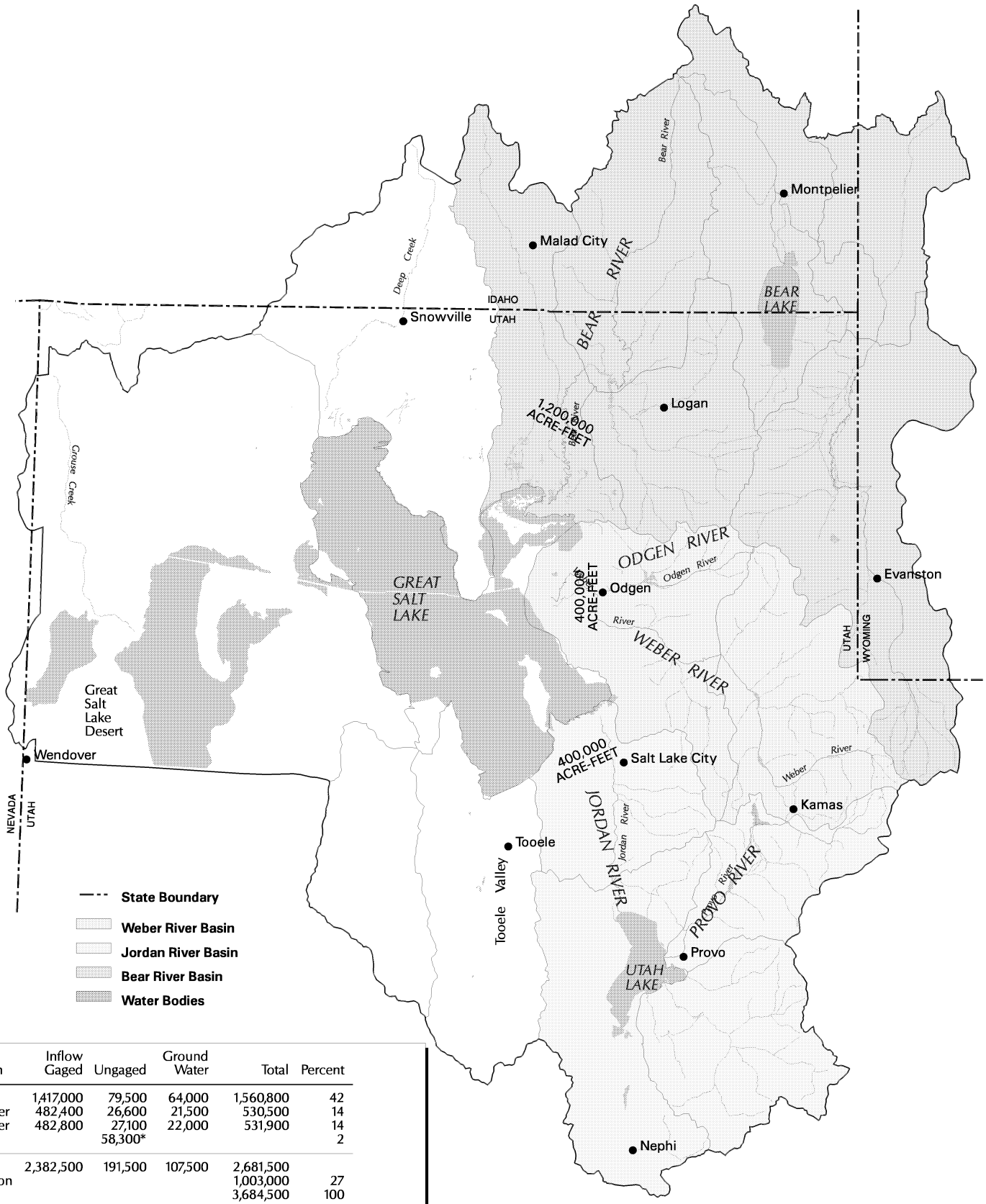
Scale 1:825000 (verify scale)

State of Utah
Department of Natural Resources

Figure 3 - Great Salt Lake Water Supply and Drainage Basins

Plotted October 19, 1999



River Basin	Inflow Gaged	Ungaged	Ground Water	Total	Percent
Bear River	1,417,000	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*			2
Subtotal	2,382,500	191,500	107,500	2,681,500	
Precipitation				1,003,000	27
Total				3,684,500	100

* Includes surface and Subsurface Flow (all flow units in acre-feet)

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

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.
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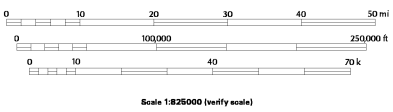

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highly developed by Weber Basin Water Conservancy District and Central Utah Water Conservancy District projects, it is expected that already diverted and developed water will be converted from agricultural uses to meet M&I demands, rather than large, 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 by the Central Utah Project (CUP). 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). Presently approximately 95,000 af/yr enter the GSL Basin from the Uinta Basin. This inflow reduces human impact on lowering the Great Salt Lake.

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.

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. 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, and is considered to be real property.

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 (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 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 upper Weber River drainage and Tooele Valley are closed to new appropriations of ground water. Ground water is still available in the Bear River drainage, the West Desert and on portions of the eastern shore of the lake.

Great Salt Lake Water Rights

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.

There are currently 11 perfected water rights to divert water from the lake, all owned by companies or individuals in the mineral extraction industry. (See Figure 4 for 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 three unapproved applications which do not divert water from the lake, but which would have a large impact on it. Both 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

The watershed of GSL responds to global and regional climatic variability (annual precipitation, streamflow, temperature and other hydrologic processes). Understanding the relationship between lake hydrology and global climatic processes is important to understand changes in lake volume and salinity. (SRC, unpub.)

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, unpub.)

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 the 4217 foot elevation. This is based on recent high lake level of roughly 4212 feet, plus three feet for wind tide and two feet for wave action.

DNR has no regulatory authority over land DNR 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 feet 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 Figure 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 feet in 1873 and a low of 4191.35 feet in 1963. (See Figure 5.) A new record high elevation of 4211.85 feet 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 feet above mean sea level, with a maximum of 4202.25 feet and a standard deviation of 2.58 feet. During the 100 year period prior to 1983, the lake's average elevation was 4198.29 feet with a high of 4207 feet 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.

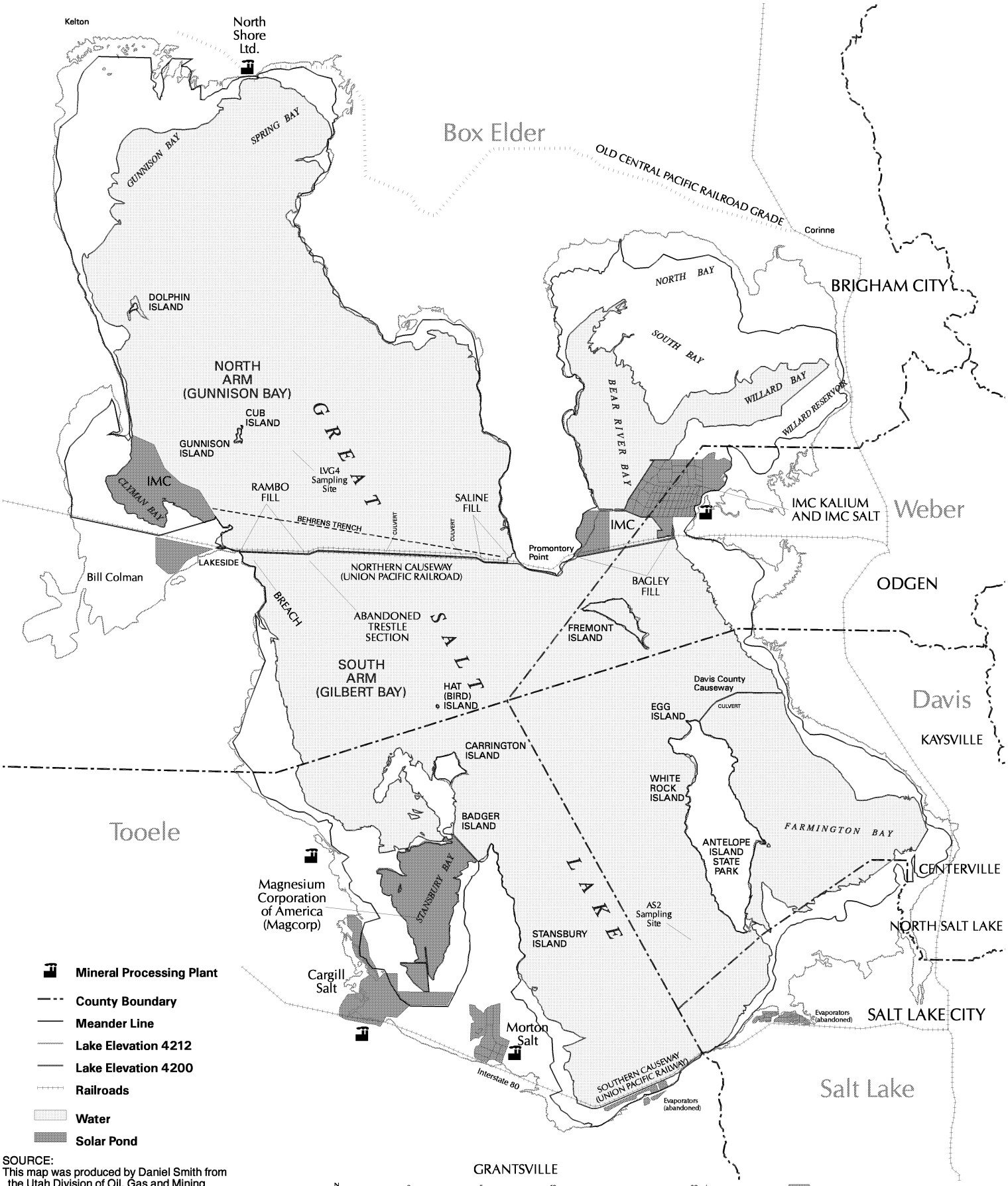
Because of the broad, shallow nature of GSL, its surface area expands rapidly as its elevation increases. Elevations 4200 and approximately 4212 feet represent a common average lake level and the historical high-lake elevation, respectively. Between these two elevations, the area of the lake increases 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 BDA along the shore of GSL between 4191.4 feet (the lake's historical low level in 1963) and 4217 feet. The strategy recommends that, within the elevation interval between 4191.4 and 4217 feet, 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, UGS would provide technical information and maps showing geologic hazards; city-county surveyors would provide a BDA line which is at the 4217 foot 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

Figure 4 - Great Salt Lake Mineral Industries

Plotted November 04, 1999

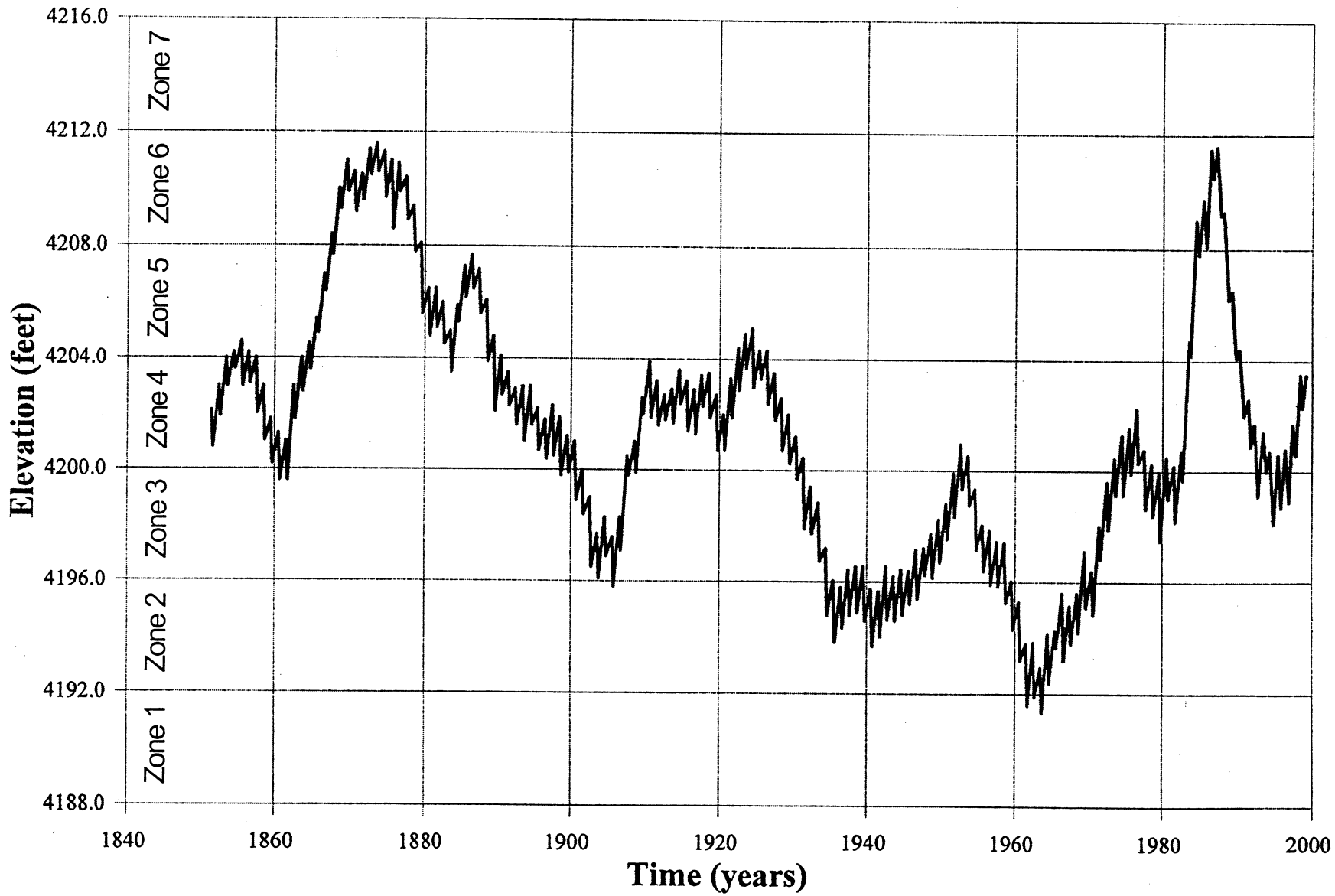


SOURCE:
This map was produced by Daniel Smith from the Utah Division of Oil, Gas and Mining
Information on this map was compiled by the Utah Department of Natural Resources and the Utah Automated Geographic Reference Center.
Official and detailed information is only available through DNR and AGRC.

State of Utah
DEPARTMENT OF NATURAL RESOURCES

Figure 5

HISTORICAL GREAT SALT LAKE HYDROGRAPH



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 feet 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 feet 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-foot level in the last 10,000 years and numerous times to elevations between 4212 and 4217 feet. The rises above the 4220-foot 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-foot 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 11 four-foot elevation zones as a tool to aid in the planing process. These zones are shown in the following table (See Table 1). Many of the figures used in this report show these zones along the elevation axis.

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 would develop their planning and management activities for each of the seven four-foot zones. The information would 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 feet. 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 (27 percent salt by weight) in the north arm of the lake and would vary from about 24 percent

salt by weight of saturation in the south arm of the lake. Vast amounts of salts would precipitate and collect on the bottom of the lake.

Zone 2. Elevation 4192-4196 feet. 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 17 to 24 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 feet. 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 12 to 17 percent salt by weight in the south arm and 24 percent to saturation in the north arm. Salts would begin precipitating in the north arm of the lake in the upper part of this zone and build up to large amounts as the lake level approached the lower part o the zone.

Zone 4. Elevation 4200-4204 feet. 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 feet. 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 9 to 12 percent salt by weight in the south arm and 20 to 24 percent salt by weight in the north arm.

Zone 5. Elevation 4204-4208 feet. 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 feet). Major transportation facilities (interstates and railroads), mineral industries and sewage treatment facilities that were generally protected above the 4208 foot elevation during the 1983-87 flooding should remain protected to at least 4208 feet. The salinity of the lake would range from about 6 to 9 percent salt by weight in the south arm and 17 to 20 percent salt by weight in the north arm.

Zone 6. Elevation 4208-4212 feet. 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 may 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 feet. 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 4 to 6 percent salt by weight in the south arm to about 15 to 17 percent salt by weight in the north arm.

Zone 7. Elevation 4212-4216+ feet. 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 feet 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 1,90,000 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) long the southern part of the lake would be flooded by the time the lake reached 4213-4214 feet. 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 Corrinne. 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 feet (perhaps up to 4220 feet) 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 to15 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 feet, 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 forecasts of future short-term forecasts of the GSL level. There, however, 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. 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.

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 feet, 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 feet.

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 and was subsequently raised two feet, to 4208.75 feet, and was paved during 1992. Use of the Davis County Causeway is adversely affected by lake levels of approximately 4204 feet 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. (See Figure 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 10 years 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 feet with some isolated areas as low as 4207 feet. 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 feet.

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, many 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 feet 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 feet 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 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 feet. Most lake-shore freshwater wetlands have been inundated with salt water when lake elevations exceed 4208 feet.

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 feet. 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 feet is $1.3 million (1993 dollars), adversely affecting several high-voltage transmission lines between the 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 feet. 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 26 percent. 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. (See Figure 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 feet. 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 feet 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 feet 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.

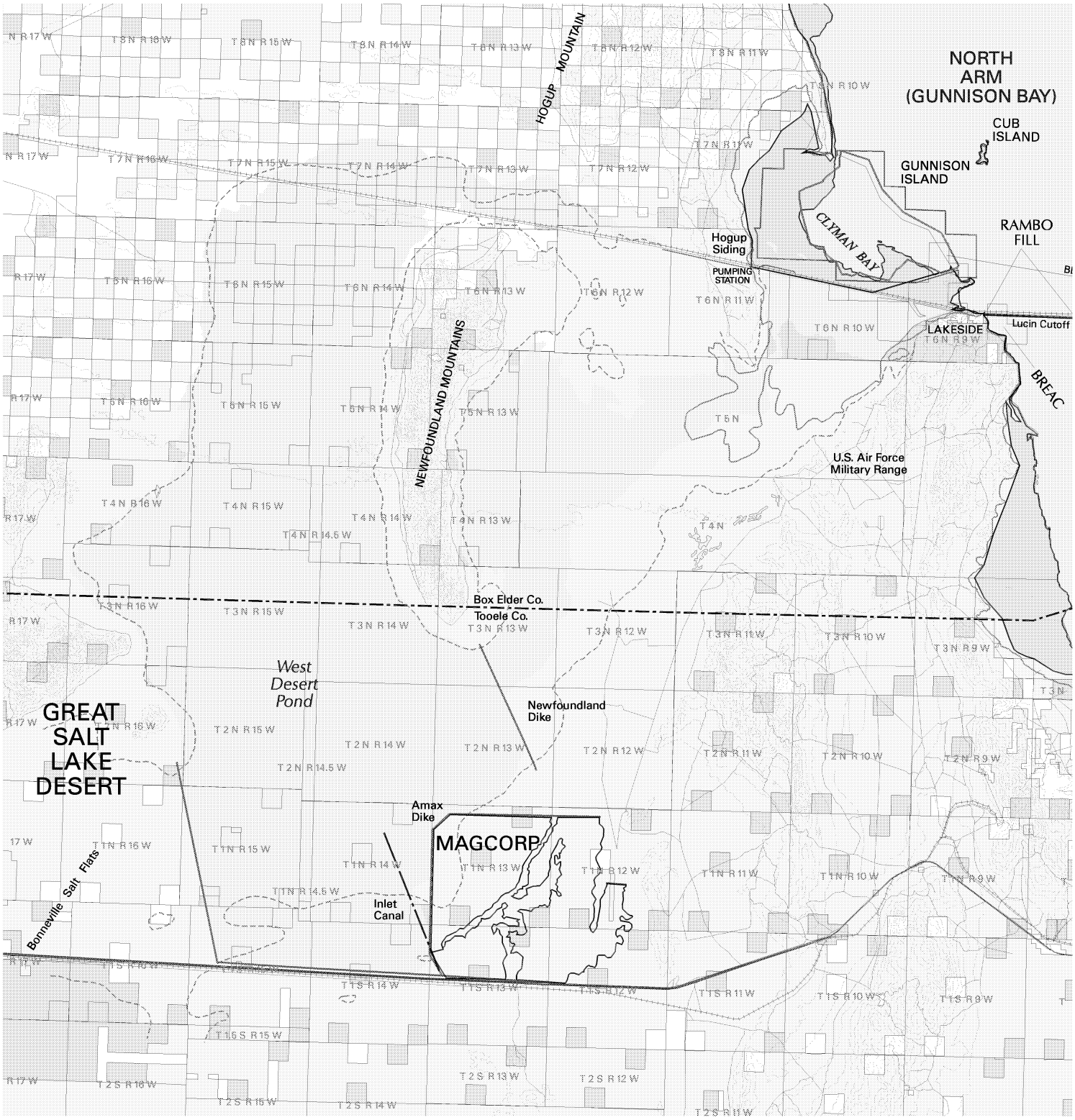
In 1994, USGS published a report entitled "Salt Budget of the West Pond, Utah, April 1987 to June 1989." The report summarized the salt budget as follows:

"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.

Figure 6 - West Desert Pumping Project

Plotted October 19, 1999



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

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

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 feet 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 Figure 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. Figure 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 feet 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 feet, 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.

State of Utah
DEPARTMENT OF NATURAL RESOURCES

Figure 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.

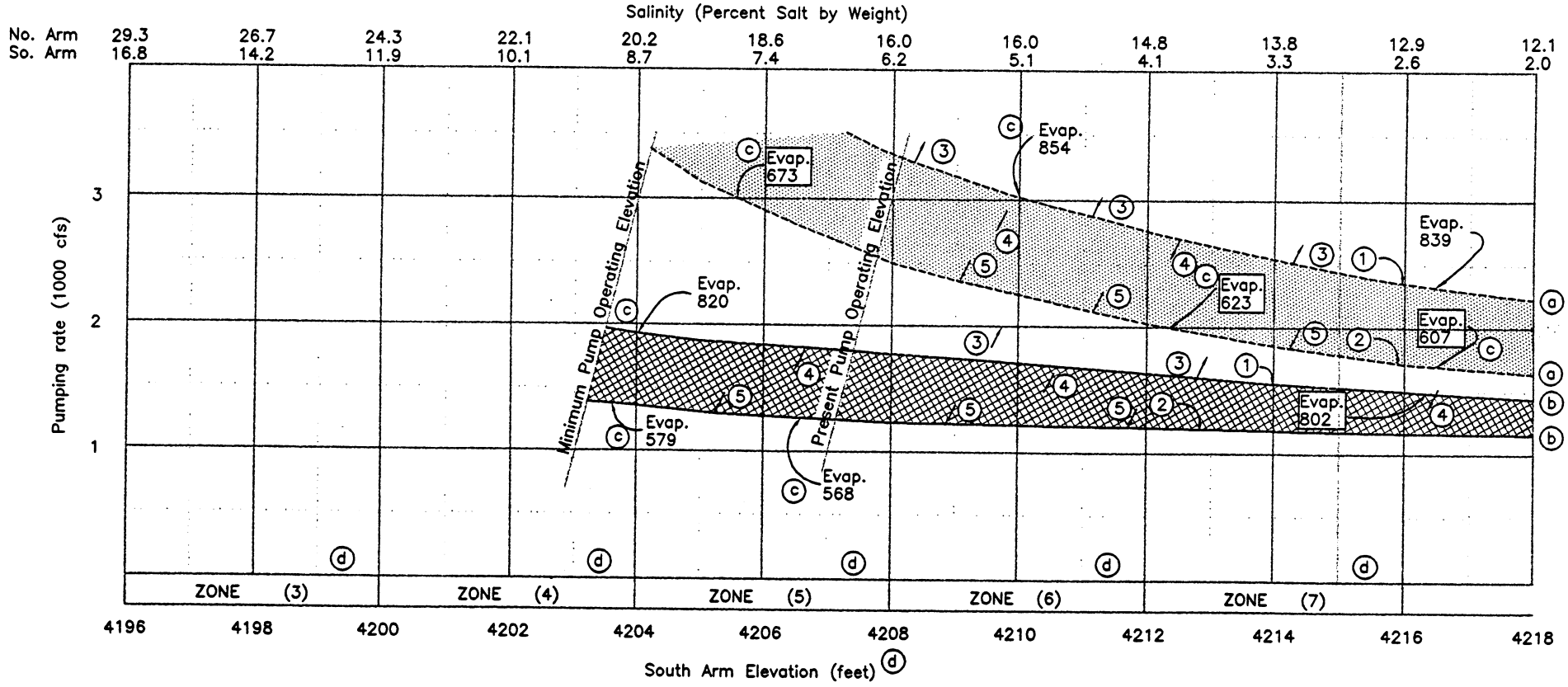
(a) ----- North Arm Brines

(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.



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 an 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 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 feet 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. 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

There are no 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.

The "Water Chemistry" section addresses the overall salinity and ion concentrations of the water of GSL. Biological and other chemical water constituents are briefly discussed in the "Water Quality" and "Biology" sections. Based on internal and external scoping, the planning team has identified five major categories of issues related to water chemistry.

The water chemistry and salinity differentials and trends are significant to the aquatic and avian biology of GSL and to the extraction of mineral salts from lake brines. The impacts of varying water chemistries and salinities to the wildlife and mineral industries of the lake are discussed in the "Biology" and "Minerals and Hydrocarbon" extraction sections, respectively. This section focuses on the physical and chemical aspects of GSL, factors influencing nutrient inputs and losses from the lake and the lake hydrologic processes.

The planning team has identified the following lake water salinity and chemistry conditions and trends as relevant to lake management:

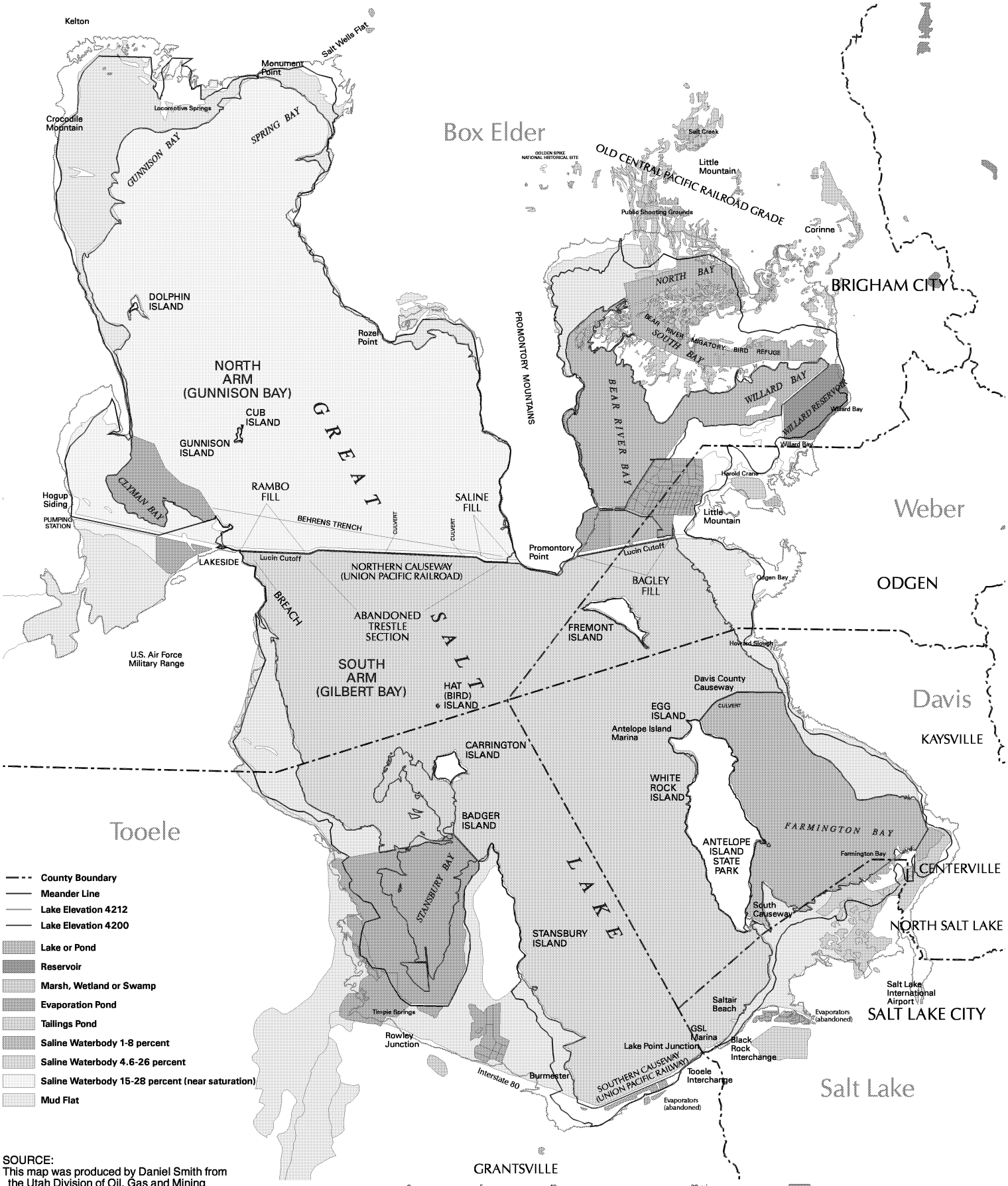
- **The continuation of separate and distinct salinity areas in GSL is an issue.**
- **There is an apparent change in the exchange of salts between the north and south arms. This has resulted in the south arm being less saline than before the high water years for a given elevation.**
- **There should be an investigation to determine if there are stable lake brine ion concentrations and isolation of quantities of soluble salts from the lake system.**
- **There is a lack of an accurate accounting for the quantities and locations of salts in the lake system.**
- **There is a lack of knowledge regarding nutrient chemistry and its influence on biological productivity in the lake.**

Separate Water Salinity Areas in the Great Salt Lake

It is believed that, prior to construction of dikes, causeways and mineral extraction facilities in GSL, lake brines were similar in composition and concentration throughout the lake (See Appendix I). Since the early 1900s, dikes and causeways have been constructed in GSL for a variety of purposes. Several of these inhibited the unrestricted movement of lake brines among large areas of the lake. Coupled with the fact that most of the freshwater inflow to the lake occurs on the eastern shore, distinct salinity conditions have developed in four main areas of GSL. From freshest to most saline, they are; Bear River Bay, Farmington Bay, the main body of the lake (sometimes referred to as the "south arm" or Gilbert Bay) and Gunnison Bay, often referred to as the "north arm". Figure 8 shows the areas of salinity in GSL. Bear River Bay

Figure 8 - Areas of Salinity

Plotted October 19, 1999



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.
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and Farmington Bay are both shown with salinities of 3-6 percent. Bear River Bay is generally fresher than Farmington Bay.

Bear River Bay is separated from the main body of the lake by IMC Kalium Ogden Corp.'s dike and the Bagley Fill which was constructed about 1900 and extends eastward from Promontory Point to Little Mountain. Construction on the northern railroad causeway began in 1956 and was completed in 1959. This rock-fill causeway separates the main body of the lake between Promontory Point to Lakeside and was known as the Southern Pacific Railroad Causeway. This causeway includes the Rambo and Saline Fills which were constructed about 1900. This created a separation between Bear River and Gunnison Bays from the main body of GSL.

With the completion of the causeway, the main body of GSL was now divided into two parts, the south and north arms. Even with the engineered permeability of the causeway and the incorporation of two 15-foot-wide by 20-foot-deep box culverts through the causeway, brine mixing was greatly diminished. Since 1960, the two main arms of the lake have developed different physical and chemical characteristics which vary as the lake level changes, and as changes are made to the structure.

Farmington Bay was part of the main body of the south arm of GSL until it was isolated by the construction of two earthen causeways. The first causeway (southern fill) was built from the south end of Antelope Island southeastward to the mainland in 1952. This structure inhibited water exchange between the main body of the lake and the bay at the south end of the island, and channeled the full flow of the Jordan River into Farmington Bay. The second causeway (Davis County) extending from the north end of Antelope Island eastward to the mainland, was constructed in 1969. With the construction of this causeway, Farmington Bay was essentially isolated from the main south arm of the lake, with the exception of two bridged openings, and mixing between the two bodies of water was severely restricted (Gwynn, 1998a).

Farmington Bay

Farmington Bay is isolated from the main body of GSL when its level is below the top elevation of the Davis County Causeway and the Antelope Island southern causeway fill. Because of the inflow of freshwater from the Jordan River and groundwater inflows, the lake brines tend to be "flushed" from the bay through openings in the Davis County Causeway. Periodically, denser brines from the main body of the lake flow back into Farmington Bay underneath the lighter, fresher brines from the bay. This phenomenon is known as "bi-directional flow," and prevents the waters of Farmington Bay from becoming completely fresh. Bi-directional flow occurs through the Davis County Causeway's bridged openings, and through a narrow culvert to the east which was installed in 1992. Bi-directional flow through these two openings is illustrated in Figure 9 and describes a similar dynamic occurring through the northern railroad causeway. When the lake's elevation is below 4208 feet, the salinity of Farmington Bay is approximately half or less than that of the main body because of freshwater flows of the Jordan River into the bay. When the lake's elevation rises above 4208 feet and the causeway is over topped, the

waters of Farmington Bay and the main body are free to mix (Gwynn, 1998a).

Brine returning to the bay from bi-directional flow tends to resist mixing with the fresher water, and remains in a fairly coherent "tongue" which extends some distance to the south underneath the lighter Jordan River/brine mixture. This forms a stratified brine condition within the central, deeper portions of Farmington Bay. The salt content of the upper Farmington Bay waters is maintained through vertical mixing of the tongue of denser, main body brine with the fresher water above it (Gwynn, 1998a).

Bear River Bay

Bear River Bay is similar to Farmington Bay as a brine system. It is separated from the main body of the lake by the rock-fill causeway which contains a mid-point, bridged opening through which bi-directional flow takes place. The brine is stratified within the deeper portions of Bear River Bay. The upper layer of water contains 1-2 percent salt. Below the upper layer of water lies a tongue of salty water which periodically moves into the bay by the bi-directional flow through the opening in the railroad causeway.

The salinity of the lower brine tongue is similar to that of the adjacent main body of the lake. The thickness of the tongue of denser brine and that of the overlying less-saline water depends upon the rate of inflow into the bay and on prevailing wind conditions. South winds raise the level of the lake at the causeway, forcing the tongue of main body brine farther into the bay, making it thicker. North winds lower the level of the south arm at the causeway, causing the brine to extend a shorter distance into the bay, and it becomes thinner. When the tongue of main body brine thickens and extends farther into the bay, the overlying fresher brine layer thins (Butts, 1998).

Gilbert Bay

The salinity (total-dissolved-solids) of Gilbert Bay varies inversely with lake elevation, and since 1966 has fluctuated from a high of 250 grams/liter in 1966 (approximately 21 percent salinity) to a low of about 50 grams/liter in 1986 (approximately 5 percent total salinity). The south arm of the lake receives nearly all of the freshwater inflow to the lake, including flows from the Jordan, Weber and Bear Rivers, and numerous, minor, east- and south-shore streams. (See Figure 3.)

From 1966 until about mid-1991, the south arm of the lake was density-stratified into two brine layers. A dense, turbid, hydrogen sulfide-laden brine extended from an elevation of about 4180 feet to the bottom of the lake. A less dense, clearer, odor-free brine extended upwards from about 4180 feet in elevation to the surface. The two brines were separated by a relatively sharp transition zone. The deeper, denser brine layer disappeared in mid-1991, after the high-water years (1983-87). During the 1980s, the surface elevation of the lake rose from about 4200 feet to nearly 4212 feet by 1986-87. The disappearance of south-arm stratification is probably due to diminished north-to-south return flow through the causeway brought about by the apparent changes in the hydraulic conductivity (permeability) in the northern railroad causeway (See Appendix I). Since mid-1991, brines of the south arm have been thoroughly mixed from top to bottom. This may have been caused by the addition of fill

material used to increase the height of the causeway from 1983 through 1987 and subsequent compaction of the causeway. It may also have been influenced by the effect of the large head differential that existed between the two arms of the lake which minimized the potential for return-flow to the south arm.

Gunnison Bay

The salinity of the north arm does not exhibit as direct an inverse relationship with lake elevation as does the south arm. This is because the north arm receives small quantities of fresh surface water inflow and large quantities of salty water inflow from the south arm. (See Figure 3.) Evaporation from the surface of the north arm is sufficient to maintain the north-arm salinity at a high concentration. From 1966 until about 1982, the salinity of the north arm remained within the 310-350 grams/liter range (25.7-28.4 percent). Due to this high salinity, a layer of sodium chloride precipitated on the lake's bottom during this time. North-arm salinity dropped to only 160-170 grams/liter in 1987 (14.5-15.3 percent), as evaporation was unable to keep up with increased, dilute inflows from the south arm. Since the high-water years, the north-arm salinity has climbed back into the 290-310 grams/liter range 24.3-25.7 percent. (See Figure 10.)

Brine stratification was not present in the north arm of the lake from 1966 until about 1983. When the lake began its rapid rise from about 4200 feet in 1983 to its historic high of 4211.85 feet in 1986-87, however, a layer of less-dense brine formed on top of the very-dense north arm brine due to increased precipitation, and the enormous inflow of less-saline, south-arm water as the railroad causeway was breached in August 1984 (see later discussion), and the large, bi-directional exchange of brines between the north and south arms through the breach opening which followed. (See Figure 4.) By mid-1991, the level of the lake had dropped below the 4199.5-foot bottom elevation of the breach opening. Because of this, the constant flow of south-arm brine into the upper light-brine layer in the north arm nearly ceased, and the stratified-brine condition in the north arm soon disappeared due to vertical mixing.

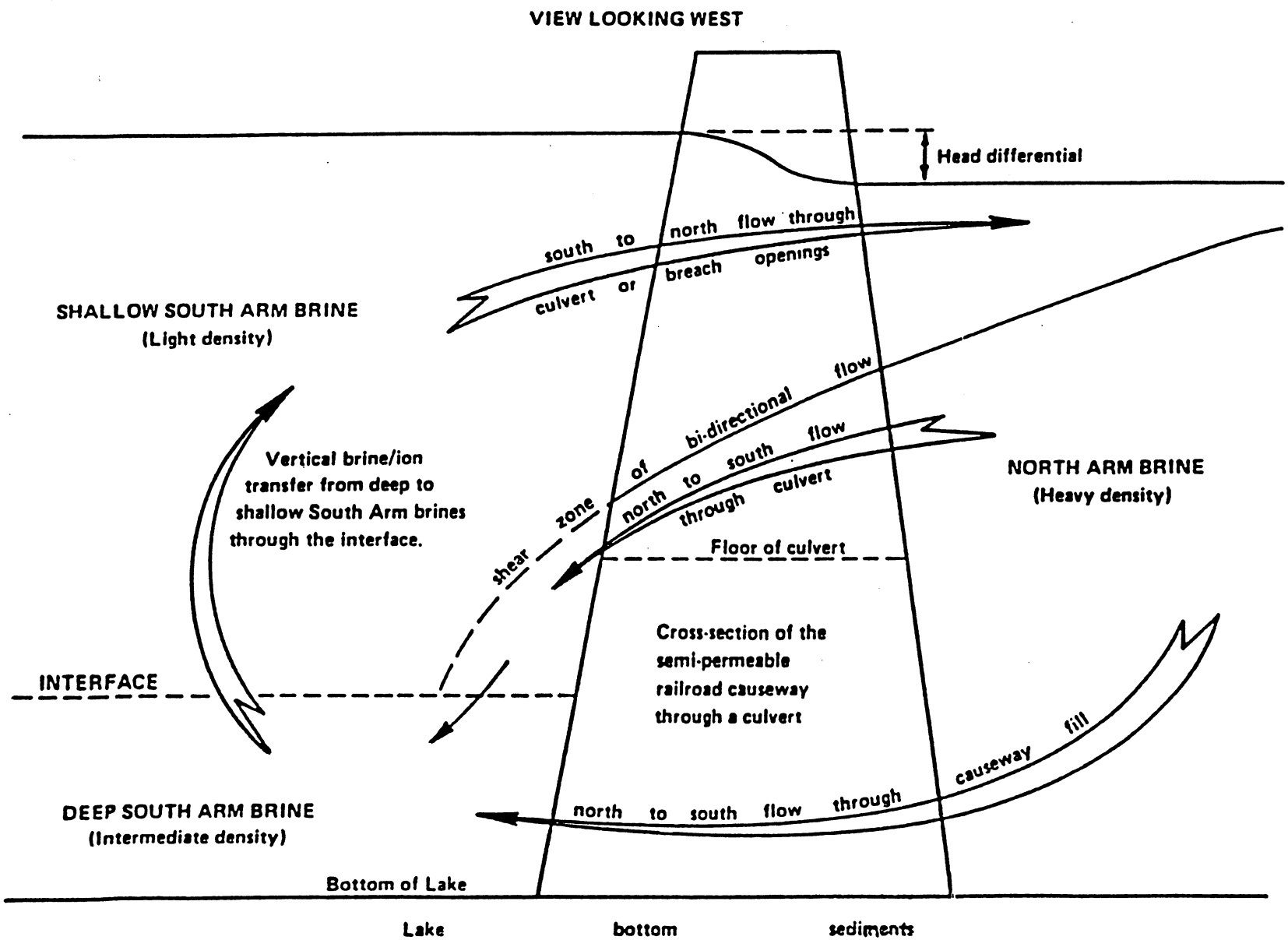
Net Northward Movement of Dissolved Salts from the South Arm to the North Arm

To help alleviate the flooding of the 1980s, the state implemented two flood-control measures which affected the dissolved-salt distribution and the total salt load within the lake.

Breaching the Northern Railroad Causeway

In August 1984, the state created a breach in the northern railroad causeway consisting of a 300-foot-long opening near Lakeside (See figure 4). At the time the breach was opened, the water elevation of the south arm of the lake was about 3.5 feet higher than the north arm. After the breach was opened, great quantities of less-concentrated south-arm brine flowed northward into the north arm, while large quantities or dense, north-arm brine flowed southward into the depths of the south arm as bi-directional flow. As a result of this bi-directional interchange of brine, the south arm density and salt load increased, while those of the north arm decreased. Bi-directional flow continued until the end of 1988 when the lake dropped to

Figure 9



Schematic of bi-directional brine movement through the causeway within the Great Salt Lake, Utah (from Gwynn and Sturm, 1987).

Figure 10

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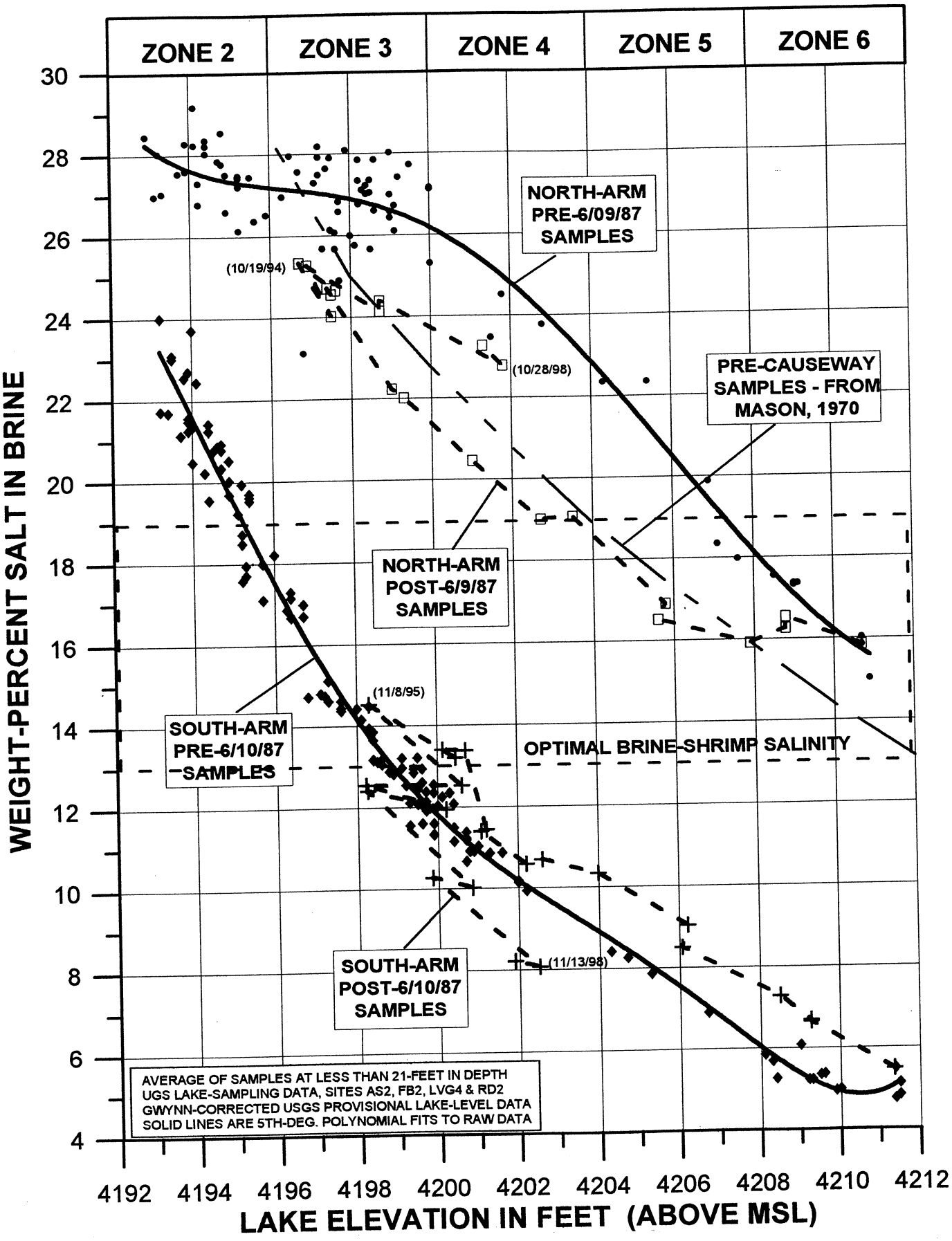


Trends in salinity versus lake elevation for the north and south arms of Great Salt Lake before and after the lake's 1986-1987 high (modified from Gwynn, 1998a).

the point that return flow through the breach opening ceased. From that time until 1999, flow through the breach opening was mainly south-to-north which has resulted in a decrease in south-arm salt load and an increase in the north arm load. During some summer months, salt has precipitated on the floor of the north arm where it will remain until conditions change and the north-arm salinity decreases.

Early in 1999 there was very little bi-directional flow observed moving through the breach. Later in the year, however, as the level of the lake rose and the head differential across the causeway decreased, deep north-to-south return flow was observed within the breach opening.

West Desert Pumping

The second emergency flood-control measure was implemented after the lake continued to rise, following the opening of the breach in the northern railroad causeway. This measure involved pumping water from the north arm of the lake out into the West Desert to increase the total evaporative surface area and to physically remove water from the lake. To accomplish this, three giant pumps were installed near Hogup Ridge (about 12 miles west of Lakeside). The water was pumped from Hogup Ridge by way of a 4.1-mile canal to the West Desert where it was impounded in a 320,000-acre pond, contained by dikes. (See Figure 6.) WDPP was successful in helping to lower the level of the lake from 1987 to 1989, but in the process 600 million tons of crystalline salt, representing 10-14 percent of the total salt-load of the lake, were precipitated and/or deposited on the pond floor when the project was suspended in 1989. (See discussion on "Operating Consequences and Constraints," page 34.)

Ion Concentrations in Lake Brines

Unlike the lake's variable salinity (total grams of dissolved salt per liter of solution), its chemical composition (ratio of various dissolved ions to one another) is relatively constant throughout the north and south arms of the lake, and within Bear River and Farmington Bays. This chemical consistency exists because: (1) chemical homogeneity existed throughout the lake prior to the construction of the railroad and other causeways and (2) continual brine mixing, however limited, occurs among all portions of the lake. Slight, long-term changes in ion-ratios have been observed throughout the lake as a whole. Table 2 gives an average chemical composition of the dissolved salts in GSL waters on a dry-weight-percent basis, as contained in the UGS-GSL database. The compositions of typical ocean and Dead Sea waters are given for comparisons.

Table 2. Average chemical composition of the dissolved salts in the waters of the GSL, Utah, typical ocean water, and Dead Sea water (dry-weight-percent basis).

Ion	GSL (%)	Ocean (%)	Dead Sea (%)
Sodium	32.1	30.8	12.3
Potassium	2.3	1.1	2.3
Magnesium	3.7	3.7	12.8
Calcium	0.3	1.2	5.2
Chloride	54.0	55.5	67.1
Sulfate	7.6	7.7	0.1
Bicarbonate*	0.62		

* Value from DWQ June 9, 1994 Lab Analysis Report for GSL Brine from UGS Sampling site AS

Table 3. In addition to the main ions listed above, the UGS database includes the three most abundant trace elements: lithium, bromine and boron. The average levels of these elements in the south and north brines are reported as follows in units of (mg/L).

Element	South Arm	North Arm
Lithium	24	45
Bromine	66	121
Boron	21	24

Table 4. The minor trace metals in GSL brines which are included in the DWQ's (June 9 and 22, 1994) Lab Analysis Reports.

Metal	Site AS2 (south arm) μg/L	Site LVG4 (north arm) μg/L
Arsenic	130	218
Cadmium	<3.0	<11
Chromium	<5	<5
Iron	<220	<220
Silver	<2	<2
Zinc	<330	360
Mercury	<.2	<.2
Barium	180	170
Copper	<220	<220
Lead	<30	<12
Manganese	<55	<55
Selenium	<12	31

(< = less than)

It has been postulated that the absolute quantities of the ions of magnesium, potassium, calcium and sulfates in lake brines is decreasing relative to sodium and chloride. Data collected by UGS since 1966 show a slight decline in the yearly average, south-arm dry weight percentages of magnesium, potassium, calcium and sulfates over time, while sodium and chloride show a slight increase (Gwynn, Work in Progress). During the low surface-elevation stages of the lake, from 1935 to 1945 and from 1959 to the mid-1960s, sodium chloride precipitated in the main body of the lake and in Gunnison Bay (the south and north arms). Madison (1970) states that salt precipitated at lake elevations below 4195 feet and Whelan (1973) reports that some 1.21 billion metric tons of sodium chloride precipitated throughout the lake at those low elevations.

While the precipitated salt in the south arm had redissolved by mid-1972, it took until about 1986 before all the salt in the north arm had been redissolved (Wold et al., 1996). In 1992, salt again began to precipitate on the floor of the north arm during the summer months, and it is believed that precipitation continued through 1997. Dry-weight percentages of magnesium, potassium and calcium were increased during historic low lake levels because sodium chloride is the first salt to precipitate as the concentration of lake brine increases. Conversely, the concentrations of magnesium, potassium and calcium are believed to be recently decreasing relative to sodium because of

the redissolution of sodium chloride from the lake bed, particularly in the south arm. Notwithstanding slight fluctuations in relative ion ratios in lake water with changes in lake elevation, it is not believed that the overall chemistry of lake brines has changed greatly. It is believed that the lake model currently being verified and calibrated by USGS will provide answers related to the salt-load balance between the two main arms of the lake and change in salinity and chemistry. (See Appendix H.)

Accounting for Quantities and Locations of Salts

The location and amount of salts in the open lake are determined through water sampling and modeling. (See Appendix H.) Data on locations and amounts of salts elsewhere are less available. Given recent attention to the salt balance in the lake and emerging disputes over mineral ownership, DFFSL would like to know more about locations and quantities of salts in the system. This information also will be useful when considering potential recovery of the economic value of stockpiled and waste salt, and when planning for eventual reclamation.

Nutrient Chemistry

The biological productivity of the GSL is largely determined by the concentrations of plant nutrients in the water. Most often, nitrogen, phosphorous or combinations of these two nutrients control plant growth in freshwater lakes. Bioassay analyses of south-arm water of the lake have indicated that nitrogen concentrations most frequently control phytoplankton growth in the lake (Stephens and Gillespie, 1976). Unlike the conservative major ions discussed previously, the concentrations of nutrients in the lake are more dynamic and controlled both by nutrient loading from tributaries and the atmosphere, as well as hydrological and biotic processes in the lake. Upon entering the lake, dissolved forms of nutrients that limit plant growth will readily be taken up by the phytoplankton passed through the food web and repeatedly recycled until organic matter sedimentation buries it in the lake bottom. Nutrients entering in particulate form may sediment out directly and not enter the lake's food web.

Relatively little information is available about the flux of nutrients into the lake and the concentrations present in the water. Studies conducted by Sturm (1980) and Wurtsbaugh (1995) reported high total phosphorus. Sturm (1980) also reported exceedingly high nitrate concentrations while a Wurtsbaugh (1988) study indicated algal nitrogen limitation. This discrepancy may be due to problems with measuring nutrient concentrations in the GSL's brines and/or different years when the measurements were made.

Anthropogenic factors undoubtedly have a large influence on the concentrations and distribution of nutrients in GSL. When tributary waters pass through wetlands prior to entering the lake, substantial portions of the nutrients may be removed (Horne and Goldman, 1994). Because most of the GSL's wetlands have been created or enhanced by diking, this likely results in a substantial loss of nutrients to the lake. Conversely, domestic sewage effluents and agricultural wastes from the watershed are possibly increasing the nutrient

loading to the lake. In-lake diking greatly influences the distribution of nutrients. The Davis County Causeway restricts water exchanges between Farmington Bay and the south arm. Because natural and anthropogenic loading into Farmington Bay is high, it is extremely productive and would be classed as eutrophic (Wurtsbaugh, 1995). Similarly, Bear River Bay receives a large portion of inflowing nutrients from the Bear and Ogden Rivers, but measurements of nutrients and biological productivity have not been made.

The northern railroad causeway influences nutrient distribution in the lake in two ways. As with the conservative major ions, nutrients are transported to the north arm, depleting the more productive south arm. Although limited measurements of nutrients have been made in the north arm, the limited available data (Sturm, 1980) found that nutrients there were often double the concentration of those in the south. However, limited bi-directional flow may also create a trap for nutrients in the south arm.

When dense underflow of highly saline water occurs, this layer does not mix readily with the overlying layer as prior to 1991. Sedimentation of phytoplankton and zooplankton carries nutrients into the deep-brine layer, thus removing them for months to years from the biological cycle. Phosphate, ammonia and total nitrogen and phosphorus concentrations in the deep brine layer were 10-100 times higher than the overlying, less-saline water (Wurtsbaugh and Berry, 1990), but it is not clear to what extent this difference was due to sedimentation of nutrients from the overlying water, and how much was due to the bi-directional flow transporting nutrients back from the north arm.

The amount of nutrient loading for the lake has not been determined. Excessive removal of nutrients would result in decreased brine shrimp and brine fly production and thus impact the bird community reliant on these food resources. Conversely, excessive nutrient loading from sewage and agricultural wastes entering the lake could produce intense and noxious blooms of algae that could be detrimental. The concentration of nutrients in Farmington Bay and the resulting biological production have produced eutrophic conditions that contribute to the odor problems in this area. Other salinity, chemistry and hydrology issues raised by the Scientific Review Committee are addressed in Appendix I.

Water - Quality

Much of the earlier work on GSL addresses the water quality of the lake without distinguishing between the lake water's natural chemistry and the presence or absence of introduced contaminants which could affect the biology of the lake or its beneficial uses. The salinity and naturally occurring constituents of the water of GSL are discussed in the section entitled "Water - Chemistry". This section addresses biological and other chemical water constituents, nutrients and the regulation and impacts of introduced contaminants on the GSL system.

As an aquatic system, the function and usefulness of GSL is highly dependent upon the chemistry and quality of the lake water. As a terminal basin, the quality of the water in the lake is highly dependent upon the quality of water currently entering the lake, and upon the quality and nature of past inflows and discharges into the lake. A wide variety of organic and inorganic materials enter the lake by both natural and human-induced causes. The sources of potential lake water contaminants include:

- Surface and groundwater inflows to the lake
- Permitted discharges directly to the lake
- Unpermitted and accidental discharges to the lake
- Lake sediments which contain non-naturally occurring contaminants
- Airborne particulates and precipitants

Because of the lake's high salinity and unique aquatic biology, some contaminants which are of great concern in fresher water systems may not be as problematic in GSL, and some may even help support the aquatic ecosystem. Others may be rendered harmless by the lake water's high salinity, but may become more bioavailable when lake water freshens. Despite a great deal of research on the lake's water chemistry and aquatic organisms, little work has been done directly on the effects of non-natural contaminants on the GSL ecosystem, or on the water quality effects of fluctuations in lake water chemistry.

The "Water Quality" section considers the presence and impacts of lake water constituents other than naturally occurring salts. Internal and external scoping identified five main areas of interest with regard to water quality.

- **Discharges to the lake and watersheds are managed by approval of discharge permits which are determined to be protective of primary and secondary contact recreation, aquatic wildlife and mineral extraction, and by development of non-point source management programs.**

- **The potential for future changes of lake water quality through loss of wetland function, non-permitted discharges and non-point source management initiatives are not well understood.**

- **The impacts of non-naturally occurring lake water contaminants**

on aquatic wildlife are not well understood.

- **Consider the possibility of establishing a DNR wetland strategy.**

- **Need to improve inter-agency coordination to protect water quality.**

Water Quality Management for Great Salt Lake

The Utah Water Quality Board and DWQ have been charged by the state Legislature to maintain, protect and enhance the quality of Utah's surface water and groundwater resources. The statutory authorities of the board and division are located in Chapter 19-5 of the Utah Code. The overall program missions of the board and the division are to protect public health and all beneficial uses of water by maintaining and enhancing the chemical, physical and biological integrity of Utah's waters.

Facilities in Utah that produce, treat, dispose of or otherwise discharge waste water must obtain a discharge permit from the DWQ under the Utah Pollutant Discharge Elimination System (UPDES). UPDES permits are required for all industrial, municipal and federal facilities, except those located on Native American lands. After a discharge application is received, a wasteload evaluation is developed to determine specific discharge limitations, required treatment and monitoring. Each permit includes effluent limitations and requirements for monitoring, reporting and sludge use or disposal requirements. Permit duration is usually five years or less, with provision for renewal.

To establish discharge standards, the Utah Water Quality Board has classified the waters of the state based on their beneficial uses and has defined numerical and narrative standards for discharges to those waters to protect beneficial uses. The main water use classes are:

Class 1	Protected for use as a raw water source for domestic water systems.
Class 2	Protected for in-stream and recreational use and aesthetics.
Class 3	Protected for in-stream use by aquatic wildlife.
Class 4	Protected for agriculture uses including irrigation of crops and stock watering.
Class 5	GSL. Protected for primary and secondary contact recreation, aquatic wildlife and mineral extraction.

Most of the main classes are divided into sub-classes which address specific pollutants and beneficial uses. GSL is in its own class (Class 5). Primary and secondary recreation, aquatic wildlife and mineral extraction are the defined beneficial uses of the lake's waters. Numerical water quality standards have not been established for GSL, but DWQ has established narrative standards for discharges to the lake and permits for waste water discharges are established on a case-by-case basis. Applications for waste water discharges are reviewed and regulated by the Water Quality Board to prevent the addition of pollutants which would be injurious to the defined uses. The general policy is that, to the extent feasible, no pollutants (discharges) should be delivered to the lake in

amounts that result in concentrations greater than those already present in the lake. The nitrogen and phosphorus in sewage effluents are not regulated by DWQ unless it can be shown that they are causing an impairment to the beneficial use in the receiving waters. Some question if this is an effective policy. Dischargers are regulated by state and federal effluent limitations for total suspended solids (TSS), biochemical oxygen demand, coliforms, pH and some metals. A public notice process is followed to allow comment on any concerns. Except for sewage treatment facilities, most facilities do not directly discharge into the lake and a mixing zone is allowed most cases.

Permitted Discharges to Great Salt Lake

Permitted discharges to GSL fall into three major classifications; municipal wastewater treatment facility discharges, mineral extraction facility discharges and other industrial facility discharges. Wastewater treatment facilities typically treat high levels of organic materials, which generate high biological oxygen demand (BOD) and bacteria. Nutrient levels (nitrogen and phosphorus) are also exceedingly high in these wastewater discharges and can lead to eutrophication. Mineral (salt) extraction industries produce bitterns or residual water from their solar evaporation ponds. These facilities withdraw water from GSL and then use solar evaporation to precipitate various salts from this water. Specific effluent guidelines and standards are applicable to discharges from salt extraction industries. The requirement is that the effluent contain only materials originally present in the intake water. Industrial discharges include effluent from the Kennecott Utah Copper (KUC) concentration and smelting operations and from oil refineries located in the North Salt Lake area. The copper mining and refining operations produce heavy metals, total and suspended solids and petroleum. Discharges from oil refineries have limitations on mass BOD, TSS, oil and grease, phenolic compounds, ammonia, sulfide and chromium. A listing of existing permits for discharges to GSL and its near-lake tributaries is in Appendix A.

Potential for Changes to Lake Water Quality

The overall quality of GSL water is good. From a biological standpoint, the lake's aquatic biological system is described as nitrogen-limited. Nitrates and phosphates, which are usually characterized as "pollutants" in freshwater aquatic systems, are almost completely consumed by lake organisms and do not pose problems in the open water of GSL that they otherwise can. In wetlands adjacent to the lake, nutrient loading may be adversely affecting buffering capability. Other factors on and near the lake, such as the wetland-marsh complexes on the east shore of the lake, are thought to be beneficial in "treating" non-point sources of potential pollution before they reach the lake. Some potential causes for water quality degradation are emergency spills and unpermitted discharges on and near the lake, possible contaminants in lake-bottom sediments and pollutants from non-point sources near the lake and entering tributaries.

Unpermitted Discharges and Spills

In the past, de-icing fluids at SLCIA have been controlled by disposal to a storm water collection area and then to wastewater treatment facilities. Due to a recent increase in the stringency of de-icing requirements imposed by the Federal Aviation Administration (FAA) regulations, the holding capacity is no longer adequate for proper containment and overloading of local treatment facilities has resulted in operational problems, including accidental discharges. The planned development of a process to recover and recycle glycols (the main component in deicing/anti-icing fluids) to eliminate the overflow discharge of contaminated storm water should be able to handle airport storm water and contaminants of concern. Biomonitoring is required where effluent toxicity is an existing or potential concern. SLCIA is considered a minor facility and its discharge is not likely to be toxic after the deicing/anti-icing diversion/recovery system is fully implemented (anticipated date of completion-January 2000) and will not require biomonitoring.

Minor fuel spills involving less than 25 gallons must be contained by the party causing the spill. In the event that fuel reaches the storm sewer it can be removed by oil/water separators located at the discharge points to the City Drain, Surplus Canal and at the entrance to the aeration lagoon of the storm water pretreatment system. All material entering the storm sewer passes through these separators. Fuel spills greater than 25 gallons must be reported to the fire department, state Health Department, DWQ and the Salt Lake City County Health Department. Upon notification the responsible party will immediately begin containment of the spill and the Airport Authority Operations Division, Maintenance Division and the Airport Environmental Specialist will provide necessary assistance.

Reporting and Cleanup of Spills

With the proximity of large industrial, transportation and sewage treatment facilities to GSL, accidental unpermitted discharges to the lake and the lake environs have occurred in the past and are likely to occur in the future. Emergency spill reporting and response is handled by several agencies with different jurisdictional responsibilities. The unpermitted release of any substance which may pollute surface or ground water must be reported immediately to DEQ, followed by a written report summarizing the incident and remedial actions taken to respond. These include releases greater than 25 gallons of used oil, damaged radiation sources, lost or stolen radioactive materials spills or releases of radioactive materials to the environment or other events causing significant human exposure or property damage. This reporting is required by both state and federal statutes. If an incident involves potential health or environmental effects which require immediate action by local authorities, the local emergency response access number should also be called. Some spills also may require notification of the National Response Center (NRC), depending on the type and amount of the release. In addition, spills, leaks, fires and other events at oil or gas drilling or production facilities must be reported within 24 hours to DOGM followed by a written report.

Releases involving oil causing a sheen on surface water, depositing sludge under the surface, or any substance that violates water quality standards must be reported to NRC. Releases to the sewer system in violation of a permit must be reported to the local sewer authority. The U.S. Fish and Wildlife Service (USFWS) receives notification through the NRC when a spill occurs that has implications for protected fish and wildlife resources.

DEQ and the Utah Department Public Safety require that releases of substances or wastes which could be hazardous to human health or the environment must be cleaned up and the wastes disposed of, in accordance with applicable standards. This requirement includes releases which are below thresholds requiring notification to local, state or federal authorities. The conduct of response and cleanup of spills is governed by contingency plans developed cooperatively among the affected resource management agencies, and depends upon the type, extent and location of the spill. Federal and state agencies respond on site and consult with the on-scene coordinator.

Potential Flood Impacts on Water Quality

Lake levels above expected highs can adversely affect existing sewage treatment facilities around the lake. During the flooding in the 1980s, several treatment plants were forced to take steps to protect their facilities from flooding. Substantial costs were incurred to protect facilities, keep them operating and prevent the discharge of millions of gallons of raw sewage into the lake. For example, the dikes of the Perry Lagoons were raised, rip rap was placed on the outside of the dikes to prevent erosion and a pump station was installed. The South Davis Sewer District built dikes around their plant and installed pumping facilities to lift the treated effluent into the lake. Although those protective structures remain in place, lakeside sewage treatment facilities are at risk from high lake levels. Also, some industries adjacent to the lake raised or relocated sediment and waste holding ponds. Magcorp relocated their wastewater holding pond further from the shoreline and put it behind a dike to provide additional protection.

Lake Bottom Sediment Contaminants

Concerns that potential lake water contaminants may be contained in lake bottom sediments have occurred on several occasions due to past discharges to Farmington Bay, the south shore of the lake and other areas of the lake. Several studies have been initiated to determine the levels of heavy metals, organic pesticides, dioxin and furans by DEQ. The USFWS, U.S. Geological Survey (USGS) and the USU have also conducted studies related to lake bottom sediments and water quality. (Discussions follow.)

Farmington Bay

The Davis County Causeway, constructed in the 1960s, inhibited the free exchange of brines between Farmington Bay and the main arm of GSL, resulting in a gradual freshening of the brines in Farmington Bay. Because of the many years of discharge of untreated sewage into Farmington Bay, concerns emerged in the late 1960s that the

freshening of the bay might allow aerobic bacteriological decomposition of organic materials previously "fixed" by the lake water's high salinity. In 1965, the Utah Department of Health reported "...positive evidence of sewage pollution in the [Farmington Bay] lake water to such an extent that bathing should not be approved of in any of these areas for this reason." A study completed in 1971 confirmed organics comprised up to 37 percent of some bottom sediment samples in the south end of the bay, and found unacceptably high counts of *E. Coli* and other coliforms at salinities up to 5.5 percent (Carter, 1971). It was subsequently suggested that an accumulated sludge layer in the bottom of Farmington Bay could be a major water quality concern if sediments were disturbed or if the water continued to freshen (DWRe, 1974).

In 1985, Utah State University (USU) conducted an investigation to determine the potential for contamination of Farmington Bay water from bay sediments in different water freshening scenarios. The study suggested the potential for contamination exists in two sediment core samples contained freshwater soluble heavy metal accumulations. The study also concluded that more information on the potential for release of toxic metals and organic materials should be gathered before any bay freshening proposals should be considered. It was suggested that if the salinity of Farmington Bay were lowered, the "consequences might be dramatic," and result in large algal blooms and resulting odors due to high nutrient levels.

Past sediment surface core sample analyses in Farmington Bay have indicated metal accumulations in bottom sediments. (USU Water Lab, 1988)

Initial results for Farmington Bay show generally low concentrations of contaminants. Lead concentrations peaked at 130 ppm about 1978 and have declined to near 70 ppm in recent years. This is likely due to declining use of leaded gasoline and lead shot for hunting.

South Arm

In 1994, USFWS conducted a limited evaluation of trace elements in brine shrimp and brine flies from the south arm of GSL. The report concluded that some trace elements are elevated to levels of concern and further study was recommended. Currently USFWS is evaluating contaminants including trace elements, polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and pesticides in wetlands associated with the lake as well as its tributaries. Although sampling has focused on biota from these areas, some sediment samples have also been collected. This current study is also expanding on the study completed in 1994 to include sediment samples as well as brine shrimp to further characterize contaminants in the food chains of the south arm of the lake.

Bear River Bay

An investigation by USFWS near the BRMBR between 1989-90 discovered no indications of the presence of hazardous materials (DNR, 1995 and Waddell et al., 1990). There is currently underway a National Water Quality Assessment (NAWQA) study to determine trends in water quality using a variety of methods including sediment coring to determine magnitude and trends in contamination.

This will be part of a wetlands study of chemical processes, and will include comparisons of sediment core samples taken at Red Butte Reservoir, a protected watershed, Farmington Bay and Decker Lake, an urban flood control basin, to evaluate and detect peaks in pesticides, heavy metals and selected organics (USGS, 1998). GSL sediment core samples were collected (1995-96) for a global climate study to provide insight into GSL Basin climate changes and evaluate environmental signals which could provide information regarding anthropogenic influences and trends in lake level and climate over time. (USGS, 1999)

South Shore

During 1995, the U.S. Bureau of Reclamation was directed by the Environmental Protection Agency (EPA) to conduct a soil and sediment sampling program to determine trace metal concentrations across the mud and alkali flats beach area of the south arm of GSL. The study area was located between Black Rock and the Davis-Salt Lake County line north of the C-7 Ditch and Goggin Drain. This study was a response to concerns regarding the migration of heavy trace metals to the south arm beaches. Other possible sources of heavy metals are the Jordan River and Goggin Drain, which flow through several active and inactive landfills, junk yards and several sewage treatment facilities. The purpose of this sampling program was to identify and determine the extent and the concentrations of heavy metals which might present a hazard to human health and the ecosystem. Arsenic and lead were targeted along with 22 other elements and this group wanted to identify the source of the metals. One hundred and twenty-five locations were sampled in a series of transects across the three main water channels, the C-7 ditch, Lee Creek and the Goggin Drain. The study concluded that concentrations of all contaminants of concern were below levels of biological concern.

Nonpoint Pollution Sources

A major source of pollution to all waters of the state, including GSL, is nonpoint source runoff, primarily from agricultural drainage and urban runoff. Because the lake receives overland flow and inflow from streams and irrigation/drainage ditches in addition to the three major river systems feeding the lake, nonpoint sources of water pollution are significant. Effective management of lake water quality is dependent upon effective nonpoint source management upstream.

In fiscal year 1999, a Phase II stormwater implementation component of the National Pollutant Discharge Elimination System (NPDES) will focus on reducing water pollution from urban runoff. Another significant modification to EPA regulations will occur next year regarding the development of Total Maximum Daily Load (TMDL) limitations to meet water quality standards. The TMDL is the quantity of pollutant allowable in a water body to meet water quality standards and avoid impairment of the water body's assigned beneficial uses. When TMDLs are established, the allowable pollutant loads will be allocated among all point and nonpoint sources to the water body in question. DEQ has determined that approximately 467 TMDLs will need to be developed during the next 12 years. That total is comprised of 313 point source TMDLs related to discharge permit renewals, with 82 watershed

TMDLs related to lakes and reservoirs and 72 river/stream segments.

Establishment of a Department of Natural Resources' Wetland Strategy

COE regulates placement of fill in jurisdictional wetlands. DNR agencies generally enforce only COE permit requirements when issuing land use authorizations that affect wetlands. DNR is considering establishment of policy that goes beyond COE requirements. This could include actions such as mitigation requirements, grazing, burning, herbicide and pesticide application and actions in non-jurisdictional wetlands.

Inter-agency Coordination to Protect Water Quality

The planning team and DNR would like to improve coordination between local, state and federal entities in protecting water quality. According to statutory code requirements (Utah Code 65A-10-8) DFFSL is responsible to "promote water quality management for the lake and its tributary streams." However, the state's GSL jurisdiction includes below meander line and extends out to other adjacent state lands. DWQ focuses their efforts and resources on high priority streams and waters where the beneficial use is impaired. This is required by law under the *Clean Water Act*. Protecting water quality and ensuring public trust resource sustainability would require political support, funding and enhanced coordination. This could include increased knowledge of water quality impacts on wildlife, improving discharge permit classification, and improving narrative standards for water quality.

Air Quality

Introduction

Air quality is an important consideration for Wasatch Front residents' quality of life and protection of GSL ecosystem. Air quality degradation has the potential to impair the aesthetic values of this viewshed (sunsets, open spaces). Planners and resource managers have recognized the importance of air quality and pollutant transport along the Wasatch. This section addresses air quality issues and regulations relating to management of the GSL system.

The planning team identified the following resource concerns:

- **Air quality impacts on trust resources are not well understood.**
- **Coordination to protect trust resources is a concern.**

Air Quality Studies

The *GSL Air Basin Wind Study* was conducted by the Wasatch Front Regional Council (WFRC, 1980) to determine the characteristics of regional wind circulation and its effect on the pollution dispersion and transport. This information was combined with results from previous wind studies in developing an air basin concept for air circulation, considering air quality impacts to individual communities and area-wide concentrations along the Wasatch Front. The transport of toxic substances, radiological materials, odor, sound propagation and wind energy were other environmental considerations (WFRC, 1980).

This study concluded that the transport and diffusion of pollutants are severely limited during inversions. Also, pollutants emitted into the lower layers of the atmosphere are not usually dispersed on a daily basis and depend on large scale weather mechanisms that are much stronger than the diurnal circulation patterns (Wasatch Front Regional Council, 1980).

This study also developed recommendations for future industrial sites and the transport of toxic substances. The confining terrain, diurnal wind circulation and high inversion frequency requires that industrial sites be very carefully considered in this air basin. The impact of a given industry will depend on the transport properties of its emissions and the dispersion characteristic of the locality. This study also recommended that the use, storage and transport of toxic chemical, biological or radiological substances be carefully monitored. Since toxicity, dilution and other factors could be distributed easily resulting in a "critical transportation zone." Odors from industrial releases, sewage treatment facilities, wetland areas and decaying organic material in the lake are also easily transported. This study suggested that additional research be conducted on pollutants and their spatial and temporal emissions and completion of an inventory expanding on the existing database and sampling programs. This would include mixing heights and determining if an ozone cell exists to improve understanding of physical air quality systems in this basin (WFRC, 1980).

Existing Regulations

The *Clear Air Act Amendments of 1990* provides the policies regarding areas not currently meeting federal health standards for certain criteria pollutants. It also requires that comprehensive state air quality plans be developed that will reduce pollutant concentrations to a safe level. The maximum allowable concentrations set by EPA for the criteria pollutants are known as the National Ambient Air Quality Standards (NAAQS). Areas failing to comply with these standards are considered nonattainment areas and can be classified as marginal, moderate, serious, severe or extreme. An area with a marginal rating will have less time to reach attainment than an extreme classification. Currently, Utah has or is in the process of writing SIPS for several nonattainment areas; these include Davis, Salt Lake, Utah and Weber Counties. These counties are nonattainment areas for any single or combination of these pollutants:

Particulate matter (PM10)
Sulfur dioxide (SO_2)
Ozone (O_3)

Each state is responsible for developing plans to demonstrate how those standards will be achieved, maintained and enforced to protect public health, according to the *Clean Air Act* (42 U.S.C. Section 7401) requirements. These requirements set limits for maximum levels of pollutants in outdoor air. The SIPS and associated rules are enforced by the state and are subject to federal approval and compliance. These plans break down specific emission contributions from vehicles, industrial sources and human activities and also provide the framework for each state's program to protect air quality.

Portions of Davis, Salt Lake, Tooele, Utah and Weber Counties have exceeded the health standards for the pollutants CO, O_3, PM10 and SO_2 and Salt Lake, Ogden and Provo/Orem cities are nonattainment areas for carbon monoxide (CO) as shown by air monitoring station data and analysis. Once air quality compliance is accomplished, the implementation plan remains in effect and a maintenance plan is prepared to demonstrate how air quality will be maintained for at least the next 20 years.

Twenty-five monitoring stations are strategically located across the Wasatch Front and collect representative data to determine how much of each pollutant is in the air. Air pollutant concentration models are used to assess area pollution levels and provide information for maintaining air quality standards (DEQ, 1999).

Air Quality Concerns

Light interacting with chlorine leads to the formation of unstable molecules that can enhance environmental conditions for ozone formation when catalysts are present. Two studies have been completed examining the effects of chlorine emissions (Hov, 1985 and Whitten, Johnson and Killus, 1982).

Magcorp operates a facility located approximately 60 miles from Salt Lake City on the west side of GSL. This facility emitted about 44,300 tons of chlorine and 440 tons of hydrochloric acid during 1988. Concerns identified in public scoping and recent events indicate a need for coordination with DAQ.

In November 1998, DEQ announced that soil and water sampling on Magcorp's property showed elevated levels of

dioxin at some sites near GSL. Dioxin is a concern because it can build up in the environment. Background levels are present in most soils due to industrial operations, incinerators and diesel engines. This information is important because it "provides evidence that dioxins have been formed in operations of the facility" (DEQ, 1998). Soil and water sampling will continue and scientists will be investigating whether the contaminant has entered the GSL ecosystem (DEQ, 1998).

Air quality relates to management of the lake when trust resources are at risk or require protection. DEQ is coordinating with other state agencies. If dioxin is entering the lake and impacting wildlife or other trust resources, DNR would be interested in actively coordinating with DEQ.

Notes:

Biology

While the term "biology" encompasses all living things, the "Biology" section of the GSL plan focuses on the wildlife species for which DWR is responsible, and on the physical and biological habitats which support those resources. The volume of biological information the planning team identified in its resource inventory is enormous. The team has endeavored to identify and synthesize here that information which is relevant to the management responsibilities of DNR. While a great deal is known about many of the species present in the GSL ecosystem, information about many species is not well known, and biological interrelationships and the effects of environmental stressors are not understood in many instances. The lack of information on natural systems was a primary reason for DWR forming the Great Salt Lake Ecosystem Project (GSLEP).

Based on the information received during internal and external scoping, the planning team identified four major areas of management interest and concern:

- **Existing DWR management programs need to be considered.**
- **Changes in lake brine salinities, with corresponding impacts to aquatic and avian populations and ecological interactions on GSL are significant concerns.**
- **Potential for changes in lake water quality and impacts to aquatic and avian wildlife are concerns.**
- **WMAs within the 39 townships identified by the Utah Code for that purpose have indefinite boundaries.**

Introduction

GSL and its environs support a number of diverse plant and animal species in a unique mosaic of upland, wetland, mudflat, river delta, brackish and freshwater marshes, ephemeral ponds and other habitat types. There are 250 species of birds which frequent the GSL ecosystems, of which 74 species are water birds and 35 species are shorebirds. GSL environs host 23 species or subspecies of fish which are found in impounded freshwater inflow areas, eight species of amphibians and 64 species or subspecies of mammals. From the federal listing, one endangered species (Peregrine falcon), one threatened species (Bald eagle) and 15 sensitive species (which includes the American pelican and the Long-billed curlew) occur on and around GSL.

At least six uniquely productive wetland and water environments exist in the GSL ecosystems. These systems provide abundant and diverse habitat for the numerous wildlife species that use the lake system. These are:

- Open-water environments of varying salinities
- Island and upland habitats associated with the saline system
- Freshwater lacustrine wetlands associated with river and stream deltas

- Brackish-water areas of fresh and saline water interface
- Spring-fed isolated wetlands
- Mudflat/playa environments

The wetlands around the lake are unique in North America because they cover a large expanse of inland alkaline and saline wetlands located in a cold desert. About 400,000 acres of wetlands exist near the shores of GSL, which represents almost 75 percent of all the wetlands in Utah.

While habitat attention generally focuses on the GSL's wetlands, adjacent upland areas are heavily used by wildlife and provide linking habitat types which create the highly productive marsh ecosystems. Upland areas provide an extraordinary amount of food and opportunities for cover, and buffer wetlands from expanding urban and industrial developments around the south and east sides of the lake. In addition, the lake is tied to the Wasatch Mountains by ribbons of riparian habitat which, in the desert west, are critical migratory and breeding habitats for a wide variety of wildlife, especially neotropical migrant songbirds, raptors and riverine mammals. The latitude of the lake makes it a significant wintering area for a number of species.

International, Hemispheric and National Significance of Great Salt Lake

The GSL wetland ecosystems have been recognized nationally, hemispherically and globally for its importance as a vital link in a migrational corridor for water birds which extends from South America to the Arctic. It has also been designated as a Hemispheric Reserve of the Western Hemispheric Shorebird Reserve Network (WHSRN), and is being considered for nomination by the Ramsar Convention on Wetlands of International Significance for listing.

- **The planning team has identified Ramsar designation as a resource concern in this planning process.**

An international convention was held in Ramsar, Iran, in 1971, to discuss the importance of wetland conservation worldwide. The name Ramsar was derived from the host city. The organizations that formed and support the Ramsar process are: the Asian Wetland Bureau, the International Waterfowl and Wetlands Research Bureau and Wetlands for Americas. The Ramsar Convention provides the framework for international cooperation for the conservation and wise use of wetlands (Ramsar, 1999a).

One outcome of the meeting was a process to offer special recognition to wetlands that met established criteria. A nomination process was put in place and recognition given to wetlands that qualified. Worldwide there are 113 Contracting Parties that have designated 957 sites for the Ramsar List, covering over 70.4 million hectares of wetlands (Ramsar, 1999b). There are 15 sites in the U.S. that recognize 1,163,690 hectares. Canada has 33 sites with 13,030,568 hectares.

Wetlands are selected on account of their international significance in terms of ecology, botany, zoology, limnology or hydrology (USFWS, 1999a). Ramsar sites meet a least one of the following criteria:

- Exemplify a specific wetland type characteristic of its region
- Have special value as habitat for rare, vulnerable, endangered or endemic species or because of the quality and peculiarities of its flora and fauna
- Support 20,000 waterfowl or substantial numbers from particular groups of waterfowl, shorebirds or wader indicative of wetland values, productivity or diversity. (Ramsar, 1999b)

Several years ago a nomination process was initiated to designate the lake as a Ramsar site. This was taken before RDCC and the process was tabled. The nomination was made by the National Audubon Society and perhaps others. GSL qualifies for this designation. However the convention also places general obligations on contracting parties relating to the conservation of wetlands and special obligations pertaining to those wetlands which are designated as Ramsar sites (Ramsar, 1999a). The planning team is concerned that this designation may not be consistent the multiple-use management framework for sovereign lands. The consequences of this designation and associated obligations could limit the states ability to respond to changing demand for public trust resources. Other Ramsar sites in the U.S. have a clear wildlife and habitat protection management focus. The state has broader management responsibilities, direction and objectives for the lake as a public trust resource.

A similar designation has been given to the lake recognizing its value to shorebirds. The WHSRN recognition carries no regulations or stipulations, simply a special recognition of the significant values.

The WHSRN was formed in 1985 to address serious concerns for shorebird population decline throughout North and South America. This group of government and private agencies is committed to shorebird conservation. The criterion for designation is that the area must support more than 20,000 shorebirds or five percent of a flyway population. This international cooperative program is helping to protect key shorebird sites throughout the hemisphere and has designated the greater GSL as one of 19 WHSRN sites (Wetlands International, 1998). The designation highlights GSL's importance as a migration corridor line for hundreds of thousands shorebirds. GSL is a significant refueling (feeding) station for shorebirds and, linked with other critical migration sites, forms a chain of such sites from northern breeding grounds in the Canadian Arctic to wintering places on remote coasts and wetlands of South America.

One reason cited for designation as a Hemispheric Reserve is that the 500,000 Wilson's phalaropes known to occur here represent the world's largest known concentration of the species. Wilson's phalaropes fly over 70 hours during their migration. These shorebirds nearly double in weight while feeding at GSL, storing the fat needed for fuel for their long flight.

Over 75 percent of the western population of Tundra swans and 25 percent of the continental Pintail population utilize the GSL area. The annual production of breeding waterfowl from the marshes adjacent to the lake is estimated to exceed 750,000 birds.

The largest nesting population of California gulls in the world is located on

the lake and its environs. North America's largest staging concentrations of American avocets and Black-necked stilts occur at GSL, and the largest breeding population of White-faced ibis occurs in the wetlands around the lake. These are only a few examples of the importance of the lake system in terms of bird use and local, national and international recognition as an important bird area.

The aquaculture industry has spotlighted GSL due to the profitable brine shrimping industry. Brine shrimp *(Artemia)* are harvested, marketed and utilized on five continents. The GSL harvest provides a significant quantity of high quality brine shrimp cysts (also known as eggs) to the international market. Brine shrimp cysts and their nauplii (larval brine shrimp) provide the live feed and protein for marine finfish and crustacean hatcheries around the world. The aquaculture industry is rapidly becoming a primary food source for humans.

Aquatic Biology

GSL aquatic biology has adapted to various saline conditions of GSL ecosystems. The interactions and relationships of the species can be complicated by environmental conditions which are constantly changing in this terminal basin lake. Salinity is a very important factor. The lake has differing characteristics in each of its main bays, but the significant differences are seen contrasting the north arm to the rest of the lake.

The north arm receives limited inflow relative to the rest of the lake. The northern railroad causeway constructed between Promontory Point and Lakeside effectively separated Gunnison Bay from Gilbert Bay. The salinity of the north arm is significantly higher than the rest of the lake, and currently is close to saturation of sodium chloride. Currently there are six algal species in this arm. There are few functioning brine shrimp populations in the north arm, and none of significance. Brine shrimp and cysts are washed in from the south arm, but the adults soon perish due to high salinities. The cysts may persist longer, but cannot hatch and grow to adults for the same reason. There may be local sites where freshwater springs discharge into the north arm that allow a small area of the bay to sustain a brine shrimp population because the salinity is locally favorable. As salinities vary, brine shrimp population abundance will change. Relative to the vigorous biota of the south arm, the north arm is comparatively depopulate.

The south arm, Farmington and Bear River Bays receive nutrient input from drainages of the GSL watershed. Nutrient data are available for some of these drainages, but the sampling points are located upstream from the freshwater marshes surrounding the lake. The cycling and discharge of the nutrients from these marshes to the lake has not been quantified at this time. The nutrients in the lake water are utilized by algae and bacteria. There are more species of algae and bacteria present in these three bays of the lake than in the very saline north arm. The numbers of species present and their abundance fluctuate with lake salinity.

Algal production in the lake is, however, nitrogen limited (Stephens and Gillespie, 1976 and Wurtsbaugh, 1988), but

Wurtsbaugh (1988) found that species (cyanobacteria) that can fix atmospheric N_2 and thus remove nitrogen limitation were limited by phosphorous. Both nitrogen and phosphorous are consequently of importance in regulating algal growth in GSL.

The primary consumers of the bacteria and algae are brine shrimp and two species of brine flies. The biomass of these organisms is significant. Brine shrimp and their eggs are eaten by birds and commercially harvested by humans. Brine flies are eaten by birds and other species in their various life stages. Dead shrimp, flies, algae, other organisms and the waste products from all, in return, are recycled through the system by decomposers as base nutrients.

Bacteria and Algae

There are many species of bacteria that inhabit the waters of GSL. Often, these organisms assist in the decomposition of dead algae, animals and organic wastes entering the lake by stream flow and wind. It was reported in 1966 by Flowers and Evans that GSL hosts eleven species of bacteria that tolerate moderate to high levels of dissolved salt concentrations. The north arm of the lake supports only two genera of bacteria, *Halobacterium* and *Halococcus*, which are extreme halophiles present in numbers from 1,000,000 to 100,000,000 bacteria per milliliter, and are evident in the pink to purple color of this part of the lake.

Relative to a freshwater lake, there are few species of bacteria and algae that exist in the hypersaline waters of GSL. However, these organisms have the potential under favorable conditions to exist in great numbers and account for a significant amount of biomass. A taxonomic study of the algal flora of the lake was done between November 1975 and July 1978. The flora consisted of four blue-green algae, seven green algae, one dinoflagellate and 17 diatoms species (Felix and Rushforth, 1979). Two species of green algae, *Dunaliella viridis* and *Dunaliella salina* occur in the lake. During the winter months when there are no brine shrimp, these species typically thrive and the lake has a green hue. After brine shrimp populations are established by spring hatching, these species are grazed off. Brine shrimp population numbers cycle over the course of the summer. Low numbers of brine shrimp allow these species to rebound and the lake can again have a green hue. Both of these species rely upon salinity levels of approximately 13-19 percent to reproduce rapidly (Van Auken and McNulty, 1973). Research is being conducted by Dr. Gary Belovsky of USU and GSLEP to further examine habitat parameters and productivity of lake algae. At the time of this writing, the experiments are still in progress.

Diatom species in the lake seem to be more abundant when salinity levels fall. An abundance of these species gives the lake water a gold hue. Pennate diatoms are oblong in shape and have a silica covering. These diatoms are too large for brine shrimp nauplii to effectively forage upon them (Stephens, 1998). Brine shrimp numbers seem to diminish when the lake is dominated by diatoms. Laboratory experiments at USU show die offs of brine shrimp in lake water that contained high numbers of diatoms and low numbers of green algae. Shrimp were observed with black spots on their bodies. This occurs when nutrition is poor and the shrimp subsequently are affected by a virus (Belovsky, 1998).

Research must continue to understand the dynamics of algal populations in the lake and how brine shrimp populations relate to the changes in salinity. Brine shrimp populations diminish when salinities are low and evidence thus far suggests that forage is a cause. The current salinity levels of the north arm are too high for many species of algae. In a 1975-78 study which found 29 species of algae living in the lake, the authors reported only two in the north arm. "The findings of (their) study reveal that significant alterations have occurred in the algal flora of the GSL since the construction of the Southern Pacific Railroad Causeway (northern railroad causeway). The migration of dissolved minerals from the south arm into the north arm has reduced the salinity in the southern areas of the lake to the point where viable diatom flora and species of algae previously unknown to the lake have become established. Also the abundance and frequency of occurrence of previous reported algal species has been significantly altered". (Felix and Rushforth, 1979.)

Brine Shrimp

Brine shrimp (*Artemia franciscana*) are found in all portions of GSL. Their occurrence is related to salinity levels and other environmental conditions. The annual life cycle of brine shrimp begins in early spring. Freshwater inflows to the lake from snowmelt and increasing water temperatures initiate egg (cyst) hatching in late January or early February. Hatching peaks in March or early April. Decreasing lake water salinity from freshwater inflow is an important mechanism in the hatching process. The cysts survive the winter in a semi-dehydrated state. When salinities decline, the cysts rehydrate, causing the shell to swell and crack, which allows the nauplii to emerge. As they mature, brine shrimp molt through as many as 12 different stages before they become adults and begin reproducing.

Brine shrimp reproduce by two methods. During the spring and summer many females give birth to live young that are hatched from eggs within their bodies. The other reproductive mechanism involves the formation of hard-walled eggs which are cast into the water by the female. These cysts must then go through a period of dormancy before they hatch. Both of these mechanisms occur throughout the summer, although the birth of live young is more prevalent. In the fall, factors such as the lack of quality food, declining water temperature, decreasing day length and increasing salinity trigger the females to start producing primarily cysts. As many as three generations of shrimp may be produced in GSL during a single growing season. When water temperatures decline below 5° C (42° F), live brine shrimp perish. No adult brine shrimp survive the winter. The population is restarted from the cysts which persisted over winter either floating on the lake's surface or deposited on the beaches. As the lake rises in the spring due to inflow, some of the cysts which washed up on the shore during the winter may end up back in the lake.

Commercial harvesting of brine shrimp began in 1950 when adult brine shrimp were harvested for tropical fish food. Several years afterward, cysts were first harvested because they could be dried, packaged, and stored for long periods of time. The eggs could then be hatched as needed. Presently, only cysts are targeted by the harvest operations but there is a small market for the adult brine shrimp

bycatch. Most of the harvested cysts are used as hatch out feeds in the aquaculture of shrimp and fish which are reared for human consumption.

Brine Flies

Often considered "noxious and insidious creatures" (Rawley et al., 1974) brine flies are actually harmless, do not bite or transmit disease and are a very important part of the overall ecology of GSL. Brine flies are the primary food source for many species of animals, spiders and birds living around the shores of the lake. A source of the misconception is their sheer numbers, reported to be over 370 million flies per mile of sandy beach, for a total of over 110 billion flies plus 10 billion pupae on approximately 300 miles of beaches around GSL.

Brine fly abundance is variable from year to year, and depends upon changes in water chemistry and other environmental conditions. The lake's rise in the 1980s probably resulted in an enormous supply of brine flies when the bullrush was inundated and new pupation sites appeared. Wind direction and velocity seem to have a direct affect on their distribution. Brine fly numbers peak during July and August, and decrease as temperatures begin to drop (Vorhies, 1917).

There are two species of brine flies, *Ephydra gracilis* and the smallest and most abundant, *Ephydra hians*, the alkali fly. Brine flies play an essential role in converting organic material entering the lake into food for wildlife living along the lake's shoreline. By removing over 120,000 tons of organic matter each year from GSL, brine flies consume great quantities of algae, bacteria and organic refuse from brine shrimp and their own life processes. It would require a 78,000,000 gallon per day waste water treatment facility about the size of the Salt Lake City municipal treatment plant to remove this much organic waste from the lake. According to biology professor Dr. Robert N. Winget, "Without brine flies or additional water treatment, lake waters would become cloudy and foul smelling, sands would be clogged with algae and decomposing organic materials, and wild animals of the lake area would be starving."

The life cycle of the brine fly consists of four stages, egg, larva, pupa and adult. Each female lays approximately 75 eggs on the surface of the water or on floating debris consisting of brine fly pupal casings, dead brine shrimp or cysts. The eggs sink to the bottom of the lake before they hatch into larvae. They obtain oxygen from the water by diffusion, and feed on blue-green algae. They become free swimming after emergence, until they find suitable habitat such as algal bioherms or other stationary objects in shallow areas of the lake on which to pupate. Nearly 10 percent of the lake bottom is covered with algal bioherms (Cohenour, 1966).

Larvae and pupae have been found in water depths of between one and 20 feet, and can obtain oxygen from the water by use of tracheal gills located in a long forked anal tube. During warm weather, the larval stage also may pupate on the surface of the lake on floating masses of algae. The pupal cases split open on the back and fully develop into adult flies. Flies emerging from the bottom of the lake float to the surface in a bubble of air. The life cycle can be completed in 21-30 days, and may extend longer during cooler temperatures. Adult brine flies only live 3-4 days. Brine fly

populations begin to expand rapidly in numbers during the first of June, and one or two generations of flies reach maturity each year. The flies survive the winter in immature stages.

Corixids

Corixids are small predatory aquatic insects that live in and around the edges of GSL. Their preferred habitat is water with salinity less than six percent along rocky shorelines (Belovsky and Mellison, 1998). Their diet includes, but is not limited to, brine shrimp. These insects have the ability to fly and are observed in the main body of the lake.

Wurtsbaugh (1992), working in Farmington Bay during the 1980s, reported that predation by corixids and copepods on brine shrimp may decrease shrimp population densities. This bay has lower salinity than the main body of the lake due to its being diked and freshwater inputs from the Jordan River. Gliwicz et al., (1995) suggested that similar salinity levels to those observed in Farmington Bay might allow corixids to decrease the brine shrimp population in the south arm of the lake during periods of lower salinity. This has led a brine shrimp harvester to argue that decreasing salinities in the south arm of the lake has led to a decline in brine shrimp populations.

Belovsky and Mellison (1998) have conducted experiments on predation by corixids on brine shrimp. This information, when combined with the corixid densities in the lake reported by Stephens (1998), indicated that corixid predation rate was 1-2 orders of magnitude less than the brine shrimp population growth rate and has negligible impact on the brine shrimp population in the south arm.

Research findings from Farmington Bay (Wurtsbaugh, 1992) are unlikely to apply to the south arm of the lake due to substantially different limnological conditions. If salinity in the south arm remains higher than six percent, conditions for corixids will be poor and their impact on brine shrimp will be negligible. Wurtsbaugh now considers corixid predation unable to decrease brine shrimp populations in the south arm without dramatic declines in salinity. Furthermore, Wurtsbaugh now considers that brine shrimp in Farmington Bay may have been reduced during his study by other factors (e.g. lack of abundance of high nutrition foods for brine shrimp) that were not examined (Belovsky, 1998).

If corixid numbers were to increase to the point of decreasing the shrimp population, there is no known remedy (e.g., insecticides) that would be environmentally acceptable. Current knowledge suggests that corixids do not limit the brine shrimp population in the lake and sampling programs will continue to monitor corixid abundance in the lake as salinity varies.

Fish

The current salinities of the north and south arms of GSL are too saline to support fishes. In the shallow water areas near fresh water inflows, fish are also important—mostly carp (and pre-carp), but sometimes Utah chub. (BRMBR, unpub., SRC, 1999c) During high lake elevation cycles, the fishery has been known to persist for several years concurrently. Both of these bays receive substantial freshwater inputs from the

Bear River and the Jordan River, respectively.

During the spring runoff period, fish are carried out into Bear River Bay from the adjacent freshwater marshes and waterways. The salinity of this bay is very low. A tongue of saline water flows into the bay through IMC Kalium Ogden Corp.'s (formerly Great Salt Lake Minerals) causeway. This layer of salt water is usually found along the bottom of the bay, and its presence and depth is influenced by south winds and the amount of inflow from the Bear River. There is a layer of fresher water on top of the saline layer. This freshwater can sustain fish populations over time. Fish species in the marshes around the lake have not been extensively studied. Piscivorous bird species such as American white pelicans, Western grebes and Double-crested cormorants use the bay as a foraging area. A strong south wind has the ability to push saline water from the south side of the causeway up into the bay, causing significant fish kills at times.

These fish may be washed out of Bear River Bay into Gilbert Bay of GSL. Dead fish can be preserved to a degree in the saltwater, and are transported around the lake surface by winds and water currents. Observations of these fish in the main body of the lake and/or on the beaches of Fremont, Antelope and other islands leads some people to the assumption there are live fish in the main body of the lake.

Farmington Bay tends to be more saline than Bear River Bay. Salinity is often at 3.5 percent, which is too saline to support freshwater species of fish. The margins of the bay adjacent to the freshwater marsh outflows are sometimes fresh enough to sustain temporary populations of fish and the birds that eat them. However the winds frequently mix the water to the point that the fish cannot survive. Occasionally some fish wash out of Farmington Bay through the Davis County Causeway into the main lake. This phenomenon is not as common as fish from Bear River Bay, because the populations of fish in Farmington Bay are rarely as abundant. The north arm does not support a population of fish because of the salt concentrations.

There are times when layers of freshwater may be temporarily found on the surface and periphery of the main body of the lake and may support fish. When lake levels rose in the mid-1980s, salinities declined to a point allowing fish to exist in shallow areas around the edges of the lake.

Terrestrial Biology

Plants

A great deal of work concerning plant life on the shores of the lake has been conducted by various investigators. (Flowers and Evans, 1966). GSL and its environs have a unique diversity of flora, due to the interface between fresh and saline marshes and soils. Halophytic species are found along and adjacent to the beaches of GSL. Freshwater from streams, drainage ditches and springs leaches some of the salt from the soils near the lake, and allows a greater diversity of plant species in some areas. Such areas are quite extensive in the deltas of the Jordan and the Bear Rivers, and smaller in other areas due to springs or seepage areas.

Playas are low flat depressions in the valley floor formed by bottom currents of ancient Lake Bonneville in its last stages of recession. The West Desert is a vast complex of playas laced with irregular bars and local depressions. Salt-tolerant species found on GSL beaches are also found in some playas, depending upon soils, salt gradients and successional stage. Saline plains or uplands extend beyond the playas and beaches around the lake up to the bases of the mountains. The flora is very diverse and includes herbs and smaller scrubs. Their frequency and location depend on the character of the soil surface and rainfall. Slight depressions usually collect water in the spring and support localized changes in plant life.

Dunes are formed along the eastern shores of the lake and on the plains and foothills bordering the salt desert. Dunes near the lake are composed of white calcareous oolitic sand formed around mineral particles and fecal material. Beach flora is distinct in some areas but in others it is mixed. Vegetation is usually restricted to the upper edge of the shoreline where wave action is less and flooding by brine laden waters is limited in frequency. Mudflats are a special aquatic site and provide important habitat for some wildlife species, such as the Snowy plover. These areas support pickleweed along the shores of the lake, an important fall and winter forage for geese and other waterfowl.

Vegetation on GSL islands is variable, and ranges from no vegetation to broad diversity on Antelope and Stansbury Islands. Some islands are mere sand bars with little vegetation or cover, some have a considerable amount of vegetation including desert shrubs, and others are quite rocky and devoid of vegetation.

The eastern shoreline of the lake is dominated by marshlands or wetland type vegetation. This narrow strip of vegetation combined with shallow water is important habitat for wildlife and millions of waterfowl, shorebirds and migratory birds. Relatively small changes in lake level inundate or expose large areas of shoreline so lakeshore flora are characterized by multiple successions.

Lake level fluctuations and the shallow gradient of the lake bottom together have a profound affect on the flora and fauna found in this zone of influence. This natural phenomena is critical to maintaining the habitat requirements of many species of birds which inhabit the lake. This mechanism (lake level fluctuation) must be present to maintain this dynamic system.

Around the shores and private lands at the north end of the lake there are extensive stands of sagebrush and this is an important winter grazing area for domestic sheep and deer. Browse-type vegetation located in the Promontory Mountains includes Mountain mahogany, Serviceberry and Bitterbrush, which are valuable to wildlife as food and cover. These areas also have juniper growing on steep and rocky hillsides.

Perennial vegetation consists mainly of grasses and various shrubs such as sagebrush, rabbit brush, greasewood and shadscale, particularly along the west side of the lake. Upland and agricultural areas also provide important wildlife habitat and serve as critical habitat when lake levels are high.

Reptile and Amphibians

Limited work has been done on the amphibians and reptiles in the GSL

ecosystem. Eight species of amphibians, two species of turtles, nine species of lizards and eight species of snakes were identified in the biological resource inventory and study at the request of the Utah Legislature prior to 1976 (Rawley et al., 1974). Some of these species occur on the islands in the lake. Locations and records of occurrence can be examined in *The Great Salt Lake Biotic System* (Rawley et al., 1974).

Mammals

A total of six species or subspecies of mammals have been identified around the lake and on islands in the main body of the lake. Many of the species are rodents. Other species present include bats, rabbits, porcupines, coyotes, foxes, bobcats, mountain lions and deer. DPR and DWR have established antelope and California bighorn sheep on Antelope Island. Locations and records of occurrence can be examined in *The Great Salt Lake Biotic System* (Rawley et al., 1974).

Birds

Avifauna associated with the lake and its environs are abundant and diverse. Groups include waterbirds, shorebirds and marsh-associated songbirds. Over 250 different species have been identified. Several million birds use the lake area in spring, summer and fall migration. Some unique winter visitors occur in the area including one of the largest concentrations of Bald eagles in the 48 contiguous United States. The lake is of hemispheric importance to many populations of birds.

Waterbirds on Great Salt Lake

GSL has extensive populations of colonial waterbirds. These species can be found on the lands or marshes adjacent to the lake, or on the islands and dikes/causeways within the lake. There are three primary habitat types utilized by these birds for nesting locations: shoreline playas, emergent vegetation and areas of woody vegetation.

Habitat Relationships

Shoreline Playas

Some examples of ground nesters include California gulls, which nest on islands in the lake and on dikes or causeways that transect the lake. Egg Island and dikes at the IMC Kalium Ogden Corp. operation in Bear River Bay are sites for gull colonies. One of the world's largest nesting colonies of White pelicans occurs on Gunnison Island. This extremely remote island provides security from disturbance and predators. The pelicans fly from the island to forage for fish in the freshwater marshes and reservoirs, then return to bring food to the pod. Adult pelicans leave the pod between 18-72 hours. Black-necked stilts and American avocets nest on mudflats and playas around the lake. These sites are adjacent to favored shallow water feeding areas. Snowy plovers select playas with little vegetation around the lake for nesting sites.

Emergent Vegetation

Birds which select the interface of open water areas and the beginning of the emergent vegetation (such as bulrush species) of the exterior marshes include White-faced ibis, Franklin gulls and tern species, which are often found together

in nesting colonies around the lake. Eared grebes also utilize this habitat type, although they are not necessarily nesting along with the species previously mentioned. The populations of these species are substantial. As lake level fluctuates, the location of the bulrush-open water interface constantly changes. The dynamic of the GSL shoreline helps to maintain pioneering stages in emergent vegetation types which are important in developing habitat edge and vegetation density. It allows for periodic open mudflats and playas important for certain bird species and breeding sites for invertebrates. Changing habitats are the key to wildlife diversity and abundance in GSL ecosystems.

Woody Vegetation

There is another group of species which utilize a relatively rare habitat type around the lake. This is woody vegetation in the form of trees and large shrubs. These are usually found along the waterways entering the marshes or planted along dikes and uplands by wildlife managers. All of the trees below lake elevation 4212 feet were killed by salt water and/or flooding during the mid-1980s. Some of the dead trees still persist and new trees have been planted or have naturally re-established. These woody plants are excellent nesting sites for such species as Great Blue herons, Snowy egrets, Black-crowned night herons and Double-crested cormorants. Other species such as raptors utilize these trees as well.

Pelagic Areas

The open or pelagic areas of the lake are very important to many birds. These areas are primarily used for either foraging or resting. Eared grebes and Red-necked phalaropes feed on brine shrimp in the open waters of the lake. Gulls are observed there as well. They feed upon dead brine shrimp and brine flies which collect in windrows on open water.

Waterfowl

GSL is located on the eastern edge of the Pacific Flyway. These corridors are the major routes that populations of birds utilize when migrating north and south. These flyways were defined for administrative considerations primarily, not biological, and are utilized in the analysis of bird banding data. It was discovered that birds typically, although not exclusively, migrate in north-south corridors.

Many species of waterfowl have been documented on and around GSL. Over 75 percent of the western population of Tundra swans utilize the lake as a stopover and foraging area during their migration. As many as 60,000 birds have been observed at peak times. They utilize the large lake areas within state WMA and BRMBR. Sago pondweed grows in these units and is a preferred forage. Trumpeter swans also occasionally inhabit the area. USFWS and DWR have been transplanting Trumpeter swans here from areas where populations have exceeded the food source as a means to broaden their wintering range across the west.

Breeding

A number of breeding ducks use marshes around the lake. The nesting habitat types used range from dry upland areas to emergent marshes.

Table 5. Waterfowl Breeding

Species	Breeding pair #
Pintail	2,000
Gadwall	40,000
Cinnamon teal	40,000
Mallard	<65,000
Ruddy duck	15,000
Northern redhead	20,000
Northern shoveler	10,000
Canada geese	2,000

The total number of individuals is double the breeding pair number.

Migration

Waterfowl that are produced elsewhere, typically north of Utah, use marshes and lake as a stopover point during their migration. Up to five million waterfowl migrate through Utah each year. Large numbers of Green-winged teal and Pintail use the lake each summer as a key molting area. They fly from other areas and use the large open water portion of the lake for security and foraging. During the waterfowl molt, the birds are flightless for a 3-4 week period. Pintail numbers in late summer historically reached about 1,000,000 birds. This is approximately 25 percent of the continental population of these birds. In the 1990s, Pintail populations are about 250,000. Green-wing teal numbers peak at 600,000 during the molting and staging period. Populations of the following species also utilize the lake during migration periods and peak at the following levels:

Table 6. Waterfowl Population Numbers

Species	Peak Population
Gadwall	100,000
Cinnamon teal	80,000
Mallard	500,000
Ruddy duck	60,000
Canada geese	50,000
Northern redhead	150,000
Canvasback	50,000
Northern shovelers	100,000

From 7,000 to 11,000 Canada geese annually molt along the west side of Bear River Bay.

Wintering populations of waterfowl are dependent upon habitat and climatic conditions, which change yearly. The amount of water which is not frozen and the availability of food are the primary factors governing abundance of birds during the winter. If the winter is severe and most of the marshes are frozen over and relatively deep snows cover the ground, birds migrate south until more favorable conditions are encountered. Mid-winter numbers of ducks range from 10,000-150,000, depending upon the weather.

DWR participates with other states and USFWS in the management of migrating waterfowl. Management of birds that can move in one day from state to state or even between countries require coordinated management. Utah conducts several bird surveys each year to determine population numbers. These counts are coordinated with other states so a continental population can be

determined. For example, all states in wintering areas conduct mid-winter surveys between January 1-15 to establish wintering population data.

Habitat Relationships

There are five major habitat types around the lake that are used by waterfowl species.

Uplands

This habitat is found at slightly higher levels than adjacent marshes, and is usually characterized by dry ground and species of grasses, forbs and shrubs that favor this condition. Uplands are the most limited types of habitat around the lake. These are the areas that are best suited to development, farming and other activities of humans. Many waterfowl species prefer to nest in upland sites, then lead their broods of ducklings to the marshes to rear them.

Freshwater Marsh

There are approximately 400,000 acres of freshwater marsh wetlands around the lake, principally on the east side. The major surface water inflows to the lake run through these areas. Many impoundments have been constructed by DWR, USFWS and private land owners which include duck clubs and the wetlands mitigation sites of KUC and SLCIA. The Nature Conservancy (TNC) and the Utah Reclamation, Mitigation and Conservation Commission (URMCC) also own emergent marsh wetlands. These areas are principally impounded water which supports marsh plants including bulrush and cattail. Other land types associated with this habitat include small ponds found within the emergent vegetation and large bodies of water where depth precludes the establishment of these species. Dikes and small islands are also found in these marshes. They are particularly important as nesting and resting sites because, as water levels change, they usually stay dry.

Mudflats and Playas

This major habitat type around the lake is characterized by a very low gradient. As the lake level fluctuates these areas become inundated and then dry out. The water levels can change due to runoff or winds. The lake is so wide and shallow that, as the wind blows across it, water is pushed to the windward side increasing water levels one foot or more due to this tide-like phenomenon. Precipitation or snow melt can also fill low spots in these areas, creating ephemeral pools which are excellent sites for invertebrates. The vegetation on mudflats and playas is often sparse and composed of plant species that are tolerant to high salinities. These include salt grass and pickleweed. Mudflats and playas are important to waterfowl for feeding and resting. Lack of vegetation provides visual security from predators.

Brackish-Water

These areas are located where the freshwater from the marshes flows into the saline water of GSL. The resultant mixing of the waters provides a range of salinities that allow a diverse groups of plants, invertebrates and sometimes fishes to exist. Water depths are often shallow and birds use these areas extensively for feeding.

Open Water or Pelagic

The main area of the lake provides this habitat type. When the surface water is relatively calm, huge numbers of waterfowl raft in these areas. Few disturbances allow birds to rest without molestation. These areas also provide important foraging opportunities. Brine flies are found on floating bits of vegetation, shrimp, and cysts floating on the lake surface. Huge flocks of Goldeneyes and Shovelers have been observed on the lake, presumably feeding on these resources, however research needs to document this information. During the winter there are other species of maritime waterfowl that are occasionally observed on these expansive open waters. These species include Oldsquaws and Scoters.

Shorebirds

GSL has one of the largest shorebird concentrations in the world. Over 35 species of shorebirds are found in the Western Hemisphere (Sorensen, 1997). Many of these visit GSL each year and commonly include American avocet, Black-necked stilt and Killdeer.

Many of these birds undertake extraordinary migrations with some birds traveling up to 2-3,000 miles. Over 50 percent of the world population of Wilson's phalaropes (500,000), the largest staging population in the world, depends on GSL. The largest population of American avocets (250,000) and Black-necked stilts (65,000) in the Pacific flyway, and over 10 percent of all Red-necked phalaropes (280,000) stop over on GSL. The lake also hosts the world's largest assemblage of Snowy plovers (10,000), and the only staging area for Marbled godwits (30,000) in the interior of the United States. Observations of over 30,000 Long-billed dowitchers have been made on a single occasion.

The GSLEP is cooperating in the development of a national shorebird management plan. When completed, the shorebird plan will be the basis for future shorebird management decisions involving the lake.

Habitat Relationships

The most significant aspect of the GSL ecosystems is the great diversity of habitats created from the integration or close association of fresh and salt water systems which create a fluctuating "mosaic" of land forms, vegetative cover, water and salinity. Several habitat types, natural and human-made, are described below to illustrate the importance of each micro-habitat. Management and conservation efforts must consider each habitat type and the species that frequent these areas.

Estuaries

Fresh and salt water interfaces are created where flowing freshwater enters directly into the lake such as the outflows of several small streams along the east shore. These areas provide important foraging areas for breeding, brooding, and staging. These areas also stay ice-free in winter and provide habitat for waterfowl.

Playas/Ephemeral Pools

Salt playas, mudflats and other lake interfaces occur at numerous locations throughout the extremely shallow, low gradient GSL Basin. These environments shift seasonally and with lake level

fluctuations. These areas are critical to Snowy plovers for nesting and provide foraging and staging areas for numerous shorebirds, including tens of thousands of Avocets and Stilts. The associated shoreline supports a robust population of brine flies which is a significant avian food source. The transitory nature of this habitat type introduces a constant dynamic state so that emergent vegetative stands are constantly shifting between early and late seral stages as the water levels advance and recede. A rich mosaic pattern of habitat types is the result. Some examples include Farmington Bay, Howard Slough and the areas west of existing WMAs and TNC's Layton Wetlands Preserve. There are numerous ephemeral pools that are associated with the mudflats and playas. They are resultant of slight changes in topography and precipitation, overland flow (runoff), wind tides from the main lake and receding lake levels. Small pools create critical habitats for waterfowl and shorebirds and create unique places for food production of invertebrates and vegetation species.

Salinity Variations

Salinity varies around the main body of the lake due to geographic location, geology and the presence of human-made structures. A variety of plants and invertebrates are dependent on these differing saline habitats. Each species has an optimum range of preferred salinity levels, and this wide spectrum of salinities provides unique and critical habitat for wildlife. Brine shrimp play a significant role in the GSL ecosystems and, along with brine flies, are the keystone species supporting many of the water and shorebird species that frequent the lake. A primary reason for the hemispherically important bird numbers at GSL is the lake's capacity to produce millions of pounds of easily foraged protein at the appropriate times for staging and molting migratory birds.

Generally, the north arm (Gunnison Bay) is extremely saline and only supports brine shrimp when the lake is at very high elevations. The west and south shores are moderately saline, and support brine shrimp at high to average lake elevations. The northeast, east and southeast sides of the lake are less saline and support brine shrimp and other invertebrates during average and lower lake elevation years. These open lake and littoral zones are exceptionally important to phalaropes, Franklin and California gulls and Eared grebes. The east shore of the lake has many productive habitats due to the freshwater deltas of the Jordan, Weber and Bear Rivers, and numerous smaller Wasatch Front streams. The water from all these drainages has been totally or partially diverted through natural or managed wetlands adjacent to the lake. The historic Jordan and the Weber River Deltas have been abandoned and receive little or no natural flow. These are very productive areas for waterfowl, colonial nesters and many shorebirds, including Dowitchers, Yellowlegs, Godwits, Avocets and Stilts.

Managed Wetlands

Managed wetlands have created unique habitats with dikes, levies, headgate systems and diversion structures. These systems enhance the opportunities for active management by changing water depths, temperature and water dispersion patterns and by controlling nutrient flows over time. These managed wetland areas accommodate seasonal use and the needs of migrating and breeding water birds.

Significant production of waterfowl also occurs in these areas.

Avian Surveys, Studies and Information

GSL is the largest permanent saline lake in the United States and is a critical habitat area for birds. There are many bird surveys conducted on and around GSL to answer specific questions such as total numbers present, peak season use, species use and habitat relationships. A waterbird survey coordinated by DWR GSLEP is the most extensive to date. It began in 1997 and is projected to continue until 2001. The count examines total number of waterbirds over time and relates this data to habitats.

In addition, there is an enormous amount of information and research (published and non-published) available on the flora and fauna of GSL. A complete literature search is currently being conducted and compiled by USU and GSLEP. This project is seeking research papers on brine shrimp in natural systems, limnology of saline lakes, avifauna ecology of hypersaline lakes in the Western Hemisphere and research on GSL. A bibliography will be available in the future.

The Utah Natural Heritage Program is a central repository for information about Utah's biodiversity including animal and plant communities. This program was initiated by TNC in 1988. The program was transferred to the state in 1991 and is currently partially funded by DWR. The program's mission is to collect information about Utah species and plant communities in a standardized and easily retrievable way and provide this information for natural resource management decision-makers.

The Utah GAP analysis program is comprised of a geographic information system (GIS) that includes map layers of habitat types, vegetation, wildlife distribution and other resources. This information can be utilized to investigate spatial relationships of resources and to track changes or trends in wildlife distribution and habitat utilization. Many master's and doctoral dissertations have been completed on the ecology of GSL and are kept at the universities where the research was originally funded. These publications will be included in the bibliography prepared by DWR and USU. Recently completed and ongoing research includes the following efforts:

- Pacific Flyway Shorebird Project (Point Reyes Bird Observatory)
- Bear River Migratory Bird Refuge Bird Abundance Surveys (USFWS)
- Canada Goose Banding (DWR)
- Pacific Flyway Duck Banding (DWR)
- Great Salt Lake Botulism Study (USU)
- Mechanisms for coexistence of two swan species at varying spatial scales (USU)
- Interactive pathways in wetland ecosystems (USU)
- Restoring breeding bird population to Bear River Migratory Bird Refuge (USU)
- Brine Shrimp Population Dynamics (USU)
- Brine Shrimp Populations and Lake Limnology (DWR & USGS)
- Salinity Model/Patterns in the GSL (USGS, DNR, Tooele County)
- Bioenergetics of the eared grebe (DWR, USU)
- Population Status of the eared grebe (DWR)
- Water Quality and Contaminant Research (USFWS & FFSL)
- Food Chain Ecology on the Great Salt Lake (USU)
- Mid-Winter Eagle Count
- Snowy Plover Surveys (1996-Weekly/Summer; American Birding Association)
- Spatial/Temporal Avian Census of the Great Salt Lake (DWR and cooperators)

Brine Shrimp Population and Harvest Census (DWR)
Brine Shrimp Ecology of Great Salt Lake Beaches (DWR)

A significant local effort is the National Audubon Society's *Feasibility Study for the South Shore Wetlands Ecological Reserve of the Great Salt Lake* (1995). This was an investigation of the potential of restoring the natural inflow of freshwater to the prehistoric river channel and delta of the Jordan River. The results of this study indicated that a state of the art ecosystem wetland habitat restoration effort would have a high likelihood of success. This is one example of an effort focusing on improving habitat for waterfowl, shorebirds and other water birds.

Research

As mentioned previously, in July 1996, DWR formed GSLEP. The purpose of this project is to exclusively dedicate personnel to research and management of the GSL ecosystems, focusing on the relationships of aquatic species of the lake to resident and migratory birds. As implementation of the project began, it became apparent that no one had previously attempted to manage a naturally occurring brine shrimp population or the bird populations that rely upon it. Therefore, the methodologies and techniques had to be developed for the first time to gain the necessary data.

GSLEP is staffed by the project leader, an aquatic biologist, a wildlife biologist, a wildlife technician and various biological aides hired seasonally. Law enforcement officers conduct field operations during the harvesting season and at other times as necessary to regulate the brine shrimp harvesters.

To address the broad ecological questions necessary for management of the ecosystem, DWR has contracted with a number of researchers. Dr. Gary Belovsky of the Department of Fisheries and Wildlife and Ecology Center at USU was contracted to research factors influencing the dynamics of the brine shrimp population and develop a population model. A preliminary model was developed using available data from the lake and pertinent literature. Model components included primary and secondary production in the lake as it influences the brine shrimp population dynamics and standing crop of shrimp, rate of shrimp consumption by harvesters and birds and the cycling of nutrients back to the system. Values from the literature were used in place of available GSL data when appropriate, however in many instances, no literature values were available for the required parameters. Many of the research endeavors of the GSLEP are targeted at these deficiencies. From the model, annual shrimp production in the lake, amount of forage required by the birds, quantity of cysts harvested and the amount of cysts that are needed to restart the population the following spring can be predicted.

Other research projects currently underway at USU include determining the overwinter mortality of cysts within the lake, construction of a literature database on salt lake ecosystems and a study of corixid predation on brine shrimp.

A research project on Eared grebe-brine shrimp interactions is underway. Dr. Michael Conover of USU is the contracted researcher.

Dr. Doyle Stephens of USGS has been contracted to conduct field sampling of sites in the south arm of GSL and conduct laboratory analysis of these samples. This information will become an input to the management population dynamics model developed by Dr. Belovsky.

In addition to this work, DWR and DFFSL have joined with other cooperators in funding data collection by USGS necessary to refine an existing water and salt balance model which predicts the transport of salts between the north and south arms of the lake. (See Appendix H.) During the GSL planning effort, USGS was contracted to conduct a bathymetric study of the lake bottom topography near the northern railroad causeway culverts.

Dr. Susan Kilham, a noted diatom researcher from Drexel University, Pennsylvania, will be conducting a one-year sabbatical study on diatoms in GSL. It is hoped that this research will provide insights into the factors controlling algal community shifts within the lake.

GSLEP personnel are also conducting research that will assist with management directly or enable future inputs to the brine shrimp model. Some of the objectives of project research include:

- Determining waterbird counts and seasonal use.
- Understanding the role of brine shrimp cysts in the diet of wintering ducks.
- Developing sampling techniques to quantify floating cyst streaks.
- Learning more of the biology of shrimp in the lake.
- Understanding the relevance of salinity to cyst characteristics.
- Understanding brine shrimp and algal population changes as they relate to salinity.
- Understanding cyst mortality in the lake over time.

An avian census program has been conducted for two years with the assistance of many volunteers. The objective of this research is to quantify timing and magnitude of bird use in various habitats around the south arm of the lake, Bear River Bay and Farmington Bay. This information will be critical input to the brine shrimp population model in understanding the needs of birds as they relate to brine shrimp. Other bird conservation needs will also be addressed. Additional work is underway with bird banding, specific grebe research and conservation planning. A Snowy plover research effort was partially supported by DWR in 1997. Study results indicate that Snowy plover population numbers were relatively unchanged from the initial study.

Existing Division of Wildlife Resources Management Programs

Functions of Division of Wildlife Resources and Wildlife Board

DWR has jurisdictional responsibility for all wildlife in the state pursuant to Section 23-15-2 of the Utah Code, which provides;

> "All wildlife within this state, including but not limited to wildlife on public or private land or in public or private waters within this state, shall fall within the jurisdiction of the Division of Wildlife Resources."

The division is "appointed as the trustee and custodian of protected wildlife..." and, subject to the broad policy making authority of the Wildlife Board, the division's responsibilities are to, "protect, propagate, manage, conserve, and distribute protected wildlife throughout the state" (Utah Code 23-14-1(2)).

The Wildlife Board's responsibility is to, "...establish the policies best designed to accomplish the purposes, and fulfill the intent of all laws pertaining to wildlife and the preservation, protection, conservation, perpetuation, introduction, and management of wildlife." The Wildlife Board relies on the division's determinations of fact, and on the recommendations of the Regional Advisory Councils (RACs) established under Section 23-14-2.6 of the Utah Code. Under Utah law, five RACs conduct hearings to collect public input, gather information from division staff, the public and government agencies, and make recommendations to the Wildlife Board in an advisory capacity.

On and near GSL, DWR's responsibilities include: research on and management of wildlife species, regulation of hunting, regulation of commercial brine shrimping, management of state WMAs, cooperative management of Antelope Island's large ungulates with DPR, cooperation with USFWS in the management and research of migrating birds and cooperation with non-governmental and other governmental agencies in the conservation of wildlife habitats.

Great Salt Lake Waterfowl Management Areas

There are eight DNR WMAs on GSL. Six are located along the shoreline of the lake, and include Farmington Bay, Howard Slough, Ogden Bay, Harold Crane, Locomotive Springs and Timpie Springs. (See Figure 1.) The others are within 10 miles of the lake and have a direct association with the lake environs. Salt Creek WMA, Bear River Access and Willard Bay are examples. A total of 87,244 acres are intensively managed by DWR. Some acres are managed under cooperative agreements with other state and federal agencies, such as DFFSL and BLM. Utah Code Section 23-21-5 identifies approximately 150,000 additional acres in the lake area which are authorized for administration by DWR for hunting, fishing and wildlife management purposes.

DWR is in the process of developing a habitat management plan for each management area. These plans describe each area, identify capital improvement needs and describe generalized management activities associated with identified goals and objectives.

General management actions include wildlife habitat enhancement through water control, agricultural practices, population monitoring, law enforcement, education and information sharing to support and build an appreciation for wildlife, habitat, wetlands, wildlife management and conservation.

WMAs can be affected by high lake water levels and have many common management issues and concerns. Important issues include securing future water supplies, access management,

balancing the needs of user groups, funding to operate and maintain facilities, urban changes in the GSL flood plain , flooding of lower tributaries, water pollution, siltation and invasion of non-native plant species such as Phragmites, Tamarisk and Purple loosestrife.

Acreages of different types of habitats were extracted from "Evaluation of Existing Wetland Habitats in Utah" (Jensen, 1974). The lake elevation was 4201 feet when this study was completed. The intent of stating the acreages is to give the reader a sense of the marsh habitat relationships. These figures have changed over time due to lake changes.

Farmington Bay Waterfowl Management Area

Farmington Bay WMA is located west of Interstate 15 between Centerville and Farmington. This area can easily be accessed from Glovers Lane west of the interstate and south along the access road. Duck clubs, city, county and private property outline the perimeter of the WMA. Farmington Bay is one of the most popular waterfowl hunting areas in Utah and also is an outstanding birding area. It is unique in that it provides important wetland and wildlife habitat based recreation close to an urban area. This 17,916 acre management area is one of the best places to observe the freshwater interface with GSL. The Jordan River is the primary water source for Farmington Bay. This area is managed primarily to provide habitat for water-dependent birds.

Farmington Bay has sufficient water rights. To protect their water rights from the potential of non-use forfeiture during the flood years, DWR filed Requests for "Extension of Time in Which to Submit Proof of Appropriation" on their uncertificated water rights and "Non-Use Applications" on their certificated water rights. Reestablishment of those water rights requires the submission of Proof of Appropriation for the uncertificated water rights and Proof of Resumption of Use for the certificated water rights by early 2000. DWR is currently preparing those proofs for submission to the State Engineer using funding obtained through the "habitat Authorization" process.

The Farmington Bay WMA was constructed in 1935 to provide habitat for nesting and migratory waterfowl. It includes 12,000 acres impounded by dikes and another 15,000 acres of natural estuary wetlands. Habitat types include:

4,301 acres open water	6,277 acres of marsh
6,174 acres of mudflats	600 acres of uplands

Farmington Bay WMA provides opportunities for hunting, bird watching, photography, nature study, hiking, biking and air boating. Currently, DWR is pursuing funding for enhanced visitor use development, which includes a visitor center on the north end of the management area to improve interpretive and education efforts.

WMAs around GSL are vulnerable to natural lake level fluctuations. The outer dikes have top elevations varying between 4204 and 4208 feet. At lake level elevations above 4204 feet, the WMA loses the ability to impound shallow water. Farmington Bay dikes were designed to impound and spread shallow water at a lake level elevation of 4198 feet. Lake level elevations higher than 4198 feet reduce management efficiency and increase loss of habitat units. At 4206 feet, nearly 80 percent of

this WMA is inundated, and above 4210 feet all created habitats are lost. Flooding impacts to the interior marshes occur incrementally between 4201 and 4212 feet.

Birds relocate when lake level fluctuations inundate suitable habitat areas around GSL. In response to this natural dynamic, DWR has designed portable structures for walk ways, restrooms and office facilities. Approximately one million dollars was required to repair damages from the 1980s flooding event. The most significant management issue at Farmington Bay is future water quality and supply. Other important issues include providing additional access and balancing diverse user groups. Expansion of the Farmington Bay WMA has been discussed, but there appears to be a limited number of willing sellers from which to acquire additional property.

Harold Crane Waterfowl Management Area

Harold Crane WMA is located on the south-west corner of Willard Bay Reservoir, and is approximately 11,300 acres of the following habitat types:

2,905 acres open water	3,805 acres marsh
3,210 acres of mudflats	1,380 acres of uplands

According to engineering data, lake flooding over the dikes occurs at elevations of 4207-4210 feet. However, in the spring of 1999, some flooding damage did occur at locations below the elevation of 4207 feet.

This area was constructed in 1964 as mitigation for wetlands lost due to the construction of Willard Bay Reservoir. Additional lands acquired in 1990 doubled its size. Foot access is permitted between September 1 and March 1. The gate is open to vehicles and small boats during hunting season, but closed to motorized vehicles and boats the rest of the year. The area is closed between March 1 to September 1 during the bird nesting season.

Howard Slough Waterfowl Management Area

This WMA is located two miles west and one mile south of Hooper in Davis County. Howard Slough was established in 1958 to create wetlands from irrigation waste waters before they entered the lake. This development was the first major wetland project along GSL in over 20 years and a subsequent 1990 expansion was Utah's first *North American Waterfowl Management Plan* cooperative acquisition. Major redesigning and restoration occurred at this time.

This area includes a total of 3,420 acres of the following habitat types:

600 acres open water	1,800 acres marsh
631 acres of mudflats	389 acres of uplands

According to engineering data, lake flooding over the dikes occurs at elevations of 4206-4208 feet. However, flooding occurred at points along the dike in the spring of 1999 when lake elevations exceeded 4203 feet.

Ogden Bay Waterfowl Management Area

Ogden Bay WMA is located on the Weber River delta of GSL, and, at over 21,000 acres, is the largest state WMA in Utah. The northwestern boundaries are indefinite. Land acquisition and

development of Ogden Bay WMA started in 1937 with a cooperative project between DWR, Weber County Wildlife Federation, USFWS and the Civilian Conservation Corps. In 1938, following the passage of the *Pittman-Robertson Act*, Ogden Bay became the nation's first Federal Aid to Wildlife restoration project. It is located two miles west and one mile north of Hooper in Davis and Weber Counties. Ogden Bay WMA contains the following habitat types (acreage numbers are estimated):

4,998 acres open water	4,780 acres marsh
5,182 acres mudflats	3,800 acres uplands

Ogden Bay WMA is also known for wildlife-related recreation on GSL. During the production period, March 1 through August 1, approximately 15 miles of dikes are open to non-motorized use. Throughout the rest of the year, 45 miles of dikes are open to non-motorized use. Several air boat ramps and parking areas are available for public use at various lake levels during the hunting season. Ogden Bay WMA has approximately 70,000 visitors each year, 28,000 of which are waterfowl hunters and the rest are other wildlife enthusiasts. The most popular activities include wildlife watching and waterfowl hunting.

Ogden Bay WMA's wetland resource values are dependent on the water levels of GSL. A series of boat ramps which are useable at various lake levels improve access. Wetland habitat, wildlife use and public recreation opportunities are greatly reduced at high lake level elevations. During the 1980s flooding, wildlife and human use decreased by over 90 percent. Lake level begins to affect Ogden Bay WMA dikes at a lake level elevation of 4203 feet, which occurred in 1998. Other dike elevations range from 4205-4212 feet, with upland areas at an elevation of 4220 feet. More than 80 percent of the area is flooded at a lake elevation of 4211 feet. Flood damages to the diking system were close to $150,000 in the 1980s.

Important issues for Howard Slough and Ogden Bay WMAs include vulnerability to flooding from the Weber River and GSL. Other management issues include additional access for air boats, visitor conflicts, water quality and high levels of sediment entering via the Weber River. The water rights are sufficient since this is one of the oldest WMAs in Utah. Another concern is diminishing agricultural habitat and food sources for White-faced ibis, waterfowl and other agriculturally-dependent species due to residential housing development on the periphery of the management area.

Timpie Springs Waterfowl Management Area

Timpie Springs WMA is located one mile north of I-80 at Rowley Junction, 15 miles northwest of Grantsville in Tooele County. This WMA is comprised of 1,440 acres. The water source is a saline spring which feeds two water impoundments created by 3.5 miles of dike. The salinity of the water source limits the vegetation of the area to salt grass. Waterfowl, waterbirds and shorebirds utilize this area. It is important because there are few significant marshes and sources of fresher water around the southwest quadrant of the lake. Bass and mosquito fish may be found in the springs. There is a half-mile long road that provides access to the area from I-80. This road terminates in a parking lot where there are informational signs. Timpie Springs has approximately 400 annual visitors, of which approximately

300 are waterfowl hunters. Walking access to the area is available all year from the parking lot. Habitat types include:

350 acres open water	400 acres marsh
390 acres mudflats	300 acres uplands

Locomotive Springs Waterfowl Management Area

Locomotive Springs WMA is an isolated, spring-fed wetland located at the north end of GSL, east of Kelton. This 17,317 acre WMA is supported by six springs and provides a much needed oasis for wildlife in the middle of the West Desert. Habitat types include the following:

1,370 acres open water	3,250 acres marsh
9,077 acres mudflats	1,455 acres uplands

The Civilian Conservation Corps created the Locomotive Springs WMA in 1931. DWR plans to expand the WMA by 2,600 acres to include protection of playas which are Snowy plover habitat. Wildlife viewing activities include some passerine and scrubland bird species. Public vehicle access around the dikes is permissible, except during waterfowl breeding and nesting season, and during falcon hacking. Bird watching, fishing and primitive camping are allowed year around. The entire WMA is accessible during hunting season. Locomotive Springs receives approximately 6,000 visitors a year, 5,000 of which enjoy hunting and fishing.

The most significant issue facing Locomotive Springs is maintaining water flow from the springs throughout the year. Since the early 1970s the spring flow has declined by 67 percent. This has resulted in diminishing wetlands by 5,000 acres in this WMA. Diminished flows have also resulted in higher salinities in the impounded waters of the marsh which affects vegetation.

Other Important State-Operated Wildlife Management Areas

Other WMAs located beyond the meander line of GSL provide a variety of different habitat types for many species that depend upon the GSL ecosystem. These areas are directly associated with the lake environs and become critically important when high lake levels inundate otherwise available habitats at lower elevations.

Public Shooting Grounds Waterfowl Management Area

Public Shooting Grounds WMA was perhaps the first area in the nation set aside specifically for hunting when it was established in 1929. It is located 10.5 miles west of Corinne on U-83 and is directly north of BRMBR. This 11,834 acre area includes cold desert upland plant species, extensive wetland vegetation, eleven developed ponds and mudflat areas providing great habitat diversity. Habitat types include:

2,305 acres open water	4,129 acres marsh
3,675 acres mudflats	1,455 acres uplands

Camping, off-highway vehicle and air boat use are subject to restriction.

Bear River Access Wildlife Management Area

Bear River Access WMA was purchased in 1989 for fisherman access to the Bear River. This WMA is small, only five acres, but includes a parking area and a hardened launch ramp for easy access. The WMA is set in a riparian valley

bottom at an elevation of 4220 feet, and is a diverse and productive area for waterfowl and wildlife. Camping, boating and fishing are the primary and popular recreational activities available in this area. Wildlife viewing opportunities include waterfowl during spring and fall, Bald eagles in the winter and a variety of other species.

Salt Creek Waterfowl Management Area

Salt Creek WMA is located eight miles west of Corinne on U-83 then north of Little Mountain. It was established in 1961 and has expanded from 1,389 acres to approximately 5,236 acres. The area provides semi-marsh habitat with open water ponds and extensive wetland vegetation. Elevations range between 4255 and 4270 feet. Upland areas include cold desert plant species. Habitat types in this area include the following:

1,208 acres open water	1,210 acres marsh
120 acres mudflats	2,006 acres uplands

Vehicle access is possible to Comptons Knoll throughout most of the year, but is difficult during winter months. However, all other access points are restricted except during the waterfowl hunting season.

Willard Bay Upland Game Wildlife Management Area

Willard Bay Upland Game WMA is located on the south side of Willard Reservoir, and consists of primarily upland habitat mixed with cultivated food plots. This provides habitat for many species of wildlife, and is particularly ideal for pheasants. Riparian wetland areas in this area are productive and attract a variety of wildlife species. Recreation activities include hunting, dog training and wildlife viewing of waterfowl and songbirds. This WMA contains 1,350 acres and is accessible along the south dike of Willard Bay just west of the south marina entrance.

Antelope Island State Park

AISP is managed by DPR and provides habitat for an unusual array of wildlife. The most visible and well-known of the park's wildlife are bison. The island bison herd, which numbers over 700 after calving season, is one of the largest public herds in the nation. The herd is maintained within a managed carrying capacity via a roundup and sale of surplus animals and limited hunting permits. The sale of bison finances the park's wildlife program.

Pronghorn were reintroduced in 1993 through a cooperative effort between DPR and DWR. A similar cooperative effort resulted in the introduction of bighorn sheep. Antelope Island provides a disease-free environment as it relates to domestic sheep, which is a key consideration for bighorns. A program goal for the island's bighorn herd is to produce a surplus for reintroduction of bighorn sheep to other historic ranges. Mule deer, coyotes, bobcats and badgers as well as numerous small mammals also inhabit Antelope Island.

The island's east shore wetlands are proximal to the mainland marshes and provide additional waterbird habitat. The island also provides important upland habitats adjacent to wetlands.

DPR established an independent Wildlife Advisory Committee to review management programs pertaining to range and wildlife issues. Outside

research projects have been funded and focus on pronghorn, bighorn sheep and bison genetics. Staff monitors range conditions and trends, herd sizes and composition and assists DWR with shorebird census projects. Future research will study recreational impacts on wildlife populations.

Important Habitat Managed by Other Entities

Many areas around the lake are managed for habitat preservation and improvement by other entities such as conservation groups, duck clubs, counties and federal agencies.

Bear River Migratory Bird Refuge

BRMBR is located west of Brigham City in Box Elder County at the mouth of the Bear River. It is the largest national refuge specifically set aside for waterfowl and shorebird management. The Bear River Delta is considered one of the most valuable water bird and wetland areas in Utah. Waterfowl, water birds, migratory birds and wildlife depend on the refuge as an important breeding, wintering and staging area (USFWS, 1993).

The refuge was established in 1928 through an Executive Order by Herbert Hoover and the permission of the State of Utah. Today, BRMBR encompasses approximately 74,000 acres providing contiguous and diverse habitat areas for wildlife. The primary management goals of the refuge include protecting and enhancing habitat to maintain or increase threatened and endangered species, providing suitable production and migration habitat to benefit migratory birds and providing a biologically diverse suite of habitat types in various successional stages to maintain healthy wildlife and fish populations. Secondary management goals include providing opportunities for the public to enjoy wildlife and to better understand their role in the environment and ensuring protection for important archaeological, historical and cultural resources. Over 43 archeological sites have been recorded on the refuge.

A 12-mile driving or hiking tour is open year round and provides an excellent opportunity for wildlife viewing and environmental education. Hunting, trapping and warm water fishing on the main river channel are popular activities available seasonally. Over 40 percent of the refuge is open to waterfowl hunting. A 1990 study to examine the economic value of the refuge indicated that 20,000 visitors equates to over $180,000 to the local economy. (Piper, 1990)

Water control structures are designed to regulate water flow into several management units to create diverse habitat areas to benefit wildlife. Approximately 18,937 acres of the refuge do not receive water from the Bear River. Water supplies are rarely at optimum levels. Flushing removes excess salts and drawdowns improve some habitat types. During the 1980s, GSL flooding caused over $42 million of flood damage including the loss of the visitor center, dikes, water control structures and roads. The outside dikes are presently at 4208.75 feet, which is a 0.75 foot increase from pre-flooding elevation.

BRMBR completed a *Long Range Water Management Plan* in 1993, to examine existing water management, enhance refuge habitat and improve future water supplies and management for the

maximum wildlife benefit. Important management concerns include water supply, water quality and disease management. Water shortages are very detrimental to wetlands and wildlife. USFWS would like to augment natural flows of the Bear River during July and August. A project to supplement these low flows with Willard Bay water was negotiated, but the project was not constructed. Future water development projects on the Bear River that are currently under consideration include plans for the Honeyville area, but there is no authorization for this dam to date. Disease management focuses on botulism outbreaks and attempting to understand ideal conditions by linking losses with water conditions and habitat indicators. Peak avian botulism losses seem to occur during above-average water years, according to USFWS. Water quality and sediment contamination have been investigated in BRMBR and in proposed acquisition areas. "Soil and water analysis from this study did not identify any toxic constituents, although further sampling of soil, water and fish tissues may be warranted in the Black Slough area to determine the source(s) or extent of DDT contamination," according to the contaminant study of Waddell et al. (1990). Also, salts were present in high levels in both water and sediments.

Layton Wetlands Preserve

Layton Wetlands Preserve is a mosaic of over 2,100 acres of wetlands, playa and upland habitats. It is owned and managed by TNC. An additional 800 acres of adjacent property is managed by TNC for URMCC. TNC continues to look for opportunities to protect important wetlands and uplands around GSL. Management of the preserve is conducted within the context of identifying conservationally important species and communities, identifying stresses or threats to those conservation targets and developing strategies to minimize the stresses or threats. One of the primary conservation strategies outlined in the plan is to allow the dynamics of GSL to act naturally upon the landscape in this undiked area.

To address management issues on the preserve, TNC is also developing visitor management, weed management and community outreach plans. Wetland restoration activities are being conducted on the preserve. Much of the work is accomplished with volunteer help and the assistance of local experts.

Inland Sea Shorebird Reserve

This 4,500 acre reserve was developed by KUC to mitigate for the tailings modernization and expansion project completed in 1993. The reserve provides a large contiguous area for nesting and resting habitat for migratory shorebirds and waterfowl. The Inland Sea Shorebird Reserve is surrounded by private duck clubs, the Gillmor Wildlife Sanctuary and the SLCIA Mitigation Project, all of which provide wildlife habitat. The reserve has three water sources, including Goggin Drain, Lee Creek and the North Point Canal. They circulate brackish water through marshes and mudflats to maximize invertebrate populations as food for visiting birds. A unique sand dune environment exists on state sovereign lands adjacent to the reserve (Neville, 1998).

Once COE approves the mitigation project, which is expected in 2002, KUC plans to allow greater public access.

Important issues for the Inland Sea Shorebird Reserve include access to sovereign lands and mosquito abatement practices.

Gillmor Wildlife Sanctuary

The land for the Gillmor Wildlife Sanctuary was donated to the National Audubon Society to help preserve the natural ecosystem of GSL. This 1,425 acre property has a variety of habitat types ranging from open water to playas and upland areas. It is located north of I-80 and west-northwest of the new SLCIA runway on the abandoned delta of the Jordan River. The *Feasibility Study for the South Shore Wetlands Ecological Reserve of the Great Salt Lake* was conducted with URMCC to investigate the possibility of restoration of the natural inflow of freshwater to this old river delta system. The hydrological study and analysis concluded that approximately 2,000 acres of potential wetland habitat could be developed or restored in this area to provide a mosaic of wetland and upland habitats for wildlife.

The goals of the adjacent property owners are compatible in developing a contiguous area of highly productive habitat suitable for breeding, nesting, foraging and resting for a wide range of species. A goal for this area is to acquire water for future improvement of wildlife habitat.

Salt Lake City International Airport Mitigation Site

The SLCIA runway expansion project required mitigation for wet meadow wetlands habitat loss. Most of this mitigation site is surrounded by private property, duck clubs and the Gillmor Wildlife Sanctuary. The mitigation site includes 1,500 acres of wetland habitat. SLCIA authorities plan to focus on increasing shorebird habitat by 70-80 acres by enhancing marginal wetlands and uplands. Issues facing this mitigation project include flooding impacts, changes in water use from agriculture to urban, non-native species invasion and future supplies of freshwater entering the mitigation site.

Great Salt Lake Duck Club Properties

According to the *South Shore Duck Club Study* (Dunstan and Martinson, 1995), 13 duck clubs exist on the south shore of GSL, with more than 16,791 acres managed as wetlands for waterfowl habitat. Many duck clubs also exist along the east and north areas around the lake. Private duck clubs develop additional habitat and actively manage and enhance existing habitat to increase wildlife use for the purpose of waterfowl hunting. Enhanced areas require active management to maintain wetland and wildlife functions. These efforts also improve habitat conditions for a variety of other species and, together with the efforts of adjacent landowners, provide a considerable amount of contiguous habitat for wildlife around GSL. The *South Shore Duck Club Study* conducted between 1994-95, examined the feasibility of a formal protection plan and the possibility of developing public support for these privately owned and managed wetland areas. This effort identified the importance of duck clubs in providing habitat for a variety of species.

Surface gradients in developed wetlands are so shallow, a one-inch change in water level can move pond shorelines hundreds of yards. Because of this

gradient, water control is the primary means of managing vegetative growth and these wetlands have extensive, precise water control systems. One 3,346-acre duck club has 18 managed water levels, 88 water control structures, over 18 miles of channels and 21 miles of dikes. Precise water control is required to prevent avian botulism which can kill tens of thousands of birds, to minimize pond siltation and to control carp and other undesirable exotics.

Water shortages cause damage and changes to vegetation and contribute to disease epidemics resulting in bird mortality. To maintain healthy marshlands, a flush of water is required to wash out toxins and provide salinity control during the spring.

Critical issues for duck club managers include securing adequate water supply, delivery timing and reliability and maintaining water quality. Flooding issues are significant since these properties are located at low elevations near the lake and most owners or managers rebuilt after the 1980s flooding. Other pressing issues include access, road maintenance, predator control, trespass grazing and non-native plant species invasions which require ongoing control and expensive eradication.

Important Island Habitat Areas

In addition to established WMAs and privately managed habitats, the islands of GSL provide isolated habitat for a variety of colonial and migratory birds. The following table was used in the "Linking Communities, Wetlands and Migratory Birds" document to describe the islands of the lake, access and wildlife use (Wetlands International, 1998). (See Table 7.)

Table 7. GSL Island Management, Acreages, Public Access and Wildlife Use

Island Name	Managing Agency	Acreage	Public Access	Wildlife Use
Antelope Island	DPR	28,240	Yes	Antelope, bison, deer, bighorn sheep, many birds and other wildlife species
Stansbury Island	BLM/Private	22,314	Partial	
Fremont Island	Private	2,945	No	Unknown
Carrington Island	BLM/Private	1,767	Yes	
Gunnison Island	DWR	163	No	Pelican rookery, gulls
Dolphin Island	Sovereign Land	60	Yes	
Bird or Hat Island	DWR	22	No	Gull and heron rookery
Badger Island	Sovereign Land	6	Yes	
Cub Island	BLM	1	Yes	
Egg Island	Sovereign Land	1	Yes	Gull rookery closed 4/1-7/31
White Rock Island	Sovereign Land	1	Yes	Gull rookery closed 4/1-7/31

Census work by DWR will better define wildlife use on the islands in the lake. Dependent upon lake elevation, there may be more or fewer islands than those listed above.

Changes in Lake Brine Salinities

Segregation of Great Salt Lake Waters into Distinct Salinity Areas

The waters of GSL are segregated into four areas of different salinity. (Bear River Bay, Farmington Bay, Gilbert Bay and Gunnison Bay) Each is influenced by differing water inflow and evaporation regimes, which results in changes to lake elevation and salinity.

In this discussion, the south arm of the lake is different from Farmington Bay and Bear River Bay. Salinities in the south arm have ranged from 5-21 percent in recent times. In August 1999, salinity is approximately 8 percent. It is this portion of the lake that is being harvested for brine shrimp and supports abundant bird populations.

Farmington Bay is that portion of the lake east of Antelope Island and isolated from the rest of the lake by the Davis County Causeway and the Antelope Island Southern Causeway. Salinities of Farmington Bay fluctuate substantially due the inflow of freshwater from the Jordan River, and the causeway-inhibited exchange of salt water from the south arm. Salinity values have ranged from 2-6 percent in recent times. Commercial harvesting of brine shrimp is prohibited in

this area to minimize impacts to bird populations, which are substantial.

Bear River Bay lies north of the causeway (Bagley Fill), on the east side of Promontory Point. Water salinity in this bay can also fluctuate substantially, but is usually very low (<2 percent). There is evidence that when the Bear River flows are very low, a layer of dense brine runs northward into the bay, especially during periods of south winds (Butts, 1998). Salinity values are being studied at the current time by DFFSL, GSLEP, UGS, DEQ and IMC Kalium Ogden Corp (formerly Great Salt Lake Minerals, Inc.). Commercial harvesting of brine shrimp is also prohibited in this bay to minimize impacts to substantial bird populations, especially fish-eating birds.

The north arm of the lake (Gunnison Bay) lies north of the northern railroad causeway between Promontory Point and Lakeside. Salinities in this portion of the lake have ranged from 14.5-28.4 percent in recent times. In August 1999 it is approximately 23 percent. There has been very little harvesting of brine shrimp in this portion of the lake. The water of the north arm is too saline to sustain meaningful populations of shrimp. Periodically, some shrimp and cysts wash through the breach and culverts, and there are a few locations in the lake where brine shrimp populations may occur, probably due to springs which dilute brine salinity. As salinities decrease, brine shrimp populations will increase. In fact, meaningful populations have historically existed and been harvested from the Gunnison Bay. Commercial brine shrimp harvesting is allowed in the north arm. Bird use of the north arm of the lake has been essentially eliminated because of the lack of viable brine shrimp populations, although some foraging occurs near the causeway breach and culverts. Gunnison Island is an important White pelican pod.

Aquatic Biota Differences

Of primary concern to wildlife managers is the current degree of difference in salinities between the north and south arms of GSL and the lack of brine shrimp productivity in the north arm and diminished cyst production in the south arm. Because brine shrimp are currently managed and considered a focus species, most of the research and attention has centered on brine shrimp. However, the same low productivity concerns extend to other aquatic species which are significant in the lake's food chain, such as algae and brine flies.

The northern railroad causeway from Promontory Point to Lakeside is inhibiting the exchange of lake brines between the north and south arms of the lake, and has caused a significant difference between the salinities of the north and south arms since its completion in the late 1950s. It is now thought that the differential, which has averaged between 10-13 percent, is increasing. (See "Water-Chemistry" section.) Because brine shrimp and brine fly productivity in the north arm has been essentially lost, and south arm production has declined, substantial negative impacts on avian species are suspected. Wildlife managers are concerned about the causeway's impact on the lake's ecology.

Brine shrimp populations flourished in the north arm of the lake during the mid-1980s, due primarily to high lake levels and resulting lower than average salinities in the north arm. It has been suggested that, at some lake levels, a

differential in brine concentrations is beneficial because when the south arm is too dilute to support a healthy brine shrimp population, the north arm may be able to. At historically high lake levels, that appears to be the case.

In 1999, salinities in the south arm have diminished to the point where the brine shrimp population is stressed and substantially reduced, while salinities in the north arm continue to be high enough to prevent the establishment of a significant, viable brine shrimp population. The south arm has experienced reductions in brine shrimp harvest and salinity.

Table 8. Brine Shrimp Harvest and Salinity

Year	Harvest (million lbs.)	Lake Salinity
1996	14.7	12-13%
1997	6.1	11-12.6%
1998	4.6	8.7%

These salinity ranges occurred during the brine shrimp production season and were measured at a sample site located in the open water area of the south arm. This circumstance has resulted in a depressed shrimp population in the lake with negative impacts on bird populations and commercial harvesting of brine shrimp. (See Table 8.)

Research on both the hydrology of the lake and the role of salinity in brine shrimp and other aquatic population ecology is continuing.

Lake Water Quality Impacts to Wildlife

A discussion of GSL water quality issues, studies and initiatives appears in the "Water-Quality" section of this statement. Little is known about the impacts of water contaminants on GSL wildlife. A research project sponsored by USFWS is expected to provide information focusing on Bear River Bay in the near future. That document will represent the latest understanding of the dynamics of water contaminants and will likely help chart the future of water quality research on GSL.

Lands Designated for Wildlife Management

Section 23-21-5 of the Utah Code provides;

> "The Wildlife Board is authorized to use any and all unsurveyed state-owned lands below the 1855 meander line of the GSL within the following townships for the creation, operation, maintenance and management of wildlife management areas, fishing waters and other recreational activities..."

The Code identifies all or part of 39 townships lying within the meander line of the lake. (See Map 7.) Some of the area within the identified townships has been formally placed within WMAs by the Board of Wildlife Resources, but much has not. The management status and responsibility for the lands identified as available for wildlife management by statute is unclear for those which have

not yet been evaluated and acted upon by the Board of Wildlife Resources. DWR will initiate the process to consider the designation of these lands.

Notes:

Ecosystem

Introduction

Great Salt Lake ecosystem is of worldwide importance for migratory bird populations, brine shrimp and mineral extraction industries. GSL is one of the premier wetlands areas of the United States and is a major recreational and aesthetic resource for Utah. (Science Review Committee (SRC), 1999c)

GSL ecosystem is comprised of many sub-ecosystems (SRC, 1999b and c) and each is strongly influenced by changing lake levels and lake chemistry. Shallow water, wetland areas and deep water portions of the lake are spatially and temporally dynamic in response to changing environmental conditions. Variations in precipitation and fresh water inflows together create a dynamic mosaic of habitat types along the shores of the lake. Variations in salinity affect species community composition and structure which also varies across all of the lake's ecosystems. There is a distinct difference in salinity between the north and south arms of GSL and this directly influences species distribution and abundance. There is also a strong east-to-west ecosystem gradient in regard to GSL habitat and productivity (SRC, 1999b). Natural and human-induced inputs and outputs occur via inflow, atmosphere and other mechanisms (SRC, 1999c). There are many other components and interactions which determine ecosystem function and productivity. GSL resources are inter-connected and human use influences ecosystem response. GSL components and interactions are closely associated, thus making the management of GSL ecosystems complex and challenging.

Great Salt Lake Subsystems

GSL and its watershed represent a complex web of interacting physical, socioeconomic and ecological systems and subsystems (SRC, 1999c). Current understanding of the complexity of GSL ecosystems and lake dynamics limits the ability to accurately describe and forecast the dynamics of the various system components (SRC, 1999c) such as hydrology, landscape, chemistry, biology, water and air. A subsystem analysis emphasizes the linkages between these components and human interactions from a large-scale perspective. Subsystems and their interactions are usually represented by using a Venn Diagram. (See Figure 11.) The subsystems approach can be a management tool for resource planners and managers to identify issues, limitations and areas of uncertainty.

These linkages are best depicted by studying cause-and-effect chains. (Figure 12 is a simplified example of GSL systems biological linkages.) Understanding cause-and-effect chains and their interconnected linkages helps resource managers identify potential methods of altering conditions or managing a system.

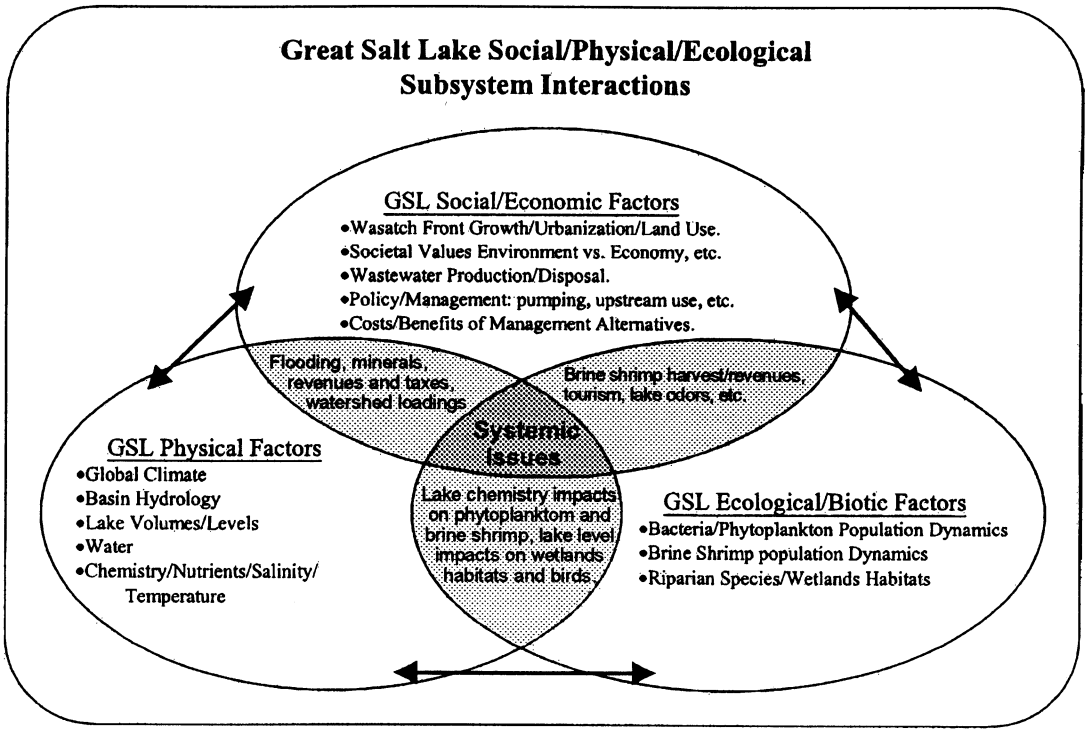


Figure 11: Great Salt Lake Subsystem Interactions and Management Problems (SRC, unpub.).

These linkage are best depicted by studying cause-and-effect chains. (Figure 12 is a simplified example of GSL systems biological linkages.) Understanding cause-and-effect chains and their interconnected linkages helps resource managers identify potential management tools.

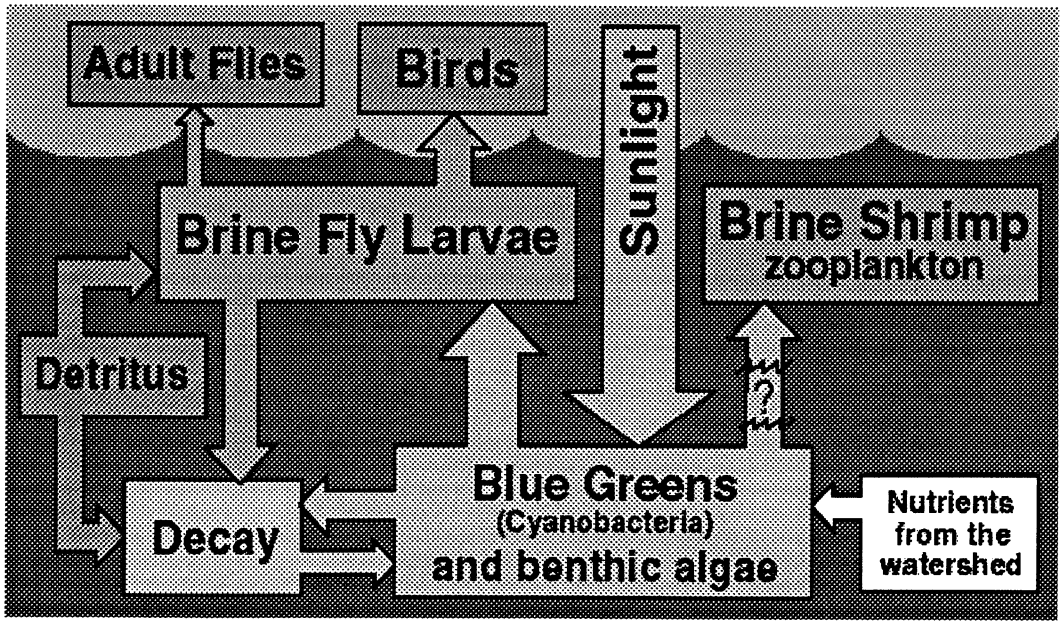


Figure 12: View of GSL Ecosystem (USGS, 1999)

Physical Subsystems

Physical subsystems are the physical environment or setting and include basin geology, global and local climate, hydrology, lake level fluctuation, hydrodynamics and lake chemistry. The geologic setting and geography of the landscape creates this watershed and terminal basin. These influence the behavior of other physical components. Lake geomorphology which includes the erosion, transport and distribution of sediments and their patterns in the ecosystem are not well understood (SRC, 1999b). Hydrologic processes cause fluctuations of lake volume, lake level and salinity. All are strongly influenced by each other and respond to regional and global climatic factors. (See the "Hydrology" section.) Climatic forces drive watershed response and lake level fluctuations at multi-year, decadal and longer time scales. The ability to predict these changes is very limited. Resource managers deal with uncertainty in the long-term behavior of lake hydrology and at best can predict lake levels in the short term (one to three years) along with some associated management implications and ramifications (SRC, 1999b).

Socioeconomic Subsystems

Socioeconomic subsystems relate to human interactions that influence ecosystem response. This subsystem includes population, economic and other human-related interactions with a system. Salt extraction, mineral production, brine shrimp harvesting and oil and gas reserves are also important lake economic resources. Tourism and recreation are additional important lake uses.

Rapid urbanization and agricultural expansion is occurring in portions of the GSL uplands and the watershed. This area contributes the vast majority of fresh water inflows to the lake. These human-induced impacts change the amount and temporal distribution of runoff into the lake, as well as the quality of runoff water. These changes affect lake level, water chemistry and ultimately other subsystem components. Management strategies may also influence lake level and chemistry, air and water quality. Upstream and watershed activities such as discharges, development and water allocation all interact with other lake ecosystems and all three conceptual subsystems. The political and economic arenas drive management actions within this subsystem. Activities within socioeconomic subsystems occur and affect the lake at seasonal to multi-year time scales.

Biological/Ecological Subsystems

These subsystems focus on biological and ecological interactions. Lake level fluctuations, salinity and water quality affect the dynamics of the lake's ecosystems. This has implications for wetland habitats and the population dynamics of brine shrimp, brine flies and birds. There are further implications for tourism and commercial brine shrimp harvesting. Nutrient availability, air and water quality have ecological consequences. Lake managers have yet to fully understand these interactions and the affect of lake chemistry on biota (some research is currently underway). The physical arrangement sets the stage for biological subsystems' ability to function. Temperature, light, salinity,

nutrients and many other factors have an effect on shallow and open-water ecosystems which create dynamic biological systems and subsystems with their seasonal and annual variability (SRC, 1999c).

There is limited information available to understand these interactions. Time scales of ecological subsystems behaviors range from diurnal to multi-year.

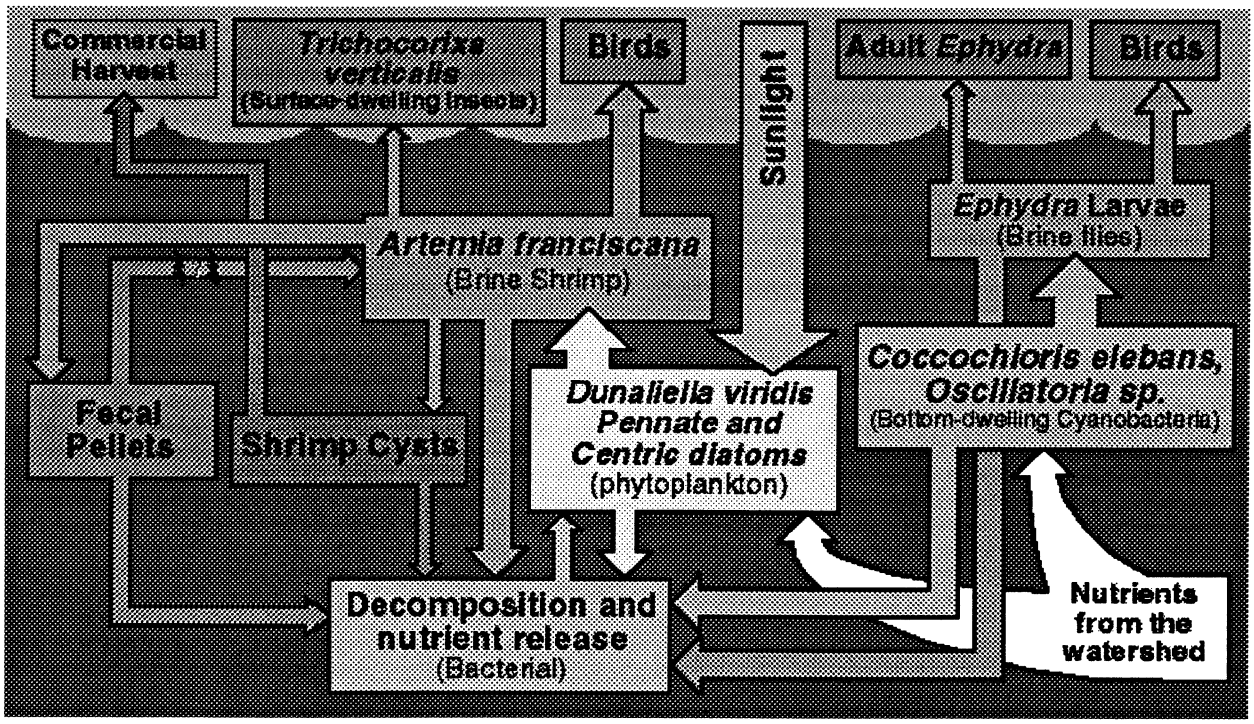


Figure 13. Components of GSL System (USGS, 1999)

Subsystems Management and Planning

Many management issues occur at the interface among these three subsystems. (See Figure 11.) Each subsystem varies spatially, temporally and structurally and impacts each of the others. Management actions intended to influence environmental conditions in one subsystem may impact another. For example, high lake levels in the 1980s and flooding (physical system changes) impacted infrastructure and other major economic resources (socioeconomic system) around the lake. Physical subsystem changes, such as lake level fluctuations and salinity variability influence lake aquatic organisms (phytoplankton and brine shrimp populations). This also has implications on the quantity of wetland and riparian habitat available to migratory birds and other wildlife, thus demonstrating that GSL subsystems have many linkages and are dynamic and interactive. (SRC, 1999c)

Lake managers currently recognize that:

- GSL dynamic subsystems operate at different spatial and temporal scales and interact with one another to produce complex nonlinear behaviors that are difficult to predict (1999c).

- Sufficient scientific understanding for management purposes is needed and includes the dynamics, complexity and uncertainty inherent in the behavior of lake subsystems (SRC, 1999c). Additional study and research is needed to better understand lake dynamics. (See the "Monitoring and Research" section.)

- Lake level fluctuation and variability in lake salinity are important aspects of ecosystems function and are important management considerations.

Ecosystem/Biological Linkages

Invertebrates and fish in some areas are important links between the primary producers (algae and macrophytes) and the bird populations that make these ecosystems valuable and unique resources. Available information on these components (Huener and Kadlec, 1992, Osmundson, 1990, Flannery, 1988 and others), is marginal. Information for invertebrates in similar ecosystems exists (Murkin and Batt, 1987; SRC, 1999e).

In shallow and less saline regions of the lake, brine shrimp are not as abundant and different invertebrate communities are more prevalent. In marshes, brine flies are not abundant but midges are usually abundant and are the main food supply for avocets (Osmundson,1990). (SRC, 1999c)

This dynamic of interconnected GSL ecosystems creates a reliable resource (major concentration area) for many species and huge populations of birds. During high water years, birds relocate to other areas and resources. High bird population numbers today suggest that this has been an extremely productive ecosystem for a very long period of time. Food resources have been reliable

for huge populations and many species of birds have developed migratory behavior that capitalizes on these resources. Variability within natural limits is good for ecosystem productivity. (SRC, 1999c)

Sustainability and Ecosystem Health

Sustainability is "a system's ability to maintain its structure (organization) and function (vigor) over time in face of external stress (resilience)"(Costanza, 1992). A system responds to outside stresses and nature of the stress may even be more significant (Smol, 1995). (SRC, 1999c)

A well buffered system is able to maintain its structure and function (SRC, 1999c). Biodiversity is another important consideration for planners and managers.

A "healthy" ecosystem is one that existed before significant anthropogenic impact (Smol, 1992), but ecosystem health is difficult to define. As environmental conditions change, the system adjusts to these changes. Therefore an "unhealthy" condition is beyond the natural range of fluctuation due to conditions resulting from some human-induced modification of the system. (SRC, 1999c)

Ecosystem Impacts

There are several types of environmental impacts that managers consider in planning and managing for important natural resources. Managers consider short- and long-term, immediate and site-specific impacts. There are also adverse, unavoidable, irreversible and irretrievable impacts.

Direct impacts are the result of circumstances or activities that occur at the same time and place and hence alter a system. Indirect impacts are further removed but are still reasonably foreseeable and influence a system. Cumulative impacts occur when there are multiple effects on the same values. Gradual impacts occur on resources when combined with past, present and future actions (BLM, 1998). There are many direct, indirect and cumulative impacts to GSL and its environs. The following list cites a few examples of human-related direct and indirect GSL impacts:

Dikes and causeways
Brine shrimp harvesting
Exotic species introduction
Mineral extraction
Oil and gas production
Lake level modification
Recreational activities
Grazing
Discharges/Accidental spills
Upstream water allocation
Water and air quality
Population growth
Wetland-nutrient loading
Loss of GSL wetlands
Agriculture activities
Road salts
Mosquito abatement
Trash and pollution

Some GSL impacts have a positive affect on lake resources, such as the creation of state and federal wildlife management areas and duck club habitat enhancements. These alterations enhance habitat resources and provide forage and cover for wildlife. Others may cause degradation over time. Ecosystem threats include population growth, water and air pollution, commercial and industrial development such as diking and mineral extraction pond conversion.

The sovereign land multiple-use and sustainable yield management framework requires that lake managers consider these and other impacts to lake resources.

Resource planners and managers consider impacts in lease permits, management activities and in protecting resource sustainability. Better monitoring and research adds to the information base and helps managers make good management decisions.

Cumulative impacts are often difficult to identify but will play an increasingly important role in lake management. As the knowledge base increases through monitoring and research, the consequences and mitigation measures to avoid cumulative impacts on lake resources will be better understood.

Great Salt Lake Impacts - Examples

Some areas of the lake are more susceptible to impacts due to their shallowness and proximity to large population centers. Farmington and Bear River Bays have very limited data to investigate the implications of possible or future impacts to these areas. Shallow water and wetland areas of the lake, especially on the north end and east side of the lake, are different both ecologically and in regard to the multitude of threats to these areas. These ecosystems are interfaces or buffers between the main body of the lake and surface and ground water inflows. (SRC, 1999c)

Environmental conditions adjust to changes in water depth, salinity, volume and chemistry of inflows. Natural and human-induced changes in water levels and salinity have major impacts on the spatial and temporal distribution of the shallow lake and lake margin ecosystems. Variability is essential to GSL ecosystems function and productivity. Ecosystem changes are likely the result of changes in individual species biology (Foote, 1992 and Engelhardt, unpub.). Often, ecosystem changes are more or less predictable depending upon available species-specific information. Some species-specific information exists (Kadlec and Wentz, 1994, Foote, 1991 and Kantrud et al., 1989). Species tolerance to changing conditions within GSL ecosystems should be better understood. (SRC, 1999c)

Lake hydrodynamics have been impacted. Water does not circulate freely throughout the system due to dikes or causeways resulting in several sub-ecosystems with different hydrologic and water chemistry characteristics. This limits the variability of lake levels, salinity and water circulation. Farmington and Bear River Bays' salinity conditions have

some positive consequences for wildlife productivity.

The multiplicity of GSL ecosystems, lake dynamic interactions and lake level fluctuation makes it difficult for resource managers to detect undesirable changes and determine their causes. Gaps in the information base limit knowledge and understanding of the GSL ecosystem and its many sub-ecosystems. A well-designed monitoring and research program can help improve lake management, evaluate lake impacts and help protect sustainability while still allowing for a wide variety of multiple uses. (SRC, 1999b and c)

Planning Team Ecosystem Health and Salinity Conclusions

The planning team has considered concerns regarding declining numbers of brine shrimp in the south arm (Gilbert Bay). Changes in salinity can change the abundance of brine shrimp (Stephens, 1998b). Brine shrimp eggs are important consumers of algae and are also an important food source for GSL birds. Brine shrimp are also commercially harvested which complicates an ecosystem analysis. Brine shrimp population studies indicate that lower salinity levels in the south arm are impacting algal community compositions, specifically *Dunaliella virdis*. These green algae are a major food source for brine shrimp and are being replaced by larger pennate diatoms, which are difficult to digest (Stephens, 1998b). Reduced salinity appears to contribute to a higher winter loss of brine shrimp cysts, making it difficult for the population to restart when conditions are favorable in the spring. Research studies in 1998-99 identified this problem. However, other environmental variables may also impact brine shrimp population numbers, and according to the SRC, brine shrimp are not the best indicator of ecosystem health or of the overall condition of the lake (SRC, 1999c).

DNR resource managers are concerned that the south arm of the lake may be trending beyond its natural range of variability due to human-induced impacts to the lake. This concern raises a sustainability issue regarding ecosystem function. The northern railroad causeway has restricted flow between the north and south arms of the lake (see "Chemistry" and "Hydrology" sections).

As resource managers, how should we then evaluate "ecosystem health?" The planning team has considered using brine shrimp as an indicator of ecosystem functioning. The SRC suggest that algae would be a good indicator since they are widespread and trackable in GSL sediments over time, plus are responsive to human-induced and environmental change. Some historical measurements of lake level and salinity are available and, along with future paleolimnological studies (SRC, 1999c), can be useful to assess the health of GSL ecosystems. An additional method would be to investigate a community or group of species response to ecosystem change, but historical data of this type are very limited. No single species is a reliable indicator of GSL ecosystem condition. The SRC suggests that we should also

study other factors whose interactions and variability are less known, such as nitrogen, water transparency, temperature, brine shrimp harvesting, algae, diatoms, other primary producers, invertebrates and their interactions. (SRC, 1999c)

Diatoms are often used as bio-indicators of environmental change (Dixit et al., 1992) and are well preserved in lake sediments. They can be used to indicate past environmental conditions (Moser et al., 1996). Other past limnological variables can be inferred from the sediment record. This makes diatoms a powerful and robust tool for ecosystem management. However, this information is either limited or not available at this time. (SRC, 1999c)

The physical, socioeconomic and biological/ecological subsystems and their resulting interactions describe one approach to investigate the implications of salinity and human impacts on GSL ecosystems. The economic and political reality in the context of GSL "ecosystems" planning is that the railroad causeway is a human-induced change that is altering the function of GSL ecosystems. Brine shrimp populations are declining in both the south arm (low salinity and south arm industry concerns) and the north arm (high salinity). The northern railroad causeway has restricted natural lake hydrodynamics (lake circulation, level and salinity or the movement of fluid with in the lake) to a point at which environmental conditions have been noticeably altered (See "Appendix H" and "Appendix I.")

A "focus species" is a species that for several reasons is a compass of changing conditions, economic and other human-induced change. The planning team believes that the GSL brine shrimp population is an indicator of the overall condition of the lake and reflects the socioeconomic factors related to recently observed salinity trends. Economic, political and environmental factors will be considered in view of ecosystem sustainability and health.

Great Salt Lake Ecosystem Management

The main ecosystem driving forces, lake level and salinity, are an integral part of the lake's ecosystems. DNR intends to allow for as much natural lake level fluctuation as reasonably possible to enhance ecosystem processes. It is also important to recognize when human-induced impacts are altering or restricting lake hydrodynamics and the ability of the lake to exist as a natural body of saline water.

Existing jurisdictional boundaries limit the ability of DNR and its divisions to consider GSL ecosystems beyond the meander line and champion or monitor GSL ecosystems. It is the intent of DNR to change this situation by improving coordination among the different divisions that have management authority on the lake. It is the role of this planning effort to initiate in-house collaborative coordination to resolve long-standing issues, integrate GSL management policies and to help determine gaps in information that require research or monitoring for this

valuable local, state and world-wide resource.

The GSL plan will provide a framework and help guide this activity. However, initiating more comprehensive planning efforts for the lake and its watershed will require legislation and financial backing. Multi-agency collaborative efforts are essential to accomplish and support plan research and ecosystem monitoring objectives and to continue ongoing efforts.

This planning process in itself has improved coordination among the divisions of DNR. GSL management requires a coordinated front to address lake management issues. However, many issues transcend the state and private land boundaries and post-plan watershed coordination will also help protect long-term sustainability.

Sustainability and Development

"In order to achieve sustainable development, policies must be based on the precautionary principle. Environmental measures must anticipate, attack and prevent causes of environmental degradation where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation" (Bergen Ministerial Declaration on Sustainable Development in the ECE Region, 1990). There is often industry and political opposition to the precautionary approach since it interferes with traditional ways of conducting business and the scientific process utilized to provide decision-making rationales (Buckingham-Hatfield and Evans, 1996). Traditional ways to conduct business may lead to over exploitation while waiting for better scientific data to be compiled. The planning team believes that the proposed salinity management preferred alternative is an example of a precautionary approach.

Jurisdictional boundaries of GSL systems for planning are limited by different land-based resource agencies which limits the effectiveness of government to plan for sustainable development. Other constraints include scientific/technical, economic factors, political and ideology and the lack of industry volunteerism. Managing for sustainability often requires a regulatory framework to protect public trust resources and to identify appropriate tradeoffs in balancing multiple-use and sustainability objectives. Sustainability is defined by societal and political values rather than a scientific based concept. The long-term viability of the resource is determined by the outcome of social values. However impacts on GSL systems cut across economic, social and political boundaries.

Sustainability is achieved by "knowing the state of the environment." This is the resource inventory and provides the baseline to evaluate monitoring and identify trends that are useful for formulating effective management policies. Managing for sustainability assumes that resource managers understand management actions and their consequences (impacts) on dynamic systems. Precise cause-and-effect observations are often vague and problematic since scientific information

may have several different interpretations. Therefore research and monitoring objectives must be carefully designed.

Sustainable planning for GSL ecosystem should include "targets" or objectives for determining the effectiveness of multiple-use and sustainable management objectives in balancing development and maintaining environmental integrity. Management targets are based on scientific understanding of GSL ecosystems limits and tolerances to human-induced change. Management targets may be established at different scales and levels. (Buckingham-Hatfield and Evans, 1996). A few ideas to evaluate management objectives are:

1. Identify sustainability indicators or targets for resource management and decision-making.

2. Identify tradeoffs and determine if acceptable tradeoffs will maintain the integrity of GSL resources to ensure that each generation should at least inherit a similar natural environment.

3. Identify environmental quality or performance measures that are reportable and measurable over time.

4. Determine a conceptual approach for monitoring and assessing the state of the environment.

5. Identify information needed to assess the "state of the environment."

6. Identify vigorous monitoring strategies.

7. Design analysis and reporting strategies.

Sustainable use of GSL ecosystems means limiting the use of renewable natural resources at a pace where they can renew themselves through natural processes (Fischer and Black, 1995). Ecosystem management objectives should include and consider:

1. Allowance for reasonable multiple-uses.

2. Wise resource allocation to ensure long-term sustainability.

3. Establish checks and balances to ensure an acceptable level of environmental protection.

4. Minimize negative impacts on GSL ecosystems.

5. Engage industry in ensuring sustainable resources by preventing and managing for crises in their operations and to help in monitoring impacts.

These measures will allow for economic growth that is mindful of the limited natural resource base (Fischer and Black, 1995). It will be challenging to balance public needs and ensure long-term resource protection with projected population growth scenarios. Sustainable management ensures that GSL natural resources will be available for future uses.

Land

Introduction

The state owns and manages the bed of GSL pursuant to the Equal Footing Doctrine discussed in the introduction to this plan. The boundary line of the bed of GSL is the "meander line," a courses and distances surveyed line established by court order. The meander line follows no particular topographic contour or elevation, but is generally located between 4202- 4212 feet above sea level in most places around the lake. These lands within the meander line are referred to as "sovereign lands" in this plan. Sovereign lands also include the unsurveyed islands in GSL; Dolphin, Badger, Egg and White Rock Islands. Hat and Gunnison Islands are owned by DWR. Stansbury, Fremont, Carrington and Cub Islands are federally and privately owned.

In addition to the sovereign lands owned by the state, DNR has acquired lands in and around GSL including Antelope Island (DPR), wetlands and uplands associated with wildlife management areas and formerly private lands needed for the WDPP operation, all of which are managed for specific purposes.

The management of sovereign lands is the responsibility of DFFSL. One of the challenges in managing sovereign lands is that the biological and physical systems of GSL do not observe property boundaries, and management decisions on sovereign lands affect, and are affected by, uses and activities on adjoining lands.

The internal and external scoping conducted by the planning team identified these areas of interest and concern with regard to the management of sovereign and other state-owned lands on and around GSL, existing uses and classifications and boundary uncertainties and disputes. A listing of the existing leases and permits on sovereign lands is in Appendix B.

- **Disclosure has to be made of known geologic hazards.**
- **Impact assessment for diking proposals needs to be considered.**
- **A review of sovereign land is needed.**
- **Use of sovereign land for BRMBR expansion is a consideration.**

Land Uses Adjacent to Great Salt Lake

Land use around GSL consists of a mix of residential, commercial, agricultural, recreational and industrial uses common to population centers. (See Figure 1.) The east side of the lake has the higher concentration and diversity of land uses. Population growth in Weber, Davis and Salt Lake Counties is resulting in the conversion of agricultural land to residential and commercial uses. Associated with this changing land use is a shift in water use from agriculture to M&I uses, with a resulting reduction in sub-irrigation ground water and return

flows to lands adjacent to the lake. As development moves lakeward, the uplands no longer provide a buffer to the lake wetlands, and diminishing irrigation return flows affect the wetland ecosystem (Davis County Government et al., 1996). In addition, runoff from urban lands introduces water contaminants different from those of agricultural lands.

A number of landowners adjacent to the lake are managing their holdings primarily for habitat protection. Approximately 150,000 acres of adjacent lands are within state and federal WMAs. In addition, approximately 10,000 acres of wetland and upland parcels are owned and managed by groups like TNC and the National Audubon Society for habitat preservation. Private hunting clubs own and manage over 50,000 additional acres on the east side of the lake, primarily adjacent to Bear River Bay and south of Farmington Bay.

Elsewhere around the east side of the lake agricultural uses predominate. Grazing and crop production from dry and irrigated acreage are the most common land uses around the north and west sides of the lake. The notable exceptions are the mineral evaporation ponds of Bear River and Clyman Bays and the south shore, and the bombing and gunnery range which lies on the western shore of the lake.

County Zoning Adjacent to Great Salt Lake

Box Elder County

Box Elder County covers approximately 800 square miles of GSL, the largest area and the longest shoreline of the five counties adjoining the lake. Several abandoned industrial ventures abut the lake, but brine shrimping is the only current lakeshore commercial activity other than mineral production. Only a portion of the lake shoreline is zoned. The area on the west side of the lake from Kelton to the southern county line is zoned M-160, multiple uses with 160 acre minimum lot size. The balance of the shoreline is not zoned.

Davis County

Zoning along the GSL shoreline in Davis County is controlled by three governmental entities; Davis County, Kaysville City and Centerville City. Most of the county-controlled land adjacent to the lake is zoned A-5 for Agriculture and Farm Industry with a five acre minimum lot size. The A-5 zone is intended to promote and preserve agricultural uses and to maintain greenbelt open spaces. Primary uses include single-family dwellings, farm industry and agriculture. Several conditional uses include stables and dog kennels. Kaysville City abuts the lake for only a few hundred feet, and is also zoned A-5 with similar uses.

Davis County and others sponsored the development of the *Davis County Wetlands Conservation Plan*, published in December 1996, as a non-regulatory, multi-faceted program, "To conserve and enhance the integrity of Great Salt Lake wetland ecosystems in Davis County,..."

(Davis County Government et al., 1996). The purposes of the plan are to define a Davis County conservation zone adjacent to the lake, "...incorporating provisions for appropriate development, infrastructure needs, resident livelihoods and quality of life, while ensuring perpetuation of these important natural resources;..." While many of the plan implementation steps remain to be completed, the conservation plan establishes a blueprint for land management and use adjacent to GSL in Davis County.

Centerville City abuts the eastern shoreline of the lake for about two and one-half miles immediately to the east of the Farmington Bay WMA. City zoning in this area is A-1, agricultural or I-D, industrial development. The A-1 zone allows both standard agricultural activities and single-family dwellings on one-half acre lots. The I-D zone allows for a wide array of industrial and commercial uses.

Salt Lake County

The shoreline of GSL in Salt Lake County is generally unpopulated, and is zoned A-20, an agricultural zone with a 20 acre minimum lot size, or CV, a commercial visitor zone. The A-20 zone provides for standard agricultural uses, but also allows solar evaporation ponds. It typically acts as a large-acre holding zone until a specific use is proposed, which can result in re-zoning for the use proposed. The C-V zone allows for commercial uses to accommodate the needs of visitors and travelers.

Tooele County

The shoreline of GSL is not specifically zoned in Tooele County, with land uses reviewed and approved on a case-by-case basis as conditional uses. Current uses include agricultural operations, brine mineral extraction and brine shrimping operations.

Weber County

Fifteen miles of GSL shoreline are within Weber County, and are zoned S-1, farming and recreation. Lands around Little Mountain are zoned M-3, manufacturing. The M-3 zone allows for the manufacture and testing of jet and missile engines, aircraft and spacecraft parts and similar heavy industry, and for the extraction and processing of brine minerals. Bordering the S-1 and M-3 zones on the east are agricultural zones A-1, A-2 and A-3.

Land Uses on Sovereign Lands

The framework for sovereign land management is found in the Utah Constitution (Article XX), state statute (primarily Chapter 65A-10), and administrative rule (R652). Commercial uses are allowed on sovereign lands only by permit.

Division rule allows for classification of sovereign lands based upon current and planned uses (R652-70-200. "Classification of Sovereign Lands." (See Appendix G, Map 3.)

Class 1: Manage to protect existing resource development uses.

Class 2: Manage to protect potential resource development options.

Class 3: Manage as open for consideration of any use.

Class 4: Manage for resource inventory and analysis.

Class 5: Manage to protect potential resource preservation options.

Class 6: Manage to protect existing resource preservation uses.

The legislature has authorized DWR to use sovereign land in all or parts of 39 townships on GSL for the creation, operation, maintenance and management of WMAs, fishing waters and other recreational activities. This geographic area covers Bear River Bay, Ogden Bay, Farmington Bay, portions of the south shore area and the north end of Spring Bay. This statutory authorization is interpreted as establishing wildlife management and wildlife-related recreation as the primary intended land use, except for areas identified for other uses through a planning process. Land uses with significant adverse impacts on wildlife and recreation values may be prohibited, even though mitigation strategies are available. Some of this sovereign land is included in AISP and is managed by DPR. Some of the land has been sold or exchanged.

The most current statement of use classifications for the sovereign and other state lands of GSL appears in the 1995 plan. The 1995 plan recommended application of the use classifications set forth in R652-70-200 to areas of GSL as follows (See Appendix G, Map 3.):

Class 1, managed to protect existing resource development.

Lands under this classification include the area around Antelope Island delegated to DPR for recreation management, the area around Saltair and GSL Marina, existing mineral extraction lease areas, and areas under special use lease for brine shrimp cyst harvest activities. These lands would be open to oil and gas leasing, but no surface occupancy will be allowed in the recreation areas.

Class 2, managed to protect potential resource development options.

This area includes the West Rozel oil field and shoreline areas from the north end of Stansbury Island south along the west side of the island and then north along the west side of the lake to the south line of Township 11 North, Salt Lake Base and Meridian (SLB&M). This area will be open to mineral leasing, developed recreation and other kinds of developments.

Class 5, managed to protect potential resource preservation options.

This classification includes lands which the legislature has authorized DWR to use for wildlife purposes under Section 23-21-5 (See Map 7), and a one-mile buffer zone around islands in the north arm of the lake. No surface occupancy for oil and gas exploration will be allowed in established WMAs or in the island buffer zones. Elsewhere, oil and gas surface occupancy constraints shall be determined in consultation with DWR. Mitigation strategies for developments not related to wildlife

management in these areas shall also be determined in consultation with DWR.

Class 6, managed to protect existing resource preservation uses.

This classification covers existing WMAs. Lands will be available for oil and gas leasing with no surface occupancy.

Class 3, managed as open for consideration of any use.

The remainder of the lake is recommended to be placed in Class 3.

Class 4, managed for resource inventory and analysis.

This is a temporary classification used while resource information is gathered pending a different classification. There are no Class 4 lands in the lake.

The mineral lease descriptions in the 1995 plan are revised by the 1996 MLP. The sovereign land mineral lease categories now in place are shown in Appendix G. (See Maps 9 and 10.)

Geologic Hazards

State law requires DFFSL to disclose known geologic hazards affecting leased property. Information on known hazards is routinely provided to lessees but, in general, there is no follow-up activity.

Tectonic Subsidence

In the event of an earthquake within the Salt Lake Valley, the potential exists for the valley floor to drop relative to the adjacent Wasatch Range. Such movement would likely occur along the multi-segmented Wasatch fault zone. Keaton (1986) suggests that displacement could be approximately five feet at the fault line. The zero-subsidence line would be about 10-12 miles west of the fault. A drop and tilt of the valley floor of this magnitude would cause (1) waters of GSL to move east, and (2) a rise in the water table in low areas near the fault. These effects could vary depending on the surface elevation of the lake at the time and the amount of displacement along the fault.

Earthquakes could also cause movement along the numerous north-south faults within and adjacent to the lake. Such movement could cause damage to highways, railroads, dikes and other existing or proposed structures in and around the lake.

Surface Faulting

Surface faulting may accompany large earthquakes (greater than magnitude 6.0-6.5) on active faults in the bed of GSL. One fault trends northwest along the west side of the Promontory Mountains and Antelope Island. Other faults are present elsewhere beneath GSL, particularly in the north arm (Hecker, 1993). Because faults in GSL do not trend onshore, surface faulting resulting from an earthquake on one of these faults would not directly affect structures along the shoreline. However, surface faulting beneath the lake may rupture dikes or in-lake structures that straddle the faults, and may generate seiches which could indirectly damage both in-lake and shoreline structures by flooding. Little is known of the earthquake history of the faults in GSL, but evidence indicates some have been active in Holocene time.

Liquefaction and Ground Failure in Sensitive Clays

Lowe (1990a) states that "ground shaking tends to increase the pressure in the pore water between silt grains, which decreases the stresses between the grains. The loss of intergranular stress can cause the strength of some soils to decrease nearly to zero. When this happens, the soil behaves like a liquid, and therefore is said to have liquefied." Four types of ground failure can occur during liquefaction: loss of bearing strength, ground oscillation, lateral-spread landslides and flow landslides. The type and severity of the failure depends greatly on the surface slope. Under some conditions, clays can become unstable by leaching salts. These are referred to as sensitive clays. During earthquakes they can lose their strength, resulting in ground failures similar to those occurring during liquefaction.

Anderson and others (1982, 1986 and 1990) and Lowe (1990a and 1990b) suggest that large areas within Salt Lake, Davis and Weber Counties east of the lake have a moderate to high potential for liquefaction during earthquakes. These areas adjacent to the lake have sensitive clay soils susceptible to liquefaction. Regarding flooding related to local and distant earthquakes, liquefaction, and wind tides, Atwood and Mabey (1990) point out the following: "Engineered structures (such as dikes and causeway embankments) founded on the lakebed, particularly those designed to provide protection from the lake water, pose special engineering-geology problems." These problems include settling, flooding, soil compaction and erosion.

Shallow Ground Water

Ground water is, by definition, water beneath the surface of the ground which fills fractures and pore spaces in rocks and the voids between grains in unconsolidated sediments. Ground water is considered shallow when it occurs at depths less than 30 feet. Lowe (1990a and 1990b) suggests that ground water adjacent to the lake, at depths less than 10 feet, may cause flooding of basements and other related problems. In the vicinity of GSL, the water table, or the top of the saturated ground, fluctuates in response to the level of the lake. During times of high-lake levels, the water table is higher than during times of low-lake levels, and larger areas around the lake will be affected.

Wind Tides and Seiches

Sustained winds blowing across the surface of GSL push the water to the shore or dike and causeway where it "piles up," forming what is known as a wind tide or wind setup. The height or magnitude of the setup depends on the speed, direction, fetch, depth of lake at that point and duration of the wind. Wind setup exceeding two feet is not uncommon, and can cause localized increased flooding and damage. The combined effects of wind setup and high waves (wave runup) can produce adverse impacts to elevations five to seven feet above the static lake elevation and locally even higher. As these winds cease or diminish, the water begins to oscillate back and forth in the lake, similar to water sloshing from end to end in a bathtub. This movement is referred to as a seiche. The period of the oscillation, or the time it takes to move from high to low and back to high, is about six hours

in the south arm (Lin, 1976; Lin and Wang, 1978b) and shorter in the north arm. Earthquakes also have the potential to cause large-scale surges and seiches in the lake. During such surges and seiches, the elevated water may cause repeated, short-term flooding around the lake. The heights of earthquake-induced surges and seiches are unknown, but may well exceed the heights of wind tides and seiches. A 1909 earthquake is reported to have generated a surge that sent water over the railroad causeway and the pier at Saltair. The extent of flood damage in an earthquake affecting the lake will depend on the level of the lake at the time of the event.

Wind-Blown Ice

During the cold winter months, freshwater from the major tributaries to the lake flows out and over the heavier saline water of the south arm and also in Bear River Bay. If this water is not mixed, it freezes and can form large sheets of ice. As the winds blow, these sheets of ice are pushed around the lake and can destroy stationary objects within the lake and at its margins.

The *1995 Comprehensive Management Plan-Planning Process and Matrix* (the 1995 plan) recommended that all five counties on the lake should establish ordinances requiring that all structures built in and around the lake be designed for additional short-term lake elevations due to wind tides (and subsequent seiches), earthquake-induced seiches and waves. Wind tides can raise the lake an additional two to four feet. Structures should be built to withstand wind-blown ice in the southern part of the lake.

The 1995 plan recommended that site-specific studies be conducted, prior to development of proposed structures in and near the lake, to identify sensitive clays, soils susceptible to liquefaction, areas susceptible to earthquake-induced flooding and shallow ground water. In addition, the plan recommended that advice on geologic hazards and mitigation measures should be provided to applicable county planning, zoning and permitting agencies. UGS suggests that general hazard maps be made available to city and county planning, zoning and permitting agencies to identify where further site-specific studies are needed. Where such maps are not available, studies addressing all these potential hazards should be required for any development between the lake and the 4217-foot contour (or high elevation if required by the permitting agency). These studies should be reviewed for adequacy by the local government or their consultants (UGS performs such reviews), and steps must be taken by local government to ensure that recommended mitigation measures are implemented.

Sovereign Lands Boundaries

Uncertainties and Disputes

The meander line, which is the legal boundary between sovereign lands and adjacent lands, was established by a series of surveys over a period of years, and does not follow a topographical contour line around GSL. A number of the original survey markers and monuments have been obliterated, and the exact location of the sovereign/private boundary is uncertain in many areas. Specific areas of uncertainty and/or dispute include (See Map 2 to Appendix B for locations):

- Bear River Duck Club (E1). Ownership questions below meander need to be resolved.
- Chesapeake Duck Club (E2). Ownership questions below meander need to be resolved.
- Canadian Goose Club (E3). Ownership questions below meander need to be resolved.
- Lands below the meander line in the proposed expansion of BRMBR.
- Lands below the meander line between Willard Bay and BRMBR.

Boundary Resolution Strategies

Section 65A-10-3 requires DFFSL to consult with the attorney general and affected state agencies to develop plans for the resolution of disputes over the location of sovereign land boundaries. With respect to the areas identified above, the division has not yet prepared such a plan, but anticipates doing so in 2000 if the records search identifies potentially legitimate private ownership claims below meander.

Dikes and Causeways

Dikes and causeways in and around GSL serve a variety of purposes. Dikes are used to impound freshwater (e.g., BRMBR, WMAs, Willard Bay Reservoir), impound brine pumped from the lake or trap brine in the lake for brine extraction (e.g., Magcorp, IMC Kalium Ogden Corp., Morton) and protect facilities from high lake levels (wastewater treatment plants, sewage lagoons, power lines). Causeways are also used for transportation facilities along the shore or across the lake (I-80, northern and southern railroad causeways, Davis County Causeway).

Dikes and causeways influence lake level, salinity, habitat and the surface area of the lake. The influence of causeways on salinity is evident. Where dikes or causeways constrain the area over which the lake could expand in high water periods, the water depth along shores may be too deep for shorebird habitat. Similarly, the formation of wetlands along shoreline areas may be affected. Some dikes and causeways constrict lake hydrodynamics and tributary flows as the water moves toward the lake, thereby exacerbating local flooding.

With the exception of studies regarding proposed large freshwater impoundments (e.g., inter-island diking, Lake Davis, Lake Wasatch), assessments of effects have focused on the intended purposes of dikes and causeways. Effects beyond the immediate vicinity have received little attention in project planning.

Minerals and Hydrocarbons

Introduction

The state owns the minerals located in the bed and waters of GSL as public trust resources. The responsibility to manage the minerals of the lake, and of all sovereign state lands, has been assigned to the DFFSL by statute. The division has specific management responsibilities for minerals of GSL pursuant to Section 65A-10-18 of the Utah Code.

Internal and external scoping conducted by the planning team focused on the DFFSL MLP categories and policies.

Although GSL is renowned for its "salt" (sodium chloride or table salt), its waters actually contain other sodium, potassium (potash), calcium and magnesium salts. GSL contains salt from a variety of sources. Rain and snow in the mountains leached saline materials from soils and rocks and carried it in solution to streams that eventually flow into the lake (Miller, 1949). GSL may be as salty as it is because much of the salt was originally in the waters of Lake Bonneville and was concentrated as those waters evaporated (Trimmer, 1998). In addition, some believe that the lake's salts were leached from deposits of oceanic salt of Jurassic age which crop out extensively in Sanpete Valley within the GSL Drainage Basin (Eardley, 1938). Due to the terminal nature of GSL, salt delivered to it remains in the lake. Water entering the lake escapes by evaporation only. GSL presently contains 4.3 billion tons of salt in its system (Trimmer, 1998).
Other geological resources under and around the lake include mirabilite and epsomite, oil and gas, oolites and quartzite. Oil has been produced at Rozel and West Rozel Point oil fields and natural gas has been produced at Farmington Bay and Bear River Bay but commercial quantities of hydrocarbons have not yet been discovered.

Mirabilite and Epsomite

The most economically important salts in the lake are table salt, potash and magnesium chloride but mirabilite and epsomite are significant resources which have been produced from the lake. Mirabilite (sodium sulfate) is a mineral that is precipitated from highly concentrated lake brines during the cold winter months. This salt is not stable and redissolves as the brine warms in the spring except where it is enclosed in sediment at the bottom of the lake.

During the construction of the northern railroad causeway in about 1900, a deposit of mirabilite was discovered west of Promontory Point. Eardley (1963b) described the deposit as lying 15 to 25 feet below the bottom of the lake, interbedded with the soft lake-bottom clays, and having a maximum thickness of about 32 feet. The salt bed extends westward about 9.5 miles from a point one mile west of Promontory Point, and is bounded on the east by a fault.

When the pilings were driven during construction of the old Saltair resort on the southern end of the lake, a hard layer of mirabilite-cemented oolites was encountered. This layer was penetrated only by steam-jetting a hole for the pilings. Soon after the pilings were installed, natural recrystallization of the

mirabilite solidly cemented the pilings in place. Mirabilite-cemented oolite beds have been found at numerous other places around the lake including: the South Shore Marina, the Antelope-Island Marina and the Morton Salt intake canal on the south end of Stansbury Island. They are probably present at many other areas around the lake. At one time, Great Salt Lake Minerals Corp. (now IMC Kalium Ogden Corp.) produced anhydrous sodium sulfate from winter-precipitated mirabilite; there is no current production of mirabilite.

Epsomite (magnesium sulfate) can be produced by the winter cooling of highly concentrated lake brines, such as those utilized by Magcorp in the production of magnesium metal and chlorine gas. Epsomite is not currently being produced from lake brines.

Rozel Point Oil Field

Naturally oozing tars have been collected from areas near Rozel Point, probably since pre-settlement times.

Shallow wells drilled near surface oil seeps at Rozel Point beginning in the early 1900s produced a small amount of oil from a fractured, Tertiary basalt reservoir. The field area lies on mudflats at the edge of the lake and is submerged at times of high lake levels. There are currently no active wells in the Rozel Point oil field. Cumulative production (to 1993) is 2,665 barrels of oil (Kendell, 1993a). The oil is thick with a high sulphur content making it difficult to produce and refine. Rozel Point field is discussed by Heylmun (1961b), Eardley (1956, 1963a) and Kendell (1993a).

West Rozel Point Oil Field

Amoco Production Company drilled 15 wells in GSL, utilizing a floating barge-mounted drill rig, from mid-1978 to 1981. The drilling resulted in the discovery of the West Rozel field, a seismically defined structural feature, three miles west-southwest of the Rozel Point oil field. The structure is a faulted anticline about three miles long and more than a mile wide, covering about 2,300 acres. The discovery well produced two to five barrels of oil per hour during production testing from perforations located 2,280 to 2,410 feet below surface in Tertiary basalt. Cumulative production (to 1993) is 33,028 barrels of oil (Kendell, 1993b). The oil is very thick and high in sulfur, making it difficult to produce and refine. West Rozel is discussed by Bortz (1983, 1987), Bortz and others (1985) and Kendell (1993b).

Additional Oil Shows

Additional oil shows were found in samples collected by Amoco during drilling in the south arm of the lake.

Farmington Gas Field

The Farmington gas field was discovered in 1891 near the shore of GSL about three miles southwest of Farmington. One well produced at a rate of 4.9 million cubic feet of gas per day from a depth of 850 feet. In 1985 a pipeline was built from the field to Salt Lake City and provided gas for 19 months until the gas was depleted or the wells sanded up. It is estimated that the field produced 150 million cubic feet of gas at a rate of 8.5 million cubic feet per month. The Farmington gas field is discussed by Heylmun (1961a).

Bear River Gun Club

Natural gas has often been encountered while drilling shallow water wells on the Bear River Delta. A water well drilled by the Bear River Gun Club was converted to gas production and provided natural gas for private use for many years until the well blew out. When attempts were made to plug the well, the gas flow cut away from the well bore and blew out through the soil. It took several days to control the flow which was estimated to be as large as a million cubic feet a day. There has never been any attempt to commercially exploit the gas resource from the delta.

Oolites

Oolitic sands are an unusual sediment type found in and around GSL at numerous locations. They are rounded, light-colored carbonate grains and range in shape from nearly spherical to cylindrical. Their surfaces are usually smooth, like a miniature pearl. The size of oolites ranges from 0.015 to 1.5 millimeters, with the average size being about 0.31 millimeters. The chemical composition of the outer shell consists mainly of calcium carbonate, though some calcium-magnesium carbonate (dolomite) is also present. The nucleus or central core is usually a mineral fragment or a brine-shrimp fecal pellet.

Some of the areas in which oolites are found include: (1) the west side of Stansbury Island in Stansbury Bay and the north end of the island extending northward past Badger Island, where beds up to 18 feet thick have been measured; (2) around Antelope Island, and especially in the area of the Bridger Bay bathing beaches, and (3) the southern shores of the lake.

Oolites have been used by Magcorp (and their facilities' prior owners) to neutralize the acidic gases produced during the processing of magnesium chloride brines into magnesium metal, and to produce calcium chloride which is used in the brine-desulfation process and as an industrial chemical. Oolites are also used as flux in mining operations and could also be used in most applications where limestone is used. Small amounts of oolitic sand are used in drying flowers.

Quartzite

Since about 1996 quartzite has been quarried near the southwest end of Stansbury Island by McFarland Hullinger Company. The quartzite is sold to KUC for flux to assist copper smelting at Kennecott's Salt Lake Valley facility.

Mineral Industry Overview

Salt extraction is one of Utah's oldest industries and salt has been harvested from the waters of GSL for over 100 years (Miller, 1949). In addition, magnesium metal, chlorine and potassium salts are harvested through extraction processes. These newer industries began in the 1970s. Currently, all major ions contained in the lake water are extracted by solar evaporation in large pond systems (Trimmer, 1998).

There are currently six companies in the GSL minerals industry. These include IMC Kalium Ogden Corp., Magcorp, Cargill Salt, Morton Salt, IMC Salt and North Shore Limited. (See Figures 4 and 8.) In 1997, existing aggregate data from DWRi indicate that in excess of 31 billion

gallons of water were pumped from GSL by mineral harvesting companies (Hudon, 1998). Sodium chloride (NaCl, or table salt) is the first salt to be precipitated out as lake brines are concentrated, and it is either sold or is a waste product, depending on the focus of each company (Trimmer, 1998).

Magcorp produces magnesium metal from lake water at its electrolytic plant in Tooele County. Chlorine gas is also produced. The plant has a capacity to produce 40,000 metric tons of magnesium metal at 99.9 percent purity annually and is the fourth largest magnesium plant in the world as of 1996. Magcorp represents 28 percent of primary U.S. magnesium capacity (Kramer, 1998a). Magcorp sells some potassium-magnesium salts to IMC Kalium Ogden Corp. (Trimmer, 1998 and U.S. Bureau of Mines, 1996).

Morton and Cargill produce only sodium chloride and return bitterns, the concentrated brine that remains after sodium chloride has crystallized, to the lake. IMC Salt is the largest salt producer on the lake and buys salt from IMC Kalium Ogden Corp. IMC produces magnesium and potassium salts, primarily sulfate of potash (K_2SO_4) rather than muriate of potash (KCl). Sulfate of potash is a higher value product than KCl. IMC Kalium Ogden Corp. produces minerals such as kainite, schoenite and carnallite in its solar ponds which are then processed to remove magnesium, chloride and sodium ions, leaving potassium sulfate. Also, under certain conditions, potassium chloride is added directly to the process where it undergoes a base conversion into potassium sulfate. A significant portion of the sulfate of potash is exported to other countries. This company retains and sells the magnesium chloride brine, but flushes excess sodium chloride and some of the low-grade magnesium and potassium salts back into the lake. Sodium chloride build-up on evaporation pond floors is a problem for both IMC Kalium Ogden Corp. and Magcorp, although IMC is able to return some waste salts to the lake (Trimmer, 1998 and Gwynn, 1998b).

North Shore Limited produces magnesium chloride brines through solar evaporation. This product is sold for nutritional supplements (Trimmer, 1998). (See Table 8.)

Table 8.

Company	Production
IMC Kalium Ogden Corp.	Magnesium and Potassium Salts ($MgCl_2$, K_2SO_4)
Magnesium Corporation of America	Magnesium Metal (Mg), Chlorine Gas (Cl)
Cargill Salt	Salt (NaCl)
Morton Salt	Salt (NaCl)
IMC Salt	Salt (NaCl)
North Shore Limited	Magnesium Brines ($MgCl_2$)

(Trimmer, 1998 and Gwynn, 1998b)

Production Trends

The salt industry is characterized by high tonnage volumes at relatively low unit values and a product which is harvested far from markets. These products face intense competition within the industry both nationally and internationally (GSLTT and DSLF, 1995). Potassium sulfate is produced at a relatively high volume with higher value per ton, while magnesium metal is produced at a relatively low volume with a high value per ton (Trimmer, 1998). The estimated average price per metric ton of K_2O in 1997 is $140 (Searls, 1998). The estimated average price per metric ton of magnesium metal in 1997 is $2,700 (Kramer, 1998a).

Harvesting is also vulnerable to weather conditions and lake level changes. Cool and wet weather slows evaporation and concentration processes. Both low and high lake levels create problems for the mineral extraction industries. When lake levels are low, intake canals to pumps must be dredged and the pumps may need to be repositioned into deeper water (GSLTT and DSLF, 1995).

High lake levels, as experienced in the mid-1980s, are much more critical to the salt industries than low levels, due to the dilution of feed brines. The economic impact of increased erosion of dikes, dike failure and rebuilding or reinforcing of dikes at high lake levels can also cost millions of dollars (GSLTT and DSLF, 1995).

As the lake level rises and falls, the strength of the brine falls and rises. This inverse relationship is a result of a relatively fixed amount of dissolved solids within the lake coupled with a fluctuating amount of water. When inflow exceeds evaporation, the lake level rises and the extra water dilutes the lake brine. Dilute brine conditions require larger pond areas for a given tonnage of salt production. With a low lake level, brine strength is higher and therefore pumping and pond area requirements are lower for a given tonnage of salt, therefore producing a greater yield. This inverse relationship is particularly applicable to the south arm of the lake, although under some circumstances, similar impacts can result in the north arm of the lake as well (GSLTT and DSLF, 1995).

Salt and brine-derived products are the largest contributors to the value of industrial minerals in Utah. The production of salt and brine-derived products is expected to continue to expand over the next several years (U.S. Bureau of Mines, 1996). For instance, IMC Kalium Ogden Corp., the largest potassium sulfate producer in North America, plans to double current production (Warnick, 1998).

Value of Production

Because there are only six companies on the lake which harvest minerals, and only five mineral commodities are harvested, data on extraction must be presented in aggregate form. Therefore instead of reporting a unit value of the product, this section emphasizes the overall value of production of the minerals harvested. Although the dollar amounts of value of production of minerals extracted is held in confidence by DFFSL, general trends can be noted.

Overall, the value of production of potassium and magnesium salts has increased more than 12-fold since production began in 1973. The value of

production of magnesium metal has increased 31-fold since production began in 1974, and the value of production of salt has increased 17-fold since 1970. These increases have not been steady however, as the value of production in all three categories declined periodically, particularly from 1986 to 1989 due to years of flooding. In total, minerals extraction from GSL amounted to a value of production of $231,611,752 in 1997 (Trimmer, 1998).(See Figure 14)

Solar salt produced from GSL represents a significant and increasing share of total domestic solar salt production. The remainder of solar salt produced in the U.S. is primarily from California with some production from New Mexico. Solar salt competes in regional markets with rock salt for chemical and industrial, water conditioning and agricultural uses. Nationwide, the consumption of rock salt is four times that of solar salt. However, USGS data show that these markets are regional and, with respect to road salt, local. Solar salt dominates in western markets and appears to be increasing in certain Midwestern markets for certain end uses. DFFSL believes that the growth of regional solar salt markets, in which Utah producers compete, could continue to grow at 3 percent per year over the next five years. This amounts to approximately 50,000 tons per year (Trimmer, 1996).

Production of magnesium metal in the U.S. declined by six percent in 1996 from 1995. World magnesium oversupply and high prices were primarily responsible. For the first time in 20 years, the U.S. imported more magnesium than it exported. However, the U.S. continued to lead the world in production and production capacity of primary magnesium (Kramer, 1998a). Utah magnesium production remained steady in 1996 while prices declined, primarily due to increased foreign competition (U.S. Bureau of Mines, 1996). Magnesium metal is used for aluminum alloying, diecasting, and automotive applications. However, demand for magnesium used in aluminum alloying dropped in 1996 and several U.S. auto manufacturers canceled some programs to incorporate more magnesium diecastings into domestic passenger vehicles due to rapidly changing magnesium costs (Kramer, 1998a).

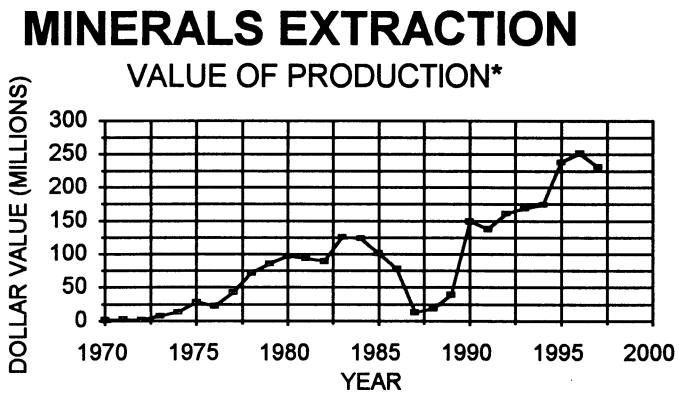


Figure 14 (Source: Utah Division of Forestry, Fire and State Lands)
* not adjusted for inflation

The outlook for global use of magnesium diecastings in automotive applications is expected to continue to grow at 15-20 percent average annual growth rate. North America and Europe are expected to be the areas with largest growth. Although magnesium prices declined in 1996 through June 1997, they began to increase slowly from mid-year. Price fluctuations were not as widely varied as in recent history. From 1993 to 1995, prices fluctuated from $2,260 to $4,138 per metric ton (Kramer, 1998a).

U.S. production of magnesium compounds increased in 1996. Magnesium chloride was used mainly as a chemical intermediate. Magnesium chloride brines were used principally for road dust and ice control. $MgCl_2$ was used in agricultural, chemical, construction, environmental and industrial applications. Year-end magnesium compound prices in 1996 did not change from those at year-end 1995 (Kramer, 1998b).

The term potash denotes a variety of mined and manufactured salts, all containing the element potassium in water soluble form. The general term potash also includes potassium sulfate (K_2SO_4), which is produced in Utah (Searls, 1998 and Trimmer, 1998). Domestic potash production comes from New Mexico, Utah and California. Because it is a source of soluble potassium, potash is used primarily as an agricultural fertilizer. U.S. potash sales were approximately 88 percent to the fertilizer industry and approximately 12 percent to the chemical industry. Production of all types and grades of potash in the U.S. declined in 1996. Sales of all types and grades of U.S.-produced potash were unchanged from 1995 to 1996. Potash consumption was only slightly above the 1995 level in 1996 (Searls, 1998).

Royalties on State Minerals

Prior to February 1997, Cargill and Morton paid a $0.10 per ton royalty to DFFSL on salt extraction, while IMC's predecessor paid an *ad valorem* royalty of approximately 2 percent of the value of the salt. Currently, Cargill and Morton pay a $0.10 per ton royalty to DFFSL, with an additional amount paid into an escrow account which is controlled by the companies. DFFSL, which administers mineral leasing on GSL, has adjusted the royalty rate to $0.50 per ton to be implemented over the next five to eight years. DFFSL reached a settlement with Morton Salt for a buyout of its outdated royalty agreement. This action is being contested by other mineral companies (Trimmer, 1998).

IMC Kalium Ogden Corp. pays an ad valorem royalty rate of 1.5-5 percent, increasing over time, on magnesium chloride and potassium sulfate. Magcorp pays a royalty rate of 0.1259-0.41967 percent, increasing over time, on sales of magnesium metal and chlorine gas. In 1986, these companies were allowed to roll-back the royalty rate to year one due to flood damage. The royalty rate has continued to advance from this base rate since that time. North Shore Limited pays a royalty of 5 percent on the value of the brine with a $5,000 minimum royalty (Trimmer, 1998).

All of the above-listed royalties are put into the restricted Sovereign Lands Management Account. This money must be appropriated by the Legislature for any use. To date, these funds have been used for DFFSL's operating costs associated with sovereign lands

management and various sovereign lands projects such as the cooperative causeway salinity study with USGS and work related to Utah Lake, the Jordan River Corridor, Bear Lake and the Colorado River (Baker, 1998 and Kappe, 1998).

Royalty Revenues

Royalties paid to the state amounted to $1,056,367 in 1997. The percent of total value of production paid as royalties declined from 1970 to 1997 with the exception of the period from 1986-1987. Currently, approximately 0.61 percent of total production value is paid in royalties. For those companies that pay a fixed rate on salt harvesting, the percent of total value paid as royalties primarily declined during this time because the selling price increased (Trimmer, 1998).

Additional Research

More research might be useful in the areas of ion depletion and accumulation of waste salts.

Mineral Leasing Plan

On June, 27, 1996, DFFSL published its *Mineral Leasing Plan for Great Salt Lake*. Development of a mineral leasing plan was one of the key recommendations of the 1995 plan. The goals section of the MLP recites:

> "The purpose of the mineral leasing plan for the Great Salt Lake is to guide DSLF [now the Division of Forestry, Fire and State Lands] in accomplishing the following goals:

Integrate minerals resource planning with other resource planning.

- To create a framework for long-term policy direction for minerals management which also has flexibility to respond to the dynamic character of GSL
- To integrate management of GSL's mineral resources with the lake's other resources so that all resources are managed for the health and integrity of GSL ecosystem
- To identify compatible uses and conflicts among mineral resource development and other resources on GSL and to provide for resolution of conflicts
- To monitor impacts of minerals operations and to collect, analyze and use data to maintain health and integrity of the ecosystem, including its mineral resources
- To monitor impacts of all diversion, dredging, causeway and diking operations and to collect, analyze and use data to maintain health and integrity of the ecosystem, including its mineral resources

Plan for leasing and efficient development of mineral resources.

- To inventory and monitor GSL's mineral resources
- To assure wise and diligent development of mineral resources within GSL's boundaries
- To provide for the orderly leasing of mineral resources to existing and potential mineral lessees
- To receive fair compensation for development and extraction of GSL's various mineral resources

Assert the role of DFFSL as a manager of state-owned lands.

- To clearly define sovereign lands for resource users, the public and other resource management agencies

The MLP identifies and evaluates the mineral resources of GSL, impacts of diking and causeways, evaporative pond impacts and constraints, issues and conflicts and the relationships of mineral operations to the other trust resources present on GSL. The plan identifies areas of potential resource conflicts and addresses them by establishing leasing "zones" in the lake and creating mitigation strategies. The plan is the result of a multi-interest, public process conducted over many months.

At this time, neither DFFSL nor DNR is aware of specific concerns with the MLP, but all aspects of the plan are open for comment as part of the current planning effort.

Notes:

Perceptions of GSL vary among local residents. Some find that the lake offers great beauty and quality recreation and significantly enhances the quality of their lives. Others view the lake negatively and find little value in GSL. Out-of-state tourists often view GSL as one of the most well-known of Utah's natural resources, and aspire to visit the lake while visiting northern Utah. The tourism industry and local residents alike desire greater access to GSL provided in a manner that does not impair lake resources (DPR, 1994).

The demand for recreational uses of GSL's resources is expected to grow in the future. The lake's extraordinary numbers of water birds, magnificent sunsets and vistas, no-sink swimming, the trails, wildlife, cultural and range resources and development of Antelope Island and open space next to a growing metropolitan area all point to growing interest in visiting and recreating at GSL.

Based on internal and external scoping, the planning team identified a number of interests and concerns with regard to management of GSL's recreation resources, including:

- **Capacities and uses of existing recreational sites, marinas and other facilities are issues.**
- **Management of AISP needs to be considered.**
- **Recreational boat navigation through existing causeways is a concern.**
- **Camping, hiking, biking, trails, automobile touring and picnicking opportunities and access are issues to be considered.**
- **Hunting, birdwatching and wildlife management area access and opportunities need to be considered.**
- **Hunting and AISP user conflicts are issues to be addressed.**
- **Resource education and interpretation opportunities are issues to consider.**
- **Cultural resource protection needs to be addressed.**
- **Recreational off-highway vehicle (OHV) use on sovereign lands is an area of concern.**
- **A centralized south shore visitors/activities area needs to be considered.**

Although a large number of specific recreation-related concerns and issues were raised during internal and external scoping, the general themes of the concerns related to the numbers and types of recreational opportunities available on GSL, user conflicts, the environmental impacts of recreational uses and educational and interpretive opportunities. Rather than devote discrete sections to discussion of each issue, this section provides a description of the kinds, locations and uses of recreational facilities and opportunities on GSL, existing interpretive and

educational opportunities and programs and cultural resource protection and interpretation.

Recreation Sites and Opportunities on Great Salt Lake

Antelope Island
(DPR)

The largest island in GSL is Utah's largest state park. Reopened in July 1993, Antelope Island's annual visitation (currently at 300,000) has grown steadily, and the island has been identified by the Utah Travel Council as one of Utah's fastest growing tourist attractions. DFFSL has signed a MOU with DPR to allow AISP to manage sovereign lands surrounding the island as a buffer zone.

Antelope Island has been called the best place to see and experience GSL, given the island's sandy beaches, lofty overlooks and amenities. Antelope Island has a unique array of wildlife—abundant large mammals adjacent to concentrations of water birds of hemispheric importance. Ungulate species on Antelope Island include the third largest publicly owned bison herd in the nation, pronghorn, big horn sheep and mule deer. The island's east shore is dominated by freshwater seeps and wetlands and is connected to the mainland marshes by playas off the south end of the island. This array of wildlife, accompanied by limited access provides outstanding wildlife viewing opportunities.

Antelope Island has important cultural sites, most significant of which is the Garr Ranch. The Garr Ranch contains some of the oldest anglo-constructed buildings in Utah and was the home ranch of some of Utah's largest ranching operations from 1848-1981. The site's interpretive focus is on the length of occupation and the evolution of large-scale western ranching from pre-mechanization to mechanization. Recreational opportunities and development include, scenic drives with bicycle lanes, a back country trail system, campgrounds and picnic areas, interpretive information and programs, a swimming beach and a marina. A private concession business, food and souvenirs, a small tour boat and guided horseback rides are located on the island.

Significant educational opportunities are available on Antelope Island. DPR, in partnership with Davis County, developed a 5,200 square foot visitor center overlooking the lake. Interpretive exhibits and programs focus on GSL including Antelope Island and the other surrounding resources. The Garr Ranch, scheduled to open daily in spring of 2000 will be another important interpretive venue. Opportunities for self-directed interpretation are available with nature trails, wayside exhibits and publications. An outdoor amphitheater, located at the visitor center enhances the park's ability to provide personal programs. The park provides educational talks to thousands of school children per year and the proximity to universities and significance of resources allows for a number of outside research projects.

Challenging issues confront AISP. Foremost is to provide greater access while still protecting the park's resources. Park staff have identified critical habitat which is inappropriate for access and development. Managing the

back country trail system is a particular challenge and management has instituted a program of area and time of use limitations. The park has an independent, outside Wildlife Committee to advise management on resource-based issues. The park is initiating social carrying capacity and wildlife protection studies in an attempt to quantify and safeguard the quality of visitor experience. Other significant issues facing the park include the potential development of a southern road access to the island, separation of waterfowl hunters from traditional park visitors, overflights from aircraft and increasing visitation and use.

Davis County Causeway
(Davis County)

In return for maintaining the causeway from Syracuse to Antelope Island, the State of Utah deeded the roadway to Davis County. Davis County now manages this causeway in cooperation with DPR. The Davis County Causeway is one of the most scenic drives around GSL, and is an outstanding birding area. The bike lanes provide one of the most popular cycling tours in northern Utah and, when combined with the new east side road on Antelope Island, offer a 36-mile round trip. Davis County has developed a trail head parking lot for cyclists and other areas with interpretive information on GSL.

The primary issue facing the causeway is maintaining the roadway at high lake levels. The causeway was constructed at elevation 4208.75 feet. The causeway is essentially a toll road, and $7.00 per vehicle collected is by AISP. Of this $2.00 is returned to Davis County. Davis County utilizes these funds to maintain the causeway. There has also been some concern that the causeway restricts water flow from Farmington Bay to the south arm of the lake and inhibits brine exchange between the bay and the main body of the lake. This results in freshening of Farmington Bay relative to the rest of the lake. This issue is discussed more completely in the "Hydrology" section.

Southern Causeway
(KUC/Private)

This unpaved causeway fill was constructed to provide a transportation route for material to complete I-80 reconstruction and to stabilize the island access road. The southern causeway provides administrative access to the south end of AISP. Occasionally, a few private landowners allow recreational activities.

At the present time, DPR does not have plans for major improvements of the existing corridor. The division would support minimal development for management access for emergency ingress and egress as well as access for non-motorized (hiking, biking) use. The division supports "low-impact" use of the corridor because of the various recreational and wildlife viewing opportunities in the area.

While the development of an access road is feasible in terms of engineering and function, development of an enhanced causeway for general access to Antelope Island would entail expenditures that are beyond the division's current budgetary scope and priorities. Similarly, the current operations, maintenance and law enforcement resources necessary to effectively manage a developed causeway would be pressed beyond reasonable limits.

The division currently uses the corridor for emergency purposes such as fire control and search and rescue activities during low lake level years. The division is also responsible for ensuring access to various structures owned by the FAA on the island. In lieu of any development activities, the division will continue to maintain emergency and management access along the corridor.

Private Duck Clubs
(Private)

There are over 25 duck clubs around GSL. Duck club properties have been formed by private groups that acquired waterfowl habitat or lands that were developed into habitat. Many of these areas are intensively managed with extensive diking systems and water control structures that allow for optimum wetlands and foraging areas for birds. Many species of birds and other wildlife occupy these areas besides waterfowl. Some duck clubs have existed for over 50 years and they cumulatively have made a significant contribution to protecting and developing wetlands on and around the lake. Many duck clubs are adjacent to state and federal marshes and form a continuum of similar developments and habitat. There are 13 clubs on the south shore of GSL that total more than 16,791 acres of managed wetlands for waterfowl habitat (Dunstan and Martinson, 1995). All of the clubs are used for hunting by members only and use is regulated with bylaws. Members also utilize the areas for wildlife observation and nature study. Other opportunities include fishing, birdwatching, walking, bicycling, ice skating and photography. The primary goal of the clubs is to create high quality wetland habitat that is used by wildlife. These areas play a significant role for waterfowl during all parts of the year including hunting seasons. Hunter activity on duck club property is relatively less than on most publicly owned and used marshes. Therefore these areas become a daytime sanctuary for waterfowl feeding and resting. Many clubs only allow hunting on selected days during the week. The net effect provides for a mosaic of habitats available to waterfowl with varying degrees of security over the course of the hunting season.

Bear River Migratory Bird Refuge
(USFWS)

At 74,000 acres, BRMBR is considered one of the premier birding sites in the nation. Given the refuge's beautiful scenic background, isolated nature and sheer abundance of water birds, its complex of freshwater impoundments has long attracted birders from around the country and is one of the best places to experience the freshwater marshes of GSL. The refuge is recognized internationally and was integral to GSL's designation as a Western Hemispheric Shorebird Reserve. The refuge is also one of the finest waterfowl hunting areas in Utah. Currently the refuge is visited by 36,000 people annually, with 11,660 being waterfowl hunters. In addition, annual visitation includes 21,000 auto tour route visits, 1,155 fishermen and 2,185 others (Bull, 1998).

The refuge was damaged extensively during the 1980s flooding, and has been being rebuilt ever since. Currently the refuge offers a 12-mile scenic drive that is popular for birding and bicycling, interpretive information, an air boat ramp that is open during hunting season and expanded access during hunting season. Fishing is allowed in the Bear River

channel. USFWS is developing plans for a visitor center to be constructed near Brigham City. This visitor center will dramatically expand interpretation opportunities of GSL's concentration of water birds. The visitor center is scheduled for completion by 2002. Currently the refuge offers educational tours by reservation. Management is working on a plan that will allow expanded fishing access, foot trails and a short canoe trip.

Given USFWS's dual mandate of protecting migrating birds and providing opportunities for hunting, the refuge follows a management mandate practiced throughout the agency. That is, 60 percent of the refuge is closed, 20 percent is open throughout the year and an additional 20 percent is opened only during hunting season.

Issues facing BRMBR include; safeguarding a dependable freshwater flow throughout the year, balancing hunting with birding, protection from industrial encroachment along the southern boundary and utilizing sovereign lands for refuge expansion.

Great Salt Lake Marina
(DPR)

The GSL Marina is the most popular launching and mooring site on the lake. The marina is a highly developed, attractive and safe mooring site for approximately 300 sailboats. Given the marina's proximity to Salt Lake City and level of development it is generally filled to capacity. The marina also provides access to the lake for boaters who do not moor their vessels at the site. Two tour boats operate occasionally on the lake—one based at Antelope Island and the other at the GSL Marina. The park staff offers educational talks by reservation. Visitation to GSL Marina in 1997 is estimated at 461,000.

Saltair/South Shore
(DFFSL)

This recreational complex consists of south shore beach areas and the Saltair Resort. It offers access to the lake and has an attractive visual impact, with its open expanse, islands and beautiful sunsets. Birding opportunities are also significant. Saltair Resort provides interpretive information, food, souvenirs, an historic site and special events ranging from concerts to beach festivals. This site provides the quickest and easiest access to the lake from downtown Salt Lake City. The entire South Shore Beach area and the marina were managed by DPR as GSL State Park. Management of the South Shore Beach Area was returned to DFFSL in 1997. At that time, over 600,000 people visited GSL State Park.

There are a number of challenges inherent to the site including fluctuating water levels, odors and proximity to the Kennecott Copper Smelter.

Farmington Bay Waterfowl Management Area
(DWR)

This 17,916-acre management area is one of the most popular waterfowl hunting areas in Utah and also is an outstanding birding area. Farmington Bay WMA is unique in that it provides important wetland habitat and wildlife-based recreation close to an urban area. The management area is also one of the best places to observe the freshwater interface with GSL. DWR manages their WMAs

to provide habitat for water-dependent birds.

Currently the Farmington Bay WMA receives 48,644 visitors annually. Of this, 20,644 are waterfowl hunters and the rest are birding or other recreationists. Staff has identified March 1 through August 1 as a critical wildlife production period. During the critical production period, a 1.5-mile road is opened, with an overlook and interpretive signing and an additional 2.5 miles is opened for non-motorized use. During the non-critical production period another 26 miles of dikes are opened to non-motorized use. An air boat ramp is opened from two weeks prior to hunting season through the hunting season. DWR is pursuing funding for enhanced visitor use development, possibly including a visitor center on the north end of the management area to enhance lake-wide interpretive and education efforts.

A number of critical issues confront the Farmington Bay WMA. These include potential impacts from the proposed Legacy Parkway, maintaining adequate water supply and water quality from the Jordan River, flooding from GSL and urban development on the boundary of the management area.

Ogden Bay Waterfowl Management Area
(DWR)

Ogden Bay WMA is over 21,000 acres and is the largest WMA in the state. Besides being a tremendous waterfowl production and habitat area, it also contributes significantly to recreation around GSL. The area hosts 70,000 visitor days per year, 28,000 of those days represent hunters during the fall waterfowl season. A portion of the area is open year around for hosted organized group tours, appointments must be made with the Area Superintendent. From April 1 until September 1, the area is closed to general public use to protect wildlife habitat values. During the balance of the year, some portions of the area are open for wildlife viewing and hunting is allowed during the prescribed seasons. There are approximately 45 miles of dikes that control water, one air boat launch that allows access to the Ogden Bay portion of GSL and several small boat ramps that allow access to interior ponds of the management area.

Water control is a critical issue at Ogden Bay WMA. The area is vulnerable to flooding, both from the Weber River and GSL. Ogden Bay is one of the oldest WMAs in Utah and has senior water rights.

Howard Slough Waterfowl Management Area
(DWR)

Howard Slough WMA is located along the Great Salt Lake shoreline between the south boundary of Ogden Bay WMA and the Davis County Causeway to Antelope Island. The area was created in 1958 to utilize irrigation water return flow to create an impounded marsh and wetlands of more than 3,500 acres. This relatively small area hosts up to 11 percent of all waterfowl hunter days in Utah. There are approximately 11,000 visitor days annually, which includes both wildlife watchers and hunters. Exact figures are difficult to establish because the manager of this area resides at Ogden Bay. The area is closed from April 1 until September 1 for general public use to protect wildlife habitat values. Different

portions of the area are open during the balance of the year for wildlife watching and hunting during the prescribed seasons. There are approximately 7.5 miles of dikes and roadways that provide pathways for access. There are several small boat ramps that provide access to interior ponds.

Most of the ponds have dikes that front the Great Salt Lake shoreline. At current lake elevations of 4203.5 feet, these dikes are being destroyed by wave action and over-topped by salt water from the lake. This saline intrusion kills the aquatic vegetation within the interior ponds resulting in diminished wildlife habitat values.

Stansbury Island
(BLM/Private)

Only a small area on the south end of Stansbury Island is opened to the public and readily accessible. Development consists of an access road and a nine-mile trail open for non-motorized use. Stansbury Island is comprised of some of the most striking rock formations surrounding GSL. The island's vistas of the lake, mountain ranges and islands are dramatic. Currently the south end of Stansbury Island is utilized for dispersed recreation including the non-motorized trail, camping, some OHV use and chukar hunting.

There has been a great deal of local interest in securing greater public access to Stansbury Island, for both motorized and non-motorized recreation. Given the island's size, location and resources, greater public access would significantly expand recreational opportunities surrounding GSL. The legality of the west side road closure is uncertain. BLM has been striving to secure greater public access to Stansbury Island. The greatest challenge will be to secure greater public access from private land owners and then appropriately manage that visitation if made accessible.

Locomotive Springs Waterfowl Management Area
(DWR)

Locomotive Springs WMA is an isolated wetland at the north end of GSL. This 17,317 acre WMA is an oasis for wildlife in the middle of the West Desert. Currently, the staff is able to flood approximately 1,200 acres and the rest of the area is comprised of playas and upland habitat. Locomotive Springs provides year around fishing and primitive camping. Public access is limited to three miles of roads. During hunting season the entire WMA is accessible. Locomotive Springs receives approximately 6,000 visitors a year, of which 5,000 are hunters and fisherman. Future plans include expanding the WMA by 2,600 acres to include protection of playas which are Snowy plover habitat. The critical issue at Locomotive Springs WMA is the diminished flows from the springs.

Timpie Springs Waterfowl Management Area
(DWR)

Timpie Springs WMA is a 1,440 wetland located near the southwest corner of the lake. Timpie Springs WMA contains two water impoundments, 3.5 miles of dikes, a half mile road, parking lot and some information signs. Timpie Springs has around 400 annual visitors of which approximately 300 are waterfowl hunters. Critical issues at Timpie Springs

WMA include adjacent land use water allocation and management.

Monument Point
(BLM/DFFSL)

This area offers one of the few OHV riding opportunities in proximity to GSL. The Monument Point area offers pedestrian access to the north arm of the lake, a stunning vista of the lake at its most remote reaches and nearby interesting historic sites. BLM has worked towards developing trail opportunities in this area and has added interpretive information. BLM is concerned with OHV access to the wetlands of Salt Wells Flat and has identified this as an "Area of Critical Environmental Concern." The key challenge is managing a growing level of dispersed recreation in a remote area. Another challenge is that a large portion of OHV use occurs on private land. BLM is also concerned with OHV use in the wetlands between Locomotive Springs and Crocodile Mountain. BLM is interested in securing a land trade that would allow the agency to develop a recreation area.

Rozel Point
(DFFSL)

The Spiral Jetty is a famous international work of art. It is an "earthwork sculpture" on sovereign land off Rozel Point in the north arm of GSL. The jetty was constructed in 1970 by Robert Smithson. In the years following its creation it received a wealth of publicity in the national press, photographs in every major art periodical, in surveys of 20th century art and magazines of more general circulation. The Spiral Jetty is among the classics of modern sculpture and has been viewed by many international visitors. (See Appendix B, SULA 889.)

Rozel Point is also one of the few access points to the north arm of the lake. Access is through the Golden Spike National Historic Site and visitors can obtain a map at the visitor center. There are no facilities at Rozel Point and the site has suffered from unauthorized dumping and construction which detracts from the beauty of the location. DFFSL is working to clean up the site.

Layton Wetlands Preserve
(TNC)

The Layton Wetlands Preserve protects approximately 2,000 acres of shoreline and upland habitat. One of the goals of the preserve is to protect upland habitat to buffer state sovereign lands below the preserve. TNC staff strive to facilitate research and can provide educational tours by appointment. There is year-around, non-motorized access to the preserve at the Gailey Access in Layton. TNC is working with URMCC to develop education programs and interpretive signs at the preserve. As part of their planning process, TNC hopes to provide greater recreational access, but stipulates that their primary mission at the preserve is to protect wetlands. The preserve plan will continue to guarantee hunting access.

Critical issues facing the preserve include potential impacts from the proposed Legacy Parkway, the development of agricultural lands for residential housing and maintaining water quality and flow to the preserve.

Inland Sea Shorebird Reserve
(KUC)

This 4,500 acre reserve was developed by KUC to mitigate for the tailings modernization and expansion project. The reserve features a relatively large contiguous acreage to provide nesting and resting habitat for migratory shorebirds and waterfowl. The reserve utilizes brackish water with mudflats and marshes to maximize invertebrate populations as food sources for birds.

Currently there is no public access to the reserve, though staff provides educational tours by appointment. Once mitigation has proven successful and COE accepts the mitigation results (scheduled for 2002), Kennecott could potentially open the reserve for greater public access. The most significant issue to the Inland Sea Shorebird Reserve would be encroachment from a potential southern road access to Antelope Island.

Gillmor Wildlife Sanctuary
(National Audubon Society)

This 1,425 acre sanctuary was donated to the National Audubon Society to preserve the natural ecosystem of GSL. The Audubon Society places value on all components, both biotic and abiotic, of the ecosystem. The sanctuary is comprised of a variety of habitats, from open water to playas and upland areas. It is situated on the former Jordan River Delta, which is considered to be the best preserved river delta on GSL.

The Audubon Society is working with URMCC to develop a hydrological engineering plan to restore water to the natural waterways of the Jordan River Delta. The plan will encompass the South Shore Wetland Ecological Reserve, which is comprised of the Gillmor Wildlife Sanctuary and parcels of land owned by several other private land owners. Currently, public access is not available to the sanctuary as it is surrounded by private land. The National Audubon Society is working on a management plan that will address the public access issue. The most significant issue facing the Gillmor Wildlife Sanctuary is a potential southern road access to Antelope Island.

Promontory Point
(Private)

Promontory Point offers a striking vista and is the only location that could provide access to both the south and north arms of GSL. The site is currently accessible via a public road, but the surrounding lands are almost exclusively in private ownership. There has been interest in acquiring greater public access to this interesting location. Multiple private land owners surrounding this site will make any expansion of public access difficult.

Willard Bay State Park
(DPR)

Willard Bay Reservoir is a U.S. Bureau of Reclamation project which provides water for irrigation, M&I use, flood control, recreation, fish and wildlife purposes. The dike that separates Willard Bay from GSL is 36 feet high and 14.5 miles long. When the reservoir is full, it exceeds the elevation of GSL. When reservoir water levels are low, GSL's old shoreline is exposed on the south and southeast side of the reservoir. DPR manages the recreation resources and

facilities, and DWR manages the fish and wildlife.

Visitation to Willard Bay State Park in 1997 was 276,059. This level of use is causing some user conflicts and degradation of the park facilities. The first phase of a Bureau of Reclamation-sponsored Resource Management Plan (RMP) has been completed. Major renovation of facilities will begin in the spring of 2000. The RMP effort will identify management goals and objectives for the reservoir. Some important issues which have emerged include improving coordination with other entities, resolving user conflicts and expanding educational and interpretive opportunities. Water quality, management of concession services, visitor needs for additional recreational facilities to reduce congestion, improved safety and resource protection are other issues to be addressed in the RMP.

Recreational Activities on Great Salt Lake

Most of the recreation that occurs on GSL is dispersed in nature and visitor counts are not well quantified.

Navigation

The navigability of GSL, which is a key component of establishing state ownership under the Equal Footing Doctrine, was challenged by the Justice Department early in the contest over ownership. This challenge was based on the theory that the shore lands were remote, and in most places along the shore the water was so shallow that it would be impracticable to construct facilities for meaningful navigation on the lake. Utah was successful in proving that, both before and after statehood, the lake had been used for a variety of navigational purposes (Utah Geological and Mineral Survey, 1980). Historical navigation includes watercraft use during construction of the Lucin Cutoff (the original northern railroad trestle and earth-fill), and tour boating during the heyday of resort development on GSL. Present navigation includes recreational sailboating, most of which occurs within six miles of the two marinas operated by DPR, a small tour boat which occasionally operates out of the Antelope Island Marina, commercial brine shrimp harvesting, salvage of the old railroad trestle, air boating, some power boating and law enforcement. Brine shrimp sampling, water quality monitoring and lake bottom measurements collected by the state and extraction industries along with search and rescue activities require boat access.

Two box culverts in the northern railroad causeway between Little Mountain, Promontory Point and Lakeside initially allowed small watercraft to pass between the north and south arms of the lake through the causeway under certain lake levels. The culverts are no longer useful for this purpose. The breach near the west end of the causeway is not generally deep enough for navigation by deep bottomed craft. However, during 1997-98 numerous large brine shrimp harvesting boats navigated through the breach. Some crafts as long as 44 feet, 14 feet wide and less than 2.5 feet draft successfully navigated through this opening.

In addition to the constraints associated with the causeway, navigation on the north arm is limited by the lack of launch and harbor facilities. Islands in the north

arm provide critical bird nesting sites. Development of facilities to accommodate north arm navigation would have to be planned carefully to minimize encroachment or visitation to the very sensitive nesting colonies.

Boating

There are two public boat ramps open year-around on the south arm; GSL Marina and Antelope Island. Both of these marinas offer safe mooring sites and are developed. These marinas are utilized almost exclusively by sailboats. GSL Marina sponsors a large number of sailing races and festivals in conjunction with the Great Salt Lake Yacht Club. Motor boating is feasible but not popular. The corrosive nature of high salinity in the lake demands extra care and rinsing of engines and equipment. Navigation in the lake demands a high level of expertise; there is no fishing, and water skiing is not popular. These factors have prevented GSL from becoming very popular for motor boating. Approximately 300 sailboats are moored at the GSL Marina and an additional 25 at the Antelope Island Marina.

Farmington Bay WMA has the only public boat ramp in Farmington Bay. This ramp is suitable for air boats and small vessels only. The ramp is open from two weeks prior to hunting season through hunting season. Ogden Bay WMA, BRMBR, Bear River Bay and Willard Spur all have boat ramps suitable for small vessels and air boats. The north arm does not have a public boat ramp.

Non-Motorized Recreation

AISP has an extensive back country trail system (20 miles) that will be expanding significantly in the coming years. Currently, nearly 10,000 people a year utilize the Antelope Island back country trail system. Stansbury Island has a nine-mile trail. DWR WMAs have extensive dike systems open for cycling. BRMBR has a 12-mile graveled auto tour open for cycling. The Davis County Causeway is seven miles long with bike lanes in both directions.

Camping

The developed campgrounds of Antelope Island are used by approximately 25,000 campers per year. There are 26 individual and five group camping sites at AISP. There is dispersed camping on BLM lands on Stansbury Island and in the area of Monument Point. Locomotive Springs WMA also allows camping.

Off-Highway Vehicles

Many of the public roads along the north and west sides of GSL in Box Elder County are open to OHV use. Sovereign lands surrounding GSL are not open to recreational use by OHVs. Through participation on the West Box Elder Access Management Team, DFFSL is considering the opening of limited sovereign lands to OHV use in the vicinity of Kelton.

Birdwatching

GSL is one the most renowned birding areas in the United States. Nearly all the recreation areas identified above have outstanding opportunities for birding.

Hunting

GSL is the most important waterfowl hunting area in Utah. It is estimated that

63 percent of Utah's total waterfowl hunting occurs at GSL, with 80-85 percent of all waterfowl harvested in Utah coming from the GSL area. The state WMAs and parts of the BRMBR were purchased and are maintained by revenues and taxes from hunting. The state WMAs, BRMBR, sovereign lands and many private lands are open for hunting. The estimated number of waterfowl hunters utilizing GSL and environs in 1996 was 22,700. The estimated number of hunter days on state-managed areas around the lake in 1996 was 53,700 (Aldrich, 1998).

Sightseeing (auto tours)

AISP and the Davis County Causeway combined offer a 42-mile round trip auto tour. BRMBR has a 12-mile auto tour. The Monument Point area and surrounding lands have many miles of remote dirt roads for auto touring. The lack of a public thoroughfare between Lakeside and Hogup Ridge on the lake's western shore precludes circumnavigation of the lake by automobile.

The impacts to the existing transportation facilities at GSL are discussed in other sections of this statement, including "Water-Chemistry." Access to and on sovereign lands is discussed in the sections which addresses the uses for which access is provided.

Interpretive and Educational Opportunities at Great Salt Lake

Interpretive and educational programs have been significantly enhanced in recent years. AISP has developed a visitor center on Lady Finger Point. The Garr Ranch is scheduled to open in 2000. The park has added wayside exhibits, nature trails and educational tours. The Salt Lake Convention and Visitors Bureau is opening a visitor center focusing on GSL. The visitor center will be located at the 7200 west exit on I-80. The bureau plans to add an observation deck and nature trails in the ensuing years.

BRMBR breaks ground on a new visitor center in 1999. Completion is scheduled for 2002. Farmington Bay WMA is initiating an effort to significantly expand interpretive development and visitor services for their north end.

URMCC completed a *Needs Assessment and Conceptual Plan for Interpretive Recreation and Education for the Greater Great Salt Lake Wetlands Ecosystem* (1995). One of the commission's key objectives of the plan is to: "Create an umbrella concept under which all local projects play a role; the entire scheme should be a nonrepetitive delivery of messages, each site carrying appropriate messages for that site and complementing efforts at other sites, thereby encouraging people to visit another location." To begin implementing this objective, the URMCC, in cooperation with DWR, is developing a "Wetlands Ecosystem Education Plan," which should be completed in the year 2000. A master plan should be completed by June 2000.

Layton Wetland Preserve is working on a plan to implement an interpretive program at the preserve. Most of the GSL attractions offer educational tours by reservation or appointment. Friends of Great Salt Lake has a hour long interpretive slide show, called *The Lake*

Affect, Living on the Shores of Something Great, and outreach programs designed to educate people about lake resources and issues.

The MLP for GSL specifies DFFSL will work with mineral lessees to provide interpretive displays of mineral development sites with particular emphasis on contributions to Utah's economy and recognizing effective mitigation efforts on the lake.

Cultural Resources on Great Salt Lake

Human activity in the region has been drawn to the lake shore for thousands of years. Prehistoric archaeological sites have been documented in and adjacent to lake wetlands. Several of the oldest documented cultural sites in the mainland U.S., Danger and Hogup Caves, are in the lake environment.

Jim Bridger is credited with the Anglo discovery of the lake. The lake was the focus of early mountain man expeditions, government expeditions and wagon trains which crossed close to the shore, sometimes with ill-fated results. With the arrival of the Mormon pioneers, resorts and other economic enterprises sprang up along the lake shore.

Cultural resources of GSL have been the subject of much research, primarily by agencies and institutions external to DNR. State agencies are required to consult with the Division of State History prior to the initiation of any project which may disturb cultural resources.

Prehistoric Resources

Use of GSL wetlands started with Paleoindian cultures as long as 10,000 years ago. Cultures primarily utilized areas immediately adjacent to wetlands. Paleoindian and later Archaic cultures utilized areas adjacent to wetlands for thousand of years. The Fremont Culture which flourished in the GSL valley from 500-2,000 years ago built permanent villages along the wetland margins. The Fremont, Paleoindian and Archaic groups hunted and gathered in the wetland ecosystem. The Fremont added farming corn, beans and squash to their subsistence base. Fremont remains are found connected to nearly every wetland around the lake. Subsequent cultures, the late prehistoric and historical tribes, also made extensive use of GSL wetlands. Today, there are nearly 400,000 acres of wetlands on GSL. Several hundred Native American archaeological sites have been identified in GSL wetlands.

Well known sites such as Danger Cave and Hogup Cave are situated near wetlands of former Lake Bonneville. Cultural deposits along GSL have supplied valuable information about prehistoric cultures. Currently, most protection of cultural resources is done through state and federal agencies, to ensure development complies with state and federal law. Cultural deposits in GSL wetlands can be difficult to locate as they are usually buried under the surface or obscured by vegetation. Often erosional events, such as wave action associated with high lake levels, expose previously buried archaeological sites and, in the past, Native American human burials have been exposed..

The most immediate threat to prehistoric cultural resources is construction activity

adjacent to the east side of the lake, such as the proposed Legacy Parkway. The Division of State History is confident that when surveying and construction is undertaken in these areas, numerous Fremont camp sites and human burials will be discovered in affected wetlands. This will necessitate archaeological surveys and compliance with the Native American Graves Protection and Repatriation Act (NAGPRA). If these human remains are treated in the same manner as those which were exposed after the 1980s floods, they will be deposited in the Native American Remains vault at This Is The Place State Park.

Unique prehistoric and historical cultural resources of significance have been identified on Fremont Island. Prehistoric sites including rock art have been discovered on Stansbury Island. Antelope Island contains prehistoric sites, and active cultural surveying will continue. Cultural resource management on state lands along the east shore is conducted on a case-by-case basis as projects are undertaken or discoveries made. It has been suggested by some archeologists that the state conduct regular monitoring of sensitive areas.

Historical Resources

More recent cultural deposits contain a record of Anglo activities on and around GSL. The islands of the lake were the focus of several early survey and exploration parties. Explorers such as Christopher "Kit" Carson, Howard Stansbury, John C. Fremont and others left marks on these islands in the form of camp sites, survey stations and markers, temporary dwellings and graffiti. Others left no physical mark, but their presence has been well documented. An old mountaineer named Daddy Stump is documented as having a small homestead on Antelope Island, perhaps prior to the Mormon arrival in the valley. Today, there are no remains of this homestead. Similarly, around the shores of GSL, early settlers left remains of varying permanence. The Garr Ranch and George Frary homestead on Antelope Island are significant sites that will be open to the public in 2000. The old Saltair Resort and the remnants of a handful of other historical resorts are located on sovereign lands.

Many of the cultural resources around GSL, both historical and prehistoric, are located on private property. These land owners are under no obligation to protect or conserve the cultural resources on their property, however, human remains on private lands are protected under state law. Many of these land owners are unaware that such resources are found on their property, or that these resources have scientific or academic value. Cultural remains which are located on state or federal lands are protected by state and federal law. Sometimes an archaeological survey must be conducted. These statutes apply to any cultural remains which are older than 50 years.

Sociological Trends

There has never been a study to predict visitation to GSL as a whole. A study performed at AISP indicated that population growth is the number one factor driving increased visitation to sites. Population growth within Utah, and particularly on the Wasatch Front, will create a comparable proportional increase in the Utah resident component

of visitation to GSL recreation sites. The Governor's Office of Planning and Budget (GOPB) estimates population along the Wasatch Front will grow at 2.1 percent annually in the ensuing years. Therefore, one can predict a base visitation increase of 2.1 percent annually to GSL recreation sites. Any development at the individual recreation sites will further expand visitation.

Out-of-state tourism is very difficult to predict as it is dependent on a number of variables. Several of these variables include level of development, tourism promotion and local amenities. Utah state park visitation data indicates 33 percent of visitation to AISP and the old Great Salt Lake State Park is from out-of-state. The Utah Travel Council indicates that traffic through SLCIA has grown steadily at an average of 9 percent per year. State and local tourism agencies and the private tourism industry will continue to promote area attractions. The 2002 Olympic Games may have a significant and lasting influence on tourism to GSL. It is safe to project a growing number of out-of-state tourists to GSL attractions, particularly to sites of national significance or easy access from the interstates.

Non-traditional Resources

Recreation and Tourism

A portion of nontraditional resources on GSL are recreational (and to some degree tourist) in nature and are those activities like wildlife viewing, boating, hiking, and hunting and fishing. It goes without saying that GSL represents one of the premier recreational sites in the state of Utah. Moreover, GSL is one of the top areas in the western U.S. for bird watching enthusiasts. Given these unsurpassed opportunities, the nontraditional resources found at GSL are important to consider and study.

Some of the bigger attractions on GSL are Antelope Island State Park, Bear River Migratory Bird Refuge (BRMBR), GSL Marina, and Willard Bay. It is interesting to note that each one has different users. Sailing is popular at GSL Marina, bird watching at BRMBR, hiking, biking, and day picnics at Antelope Island, and boating and fishing at Willard Bay. Additionally, duck hunting is extremely popular on GSL, accounting for 60% to 65% of the waterfowl hunting days in the state and about 80% of the total ducks bagged in Utah, according to state waterfowl managers.

The significance of recreation and tourism extends beyond the activities themselves, for they also translate into economic activity, or spending. Obtaining true amounts of spending are for the most part difficult. In the case of direct fees or charges, like the fee to use the Davis County Causeway or the fee to moor a boat at the GSL Marina, valuation is simple: number of visitor units multiplied by the fee or charge. From this point, however, valuation becomes more complex and less objective. There are existing models that provide estimates for the amount of money spent per hunter day or spent by a typical angler. Data of this kind can be found in sources like the U.S. Fish and Wildlife Service's *National Survey of Fishing, Hunting, and Wildlife-Associated Recreation* for Utah, which provides proxy data for expenditures spent on such activities. However, these figures may be subject to scrutiny,

because they are sometimes regional estimates and therefore may not reflect the "true" amount of spending for a particular city or county. Moreover, it is often argued that if one particular area is closed, resident visitors will just shift their attention to another recreation area within the state. Thus, the state's aggregate spending associated with non-consumptive use remains the same; a dollar spent at a state park is a dollar spent regardless of which state park collects the dollar.

Clearly, however, the argument above ignores the effect felt by communities surrounding GSL should recreation and tourism shift from GSL to other attractions. Further, for some of the activities suitable replacement sites may not exist. For instance, GSL bird watching is truly unique. It is also debatable whether the state's other waterfowl hunting sites could fully absorb all the duck hunters that typically use GSL. Therefore, GSL should be respected for its rich, diverse recreational and tourist resources and that these opportunities are truly a treasure for Utah's citizens and out-of-state visitors.

Even more problematic is the method of valuation used to place a price on the loss of a physical system. Rhetorically the question is posed, how should one assign a value to losing a wetlands area or marshland? Since physical systems rarely contribute tangible goods or services to the economy (excluding agriculture), their valuation must be measured in something other than production costs and revenues. Measures can be made in terms of the spending or expenditures associated with the recreational uses. However, this only considers one dimension of the equation. The actual loss of an area or system must be accounted for in and of itself, which is a problem encountered by natural resource economists. Although the planning team would prefer to have estimations on the value of GSL marshes, wetlands, and other sub-ecosystems, to do so required resources beyond our means. Therefore, we assume the value and the health of GSL ecosystem(s) is (are) paramount and hope that future methodologies may develop to assist in this type of analysis.

Additional nontraditional resources stem from the non-market goods and services associated with GSL. This class of nontraditional resources is exemplified by the natural functions performed by GSL, such as soil formation, flood and erosion control, biological control of waste and detritus, climate regulation, and education. These functions have both qualitative and quantitative aspects. Regarding the former, the lake and its environs contribute to the quality of life along the Wasatch Front because the lake performs such functions without people having to pay for them. Additionally, people enjoy living near the lake and the physical and aesthetic amenities it offers. The lake is also a source of distinction and opportunity unsurpassed in the region. The quantitative aspect of these functions is more problematic to determine. In the event that humans had to mimic such functions the cost to do so would be very large. Moreover, some natural functions like climate regulation could not be supplanted via human means. Imagine trying to duplicate the "lake effect" on snow storms; Wasatch Front ski areas would be hard pressed to implement snow making equipment that could do so. In the absence of a rigorous, long-term research analysis to put a value on the natural services offered by GSL, we can only conclude that they are priceless.

DNR has not been responsible for some of the non-traditional resources of the lake such as eco-tourism, opportunities for world class research concerning climate change, cultural resources and geo-antiquities. These resources are non-economic and constituencies that advocate the development or preservation of these resources expect DNR to manage these resources. These resources have poorly defined economic values and are poorly inventoried and understood. Cultural resources have been protected by law and are valued by society even though they have limited economic value. (SRC, unpub.)

Eco-tourism

Eco-tourism is becoming an important resource value (SRC, unpub.). DWR, URMCC and USU Extension Services are currently designing GSL eco-tourism opportunities. Davis County promotes GSL wetlands, birds and Antelope Island State Park as an eco-tourism resource. A Bird Festival in Davis County was held in1999 and was considered a success first year event. The county also sells t-shirts and other souvenirs in local stores. Brigham City, is proud that it is the gateway to the Bear River Migratory Bird Refuge which also hosts a large bird event each year. Generally, eco-tourism is a new resource value, and is currently underdeveloped as an economically productive non-traditional GSL resource. Eco-tourism is becoming an important management consideration as new opportunities are developed and public awareness increases, GSL resources will increase in social value and economic potential.(SRC, unpub.)

World Class Research Opportunities

Rapid urbanization and population growth is destroying the unusually rich record of earth history preserved in lake sediments. GSL and its environs has one of the best preserved and easily accessible earth systems history of lake processes in the world as well as a complete climate record extending back several thousand years. Urbanization and development within the flood plain (lakebed) has destroyed this record at an alarming and accelerating rate. Climatic change is relatively well-funded field. GSL offers one of the best historians of climate change and Utah higher learning institutions have a great opportunity to contribute to climate change research. (SRC, unpub.)

Great Salt Lake Educational Resources

Educational resources are recognized by state universities and other educational professionals, Natural History Museum, Utah Society for Environmental Education, Friends of Great Salt Lake, Great Salt Lake Coalition, The Nature Conservancy, National Audubon Society and others. GSL and its environs provide an excellent field educational opportunity for Utah's school children. The complexity and the dynamics of the lake's hydrology, chemistry, geology and biology provide outstanding opportunities to teach several subjects from kindergarten through high school. Service learning is a new way to teach science subjects at universities and GSL provide many hands-on opportunities. An outdoor classroom provides an effective setting for learning. GSL is an important educational resource and planners and

managers benefit from a better understanding of the lakes resources. (SRC, unpub.)

Lake Influences on Local Climate

The size of the lake and its salinity play a role in the locate climate of the Wasatch Front. A variety of dynamic feedback mechanism exist between weather and climate systems and any large lake. The "lake effect" occurs when relatively warm lake water enhances the moisture content of storm systems. This produces heavy precipitation which is deposited on the leeward side of the lake. GSL has a very steep mountain range also on the leeward side of the lake. Orographic precipitation occurs when air masses move over topographic barriers such as mountain ranges and cool due to increasing elevation and temperature. Exceptional skiing conditions are a result of this geographic coincidence of a large lake located upwind of a steep mountain front. The "lake effect" plays a significant role in the economic benefits of Utah's ski industry.(SRC, unpub.)

The size and salinity of the lake intensifies lake effect storms. High salinity levels can significantly retard the amount of water. The saturation vapor pressure of GSL brines are near saturation (NaCl) is approximately 60 percent of fresh water (Dickson et al., 1965).

A variety of scientific studies have been undertaken regarding the importance of the GSL on local climate. The most recent scientific summary is Carpenter (1993). The University of Utah is also conducting an intensive study of region weather and climatology associated with GSL. There is also information regarding local wind patterns over the lake (Wasatch Front Regional Council, 1980). As is the case with any water body, surface winds tend to have a divergent pattern near the lake in response to terrestrial heating during the day and this pattern is reversed when land masses cool at night (Wasatch Front Regional Council, 1980).

The sovereign lands and resources of GSL are utilized for a variety of commercial, industrial and agricultural purposes. The most extensive use, mineral salt extraction from the lake's brines, is discussed separately under the "Minerals and Hydrocarbons" section of this statement. The second most extensive in terms of numbers of employees involved and the value of products produced is brine shrimp harvesting, which is discussed here. Other existing uses include recreation-oriented commercial concessions (Saltair and Antelope Island), industrial uses (Thiokol), military uses (USAF), art (the Spiral Jetty) and grazing. (See Appendix B.)

The economic significance of commercial and industrial activities which are dependent on sovereign lands and resources is substantial. The direct economic benefits of extractive industries are discussed in the section on minerals and hydrocarbons, and brine shrimping is discussed here. Indirect benefits also accrue. It has been estimated that there are at least 1,304 jobs provided by minerals extraction and brine shrimp harvesting on the lake. Of these, 1,127 are employees in the mineral extraction industry and 177 are employees in the brine shrimp industry. Data for all companies is not available, so 1,127 should be considered a minimum number of jobs (Hall, 1999).

The planning process disclosed interest in three broad areas of commercial and industrial activity on sovereign lands of GSL:

- **Existing levels and types of commercial and industrial activities on GSL (appropriate balance of statutory and administrative charges) must be considered.**
- **Policies with regard to future commercial and industrial activities (brine shrimp harbors and unauthorized construction) need to be addressed.**
- **Future studies of the nonmarket value of lake resources could be conducted. This would require additional time, staff and funding. The results would be an evaluation of all lake resources, not just those with obvious economic value.**

Brine Shrimp Harvesting on Great Salt Lake

Industry Overview

The presence of brine shrimp in GSL is noted as early as 1900 even though at that time, the "popular literature of the day persists in asserting that no living thing exists or can exist in the dense brine of the Great Salt Lake" (Talmage, 1900). Brine shrimp cysts are harvested from the lake's surface in the fall. The cysts, which are a form of egg, are used by commercial aquaculture operations around the world. Cysts are hatched, and the young brine shrimp are used as feed for fish and shrimp for human consumption. There are currently 32

companies permitted to harvest brine shrimp on GSL (Bath, 1998).

Brine shrimp cysts harvested from GSL provide a significant but declining proportion of the world's supply of cysts used for feeds for aquaculture and ornamental fish (Leonard, 1999). That market share has diminished because of recent low harvests from the lake. GSL cysts are known for their consistency, small nauplii (the young brine shrimp), low contamination and competitive price. The majority of cysts sold (80 percent) are used in Thailand, China, Indonesia and Ecuador in panaeid shrimp hatcheries. Panaeid shrimp are those cultivated for human consumption. The rest are consumed in shrimp operations in other parts of the world as well as by marine finfish, primarily in Europe, Korea, Japan, China and Taiwan (Newman, 1998). The following chart denotes harvesting trends from the 1985-1986 harvest season to the 1997-1998 harvest season. The harvest numbers are as reported by the harvest companies to DWR. (See Figure 15.) During the high waters years of the 1980s, harvesting occurred in the north arm. At that time, it was dilute enough to support brine shrimp. Note that many variables influence the total number of pounds harvested. These variables include (1) legal harvest season rules; (2) number of harvesters; (3) shrimp populations; (4) market demand; (5) processing, selling and inventory needs; and (6) area of the lake being harvested (Perschon, 1998).

Table 10.

Harvest Year	# of Companies	# of Certificates of Registration (COR)	Total Harvest (lbs.)*
1985-1986	4		298,035
1986-1987	4		1,887,300
1987-1988	4		7,012,775
1988-1989	9		6,806,415
1989-1990	12		10,268,232
1990-1991	11		8,927,818
1991-1992	11	26	13,532,797
1992-1993	12	20	10,172,399
1993-1994	12	18	8,864,092
1994-1995	14	25	6,485,954
1995-1996	21	63	14,749,596
1996-1997	32	79	14,679,498
1997-1998	32	79	6,113,695
1998-1999	32	79	4,606,352

*Denotes the total pounds (unprocessed) of biomass harvested that year as reported to DWR. (Biomass includes cysts, cyst shells, shrimp, brine fly pupal chambers, algae, etc.) (Perschon, 1998).

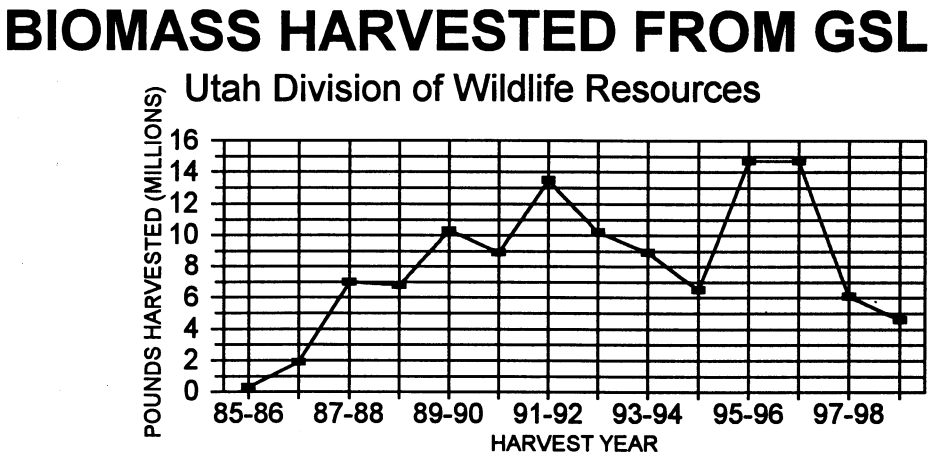


Figure 15 (Source: DWR)

"If the shrimps could be caught and preserved in quantity, I doubt not they would soon be classed as an epicurean delicacy" (Talmage, 1900). Although this prediction from James E. Talmage in 1900 did not turn out to be true for humans, brine shrimp have become an important food for aquacultured animals. Because brine shrimp cysts are sold primarily as a food source for aquaculture, it is important to note trends in the aquaculture industry as they directly affect the demand for cysts. The global production of fish, crustaceans and molluscs equaled 18.5 million metric tons in 1994, a figure 140 percent higher than the 1985 total. Asian production is the dominant proportion of global aquaculture production. The total value of all global aquaculture products in 1994 exceeded U.S. $33.5 billion (New, 1997).

As mentioned previously, the majority of brine shrimp cysts are sold to panaeid shrimp hatcheries. Panaeid shrimp can be aquacultured in either inland or marine environments (Perschon, 1998). Production of farmed marine shrimp increased by 332 percent from 1985 to 1994. Although output from freshwater crustacean culture only expanded by a factor of 1.5 from 1985 to 1994, production from freshwater prawn culture expanded by 252 percent (New, 1997).

Value of Production

A total of 109,798,606 pounds of biomass were harvested from GSL between 1985-98. In the 1997-98 harvest season, 6,113,695 pounds of biomass were harvested by 32 companies that hold 79 certificates of registration (CORs). DWR charges a registration fee of $10,000 per COR per year. More than one COR can be held by a company, and COR registration ranges from one to nine per company (Perschon, 1998).

As part of implementation of the regulations requiring payment of royalties on brine shrimp harvested, the Utah Tax Commission establishes a unit price for unprocessed brine shrimp eggs harvested during the current season to ascertain a royalty value. In the 1997-1998 season, the first year the royalty was imposed, the unit price equaled

$0.4453 per pound for raw, wet, unprocessed cysts. The Tax Commission also assumes that 40 percent of the biomass harvested is debris (dead shrimp, algae, bird feathers, floating wood, etc.) (Bath, 1998). Multiplying the assumed net weight of 3,668,217 lbs. by the unit value of $0.4453 yields a total value of $1,633,457 (in a raw, wet, unprocessed state).

The market value for the processed cysts is substantially higher than the estimated unit value of unprocessed cysts as determined by the Tax Commission. The market value of the cysts varies based on cyst quality (the percentage hatch rate), availability and other factors. It should be noted that processed cysts are a value-added product. The Tax Commission charges the royalty rate only for the resource being used, which it deems to be the unprocessed cyst (Bath, 1998).

The current value for processed cysts is hard to determine. Prices vary according to season sold, quality, global supply and demand. These variables and others create high price volatility. Estimates from two individuals involved in the brine shrimp industry for the average value per pound of the cysts in 1998 ranged from $7-$12. According to Bob Valentine, Utah Brine Shrimp Industry Council, the current value for processed cysts ranges from $5 per pound for low quality to $35-40 per pound for high quality with $7-8 per pound being average (Valentine, 1998). Don Leonard believes that $12 per pound is the average value for 1998 (Leonard, 1998).

According to representatives of the brine shrimp coalitions, at least 85 percent of the GSL cysts are processed in state (Valentine, 1998 and Leonard, 1998). Some Utah companies import cysts from outside the state for processing in Utah. Approximately half of the companies currently harvesting in GSL also process cysts. The other half sell the product for processing or maintain an interest in the final product value. In the latter case, the buyer gives the seller an up-front payment and then the two agree to an additional payment when the cysts are sold based on a percentage of the final sales revenues (Leonard, 1998).

Royalties

In 1997, the state decided that a royalty should be paid by the brine shrimp harvesters to compensate the state for the use of brine shrimp eggs.

> "It is the policy of the state that when its natural resources are used, a royalty should be paid to compensate the state for the use of the natural resource. The state receives royalties on minerals extracted from the GSL. A market has developed for brine shrimp eggs; therefore, the state should be compensated for the use of this natural resource" (Section 59-23-2, Utah Code).

The brine shrimp royalty equals 3.5 percent of the value of unprocessed brine shrimp eggs (Section 59-23, Utah Code). The Tax Commission annually determines the value of unprocessed brine shrimp eggs. All revenue generated by the brine shrimp royalty is deposited in the Species Protection Account. These funds can then be appropriated by the Legislature for actions to protect any plant or animal species identified as sensitive by the state or as threatened or endangered under the *Endangered Species Act of 1973*, U.S.C. 16, Sec. 1531 et seq. (Section 63-34-14, Utah Code).

According to brine shrimp harvesters, 40 percent of the total harvest consists of debris. The remaining 60 percent, which is referred to by the Tax Commission as "Net Weight," is multiplied by the unit price established by the Tax Commission for unprocessed brine shrimp eggs harvested during the current season to ascertain the royalty value. In the 1997-1998 season, the unit price equaled $0.4453 per pound. The royalty value is then multiplied by the royalty rate, which is equal to 3.5 percent. Brine shrimp harvesters paid $60,790.81 in royalties for the 1997-1998 season. It should be noted that since the statute regarding the royalty first came into effect in this season, the data reported by the companies regarding gross proceeds reflected only proceeds accrued as of January 31, 1998 (Bath, 1998).

Additional Research

More data on harvests and market price would be useful.

Access and Impacts

Commercial brine shrimping is regulated by DWR and the Wildlife Board to guard against over-harvesting and ensure compliance with operational rules. The shrimping season generally begins on October 1st of each year, and continues until January 31st of the following year by rule. However, the division may close the season early if it determines that the harvestable surplus of brine shrimp cysts has been collected. The 1998-99 season was closed early and the 1999-2000 season was delayed. A sufficient number of cysts are left unharvested to leave an overwintering supply to ensure a viable brine shrimp population in GSL the following spring, and to provide forage for birds. Ongoing research by the division is focused on developing a better understanding of the life cycles of, and environmental stressors on, brine shrimp.

The conduct of commercial brine shrimping requires both access to navigable harbors on the lake, an area for staging, maintenance and storage of materials. Current access is from both the public marina at Antelope Island and a number of privately constructed and operated harbors around the lake. The policy of DFFSL is that new harbor facilities constructed on sovereign land must be made available to all users. Current plans are to provide access to GSL at dispersed strategic locations where water depth is suitable, access is reasonably available and conflicts with other public trust resources are minimized. The south arm sites determined to satisfy these criteria are Black Rock, Stansbury Island/Magcorp dike, Lakeside, Promontory Point and Antelope Island. The Antelope Island marina will be available for commercial uses until DPR determines commercial use to be in significant conflict with recreational use of the marina, and that adequate alternative access for brine shrimping exists.

Permitting and Classification Processes

Land use authorizations issued by DFFSL include materials permits (usually sand and gravel), mineral leases, special use leases (classified as commercial, industrial, agricultural or recreational) easements, rights of entry, grazing permits, general permits and exchanges. Permits, leases and other authorizations are issued following two general

procedures. The first is over-the-counter transactions which are largely administerial in nature. Grazing, rights-of-entry and burning permits are examples. Other actions like easements, special use leases and exchanges trigger a site-specific planning process and the preparation of a record of decision.

In site-specific planning, the division provides notice that the process is under way to affected parties, usually adjoining landowners and lessees and permittees of record for the affected land, and to GOPB for inclusion in the Resource Development Coordinating Committee (RDCC) agenda packet and the weekly status report. In some cases notice in newspapers of general circulation in the local county is required. The division relies upon the RDCC process as the primary method through which the public is apprised of proposed actions and given the opportunity to provide comments to the division.

The division is required to respond to all commenting parties and give the rationale for acceptance or nonacceptance of the comments. Records of decision are subject to a 20-day review period. Within 20 days of any division action any party aggrieved by the action may petition the executive director of DNR to review the action for consistency with statutes, rules and policy.

The decision whether to issue any particular land use authorization includes consideration of the sovereign land classification for the affected land. If a proposed use is not consistent with the land classification, DFFSL would have to go through the plan amendment process specified in rule. This process requires public notification.

Agriculture

The only current agricultural use of sovereign lands is grazing. There are nine grazing permits on sovereign lands west of Kaysville and Layton, adjacent to the Layton-Kaysville marshes on Farmington Bay, and one permit in Bear River Bay. The permits cover 1,878 acres, and are held by landowners adjacent to sovereign lands who utilize sovereign land in conjunction with grazing on private land. Grazing use on sovereign lands is declining, perhaps due to the flooding of the late 1980s and current high lake water levels. The planning team identified the following resource concern:

- **Grazing management and permitting is a concern to be considered.**

Issuance of grazing permits by DFFSL is usually an over-the-counter land use authorization. In response to grazing permit applications for lands within the townships DWR is authorized to use for wildlife purposes, DFFSL consults DWR for inclusion of stipulations to address DWR's concerns. This usually takes the form of seasonal restrictions and a stipulation to allow early cancellation of the permit.

Notes:

Transportation

Existing transportation uses on sovereign lands include the northern and southern railroad causeways and portions of I-80 along the south shore of the lake. Both railroad causeways are located on easements granted by the predecessor to DFFSL or the Legislature for those purposes. Causeway easements vary in width between 200 and 2900 feet, and allow for construction, operation and maintenance of structures within the easement to support and facilitate the transportation uses. The Davis County Causeway is a county road right of way. The planning team identified the following resource concern:

- **Designation of roads, causeways and utility corridors needs to be considered.**

For information on proposals concerning transportation, refer to the southern causeway and inter-island diking sections of this document.

Notes:

Law Enforcement, Search and Rescue

Given that GSL is divided by causeways and under the jurisdiction of five counties, coordination of search and rescue operations is a key challenge. Coordination is accomplished through the local County Sheriff jurisdiction but more often through two or more counties, since emergency response usually covers more than one county on GSL. Every major search and rescue effort follows an established five county operational pre-plan for the lake. The purpose of the pre-plan is to bring together all agencies with search and rescue responsibilities. The objective is to coordinate search and rescue activities in a timely and professional manner with all five counties and DPR. Coordination is accomplished by inter-local agreements and a coordinating council comprised of representatives of each jurisdiction. A coordinated training effort is conducted at least yearly on the lake along with other meetings.

The planning team identified the following resource concerns:

- **Identify the meander line to enhance law enforcement.**
- **Access for search and rescue needs to be improved.**

Two state parks on GSL provide equipment and expertise for search and rescue: Saltair Marina provides 24-hour service with a 36 foot Boston Whaler, Antelope Island provides 24-hour service with a 25 and 27 foot Boston Whaler, an 18 foot air boat and 16 foot Pram. The initial information collected by agencies receiving emergency messages will dictate what boat or boats will respond to the incident. Currently resources are not available to respond adequately to an airliner crashing on approach or departure from SLCIA. The flight paths direct aircraft over Bear River Bay; Ogden Bay and Farmington Bay. It is difficult to place rescue equipment into these shallow areas, and the response will usually be by air boat only. DPR has an air boat assigned to Willard Bay and one on Antelope Island. If an airliner goes down, other sources of boats will be from DWR, the Utah Air Boat Association, brine shrimpers and recreational boaters. The association has offered their help at anytime when requested. Air boats can generally carry only four passengers safely.

Response time to 90 percent of search and rescue requests is usually 30 minutes or less, depending on the time of day. Response time to outlying areas such as the Bear River Bay or the north arm can take over two hours, since boats must be trailered to other locations and launched. The only boat ramp (Little Valley Harbor) available for rescues on the north arm is of poor quality. The poor quality and relative inaccessibility (across private land) of the Little Valley Harbor ramp complicates rescues on the north arm.

DPR staff will most likely get involved on all emergencies due to location, expertise and equipment. All five counties have assorted equipment and volunteer search and rescue teams to assist with various types of emergencies. To improve rescue operations 5-10 passenger hovercrafts are needed due to shallow water conditions.

Notes:

This section focuses on open space, critical lands and visual resource management. DNR is currently investigating protection of critical lands and open space. In order to develop critical land, open space and visual resource management strategies for GSL would require that DNR coordinate and develop site specific goals and objectives. The planning team identified two resource concerns:

- **Open space and critical lands need to be considered.**
- **Visual resource management must be addressed.**

Open Space and Critical Lands

DNR participates in the protection of open space and critical lands through technical or financial assistance to other entities and through direct acquisition of fee title or conservation easements. Three divisions have active fee title or conservation easement acquisition programs. DWR uses habitat fund revenues for acquisitions coordinated through the Habitat Council, and federally-funded programs. DPR provides pass-through federal funds and acquires lands for recreation-related purposes. DFFSL administers a federal program for acquisitions of environmentally important forest land threatened by present and future conversion to nonforest uses. Other divisions have more limited programs. DOGM may acquire land associated with abandoned mine reclamation. DWRe has acquired land for the WDPP.

DNR defines critical lands as being those lands having scarce or unique natural resource amenity values— not necessarily based on the highest and best use—that will serve the interests of DNR divisions and the citizens of Utah, and face the threat of exclusive or conflicting uses or designations. These amenities may include, but not be limited to:

- Critical and high value wildlife habitat
- Unique recreational opportunities
- Rich biological diversity
- Access to public lands
- Paleontological, archeological or historic significance
- Protect watersheds and water recharge areas
- Unique geological or scenic values
- Sustainable resource productivity
- Scarcity and fragility of unique natural resources
- Potential water and resource development opportunities

Visual Resource Management

Visual resource management is a planning tool utilized to protect and enhance the scenic quality of a particular area, like GSL. During public scoping the team received comments regarding protection of the lake and its unique aesthetic value. However, protecting and enhancing visual resources should be balanced with development and other multiple-use management objectives.

Developing a visual resource management strategy for this viewshed would include investigating some of the following topics:

- Identify areas of visual significance and sensitivity
- Identify important near and far (panoramic) view areas
- Identify compatible activities and viewshed impacts
- Identify scenic travel corridors
- Describe the landscape setting (land uses, landforms, vegetation patterns)

(Columbia River Gorge Commission and USDA Forest Service, 1992)

These are a few topics that distinguish GSL ecosystems from other ecosystems and could facilitate development of visual resource management goals and objectives. This information might also become a part of future resource allocation and assist in decision-making.

Management Alternatives

Great Salt Lake Management Alternatives

Introduction

The planning team developed an array of GSL management alternatives for public review and comment after completing public scoping. This array of alternatives was presented in a second series of public meetings to enhance the planning process. In response to public comment the array of alternatives was revised for this draft.

GSL management alternatives A, B, C and CS are defined as:

"CS" is the current situation or status. This is a brief statement of the current situation regarding a specific resource concern. "Alternative A" is the preferred management alternative. "Alternative B" represents an environmentally weighted management alternative. "Alternative C" is weighted in favor of commercial or development values. The alternatives are presented below:

1. Hydrology

1.1 For planning purposes, define GSL's flood plain. This is in response to a specific statutory charge and will apply to DNR lands. This is not intended to preempt the regulatory role of FEMA and local government on other lands.

CS. Development discouraged below 4217 feet. DNR is not currently informed by local entities what local government zoning or mitigation may occur. The state, COE and the FEMA use various elevations and maps to identify the extent of the flood plain.

A. For planning purposes, designate a 4217 foot elevation as the extent of the flood plain of GSL and encourage others to avoid development below 4217 feet.

B. Same as A.

C. Designate the flood plain at 4212 feet for planning purposes.

1.2 Develop strategies to deal with a fluctuating lake level.

CS. Lake level zones are clearly defined in the 1995 plan, but agency actions are not.

A. Accommodate fluctuating lake level by associating lake levels with different zones for planning and managing activities occurring on state land. DNR agencies would specify agency actions for the lake's level changes from zone to zone. Other entities would be encouraged to do the same for other lands.

B. Do not associate lake level with zones to identify agency actions to respond to flooding. Under this alternative, DNR agency response to fluctuating lake levels would be determined on a case-by-case basis.

C. Same as A.

1.3 Determine the policy for West Desert Pumping Project operation

CS. Pump at 4208 feet with north arm brines only to reduce impacts of high lake levels. Pumps could be shut off during any point of the evaporation cycle.

A. Utilize the WDPP to reduce impacts of high lake levels. Recommend pumping at a lake level elevation of 4208 feet with a mixture of south and north arm brines. Modify the intake and discharge channels to accomplish this objective. Complete a full cycle (start pumping in early spring and end pumping in early winter) before turning off the pumps.

B. Do not use the WDPP to reduce high lake levels. Allow maximum variation in lake level.

C. Recommend pumping at 4205 feet using only south arm brine. This would implement the recommendation made in the 1995 plan.

1.4 Declining flows at Locomotive Springs Waterfowl Management Area

CS. Declining flows in Locomotive Springs WMA are currently under study.

A. Determine the causes of low flow from Locomotive Springs and develop strategies to mitigate and remediate this situation that may involve Idaho.

B. Same as A.

C. No change in present management in regard to water rights allocations in Utah and Idaho.

1.5 Administration of water rights and supply in GSL drainage basin (GSL Water Budget)

CS. Acquire water rights for specific areas, such as state WMAs and other important habitat areas around GSL to maintain these wetlands.

A. Same as CS.

B. Discontinue new diversions from GSL at extremely low lake levels, if lake level enters Zone 2 (starting at a lake elevation of 4196 feet.) Water rights for diversions from the lake granted after the plan is approved would

stipulate that this will happen. Water rights granted prior to plan approval would not be affected.

C. No change in present management.

1.6 Determine state policy regarding creating large freshwater embayments like Farmington Bay/Lake Davis/ and inter-island diking/Lake Wasatch proposals.

CS. Proposals are presented and studied periodically but there are no proposals at this time.

A. Do not support creation of large freshwater embayments in GSL. DNR policy would not allow projects on sovereign land.

B. Same as A.

C. DNR will consider support of these proposals if locally-funded and the proposals are consistent with other lake management values.

2. Chemistry

2.1 Identify salinity management regime for GSL.

CS. The south arm is freshening and salts are being sequestered in the north arm. The trend for south arm salinity is outside the historical range. The effects are a concern from an ecological perspective.

G. Reduce and mitigate the impacts of salinity differences between the north and south arms (excluding Farmington Bay and Bear River Bay) of GSL by increasing the bidirectional exchange of flow through the causeway to restore south arm salinity to its historical range. DNR would work with the railroad to keep the culverts open and deepen the breach. An assessment of the need for further action would be based upon the degree to which the trend for south arm salinity recovers.

H. Minimize the salinity differential between the north and south arms (excluding Farmington Bay and Bear River Bay). DNR would work with the railroad to create an opening in the causeway sufficient to eliminate any significant head differential and allow salinity to approximate pre-causeway conditions.

I. Support separate and distinct salinity levels in particular areas. The desirability of the mineral extraction and habitat-related effects of existing causeways would be determined.

2.2 Account for the locations and quantities of salts in the GSL system (north arm, West Pond and mineral extraction pond facilities).

CS. Salts are not fully accounted for or monitored in areas around GSL.

A. Initiate active monitoring and identify the location of all salts in the lake system. This would include lake water, West Pond, stockpiles, waste piles and precipitates on pond floors and lake bottom.

B. & C. Same as A.

3. Water Quality

3.1 Develop a strategy to ensure water quality protection for GSL ecosystem.

CS. Continue existing narrative standards and water quality protection programs and case-by-case evaluation of discharge permits.

A. Support DWQ considering a higher level of protection for wildlife classification and water quality. Investigate improving narrative standards by considering water parameters.

B. Develop numerical standards. DNR and DEQ would cooperate to find financial partners for development of scientifically-defendable standards.

C. Same as CS.

3.2 Determine GSL wetland policy.

CS. Follow existing federal requirements (COE Clean Water Act 404 Permit Process).

A. DNR develop GSL wetland protection strategies and evaluate their water quality function in this system. Require mitigation for any wetland loss on sovereign lands. DNR would develop and implement policy pertaining to subjects not presently addressed in the federal regulatory framework, e.g., non-jurisdictional wetlands, activities other than placement of fill. The policy would take into account the state wetlands management strategy and would set guidelines for mitigation of projects in wetlands on DNR lands.

B. Same as A.

C. Same as CS.

4. Air Quality

4.1 Protect public trust resources related to air quality.

CS. DNR is not actively involved in assessing and developing remediation strategies for air quality protection of public trust resources.

A. Improve coordination with DAQ in assessing impacts on public trust resources and in determining remedial response when public trust resources are involved.

B. Same as A.

C. Same as CS. GSL airshed is within non-attainment area and air quality issues will require coordination and mitigation.

5. Biology

5.1 Identify strategies to preserve and maintain wildlife and habitats on GSL to preserve the integrity of this ecosystem.

CS. DWR is concerned about all habitats on and around GSL but focuses on WMAs because the division has primacy there and has most influence over habitat.

A. All management decisions based on recognition and emphasis of wildlife values on GSL. More habitat should be formally protected. The Wildlife Board would be asked to determine which sovereign lands listed in Section 23-21-5 are to be designated waterfowl/wildlife management areas.

B. Wildlife has primacy over other multiple-uses. More habitat should be formally protected. The Wildlife Board would be asked to determine which sovereign lands listed in Section 23-21-5 are to be designated waterfowl/wildlife management areas.

C. Commercial interests have more importance. No priority for wildlife habitat but it would be considered. Market forces drive management decisions. No specific request would be made to the Wildlife Board.

6. Land

6.1 Determine the appropriate mix of sovereign land classifications on GSL.

CS. Use existing 1995 plan recommendations regarding sovereign land classifications.

A. Formally designate all or part of sovereign lands within the 39 townships identified by the Utah Legislature for wildlife management. Use the 1995 plan recommendations except include the following changes.

- Add a one-mile Class 5 zone around Hat Island
- Split up old South Shore GSL State Park area in accordance with the DNR MOU (designate the area from old Saltair to Goggin Drain as Class 5)
- Add development classification (Class 2) to Rozel Point and Black Mountain

B. Same as A and draw a Class 5 new boundary line that is located a few miles west of AISP.

C. Same as CS, except add development areas at the southern tip of GSL Class 1, Black Mountain and Rozel Point (Class 2).

6.2 Consider geologic hazards in all sovereign land-use decisions.

CS. Determine what will be required on a case-by-case basis after RDCC review.

A. Incorporate geologic hazard identification and analysis in all sovereign land-use decisions. This would occur through RDCC and/or consultation with UGS.

B. Same as A.

C. Identification of geologic hazards, but no analysis required for sovereign land decision-making. This would occur through RDCC and/or consultation with UGS.

6.3 Bear River Migratory Bird Refuge expansion

CS. USFWS and DFFSL reviewing ownership records. Sovereign lands would be made available if these areas remain open to hunting, firearms and other restrictions on sovereign lands be governed by state law, not by federal refuge regulation. Sovereign land within the old refuge boundary would continue to be managed under federal refuge regulation.

A. Same as CS.

B. Sovereign land available without conditions. Sovereign land within the old refuge boundary would continue to be managed under federal refuge regulation.

C. Sovereign land not available. Sovereign land within the old refuge boundary would continue to be managed under federal refuge regulation.

6.4 GSL diking policy

CS. Diking proposals evaluated primarily for the purpose of the dike rather than off-site impacts.

A. Require assessment of wetland, wildlife habitat, lake level, water quality, navigation and other management impacts for each diking proposal. Include cumulative impact assessment.

B. Same as A.

C. Same as CS.

7. Minerals and Hydrocarbons

Review the MLP effectiveness in addressing minerals and hydrocarbon management objectives to provide for economic recovery of sovereign minerals, ensuring public benefit from the development of these resources and protecting the state's trust resources.

7.1 Review the Mineral Leasing Plan zones.

CS. Use the MLP categories and zones.

A. Same as CS.

B. Use the MLP except no new mineral extraction ponds permitted on sovereign land except existing leases and lease exchanges.

C. Use the MLP categories except open more areas for oil, gas and hydrocarbon leasing. Except for an area around Gunnison Island, the whole lake would be available for OGH leasing under various restrictions.

7.2 Review Mineral Leasing Plan policies

CS. Use the MLP policies.

A. Same as CS.

B. Same as CS and do the following: clean up oil field debris on state and private land at Rozel Point and include additional wildlife and recreation protection stipulations in leases.

C. Use the MLP recommendations except do not require competitive bidding (a lease is available after nomination, determination of appropriate lease size, lease rental and lease stipulations).

8. Recreation and Tourism - Water

8.1 Provide additional recreational opportunities in response to specific demands or needs, consistent with the protection of trust resources.

CS. Use existing marina capacities, boat ramps and facilities to meet current and future demands.

A. Use existing recreational marina capacities and make the planned Black Rock commercial use harbor open to recreational use.

B. Use existing launch facilities except no public motorized vessels allowed within state WMAs. Motorized vessels would be allowed in WMAs only for administrative purposes.

C. Allow additional boating access and facilities in north and south arms of the lake.

8.2 Navigability on GSL

CS. Limited navigation through the northern railroad causeway and other causeways closed to navigation.

A. Same as CS.

B. Reduce the number or alter existing dikes and causeways to accommodate navigation for more recreational and commercial watercraft.

C. Allow for unlimited access through causeways for all except the largest watercraft on the lake.

9. Recreation and Tourism - Land

9.1 Develop opportunities on sovereign lands for off-highway vehicles.

CS. No OHV use allowed on sovereign lands.

A. Limit recreational OHV use on state WMAs and sovereign lands in accordance with WMA management plans and those of other adjacent land managers and landowners. Consider additional access in particular areas. Under this alternative sovereign land in T11N, R11W would immediately be open to OHV use in accordance with the access management plan for west Box Elder County.

B. No OHV use on sovereign lands.

C. Open all state lands for OHV use except where excluded in specific management plans.

9.2 Improve recreational opportunities and access.

CS. Support and recommend only AISP, WMAs and URMCC recreation enhancement strategies.

A. Provide additional hiking, biking, trails and picnic access and opportunities. Possibilities include: a day-use area at the southeast end of Magcorp's dike on Stansbury Island; a day use area on land acquired by Weber County on Little Mountain; additional trails at AISP; additional public access to the Spiral Jetty at Rozel Point; and additional public access to the Little Valley harbor.

B. Same as A, except add an automobile route around GSL. Under this alternative DNR would work with the railroad to provide public access from Lakeside to Hogup Ridge to complete the automobile route. The rest of the route would use existing public roads.

C. No additional access.

9.3 Improve education and interpretation opportunities.

CS. Use existing opportunities Farmington Bay, BRMBR, Saltair and AISP.

A. Improve existing and develop new education and interpretation opportunities (geology, industry brine shrimp/salt extraction, cultural, wildlife, etc.). Coordinate with URMCC and others regarding Little Mountain, Rozel Point, Kelton, Locomotive Springs, Timpie Springs and cultural resource management at river deltas.

B. Same as A.

C. Same as A, but focus on creating cooperative industrial/commercial education and interpretive opportunities.

9.4 Hunting conflicts on sovereign lands

CS. Sovereign lands open to hunting except for parts of state WMAs and parks, state marinas, minerals and recreation developments where public safety is a concern.

A. Clarify or modify the boundaries of hunting areas to reduce user conflicts on AISP. Establish a 100-yard non-hunting buffer zone lakeward from upland vegetation on Antelope Island from the Garr Ranch on the east side, around the north end of the island to Elephant Head on the west side.

B. Same as A.

C. Open all lands within state WMAs. Some sovereign land inside WMAs is closed to hunting to provide rest areas for waterfowl. Under this alternative all sovereign lands in WMAs would be open to hunting.

10. Commercial and Industrial

10.1 Identify an acceptable mix of the department's statutory requirements in regard to commercial and industrial use of the lake's resources.

CS. Use 1995 plan recommendations regarding sovereign land classifications.

A. Maintain existing commercial and industrial uses and respond to new proposals on case-by-case basis. Change existing sovereign land classification as needed to balance multiple-uses. Land uses not consistent with existing sovereign land classifications would be allowed after an off-setting change is made to classifications.

B. Reduce or relocate commercial and industrial uses to limit impacts on trust resources. Opportunities for relocation to less environmentally sensitive areas would be pursued.

C. Develop strategies for identifying and attracting additional targeted uses for commercial and industrial development.

10.2 Open specific areas of the lake for commercial harbors for the brine shrimp industry.

CS. Permitted sites at AISP, Promontory Point and Stansbury Island and unpermitted sites at Rozel Point, Black Mountain, Little Valley, Magcorp and Lakeside. Black Rock is in the permitting process. Limit availability of Antelope Island State Park Marina for use as a brine shrimp harbor.

A. Identify and open areas (zone) around the lake for brine shrimp harbor development in the north and south arms of the lake and maintain existing policy regarding no exclusive use (also open for other brine shrimp companies). North Arm-Little Valley, Rozel Point and Black Mountain/ South arm-Black Rock, Lakeside, Promontory Point, Stansbury Island, Magcorp. Limit availability of Antelope Island State Park Marina for use as a brine shrimp harbor.

B. Same as A, except only use Little Valley for a north arm brine shrimp harvesting harbor. Limit availability of Antelope Island State Park Marina for use as a brine shrimp harbor.

C. Change DNR policy to allow exclusive leases for individual brine shrimp companies. Respond to proposals on a case-by-case basis.

10.3 Establish policy regarding unauthorized construction below meander line for the development of harbors, ramps or any other structures.

CS. Use current trespass policy. Allow flexibility in the current trespass policy which requires a damage liability of three times the cost of permit (65A-3-1(2)).

A. Link a specific enforceable penalty to other DNR permits, licenses and applications. Under this alternative, DNR agencies would decide which permits would be linked together to encourage compliance with rules.

B. Same as A.

C. Same as CS.

11. Agriculture

11.1 Allow grazing on sovereign lands to the extent that it is consistent with public trust responsibilities.

CS. Grazing permit applications are currently evaluated on a case-by-case basis by DFFSL through consultation with the DWR.

A. Grazing in the 39 townships identified by the Utah Legislature for wildlife management will be managed by DWR. Grazing on all other sovereign lands will be managed by DFFSL. Existing grazing permits would be transferred from DFFSL to DWR after the status of 23-21-5 lands (Issue 6.1) is determined.

B. No grazing allowed on sovereign lands. Terminate existing grazing permits.

C. All sovereign lands open to grazing. DFFSL would manage, monitor and coordinate law enforcement through consultation with DWR.

12. Transportation

12.1 Designate roads, causeways and utility corridors.

CS. Keep north and south railroad causeways, I-80, Davis County Causeway and direct utilities to existing corridors on the east side of the lake and existing causeways across the lake. Periodically evaluate the need for the southern causeway fill and react to intra-lake proposals on a case-by-case basis.

A. Same as CS above, except do not support AISP southern causeway fill.

B. Same as A.

C. Same as CS, except consider support of AISP southern causeway and entertain intra-lake transportation proposals on a case-by-case basis.

13. Law Enforcement

13.1 Identify the meander line on the ground for law enforcement purposes.

CS. Continue coordinated law enforcement within the DNR. Investigate available methods for helping locals identify the sovereign land boundary.

A. Coordinated DNR role. Evaluate methods of identifying the location of the meander line.

B. Same as A.

C. Same as CS, except no readily identifiable sovereign land boundary.

14. Search and Rescue

14.1 Improve search and rescue access and operations

CS. It is currently difficult to access the north arm of the lake and the Farmington Bay area.

A. Improve search and rescue access, particularly the boat ramp at Little Valley Harbor, and encourage acquisition of better vessels (hovercraft).

B. & C. Same as A above.

15. Ramsar

15.1 GSL and its surrounding wetlands have been nominated for a Ramsar Wetland of International Importance. An application for Ramsar designation must be endorsed by state government.

CS. The Ramsar designation implications on other trust resources and uses are unknown.

A. No designation at this time. DNR would recommend to the governor that no application be endorsed at this time.

B. Support a Ramsar designation for the 39 townships identified by the Utah Legislature for wildlife management. DNR would recommend to the governor that an application for these lands be endorsed.

C. Do not support a Ramsar designation. DNR would recommend to the governor that no application be endorsed.

16. Open Space and Critical Land Management

16.1 Protect open space and critical lands near the lake.

CS. Use existing critical lands and open space protection programs of DPR and DWR.

A. Acquire additional property or conservation easements in support of DNR open space and critical lands policies.

B. Same as A.

C. Do not acquire additional property or easements.

16.2 Protect the viewshed or the visual aesthetics of GSL

CS. Case-by-case consideration of development proposals after RDCC review.

A. Develop a visual resource management zone on GSL. Remove or modify visual barriers where possible (remove Jersey barriers along the frontage road at Saltair). Develop mitigation strategies (protect open space and traditional land use). A visual resource management plan would be prepared subsequent to approval of the CMP.

B. Same as A, but emphasize mitigation.

C. Same as CS.

Great Salt Lake Proposed Alternatives Analysis

Great Salt Lake Proposed Management Alternatives Analysis

The purpose of this analysis is to provide a framework for a general comparison of management alternatives. Please refer to the narrative form of the GSL "Management Alternatives" section of this document for a description of alternatives.

This analysis uses four general criteria to evaluate the proposed management alternatives.

- Feasibility/Effectiveness
- Possible Impacts
- Conflicts/coordination
- Public Trust Protection

Feasibility includes consideration of the time, money and other resources required. Effectiveness indicates how successful the considered alternative would be in a general context. Possible impacts included in the consideration of ecosystem, ecology, industry and other impacts. Conflict and coordination examines user group, agency and other conflicts, and any required coordination. Public trust is a broad criterion which examines degradation or improvement in public trust values. Public trust values include the GSL management policies established by the Legislature. These management responsibilities in Section 65A-1-8 of the Utah Code are described in the SCCT section of this document.

1. Hydrology				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
1.1 Define GSL flood plain for planning purposes.				
Feasibility/ Effectiveness	1995 plan recommends BDA below 4217, but not fully implemented at the local level.	Based on the recent highest historical lake level 4212 plus 5 ft. of wind tide and wave action. Effectiveness depends upon local zoning, COE and FEMA flood plain mapping. They would not necessarily agree with DNR's demarcation.	Same as A.	Effectiveness depends upon local zoning, COE and FEMA flood plain mapping. They would not necessarily agree with DNR's demarcation.
Possible Impacts	Different flood plain boundary lines for different entities.	Possible perceived conflict with private property rights.	Same as A.	Same as A, except use 4212 elevation.
Conflicts/Coordination	DNR's definition of flood plain is not intended to preempt the regulatory role of COE, FEMA and local government.	Same as CS.	Same as CS.	Same as CS.
Public Trust/Protection	On DNR land resources are protected through combination of flood plain designation and sovereign lands classifications.	If local planning and zoning agree with DNR, provides the greatest level of protection of public trust resources considering recent highest historical lake level.	Same as A.	If local planning and zoning agree with DNR, provides a relatively lower level of protection of public trust resources considering recent highest historical lake level.

1. Hydrology				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
1.2 Develop strategies to deal with a fluctuating lake level.				
Feasibility/ Effectiveness	1995 plan, but not implemented.	Requires lake level forecasting and potential damage assessment. Costs not certain.	No action required.	Same as A.
Possible Impacts	DNR management implications uncertain.	Impacts on the ecosystem would depend upon actions taken under the strategies.	No implications. Does not satisfy statutory requirement, an alternative strategy would have to be identified.	Same as A.
Conflicts/Coordination	Haphazard planning. Poor coordination.	External agencies and entities can use the same approach. Better planning and coordination.	Same as CS.	Same as A.
Public Trust/Protection	Resource implications uncertain.	Resource implications will be identified during damage potential assessment.	Same as CS.	Same as A.

1. Hydrology				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
1.3 Determine the policy for West Desert Pumping Project operation				
Feasibility/ Effectiveness	Not efficient operation and less effective (less evaporation/unit of water pumped). Crisis management costs more. Pumping < 9 percent of time.	Requires public investment under uncertain circumstances. Efficiency and effectiveness would improve. Revised operational policy would be established and announced. Pumping ~ 9 percent of the time.	Costs reflect flood damage and diking. No WDPP project costs. Pumping 0 percent of the time.	Pumps operate more frequently. Highest operational costs. Requires public investment under uncertain circumstances. Pumping 33 percent of the time.
Possible Impacts	Salts are not returned. Infrastructure, industry and DNR investments protected except WMA dikes up to 4208 feet, but no guarantees.	Less salt lost from GSL. Added measure of protection for infrastructure, industry and DNR investments, but no guarantees.	No protection of infrastructure, industry and DNR investments, except protection provided by dikes. Industry bears entire cost of protecting their facilities. Allows for more natural lake fluctuation.	Highest level of protection from high lake level. State bears larger portion of the costs to prevent damage from high lake levels.
Conflicts/Coordination	This would require last minute coordination with COE, BLM, USAF, SITLA and others to receive emergency permits to pump.	Coordination achieved through land use permits issued in the normal course of business- no crisis.	A precedent has been set for the state to participate in protection above 4208 ft.	Shifts from emergency to lake level management. This will require additional coordination, National Environmental Policy Act (NEPA) work and reconvincing affected entities of the merits.
Public Trust/Protection	Economic and ecosystem implications of "lost" salt. Less efficient method of operation.	Economic and ecosystem implications of "lost" salt. More efficient method of operation.	No future salt loss. More natural lake level fluctuation.	Economic and ecosystem implications of "lost" salt. Efficient method of operation.

1. Hydrology				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
1.4 Declining flows at Locomotive Springs Waterfowl Management Area				
Feasibility/ Effectiveness	Currently under study.	Cooperation with Idaho necessary. Limited resources required. Some data are available.	Same as A.	No action proposed at this time.
Possible Impacts	Long-term jeopardy for this WMA, if conditions persist.	Water supply at this WMA could improve. Trade-offs and interstate compact required.	Same as A.	Same as CS.
Conflicts/Coordination	Currently under study.	Involvement with Idaho essential and probable involvement of Curlew Valley water users.	Same as A.	DWR habitat targets may not be met. Other alternatives may be explored through the State Engineers Office.
Public Trust/Protection	Habitat and wildlife numbers may decline. Hunting and fishing opportunities may decline. Potential for salt water intrusion.	Offers greatest level of habitat and wildlife protection. Recreation use continues. Less potential for salt water intrusion.	Same as A.	Same as CS.

1. Hydrology				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
1.5 Administration of water rights and supply in GSL-Water Budget				
Feasibility/ Effectiveness	Acquisitions are completed on a case-by-case basis as opportunities arise.	Same as CS.	Ability to do this can be incorporated in new lake rights where granted. Not feasible for upstream rights due to their senior priority. Limited effectiveness because of the low percentage of the time that the lake is < 4196 or in Zone 2.	Same as CS.
Possible Impacts	No long-term strategy regarding where and how much to acquire. Acquisition would protect habitat. Availability of resources is improving with the DWR habitat fund.	Same as CS.	Mineral industry expansion may be limited. More water in GSL during periods of drought up to a critical threshold. Shallow water habitat protection to some degree.	Same as CS.
Conflicts/Coordination	DWR Habitat Council sets priorities. Willing seller basis-so no conflict with users.	Same as CS.	Mineral industry expansion ability may be limited. More water in GSL during periods of drought.	Same as CS.
Public Trust/Protection	Acquisitions do protect habitat and wildlife.	Same as CS.	Modeling may be required to evaluate the overall benefit. More water in GSL during periods of drought.	Same as CS.

1. Hydrology				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
1.6 Determine state policy regarding creating large freshwater embayments like Lake Wasatch, Davis and other inter-island diking proposals.				
Feasibility/ Effectiveness	Proposals arise from time to time, probably technically feasible but benefit may not justify the cost or the impacts to GSL ecosystems. Studies have shown these not feasible as water development projects because of poor water quality, shallow depth and other related impacts.	Citizen involvement at the local level requires DNR to periodically consider these proposals.	Same as A.	DNR would establish screening criteria to evaluate feasibility (water quality, high maintenance, odor, shallow water, recreation, drought and wet cycle concerns).
Possible Impacts	NA	Proponents may have serious concerns. No substantial GSL ecosystems or geohazard impacts.	Same as A.	Ecosystem impacts may be too great. Impact state WMAs, other habitat and wildlife around GSL. Might enhance transportation and real estate development options.
Conflicts/Coordination	Proponents may continue to pursue DNR support. Time and money spent on reviewing proposal may be better spent elsewhere.	The process for considering proposals is in this CMP.	Same as A.	Extensive coordination with regulators would be required to address GSL ecosystems and geohazard impact concerns.
Public Trust/Protection	NA	Provide the highest level of protection to GSL resources. Does a better job of mimicking a natural saline body of water considering existing conditions.	Same as A.	The significant changes to GSL ecosystems may be difficult to justify under the public trust doctrine.

2. Chemistry				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
2.1 Identify salinity management regime for GSL.				
Feasibility/ Effectiveness	Now have separate and distinct areas of salinity more than what would exist under pre-diking conditions.	Causeway modifications are feasible, impact on salinity is reasonably predictable. Engineering required. RR responsible for cleaning culverts. Responsibility for breach maintenance not decided.	Causeway modifications are feasible, impact on salinity is reasonably predictable. Engineering required. Most expensive alternative. Responsibility for bearing cost not determined.	Now have separate and distinct areas of salinity.
Possible Impacts	Ecosystems could change if favorable conditions for brine shrimp and other species are lost. Lowered efficiency for S arm salt producers and better for N arm producers. Difficult for swimmers to float like a cork. Brine shrimp population is stressed.	Exchange of brines would be roughly equal to what existed when salinity was less overall concern from ecological and economic perspective. S arm industry efficiency improves. N arm industry efficiency declines.	Best for S arm industry efficiency. Decreased N arm industry efficiency.	Ecosystem could change if favorable conditions for brine shrimp and other species is lost. Decrease S arm industry efficiency.
Conflicts/Coordination	Disagreement over permeability of the RR causeway.	GSLEP studies must continue in order to evaluate monitoring results.	Possible slowing of railroad traffic across GSL during construction.	Disagreement over beneficial or detrimental effect of relatively fresher Bear River Bay and Farmington Bay.
Public Trust/Protection	Net loss of salt to N arm perceived not to be good. Uncertainty regarding benefit of some difference between the north and S arms.	Better level of protection for lake's ecology. Provides some place for the brine shrimp to thrive under most salinity scenarios.	Better level of protection for lake's ecology.	Same as CS.

2. Chemistry				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
2.2 Account for the locations and quantities of salts in the GSL system N arm, west desert and mineral extraction pond facilities.				
Feasibility/ Effectiveness	Has contributed to dispute over ownership of salt in West Pond.	Methodology would have to be developed for sequestered areas. Monitoring program costs would need to be determined.	Same as A.	Same as A.
Possible Impacts	Limits ability to influence salinity if we choose to do so.	Slightly enhanced ability to influence salinity, if we choose to do so.	Same as A.	Same as A.
Conflicts/Coordination	NA	Will require extraction industries to participate.	Same as A.	Same as A.
Public Trust/Protection	Uncertainty over locations and quantities of slat somewhat limits reclamation planning.	Can enhance reclamation planning.	Same as A.	Same as A.

3. Water Quality				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
3.1 Develop a strategy to ensure water quality protection for GSL ecosystem.				
Feasibility/ Effectiveness	Narrative standards are developed, applied and implemented.	DNR would need to invest time and money to actively participate with DWQ in improving specific narrative standards. DNR recommends acquiring funding to conduct studies to improve our knowledge base.	Expensive to develop new methodology. Literature regarding pollutant impacts on GSL is very limited. Would require huge financial investment in sampling, monitoring and analysis.	Same as CS.
Possible Impacts	Would not provide the highest level of protection.	Some short and long-term improvement in water quality protection.	Improved and more measurable standards. Would provide the highest level of protection.	Same as CS.
Conflicts/Coordination	DWR and DFFSL would like to see standards for GSL and some of its tributaries changed.	DNR would need to be actively involved in establishing more specific narrative standards. If necessary reevaluate the adequacy of the regulatory framework in protecting GSL resources.	Funding partners required. Might require best available retrofit technology to maintain compliance. Conducting necessary studies and required compliance would be very expensive.	Same as CS.
Public Trust/Protection	Potential for standards to become ineffective as water quality deteriorates. Might not provide the highest level of protection of public trust resources.	Some short and long-term improvement in water quality and public trust resource use and protection.	Would provide the highest level of protection of water quality and public trust resources.	Same as CS.

3. Water Quality				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
3.2 Determine GSL wetland policy.				
Feasibility/ Effectiveness	Effective in dealing with common impacts to jurisdictional wetlands.	Research to evaluate water quality function of GSL wetlands. DNR resources required.	Same as A.	Same as CS.
Possible Impacts	COE regulations address only placement of fill.	Possibly enhanced wetland function.	Same as A.	Same as CS.
Conflicts/Coordination	Routine coordination DNR and COE.	Concerns related to the state being more strict than the federal government. May make projects more difficult to permit below meander.	Same as A.	Same as CS.
Public Trust/Protection	COE regulations do not address all activity that may occur in wetlands.	May provide higher level of protection, especially in regard to water quality and habitat availability.	Same as A.	Same as CS.

4. Air Quality				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
4.1 Protect public trust resources.				
Feasibility/ Effectiveness	No active coordination with DAQ at this time.	Resources required to improve coordination to assess impacts and in determining remedial response. Requires participation in studies, monitoring and offering technical assistance.	Same as A.	Same as CS.
Possible Impacts	Level of public trust resource protection unknown.	DNR would take a more proactive role in air quality issues related to management of GSL.	Same as A.	Same as CS.
Conflicts/Coordination	Some groups advocate a stronger DNR role in regard to air quality affecting GSL.	Need for a process to improve coordination. If necessary reevaluate adequacy of the regulatory framework in protecting GSL resources. Need to determine DNR's strategy to protect public trust resources from actions above meander.	Same as A.	Same as CS.
Public Trust/Protection	The full extent of impacts unknown.	Improved level of public trust resource protection.	Same as A.	Same as CS.

5. Biology				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
5.1 Identify strategies to preserve and maintain habitat and wildlife on GSL in order to preserve the integrity of this ecosystem.				
Feasibility/ Effectiveness	Effective, however the ability to work within WMAs is limited to funding availability. Work outside WMAs is conducted through coordination.	DWR has capability to work on 39 townships. Improve coordination within DNR (statutory authorization). Allows for acquisition above meander as funding/policy support these actions. Requires some additional resources through prioritization.	Feasibility is limited by statutory multiple-use directives for sovereign lands. Would be most effective approach to protecting habitat and wildlife.	Feasibility is likely limited by concern over extensive environmental litigation and statutory directive regarding multiple-use on sovereign lands. Not effective in protecting habitat and wildlife values.
Possible Impacts	Limited ability to effectively protect habitat and wildlife populations (constrained by funding and land ownership).	More direct DWR management responsibility and influence over a larger part of GSL. Stipulations on development activities that affect habitat and wildlife would be required. Improves the buffering capability of GSL ecosystems to absorb adverse impacts caused by development on adjacent state and private land.	DWR would have a stronger influence in management over the entire GSL. New development not related to habitat, wildlife or recreational could be curtailed.	Could result in a reduction of habitat and wildlife populations of hemispheric importance. May be beneficial to industry and economic development at the expense of habitat and wildlife values. Increased potential for loss of important habitat and its function.
Conflicts/Coordination	Ability to respond to negative impacts is limited-funding, land ownership, legal authority, etc. Coordination with other entities required-COE, URMCC, local government and landowners.	Requires closer coordination in DNR. Potential conflict with development projects, if proponents are interested in developing in sensitive areas.	More conflicts with industry. Requires extensive coordination with developers if projects would be able to proceed.	Increased conflicts with habitat, wildlife and other ecosystem values would be largely unresolved. Decreased need for coordination. Reduced ability of the ecosystem to absorb and buffer against development impacts.
Public Trust/Protection	Not currently able to apply the appropriate response measures; resolve important ecosystem management concerns in a timely manner. Not the best level of public trust resource protections.	Improved protection of wildlife and habitat aspects of the public trust doctrine. Shifts more attention toward habitat and wildlife preservation. Improves some recreational values.	Ability to pursue statutory multiple-use directives would be hampered. Would provide the highest level of protection for habitat and wildlife related public trust resources.	Habitat, wildlife and other ecosystem impacts would be difficult to justify from public trust perspective.

6. Land				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
6.1 Determine the appropriate mix of sovereign land classifications on GSL.				
Feasibility/ Effectiveness	In place now and effective.	Time and money required, however not significant cost.	Same as A.	Same as A.
Possible Impacts	Visual impacts and seasonal disturbance of gull rookery at Black Rock. Some loss of shorebird habitat at the south shore, north and east of old Saltair.	Hat Island nesting areas are better protected. Shorebird habitat between old Saltair and Goggin Drain better protected. Harbor sites at Black Mtn. and Rozel Point made available. Fragmentation of habitat at these potential harbors.	Same as A, but viewshed and open water bird use west of AISP would be better protected.	Same as CS, but more development would be allowed at the south tip. Harbor sites at Black Mtn. and Rozel Point made available. Fragmentation of habitat at Black Mtn. and Rozel Point.
Conflicts/Coordination	Conflict with Section 23-21-5 areas. Development coordinated through RDCC. Consultation with USFWS regarding Black Rock area migratory birds.	Better opportunity for coordination with the Inland Sea Shorebird Reserve.	Same as A.	Same as CS.
Public Trust/Protection	Sovereign land classifications change in response to public demand and the need for resource protection.	Same as CS.	Same as CS.	Same as CS.

6. Land				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
6.2 Consider geologic hazards in all sovereign land-use decisions.				
Feasibility/ Effectiveness	In place, based on RDCC review. Costs contingent upon action taken by the developer.	Requires UGS review of proposed actions not currently reviewed by RDCC. Not a significant time commitment, but may increase developers costs.	Same as A.	Not effective in satisfying the intent of state law requirements regarding disclosure of geologic hazards.
Possible Impacts	Most geologic hazards taken into account, but not mitigation and risk reduction necessarily prior to project approval. Some damage potential exists.	All geologic hazards would be taken into account and mitigation or risk reduction would be prerequisites to project approval. Less potential for damage caused by hazards and reduced long-term costs.	Same as A.	Same as CS.
Conflicts/Coordination	Routine RDCC coordination and little follow-up with developers.	Closer coordination required with UGS and developers.	Same as A.	Same as CS.
Public Trust/Protection	Public trust resources are at risk from damage to project development caused by geologic hazards.	Highest level of public trust resource protection.	Same as A.	Same as CS.

6. Land				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
6.3 Bear River Migratory Bird Refuge expansion				
Feasibility/ Effectiveness	Feasible, if the refuge managers accept the proposed statutory and administrative conditions under which sovereign lands will be made available.	Same as CS.	Feasible, if state law regarding hunting is adequately addressed.	Same as CS.
Possible Impacts	Refuge expansion objectives could be achieved. Sovereign land remains open for hunting. USFWS would have to reconfigure hunting area boundaries. Some federal lands now open for hunting may be closed.	Same as CS.	Refuge expansion objectives would be achieved. Some sovereign land could possibly be closed to hunting.	Refuge expansion objectives will probably not be achieved. Sovereign lands would remain open for hunting.
Conflicts/Coordination	Ownership issues below meander would need to be resolved with several entities-duck clubs, farmers, USFWS and others.	Same as CS.	Same as CS.	Same as CS.
Public Trust/Protection	No apparent difference between state and federal management. No change in managers and no change for public trust resources.	Same as CS.	Same as CS.	Same as CS.

6. Land				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
6.4 GSL diking policy				
Feasibility/ Effectiveness	Currently decided on a case-by-case basis and depends primarily on the purpose of the diking proposal.	Project proponents may incur additional costs.	Same as A.	Same as CS.
Possible Impacts	Effect of dikes on wildlife, habitat, shoreline fluctuations and depth and navigation is not always evaluated.	Effect of dikes on wildlife, habitat, shoreline fluctuations, water depth and navigation would be always evaluated.	Same as A.	Same as CS.
Conflicts/Coordination	COE is the primary regulator and has concerns about GSL diking. State will be more closely scrutinized in regard to diking related management actions.	Extensive coordination with COE required. DNR would take a more active role in evaluating diking proposals, especially as they relate to navigation.	Same as A.	Same as CS.
Public Trust/Protection	Possible long-term adverse consequences for shoreline habitat and GSL ecosystem dynamics. Navigation remains difficult.	Provides the highest level of public trust resource protection. Possible opportunity for synergism between federal, state and local government. Potential for navigation to improve on GSL.	Same as A.	Same as CS.

7. Minerals and Hydrocarbons				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
7.1 Review the 1996 Mineral Leasing Plan zones.				
Feasibility/ Effectiveness	1996 MLP in place. No cost or time implications.	Same as CS.	No new salt lessees could build new evaporation ponds on sovereign lands.	Future OGH lessees may incur substantial costs in satisfying lease and other permit requirements.
Possible Impacts	East side of GSL not open to new OGH or salt leasing.	Same as CS.	Possible decrease in economic development potential. Shorebird habitat in potential ponding areas may be better protected.	Effect on wetlands, recreation, wildlife and viewshed would have to be addressed with a two step process-1. Determine stipulations and 2. DOGM hearing. Increases economic development potential.
Conflicts/Coordination	Conflicts would be addressed during leasing and permitting. The 1996 MLP was developed in close coordination with other agencies and routine public involvement.	Same as CS.	New ponding sites identified in the 1996 MLP would not be available, except under lease exchange.	Conflicts would be addressed during leasing and permitting. Potential conflict with USFWS at BRMBR and with DWR at WMAs, recreation around AISP and GSL, existing leases at evaporation ponds.

7. Minerals and Hydrocarbons				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
Public Trust/Protection	Consistent with implied conservation management objectives of Section 23-21-5.	Same as CS.	Shifts management direction toward wildlife, scenic and recreation resource protection.	Allows OGH resource development if compatible with other resource values. Stipulations may be so onerous in some locations that OGH development would not be economically feasible. Wetlands, recreation, wildlife and viewshed values relatively more at risk.
7.2 Review Mineral Leasing policies.				
Feasibility/ Effectiveness	No time or cost implications.	Same as CS.	Minimal cost to determine new stipulations. Significant costs involved in cleaning up Rozel Point.	Minimal cost savings by eliminating competitive bidding process, but increases the potential for some reduction in income from lower lease rental.
Possible Impacts	Procedures and lease zones provide long-term resource protection.	Same as CS.	More lease stipulations will be made known up front in procedure. Potential for an added measure of protection through more stipulations.	Same as CS. Absence of competitive process may result in more acreage under lease thereby increasing economic development potential.

7. Minerals and Hydrocarbons				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
Conflicts/Coordination	Conflict resolution through extensive interagency coordination takes place prior to lease offering. Would have to be consistent with GSL plan.	Same as CS.	Same as CS.	Same as CS.
Public Trust/Protection	Consistent with implied preservation management objectives of Section 23-21-5.	Same as CS.	Shifts management direction more toward wildlife and recreation resource protection.	Same as CS, except minor potential for increased pressure on wildlife and recreation resources.

8. Recreation and Tourism - Water				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
8.1 Provide additional recreational opportunities in response to specific demands or needs, consistent with the protection of trust resources.				
Feasibility/ Effectiveness	GSL marina docks used close to capacity, AISP Marina is in use but not close to capacity. Both launch ramps are available with little wait.	Lease applicant at Black Rock appears to be willing to open their marina to recreational use when demand is . sufficient.	Same as A, plus additional restrictions in WMAs.	Feasible in the S arm of the lake. Possible problem providing public access to a N arm facility. Little demand for N arm facility at this time.
Possible Impacts	No apparent impacts at existing facilities. Dock space limitations at GSL Marina may shift use to other marinas to meet public demand.	Same as CS. More than seasonal brine shrimp use at Black Rock may be more disruptive to gulls and shorebirds.	Same as CS. Limited impacts related to boat motors used in WMAs. Waterfowl hunters may be adversely affected.	Encroachment upon sensitive N arm nesting sites may become a serious concern.
Conflicts/Coordination	Parks and Recreation coordination required between GSL marinas to meet demands.	Black Rock applicant will need some lead time to develop and prepare the facility for recreation use.	Same as A, with plenty of advance notice to prepare hunters.	Law enforcement coordination required for the N arm in regards to island protection. Public safety, search and rescue capacity may need improvement.
Public Trust/Protection	Public trust concerns when demands for facilities exceed capacity. At what point do we decide to accept limited facilities?	Same as CS, but there would be some delay in response to meeting public recreational demand on existing facilities and any necessary modifications.	Same as CS, but what would justify closure of WMAs to motorized boats? Shifts management direction towards preservation.	Same as CS.

8. Recreation and Tourism - Water				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
8.2 Navigability on GSL				
Feasibility/ Effectiveness	Somewhat limited navigability, but has some effectiveness in protecting N arm island resources.	Same as CS.	Limited feasibility. Extremely expensive and would involve major trade-offs. Require the development of a strategy.	Low feasibility. Extremely expensive.
Possible Impacts	Sensitive island habitat is protected in the N arm. Perpetuates salinity differentials. Little access in the N arm for recreation and limited for commercial and scientific purposes.	Same as CS.	Purpose for which dikes and causeways were intended would be adversely impacted. Disruption of transportation activities could occur.	Possible impacts depends on the size of the opening. Critical isolated island habitat could be at risk requiring more law enforcement to protect public resources.
Conflicts/Coordination	Search and rescue access is limited. Good for some industries, bad for others.	Same as CS.	Extensive coordination required with users of affected dikes and causeways. Good for some industries, but bad for others. Law enforcement and search and rescue obligations would need to be extended to the N arm.	Extensive coordination required with COE and users of the affected dikes and causeways. Good for some industries, but bad for others. N arm enforcement concerns to protect public trust resources.
Public Trust/Protection	Limited navigation protects isolated critical island habitat and rookeries.	Same as CS.	Critical island habitat could be at risk. A developed strategy would have to be consistent with balancing all other uses and trade-offs involved.	Same as B, but even more law enforcement required to protect critical island habitat. Increased salinity concerns in Farmington Bay and possible changes in ecosystem dynamics.

9. Recreation and Tourism - Land				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
9.1 Develop opportunities on sovereign lands for off highway vehicles.				
Feasibility/ Effectiveness	NA, except some law enforcement concerns	Would require some additional law enforcement resources, an OHV strategy and monitoring program.	Same as CS.	Would require expensive monitoring, planning/strategy and law enforcement.
Possible Impacts	Lack of enforcement in some areas-increase in wildlife and habitat impacts. No OHV use limits some recreational opportunities. Provides some sovereign land and ecosystem protection.	Some adverse habitat impacts could result-mudflats and bird habitat. Increased recreational opportunities, yet affords adequate resource protection.	Same as CS.	Potential for significant habitat impacts. Lack of resources for adequate law enforcement is a serious concern. Provide the greatest opportunity for OHV users. Possible viewshed and other users satisfaction could be limited.
Conflicts/Coordination	OHV user conflicts because rules limit opportunities. Inconsistent enforcement poses conflicts between different user groups-duck hunters, brine shrimp harvesters, mosquito abatement. Violations lead to private property trespass.	Would require monitoring, coordination between users, state, local governments and adjacent landowners. Decrease users conflicts and require a strategy and some planning.	Same as CS.	Highest potential to increase unauthorized trespass on public and private lands. Meet OHV demands, but increase conflicts due to too many users and over-use. Would require extensive coordination with user groups, state, regulators, adjacent landowners and local governments.
Public Trust/Protection	Provides the highest level of public trust resource protection, but limits some recreational and other multiple-use opportunities.	Provides for some site specific OHV use and increased recreational opportunity, yet provides protection of public trust values.	Same as CS.	Provides the lowest level of public trust resource protection. Provides the highest level of OHV use opportunities, but would pose serious viewshed protection and user satisfaction concerns.

9. Recreation and Tourism - Land				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
9.2 Improve recreational opportunities and access.				
Feasibility/ Effectiveness	Few additional resources required. Cost effective management strategy. Funding partnerships required.	Additional resources required. Effective in meeting public recreation demands. Funding partnerships encouraged with user groups and other agencies. Strategy required.	Same as A, except feasibility of a circum-navigation route would be questionable because of agreements with outside parties and lack of funding. Strategy required.	Would not respond to increasing public demand. No additional resources required.
Possible Impacts	Minimal impacts on GSL ecosystems especially if monitoring is ensured. Provides additional access and recreational opportunities.	Some potential increase in ecosystem impacts. Would require adequate monitoring. Provides additional access and recreational opportunities. Requires law enforcement.	Same as A, plus additional transportation related impacts on the ecosystem. Would require significant monitoring. Provides more recreational and access opportunities on the W side of GSL.	Otherwise, no additional ecosystem impacts. Potential for increased impacts on existing recreation and access resources.
Conflicts/Coordination	Could create some user conflicts. Requires DNR coordination between AISP, WMAs, URMCC and recreation user groups.	Potential increase in trespassing. Conflict between recreation user groups and preservationists. Require more proactive DNR role in providing recreation opportunities. Extensive coordination with state, local government, landowners, user groups.	Same as A, plus more coordination with UDOT and user groups. The number of trespass incidents on the military range and private property may increase.	Significant conflicts in not being able to meet user demands. Puts more demands on existing resources.

9. Recreation and Tourism - Land				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
Public Trust/Protection	Supportive of other efforts in public trust protection and in offering more recreation opportunities. Limited state involvement-not as proactive. Limited recreation use access and opportunities.	Provides additional recreational use and access opportunities. Shifts management toward more recreation and access opportunities.	Same as A.	Shifts management away from public use and access and does not respond to demand for new opportunities. Trespass could impact public trust and ecosystem protection. Effective monitoring and law enforcement would provide an increased level of protection. Provides fewer opportunities and could pose significant impacts on public trust resources as demand increases.

9. Recreation and Tourism - Land				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
9.3 Improve education and interpretation opportunities.				
Feasibility/ Effectiveness	Minimal additional resources required. Positive influence on users-effective. Not many existing opportunities.	Would require funding partnerships to support maintenance, law enforcement, displays and to develop a strategy.	Same as A.	Same as A.
Possible Impacts	Improved educational opportunities leads to better stewardship. Limited existing opportunities, but a mixture of environmental and industry/ commercial education and interpretation opportunities.	More opportunities for education may lead to even better stewardship and reach more people. Focuses on historic, cultural, commercial and environmental messages.	Same as A.	Industry may best be able to fund educational opportunities.
Conflicts/Coordination	Public demand exceeds existing opportunities.	Improve educational and recreational opportunities would potentially reduce user conflicts and improve stewardship of GSL resources.	Same as A.	Same as A.
Public Trust/Protection	Increased impacts as demands for additional opportunities increases. Lack of education about the value of GSL-lower level of public trust protection.	Increased public trust resource protection. Broader distribution of recreation related impacts and less site-specific impacts. Provide the greatest and most diverse number of education and interpretive opportunities.	Same as A.	Same as A, but less diverse opportunities- more focused emphasis on economics.

9. Recreation and Tourism - Land				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
9.4 Hunting conflicts on sovereign lands				
Feasibility/ Effectiveness	NA	Minor investment in buoys and signs. Effective.	Same as A.	No additional resources required.
Possible Impacts	Increase in bird watching and some OHV trespass. Slightly reduced hunting areas. Increase in user conflicts over time.	Hunters lose a little hunting area. Bird watchers gain some enhanced opportunity. Decrease in user conflicts.	Same as A.	Loss of some rest areas for birds. Areas are set up for biological reasons, not for birdwatching. Hunters gain a little GSL hunting area.
Conflicts/Coordination	User conflicts would increase over time with wildlife viewing. OHV trespass and public safety concerns. Some coordination with user groups required.	Reduced conflict between hunters and other user groups. Coordination required between DWR, DPR, DFFSL and others.	Same as A.	Increase risk of trespass where no-hunting zones buffer adjacent private property.
Public Trust/Protection	Other than user conflicts, no apparent threat to public trust resource protection.	Shift in management toward non-consumptive use along the E shore of AISP.	Same as A.	Wildlife protection decreased in these areas due to the loss of rest areas.

10. Commercial and Industrial				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
10.1 Appropriate mix of statutory and administrative charges				
Feasibility/ Effectiveness	In place now with the 1995 plan.	Little difference from CS.	Relocation and reduction of improvements may be feasible, but would be very expensive.	Ultimately would be market driven. Some costs associated with a proactive approach, but would involve potential payback.
Possible Impacts	No significant impacts have been identified.	Increased potential for viewshed and habitat degradation over CS. Provides a little more flexibility in implementing multiple-use mandates.	Most relocations would be done in favor of ecosystem preservation. Improved habitat and decreased commercial value.	Habitat protection would require stipulations. Increased opportunities for commercial development and economic gain.
Conflicts/Coordination	Improved communication within DNR required for enforcement. Disagreement within DNR regarding implementation of statutory charges.	Increased appeals to decisions. Increased conflicts between user groups and agencies.	Conflicts with property rights and vested interests of commercial developers. Some coordination required.	Conflicts between some user groups-wildlife vs commercial values. Some coordination required.
Public Trust/Protection	1995 plan categories have been reasonably effective in regard to public trust resource protection.	May allow more development to occur, but the regulatory framework will protect other public trust uses and resources.	Most relocations would be pursued to protect sensitive environments. Improved habitat and decreased commercial value.	Coordination required to resolve potential public trust and habitat impacts. Increased commercial value.

10. Commercial and Industrial				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
10.2 Open specific areas of the lake for commercial harbors for the brine shrimp industry.				
Feasibility/ Effectiveness	Demand exceeds existing permitted facilities. Present availability of unpermitted sites helps meet demand. Viability of the brine shrimp industry requires access to the lake.	Effective in providing access for the existing number of CORs. Enhances industry viability.	Feasible, but access uncertain. Less effective in providing N arm access.	In place prior to 1996. Not effective in providing access for existing number of CORs.
Possible Impacts	Fragmentation of habitat is localized and difficult to avoid. No significant impacts have been identified. Control of access points have been used as an attempt to limit competition on the open water. Black Rock viewshed concerns and dredging poses water quality concerns, but will be monitored.	Provides geographic diversity of access sites. Improves navigation safety. Eliminates access control as a competitive strategy. Black Rock viewshed concerns and dredging poses water quality concerns, but will be monitored.	S arm access not changed. May be a safety concern in N arm with all of the operators using Little Valley Harbor. Black Rock viewshed concerns and dredging poses water quality concerns, but will be monitored. Fragmentation of habitat would be reduced.	More harbors would increase potential adverse impacts and fragmentation. Access control would become an industry competitive strategy. Black Rock viewshed concerns and dredging poses water quality concerns, but will be monitored.
Conflicts/Coordination	DWR and DFFSL coordination required for adequate access for the number of CORs available for industry. Harbor site planning will require coordination with upland owners.	Same as CS. Reduced potential for conflicts between commercial and recreational use at AISP Marina.	Same as CS. Increased conflicts with many operators located in one area. Reduced potential for conflicts between commercial and recreational use at AISP Marina. Reduced potential for conflicts between commercial and recreational use at AISP Marina.	DWR and DFFSL coordination required for adequate access for the number of CORs available for industry. Harbor site planning will require coordination with upland owners. Reduced potential for conflicts between commercial and recreational use at AISP Marina.

10. Commercial and Industrial				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
Public Trust/Protection	Brine shrimp harvesting industry is a legitimate part of an integrated industrial complex and contributes to Utah's economy. Limited harbor access will still create a competitive advantage for some companies.	Same as CS. Brine shrimp harvesting industry is a legitimate part of an integrated industrial complex and contributes to Utah's economy. Provides more access to the lake for industry.	Same as CS. Brine shrimp industry is a legitimate part of an integrated industrial complex and contributes to Utah's economy. Provides less access to the N arm than alternative A for the brine shrimp industry.	Brine shrimp harvesting industry is a legitimate part of an integrated industrial complex and contributes to Utah's economy. Case-by-case evaluation of public trust resource impacts related to exclusive leases required.

10. Commercial and Industrial				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
10.3 Establish policy regarding unauthorized construction below meander line for the development of harbors, ramps or any other structures.				
Feasibility/ Effectiveness	Feasible, but not yet strictly enforced regarding brine shrimp harbors and grazing.	Feasible. Possibility of losing other DNR permits would discourage trespass.	Same as A.	Same as CS.
Possible Impacts	Removal and/or reclamation are available options to lessen impacts. Short-term impacts from trespass are unavoidable.	Same as CS. Short-term impacts will decrease with less trespass.	Same as A.	Same as CS.
Conflicts/Coordination	Coordination and conflicts would be considered in determining the appropriate action.	Same as CS.	Same as A.	Same as CS.
Public Trust/Protection	Public trust resource protection would be considered in determining the appropriate action.	Same CS with an added measure of protection when trespass becomes a more serious offense.	Same as A.	Same as CS.

11. Agriculture				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
11.1 Allow grazing on sovereign lands to the extent that it is consistent with other public trust responsibilities.				
Feasibility/ Effectiveness	Little demand at this time.	Same as CS.	Same as CS.	Same as CS.
Possible Impacts	Some concerns regarding habitat, wildlife and nest impacts on 1,500 acres. Limited interest has kept impacts minimal. Little increase in demands for grazing opportunities are anticipated.	DWR's field presence may enhance monitoring of grazing in the 39 townships designated for wildlife management.	Minor loss of grazing opportunities for the agricultural industry for 1,500 acres below meander line. Reduced monitoring workload. No grazing impacts.	Potential for increased wildlife and habitat loss if more acres are open for grazing. May require more monitoring and enforcement. Little increase in demand is anticipated.
Conflicts/Coordination	Minor coordination between DWR and DFFSL. Some trespass on uplands above meander.	Same as CS.	No coordination required. No significant conflicts.	Same as CS. Increased potential for conflicts with upland owners.
Public Trust/Protection	Provides grazing opportunities consistent with public trust management objectives. Ability to cancel permits protect public trust resources.	Same as CS.	Eliminates grazing as a multiple-use option.	Same as CS.

12. Transportation				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
12.1 Designate roads, causeways and utility corridors.				
Feasibility/ Effectiveness	Existing routes are helpful in meeting transportation demands.	Feasible. Effectiveness, same as CS, but would reduce resources required to consider and study future intra-lake proposals. Usually politically driven.	Same as A.	AISP southern causeway and intra-lake proposals are technically feasible. Very expensive.
Possible Impacts	Salinity differential, navigation, water quality and other ecosystem impacts are recurring concerns.	Same as CS to the extent that planning can influence further studies of new proposals. Potential to save some time and money.	Same as A.	Same as CS, but greater impacts and concerns due to additional structures in GSL. Potentially beneficial for transportation system. Public and private investments, industry, search and rescue. AISP impacts depend upon the routes chosen.
Conflicts/Coordination	Search and rescue access is difficult in some locations. Maintenance of drainage structures and flow devices requires coordination.	Same as CS, but added conflict with project proponents.	Same as A.	Extensive conflict resolution required. Conflicts would need to be addressed in required environmental documents and in the permitting process.
Public Trust/Protection	Impact on salinity and ecosystem is the biggest public trust concern.	Same as CS.	Same as CS.	Same as CS. Management direction would favor development over preservation.

13. Law Enforcement				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
13.1 Identify the meander line on the ground for law enforcement purposes.				
Feasibility/ Effectiveness	Effectiveness sometimes affected by uncertainty over the sovereign land boundary line location.	Effective in responding to law enforcement needs, but could require local government and landowners support, study and planning. Some additional technical and financial resources would be required.	Same as A.	Same as CS.
Possible Impacts	Coordinated DNR role results in efficiency. Lack of an identifiable boundary results in some trespass situations.	Positive influence on resource protection and effective management. Improved law enforcement coordination regarding management on GSL would reduce OHV, building of structures on sovereign lands and other trespass. Provide a better user experience.	Same as A.	Same as CS.
Conflicts/Coordination	Users and land administrators are generally equally concerned about the inability to quickly locate the meander line boundary.	When a method to locate the meander line boundary is identified and used, it could be made available to the public.	Same as A.	Same as CS.
Public Trust/Protection	Some public trust resources could be adversely impacted by sovereign land trespass.	Improved measure of public trust resource protection through better law enforcement and resource management.	Same as A.	Same as CS.

14. Search and Rescue				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
14.1 Improve search and rescue access and operations.				
Feasibility/ Effectiveness	Effectiveness is adversely affected by access and equipment constraints.	DNR's role is probably limited to support acquisition of better vessels, primarily hovercraft, by other agencies.	Same as A.	Same as A.
Possible Impacts	Public safety adversely affected by access and equipment constraints.	Improved public safety and response on GSL.	Same as A.	Same as A.
Conflicts/Coordination	Coordination achieved through implementation of formal and informal agreements.	Coordination and funding partners required.	Same as A.	Same as A.
Public Trust/Protection	NA	NA	NA	NA

15. Ramsar Designation				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
15.1 GSL and its surrounding wetlands have been nominated for a Ramsar designation.				
Feasibility/ Effectiveness	Additional study may improve understanding of implications associated with this designation.	Allows additional time for more study and consideration.	Effective in providing GSL recognition.	Affects unknown.
Possible Impacts	NA	Unknown. Potential conflicts are avoided and benefits lost in the short-term.	Implications on other public trust resources unknown. May restrict some other multiple-use objectives. International recognition may enhance the ability to acquire funding for GSL management activities. May improve tourism to GSL.	Unknown. Potential conflicts of alternative B are avoided. Potential benefits of B are lost.
Conflicts/Coordination	Preferred alternative under Biology expresses the importance of GSL wetlands. Contact with administrators at other Ramsar sites may improve understanding in regards to any management implications.	Ramsar debate, consultation and study would continue.	Conflicts due to potential consequences restricting multiple-use activities would require contact with managers of Ramsar sites which might improve understanding in regards to possible management implications. Must resolve these conflicts prior to recommending this designation.	Preferred alternative under "Biology" expresses the importance of GSL wetlands. Ramsar debate, consultation and study would continue.
Public Trust/Protection	NA	Unknown. Potential conflicts are avoided and benefits lost in the short-term.	Designation could enhance ability to acquire funding to conduct studies, monitoring, planning and other management activities.	Unknown. Potential conflicts of alternative B are avoided. Potential benefits of B are lost.

16. Open Space and Critical Lands				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
16.1 Protect open space and critical lands near GSL.				
Feasibility/ Effectiveness	In progress now. Effective to the extent that funding and policy allow acquisition.	Same as CS, but with additional acquisitions by other DNR agencies.	Same as A.	Existing programs would be eliminated.
Possible Impacts	Lands and resources acquired with broad policy objectives in mind.	Lands and resources specific to DNR goals would be acquired under close scrutiny. Quality emphasized over quantity.	Same as A.	Significant habitat, wildlife, water quality, wetlands and other ecosystem impacts due to increase development near GSL. Land use change over from agriculture to urban use.
Conflicts/Coordination	Possible loss of some local tax base if property acquired was previously on tax rolls. Potential conflict with local government.	Same as CS, plus coordination with critical lands committee required.	Same as A.	Difficulty in reaching DNR goals-wildlife, habitat, wetland and other resource protection. Critical lands would diminish or be eliminated and buffering capability lost. This would require more protection of existing sovereign land resources and require reevaluation of management objectives.
Public Trust/Protection	Provide ecosystem protection which benefits public trust resources. Additional multiple-use opportunities made available.	Same as CS.	Same as CS.	Provides the lowest level of ecosystem protection and would decrease sustainability over time. Shifts management more towards development interests.

16. Open Space and Critical Lands				
	Current Situation (CS)	**Alternative A**	**Alternative B**	**Alternative C**
16.2 Protect the viewshed or the visual aesthetics of GSL.				
Feasibility/ Effectiveness	No consistent consideration of visual resource management (VRM) implications in sovereign management activity.	Effective in providing viewshed protection in conjunction with other multiple-use opportunities. Would require DNR investment to develop and implement VRM program. Mitigation measures may be expensive for developers.	Same as A.	Same as CS.
Possible Impacts	Potential for decrease in aesthetic value of the lake and user satisfaction.	Mitigation measures may be expensive for developers. May decrease economic feasibility of future development. Improved aesthetic value and user satisfaction.	Same as A.	Same as CS.
Conflicts/Coordination	Multiple-use conflicts in regards to VRM. Some coordination with DNR required.	Same as CS and more coordination with developers required.	Same as A.	Same as CS.
Public Trust/Protection	VRM not always addressed in the permitting process. Limited aesthetics consideration.	VRM routinely included in the permitting process. Improved aesthetic value of GSL.	Same as A.	Same as CS.

Economic Analysis Executive Summary

Economic Analysis Executive Summary

The Office of Energy and Resource Planning (OERP) evaluated the economic impacts of three management recommendations contained in the GSL CMP. The GSL CMP lists the three as:

1.2 Develop strategies to deal with a fluctuating lake level
1.3 Determine the policy for the WDPP operation
2.1 Identify salinity management regime for GSL

The first two recommendations relate to lake level, the other to salinity. Both lake level and salinity represent critical considerations to those entities which use the lake for mineral extraction, brine shrimp harvesting, wildlife habitat management, and recreational opportunities. This summary provides the results of the economic analysis for these management recommendations.

Assumptions and Reliability of Data

The results of the economic study are based on data gathered in the summer of 1999 from surveys sent to various entities around GSL. The responses varied significantly in the level of detail provided to survey questions. Further, the information is not audited or verified although the economic team consulted state employees with some knowledge of the industries and entities as a way of gauging the accuracy of the survey results.

Surveys were not returned by UDOT, Morton Salt, and BRMBR. These entities all had significant capital losses/investments during 1983-1987 time period. Additionally, the economic team obtained limited data from the brine shrimp industry, receiving five responses out of 30 surveys. Therefore, the economic planning team consulted with DWR officials to supplement this weakness in data.

The economic study, in analyzing survey data, made certain assumptions about how lake level would increase, the effectiveness of the pumps, when the pumps would be used, and how differences in salinity and lake level would affect brine shrimp or mineral harvests. These assumptions can be changed as directed by the planning team with, of course, different results. It is important to remember, in any case, that the data are to be used to compare alternatives rather than an accurate predictor of losses or impacts. All forecasts and predictions in the economic analysis are as accurate as the data and methodology allow. It is important to note that these results are somewhat sensitive to assumptions about pumping effectiveness, the timing of pumping, and investment during a rising lake level. Results for alternative C, especially, are sensitive to various assumptions regarding pumping and investment.

Lake Level Management

Capital Losses, Operation and Maintenance Expenses

Results of this section of the economic study are summarized below.

- Data pieced together from various historical sources for capital damages/expenditures during the 1983-1987 high water years are reasonably good. The study categorizes these damages/expenditures by the sector which sustained losses, and whether losses were paid out of state, private, local or federal funds (including federal emergency funds). These estimates are actual expenditures, not adjusted to 1999 constant dollars. (These appear in Table 1-1.) The data show that during the 1983-1987 high-water years, significant expenditures began at 4205 feet, particularly for private and state funded structures. By lake level 4208 feet, state and federally-financed entities incurred significant expenditures, primarily for transportation-related expenditures. Capital damages and expenditures more than doubled to over $200 million as the lake rose from 4208-4210 feet and climbed to an estimated $280 million at the high-water elevation. Those entities suffering the greatest losses were the mineral, railroad, utility, and transportation sectors.

- If the lake level rise and fall during the 1982-1993 time period were to be repeated, the economic study estimates of capital expenditures or losses at various lake levels, even with no pumping, would be less than incurred at same levels during flood years. This is due in part to incomplete information, since surveys were not returned by UDOT, Morton and BRMBR, all of which sustained significant damage during the lake's high-water years. However, even allowing for missing data, several sectors around the lake appear to be better protected except at lake levels above 4208 feet. Some, like local entities, utilities, the SLCIA are adequately protected to 4212 feet. Further, the estimated losses for mineral companies and railroads are approximately the same at or above 4210 feet. However, damage is less for the railroad when compared to the 1983-1987 period after 4210 feet. In part, this is due to the better protection of the southern railroad causeway. Finally, losses for state WMAs are very similar to the 1983-1987 period but DWR acknowledges the benefits from periodic flooding of its protected marshes. (Compare Table 1-1 and Table 1-2.)

- The minerals industry and railroad incur the largest capital loss or maintenance expenditures and the largest potential reduction in revenues. In particular, IMC Kalium, Magcorp, and the northern railroad causeway experience significant expenditures beginning at 4205 feet. Similarly, the Davis County Causeway requires significant maintenance as the lake rises above 4205 feet. These entities benefit the most from alternative C (assuming lake level forecast and effectiveness of pumps are accurate in the estimates) which reduces losses by maintaining (under assumptions used in the study) lake level at 4208 feet. (See Table 1-3 and Figure 1 for estimates of capital expenditures under each of the alternatives as lake level rises. See Figure 2 for assumptions about effectiveness of pumps.)

- Capital expenditures (capital investment and operation and maintenance costs) over an eleven year period range from a high of $227 million (no pumping) to a low of $65 million (pumping at 4205 feet). No expenditure estimates are made for those sectors which did not return surveys. Estimate of capital expenditures for current management is $100 million and $94 million for alternative A. (See Table 1-4 and Figure 3.)

- Under the assumptions of the economic model, the most significant differences in capital expenditures among the pumping alternatives occurs as the lake is rising rapidly. Under this scenario, entities around the lake are investing to protect facilities, with the most investment for the current management option at $50 million and the least for alternative C at $25 million. Costs are also incurred for operation and maintenance costs over the eleven year hypothetical period. These are similar among all the pumping options, ranging from $50 million for the current management and $40 million for alternative C. For the no pumping alternative, capital expenditures turn into losses as facilities are flooded. (See Table 1-3 and Figure 1 for estimates of capital expenditures under each of the alternatives as lake level rises.)

- Comparing the current management pumping alternative with pumping alternatives A and C, the economic study predicts differences of revenues at high lake levels of $80 million for alternative A and $100 million for alternative C. These differences in revenues are born almost entirely by private industry. IMC Kalium and UPRR are the industries most likely to suffer reductions in revenues or business interruption at high lake levels. For IMC Kalium, these interruptions can be for 2-5 years as the lake level rises and primarily mean cessation of potash operations; the company could probably maintain salt and magnesium salt operations. Salinity management decisions would also have an impact on when the company would cease production as costs exceed revenues. For UPRR, the economic model predicts equal reductions in revenues over current management for both alternatives A and C.

- For recreation, the economic model predicts no difference in revenues among the pumping alternatives. This is because under all pumping alternatives, the Davis County Causeway must be closed at lake elevations approaching 4208 feet and may close 2-3 feet below 4208 feet depending on wind and wave action. Inundation of mineral industry and railroad facilities occurs only with the no pumping options. (Table 1-5 and 1-6.)

- Closing the Davis County Causeway results in revenue losses to local economies, because the closure prevents visitation to AISP and thus eliminates visitor spending associated with the state park. The economic study found no significant difference in these lost revenues among the pumping options. However, the study does estimate $35 million loss in revenues for the no pumping alternative as compared to the pumping options over the 11 year period. (Table 1-6.)

- WMAs incur significant flooding between 4205-4208 feet under all management options. However, even at high lake levels, GSL marshes continue to be an important destination for waterfowl hunters, even though visits are reduced. Therefore, the differences in revenues from wildlife-related activities among the various management options are not significant.

- There is some ability for many entities to protect themselves up to lake levels of 4210 or 4212 feet. IMC Kalium, several local entities, UDOT and some of the utilities have spent significant amounts to protect their facilities from high lake levels. One limitation preventing greater protection is financial cost—for example from $12 million (on top of $15 million already spent) by IMC Kalium to $150 million estimated by DWR to completely flood proof WMAs. A second limitation is the technical and engineering ability to raise dikes, especially those subject to continued subsidence and rotational failure over time. Finally, diking does not protect against some aspects of high lake level, such as salt water intrusion or reduced drainage capacity. (See Table 1-7.)

Salinity Management

Results of this section of the economic study are summarized below.

- The cost curves for the minerals industry were confirmed or corrected by three of the six companies to whom surveys were sent. At lake level 4200 feet, minimum salinities at which companies can operate (cost per ton = expected revenues per ton) are 13 percent for potash, 5 percent for salt (Cargill is insulated from salinity changes because it gets its brines from Magcorp), and 5 percent for magnesium. For potash and magnesium in particular, this minimum salinity increases as lake level increases because of increased costs of production. Minimum salinity at 4212 feet (assuming operations are not flooded) is estimated at 16 percent for potash and at 7 percent for magnesium. IMC operations are most sensitive to salinity changes because of the higher salinity necessary to extract potassium ions. (See Table 2-2.)

- The economic study team estimated total revenues, payroll, employment, and taxes for the mineral and brine shrimp industries for seven different salinity management regimes at five different lake levels using the DWRe estimates of how they would affect salinity patterns at different lake levels. These alternatives are: 1) existing conditions, culverts open; 2) existing conditions, culverts closed; 3) breach four feet lower, culverts open; 4) breach four feet lower, culverts closed; 5) two breaches, culverts closed; 6) breach eight feet lower, culverts closed; and 7) no causeway (pre-causeway). The lake levels analyzed were 4195, 4200, 4205, 4210, and 4212 feet. (See Table 2-1.) For all except two management scenarios (base condition and pre causeway) projected revenues are highest at lake level 4200 feet. At this lake level, total annual revenues ranged from $244 million for existing conditions, culverts closed to $368 million for three management scenarios: breach

four feet lower, culverts open; two breaches, culverts closed; and pre-causeway. There are corresponding changes in employment, payroll, state and local taxes and royalties. (See Table 2-3, Appendices 1-1 and 1-2.)

- At lake levels of 4195 feet, the economic study predicts a range of revenues from $136 million for base condition and for breach four feet lower, culverts closed to a high of $336 million for breach eight feet lower, culverts closed. At all low lake levels, brine shrimp industry revenues are lowest. (See Table 2-3, Appendices 1-1 and 1-2.)

- In general, total revenues also decline as lake level rises above 4205 feet. This decline is attributable to decreases in revenues from the north arm mineral and brine shrimp industries. However, at the same time, there is an increase in the proportion of revenues attributable to the brine shrimp industry. At 4212 feet, revenue differences among management regimes (except pre-causeway conditions) were much smaller, and a ranged from $191 to $213 million. (See Table 2-4, Appendices 1-1 and 1-2.)

- North arm mineral industries contribute revenues of a maximum of $136 million and a minimum of $34 million depending on lake level and salinity. South arm mineral industries contributed revenues of a maximum of $174 million and a minimum of $0 depending on lake level and salinity. The brine shrimp industry revenue ranged from a maximum of approximately $115 million when producing 9,000 tons from both arms of the lake and a minimum of $0 when the south arm is at very low salinity and the north arm salinity is too high. (See Table 2-3 and Appendices 1-1 and 1-2.)

- The economic study assumes that brine shrimp cyst harvest can reach 9,000 tons when both arms of the lake are within the optimum salinity range for brine shrimp. This would be double the harvest of brine shrimp cysts taken from the lake in any season. The economic study did not examine what the impacts of doubling brine shrimp harvests might have on markets and prices for processed cysts.

Conclusions

Lake Level Management

The economic study evaluated potential damages to lake level 4212 feet and confirms significant capital investment, operation and maintenance costs and revenue losses beginning at 4208 and 4210 feet. The GSL planning team believes the ability to control the lake's fluctuations or to protect facilities with dikes and other structures is limited. Pumping options may modify the rise of the lake but do not guarantee any given lake level. Various entities have made investments in protective structures but have achieved only limited protection. However, it remains the state's obligation to promote public safety and to responsibly manage state and federal funds. The preferred management

alternative therefore encourages prudent development which respects natural lake fluctuations. Without establishing zones with specific actions, the state will continue to be called upon to provide public funds for protection and restoration of facilities damaged by a rising lake despite its limited ability to do so.

From an economic perspective, alternative C appears to have greater benefits than the preferred alternative. Under the assumptions of the economic study, by investing an additional $11 million in the WDPP operation over alternative A expenditures, capital investments and losses are reduced by approximately $30 million while revenues for lake industries are increased by $20 million. However, there are several caveats to temper these findings. These are:

- The economic analysis for lake level management is based upon several assumptions, as is appropriate. Changing any of these assumptions—to what elevation the lake rises, how quickly the lake rises, how effective pumping is, how various entities react with capital investments—will change the findings of the study. The extent that alternative C can mitigate economic losses in comparison with other pumping alternatives is therefore uncertain. Additionally, the CMP must provide a management regime that allows for flexibility and balance in the management of a natural system. Choosing alternatives based largely or solely on economic considerations does not permit this flexibility or may discount equally important criteria, such as biological resources or hydrology, for uncertain economic gains.

- If the lake rises rapidly, the economic study finds that alternatives A and C may not be as effective in reducing losses as in cases with a more moderate lake rise since there may be no opportunity to begin pumping earlier (for example, if the lake rises from 4205 to 4209 feet or 4210 feet as in the 1983-1987 period). This depends in part on how entities around the lake invest in protective measures based on their judgment of what lake level will do in the coming years and to what extent pumping can mitigate lake rises. In the assumptions used for the economic study, there is no difference in annual capital expenditures among the pumping alternatives until the fourth year of lake levels above 4205 feet.

- Alternative A allows a full pumping cycle each year, thereby assuring the return to the lake of salts contained in brines. Alternative C represents a scenario in which full-cycle pumping is not assured, thereby risking the loss of several hundred thousands tons of salts because of precipitation onto the West Desert. The economic study does not address the economic impacts of this loss.

- The CMP must balance the investments necessary to change the configuration and frequency of pumping with the responsibility of each entity on the lake to make investments to protect its resources. The economic study includes both capital investments and operation and maintenance costs in its assessment of the four alternatives. The operation and maintenance costs of between $40 to $50 million for all pumping alternatives will be incurred no matter which pumping alternative is selected. The difference among pumping alternatives is in the amount of periodic

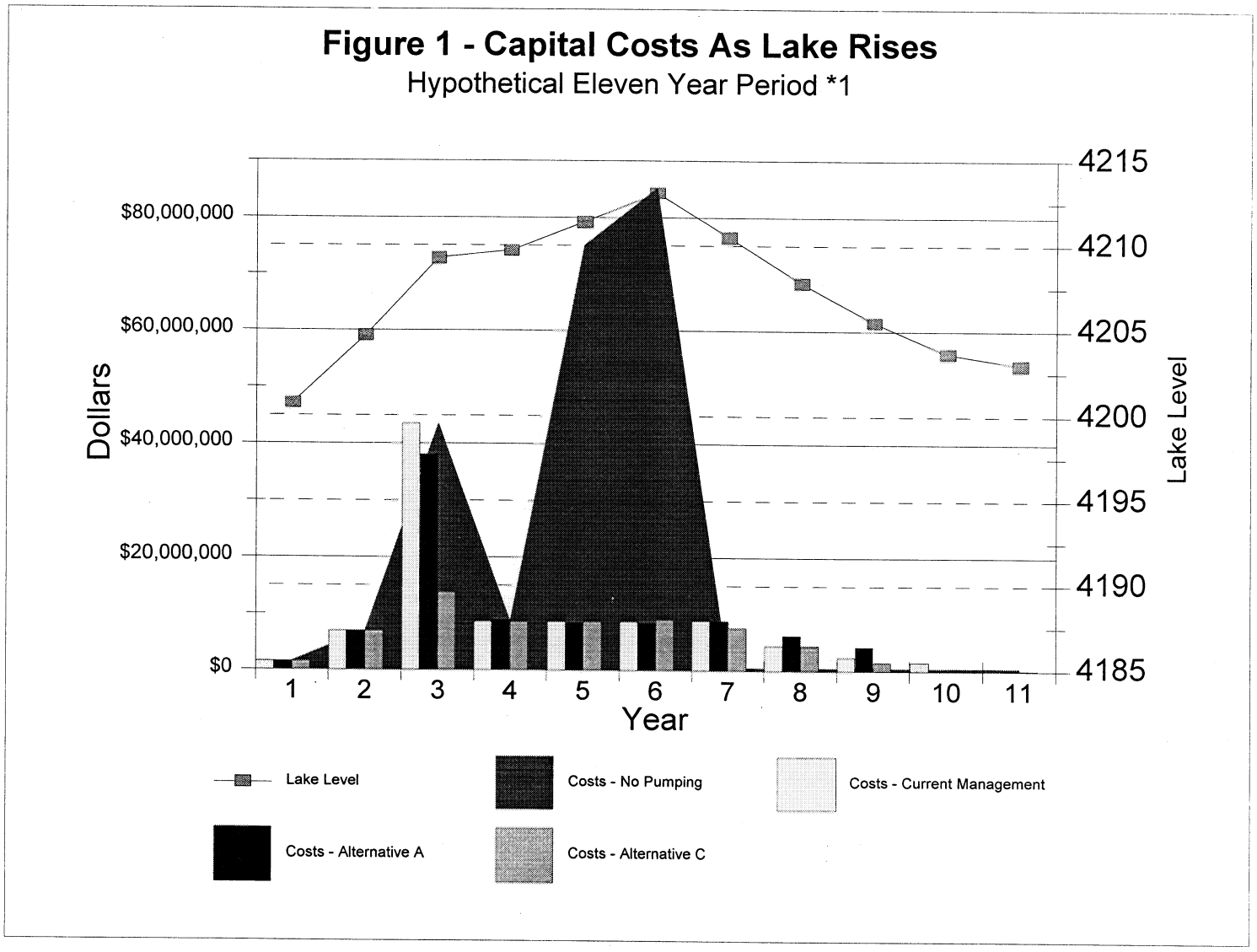
capital investments which range from $25 million for alternative C and $45 to $50 million for Current Situation and alternative A.

- With respect to protection and management of those resources which are the direct responsibility of the state, such as wildlife, recreation, hydrology, or ecosystem health, the economic study found no significant advantage in controlling lake level. Human activities related to the enjoyment of these resources might be curtailed during periods of high lake level but would still continue. Wildlife managers see benefit in periodic flooding of managed marshes, worth the cost of replacing damaged structures.

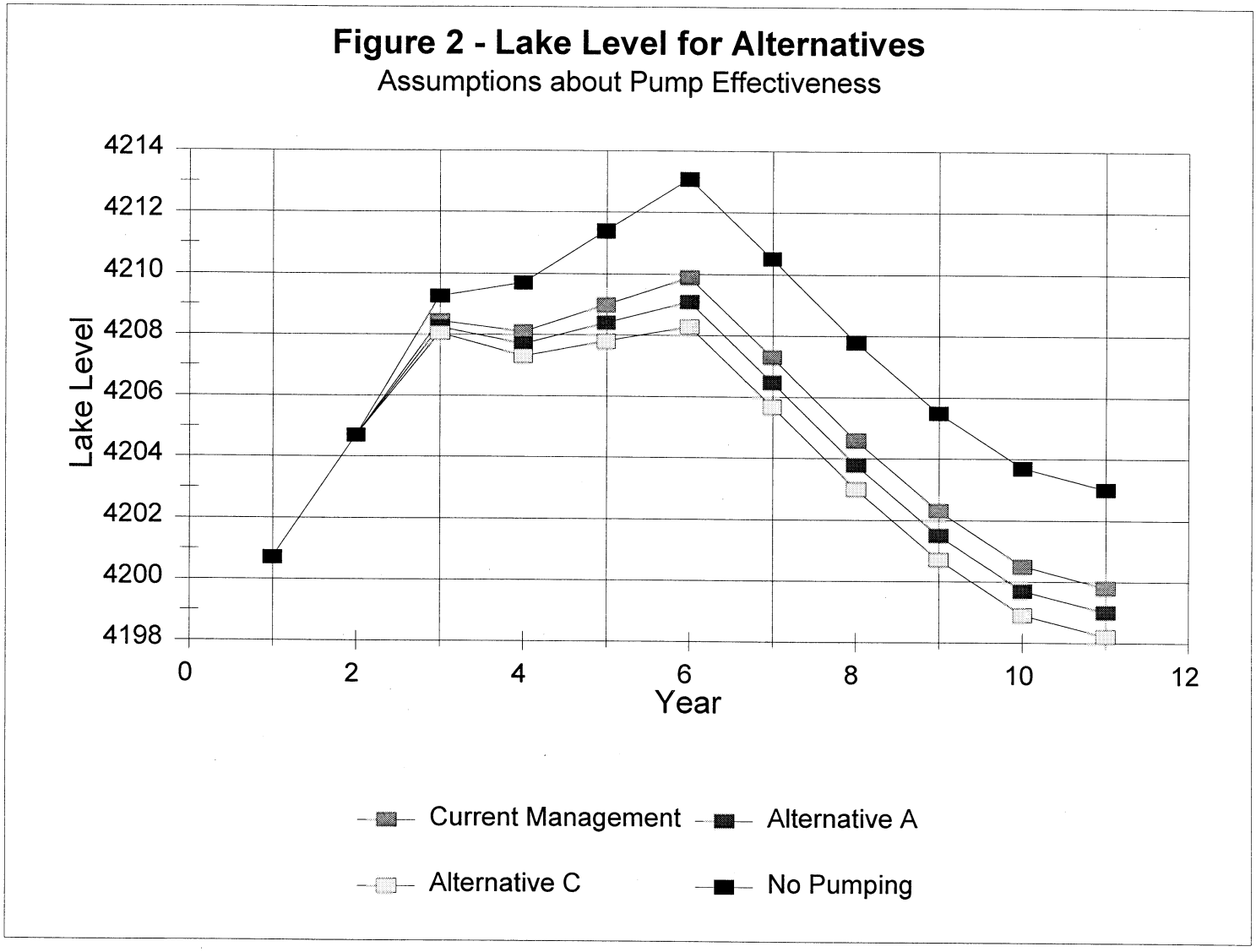
Salinity Management

The economic study supports the selection of salinity management regimes which minimize differences in salinity between the north and south arms by at least two important measures: the amount of revenues which are generated over a range of lake levels and stability provided for all industries which currently rely on lake salinity. The preferred management alternative proposed by DNR (lower the breach by four feet and keep culverts open) also has the advantage of moderate modifications to the causeway.

The economic study finds the highest potential for total revenues by keeping the south arm of the lake at salinity above 10-11 percent except during period of very high lake levels. The study also finds that as long as salinity in the north arm are maintained at 17-19 percent or higher salinity level, that all industries (e.g., brine shrimp, north and south mineral industries) have the potential to achieve production levels that meet or exceed current production for years when lake level is below 4205 feet. The differential between north and south arm still exists, but allows north arm mineral and brine shrimp production. This is in contrast to the extremes (current conditions, culverts closed on the one hand or pre-causeway, with a uniform salinity in the main body of the lake on the other), where there are significant swings in production for the brine shrimp and north arm mineral industries, in counterpoint to each other. Under the preferred alternative, there are no swings in production for any lake industry. Some production is maintained although there may be greater production or profitability under certain lake conditions. The south arm mineral industries experience less fluctuation in their ability to produce under a given range of lake level and salinity conditions although they experience reduced profits in periods of lower salinity.



*1 An 11-year period with annual lake level peaks similar to the 1982-1993 period.



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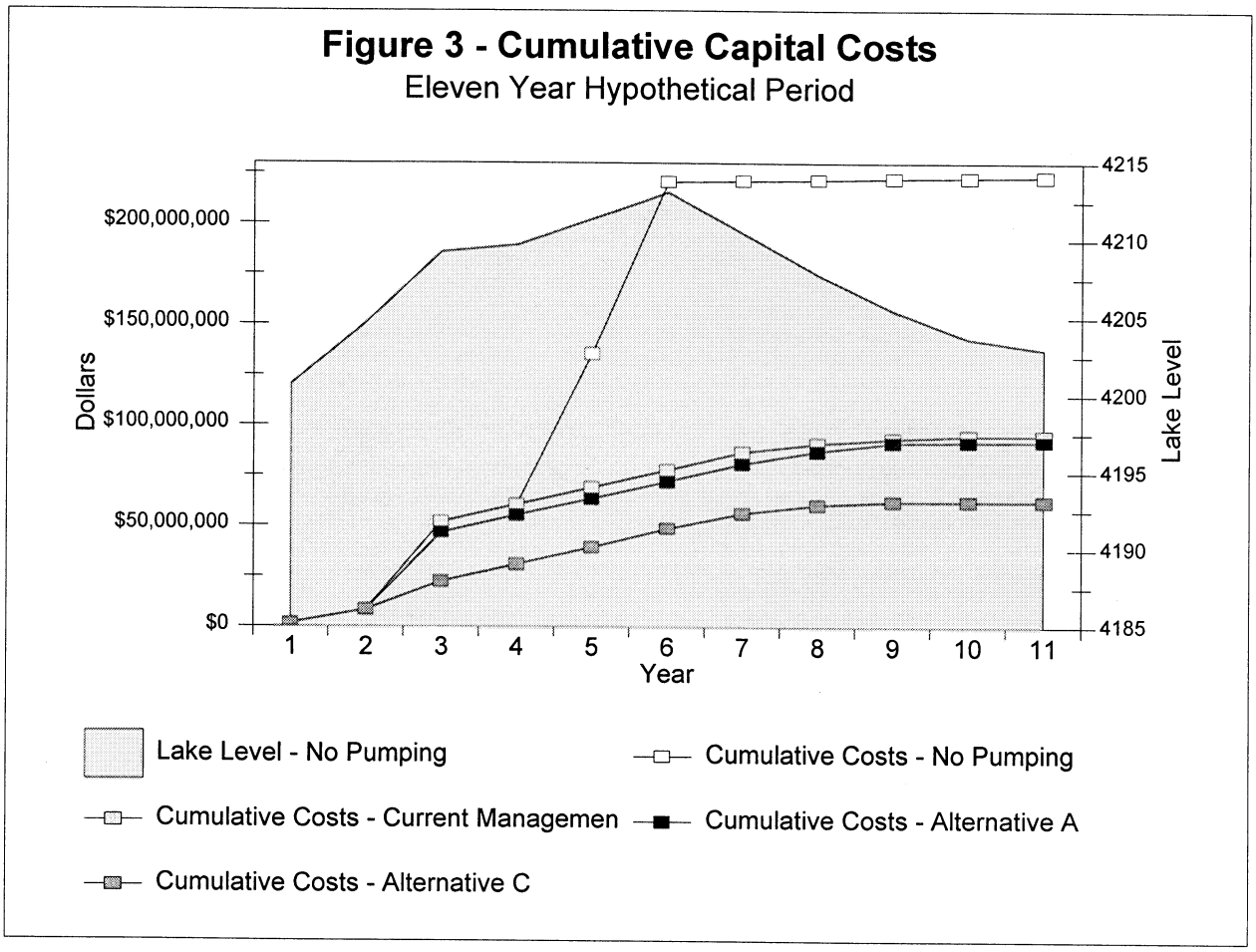


Figure 3 - Cumulative Capital Costs
Eleven Year Hypothetical Period
Dollars
$200,000,000
$150,000,000
$100,000,000
$50,000,000
$0
1
2
3
4
5
6
7
8
9
10
11
Year
4215
4210
4205
4200
4195
4190
4185
Lake Level
Lake Level - No Pumping
Cumulative Costs - No Pumping
Cumulative Costs - Current Managemen
Cumulative Costs - Alternative A
Cumulative Costs - Alternative C

Table 1-1. Capital/Operation and Maintenance Expenditures for 1983-1987 High Water Years

(000 dollars)

Lake Level at 4205		Total	Private	State	Federal	Local
Mineral	36%	$19,276	$19,276			
Wildlife	5%	$2,500	$20	$2,100	$360	
Recreation	10%	$5,657	$317	$4,340		$1,000
Local	3%	$1,801		$1,159		$642
Railroad	42%	$23,037	$23,037			
Transportation	3%	$1,812		$1,812		
Utilities	0%	$203	$203			
		$54,286	$42,853	$9,411	$360	$1,642
			78.94%	17.34%	0.66%	3.02%
Lake Level at 4208		**Total**	**Private**	**State**	**Federal**	**Local**
Mineral	29.0%	$25,000	$25,000			
Wildlife	15.9%	$13,700	$685	$1,370	$11,645	
Recreation	11.3%	$9,707	$2,367	$6,340		$1,000
Local	2.1%	$1,801		$1,159		$642
Railroad	28.5%	$24,537	$24,537			
Transportation	12.4%	$10,700		$2,140	$8,560	
Utilities	0.8%	$710	$710			
		$86,155	$53,299	$11,009	$20,205	$1,642
			61.9%	12.8%	23.5%	1.9%
Lake Level at 4210		**Total**	**Private**	**State**	**Federal**	**Local**
Mineral	12.3%	$25,000	$25,000			
Wildlife	11.6%	$23,700	$935	$6,870	$15,895	
Recreation	6.8%	$13,948	$2,367	$10,581		$1,000
Local	8.7%	$17,842		$13,846	$3,273	$722
Railroad	45.4%	$92,600	$92,600			
Transportation	6.7%	$13,700		$2,740	$10,960	
Utilities	8.5%	$17,255	$17,255			
		$204,046	$138,157	$34,038	$30,128	$1,722
			67.7%	16.7%	14.8%	0.8%
Lake Level at 4212		**Total**	**Private**	**State**	**Federal**	**Local**
Mineral	17.7%	$50,000	$50,000			
Wildlife	20.5%	$57,875	$875	$15,000	$42,000	
Recreation	4.9%	$13,948	$2,367	$10,581		$1,000
Local	11.0%	$31,204		$24,825	$3,273	$3,105
Railroad	32.7%	$92,600	$92,600			
Transportation	7.1%	$20,000		$4,000	$16,000	
Utilities	6.1%	$17,255	$17,255			
		$282,883	$163,097	$54,407	$61,273	$4,105
			57.7%	19.2%	21.7%	1.5%

TABLE 1-2 Estimates for Current Capital Expenditures and Operation and Maintenance, No Pumping Alternative over Eleven Year Hypothetical Period

(000) Dollars

Lake Level at 4205		Total	Private	State	Federal	Local
Mineral	36.15%	$3,050	$3,050	$0	$0	$0
Wildlife	9.93%	$838	$0	$338	$500	$0
Recreation	0.59%	$70	$0	$20	$0	$50
Local	0.00%	$0	$0	$0	$0	$0
Railroad	53.33%	$4,500	$4,500	$0	$0	$0
Transportation	0.00%	$0	$0	$0	$0	$0
Utilities	0.00%	$0	$0	$0	$0	$0
		$8,458	$7,550	$358	$500	$50
			89.27%	4.23%	6.50%	0.59%

Lake Level at 4208		Total	Private	State	Federal	Local
Mineral	40.15%	$20,750	$20,750	$0	$0	$0
Wildlife	11.96%	$6,181	$750	$4,431	$1,000	$0
Recreation	10.74%	$6,170	$0	$140	$0	$6,030
Local	0.40%	$205	$0	$0	$0	$205
Railroad	36.76%	$19,000	$19,000	$0	$0	$0
Transportation	0.00%	$0	$0	$0	$0	$0
Utilities	0.00%	$0	$0	$0	$0	$0
		$52,306	$40,500	$4,571	$1,000	$6,235
			77.43%	8.74%	1.91%	11.92%

Lake Level at 4210		Total	Private	State	Federal	Local
Mineral	37.89%	$22,950	$22,950	$0	$0	$0
Wildlife	12.14%	$7,356	$1,000	$4,356	$2,000	$0
Recreation	9.99%	$7,170	$0	$640	$0	$6,530
Local	0.68%	$410	$0	$0	$0	$410
Railroad	38.80%	$23,500	$23,500	$0	$0	$0
Transportation	0.00%	$0	$0	$0	$0	$0
Utilities	0.50%	$450	$450	$0	$0	$0
		$61,836	$47,900	$4,996	$2,000	$6,940
			77.46%	8.08%	3.23%	11.22%

Lake Level at 4212		Total	Private	State	Federal	Local
Mineral	44.18%	$98,650	$98,650	$0	$0	$0
Wildlife	11.59%	$25,891	$1,000	$19,391	$5,500	$0
Recreation	6.52%	$18,420	$0	$1,890	$0	$16,530
Local	0.84%	$2,075	$0	$0	$0	$1,865
Railroad	21.72%	$48,500	$48,500	$0	$0	$0
Transportation	0.00%	$0	$0	$0	$0	$0
Utilities	15.16%	$34,000	$34,000	$0	$0	$0
		$227,536	$182,150	$21,281	$5,500	$18,605
			80.05%	9.35%	2.42%	8.18%

***1 Data derived from surveys sent to representatives of the mineral industry, utilities, railroad, wildlife, transportation, and local sectors. Cumulative damages where estimated using an eleven year period with annual lake level peaks similar to the 1982-1993 period Each entity is assumed to pay for its own losses.**

TABLE 1-3 Estimates for Cumulative Damages for Capital Expenditures and Operation and Maintenance for all Management Alternatives at Lake Levels 4205, 4208, 4210 and 4212 (000) Dollars

Lake Level below 4205	Current Mgmt	Alternative A	Alternative B	Alternative C
Mineral	$3,050	$3,050	$3,050	$3,050
Wildlife	$838	$838	$838	$838
Recreation	$70	$70	$70	$70
Local	$0	$0	$0	$0
Railroad	$4,500	$4,500	$4,500	$4,500
Transportation	$0	$0	$0	$0
Utilities	$0	$0	$0	$0
	$8,458	$8,458	$8,458	$8,458
Lake Level below 4208				
Mineral	$9,750	$9,750	$20,750	$9,750
Wildlife	$3,438	$3,4381	$6,181	$3,438
Recreation	$440	$440	$6,170	$440
Local	$5	$5	$205	$5
Railroad	$19,000	$19,000	$19,000	$9,000
Transportation	$0	$0	$0	$0
Utilities	$0	$0	$250	$0
	$32,633	$32,633	$52,556	$32,633
Lake Level below 4210				
Mineral	$11,950	$11,950	$22,950	$11,950
Wildlife	$5,288	$5,288	$7,356	$5,288
Recreation	$710	$710	$7,100	$710
Local	$10	$10	$410	$10
Railroad	$23,500	$23,500	$23,500	$23,500
Transportation	$0	$0	$0	$0
Utilities	$300	$300	$300	$0
	$41,758	$41,758	$61,616	$41,458
Lake Level below 4212				
Mineral	$30,100	$28,450	$98,650	$16,900
Wildlife	$14,418	$13,406	$25,891	$9,825
Recreation	$2,320	$2,120	$18,420	$1,320
Local	$225	$220	$2,075	$20
Railroad	$53,000	$50,000	$48,500	$37,000
Transportation	$0	$0	$0	$0
Utilities	$250	$250	$34,000	$0
	$100,313	$94,446	$227,536	$65,065

***1 Data derived from surveys sent to representatives of the mineral industry, utilities, railroad, wildlife, transportation, and local sectors. Cumulative damages where estimated using an eleven year period with annual lake level peaks similar to the 1982-1993 period Each entity is assumed to pay for its own losses.**
***2 The effectiveness of the pumps in moderating lake peaks during periods of pumping was assumed to be .8 foot for current management, 1 foot for Alternative A and 1.2 feet for Alternative C. Lake levels are without pumping.**

TABLE 1-4 Comparison of Capital Damages Among Management Alternatives over Hypothetical Eleven Year Period*1,2

(000) Dollars

Current Management		**Total**	**Private**	**State**	**Federal**	**Local**
Mineral	30.01%	$30,100	$30,100	$0	$0	$0
Wildlife	14.37%	$14,418	$1,000	$9,418	$4,000	$0
Recreation	2.31%	$2,320	$0	$720	$0	$1,600
Local	0.22%	$225	$0	$0	$0	$225
Railroad	52.83%	$53,000	$53,000	$0	$0	$0
Transportation	0.00%	$0	$0	$0	$0	$0
Utilities	0.25%	$250	$250	$0	$0	$0
		$100,313	$84,350	$10,138	$4,000	$1,825
			84.09%	10.11%	3.99%	1.82%
Alternative A		**Total**	**Private**	**State**	**Federal**	**Local**
Mineral	30.12%	$28,450	$28,450	$0	$0	$0
Wildlife	14.19%	$13,406	$1,000	$8,906	$3,500	$0
Recreation	2.24%	$2,120	$0	$720	$0	$1,400
Local	0.23%	$220	$0	$0	$0	$220
Railroad	52.94%	$50,000	$50,000	$0	$0	$0
Transportation	0.00%	$0	$0	$0	$0	$0
Utilities	0.26%	$250	$250	$0	$0	$0
		$94,446	$79,700	$9,626	$3,500	$1,620
			84.39%	10.19%	3.71%	1.72%
Alternative B		**Total**	**Private**	**State**	**Federal**	**Local**
Mineral	43.36%	$98,650	$98,650	$0	$0	$0
Wildlife	11.38%	$25,891	$1,000	$19,391	$5,500	$0
Recreation	8.10%	$18,420	$0	$1,890	$0	$16,530
Local	0.91%	$2,075	$0	$0	$0	$2,075
Railroad	21.32%	$48,500	$48,500	$0	$0	$0
Transportation	0.00%	$0	$0	$0	$0	$0
Utilities	14.94%	$34,000	$34,000	$0	$0	$0
		$227,536	$182,150	$21,281	$5,500	$18,605
			80.05%	9.35%	2.42%	8.18%
Alternative C		**Total**	**Private**	**State**	**Federal**	**Local**
Mineral	25.97%	$16,900	$16,900	$0	$0	$0
Wildlife	15.10%	$9,825	$1,000	$5,825	$3,000	$0
Recreation	2.03%	$1,320	$0	$220	$0	$1,100
Local	0.03%	$20	$0	$0	$0	$20
Railroad	56.87%	$37,000	$37,000	$0	$0	$0
Transportation	0.00%	$0	$0	$0	$0	$0
Utilities	0.00%	$0	$0	$0	$0	$0
		$65,065	$54,900	$6,045	$3,000	$1,120
			84.38%	9.29%	4.61%	1.72%

***1 Data derived from surveys sent to representatives of the mineral industry, utilities, railroad, wildlife, transportation, and local sectors. Cumulative damages where estimated using an eleven year period with annual lake level peaks similar to the 1982-1993 period Each entity is assumed to pay for its own losses.**

***2 The effectiveness of the pumps in moderating lake peaks during periods of pumping was assumed to be .8 foot for current management, 1 foot for Alternative A and 1.2 feet for Alternative C. Lake levels are without pumping.**

Table 1-5 Comparison of Capital Damages Among Management Alternatives over Hypothetical Eleven-Year Period *1,2 (000) Dollars

Current Management	Total	Private	State	Federal	Local
Mineral *1	$2,445,022	$2,373,347	$47,467	$0	$24,208
Wildlife *2	$103,196	$0	$0	$14,696	$88,500
Recreation *3	$49,000	$0	$0	$0	$49,000
Local	$0	$0	$0	$0	$0
Railroad *4	$4,746,825	$4,653,750	$46,538	$0	$46,538
Transportation	$0	$0	$0	$0	$0
Utilities	$0	$0	$0	$0	$0
	$7,344,043	$7,027,097	$94,004	$14,696	$208,246
		95.68%	1.28%	0.20%	2.84%
Alternative A	**Total**	**Private**	**State**	**Federal**	**Local**
Mineral *1	$2,454,817	$2,382,855	$47,657	$0	$24,305
Wildlife *2	$104,096	$0	$0	$14,696	$89,400
Recreation *3	$49,000	$0	$0	$0	$49,000
Local	$0	$0	$0	$0	$0
Railroad *4	$4,816,631	$4,722,188	$47,222	$0	$47,222
Transportation	$0	$0	$0	$0	$0
Utilities	$0	$0	$0	$0	$0
	$7,424,545	$7,105,043	$94,879	$14,696	$209,927
		95.70%	1.28%	0.20%	2.83%
Alternative B	**Total**	**Private**	**State**	**Federal**	**Local**
Mineral *1	$1,743,121	$1,692,022	$33,840	$0	$17,259
Wildlife *2	$87,694	$0	$0	$5,344	$82,350
Recreation *3	$14,000	$0	$0	$0	$14,000
Local	$0	$0	$0	$0	$0
Railroad *4	$4,258,181	$4,174,688	$41,747	$0	$41,747
Transportation	$0	$0	$0	$0	$0
Utilities	$0	$0	$0	$0	$0
	$6,102,996	$5,866,709	$75,587	$5,344	$155,355
		96.13%	1.24%	0.09%	2.55%
Alternative C	**Total**	**Private**	**State**	**Federal**	**Local**
Mineral *1	$2,474,408	$2,401,871	$48,037	$0	$24,499
Wildlife *2	$104,696	$0	$0	$14,696	$90,000
Recreation *3	$49,000	$0	$0	$0	$49,000
Local	$0	$0	$0	$0	$0
Railroad *4	$4,816,631	$4,722,188	$47,222	$0	$47,222
Transportation	$0	$0	$0	$0	$0
Utilities	$0	$0	$0	$0	$0
	$7,444,735	$7,124,059	$95,259	$14,696	$210,721
		95.69%	1.28%	0.20%	2.83%

***1 Mineral revenues are calculated over the eleven year period with salinity assumed to be similar to the present conditions--causeway with culverts closed. State revenues (taxes and royalties) are estimated at 2% of mineral revenues. Local revenues (property taxes) are estimated at 1% of mineral revenues.**

***2 Wildlife revenues are estimated from data on waterfowl hunting in "The Economics of the Great Salt Lake" (draft), Alan E. Isaacson, BEBR, prepared for an upcoming book on Great Salt Lake, edited by Wally Gwynn. These expenitures on equipment and travel are assumed to benefit local economies.**

***3 Recreation revenues are based on visitor day use at Antelope Island as reported by the Utah Division of Parks and Recreation. Expenditures are assumed to be $20/visitor day. Visitor days are based on average visitation in 1998. Visitation is suspended at 4208 when causeway is assumed closed or flooded. As with revenues from waterfowl hunting, these reven ues benefit local economies.**

***4 Railroad revenues are based on an estimate of 40 trains per day which use the north and south railroad causeways. Each train is assumed to be 25 cars, 100 tons, at a rate of $15.00/ton. Rail trips are reduced or rerouted out of state as the lake reaches elevations of 4208 and above. State and local revenues (taxes) are estimated at 1% each of rail revenues.**

TABLE 1-6 Cost Benefit Estimates of Current Management, Alternative A and Alternative C over No Pumping Alternative

(000) Dollars

Current Management (Pumping at 4208 from North Arm Brines)*1

	Difference in Flood Damages	Increases in Revenues	Pumping Capital Investment and Costs		
			Capital Costs	O&M	Total
Private	$97,800	$1,160,388			
State	$11,143	$18,417			
Federal	$1,500	$9,352			
Local	$16,780	$52,890			
Total	$127,223	$1,241,047	$0	$(9,000)	$(9,000)

Alternative A (Pumping at 4208 from North & South Arm Brines)*1

	Difference in Flood Damages	Increases in Revenues	Pumping Capital Investment and Costs		
			Capital Costs	O&M	Total
Private	$102,450	$1,238,334			
State	$11,655	$19,292			
Federal	$2,000	$9,352			
Local	$16,985	$54,572			
Total	$133,090	$1,321,460	$(3,476)	($9,000)	($12,476)

Alternative C (Pumping at 4205 from North & South Arm Brines)*1

	Difference in Flood Damages	Increases in Revenues	Pumping Capital Investment and Costs		
			Capital Costs	O&M	Total
Private	$127,250	$1,257,350			
State	$15,236	$19,672			
Federal	$2,500	$9,352			
Local	$17,485	$55,366			
Total	$162,471	$1,341,740	($12,768)	($11,000)	($23,768)

***1 Pumps are assumed to moderate lake level by .8', 1' and 1.2' for Current Management, Alternative A and Alternative C respectively for years pumps are used.**

Table 1-7 Diking and Structure Improvements to Protect Resources

Facility	Type of Facility	Lake Level Protection	Action Taken/Options to Protect or Improve Dikes	Cost	Limitations to Dike or Structure Improvements
Davis County Public Works (Antelope Island Causeway)	Recreation /local	4206-4208	Could raise dike to 4212'	$3-5 million	Still vulnerable to high maintenance costs, causeway damage and road closures at high lake levels
Weber County	local	4210	No plans		Dikes don't protect against salt water intrusion into river, rise in groundwater, or against reduced drainage capacity in river and stream channels.
IMC Kalium	Mineral	4205-4213	Perimeter dikes for potash pond dikes have been built to 4212. Could raise dikes in east ponds to 4212	Has spent $15million; additional cost is $3 million/ foot increase from 4208 for east ponds.	Cost; Dikes must be raised in increments over time to be stable.
Magnesium Corporation	Mineral	4207-4208	Could raise dikes to 4210 Could raise dikes to 4215 Could raise dikes to 4220	$8-15 million $25-40 million $50-100 million	Captital costs
Cargill Salt	Mineral	4210	Relies on MagCorp's dikes	Invested $5 million in MagCorp's southern dikes.	Settlement of dikes over time.
Union Pacific RR	Railroad	4209-4210	Could raise causeway to 4212		Continued settlement
Division of Wildlife Resources	Wildlife	4205-4208	Could raise dikes and install pumps to make ponds flood-proof.	$150 million	Cost; Benefits to wildlife areas of periodic flooding.
Ambassador Duck Club	Wildlife	4205-4208			Dikes are to hold fresh water, not keep out salt water

Table 2-1. Salinity Variations at Various Lake Levels for Seven Salinity Management Alternatives *1

Management Alternative	Base Case, Culverts Closed	Current Conditions, Culverts Open	Breach 4' Lower, Culverts Closed	Breach 4' Lower; Culverts Open	Two Breaches, Culverts Closed	Breach 8' Lower Culverts Closed	Pre Causeway
Lake Level	4195	4195	4195	4195	4195	4195	4195
North Arm	28%	28%	28%	28%	28%	28%	28%
South Arm	4%	10%	4%	10%	12%	13%	28%
Lake Level	4200	4200	4200	4200	4200	4200	4200
North Arm	28%	28%	28%	26%	24%	26%	22%
South Arm	6%	12%	10%	14%	15%	14%	22%
Lake Level	4205	4205	4205	4205	4205	4205	4205
North Arm	22%	19%	20%	19%	17%	19%	18%
South Arm	8%	10%	10%	11%	11%	11%	18%
Lake Level	4210	4210	4210	4210	4210	4210	4210
North Arm	15%	14%	14%	14%	14%	15%	15%
South Arm	8%	8%	8%	8%	9%	9%	15%
Lake Level	4212	4212	4212	4212	4212	4212	4212
North Arm	13%	13%	13%	12%	11%	13%	13%
South Arm	7%	8%	8%	8%	8%	8%	13%

*1 Salinities at lake levels 4195, 4200, 4205, 4210 and 4212 are taken from water and salt balance model runs provided by the Division of Water Resources.

Table 2-2 Minimum and Optimum Salinity Range for Production of Mineral Products from Great Salt Lake Brines

Mineral	Minimum Salinity	Optimum Salinity Range
Sodium Chloride	5% salinity	11-28% salinity
Magnesium Chloride (feedstock for magnesium production)	5% salinity at 4200 9% if lake rises to 4212	11-28% salinity at lake levels of 4200; 14-28% if lake level rises to 4212 (At this lake level, mineral companies are struggling to maintain dikes and pond systems)
Potassium/Magnesium Salts (feedstock for potassium sulfate)	13% salinity at 4200 16% if lake level rises to 4212.	16-28% salinity at lake levels of 4200; 19-28% if lake level rises to 4212 (At this lake level, mineral companies are struggling to maintain dikes and pond systems)

TABLE 2-3 Summary of Economic Indicator Changes as Salinity Changes, Brine Shrimp and Mineral Industries (000 Dollars)

Base Case (Existing Causeway Conditions with Culverts Closed)

Lake Level	Revenues	Employment (FTE)	Payroll	State and Local Taxes	Royalties
4195	$136,439	345	$17,094	$2,726	$2,004
4200	$244,139	844	$38,391	$4,660	$2,278
4205	$266,621	908	$40,074	$5,332	$2,331
4210	$277,048	956	$43,041	$5,541	$1,820
4212	$191,367	764	$33,702	$3,827	$1,933

Existing Causeway Conditions with Culverts Open

Lake Level	Revenues	Employment (FTE)	Payroll	State and Local Taxes	Royalties
4195	$298,739	1,029	$46,039	$5,752	$2,407
4200	$327,039	1,134	$50,405	$6,318	$2,473
4205	$323,253	1,141	$51,273	$6,465	$2,366
4210	$253,995	933	$41,975	$5,080	$2,120
4212	$202,617	764	$33,702	$4,052	$1,960

Breach 4' Lower, Culverts Closed

Lake Level	Revenues	Employment (FTE)	Payroll	State and Local Taxes	Royalties
4195	$136,439	345	$17,094	$2,726	$2,004
4200	$313,189	1,123	$49,872	$6,041	$2,441
4205	$275,452	941	$41,673	$5,509	$2,291
4210	$250,219	933	$41,975	$5,004	$2,101
4212	$191,367	764	$33,702	$3,827	$1,933

Breach 4' Lower, Culverts Open

Lake Level	Revenues	Employment (FTE)	Payroll	State and Local Taxes	Royalties
4195	$298,739	1,029	$46,039	$5,752	$2,367
4200	$368,339	1,253	$55,794	$7,144	$2,568
4205	$334,503	1,152	$51,806	$6,690	$2,352
4210	$285,411	956	$43,041	$5,708	$2,231
4212	$199,408	753	$33,169	$3,988	$1,960

Two Breaches, Culverts Closed

Lake Level	Revenues	Employment (FTE)	Payroll	State and Local Taxes	Royalties
4195	$327,039	1,134	$44,544	$6,318	$2,473
4200	$368,339	1,253	$55,794	$7,144	$2,568
4205	$340,556	1,287	$57,288	$6,811	$2,393
4210	$248,651	889	$39,834	$4,973	$2,097
4212	$213,849	764	$33,702	$4,277	$1,939

Breach 8' Lower, Culverts Closed

Lake Level	Revenues	Employment (FTE)	Payroll	State and Local Taxes	Royalties
4195	$336,489	1,175	$52,055	$6,507	$2,493
4200	$368,339	1,253	$55,794	$7,144	$2,568
4205	$334,503	1,205	$53,988	$6,690	$2,400
4210	$274,348	956	$43,041	$5,487	$2,165
4212	$199,408	753	$33,169	$3,988	$1,905

TABLE 2-3 Summary of Economic Indicator Changes as Salinity Changes, Brine Shrimp and Mineral Industries (000 Dollars)

Lake Level	Revenues	Pre Causeway Employment (FTE)	Payroll	State and Local Taxes	Royalties
4195	$310,739	1,053	$46,194	$5,992	$2,428
4200	$310,739	1,053	$46,194	$5,992	$2,428
4205	$381,856	1,365	$61,028	$7,637	$2,488
4210	$361,098	1,293	$57,406	$7,222	$2,385
4212	$285,117	997	$43,020	$5,702	$2,096

TABLE 2-4 Summary of Revenue Changes as Salinity Changes, North vs South Arms

Assumes Maximum Production at Optimum Salinities - For Purposes of Comparison Only

Base Case (Existing Causeway Conditions with Culverts Closed)

Lake Level	Revenues (000)	Revenues (000)	
	Total	**North Arm**	**South Arm**
4195	$136,439	$136,439	$0
4200	$244,139	$136,439	$107,700
4205	$266,621	$136,421	$130,200
4210	$277,048	$129,198	$147,850
4212	$191,367	$72,417	$118,950

Existing Causeway Conditions with Culverts Open

Lake Level	Revenues (000)	Revenues (000)	
	Total	**North Arm**	**South Arm**
4195	$298,739	$136,439	$162,300
4200	$327,039	$136,439	$190,600
4205	$323,253	$157,753	$165,500
4210	$253,995	$123,795	$130,200
4212	$202,617	$72,417	$130,200

Breach 4' Lower, Culverts Closed

Lake Level	Revenues (000)	Revenues (000)	
	Total	**North Arm**	**South Arm**
4195	$136,439	$136,439	$0
4200	$313,189	$136,439	$176,750
4205	$275,452	$113,152	$162,300
4210	$250,219	$120,019	$130,200
4212	$191,367	$72,417	$118,950

TABLE 2-4 Summary of Revenue Changes as Salinity Changes, North vs South Arms

Assumes Maximum Production at Optimum Salinities - For Purposes of Comparison Only

Breach 4' Lower, Culverts Open

Lake Level	Revenues (000)	Revenues (000)	
	Total	North Arm	South Arm
4195	$298,739	$136,439	$162,300
4200	$368,339	$136,439	$231,900
4205	$334,503	$157,753	$176,750
4210	$285,411	$137,561	$147,850
4212	$199,408	$69,208	$130,200

Two Breaches, Culverts Closed

Lake Level	Revenues (000)	Revenues (000)	
	Total	North Arm	South Arm
4195	$327,039	$136,439	$190,600
4200	$368,339	$136,439	$231,900
4205	$340,556	$149,956	$190,600
4210	$248,651	$100,801	$147,850
4212	$213,849	$65,999	$147,850

Breach 8' Lower, Culverts Closed

Lake Level	Revenues (000)	Revenues (000)	
	Total	North Arm	South Arm
4195	$336,489	$136,439	$200,050
4200	$368,339	$136,439	$231,900
4205	$334,503	$157,753	$176,750
4210	$274,348	$129,198	$145,150
4212	$199,408	$69,208	$130,200

Pre Causeway

Lake Level	Revenues (000)	Revenues (000)	
	Total	North Arm	South Arm
4195	$310,739	$136,439	$174,300
4200	$310,739	$136,439	$174,300
4205	$381,856	$149,956	$231,900
4210	$361,098	$129,198	$231,900
4212	$285,117	$72,417	$212,700

Table 2-5 Brine Shrimp Harvest by Causeway Management Alternative and Lake Level

Management Alternative	North Arm Brine Shrimp Harvest (tons)	South Arm Brine Shrimp Harvest (tons)	Total Brine Shrimp Harvest (tons)
Base Case Current Conditions Culverts Closed	At lake levels below 4207: 0 At lake levels above 4,207: 4,500	At lake levels below 4202: 1500 At lake levels between 4202 and 4204: 2,000-3,000 At lake levels above 4204: 1500	At lake levels below 4202: 1500 At lake levels between 4202 and 4207: 1500-3000 At lake levels above 4207: 6,000
Current Conditions, Culverts Open	At lake levels below 4205: 0 At lake levels above 4205: 4,500	At lake levels below 4210: 2,000-3,000 At lake levels above 4210 1,500	At lake levels below 4205: 2,000-3,000 At lake levels between 4205 and 4210: 6,500-7,500 At lake levels above 4210: 6,000
Breach 4' Lower Culverts Closed	At lake levels below 4206: 0 At lake levels above 4206: 4,500	At lake levels below 4197: 1,500 At lake levels above 4197 2,000-3,000	At lake levels below 4197: 1,500 At lake levels between 4197 and 4206: 2.000-3,000 At lake levels above 4206: 6,500-7,500
Breach 4' Lower Culverts Open	At lake levels below 4205: 0 At lake levels above 4205: 4,500	At lake levels below 4197: 2,000-3,000 At lake levels between 4197 and 4201: 4,500 At lake levels above 4201: 2,000-3,000	At lake levels below 4197: 2,000-3,000 At lake levels between 4197 and 4205: 2,000-4,500 At lake levels above 4205: 6,500-7,500
Two Breaches Culverts Closed	At lake levels below 4203: 0 At lake levels above 4203: 4,500	At lake levels below 4195: 2,000-3,000 At lake levels between 4195 and 4203: 4,500 At lake levels above 4203 2,000-3000	At lake levels below 4195: 2,000-3,000 At lake levels between 4195 and 4203: 4,500 At lake levels above 4203: 6,500-7,500
Pre Causeway	At lake levels below 4,203: 0 At lake levels above 4,203 4,500	At lake levels below 4,203: 0 At lake levels above 4,203 4,500	At lake levels below 4,203: 0 At lake levels above 4,203 9,000

Appendix 1-1. Comparison of Economic Indicator Changes as Salinity Changes, North Arm vs South Arm

Base Case (Existing Causeway Conditions with Culverts Closed)

Lake Level	Revenues		Employment		Payroll		State and Local Taxes		Royalties	
	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm
4195	$136,439	$0	345	0	$17,094	$0	$2,726	$0	$1,214	$1,153
4200	$136,439	$107,700	345	500	$17,094	$21,297	$2,726	$1,934	$1,214	$1,355
4205	$136,421	$130,200	257	651	$12,728	$27,347	$2,728	$2,604	$1,214	$1,139
4210	$129,198	$147,850	385	571	$18,706	$24,335	$2,584	$2,957	$1,820	$411
4212	$72,417	$118,950	222	542	$10,724	$22,978	$1,448	$2,379	$1,632	$327

Existing Causeway Conditions with Culverts Open

Lake Level	Revenues		Employment		Payroll		State and Local Taxes		Royalties	
	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm
4195	$136,439	$162,300	345	684	$17,094	$28,945	$2,726	$3,026	$1,214	$1,193
4200	$136,439	$190,600	345	789	$17,094	$33,311	$2,726	$3,592	$1,214	$1,260
4205	$157,753	$165,500	457	684	$22,328	$28,945	$3,155	$3,310	$1,963	$403
4210	$123,795	$130,200	385	549	$18,706	$23,270	$2,476	$2,604	$1,793	$327
4212	$72,417	$130,200	222	542	$10,724	$22,978	$1,448	$2,604	$1,632	$327

Breach 4' Lower, Culverts Closed

Lake Level	Revenues		Employment		Payroll		State and Local Taxes		Royalties	
	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm
4195	$136,439	$0	345	0	$17,094	$0	$2,726	$0	$1,214	$790
4200	$136,439	$176,750	345	778	$17,094	$32,778	$2,726	$3,315	$1,214	$1,227
4205	$113,152	$162,300	257	684	$12,728	$28,945	$2,263	$3,246	$1,097	$1,193
4210	$120,019	$130,200	385	549	$18,706	$23,270	$2,400	$2,604	$1,774	$327
4212	$72,417	$118,950	222	542	$10,724	$22,978	$1,448	$2,379	$1,632	$301

Breach 4' Lower, Culverts Open

Lake Level	Revenues		Employment		Payroll		State and Local Taxes		Royalties	
	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm
4195	$136,439	$162,300	345	684	$17,094	$28,945	$2,726	$3,026	$1,214	$1,153
4200	$136,439	$231,900	345	908	$17,094	$38,700	$2,726	$4,418	$1,214	$1,355
4205	$157,753	$176,750	457	695	$22,328	$29,478	$3,155	$3,535	$1,923	$430
4210	$137,561	$147,850	385	571	$18,706	$24,335	$2,751	$2,957	$1,862	$369
4212	$69,208	$130,200	211	542	$10,191	$22,978	$1,384	$2,604	$1,632	$327

Two Breaches, Culverts Closed

Lake Level	Revenues		Employment		Payroll		State and Local Taxes		Royalties	
	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm
4195	$136,439	$190,600	345	789	$17,094	$27,450	$2,726	$3,592	$1,214	$1,260
4200	$136,439	$231,900	345	908	$17,094	$38,700	$2,726	$4,418	$1,214	$1,355
4205	$149,956	$190,600	457	830	$22,328	$34,961	$2,999	$3,812	$1,924	$470
4210	$100,801	$147,850	318	571	$15,499	$24,335	$2,016	$2,957	$1,727	$369
4212	$65,999	$147,850	200	564	$9,658	$24,044	$1,320	$2,957	$1,570	$369

Breach 8' Lower, Culverts Closed

Lake Level	Revenues		Employment		Payroll		State and Local Taxes		Royalties	
	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm
4195	$136,439	$200,050	345	830	$17,094	$34,961	$2,726	$3,781	$1,214	$1,280
4200	$136,439	$231,900	345	908	$17,094	$38,700	$2,726	$4,418	$1,214	$1,355
4205	$157,753	$176,750	457	748	$22,328	$31,661	$3,155	$3,535	$1,963	$437
4210	$129,198	$145,150	385	571	$18,706	$24,335	$2,584	$2,903	$1,030	$1,135
4212	$69,208	$130,200	211	542	$10,191	$22,978	$1,384	$2,604	$1,578	$327

Pre Causeway

Lake Level	Revenues		Employment		Payroll		State and Local Taxes		Royalties	
	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm	North Arm	South Arm
4195	$136,439	$174,300	345	708	$17,094	$29,100	$2,726	$3,266	$1,214	$1,214
4200	$136,439	$174,300	345	708	$17,094	$29,100	$2,726	$3,266	$1,214	$1,214
4205	$149,956	$231,900	457	908	$22,328	$38,700	$2,999	$4,638	$1,924	$565
4210	$129,198	$231,900	385	908	$18,706	$38,700	$2,584	$4,638	$1,030	$1,355
4212	$72,417	$212,700	156	841	$7,527	$35,494	$1,448	$4,254	$1,586	$510

Appendix 1-2. Comparison of Economic Indicator Changes as Salinity Changes, Brine Shrimp vs North Arm Mineral Industry vs South Arm Mineral Industry

Base Case (Existing Causeway Conditions with Culverts Closed)

Lake Lev	Revenues			Employment			Payroll			State and Local Taxes			Royalties		
	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp
4195	$136,439	$0	$0	345	0	0	$17,094	$0	$0	$2,726	$0	$0	$1,214	$0	$790
4200	$136,439	$88,500	$19,200	345	433	67	$17,094	$18,100	$3,197	$2,726	$1,550	$384	$1,214	$228	$837
4205	$136,421	$111,000	$19,200	257	584	67	$12,728	$24,150	$3,197	$2,728	$2,220	$384	$1,214	$281	$837
4210	$71,598	$122,250	$83,200	185	482	289	$9,106	$20,073	$13,862	$1,432	$2,445	$1,664	$890	$307	$623
4212	$34,017	$99,750	$57,600	89	475	200	$4,330	$19,781	$9,590	$680	$1,995	$1,152	$702	$254	$977

Existing Causeway Conditions with Culverts Open

Lake Lev	Revenues			Employment			Payroll			State and Local Taxes			Royalties		
	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Inc. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp
4195	$136,439	$133,500	$28,800	345	584	100	$17,094	$24,150	$4,795	$2,726	$2,450	$576	$1,214	$333	$860
4200	$136,439	$155,400	$35,200	345	667	122	$17,094	$27,450	$5,861	$2,726	$2,888	$704	$1,214	$384	$876
4205	$100,153	$133,500	$89,600	257	584	300	$12,728	$24,150	$14,395	$2,003	$2,670	$1,792	$1,032	$333	$1,000
4210	$66,195	$111,000	$76,800	185	482	267	$9,106	$20,073	$12,797	$1,324	$2,220	$1,536	$863	$281	$977
4212	$34,017	$111,000	$57,600	89	475	200	$4,330	$19,781	$9,590	$680	$2,220	$1,152	$702	$281	$977

Breach 4' Lower, Culverts Closed

Lake Lev	Revenues			Employment			Payroll			State and Local Taxes			Royalties		
	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Inc. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp
4195	$136,439	$0	$0	345	0	0	$17,094	$0	$0	$2,726	$0	$0	$1,214	$0	$790
4200	$136,439	$144,750	$32,000	345	667	111	$17,094	$27,450	$5,328	$2,726	$2,675	$640	$1,214	$359	$868
4205	$113,152	$133,500	$28,800	257	584	100	$12,728	$24,150	$4,795	$2,263	$2,670	$576	$1,097	$333	$860
4210	$62,419	$111,000	$76,800	185	482	267	$9,106	$20,073	$12,797	$1,248	$2,220	$1,536	$844	$281	$977
4212	$34,017	$99,750	$57,600	89	475	200	$4,330	$19,781	$9,590	$680	$1,995	$1,152	$702	$254	$977

Breach 4' Lower, Culverts Open

Lake Lev	Revenues			Employment			Payroll			State and Local Taxes			Royalties		
	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Inc. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp
4195	$136,439	$133,500	$28,800	345	584	100	$17,094	$24,150	$4,795	$2,726	$2,450	$576	$1,214	$333	$820
4200	$136,439	$174,300	$57,600	345	708	200	$17,094	$29,100	$9,600	$2,726	$3,266	$1,152	$1,214	$424	$930
4205	$100,153	$144,750	$89,600	257	584	311	$12,728	$24,150	$14,928	$2,003	$2,895	$1,792	$1,032	$359	$960
4210	$79,961	$122,250	$83,200	185	482	289	$9,106	$20,073	$13,862	$1,599	$2,445	$1,664	$932	$307	$993
4212	$34,008	$111,000	$54,400	89	475	189	$4,330	$19,781	$9,058	$680	$2,220	$1,088	$702	$281	$977

Two Breaches, Culverts Closed

Lake Lev	Revenues			Employment			Payroll			State and Local Taxes			Royalties		
	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Inc. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp
4195	$136,439	$155,400	$35,200	345	667	122	$17,094	$27,450	($0)	$2,726	$2,888	$704	$1,214	$384	$876
4200	$136,439	$174,300	$57,600	345	708	200	$17,094	$29,100	$9,600	$2,726	$3,266	$1,152	$1,214	$424	$930
4205	$92,356	$155,400	$92,800	257	708	322	$12,728	$29,100	$15,461	$1,847	$3,108	$1,856	$993	$384	$1,016
4210	$62,401	$122,250	$64,000	185	482	222	$9,106	$20,073	$10,656	$1,248	$2,445	$1,280	$844	$307	$946
4212	$33,999	$122,250	$57,600	89	475	200	$4,330	$19,781	$9,590	$680	$2,445	$1,152	$702	$307	$930

Breach 8' Lower, Culverts Closed

Lake Lev	Revenues			Employment			Payroll			State and Local Taxes			Royalties		
	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Inc. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp
4195	$136,439	$164,850	$35,200	345	708	122	$17,094	$29,100	$5,861	$2,726	$3,077	$704	$1,211	$404	$879
4200	$136,439	$174,300	$57,600	345	708	200	$17,094	$29,100	$9,600	$2,726	$3,266	$1,152	$1,211	$424	$933
4205	$100,153	$144,750	$89,600	257	626	322	$12,748	$25,800	$15,441	$2,003	$2,895	$1,792	$1,031	$359	$1,010
4210	$71,598	$119,550	$83,200	185	482	289	$9,106	$20,073	$13,862	$1,432	$2,391	$1,664	$888	$298	$979
4212	$34,008	$111,000	$54,400	89	475	189	$4,330	$19,781	$9,058	$680	$2,220	$1,088	$699	$281	$925

Pre Causeway

Lake Lev	Revenues			Employment			Payroll			State and Local Taxes			Royalties		
	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Inc. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp	Mineral Ind. North Arm	Mineral Ind. South Arm	Brine Shrimp
4195	$136,439	$174,300	$0	345	708	0	$17,094	$29,100	($0)	$2,726	$3,266	$0	$1,214	$424	$790
4200	$136,439	$174,300	$0	345	708	0	$17,094	$29,100	($0)	$2,726	$3,266	$0	$1,214	$424	$790
4205	$92,356	$174,300	$115,200	257	708	400	$12,728	$29,100	$19,200	$1,847	$3,486	$2,304	$993	$424	$1,071
4210	$71,598	$174,300	$115,200	185	708	400	$9,106	$29,100	$19,200	$1,432	$3,486	$2,304	$890	424	$1,071
4212	$34,008	$174,300	$76,809	89	708	200	$4,330	$29,100	$9,590	$680	$3,486	$1,536	$702	$424	$969

Notes:

Scientific Review Committee Letter and Report

EVALUATION OF THE SCIENTIFIC UNDERPINNINGS OF THE MAY 1, 1999 GREAT SALT LAKE PLANNING DOCUMENT

Final report (9/20/99) of the Great Salt Lake Scientific Review Committee consisting of:
Genevieve Atwood, Paul W. Jewell, John A. Kadlec, Mac McKee, and Katrina A. Moser
Staff: Brenda Landureth, DNR Administration

INTRODUCTION

The purpose of this document: In May 1999 the State of Utah Department of Natural Resources (DNR) selected this Scientific Review Committee to "verify and validate the scientific information presented in the *Great Salt Lake Comprehensive Management Plan: Planning Document* of May 1, 1999." DNR requested that the reviewers focus on an evaluation of the scientific underpinnings presented in the "*Statement of Current Conditions and Trends*" section of the planning document and resist looking at the entire body of information available about the lake and its environs. The scientific review process was to offer an unbiased assessment of the technical information base utilized by DNR to make decisions and tradeoffs concerning Great Salt Lake (GSL). Furthermore, the scientific review process was to evaluate the DNR use of available technical information, identify information that was limited or missing, forewarn the DNR of potential criticisms of its information base, and enhance the credibility of the DNR planning process. DNR asked the Scientific Review Committee to ignore political and economic issues of GSL and focus only on the science.

The Scientific Review Committee reviewed the *Great Salt Lake Comprehensive Management Plan: Planning Document* (Planning Document) in detail. This included attending briefings by the U.S. Geological Survey and DNR staff concerning computer modeling of the water balance and salt balance of GSL and included interviews with many government and industry scientists. The committee held its organizational meeting in May, met twice in June including a two-day working session in Logan, once in July and twice in August. The July 19 meeting included discussions with DNR-GSL Planning Team. The August 23 meeting included a debriefing with Kathleen Clarke, Executive Director of DNR.

This report summarizes the deliberations of the Scientific Review Committee. It consists of a general evaluation of the major scientific information bases underpinning

the Planning Document. As part of its deliberations the Scientific Review Committee examined some topics in considerable detail. The Committee has shared and will continue to share their insights with the Planning Team.

The committee wishes to acknowledge the many agencies and individuals who have contributed to this review and shared their information and perspectives.

For further information on the Scientific Review Committee, its deliberations, and its members, please contact: James Springer, DNR Administration, 801/538-5324.

EVALUATION OF THE SCIENTIFIC UNDERPINNINGS OF THE MAY 1, 1999 GREAT SALT LAKE PLANNING DOCUMENT

LAKE LEVEL FLUCTUATIONS

1. Geologic and historical context

a.) The high-level fluctuations that GSL stakeholders should expect to see over time for GSL are:

- 4212 feet above sea level -- the still-water level of the historic highstand
- 4217 feet -- the still-water highstand level expected in our present climate regime
- 4221 feet -- the unusual but documented highstand of the past 8,000 years.

b.) Lake level is intricately tied to global and regional climate. Annual precipitation, cloud cover, wind patterns and temperature affect lake volume through a variety of hydrologic processes, which in turn can affect important ecosystems and socioeconomic factors. Knowledge of the relationship between lake hydrology and global climatic processes should be important to DNR managers, yet there is virtually no mention of climate in the PD.

c.) The physical configuration of the lake basin including its natural expansion to the west naturally slows lake level rises dramatically at 4215 - 4217 feet and above. When DNR plans for flooding to 4217 feet it is respecting a danger that is possible within our present climate regime.

d.) Flooding damage will occur above the still-stand level due to storm action, groundwater effects and changes in foundation properties.

e.) The PD does not discuss drought as a serious concern. DNR should expect GSL to decline to levels equal to or lower than those of the 1960s with attendant problems. As with highstands, the timing of lowstands of the lake is uncertain.

f.) DNR has not succeeded in getting other federal, state and local agencies to recognize and respect lake level fluctuations. The PD does not acknowledge that DNR is the most logical agency to provide leadership and influence entities to recognize flooding hazards and accept risks when they build on the lake's flood plain.

g.) The concept of management zones based on elevation of GSL makes sense. At some lake levels public safety is more at risk than at others. At some levels cultural resources are more impacted, etc.

2. Lake level prediction

a.) Lake level trends are studied for several reasons including:

A desire to predict future trends in lake level.

A desire to understand and explain the timing and processes that cause lake level fluctuations.

b.) Short-term forecasts can be the basis for contingency planning by the State of Utah and all GSL stakeholders.

c.) Present techniques such as those of the UWRL may help DNR managers make short-term decisions based on lake level forecasts 1-3 years into the future. Short-term forecasts can provide confidence intervals around the level the lake is likely to reach in the immediate future.

d.) Longer-term predictions are only as good as the projections of precipitation over the GSL watershed. At present, such long-term predictions for GSL have not proven effective and are not given great confidence by the scientific community.

e.) With little financial cost, DNR could establish a program to assess the utility and accuracy of predictions made by various individuals and organizations for future GSL fluctuations. In a decade or so DNR could then evaluate the usefulness of these predictive tools.

3. Lake level control

a.) Hydrologically, it is not possible to regulate the lake at a specific level in any given year or control lake level changes during significant wet or dry cycles. Stakeholders should not expect the State to possess or develop a capability to control lake levels. Natural lake level fluctuations are an important component of the GSL ecosystem and should be recognized as such by the State of Utah.

b.) A small reduction in annual maximum lake elevation is possible within the range of approximately 4207-4215 feet above sea level. The DNR during the 1980s studied many options for reducing lake level fluctuations. Presently, the only viable short-term mechanism for lake level reduction is the re-activation of the WDPP. The environmental costs of using the pumps in the 1980s is presently unknown, but if there are plans to re-activate the pumps these costs should be determined. If a decision is made to reactivate the WDPP a strong justification exists for modifying the intake system to enable the pumps to take the less saline water from south of the causeway and the return system to re-circulate water and salt back to the lake.

c.) Selective diking can protect critical public facilities. It does not protect the railroad causeway.

SALINITY ISSUES

1. Data gathering and model development

a.) State and Federal agencies are to be commended for the large amount of high-quality lake elevation and salinity data collected over the past fifty years.

b.) The USGS has developed a model capable of explaining lake elevation and salinity of GSL when GSL is considered one lake with only two parts, Gunnison Bay and the rest of the lake (i.e. Gilbert Bay, Bear River, Ogden Bay and Farmington Bay).

c.) Uncertainties in the datums used for measurements of historic water surface elevations at various lake locations should be resolved as soon as possible. When the elevation difference across a causeway is important, monitoring should be done on both sides of that causeway and not projected across many miles. Changes in technology may result in less labor-intensive monitoring programs. The State should continue its cooperative program with the USGS to monitor lake levels at the two locations in Gilbert Bay and one location in Gunnison Bay (i.e. Saline, Promontory, and Saltair) as long as the effects of the railroad causeway are of concern.

d.) Analyses and results of modeling should be validated to make sure they are free of substantive error that may have been introduced by errors in reporting of historic lake elevations.

e.) The PD implies that a change in upstream depletions of 100,000 acre-feet per year will affect lake elevation by about one foot. It is not clear whether the one-foot differential would be the cumulative result over time or that for a given year. Further the PD offers no detailed analysis of the net change in lake inflows that will result from anticipated or planned upstream diversions and water imports. More information regarding future water development in the watershed of GSL is available within DNR and should be used to address concerns about changes in magnitude and direction of lake level due to human intervention. Freshwater embayments become reservoirs behind dikes, which are in essence, dams. Their construction should meet all State of Utah and Federal dam safety standards.

f.) Schemes to impound fresh water and stabilize the lake level of certain portions of the east side of the GSL magnify the variability in the remainder of the lake. These may change what is presently a property damage problem into a life-safety problem along developed shorelines.

2. Data analysis

a.) The natural variability of GSL is not adequately addressed in the PD. Pre-causeway salinity conditions have not been adequately discussed.

b.) The PD states that "there is an apparent change in the exchange of salts between north and south arms." The PD does not include the presentation of a detailed salt

balance through time (i.e. mass -- not concentration -- of salt in the various lake bodies vs. time) to support this claim. This information is available from the modeling work currently being conducted by DNR-USGS and should be included.

c.) The hysteretic behavior of salt mass - lake volume changes has not been adequately discussed and evaluated with respect to salt balance implications of GSL.

d.) Published literature reports a possibly significant difference in the chemistries of pre-1991 deep brine layer in Gilbert Bay and Gunnison Bay brines. This should be examined so that questions of the source of the brine layer in Gilbert Bay and its disappearance can be addressed.

e.) Insufficient effort has been invested in analyzing and documenting what can be learned about lake salinity from the available data on individual ions, especially K or Mg.

3. The causeway

a.) The causeway created two water bodies where there was one. The causeway has resulted in an increase in salinity in Gunnison Bay with respect to Gilbert Bay.

b.) The assumption that the permeability of the older causeway fill materials has dramatically decreased has not been verified.

4. The USGS model

a.) The model calibration work currently underway has basically used only one parameter -- causeway permeability -- to calibrate the model. Is it possible that other potential calibration variables (such as assumed causeway flows, evaporation rates and/or estimates of net lake inflows, etc.) could produce as good or better calibration results?

b.) Good modeling procedures include sensitivity analyses on all variables in which there is substantial uncertainty. Current plans for model sensitivity analyses do not include an examination of the sensitivity of model behavior due to uncertainty in input variable values and boundary conditions. Such analyses could shed further light on the quality of the calibration process and provide insight to critical system components.

c.) Available publications show that previous calibrations of the USGS model consistently under-predict the elevation differential between Gunnison and Gilbert Bays prior to the causeway breach, and generally over-predict the elevation differential after the breach. This is perhaps a symptom of a systematic problem with the calibration, and if so might reflect directly on the principal calibration parameter considered, mean causeway permeability.

d.) The USGS modeling effort used all available total salt and hydrologic data for the calibration, leaving no data for model validation. Had some data been reserved against

which the model calibration could be compared, many of the criticisms of the water and salt balance work offered by IMC-Kalium could be addressed.

e.) It should be possible to address many issues surrounding model validation by applying the current calibration results to an analysis of the behavior of one or more specific ion forms (K or Mg), and comparing the model outputs against historic ion concentrations. This could be done both for ions that precipitate and ions that do not.

f.) The model could be used to explore the effects of the 1980s WDPP and causeway breach by simulating the behavior of the lake had these not occurred. This would shed light on the impacts that these events have had on the lake over the past several years.

THE ECOSYSTEMS

1. Importance

a.) GSL is an important ecological resource from a global perspective.

b.) The GSL is not a single ecosystem but several ecosystems that vary spatially and temporally.

c.) The PD uses the terminology "north and south arms" to describe the main areas of the lake. This obfuscates the even more important east-west contrast of ecosystems of the lake.

d.) There is not sufficient information in the PD regarding chemistry and ecology interactions on which to base or justify decisions. A systematic monitoring program should be instigated to develop a base line so trends in ecosystem response to change can be recognized.

2. Trace metals and nutrients

a.) More complete information on nutrient loading to GSL can be acquired from sewage treatment facilities and increased monitoring sites. Until recently there has been no pelagic monitoring of nutrients. Monitoring of pelagic nutrient levels, in conjunction with studies of brine shrimp ecology, started in 1996. It is recommended that this monitoring be continued and expanded to include more sampling sites covering more of GSL, and that sampling frequency be increased.

b.) Trace metals concentrations should be measured in lake and wetland sediments. More information should be acquired regarding bio-accumulations of metals in organisms.

3. Brine shrimp
a.) Brine shrimp populations are affected by many factors, including salinity, temperature, types and amounts of algae available, brine shrimp harvesting, and others.

b.) Brine shrimp are not widespread or sensitive enough to be used as the best indicator of the overall condition of the lake. Monitoring the condition of the GSL system should consider a community of species rather than a single species as an indicator species.

4. Additional ecosystem components
a.) Other invertebrates are important in areas where brine shrimp are scarce or are absent (given the variability of GSL no one species or group is a reliable indicator of ecosystem condition). Primary producers are the most sensitive indicators of abiotic components of this system.

b.) A huge data gap exists in DNR's understanding of winter productivity of GSL.

c.) Spatial and temporal variability is likely the reason for the incredible productivity of this system. A healthy GSL ecosystem is a variable one.

d.) The impacts of temperature, light, nutrient availability, and possibly other factors, as well as combinations of variables, on the GSL ecosystem are not adequately considered. In order to address the question of whether GSL ecosystem is "healthy", long term (10s to 100s of years) data is needed. For certain critical variables, for example nutrients, such data is presently unavailable.

e.) The role of sediments and sedimentation patterns in the ecosystem throughout the lake is not well understood.

f.) The PD should expand its discussions of fish to include carp in Bear River Bay and the native chub.

5. Management issues
a.) Lake level fluctuations are an integral part of the lake ecosystem. To the extent that DNR managers can allow for natural fluctuations into their plans rather than attempting to control fluctuations, they will enhance ecosystem processes.

b.) Bureaucracies have trouble looking at systems as systems. Present institutional boundaries limit the ability of DNR to consider ecosystems. There is no agency within DNR assigned to champion or monitor the GSL as a system.

c.) The PD grossly undervalues the non-traditional resources of GSL. Cultural resources are discussed (2 pages) but the PD does not recognize the value of the sediments of GSL for their historic record of climate change and documentation of earth system processes. Educational resources of GSL are discussed primarily in terms

of interpretation. Eco-tourism is subsumed in the discussions of recreation and tourism. GSL ecosystems are phenomenal for their non-traditional resources.

INFORMATION MANAGEMENT

a.) Convert all available data on the GSL from local, State, and Federal sources into digital format.

b.) Use the Great Lakes Research Institute as a model for disseminating information regarding GSL.

c.) Create a Web page containing the following features:

- Links to GSL data sets at Federal, State, local and university sources
- Information on current research projects regarding GSL.
- Current and proposed management strategies for GSL.

d.) Arrange annual or bi-annual meetings of all interested stakeholders and managers of GSL to exchange data and management ideas.

e.) Encourage the continuance of the Planning Team activities and recognize the effort it takes to successfully manage (not control) the GSL.

August 31, 1999

Kathleen Clarke
Executive Director
Department of Natural Resources
1594 West North Temple, Suite 3710
Salt Lake City, Utah 84114

Dear Ms Clarke,

We appreciate the opportunity to have participated with the Department of Natural Resources (DNR) in a review of the scientific underpinnings of "Great Salt Lake, Comprehensive Management Plan -- Planning Document." The DNR has on its staff some of the authorities on Great Salt Lake (GSL) and it was a pleasure for us to work with them. We have informally shared our thoughts directly with the Planning Team. Following are six perspectives that we believe will assist you in providing leadership to the development of the draft Planning Document.

1- **Knowledge pays off.** The information collected on the water balance, salt balance, and lake fluctuations of GSL provides a narrow but adequate underpinning for much of the discussion in the Planning Document. Without the decades of monitoring of lake levels and salinity of GSL the scientific foundation would be woefully inadequate for defending management decisions. Much is known about the lake, but there is a great deal we do not know. The elevation of the lake surface has been monitored for over a century. The State has a relatively good information base for the salt balance of the lake based on monitoring of lake salinity since construction of the causeway. There are, however, almost no comprehensive, integrated information bases for GSL ecosystems. The present relative ignorance, due to lack of data, about the ecosystems of the lake makes it very difficult to make management decisions designed to protect the ecosystems based on scientific reasoning. The DNR should support and expand monitoring programs and research to better understand natural and human-caused changes of the lake. All currently available data on the GSL should be accessible in electronic form.

2- **The lake is a system of interlocking subsystems.** The lake is several water bodies and differs as much east-west as north-south. The lake's physical, chemical, biological, ecological, economic, and social systems are dynamic and interact to influence the

behavior of each other in complex ways. The Planning Document approaches GSL issues based on constituencies. Resources of the lake that have constituencies are well considered in the report while resources that do not have constituencies are not. The lake should be thought of as a complicated set of subsystems rather than as a collection of individual components. Managing the lake as a system recognizes that each management decision impacts the total system. The scientific database to support this kind of systems management should emphasize interactions among the components in addition to the components themselves.

3- **Recognize and to the extent possible welcome lake level fluctuations.** The idea that the State of Utah can control the lake within a range of a few feet is unrealistic. The Planning Document gives the impression that the State of Utah can control the lake rather than living with its fluctuations. Hydrologically, it is not possible to control lake level changes, nor should stakeholders expect the State to possess or develop a capability to do so. The State should accept occasional flooding and work with other state and federal agencies and local governments to respect and plan for fluctuations in the lake level. Given the time scale on which human activities operate, predictions of the range of lake level fluctuations have some use in the short-term (1-3-year period). Longer-term predications, however, are not reliable enough for planning purposes. The state should assume the lake will rise to the historic high levels (4212 ft a.s.l.) during the lifetime of most facilities and that the lake can rise even higher (4217 ft. a.s.l.) in today's climate regime. Given that lake level fluctuations will occur, any policy that does not acknowledge probable flooding levels is not on strong scientific footing.

4- **The salt balance of the lake is well understood in its broadest terms.** The railroad causeway created the dramatic dynamics that determine the salt balance between Gunnison (north part) and Gilbert (south part) Bays. In the past few years of rising lake level, Gunnison Bay has gained salt at the expense of Gilbert Bay. This is a transitory and expected phenomenon. However, when the lake is at high levels and declining, there is a net movement of salt from Gunnison Bay into Gilbert Bay. Thus, on the time scale of decades, the difference in salinity between Gunnison and Gilbert Bays is relatively constant. Analyses of lake chemistry by DNR and IMC Kalium, as well as results from a numerical model developed by the U.S. Geological Survey, have been used as tools to understand these dynamic changes in the salt load of the lake. All parties agree that approximately 12% of the total salt load of the lake was lost to the West Desert as a result of pumping from 1987 to 1989. IMC Kalium and the DNR-USGS model differ in their interpretation of the effect of the breach in the causeway and the role of changing causeway permeability. The former concern can probably be resolved using existing data while the latter will require geotechnical information that has not yet been assembled. We have provided details of these issues in our discussion points with the Planning Team.

5- **The health of the GSL ecosystems should be of paramount importance.** DNR is wise to be concerned about the health of all of the GSL ecosystems. A "healthy" ecosystem can be defined as an ecosystem that is within natural variability; whereas, an

"unhealthy" ecosystem is one that has been impacted to such an extent by human activity that it is no longer within natural variability. Some ecosystems, probably including the ecosystems of GSL, are naturally variable and may depend on this variation to redistribute nutrients and support diverse communities. A tough question facing DNR is whether the ecosystems of GSL are "healthy". In order to answer this, we need know the natural variability of the GSL ecosystems, and to answer that we need long-term data (several 10s-100s of years). For certain important variables, for example nutrients, we have virtually no data from which to determine natural variability or trends. Understanding the impacts of changes in nutrients and salinity on GSL biota are essential for determining the functioning of GSL ecosystems. Based on the data available to us, we know that at sometime in the past GSL has probably been as saline as Gunnison Bay and as fresh as Gilbert Bay are today. Construction of the railroad causeway created a very different set of GSL systems than those that existed prior to 1959. Also, the WDPP significantly reduced the salt load in the main body of GSL. Were the WDPP re-instituted and more salts deposited from the lake to the West Desert Pond, the salt problems might be exacerbated to such an extent that the lake would reach a crisis state. The DNR should expand monitoring presently underway to include all key components of the GSL ecosystem and to be spatially and temporally comprehensive. Such a monitoring program should identify trends that indicate when the lake is on a dangerous trajectory and act as an early warning system of "unhealthy" lake conditions.

6- **Respect the lake and appreciate its diverse resources and ever changing boundaries.** We suggest that the GSL is a phenomenal asset to the State of Utah. Its mineral resources have been appreciated for almost 150 years. The brine shrimp are now appreciated because they are economically valuable. To only a very limited extent is the lake appreciated for tourism, for culture, for earth systems history, and for education. We fear that the present constituencies drive the DNR approach to management and that these policies may eventually diminish the net social value of the lake to the citizens of the State of Utah.

Thank you for this opportunity to share our perspectives with you.

Respectfully,
GSL Science Review Committee

Genevieve Atwood
John A. Kadlec
Paul W. Jewell
Mac McKee
Katrina A. Moser

Planning Process and Structure

Planning Process and Structure

The Planning Process

In August 1997, the DNR assembled the Great Salt Lake Project Planning Team of representatives from each of the divisions of DNR, with the charge to develop a resource management plan for DNR and all its divisions. The planning process utilized by the team is based on the land management planning process set forth in Section 65A-2-4 of the Utah Code, and in implementing rules found at R652-90 adopted by DFFSL, specifically the processes for CMPs. Because of the scale of GSL as a planning unit, and because of the complexity and significance of the lake and its resources, the planning team has implemented steps and public processes in addition to those set forth in the R652 rules.

Public involvement in the planning process was officially initiated on February 3, 1998 with a notification of State Action to RDCC and locally published public notices inviting participation in several scoping meetings conducted in each of the five counties in which GSL is located. However, starting in November, the planning team also conducted informal internal and external scoping and issues identification, and attended a number of association, club and individual agency meetings to discuss the plan and the planning process.

Comprehensive Management Plan

It is anticipated that the Great Salt Lake CMP will have a life span of a minimum of 10 years. The plan is subject to review and revision as the need arises.

DFFSL will be the administrator of the plan process. This division will be responsible for implementing the recommendations of the plan. It will also be the central point of contact for anyone wishing to receive information on the plan or to inquire on an aspect of the plan. The division's office will act as the repository of information for all information pertaining to the development and completion of the plan.

DFFSL will work with the entire DNR and other agencies to allocate and protect the public trust resources of GSL. Routine allocation issues such as leasing and permitting for land use will be handled by DFFSL. Other issues will be referred by DFFSL to divisions as needed.

The Decision on the Preferred Alternative

The decision on alternatives and description of management allocations will appear at this location in the final version of the *Great Salt Lake Comprehensive Management Plan*. The decision and document are scheduled to be available in 2000.

The recommendation of the Great Salt Lake Planning Team and DNR's division directors upon printing of this draft plan is found in the "Preferred Alternative Rationale." This

recommendation provides an appropriate mix and balance between the GSL ecosystem and the economic goods and service benefits it offers. Input and data for this recommendation have been based on previous plan information, scientific data and identified citizen preference.

The Preferred Alternative is our best effort to provide guidance to resource managers, lake beneficiaries and the citizens of Utah on how to approach future management of sovereign land, lake use and allocations with a minimum of irreversible decisions. This approach will provide the maximum benefits to support multiple use principles of our public trust responsibilities. However, it is only after thorough review and analysis of new scientific data and other information offered during the 45-day comment period that a final mix and balance will be offered to the decision making process. Please participate with us in creating the comprehensive management plan that will guide the future of this great natural resource.

Rationale Behind the Preferred Alternative

1.1 Define the GSL flood plain for planning purposes.
The 4217 foot elevation is based upon the most recent historic high lake level of approximately 4212 feet, with the addition of three feet for wind tide and two feet for wave action. DNR believes it is reasonable to assume that the lake will again reach 4212 feet during the lifetime of most facilities located near the lake. The practical reality regarding flood plain management is that DNR's influence is limited to the power of persuasion. DNR's power of persuasion may have been enhanced by the availability of state funds to help local government recover after the 1980s flooding. Planning and zoning are a function of local government, not state government. Development above the surveyed meander line is and will continue to be controlled through local planning and zoning functions irrespective of what DNR calls the flood plain.

1.2 Develop strategies to deal with a fluctuating lake level.
The basic premise is that lake level is far more a function of climate and precipitation than any human influences. Upstream diversions, inter-basin water transfers, and WDPP have some effect on lake level, but do not come close to what could be considered "control" of the lake. Understanding that lake level fluctuations will occur, that there is little anyone can do to limit fluctuations, and that shoreline habitat has and will continue to change in response to changing lake levels, DNR's preference is to respond to lake level fluctuations. Four-foot zones were used in 1995 to characterize potential flood damage and to describe the relative amount of time the lake is at a certain level. Given the extent of annual fluctuations, DNR sees no particular advantage in using a different elevation zone classification. To the extent that other entities care what DNR does, they may take into account DNR actions when planning their actions.

1.3 Determine the policy for WDPP operation.
The 1995 Great Salt Lake Comprehensive Management Plan recommended the WDPP begin operation when the GSL elevation exceeds 4205 feet. In 1995, the feasibility of

extending the inlet channel and other related modifications was studied and feasibility costs estimated. In the absence of an emergency, DNR was discouraged from pursuing funding for modifications to the WDPP. Also, institutional factors such as those related to Hill AFB Bombing and Gunnery Range discouraged pursuing some resolution of the 1995 plan.

The present Great Salt Lake Comprehensive Management Plan has re-addressed the WDPP and has recommended as the preferred alternative a plan to extend the inlet canal and resolve the return brine channel with the Hill AFB, but start pumping at 4208 feet, not 4205 feet as proposed in the 1995 plan. In a general sense, more is known about the lake's ecosystem after flooding occurs. The relatively quick recovery of habitat and the renewal of vegetation after the high water years brought about an increased appreciation for lake level fluctuations.

DNR has consulted lake industries, UDOT, UPRR, etc., and has estimated the differences in damages between not pumping, beginning to pump at 4205 feet, and beginning at 4208 feet. The cumulative damage numbers are in thousands.

Lake Elevation	Current Situation	Alt. A	Alt. B	Alt. C
4205	$8,438	$8,438	$8,438	$8,438
4208	$51,731	$46,281	$51,731	$22,338
4210	$63,756	$55,341	$64,256	$30,948
4212	$95,056	$91,976	$223,306	$62,293

Economically, it is recognized that Alternative C minimizes the damage and cost to GSL industry and other structures and facilities around the lake. The reduction in damages is greater by beginning pumping at 4205 feet than waiting until 4208 feet. However, the GSL is a physical system composed of many natural elements. Economics alone can not be the deciding factor regarding WDPP operation. Alternative C represents a pumping scenario that most likely means that a full pumping cycle will not be possible. Pumping through a full cycle is paramount because it minimizes the deposition of salt on the west desert. The costs of modifying the WDPP to operate at 4205 feet, the increased difficulties of returning the minerals from the West Desert Pond, the institutional factors, and operating time considerations (less than 10 percent of the time for Alternative A, over 30 percent of the time for Alternative C) provide the rationale for selecting the 4208 foot preferred alternative. The other aspects of Alternative A, which take into account the lake's natural features, better corroborate the balanced approach the CMP takes for management of the lake.

1.4 Declining flows at Locomotive Springs WMA.

No continuous, representative discharge records exist for the springs. This data should be collected to determine if the flow to the springs is actually declining due to human interference. It would not be prudent to plunge into a "solution" to the issue of spring flow without a good understanding of how the flow system functions. Water supplying

the springs is thought to originate in the alluvial aquifers of the Holbrook-Snowville flow system to the north, or the deep regional carbonate aquifer which underlies western Utah and eastern Nevada, or a combination of the two. Studies to determine how much water each system contributes are essential to determine if a problem exists and to craft an effective mitigation and/or remediation plan. To be valid, these studies would require the cooperation, or at least the acquiescence, of the State of Idaho. DWRi has sent two letters to the State of Idaho on this matter, neither of which has received a response.

1.5 Administration of water rights and supply in GSL drainage basin.
Many of the drainage basins tributary to the lake are closed or restricted for new appropriations of water. As a result, the acquisition of water rights to supplement existing and future activities in and around the lake will proceed on a willing seller/willing buyer basis. Planning activities dealing with water rights above the lake's meander line are beyond the scope and authority of this planning effort.

1.6 Determine state policy regarding creating large fresh water embayments like Lake Wasatch, Lake Davis, and other inter-island diking proposals.
Several proposals for inter-island diking and fresh water embayments on GSL have been funded and studied to varying degrees over the years. None of the proposals have been implemented due to the lack of political and financial support. DNR does not support the proposals because of extensive impacts on sovereign land, lake resources and risk associated with geologic hazards. The locations of the proposed projects are on lands the legislature has authorized DWR use for wildlife purposes. The likelihood that impounded water will be suitable for its intended use is questionable. DEQ/DWQ agrees with this assessment. There are a variety of other reasons (see pages ?). The preferred alternative would not permanently preclude developments of this kind, but it would require a plan amendment if projects were to be approved. The amendment process would ensure extensive public review of proposals.

2.1 Identify the salinity management regime for GSL.
DNR acknowledges the effect human-made structures have on GSL. Evaporation ponds can increase salinity to the point that shoreline habitat is lost. Causeways affect the interchange of brines: (1) Farmington Bay is less saline than would be under natural conditions for a given lake level; (2) the north arm (Gunnison Bay) is more saline and the south arm (Gilbert Bay) less saline than would be under natural conditions for a given lake level. The WDPP deposited a substantial volume of salt on the west desert, thereby affecting the salt balance in the lake. To one degree or another, bird refuge and WMA dikes impound fresh water and prevent lake water from reaching what would be natural shoreline areas. In actively managed areas, such as solar ponds and WMAs, the desired effect is achieved by influencing salinity. All of these effects are acceptable in the context of public trust management and multiple-use framework for GSL as long as sustainability is not jeopardized.

Much of the sustainability question is a social, economic and political matter and it deals with the acceptability of varying degrees to which natural systems are impacted. But there must be a standard that constrains the range of social and political decision-making. The measure of sustainability DNR chooses to use, and against which future management

actions will be evaluated, is the degree to which beneficial uses of sovereign land are judged to be impaired or enhanced, against a backdrop of preservation of most of GSL as a natural body of saline water. A natural body of saline water is defined as water with salinity (average of the entire water column) within the range of salinity variation over the last 150 years. This is the lake's historical range.

In choosing among alternatives the fundamental concern is not the particular economic impacts to a specific industry, company or activity. It is not the relative advantages of companies competing with each other. It is not to afford relief to south arm industries at the expense of north arm industries, nor to protect any special advantage of north arm industries against the complaints of south arm industries. The fundamental parameter is the public interest. The public interest is statewide, and in some respects the lake serves national and international interests. Protection of the lake's ecology will serve the public interest.

For the first time on record the trend for salinity in the south arm of the lake is heading outside the historical range. This is a consequence of human disruption in the form of the northern railroad causeway and WDPP. In DNR's judgement salinity levels outside historical variation behind project-specific dikes and impoundments are acceptable because the change in salinity is the desired effect. The south arm, however, is too much of the lake to allow it to exceed historical salinity variation.

DNR has concluded that the permeability of the northern railroad causeway has decreased. (See Appendix I.) Prior to the 1980s high lake level, the causeway fill provided 70 percent of the brine interchange, the culverts 30 percent. Compaction of the fill, introduction of organic and inorganic fine material over time and the addition of fill required to keep the causeway above rising water in the 1980s has significantly decreased permeability. Removal of some 600 million tons of salt from GSL by WDPP has contributed to the south arm salinity concern. Initial results of USGS and DWRe modeling (See Appendix H.) shows that approximately 80 percent of the salinity difference between the 1980s to the present is attributable to decreased permeability of the causeway. The remaining 20 percent of the difference is attributable to WDPP.

The salinity concern may be alleviated to some degree by operating WDPP through a full cycle to return some of the salt deposited in the west desert, but in the absence of a flooding emergency, WDPP modification, startup and operational costs are prohibitive. The most cost effective, long-term remedy is causeway modification to increase the exchange of brine. To compensate for the loss of salt to the West Pond and decreased causeway permeability, the causeway breach will be deepened about four feet to its original design depth of about 4195 feet. Structural integrity of the bridge will not be affected by this excavation. The culverts will be kept clean by the railroad. The effect of the causeway modification on south arm salinity will be monitored. The potential for additional openings in the causeway will be studied in the event DNR determines that open culverts and a deepened breach are not sufficient to keep south arm salinity within its historical range.

As noted in the ecosystem section, lack of full scientific certainty should not be used as a reason not to initiate measures to prevent environmental degradation. A precautionary

approach is prudent. Implementation of the preferred alternative may be the first step or it may be the final step in salinity management. The continuing studies under DWR's GSLEP and a few years of monitoring the effect of the causeway modification will aid DNR's decision process in reaching the desired historic salinity levels.

2.2 Account for the locations and quantities of salts in the GSL system.
In light of lake salinity issues and disputes over ownership of salt in the lake system, DNR believes it is important to know the locations and amounts of GSL salts. Some locations hold relatively small quantities. An accounting of all salts in the lake system can serve as a baseline for future studies.

3.1 Develop a strategy to ensure water quality protection for the GSL ecosystem.
Existing water quality narrative standards for discharges to the lake and permits are determined on a case-by-case basis. The general policy is stated as follows "to the extent feasible, no pollutants should be delivered to the lake in amounts that result in concentrations great than those already present in the lake." This policy does not prevent gradual water quality degradation over time and this general statement allows room for interpretation in regard to permit approval. Because GSL is a terminal basin pollutants to the lake will gradually increase this baseline condition over time. Salinity, temperature, lake currents, contaminants in lake sediments and many other factors play a role in altering the chemical nature and the physical conditions that might increase heavy metals bioavailability. Impacts resulting from non-point source and point source pollutants on wildlife and could impair other multiple-use management objectives. DNR would investigate options to improve the existing water quality narrative standard to ensure protection of public trust resources by adding some reasonable additions to this policy through improved coordination. One option is to change the classification for GSL to 3C or 3D during the next review period in 2002. This will affect classifications for tributaries.

Nutrient loading in GSL wetlands and dynamics in the open water are not well understood. Coordination would identify management objectives to investigate nutrients, help in developing studies and in determining management response.

3.2 Determine GSL wetland policy.
Federal regulations provide for the bulk of wetland protection measures and are generally adequate. On Great Salt Lake, actions in unregulated (non-jurisdictional) wetlands and actions such as excavation, grazing, burning and chemical application that are not covered by federal regulation may affect important wetland resources. DNR wants to take advantage of the opportunity to consider these actions in a policy framework to allow an added measure of protection.

4.1 Protect public trust resources (relates to air quality impacts).
Improved coordination is needed to improve the assessment of impacts to public trust resources and for remedial response. DNR would recommend additional air quality monitoring stations to evaluate air quality trends and studies to investigate air quality impacts on wildlife (aquatic organisms, water birds and other species). Air quality is also important in regard to resource protection and other multiple-use management objectives. Air quality degradation could alter resource allocation decisions in the

future (where and how particular activities are allowed) and impact existing resources and activities such as recreation and viewshed values.

5.1 Identify strategies to preserve and maintain habitat and wildlife on GSL in order to preserve the integrity of this ecosystem.
The wildlife values of GSL have been maintained previously because the lake and surrounding marshes have been inaccessible to people or undesirable for recreation activities relative to others areas of Utah. People see the lake every day but rarely, and in some cases never, go there. Industrial development has had a substantial impact on the lake. Creation of dikes to impound brines in large shallow basins has substantially reduced wildlife values on significant acreage. The lack of knowledge about the wildlife values lost, and lack of appreciation for those losses because they occurred in areas seldom visited by people, are reasons for the occurrences. DNR believes a greater effort is needed to understand the wildlife functions within the ecosystem and manage to protect the existing values, mitigate the losses when practicable, and extend greater protection than has occurred historically.

6.1 Determine the appropriate mix of sovereign land classifications.
DNR believes that GSL is large enough to accommodate the legislative policy regarding specified multiple uses without significant adverse effects. Sovereign land classifications are very similar to those in the 1995 plan.

With exception of existing mineral leases in Bear River Bay, a zone managed by the DPR around Antelope Island and a stretch of beach area from old Saltair to Black Rock, sovereign land in the east side of the lake is managed for resource preservation (this includes WMAs). As private land development moves closer to the lake, sovereign land habitat increases in importance. The proposed classification protects habitat and vistas on the east side.

While little development on the west shore is expected, it is available for development uses. This is where conflicts with wildlife and viewshed are fewer. The significant exception is resource preservation zones in the north part of the north arm, and around Hat, Gunnison and Dolphin islands, which are the relatively more important wildlife use areas on the west side. The Rozel Point and West Rozel oil fields are managed for development, as are shoreline areas suitable for brine shrimp harbors.

Much of the lake is classified as open for consideration of any use, but developments in open water areas are not expected. By protecting the more important wildlife areas, protecting existing mineral leases, allowing for development of known mineral resources, and allowing for intensive recreation development somewhere along the south shore, a reasonable mix of sovereign land classifications is provided.

6.2 Consider geologic hazards in all sovereign land use decisions.
Statute requires that DFFSL disclose any known geologic hazard affecting leased property. As a matter of routine the UGS identifies geologic hazards through the RDCC process when UGS is apprised of proposed state actions submitted to RDCC by DFFSL. DFFSL routinely passes on the information to lessees. There is little if any follow up. Under the preferred alternative DFFSL would follow up by requiring a site-

specific analysis of potential hazards and consulting with UGS regarding the adequacy of proposed mitigation if required by DFFSL. DNR believes this is a logical result of the requirement to disclose hazards. It makes little sense to disclose known hazards but then require nothing further. The preferred alternative ensures full consideration of geologic hazards.

6.3 Bear River Migratory Bird Refuge expansion.
Expansion of BRMBR is consistent with wildlife use for specific, legislatively-designated sovereign land, except for the management agency (DWR or USFWS). The conflict lies in regulation of hunting. Sovereign land in the expansion area technically open to hunting under state law may be closed to hunting by BRMBR, and hunting may be governed by BRMBR under federal regulation. Assuming these conflicts can be resolved, sovereign land will be made available for BRMBR expansion. There would be no change to the administrative framework within the old refuge boundary.

6.4 GSL diking policy.
Given the increasing appreciation for habitat-related beneficial effects of fluctuating lake levels, the objective is to make sure that on-site and off-site impacts of dikes are taken into account when diking activity is planned. The policy will apply in-house as well, for example state WMA dikes.

7.1 Review the Mineral Leasing Plan zones.
The 1996 MLP was prepared under existing rule with associated public review and comment. The MLP precludes new leasing of any kind in most of the east side of the lake. This restriction was based on the importance of recreation and wildlife values and low mineral potential in the area. An exception was made for salt leasing potential (suitable ponding site) at the south end of the lake. This area is available for salt leasing under special stipulations. With known oil fields and potential ponding sites available for leasing, important recreation and wildlife areas not available for leasing, and operational constraints over much of the rest of the lake, legislative policy to encourage the use of appropriate areas for extraction of brine, minerals, chemicals, and petrochemicals is implemented.

7.2 Review Mineral Leasing Plan policies.
Implementation of MLP policies, so far, has resulted in the desired effect. The nomination process works well for identifying special concerns, determining lease stipulations in response to those concerns, and making the stipulations known at the time the lease is offered for competitive bid. Acreage under lease in important wildlife areas has been reduced. This planning issue generated virtually no public comment that indicated the need for change.

8.1 Provide additional recreational opportunities in response to specific demands or needs, consistent with the protection of trust resources.
This issue deals exclusively with recreational boating and the facilities to accommodate this use. The Great Salt Lake Marina and Antelope Island Marina currently provide access to the lake. DNR anticipates no further public investment in marina facilities. Instead, DNR wants to encourage private investment to provide additional marina

facilities, if needed. So far, the potential lessees of the Black Rock commercial marina are willing to open that facility, when built, to recreational use if requested by DPR.

8.2 Navigability on GSL.
Limited recreational and commercial boating access into the north arm from the south arm is available through the northern railroad causeway breach near Lakeside. Any effort to breach the northern railroad causeway to facilitate full navigational access between the south and north arms would be very costly. Full navigational access can be accomplished in one of two ways: 1) breach the causeway and construct a bridge that will accommodate high vessel passage; or 2) breach the causeway and abandon railroad traffic across it. Any breach in the causeway designed to fully accommodate navigational access without disrupting railroad traffic will need to occur in water depths sufficient for deep keel boat passage. The bridge system spanning the breach must not only allow railroad traffic across the causeway, but also have sufficient height or mobility to allow passage of sailboats with tall masts. The geology of the lake bed in the deeper waters is such that engineering and constructing a bridge will be extremely expensive, if not impossible. The second scenario for full navigational access circumvents the geologic and engineering impediments associated with constructing a bridge, but requires the railroad to abandon the causeway and re-route the displaced train traffic. This alternative is obviously very damaging and costly to the railroad and those who use rail transport.

Although the causeway acts to restrict, through size limitation, the number of vessels capable of navigating into the north arm, sensitive ecological interests are buffered by the reduced access. The small islands located in the north arm provide critical habitat and nesting grounds for American white pelicans and other shorebirds. Gunnison Island hosts one of the three largest nesting colonies of American white pelicans in North America. The pelicans and other shorebirds rely heavily upon the habitat provided on these isolated islands during the annual nesting season, and even minimal human presence has shown to disrupt them to the point that they move off the island to less productive habitat.

9.1 Develop opportunities on sovereign land for off-highway vehicles.
A public planning process conducted by the ad hoc West Box Elder Access Team under the auspices of Box Elder County identified sovereign land in T11N, R11W as suitable for OHV use. This is consistent with OHV designations for adjacent upland. Some DNR divisions participated on the team. Box Elder County has passed the ordinance that deals with implementing the access team's recommendation. It is appropriate that DNR now follow through on its obligation to implement the access management plan. The preferred alternative does this. Monitoring and enforcement are part of OHV management in the area. If monitoring shows unacceptable resource damage, OHV use on this sovereign land may be modified or terminated. The Box Elder plan addressed OHV problems related to resource damage on public and private land at Monument Point and Salt Wells areas. Opening sovereign land in T11N, R11E, as part of a multi-jurisdictional plan, is a reasonable tradeoff against the difficult enforcement problems on sovereign land elsewhere in west Box Elder County.

9.2 Improve recreational opportunities and access.
The specified locations are not exclusive. They are locations which, based on existing visitation, scoping comments or expressions of interest at public meetings are viable access points. There are potential constraints or conflicts to be resolved for some locations. The preferred alternative is an expression of interest in pursuing the opportunities.

9.3 Improve education and interpretation opportunities.
The specified locations and potential cooperators are not exclusive. They are locations which, based on existing visitation, scoping comments or expressions of interest at public meetings, are viable interpretation and education opportunities. There are potential constraints or conflicts to be resolved for some locations. The preferred alternative is an expression of interest in pursuing the opportunities.

9.4 Hunting conflicts on sovereign land.
The proposed alternative will clarify where waterfowl hunting will be allowed near Antelope Island. Working with the Utah Air Boat Association and other publics, a 100-yard buffer was determined to be an acceptable buffer to reduce conflicts near developed areas on the island. The posting of no hunting areas around the GSL State Marina has addressed conflicts there.

10.1 Identify an acceptable mix of DNR's statutory requirements in regard to commercial and industrial use of the lake's resources.
As stated in Issue 6.1, DNR believes GSL large enough to accommodate the legislative policy regarding specified multiple uses without significant adverse effects. No new commercial or industrial use of GSL and its resources is anticipated, nor is there reason to expect that existing commercial and industrial uses cannot operate within the constraints of sovereign land classifications and mineral lease zones. If something new arises but cannot be accommodated under existing classifications or zones, a plan amendment will be considered. If an amendment is proposed, it will include an offsetting change in classification or zone. The offset will be based on factors including acreage, function and public trust value. Under this amendment approach, adequate mitigation will be ensured until a new planning cycle is completed.

10.2 Open specific areas of the lake for commercial harbors for the brine shrimp industry.
At a public meeting on June 16, 1995, DNR's brine shrimp task force made several announcements regarding brine shrimping. The announcements included the policies that no new exclusive special use leases for harbors will be issued and that the Antelope Island Marina will be available for commercial use until commercial use becomes incompatible with recreational use or adequate alternative facilities are available. These policies remain in effect.

The south arm sites were identified by the task force as dispersed strategic locations where water depth is suitable, access is reasonably available and conflicts with public trust resources are relatively minimal. The north arm sites are locations where harbors already exist in one form or another. Additional harbor development at these locations will not result in significant adverse effects. The intent of the harbor policy is to

eliminate access to the lake as a competitive factor in the brine shrimp industry and to encourage its members to work together on harbor construction in order to concentrate development and confine impacts from harbor construction to a few strategic locations.

10.3 Establish policy regarding unauthorized construction below meander line for the development of harbors, ramps or other structures.
The proposed action deals with more than construction by potentially linking penalties for violations of one DNR agency's statutes and rules to the full range of permits and licenses issued by all DNR agencies. This will further enhance DNR law enforcement on the lake. Rather than each division separately imposing sanctions for violations, all permits and licenses issued by DNR agencies may be subject to suspension, termination or other action.

11.1 Allow grazing on sovereign lands to the extent that it is consistent with public trust responsibilities.
The majority of sovereign land grazing potential on the lake is on lands within the 39 townships specified in Section 23-21-5. Several existing permits allow cancellation, after notice, if DWR decides grazing is having an unacceptable adverse effect on nesting habitat or other wildlife value. All permits contain a provision allowing for cancellation if the land is committed to a higher and better use. Since DWR is better prepared to determine impacts to wildlife values and has a greater on-the-ground presence than DFFSL, it makes sense to transfer administration of grazing permits to DWR.

12.1 Designate roads, causeways and utility corridors.
Use of existing corridors for transportation and utilities will minimize impacts because there will be no new ground disturbance. The two railroad causeways provide east-west corridors and are important transportation links. A utility, railroad and highway "corridor" already exists east of the lake. The Davis County Causeway provides access to AISP. The AISP southern causeway is not supported because it traverses private property and important south shore wildlife habitat. As discussed in the Antelope Island Resource Management Plan the causeway would result in access management problems for the park.

13.1 Identify the meander line on the ground for law enforcement purposes.
This reflects the current law enforcement approach, with addition of linking DNR-issued permits (Issue 10.3) and using orthophoto mapping technology to identify the meander line. The orthophoto maps will be a useful guide to the general location of meander for law enforcement purposes, but it is likely that actual surveys will be needed on a case-by-case basis when serious disputes arise regarding the meander location.

14.1 Improve search and rescue access and operations.
All search and rescue efforts are the responsibility of county sheriffs' offices. Due to the location of AISP and GSL State Marina facilities and the availability of DPR resources, the majority of search and rescue efforts will involve DPR. The five counties around the lake have an Operational Preplan for GSL rescues. Utility of the boat ramp at Little Valley Harbor is limited by water depth. Improvements would

include dredging near the ramp area. The Operational Preplan is an inter-local agreement that coordinates resources and representatives directed by a council. One council recommendation is to acquire better vessels for rescue purposes.

15.1 GSL and its surrounding wetlands have been nominated for a Ramsar designation.
DNR encourages interested persons to assist in investigating resource management implications of Ramsar designation. Preliminary indications are that existing Ramsar designations in the U.S. are typically sites that focus on wildlife and habitat protection where Ramsar designation nicely complements the dedicated use of resources. The extent to which a variety of uses under the Public Trust Doctrine and the legislature's multiple-use mandate can be accommodated under Ramsar designation is not certain. The reasoning some advocates offer that Ramsar heightens appreciation for wetland values and provides protection but does not effect management requires more investigation. The requirement to report to an international organization on management actions if GSL were to become a Ramsar site is somewhat an affront to state sovereignty. The preferred alternative does not preclude designation; it ensures full assessment of management implications.

16.1 Protect open space and critical lands near the lake.
DNR supports preserving open space and critical lands and will look at acquiring property or conservation easements on a case-by-case basis consistent with DNR policy.

16.2 Protect the viewshed or the visual aesthetics of GSL.
Lake users value the viewshed and aesthetics of GSL. DNR supports working towards a visual resource management plan. This could include removal of existing visual barriers and placing restrictions on future barriers. It could also address viewshed mitigation strategies as part of the permit approval process.

Appeal Process

In accordance with Utah Code Ann. Section 65A-1-4, "Division of Forestry, Fire and State Lands -- Creation -- Power and authority," an aggrieved party to a final action by the director of DFFSL may appeal that action to the Executive Director of DNR within 20 days after the action. The executive director shall rule on the DFFSL director's action within 20 days after receipt of the appeal. The specific procedure through which any party aggrieved by a DFFSL action may appeal is outlined in Utah Admin. R. 652.

Implementation Schedule

Developing specific implementation activities are an important part of GSL planning and issue resolution. The following implementation activities are specific actions that reflect the current management direction for the lake and its resources based on the best and wisest use and a balance of public needs at this time. The implementation table also lists activities that the planning team believes are economic feasible and reasonably attainable actions based on management tradeoffs and sustainable protection of this unique resource. Implementation requires stakeholder and local, state and federal coordination, policies, site specific plans, research, monitoring and identification of future actions to accomplish these implementation activities.

This schedule specifies the actions to be taken to implement this CMP, lead agency responsibility for the action, and the time frame within which the action will be taken. This schedule is organized by planning issue (resource concern) as presented in the plan.

Planning Issue	Implementation Action/Product	Responsible Party (Lead Agency)	Target Date
1.1 flood plain	1. define flood plain in GSL Plan 2. coordinate with local government	1. DNR 2. FFSL	1. plan approval 2. 12/31/99
1.2 lake level strategies	specify actions to be taken	DNR, other entities may do same	3/31/00
1.3 WDPP policy	specify policy	DNR	plan approval
1.4 Locomotive Springs flows	investigate causes and mitigate impacts	DWRi	ongoing (1)
1.5 water right acquisition	case-by-case acquisition	DWR	continuous (2)
1.6 embayment policy	specify policy	DNR	plan approval
2.1 salinity	1. clean/modify causeway openings 2. monitor salinity 3. determine need for further action	1. FFSL 2. UGS 3. FFSL	1. ongoing 2. ongoing 3. continuous
2.2 salt accounting	develop, implement methodology	FFSL	12/31/00
3.1 water quality	1. refine DWQ standards 2. pursue grants (3)	DNR	1. 2002 2. continuous

Planning Issue	Implementation Action/Product	Responsible Party (Lead Agency)	Target Date
3.2 wetland policy	policy statement	DNR	6/30/00
4.1 air quality	1. negotiate MOU with DEQ 2. establish new monitoring station	DNR	12/31/00
5.1 23-21-5 lands	proposal to designate WMA lands	DWR	3/31/00
6.1 sovereign land classifications	change designations	FFSL	plan approval
6.2 geologic hazards	identify and analyze on case-by-case basis	FFSL	plan approval
6.3 BRMBR expansion	negotiate land use authorization	FFSL	after ownership below meander is determined
6.4 diking policy	require assessments	FFSL, DWR (4)	plan implementation
7.1 ML zones	implement MLP	FFSL	ongoing
7.2 ML policies	implement MLP	FFSL	ongoing
8.1 boat harbors	make Black Rock harbor available	FFSL	upon recommendati on by DPR
8.2 navigation	consider navigation when causeway modifications are evaluated	FFSL	ongoing
9.1 OHV	1. open T11N, R11E 2. address OHV use in WMA plans 3. enforcement	1. FFSL 2. DWR 3. DPR	1. plan completion 2. routine WMA plan cycle 3. continuous
9.2 access	improve access as opportunities allow	DNR	continuous
9.3 interpretation/ education	improve as opportunities allow	DWR, FFSL, DPR (5)	continuous

Planning Issue	Implementation Action/Product	Responsible Party (Lead Agency)	Target Date
9.4 hunting conflicts	proclamation	DWR	ongoing
10.1 sovereign land classifications	change as needed	FFSL	continuous
10.2 boat harbors	make sovereign land available	FFSL	ongoing
10.3 trespass	determine linkage among permits	DNR	10/31/00
11.1 grazing administration	transfer to DWR on WMA lands	FFSL	plan completion
12.1 transportation	designate corridors	FFSL	plan completion
13.1 law enforcement	identify meander on orthophoto maps	FFSL	3/1/00 (6)
14.1 search and rescue	improve Little Valley harbor launch ramp	FFSL	3/1/00
15.1 Ramsar	1. apprise Governor's Office 2. monitor	DNR	1. plan completion 2. continuous
16.1 open space	1. identify critical land priorities 2. fee title and conservation easement acquisition	DNR	ongoing
16.2 visual resource management	VRM Plan	DNR	12/31/00

Notes.

(1) "Ongoing" means the action occurs presently and continues indefinitely as opportunities or routine scheduling allow.

(2) "Continuous" means the action begins with plan approval and continues indefinitely as opportunities or routine scheduling allow.

(3) Grants primarily oriented toward determining the effects of potential contaminants in hypersaline environment.

(4) DWR on WMA lands designated pursuant to planning issue 5.1, FFSL on other lands.

(5) On lands administered by the respective agencies.

(6) March 2000 for existing orthophoto maps, continuous as new maps become available. Plan Implementation

Monitoring and Research

The planning team identified and prioritized monitoring objectives based on issues identified in this planning process. Responsible agencies and partners were also identified. Research objectives included in this table are not a complete listing because these objectives require additional stakeholder, state, federal, university, and local agency coordination and input. The GSL Monitoring and Research Table does provide solid monitoring objectives.

A substantial part of CMP implementation directly involves monitoring, primarily for determining the efficacy of implementation actions and/or assessing the need for further action. The consensus among the planning team is that monitoring related to habitat condition and public use are most important. This includes:

- lake level and inflows
- salinity
- causeway flows
- bird populations
- brine shrimp populations
- algal populations
- nutrient loading
- encroachment on habitat
- wetland mitigation (related activities)
- recreation and OHV impacts
- access conflicts and boundary enforcement
- pollutant concentration in wetland sediments

Of these monitoring actions the following are ongoing at an approximate annual cost of approximately $1,000,000 and can reasonably be expected to continue under existing base level budgeting:

- lake level (two of three required gauges) and inflows
- salinity
- causeway flows
- bird populations
- brine shrimp populations
- algal populations
- wetland mitigation
- recreation and OHV impacts

The following are new monitoring actions and will require additional funding or a shift in funding from other programs:

• lake level (one additional gauge)	$9,500/year
• nutrient loading sampling	$20,000/year
• nutrient loading modeling	$15,000 one-time cost
• habitat encroachment	$3,000/year

• access conflicts and boundary enforcement	$25,000/year
• pollutant concentration in wetland sediments	$10,000/year
Total	**$82,500 first year** **$67,500/year**

The following monitoring actions are not a necessity but would contribute to a better understanding of human-caused impacts to the GSL system and how the system responds to the impacts. These monitoring actions and tools include:

• satellite imagery	$15,000/year
• grazing transects	$5,000/year
• discharges to lake and tributaries (gauge reading)	$8,000/year
• discharges to lake and tributaries (gauges)	$28,500 one-time cost
• recreation trends	$10,000/year
• air pollution effect on visibility and wildlife	$50,000/year (one FTE)
Total	**$116,500/first year** **$88,000/year**

Environmental monitoring and research is the key to developing sustainable resource allocation and in implementing effective management strategies. It is challenging to manage GSL for multiple-use and sustainability without a well developed, accurate, reliable and focused database. Decision-making is currently based on the best available information. Without existing data and monitoring resource allocation and decision-making would be haphazard. Managers are fortunate that there is data available on lake level, water quality and salinity. (SRC, unpub.)

However little information is currently available that monitors or evaluates ecosystem function and health. GSL ecosystem management and decision making would benefit from additional monitoring and research. A well-designed monitoring and research program would be of great value in assessing trends that will drive GSL ecosystems beyond it's natural range of variability, improve management effectiveness and our understanding of the behavior of GSL ecosystems. (SRC, unpub.)

Success in developing good baseline information depends upon well-designed research, state-of-the-art systematic monitoring, analysis and reporting and available funding. Monitoring parameters must be spatially and temporally representative to identify trends and assess the state of the environment. Monitoring is most useful when it is designed to answer the right questions. The planning team has identified, developed and prioritized monitoring and research objectives. (See "Monitoring and Research Table.") This information will be presented to the state legislature with a request for funding.

It is impossible to bridge all gaps in information and understanding due to the dynamic nature of the lake and its environs, the various time scales involved in ecosystem function and degradation and limited funding available for research and monitoring. It is more important to focus on the quality of data rather than the quantity. Some of the identified gaps in information include:

- Winter ecology
- Nutrient loading (open water and wetlands)
- Ecosystem health, function and variability
- Aquatic ecology-air and water quality impacts
- Implications of salinity and lake level on ecosystem function
- Lake chemistry and ecology interactions
- Trace metal concentrations in lake water and sediments
- Bio-accumulation

DNR will coordinate with other agencies and stakeholders to develop a list of gaps in information and compile a list of GSL research topics for state universities to consider for graduate and doctorate studies. Improved research and monitoring coordination will help managers focus research on critical needs and build GSL information database. DNR will seek funding partnerships with EPA, other agencies and stakeholders.

Monitoring and research helps resources managers improve overall management, determine carrying capacities, better understand ecosystem linkages and ecological impacts to ensure ecological and long-term economic sustainability.

The planning team identified and prioritized specific monitoring activities based upon the issues identified in this planning process. Potential partners are also identified. Research activities included in this table are not completely fleshed out because these objectives require additional stakeholder, state, university and local, state and federal agency coordination and input. The GSL Monitoring and Research Table provides solid monitoring and objectives and a few research topics.

Great Salt Lake Monitoring and Research

GSL Document Section	Priority	Present/ Future Planning	Sub-Categories or Activities	Responsible Agency	Resources Required How to Accomplish Monitoring	Potential Partners
HYDROLOGY						
Lake Level						
Flooding / Facilities Protection	A	O/F	Collect lake level data, location condition of dikes. Monitor lake level.	DFFSL (gauges)	Fund gauges/USGS $8,000.00/ year	USGS
Utilize Satellite Imagery	B	F	Inventory & database	DNR/AGRC	To be determined $	DWR/ Davis County/ UP&L/UDOT/ Facility Operators
Flow Through Causeway	A	O/F	Measure breach & culvert flows	DFFSL DWRe	To be determined $	USGS/ GSLTT
Inflow-Lake, Rivers and Springs	A	O/F	Evaluate totals required (5 springs/ 3 rivers)	DWRi State Engineer	To be determined $	DWRi/ USGS State Engineer
CHEMISTRY						
Movement & Changes in Salinity	A	O/F	West Desert North and south arms	DFFSL/UGSDEQ-WQ	To be determined $	USGS/ DEQ/UGS/ IMC
Total Salt Load & Inflow	A	O/F	Ions How much? Where? All Industry	DWR/USGS	To be determined $	Mineral Industries BLM
Mineral Production	B	O/F		DFFSL/UGS DFFSL	To be determined $	Mineral Industry

GSL Document Section	Priority	Present/ Future Planning	Sub-Categories or Activities	Responsible Agency	Resources Required How to Accomplish Monitoring	Potential Partners
WATER QUALITY						
Discharge Impacts to the Lake	B	O/F	Where? What? How much (quantity)?	DEQ/DWR	To be determined $	National Science Foundation, Private Foundations, EPA Universities, USFWS, GSLTT?
Impacts to Species	A	O/F		DEQ/DWR	Study Plan Analysis	
Nutrient Loading in GSL Wetlands	A	F		DEQ/DWR		
Heavy Metals & Contaminants	A	O/F		DEQ/DWR USFWS		
Enforcement	C	F		DEQ/DWR		
Nutrient Load (sewage treatment facilities)	A	F		DEQ		Sewage Treatment Facilities
AIR QUALITY						
Air Borne Contaminants	B	O	Existing programs, studies, additional monitoring stations	DEQ-AQ	To be determined $	DEQ-AQ
Viewshed-Air Quality Impacts	B	O				
BIOLOGY						
Bird Populations	A	O	Species baseline abundance & distribution studies, limnological data population	DWR	To be determined $	USFWS, USU, Volunteers

GSL Document Section	Priority	Present/ Future Planning	Sub-Categories or Activities	Responsible Agency	Resources Required How to Accomplish Monitoring	Potential Partners
Brine Shrimp Indicators	A	O/F		DWR	To be determined $	USGS, USU
Wetland Mitigation on Sovereign Land	A	F	Develop policy objectives	DFFSL, DWR, COE	To be determined $	COE, Counties
Impacts & Encroachment on Critical Habitat	A	O/F	RDCC process, field staff support, county zoning	DFFSL, DWR	To be determined $	URMCC above meander, Counties, RDCC
Enforcement	C	O/F	Recreation activities, boating, hunting, brine shrimp harvesting and OHV use	Parks, DWR	To be determined$ Transportation vehicles (boats, ATVs, tracking system and other equipment)	County Sheriffs's Dept., RDCC

GSL Document Section	Priority	Present/ Future Planning	Sub-Categories or Activities	Responsible Agency	Resources Required How to Accomplish Monitoring	Potential Partners
LAND						
Enforcement Meander Line Boundary	A	F	Combine orthophotos and coordinates, GPS, inventory, survey and mark trespass problem areas.	DNR, DWR, PARKS, DFFSL, USFWS	Contract To be determined GPS Equipment	DNR, Counties, BLM, Dept. of Interior
Sediment Research	B	F	Identify climate and ecosystem historical trends.			
RECREATION & TOURISM-LAND AND WATER						
Recreation Demand, Access, Trends and Visitor Use	B	O/F	Surveys, visitation, counting/sampling access points, marina numbers and other recreation use. WMA numbers.	PARKS	Antelope Island Causeway Gate To be determined $	5 Counties, USU, DWR, USFWS (BRMBR)
User Conflicts	B	O/F	Surveys, track complaints and conflicts.	PARKS, DWR, DFFSL	To be determined $	UABA, University, Counties, DWR
Recreation Impacts	A	O/F	Investigate and tract impacts, user surveys (SCORP/VERP studies)	PARKS	To be determined $	Counties, SHPO Universities, DWR, Counties
Trends & Response to Social Landscape & Implementation Needs	B	F	Track using formal studies, social carrying capacity, destinations and user days. (VERP studies)	PARKS	To be determined $	Counties (economic develop-ment), Universities, State History

GSL Document Section	Priority	Present/ Future Planning	Sub-Categories or Activities	Responsible Agency	Resources Required How to Accomplish Monitoring	Potential Partners
COMMERCIAL & INDUSTRIAL						
Industry Access Conflicts & Impacts/Unauthorized Construction	A	O/F	Inventory brine shrimp harvesting access. Clean up egg bags, booms, OHV and other items.	DFFSL	Requires boats? To be determined $	DWR, PARKS, DWRi
OHV Impacts	A	F	Monitor activity and impacts.	DFFSL, PARKS	To be determined $	Counties
Mosquito Abatement	B	F	Monitor wildlife and OHV impacts	Counties, Districts	Unknown	Counties, Mosquito Abatement
AGRICULTURE						
Grazing Impacts	B	O/F	Monitor grazing impacts, transect analysis. Develop a grazing plan and policy.	DWR	To be determined $	TNC, USFWS
OPEN SPACE & CRITICAL LANDS						
Impacts & Encroachment on Critical Lands	A	O/F	Monitor trespass. Measure degradation. Identify critical areas. Survey acres preserved.	DFFSL, DWR, PARKS	To be determined $	USFWS, UDOT, COE, State of Utah

GSL Document Section	Priority	Present/ Future Planning	Sub-Categories or Activities	Responsible Agency	Resources Required How to Accomplish Monitoring	Potential Partners
VIEWSHED PROTECTION						
Viewshed Impacts	B	F	Monitor air quality (stations). Designation thru rule Class 1 monitor using photopoints. Support protection by identifying scenic viewshed areas.	DFFSL, DWR, PARKS	To be determined $	DEQ/DAQ, State of Utah

Priority Legend

A = Essential Monitoring Activity
B = Monitoring is Good Idea (Now or at some future date)
C = Not Essential (At this time but good for future monitoring)

Decision Process for Proposals on GSL

DFFSL will be the keeper of the CMP and will be the formal point of contact for proposals on sovereign land. Before making formal contact with DFFSL proponents are encouraged to contact other divisions and agencies regarding how the proposal may affect them.

A "new" proposal is a proposed land use that is either new for GSL or of such size that, in DFFSL's judgement, there is potential for significant adverse effects. DFFSL will determine if a proposal is a new proposal for which a presentation to the GSL Board of Directors (Board) is required. The Board includes DNR's division directors and executive management. For land uses that are not new proposals, DFFSL will accept an application or refer the proponent to the appropriate DNR division for routine application processing.

The Board will convene and hear presentations on new proposals by proponents. Since some detail of a proposal likely will not be available when a presentation is made, and because a proposal likely will not have undergone environmental review at the time a presentation is made, the Board will only approve or reject the proposal in concept. If a proposal is approved in concept, the proponent will be referred to the appropriate division which will process an application through standard procedures. If a proposal is rejected in concept, it is not necessarily the end of the line for a proposal. A proponent may still file an application and await final action by a division. In either case, the final action by a division is subject to appeal through administrative processes.

The Great Salt Lake Technical Team (GSLTT)

Section 65A-10-8-(11) provides that the division shall:

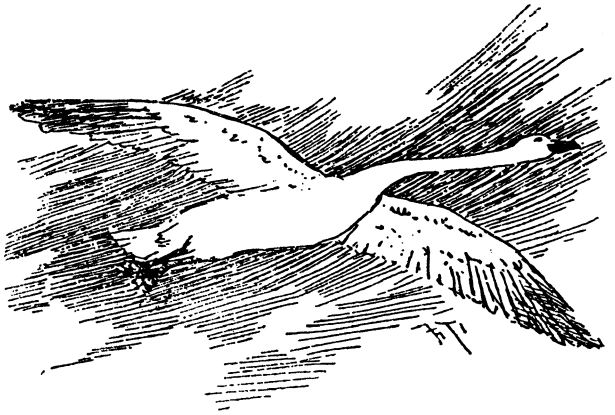
"Retain and encourage the continued activity of the Great Salt Lake Technical Team."

GSLTT members, because of their knowledge of the lake and their agencies' responsibilities and experience with lake problems and programs, provide valuable technical information that augment and enhance The Comprehensive Management Plan. This group is a forum for the interchange of information, studies, research, ideas and programs that affect the activities and natural systems of Great Salt Lake. Working as a team, the members review issues, examine alternatives and make recommendations through consensus. Each state division involved in the lake's management is asked to provide representation for the Technical Team. Each of the five counties involved with the lake is also asked to have a representative. Other interests and groups will serve by invitation as members to provide information.

The activities and reports of GSLTT will be presented to the Department of Natural Resources Directors (CMP Board of directors) after review and analysis by staff from Forestry, Fire and State Lands. The GSLTT will be self governing with staff support from the Department as requested and will be asked to convene for conduct of business at least two times per year.

Persons or groups interested in being associated with the activities of the GSLTT should submit a written request to the Director, DNR requesting notification of meetings and work groups.

Appendices



Appendix A

Wastewater Discharge Permits Around Great Salt Lake

Wastewater Discharge Permits Around Great Salt Lake

Sewer Treatment Facilities

South Davis County North Wastewater Treatment Plant - Permit Number UT0021636 The plant is located at 1800 West 1200 North in West Bountiful, Utah with the outfall(s) located at latitude 40 degrees 56' 94" to its receiving waters, the State Canal (Class 6) which flows into Farmington Bay Bird Refuge (Class 3C & 3D) and then to GSL. This facility serves the cities of Centerville, West Bountiful, Woods Cross and parts of Bountiful. During 1991, this plant completed its expansion and rehabilitation improvements.

South Davis County South Wastewater Treatment Plant - Permit Number UT0021628
The plant is located at 2500 West Center Street in North Salt Lake City in Davis County. The outfall is located at latitude 40 degrees 50' 33" and longitude 111 degrees 56' 30" to discharge into the Jordan River (Class 2B, 3B, 3D, and 4) and to GSL after a partial diversion into a canal that waters the Farmington Bay Waterfowl Management Area (Class 3C and 3D) and adjacent wetlands. This facility was established in 1962, but was expanded and upgraded in 1994. It services Bountiful, North Salt Lake and Woods Cross with a service population over 46,000.

North Davis County Sewer District - Permit Number UT0021741
The plant is located at West 2200 South, Syracuse, Utah with outfalls located at latitude 41 degrees 05' 04" and longitude 112 degrees 06' 30" at 4252 which empties into an unnamed irrigation return drainage ditch that flows into GSL. This district serves the municipalities of Clearfield, Clinton, Layton, Roy, Sunset, Syracuse and West Point and portions of unincorporated Davis County in addition to Hill Air Force Base and the Freeport Center with a total population of approximately 125,000 people. The facility completed its most recent upgrade during 1990. This plant generated over 3200 dry tons of digested sludge in 1997 which is stored for at least one year and then is transported to the East Carbon Landfill.

Central Davis County Sewer District - Permit Number UT0020974
The plant is located approximately two miles south of Kaysville, Utah in Section 15, Township 3 North, Range 1 West. This facility empties into an unnamed irrigation ditch south of the plant into outfall 001 and to another unnamed irrigation ditch west of the treatment plant from outfall 003 both of which terminate into GSL.

Central Weber Sewer Improvement District - Permit Number UT0021911
The plant is located at latitude 41 degrees 16' 18" and longitude 112 degrees 02' 49" and discharges into the Warren Canal (Class 4), thence to the Weber River (Class 2B, 3C, 3D, and 4) and finally empties into GSL. This facility serves Farr West, Harrisville, North Ogden, Ogden, Pleasant View, Riverdale, South Ogden and Washington Terrace with a population of over 150,000.

[Salt Lake City Wastewater Treatment Plant]

[Magna Wastewater Treatment Plant]

Mineral Extraction Industries

Magnesium Corporation of America - Permit Number UT0000779
Magcorp manufactures chlorine and calcium chloride as by-products of its magnesium production process. The plant is located on the west side of the lake in Rowley, Utah at approximately latitude 40 degrees 56' 43" and longitude 112 degrees 42' 20". Magcorp has a no discharge permit and discharge from or bypass of the holding pond is specifically prohibited for this facility; however, they are required to monitor calcium, Total Dissolved Solids (TDS), iron and pH on a quarterly basis by grab sample at a test well and on standing water between the wastewater pond dikes and GSL. A pH lower than 6.5 requires State and EPA notification. If this data suggests any seepage from Magcorp's wastewater pond, Magcorp must develop and implement a control plan. The plant discharges 2 million gallons of low pH wastewater per day into a total containment pond and a portion is reacted with calcium carbonate which raises the pH and produces calcium chloride as a by-product. Two incidents of seepage have been detected since November, 1989, and neither of these qualify as outfalls because they did not result in a discharge into waters of the United States (as of a 1993 letter-checking with Gayle Smith-DEQ).

IMC Kalium Ogden Corp. (former Great Salt Lake Minerals) - Permit Number UT0000647 IMC Kalium Ogden Corp is located in Ogden, Utah and produces potassium sulfate (potash), sodium chloride and magnesium chloride. The wastewater from the processing of potash with lignonsulfonates which are used as a binder in the compaction process. This process produces dust that is controlled by a wet scrubber. The wastewater is discharged back to GSL with bitterns. The discharge point is located at approximately latitude 41 degrees 17' 0" and longitude of 112 degrees 13' 45" and the average flow is 4.5 million gallons per day. Wash water is taken from Harold Crane WMA. The average concentration of TSS is greater in the influent than in the effluent (more solids are brought into the system than are discharged) and this makes it difficult for IMC Kalium Ogden Corp to meet its TSS limits. IMC Kalium is also required to develop a spill prevention control and countermeasure plan for those areas where lignonsulfonate is stored and shall only use lignonsulfonate produced without the use of chlorine. A new proposal to discharge is under consideration and involves pushing salt off the western edge of the dikes on their evaporation ponds into the Bear River Bay. Salt is currently disposed of by flushing the evaporation ponds with water from Bear River Bay and delivering it into the main body of the lake and Bear River Bay. USFWS, DNR, DEQ and IMC Kalium are working together to conduct a monitoring program to determine potential impacts, if any, to Bear River Bay.

Akzo Salt Incorporated (formerly Cargill Salt) - Permit Number UT0000639 This permit is currently being revised.
There are two points of discharge, one at Lake Point and the other at Timpie Springs. The Lake Point facility discharges process scrub and wash water, that is used to clean

the salt. It is then directed into their solar ponds which eventually empty into GSL. The Lake Point outfall is located at latitude 40 degrees 41' 14" and a longitude of 112 degrees 16' 43". The Timpie Springs outfall is located at latitude 40 degrees 45' 0" and discharges bitterns and some wash water into the lake.

Morton/Grantsville Salt - Permit Number UT0000523
Morton returns bitters to the lake via discharge 001, which is located at a latitude of 40 degrees 45' 7" and a longitude of 112 degrees 30' 00". The salt is washed with lake water that is also used to operate a dust collector. One well on the property is used for fire control. Drinking water is hauled in from Grantsville and office wastewater is disposed of in a septic tank and drain field.

Salt Lake City International Airport

This facility is a public transportation airport that leases space and services to airline companies and others providing support services. SLCIA is located at 776 North Terminal Drive in Salt Lake City, Utah and has three outfalls located at: outfall 001-latitude 40 degrees 47' 23" longitude 111 degrees 57' 28"; outfall 002-latitude 40 degrees 46' 22" longitude 111 degrees 58' 39" and outfall 003-latitude 40 degrees 47' 29" longitude 112 degrees 00' 03". Outfall 001 is a storm water runoff discharge that flows to the City Drain (Class 6). Outfalls 002 and 003 discharge into the Surplus Canal (Class 3B, Class 3D, and Class 4) that empties into GSL. The north end portion of the SLCIA property drains northward over a natural gradient through grass and marsh towards GSL and is not regulated by this permit because it is considered a non-point discharge. Possible contaminants discharged with storm water or conveyed to the sanitary sewer at the airport include airport de-icing/anti-icing fluids, spills of fuel oil, hydraulic oil, solvents, solids, detergents, metals, fire fighting fluids and lavatory waste.

Mining and Oil Refining Industries

Kennecott Utah Copper - Permit Number UT 0000051- KUC operations include a large open-pit mine and main concentrator facilities near Copperton, and a second concentrator, tailings impoundment, power plant, smelter, and a refinery complex located near Magna, both in western Salt Lake County. The process water system includes a leach water collection system and the double lined Small Bingham Reservoir, which is protected from overflow by the Large Bingham Reservoir. The mining and processing facilities have discharge outfalls at four points of discharge to the C-7 ditch (Class 6), one to the Jordan River and Little Valley Wash. Until recently, tailings pond discharges were routed to the C-7 ditch that emptied directly into GSL. The C-7 ditch has been rerouted to discharge into Lee Creek for the duration of a tailings impoundment expansion project. Lee Creek discharges into GSL. A new facilities sewage treatment plant will discharge to the West C-7 ditch (Class 3E) or effluent will be recycled to the process water circuit. Storm water from the smelter area flows into an unnamed drainage and then into GSL. Active mine drainage can be discharged to the Jordan River and into Pine Canyon Creek, which is an ephemeral stream in Tooele County. Storm water from an area located to the southeast of the north concentrator complex may flow into Little Valley Wash, which is usually dry. Potential

contaminants include heavy metals, pH and TSS. However, effluent limitations restrict the amount of heavy metals released and the pH must be between 6.5 and 9.0. Suspended sediment limitations also apply.

Chevron USA Inc - Permit Number UT0000175-Chevron operates a petroleum refinery facility located at 2351 North 1100 West in Salt Lake City, at a latitude of 40 degrees 49' 39" and longitude 111 degrees 55' 50". The waste water treatment system (WWTS) was modified between 1994-95. The five aerobic treatment lagoons were eliminated and replaced by a biological/mechanical system. The discharge flows into the Oil Drain Canal (Class 6) and eventually into GSL. The average discharge flow is 0.85 million gallons per day and all refinery, pipeline, marketing operations, wastewater and storm water is treated by this improved WWTS.

Appendix B

Existing Uses, Leases and Permits

Existing Uses, Leases and Permits

Grazing Permits and Easements

There are nine active grazing permits on sovereign land in the west Kaysville and west Layton marshes in Davis County. Sovereign land grazing permits may be terminated on short notice. Easements on sovereign land include two railroad crossings, Antelope Island access (north and south), power lines, and mineral-related developments (e.g. brine intake canals, the Behrens Trench).

Sovereign Land Surface Leases (with Map B1 reference)

Military Buffer Zone, Special Use Lease 451 (A1).
This lease covers the lakeward extension of the Hill Air Force Bombing and Gunnery Range. The lease grants exclusive rights to the surface use of the land whether inundated or not. The primary purpose is to provide a buffer around live fire target areas. Because the area was used for bombing practice during World War II, and since errant projectiles occasionally land on the property under the present use, unexploded ordinance likely exists on sovereign land.

Lake Front Duck Club, Special Use Lease 630 (A2)
This lease is part of a negotiated settlement of a land ownership dispute in the area. The lease authorizes maintenance of waterfowl habitat, waterfowl propagation, recreation and activities relating to waterfowl hunting by club members. Except for the creation of waterfowl habitat, the sovereign land is to remain in a natural state.

Spiral Jetty, Special Use Lease 889 (A3)
The spiral, built of basalt rock, is about 1500 feet in length inside an area approximately 300 feet long and 150 feet wide. The site is accessible via roads that lead to Rozel Point from Golden Spike National Historic Site. Originally created for visual enjoyment from the air, shore and on the jetty itself, it may be very difficult to see. During construction the north arm elevation was around 4195 feet and the jetty extended generally less than two feet above the water. The jetty now lies under water but is exposed from time to time.

Boat Harbor, Special Use Lease 964 (A4)
This lease provides a private harbor for brine shrimp harvesting.

Industrial Buffer Zone, Special Use Lease 980 (A5)
This lease provides a buffer zone around Thiokol's illumination flare test site. Permitted activities in the buffer zone include infrequent (two to three hours per day, several days per month) control of public access, use of off highway vehicles and retrieval of errant hardware.

Boat Harbor, Special Use Lease 1017 (A6)
This lease provides a private harbor for brine shrimp harvesting. The harbor also is used by Trestlewood for the salvage of the old railroad trestle.

Saltair, Special Use Lease 30000008 (A7)
This lease is for the purpose of developing and operating recreation-oriented concessions. Saltair Resort is located here.

Special Use Lease 30000006 (C3).
This lease is for the development and operation of a commercial boat harbor.

Sovereign Land Mineral Leases (with Map B1 reference)

IMC Kalium Ogden Corp. Holds nine separate leases covering approximately 100,000 acres. Major developments include evaporation ponds in Bear River Bay (B1), Clyman Bay (B2) and a pumping facility on the west side of Promontory Point (B3). Concentrated brine from the Clyman Bay pond is transported to the pumping facility via the "Behrens Trench", an underwater canal in the north arm.

Morton International holds an 83 acre lease for a brine intake canal (B4) east of Stansbury Island. Morton's evaporative pond system (B13) is on private and school trust land.

Magcorp holds a 75,610 acre lease on the west side of the lake. The lease includes the Stansbury Basin (B5), acreage at Lakeside (B15), and acreage for a brine canal between these two areas. The major development on sovereign land is the evaporation basin formed by a dike running from Stansbury Island to Badger Island to the plant at Rowley. Some brine shrimp companies have constructed harbor facilities off the Magcorp dike.

Cargill holds no sovereign land leases. Brine is supplied to Cargill under an agreement with Magcorp. Cargill's ponds (B14) are on private and school trust land.

Oil, gas and hydrocarbon leases. There are six active leases on the lake. Two of the leases are at Rozel Point (B6, B7), two in the West Rozel oil field (B8, B9), and two off Antelope Island at Sea Gull Point (B10, B11). None are producing at this time.

North Shore Limited (B12) holds an easement for a brine intake canal and royalty agreement for production of concentrated brine from ponds on private land.

Wildlife and Waterfowl Management Areas, Refuges and Sanctuaries (with Map B2 as reference)

Locomotive Springs Waterfowl Management Area (D1).
Managed by the Division of Wildlife Resources on state land.

Public Shooting Grounds Waterfowl Management Area (D3).
Managed by the Division of Wildlife Resources on federal, state and school trust land.

Harold Crane Waterfowl Management Area (D4).
Managed by the Division of Wildlife Resources on state land.

Ogden Bay Waterfowl Management Area (D5).
Managed by the Division of Wildlife Resources on state land.

Howard Slough Waterfowl Management Area (D6).
Managed by the Division of Wildlife Resources on state land.

Farmington Bay Waterfowl Management Area (D8).
Managed by the Division of Wildlife Resources on state land.

Farmington Bay Waterfowl Management Area (D8).
Managed by the Division of Wildlife Resources on state land.

Parks and Marinas (with Map B2 reference)

Willard Bay State Park (F1).
Managed by the a Division of Parks and Recreation on federal land.

Antelope Island State Park (F2).
Managed by the Division of Parks and Recreation on state land.

Great Salt Lake Marina (F3).
Managed by the Division of Parks and Recreation on state land.

Pending Lease Applications (with Map B1 reference)

Special Use Lease 973 (C1).
This application is for commercial harvest of algae from existing evaporative ponds. A record of decision has been issued. Lease negotiations continue.

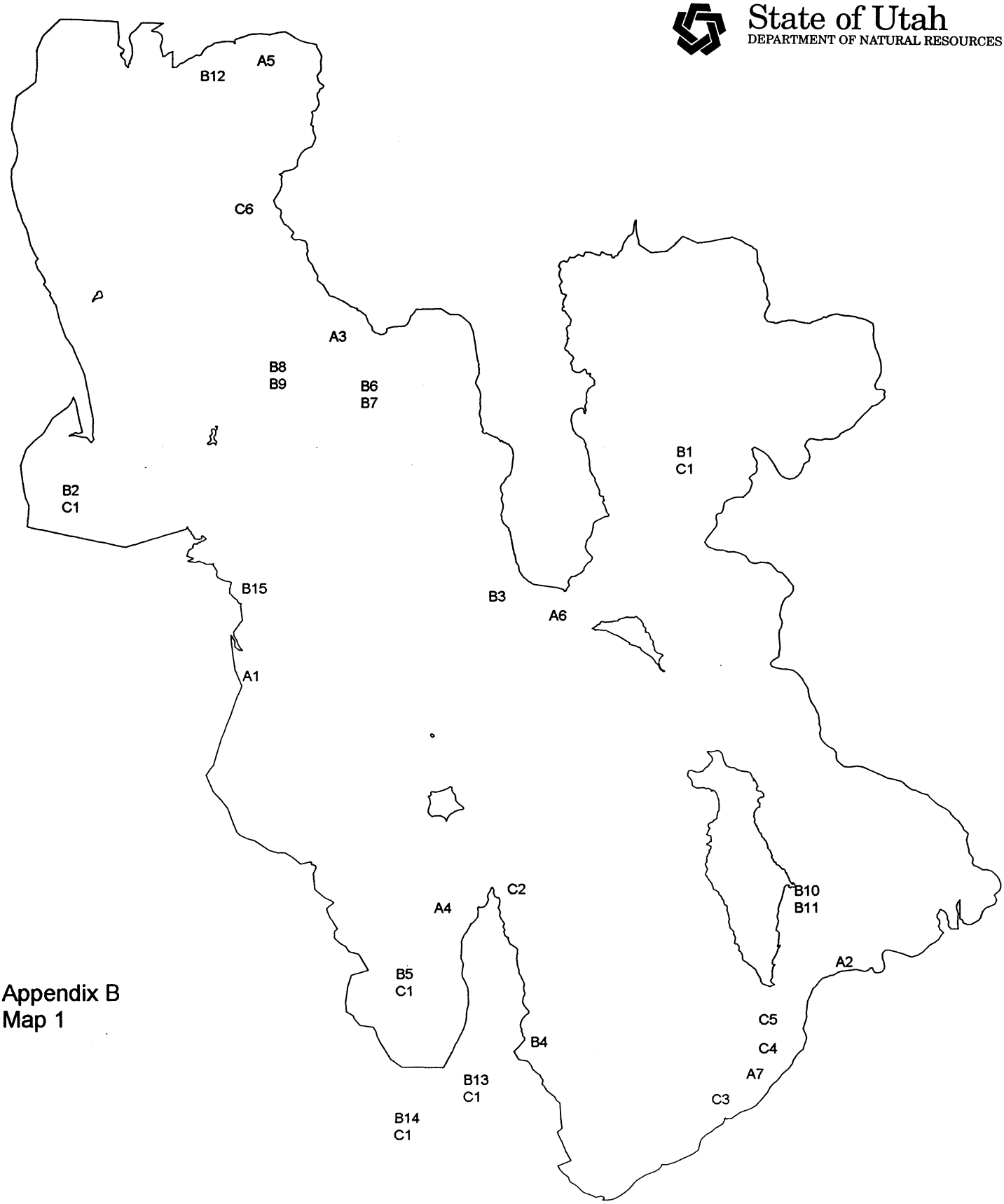
Special Use Lease 995 (C2).
This application is for the development and operation of a commercial boat harbor. The application is being processed.

Special Use Lease 30000010 (C4).
This application is for developed recreation facilities along the beach area east from Saltair to and including the old Saltair power substation. The application is being processed.

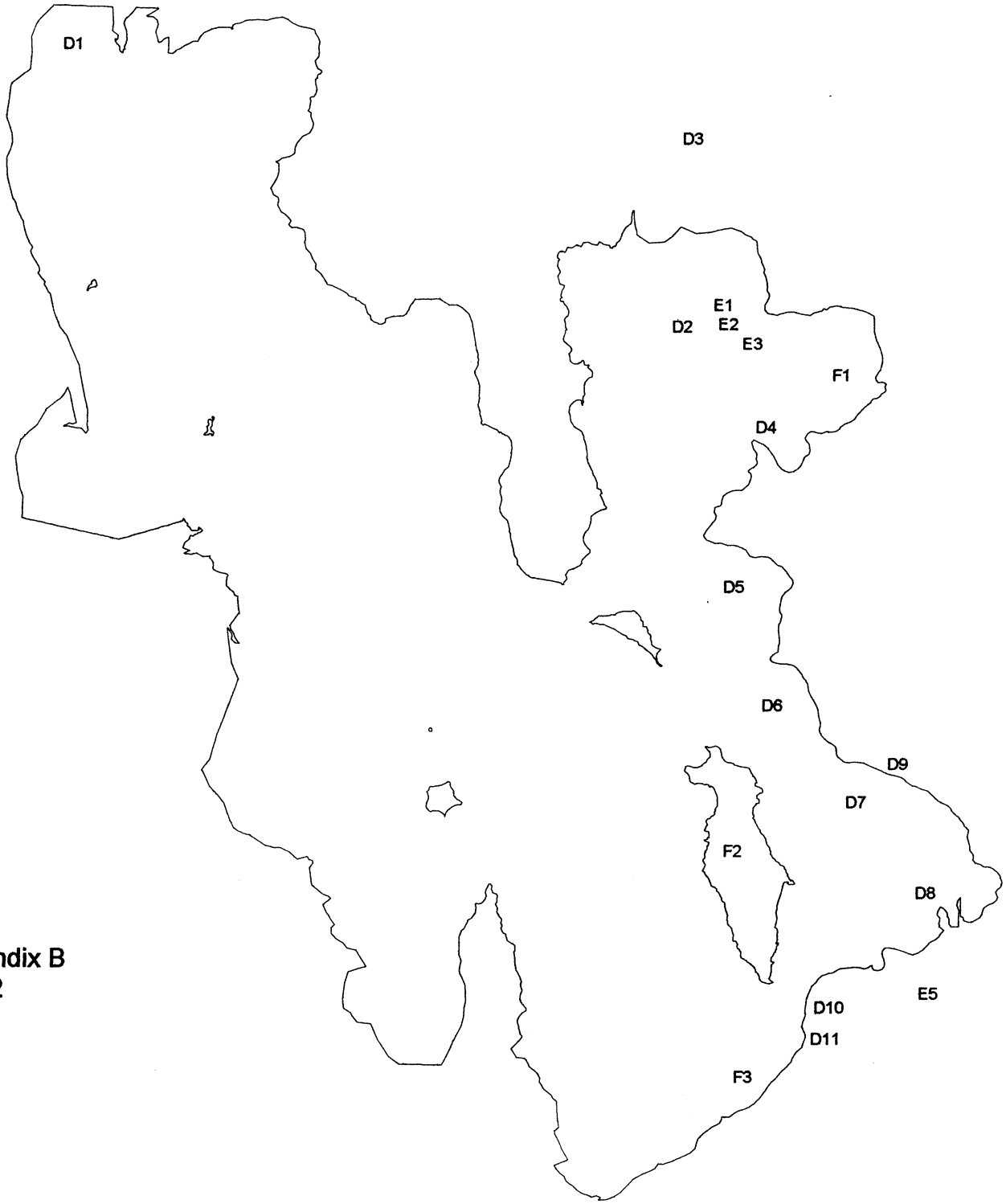
Special Use Lease 30000011 (C5). This application is for the use of old Saltair power substation building for storage and some adjacent sovereign land for developed recreation. The application is a competing application with 30000010 and is being processed.

Special Use Lease 30000009 (C6). This application is for the development and operation of a commercial boat harbor. The application is being processed.

State of Utah
DEPARTMENT OF NATURAL RESOURCES



Appendix B
Map 1



Appendix B
Map 2

Notes:

Appendix C

Public Involvement

Public Involvement

Overview

Issues Assessment/Scoping

State Agencies:
Department of Natural Resources
- Division of Forestry, Fire & State Lands
- Division of Oil, Gas & Mining
- Division of Water Rights
- Division of Wildlife Resources
- Division of Parks & Recreation
- Division of Water Resources
- Utah Geological Survey
- Office of Energy and Resource Planning
- Attorney General's Office

Department of Environmental Quality
- Division of Water Quality
- Division of Solid & Hazardous Waste
- Division of Air Quality
- Division of Environmental Response & Remediation

Department of Community & Economic Development
- Division of State History
- Division of Indian Affairs
- Division of Business & Economic Development

Department of Agriculture

Department of Public Safety
- Division of Comprehensive Emergency Management

General Public:
Five public meetings were held in Weber, Box Elder, Davis, Salt Lake and Tooele counties in February and March 1998. Approximately 80 people attended these meetings.

Stakeholder Meetings:
Meetings were held with federal agencies, local government officials citizen and industry groups and interested individuals. Through stakeholder meetings, correspondence, and other conversations, 550 people interacted with members of the planning team from November 1997 to April 1998.

Newsletter:
A newsletter was sent out to everyone on the mailing list. At this time, the general mailing list, which includes members of the Great Salt Lake Technical Team, contains at least 530 names.

Statement of Current Conditions and Trends

Distribution:
Approximately 500 copies of the Great Salt Lake Statement of Current Conditions and Trends were given out. In addition individuals contacted the web site.

Some written comments on the *Great Salt Lake Statement of Current Conditions and Trends* were received.

Technical Team:
A meeting reconvening the Great Salt Lake Technical Team was held at the Department of Natural Resources on February 23, 1999. Approximately 43 members of this advisory group attended the meeting. Currently there are 439 people on the GSLTT mailing list.

Alternatives Analysis

General Public:
Five public meetings were held in Weber (10), Box Elder (17), Davis (20), Salt Lake (38) and Tooele (18) counties in January and February 1999 Approximately 103 people attended these meetings.

Stakeholder Groups:
Several stakeholder meetings were held with industry, local government and environmental groups. Approximately 61 people attended these meetings.

Legislative Presentation:
On February 23, the planning team made materials on the baseline data and management alternatives available to legislators and state employees through a presentation at the Capitol rotunda.

Written Comments:
Thus far, the planning team has received 37 comment letters.

Verbal Comments:
In addition to collecting and analyzing written comments, the planning team also kept summaries of verbal comments received at these various public meetings. Comments received verbally, although they are not formally tracked, will be included in the final CMP to as great extent possible.

Media

Great Salt Lake Planning Team
Media Report

Summary: From October 1998 to February 1999 Public Affairs issued 4 press releases and 1 public service announcement which resulted in 22 newspaper stories, 9 television reports and an indeterminate number of radio reports.

Press Releases:
Oct 22, 1998- Announced release of "Statement of Current Conditions and Trends." Sent to all newspapers, radio and television stations statewide.

Dec 21, 1998- Announced schedule of public information meetings. Sent to all newspapers, radio and television stations statewide.

Dec 21, 1998- Radio public service announcements sent to all radio stations in five counties surrounding GSL (Weber, Box Elder, Davis, Salt Lake and Tooele).

Jan 13, 1999-Press Release on public meeting schedule sent to all newspapers, radio and television stations in five counties surrounding GSL.

Apr. 5, 1999 - Announced revision of planning schedule to allow for scientific review and economic analysis.

Coverage:

Newspaper	Date	Subject
Tooele Transcript	10/18/98	GSL Plan Process
Ogden Standard Examiner	10/22/98	Release of SCCT
Logan Herald	10/22/98	Release of SCCT
Provo Daily Herald	10/22/98	Release of SCCT
Magna Times	10/29/98	Release of SCCT
West Valley News	10/29/98	Release of SCCT
Park City Record	11/4/98	Release of SCCT
St. George Spectrum	11/6/98	Release of SCCT
Box Elder Journal	11/18/98	Release of SCCT
Tooele Transcript	12/24/98	Public Meeting Schedule
Davis County Clipper	12/25/98	Public Meeting Schedule
Ogden Standard Examiner	1/4/99	Public Meeting Schedule
Salt Lake Tribune	1/19/99	Public Meeting Schedule
Ogden Standard Examiner	1/21/99	Weber County Meeting/Rest of Schedule
Salt Lake Tribune	1/24/99	Salinity/Public Meeting Schedule
Provo Daily Herald	1/25/99	Salinity/Public Meeting Schedule
Orem Daily Journal	1/25/99	Salinity
Logan Herald Journal	1/25/99	Salinity
Deseret News	1/25/99	Salinity/Davis County Meeting
Tooele Transcript	1/28/99	Public Meeting Schedule
Davis County Clipper	1/29/99	Salinity/Public Meetings

Box Elder Journal	2/16/99	Issues/Public Meetings
Ogden Standard Examiner	4/11/99	Scientific Review
Salt Lake Tribune	4/18/99	Alder Watershed Approach
Davis County Clipper	6/10/99	GSL Level
Salt Lake Tribune	6/28/99	GSL Level
Ogden Standard Examiner	7/07/99	GSL Overview
Ogden Standard Examiner	7/12/99	Editorial - GSL Health
Salt Lake Tribune	8/01/99	Scientific Review
Ogden Standard Examiner	8/19/99	Editorial - Legacy Diking
Davis County Clipper	8/26/99	GSL County Officials Tour

Television:

Station	Date	Time
KSTU-13	1/3/99	9:00 p.m.
KSTU-13	1/10/99	9:00 p.m.
KSTU-13	1/17/99	9:00 p.m.
KSTU-13	1/20/99	9:00 p.m.
KSTU-13	1/25/99	9:00 p.m.
KSTU-13	2/14/99	9:00 p.m.
KSL-5	1/25/99	5:30 p.m. & 10:00 p.m.
KSL-5	1/26/99	6:00 p.m.

Radio:
Cannot be determined. Interviews were given to KCPW- Park City, and KSL-1160.

Public Comments and Responses on Alternatives

Introduction

The Great Salt Lake Planning Team developed an array of alternatives for public meetings in the five counties around the lake. These presentations were conducted from January 20, 1999 to February 16, 1999. The comment period began on January 20, 1999 and comments were accepted until March 5, 1999. The public was asked to comment on the array of alternatives, new alternatives or combinations of these options to create viable solutions to management issues identified during public scoping and throughout the process.

The alternatives followed several themes. Alternative A is the preferred recommendation of the planning team. Alternative B is an environmentally-weighted alternative. Alternative C is geared toward development or commercial use. These alternatives were developed to provide a range of options for the public to consider.

DNR received 40 comment letters. Each letter was numbered internally for tracking purposes. Some letters did not require a response and five were compilations of concerns identified through stakeholder meetings, public meetings and the GSLTT meeting held on March 22, 1999. There was only one multiple signature letter. Planning team members and other experts were assigned comments for response.

The planning team summarized these comments in 16 subject areas and formulated responses for each concern. Topics that were outside the proposed array of management alternatives were labeled "other" within the subject area. A public comment summary for each resource proceeds the comments and provides an overview of the questions, concerns and recommendations received by the planning team. The planning team avoided counting responses and instead offers a general overview of the comments received. Coordination with state employees, outside agencies and interested stakeholders was required in some instances to respond to these concerns. Public comments appear in *italics.*

The planning team considered the public comments in formulating recommendations to the GSL Board of Directors and DNR Administration. The directors and administration then determined if changes to the draft array of alternatives were necessary.

1.0 HYDROLOGY

1.1 For planning purposes, define GSL flood plain

The majority of those who commented support the preferred alternative suggesting designating the flood plain at 4217 feet. Most agree this represents the most recently established level and reflects the flood events of the 1980s. Industry supports using 4212 feet and managing lake level to protect assets above 4212 feet. Other stakeholders support a scientifically determined flood plain.

The extent of the flood plain for planning purposes should be 4217 feet since this represents the most recently established level and reflects 1980s flood events. However, there is evidence of lake flooding at even higher elevations in historical times. The flood plain should be considered 4217 feet to manage the shoreline to prevent or minimize encroachment below that level.

Development on the flood plain needs to be restricted to enterprises that expect to be abandoned by flooding or to take the responsibility for their own relocation or diking and pumping. There should be no development on sovereign land that interrupts the dynamic and function of the lake below meander line.

While the state does not have jurisdiction of lands above meander line, entities around the state will look to see which line the GSL plan recognizes. DNR should set the precedent by recognizing the best technically defensible flood plain line in this plan.

Alternative C is not economically feasible, nor is it wise because it would encourage development to 4212 feet which is an invitation for disaster as evidenced by events in the 1980s.

Box Elder and Davis Counties have developed a flood plain line with the COE that is based on engineering studies and evaluates lake fetch and bathymetry to determine the extent of flooding and wave run-up during high water periods. This is more accurate than choosing a specific elevation.

A flood plain elevation of 4217 feet is based upon the recent (since 1847) high lake level of 4212 feet, plus three foot wind tide and two foot wave action. DFFSL is not aware of flooding above 4217 feet in historical times. The amount of influence associated with any DNR-designated flood plain is minimal. Statute requires definition of the flood plain and imposes that the flood plain be maintained as a hazard area. This can readily be accomplished on state land, and will occur through the preferred alternative, but on other land, planning and zoning are the responsibility of local government. The three main reasons the team chose a particular elevation are: 1) to make a statement regarding natural lake level fluctuation; 2) to recognize recent flooding during the 1980s when the lake rose to 4211.5 feet; and 3) to discourage development below meander where possible to respond to our statutory code responsibilities (65A-10-8). DNR recognizes the detailed study that can occur on a case-by-case basis for the FEMA flood plain and yields to local authority on development in the flood plain above meander.

The diking policy proposed under the preferred alternative would provide for assessment of shoreline-related impacts of sovereign land developments.

1.2 Develop strategies to deal with fluctuating lake level

Public comments indicate considerable confusion regarding use of lake level zones for management and flood response. The public requested additional information on possible management actions, consequences and the reasoning supporting use of these zones. More organization would also assist discussions on this topic and provide a framework for developing planning strategies for various lake levels. Comments

focused on control of the lake level. Industry supports controlling lake level to protect investments and to allow for ongoing operation during periods of high lake level. Other stakeholders prefer allowing for natural lake level fluctuation and see no need for use of lake level zones.

Allow for natural lake level fluctuation and refrain from pumping to control lake level to allow succession and to increase wetland productivity. Managing lake level may have unpredictable and possibly undesirable effects on the ecosystem.

Instead of using the WDPP to mitigate effects of high lake levels, the state should dig a canal and let water gravity flow out to the West Desert.

The lake is predicted to reach 4212 feet by 2007. Has the team considered lake level predictions in this planning process?

Using lake level zones for planning and management is too abstract and needs to be explained in the context of an overall planning framework. The lake level fluctuation dynamic is too complex to simply use zones to define management strategies. The nature of these impacts needs to be described more clearly.

Will information to predict damage to industries at different lake levels be included in this planning document?

The proposal under alternative A is not really to "define the strategy by lake zone," but rather for those having management responsibilities on/near the lake to define a detailed strategy for management at different lake elevations and then associate that with a given zone.

A key omission is a failure to identify the significance of lake level management as essential to overall management of the lake. Trend analysis is needed to evaluate economic and ecosystem impacts of lake level.

Data should be as recent as possible. Annual fluctuations in lake level should be averaged through 1998. USGS errors should be corrected, such as the number 4211.85 feet should be changed to 4211.55 feet in the Lake Level Fluctuations and Flooding section.

Alternative B does not specify any strategy for dealing with fluctuating lake level. This is a non-alternative and should be clarified or restated as the current situation.

These are among the factors to be considered in determining the policy for WDPP operation. To the extent that pumps can reduce peak lake level their operation should be considered.

It must be considered that 1) the West Desert area slopes to the lake and therefore a canal could not carry water away from the lake into the desert by gravity, 2) some damage could be prevented by pumping and 3) ecosystem dynamics require fluctuating

lake levels to achieve full enhancement. Under existing conditions, the state can operate WDPP at 4208 feet.

The 1995 plan and this planning effort have suggested the idea of zones for planning purposes. Specific plans could be devised for resource management if the lake level was in one of the seven zones. Although predicting lake level has not proven to be very reliable, this plan does, by planning for all levels of the lake, address the possibility of the lake reaching 4212 feet by 2007. Trend analysis of lake levels would be of benefit to future planning and management for the lake.

Some economic analysis has been conducted as part of the planning process and information on predicted damages to industries will be considered.

The most recent data available are included. Much of the information provided in the original SCCT, while current at its writing, is now out of date. There must be a reasonable cutoff point for data.

The strategy in alternative B would be to determine actions on a case-by-case basis rather than specify actions ahead of time.

1.2 a Other
Weather trends need to be included in the analysis of lake level in regard to lake level management.

It is not the intent of DNR to actively manage the level of the lake, which would be economically unfeasible.

1.3 Determine policy for WDPP operation
Generally, comments supported the preferred alternative to utilize the WDPP to respond to emergency flooding situations to protect important infrastructure. There was considerable agreement that a mix of north and south arm brines should be routed to the WDPP. This would require several modifications. Ensuring a full return cycle to return salts to the lake was also supported by nearly all respondents. Industry adjacent to the lake generally supports pumping at 4205 feet. Other stakeholders do not want to utilize the pumps to protect industry or other resources and support natural lake level fluctuation for ecosystem health reasons. Approximately 30 percent of the respondents had an opinion or comment regarding operation of the WDPP.

Will additional breaching solve the salinity problem?

High tax payer costs were associated with the WDPP to protect infrastructure and industry at risk. Attempting to manage lake level or enhance the operation of this facility for those that benefit by occupying this hazardous flood plain extends this free ride and should require an environmental assessment.

It is very unlikely that planners will be able to obtain funding, overcome constraints and resolve other associated problems related to ensuring salt return.

The WDPP was designed to mitigate flood damage occurring at a lake level above 4207 feet; therefore development below 4217 feet should not be discouraged. Development on trust lands could be adversely affected in regard to potential development and also result in flood damage to existing improvements. The team should adopt a policy to commence pumping of GSL waters at 4205 feet .

The SCCT is misleading. The 1995 plan recommends pumping south arm brine at 4205 feet. The SCCT should describe what if any action has occurred on the 1995 plan regarding WDPP recommendations.

DWRe should have a plan for operation of WDPP based on projected lake level. The minimum operating level of WDPP is not 4208 feet, as the SCCT states. There should be a plan for action in the event the lake level rises again. It should be initiated at 4203 feet and continue forward as lake level increases. Funding and resources should be identified and included in this planning procedure before a crisis occurs.

The SCCT incorrectly states a loss of 400 to 600 million tons of salt. This figure is also not substantiated. The claim that 180 million tons were dissolved from the West Desert and returned to the lake is also not substantiated and is incorrect.

Any modifications to the intake or discharge channels of the WDPP which would traverse trust lands or return of brines should not interfere with development on trust lands and would require prior approval.

Pumping should not be allowed below 4208 feet since that would drastically constrain the dynamic processes that are essential to sustain the ecosystem. WDPP operation criteria should follow basic resource planning objectives that have been established and consider ecological impacts and the associated economic costs and benefits.

The value of pumping at 4205 feet is misrepresented by classifying it as an alternative that favors development. Such a designation ignores the tremendous loss of waterfowl habitat from flooding state WMAs. At 4208 feet, damage can be expected to many private and public facilities. No economic (infrastructure, etc.) or ecological assessment of the beneficial impact of lake level management is mentioned.

It is economically wise to invest the resources today to insure that all permitting and approvals are in place so that the pumps can operate at a lake level of 4205 feet.

There is some conjecture among citizens of the state that the WDPP is no longer operable. It is, but there are certain expenditures that must be made to enable lake brine to reach the pumps and some permitting is also necessary to formalize previous agreements.

In the event that the WDPP is utilized again, the salts in the West Desert should be returned to the lake.

The WDPP should not be seen as a "preventative measure" to flooding. It should not be utilized to protect property. Who would pay for this? How effective are the pumps in

mitigation for flooding? What are the environmental benefits? This would require further analysis.

The draft plan should better explain what "complete a full return cycle" means. What management criteria would be used to determine how the mixture of north and south arm brines would be formulated? When low salinity is a threat to the GSL ecosystem, pumping any brines from the north arm seems unwise.

Pumping at 4205 feet seems unwise because it is too constraining on the lake. Lake level fluctuation distributes salinity throughout the ecosystem and rejuvenates the surrounding wetlands. This ecosystem evolved with this natural lake level fluctuation dynamic and this is a necessary function to sustain the ecosystem with its shifting mosaic of wetland types.

Do not utilize the pumps or other means to regulate or mitigate the impact of high lake levels. The use of pumps will encourage increased development below 4217 feet. Allow the maximum variation in lake level to sustain the natural wetland and wildlife resources of the lake. However, pumps could be used to provide protection for existing structures.

Efforts to deal with the high lake level in the 1980s caused some problems to the overall ecology of the lake. This plan, through an updated water salt balance model by USGS and ecology studies, will make recommendations to address the salinity/ecosystem of the lake.

The WDPP was initiated by the state as an emergency flood-control procedure, not for lake-level management. The purpose of the project was to help reduce flooding impacts. Comments are well taken that many concerns need to be considered in developing an operating policy for the WDPP. The pumps are currently "moth-balled."

Funding requests for WDPP operation would be submitted through budgetary processes. The ultimate funding decision rests with the Legislature. There will be some unavoidable loss of salt to the West Desert with whatever pumping policy is implemented.

There is no expectation that the lake can be managed at a given level.

DNR acknowledges the need to coordinate with SITLA on WDPP operation. Initial contact has been made. Consultation will continue.

Analysis to address objectives, economic/ecological costs and benefits is important.

Additional information will be added to the report regarding the current situation for pumping.

The recommendation in the 1995 plan is an alternative to the current situation and is categorized this way because of the review this issue has undergone since the 1995 plan. In 1995, the feasibility of re-plumbing WDPP to enable pumping at lower levels

was studied. DNR was discouraged from requesting the funding necessary to implement the recommendation. The relatively quick recovery of habitat and renewed successional vegetation after recent high lake levels is a factor. Physical damage to WMA dikes remains a concern. Although some of the public works infrastructure (e.g., transportation and water treatment facilities) is now better protected from high lake levels through diking that resulted from high lake levels of the 1980s, there is no pumping scenario which would prevent damage to.

There is concern that the pumps would be operating relatively frequently if pumping commenced at 4205 feet. This would shift policy from emergency operation to lake level management, resulting in higher pumping cost and increased frequency of adverse impacts. If pumping was started at 4205 feet rather than 4208 feet, the WDPP system would have to be operated 25 percent more often.

The planning team has recommended investments be made only to the 4208-foot level. An economic analysis will allow some comparisons between alternatives.

Additional expenditures would be necessary under various alternatives.

The intent of alternative A is to minimize the salt left in the West Desert if pumping occurs again.

Flooding would still occur under alternative A.

The meaning of "complete a full return cycle"is addressed in the report. Completing a full return cycle basically means pumping should end in the winter period when the maximum amount of salts in the evaporation pond could be returned.

1.4 Declining flows at Locomotive Springs WMA

The preferred alternative was supported by all respondents. However some stakeholders questioned if this issue should be considered in this general planning effort and why other areas were not identified or evaluated around the lake for adequate water supply.

Locomotive Springs WMA should document declining flows, their impacts and take action against over-allocation of water that directly feeds this area. Freshwater wetlands are an invaluable resource to this state and the world and we should work hard to preserve these areas.

It is now time to devise strategies to protect inflows. This plan should raise the priority of inflows as a beneficial use, pre-empt new diversions and prevent the construction of new dams in the GSL watershed with their increased evaporative loss. The recommended alternative is a start but not sufficient.

Water rights and associated habitat issues should not be addressed in an isolated way. This issue should be addressed on a broader scale to include all habitats within state jurisdiction.

Assure adequate water is reserved in order to maintain the function of developed wetlands, both public and private.

The State Engineer has been researching the Curlew Valley aquifer system for the past two years and plans to continue the effort into the near future. The collected data was published in 1999 as Hydrologic Data Report No. 2. A public meeting was held in Snowville in February 1999 to apprise valley residents of the research and solicit their comments. A letter was sent to the State of Idaho in February 1999 requesting their cooperation in managing the Curlew Valley ground-water system. The State Engineer is moving ahead with plans to manage the valley's water resources in accordance with available hydrologic data, valid existing water rights, applicable statutes and court decrees.

Strategies to protect lake inflows and prevent dam construction in the watershed would require legislative action and are beyond the scope of this plan. Alternative 1.5 B addresses new diversions from the lake.

The team considered other areas, however, Locomotive Springs WMA was a high priority. Other areas have adequate water rights.

Except for Locomotive Springs WMA, future acquisitions will be considered on a case-by-case basis. DWR will identify future water needs as part of their WMA planning processes. Private wetland landowners should purchase necessary water rights.

1.5 Administration of water rights and supply in GSL drainage basin
The public supported acquiring water rights for particular areas (WMAs and other important habitat) to maintain GSL wetlands and discontinuing new diversions at extremely low lake levels. The public suggested that both should be considered together in the preferred alternative to best address this issue. Mostly conservation-oriented organizations and agencies responded to this resource concern.

We agree with acquiring additional water rights for WMAs but the question of suspending water diversions at low lake levels is very complex to deal with in the manner suggested without a comprehensive resource planning framework.

Acquisition of water rights should be targeted to specific wetlands. No new water diversions from the lake beginning at 4196 feet should be allowed.

More detail is needed in the draft plan. When and how would new diversions be denied or be conditional? How would changing lake levels be accommodated for in this new strategy? How would this strategy accommodate human induced changes on lake level?

Acquiring water rights for maintaining wetlands and discontinuing new diversions at low lake levels should be considered together, not as mutually exclusive activities.

Only water rights granted after the adoption of this plan would be required to cease diversions at water levels less than 4196 feet; current valid water rights would not be

affected. See alternative 1.5 B. Once lake levels rise above 4196 feet, diversions could resume. This strategy accommodates changing lake levels.

The planning team will consider combining alternatives 1.5 B and 1.5 A.

1.6 Determine state policy regarding large freshwater embayments like Lake Davis/Lake Wasatch and inter-island diking proposals

The majority of those who commented supported the preferred alternative not to support creation of large freshwater embayments. Very few stakeholders support these proposals. The public requested more detail or clarification on this topic to better evaluate these alternatives.

Impounding freshwater on the east side of a new causeway/road to link Fremont and Antelope Islands to Promontory Point and the south end of the lake.

The state should not allow freshwater embayments or further inter-island diking and highway proposals across the lake. The plan should identify lake dynamics and ecosystem health as the main reasoning to deny any additional major diking proposals.

Many of the management issues and problems we are dealing with now stem from too much diking on the lake. No further large-scale or inter-island diking should be considered. This would save a lot of time and money.

DNR should study the implications of removing some dikes (northern railroad causeway or the conveyor fill material that connects the southern causeway fill with AISP). By addressing and documenting the full range of implications, we can learn about the associated tradeoffs of keeping or removing some existing dikes.

What kind of management values are consistent with creating freshwater lakes in a vibrant saline ecosystem? Whose values are these?

The planning team has not addressed possible locations of the Legacy Highway. It is beyond the scope of this project. Freshwater impoundments have, however, been addressed. The large impoundments that would be formed by a dike, or road from Antelope Island to Fremont Island and to Promontory Point was investigated by the GSL Development Authority, created by the Utah Legislature in 1989. This group and others have recommended strongly against an east bay type of impoundment. It was found that such a bay would disrupt many of the natural functions of the lake and cause other impacts. Additional information has been added to the SCCT to identify the concerns with freshwater embayments.

The implications of removing dikes will be discussed again as final alternatives and recommendations are made.

These proposals reappear and are studied on a regular basis by those interested in creating a freshwater embayment.

Studies have shown that the quality of water collected in any large impoundment in the lake does not meet qualities needed for M&I or agriculture uses without very expensive treatment. Water needed for agriculture or M&I uses should be captured before it reaches the lake. Alternatives proposed by the planning team considered reducing new dikes, impoundments and other human-induced changes in the lake.

1.7 Other hydrology topics

It is our understanding that a watershed management plan is being considered by another entity. This should be studied, developed and implemented to manage the whole GSL watershed. It is difficult to manage a watershed at the lowest point in the system.

Comprehending the meaning of population growth, air and water pollution interactions is utterly impossible unless watershed assessment and monitoring capabilities are created now and fully integrated into GSL planning.

A watershed approach to this plan has been considered. Focusing on state lands below or adjacent to the meander line was deemed the most practicable approach at this time. DNR will pursue options for achieving watershed-oriented objectives through planning processes of other entities. DNR understands and agrees with arguments in favor of watershed-based planning. With the exception of water quality standards, DNR believes the regulatory and non-regulatory framework for natural resource management in the watershed is adequate and that lake-related issues can be addressed through participation in planning efforts undertaken by other entities. Currently, there is no basin-wide coordination.

The draft plan should discuss water circulation in the lake. It is important for lake salinity and for other aquatic constituents that natural circulation patterns be restored and are unimpeded.

The plan does not explicitly address water circulation. To totally restore "natural" circulation, all dikes would have to be removed. The plan does not propose this option; however, the team has proposed alternatives to change the current conditions where reasonable.

The lake's function as a basin sink must be recognized. Although this effort may be constrained to involve only sovereign lands, standards and thresholds for the lake should be specified and serve to guide or regulate watershed influences (input of sediments, sewer effluent, etc.).

The alternatives for the flood plain, pumping and salinity are all based on the basin being a sink. Comments indicate this fact is not well recognized. Refer to "Water Quality" section of the SCCT.

2.0 WATER CHEMISTRY

2.1 Identify salinity management regime for GSL

Salinity is the most contentious issue in this planning process. The majority of the respondents support DNR in taking action to reduce or minimize the salinity difference

between the north and south arms of the lake to sustain and protect GSL ecosystems. One respondent supported alternative C. Alternatives A and B had many comments and were equally supported. Over 75 percent of the respondents provided comments regarding some aspect of salinity. Some comment letters focused entirely on this issue.

The railroad causeway is not permeable. Tax payers in Utah should get an explanation about what went wrong and why the original contract cannot be enforced. Will deepening the breach and cleaning the culverts solve the salinity problem? Salinity should be better defined.

Have we been such poor stewards that we have killed part of the lake (the north arm)?

Create new causeways, channels, pumping devises or dikes to alleviate or control the salinity difference between the north and south arms of the lake.

There are many ideas that may have a positive effect on the expressed goal of alternative A to increase flow exchange between the north and south arms and to lower salinity differences.

The planning project should make a powerful stand to restore free circulation between the north and south arms of the lake in protecting ecosystem health.

Include prompt and meaningful action to address the salinity crisis, navigation and protecting the ecosystem.

Deepening the breach would not help circulate brines because this is a very shallow area.

Return salts in the West Desert to the south arm of the lake to increase salinity. If the pumps are to be utilized again during an emergency situation, a full return cycle should be ensured.

A salinity management regime should be designed to minimize the disparity in salinity levels. This will ensure parity between the mineral lessees on the north and south arms and also maximize biological productivity.

Which agencies made the analyses to demonstrate the immediate need for a major breaching, on what basis or justification they came to these conclusions (help to salt or the brine shrimp industries, lake ecology, or what else?), and who should be responsible for breaching the causeway and its associated costs?

The state wants to know what, if anything, should be changed for the good of the lake as a healthy ecosystem. What is meant by a healthy ecosystem? Does this mean that the entire lake must be the same, or is there some merit to having differing salinity in the south and north arms? Does parity between the mineral lessees on the north and south arms play a viable role in a healthy lake ecosystem?

Will having near equal salinities in the north and south arms improve biological productivity? There is insufficient pre-and post-causeway baseline data (salt tolerance, nutrient availability, population dynamics, etc.) to support this view one way or another. DWR is currently studying a number of these factors, and it would be prudent to see the outcome of their investigation before decisions are made concerning equalizing the salinities in the north and south arms.

Is the railroad obligated to maintain the culverts and breach to allow for bi-directional flow? The state should take action to rectify this situation and enforce its contract with the railroad.

The railroad has utilized fill and riprap material to fortify the causeway which has contributed to settling, reduced the permeability of the causeway and as a result reduce bi-directional flow through the causeway. Any attempts to remove debris in the culverts has been unproductive due to natural events like sedimentation and mild storms.

Improvements to the causeway should include additional breaches with wing walls on any new and existing culverts to reduce the quick reversal of dredging efforts. Initially, inspections should be conducted at least monthly to determine when it is necessary to clear the culverts.

The current situation is based on speculation not fact. The state has not addressed all of the facts regarding salinity in the draft SCCT. The public has been mislead. There is not an increase in salinity of the north arm relative to the south arm.

The difference in salinity has not changed from past values when accounting for the influence of the rising and falling lake level. The difference in salinity increases when the lake rises and decreases when the lake level falls.

In 1984, the salinity difference decreased in spite of the lake level rising. This deviation from the pattern of the previous 17 years was due to the breach in the causeway and the subsequent 1987-1989 pumping of north arm brine into the West Desert and north replacement with south arm brine. Both operations reduce the salinity difference.

The salinity difference after 1995 is no greater in magnitude or rate of increase than the measurements before 1984.

The total salinity mentioned in the SCCT did not account for the effect of salt precipitation in the West Desert or dissolution in the north arm. This uncertainty is removed by analyzing the concentration of a single ion that does not precipitate, such as potassium which indicates no greater difference between the north and south arms of the lake.

The UGS measurements of the south and north arm concentrations do not support the current condition in regard to salinity.

The salinity disparity is no greater than past measurements and therefore cannot adversely affect the ecosystem any differently than the past 30 years.

Wildlife managers have raised unjustified alarm about the effect of changing salinity without consideration of historical lake levels and an understanding of the long-term cyclic nature of lake chemistry.

IMC Kalium experiences hardships from lower lake concentrations. Potassium content of the lake should be analyzed relative to WDPP. The reduction of potassium content cannot be attributed to IMC's mineral extraction and is further evidence that there is not a net migration of minerals to the north arm from the south arm. The statement in the SCCT that says the relative ion ratios in the lake remain unchanged should be modified.

The south arm brine layer has been measured on the surface and this information should be included in the SCCT.

The north arm has been saturated only four of the past 16 years. Salt was not deposited in the north arm in 1998. Only portions of the north arm have experienced salt deposition, not the entire north arm. There is a lack of in-depth technical analysis of the lake's water chemistry.

The SCCT has not adequately analyzed the lake brine chemistry changes and their causes. There is no net northward movement of salts. Both north and south arm brines are lower in salinity relative to equivalent lake levels of the past by an amount equal to the 12 percent loss to the West Desert. The decrease in south arm salinity is not due to a net flow of salt north because of decreased causeway permeability. The statement that declining south arm salinity is expected to continue until the overall lake elevation rises enough to allow substantial bi-direction flow through the causeway and its openings is incorrect. There is evidence that bi-directional flow exists and there is no evidence of declining south arm salinity in the SCCT. There is no evidence listed supporting the claim that there have been changes in the hydraulic conductivity through the northern railroad causeway.

The inverse relationship between lake level and mineral concentration is equally applicable to the north and south arms.

This is the most critical issue on the lake and should be addressed immediately before the ecosystem collapses. The breach should be deepened and the culverts cleaned and maintained. A long-range plan to breach the causeway should be developed.

The current situation to keep the two bodies of water separated is not in the best interest of industry or the ecology.

The state does not understand salinity of the lake. Encouraging mixing between the north and south arms would not make a difference or accomplish anything positive.

Before developing new breaches, the effect of storm winds that blow southward and northward across the lake should be examined and may be the only hope for sufficient mixing with one or two breaches.

Optimal biological productivity is paramount to a sustained "healthy" ecosystem. This should be the goal of salinity management of the lake regardless of the degree of impact this might have on industry and commercial development.

Industry has shown ingenuity in adjusting to changing lake conditions and will continue to do so. They were astute to take advantage of the salinity imbalance that has occurred but DNR should not limit their latitude to restore the lake's natural functioning because a handful of entities are reliant on lake conditions remaining static.

There is a lack of detail in the draft plan regarding this alternative.

Segmenting the lake into two separate arms has disrupted the natural functioning of the ecosystem. Human manipulation through creation of the northern railroad causeway now threatens one of the most critical links in this food web. We need to recognize the error of our previous actions and undo them because we are responsible for maintaining the food web of this globally important ecosystem.

What would be the benefit to the public trust of maintaining separate and distinct salinity levels in particular areas of the lake? A few industries may benefit in the short-term, but the more the natural salinity dynamics of the lake are altered, the less the system will be able to maintain future viability.

What is the commodity benefit of maintaining separate and distinct salinity levels in particular areas of the lake? The objective of this alternative needs to be stated.

Actions that serve to separate one part or attribute from others, or which constrain, impede or alter the nature of dynamic processes or conditions should be avoided or corrected.

Basic lake attributes should be protected (chemical composition, salinity levels, water circulation patterns, extent of the flood plain and natural vegetation). Activities or conditions that would alter these attributes on a short- or long-term basis should be prohibited. Where activities already exist they should be modified to protect or restore these basic attributes.

The salinity imbalance in the lake is well beyond the "disparity threat." It is a "serious threat to ecosystem health in the lake." This is a crisis/emergency situation and should be restated to capture the full nature of the problem.

The alternatives are not forceful enough to respond to the acknowledged salinity and ecosystem crisis. Alternatives A and B have elements that should be pursued to resolve this difference in salinity and protect the ecosystem.

Studies indicate that merely an improvement in the operations of the causeway culverts will not resolve the more serious problem of this salinity crisis, but only help slow the deterioration of the salinity imbalance and continue to damage the ecosystem.

The lake should be restored to a close approximation of a natural condition. This would provide for natural lake level fluctuation and improve brine distribution. All users should adjust to natural changes rather than dealing with human-made changes. The goal should be for the lake to have a balanced ecosystem.

There is a net movement of salt from south-to-north during the times that the lake is rising, but that the opposite is true during times of declining lake levels. IMC further points out that the decline in potassium values in the north arm brines has occurred at a greater rate than changes in the north arm's overall salinity.

Between 1970 and 1972, a study by Waddell and Bolke (UGMS Water-Resources Bulletin 18, 1973) reports that "...the discharge through the fill comprises more than 80 percent of the total flow through the causeway." It is suggested that this condition may have lasted until the SPRR tracks were raised during the 1980s flooding, but there are no studies to confirm this. To keep ahead of the rapidly rising waters, the tracks and fills had to be quickly raised 6-10 feet to keep a bare minimum free board of two feet. During peak production the track was raised an average of one-half to one foot-file per day with the use of on track hydraulic liner/lifters (shifter/lifters), tampers and off-track backhoes. The northern railroad causeway was raised using crushed ballast from the Lakeside Quarry and quarry-run rock, as noted in a SPRR report. Over 90 percent of the fill material was quarry-run rock from the Lakeside Quarry and the remainder was pit-run sand and silt from a track-side pit located at Promontory. The causeway's permeability has been decreased by the addition of this material, but to what degree is not known. Ongoing modeling by USGS is being done in an attempt to estimate its present-day permeability.
Cleaning the culverts will have an impact on the salinity difference between the south and north arms depending upon a number of hydrologic parameters such as lake elevation, water densities and the head differential between the north and south arms. The overall effect is unknown. Deepening the breach in conjunction with the construction of a breach-depth channel into the south arm, would be another option to equalize the salinity. Other alternatives also exist. These can be evaluated in the USGS model before costly actions are taken.

Salinity, as the term is being used here, means that amount of salt (grams) that is contained in a quantity (Liter) of brine, thus (g/L). It can also be expressed in terms of the percent of salt in the brine.

The flow of water through the causeway was a concern when the original right-of-way was granted but there is no enforceable provision in the document specific to permeability. The railroad has acknowledged a responsibility to keep the culverts open. The railroad has been apprised of salinity concerns and is willing to continue working with DNR to address the issues.

Historical experience suggests that when there was greater mixing of north and south arm brines, brine shrimp populations were more robust.

The lake is dynamic in that it fluctuates and thus its salinity falls and rises accordingly. Brine shrimp may live in brines of up to 20 percent salt. Prior to the construction of the

causeway, there were times that the entire lake was at saturation, similar to the north arm today. The brine shrimp survived, as we still have brine shrimp today. While we have brine shrimp in the south arm today and not in the north, the opposite was true during the 1980s high-water years. During that time, the north arm had a salinity of about 16 percent and the south arm was around 5 percent. The majority of the brine shrimp were living in the north arm. Having a two-salinity system lake may provide a means of protection to the brine shrimp as the lake fluctuates through its natural cycles.

Work is presently ongoing by the GSL planning team, DWR and other private and public entities to learn more about the lake, its dynamic nature and its ecology. Additionally, USGS is updating its water salt balance model which can be used to determine the effects that different actions (causeways, channels, pumping, dikes, etc.) would have on the lake as a whole. Future decisions on lake management will take into account the results of these studies.

The driving concern for increasing the salinity of the south arm without changing the overall present nature of the lake is the historical salinity range.

Breaching was done to lower the south arm relative to the north arm, not to relieve long-term flooding. Maintaining the north arm as a storage area (higher than the south arm) was investigated and rejected due to cost, difficulty and overall disruption of the salinity and nature of the lake.

The pumping project removes water from GSL, reducing the peak of high lake levels by increasing evaporation.

Since the WDPP is already in place, a new dike, etc., to serve the same purpose as the pumps has not been recommended.

None of the alternatives investigated in the 1980s could manage the level of the lake. The WDPP was selected to increase evaporation from the lake.

A downward-grading, full-breach-depth channel would need to be constructed from the breach opening out into the south arm. The water salt balance model indicates that lowering the breach to lake bottom will have some positive effect on salinity distribution. Lowering the bottom of the breach, therefore, is being considered as part of the solution.

The concept of re-plumbing and pumping a full return cycle would leave the minimum salt load possible in the West Desert if the project is used again.

The alarm is based upon lack of brine shrimp populations in the north arm and declining brine shrimp in the south arm of the lake, a circumstance that can be remediated by addressing the salinity imbalance. The water-salt balance model being developed by USGS will determine if changes have occurred to the long-term cyclic nature of the lake's water chemistry.

The general consensus expressed in the SCCT is that the south arm of the lake is in the process of abnormal freshening, that the permeability or transmissivity of the northern railroad causeway is significantly less now than before the 1980s flooding period (due to the addition of fill material and compaction) and that there has been a dramatic reduction if not cessation of return flow from north-to-south through the causeway structure.

There are many points concerning lake dynamics and chemistry on which the state and some industry representatives agree, and some on which we may disagree. It depends on interpretation of a common database by different individuals and their individual assumptions. An important step to overcome these differences will be to agree on a common interpretation of the database being used.

Once the USGS water-salt balance model is updated and is used to make some runs, questions about the validity and accuracy of the model will be answered. If the model tracks well, it can then be used with some confidence to follow changes in salt loads and salinities over changing lake levels, and make some estimates of the causeways permeability over time (pre and post late-1980s flooding). If the model does not track well, many of the present questions and points of disagreement that have been posed by industry representatives will remain. Additional work is needed to minimize the existing differences of opinion.

When the USGS water salt balance model is completed, DNR engineers will utilize it to determine how salinity imbalance is occurring and what changes can be made to remediate the problem and the impacts to the GSL ecosystems. There are several possibilities to remediate the problem and sound data are needed to make the best decisions.

The planning team is concerned that salinity trends are having a negative impact on the ecosystem. This planning effort provides an opportunity to change these trends and prevent further negative impacts.

Storm winds cause seiches and can cause a buildup or pull down of the water elevation at either end of the lake and/or against the causeway. These are short in duration, however. The head differential across the causeway, the differences in brine density, the area of the openings (square feet) within structures such as the breach and the culverts and the overall permeability of the northern causeway (whatever that may be) probably play a greater part in the movement of brines south-to-north and north-to-south than the short-term effect of seiching.

Optimal biological productivity is hard to define and measure. However, biological productivity is a basic component providing for diversity and abundance of lake wildlife. Biologists recognize that meeting habitat needs of wildlife populations will help assure their sustainability. The biological productivity of the lake is important to provide for wildlife habitat needs.

To restate the intent of A, maintain salinity within its historical range with the least impact on mineral extraction as possible.

Since the northern railroad causeway is in place and because two different salinities have resulted from its presence, perhaps the question might be better stated as: "would changing the current conditions in the lake (equalizing north and south-arm salinities) be of benefit to the state's public trust?" If so, in what way? Specific evidence and reasons are certainly needed before any action can or should be taken. Will there be an overall economic or commodity benefit to the mineral extraction industries and the brine shrimp industry? With respect to restoring basic attributes, this means changing conditions to approximate pre-1980s flooding, pre-causeway and pre-1847.

Bear River Bay and Farmington Bay are examples where maintenance of separate and distinct salinity may be appropriate. Is the wildlife habitat associated with these relatively lower salinity areas by some measure "better" than would exist under more natural saline conditions? What would happen to the wildlife now using the areas if salinity were more natural? Do the dikes of BRMBR provide better habitat than would exist without the dikes?

The plan does not explicitly address water circulation. To totally restore "natural" circulation, all dikes would have to be removed.

The state RDCC reviews proposed development activities that require permitting. An objective of this process is to bring all affected divisions together to consider these actions and minimize or eliminate impacts that damage other resources. The intent of this plan is to provide for more specific management and conservation.

Work is presently ongoing by the GSL planning team, DWR and other private and public entities to learn more about the lake, its dynamic nature and its ecology. DNR will consider the results of these studies when considering further lake-altering actions.

Comments on design or methods of keeping culverts open were not included in the plan but have been discussed.

A decision to add another opening in the causeway is a major (costly) one. The plan has purposely deferred any recommendation on a new opening until the benefits of keeping the culverts clean and lowering the bottom of the breach can be determined.

2.2 Account for locations and quantities of salts in the GSL system

The majority of the respondents supported the preferred alternative and were interested in knowing where lake salts are located and how much is sequestered. One respondent preferred no action. Nearly 30 percent of the respondents mentioned this resource concern.

If salinity in the south arm is decreasing, then it can only be the result of salt mining by the chemical industries. If salt mining is the cause, why would tax payers have to pay to correct this situation?

The composition of salts (minerals) is also changed by the chemical industries who selectively remove only certain minerals. Bringing this "depleting" mineral from the

north arm into the south arm would improve their efficiency of mining of these minerals, but would it improve the balance of the ecosystem for the brine shrimp and other species?

To avoid potential conflicts concerning ownership of minerals derived from the lake, an accounting of the location and quantities of lake mineral assets would be a necessity.

Focus on only reporting changes in salt ponds when accounting for lake salts since these areas are stagnant.

The statement that "salts are not currently fully accounted for or monitored in areas around GSL" is technically accurate but practically misleading. A 1994 USGS report states that 12 percent of the lake's total minerals are deposited in the West Desert therefore any other "unaccounted" volumes are only a fraction of that figure.

The lake contains 4.3 billion tons of salt now that 600 million tons were transferred to the West Desert.

It is important for the state to know where lake salts are located.

The removal of salt by the mineral extraction industries represents a very small percentage of the total salt load of the lake. Some 2-3 million tons of salt are removed annually from the lake at the present time, which represents approximately 0.06 percent of the lake's 4.5 billion tons of salt. Certain industries selectively remove certain salts from the lake. Sodium chloride accounts for the largest percent of the salt that is removed. The removal of magnesium and potassium products accounts for a very small percentage. From this it can be seen that the removal of salt by the mineral extraction industries has a minimal effect on the overall salt content of the lake.

Brine is extracted from both the south and north arms of the lake: Morton Salt, Cargill Salt and Magcorp take brines from the south arm of the lake. And, until a few years ago, North American Salt (now IMC Salt) took brine from the south arm as well. IMC Kalium (formerly Great Salt Lake Minerals) has always taken brine from the north arm.

The northern railroad causeway, which divides the main body of the lake into its south and north arms and WDPP are responsible for the differences in salinity between the two parts of the lake. Nearly all the freshwater inflow to the lake enters the south arm of the lake. The north arm receives mainly salty water from the south arm. When the hydrologic conditions are right, there is south-to-north and north-to-south exchange through the causeway and its openings (two 15 x 20-foot culverts, and the 300-foot breach). Under some hydrologic conditions, however, the majority of the flow is from the south arm, through the causeway, to the north arm. Under these conditions, there is a net loss of salt from the south to the north, and thus a freshening of the south arm. This freshening of the south arm has little if anything to do with the salt extracted from the lake by the salt industries.

There was a massive redistribution of salt between the north and south arms when the state breached the railroad causeway in 1984. And, during 1987-1989, the state pumped over 600 million tons of salt out of the north arm of the lake as a result of WDPP. WDPP removed 12 to 14 percent of the total salt load of the lake, much of which has not been returned to the lake but remains out in the West Pond. The natural precipitation of salt on the bottom of the lake during low-lake periods can temporarily sequester large amounts, perhaps as much as 25 percent. These actions have also had an impact on the salinity distribution within the lake as a whole.

Increasing the return of salts from the north to the south arm would restore salts to the south. The results of ongoing research by various state, federal and private entities will provide answers as to how changes in the lake will produce changes in its ecology.

The salinity of GSL is composed of different ions. Brine shrimp (focus species) have many different life requirements over the course of their existence. Historical experience has suggested that brine shrimp and cyst production is best when salinities are between 12-18 percent. When salinities are outside this range, shrimp population productivity is substantially diminished. The following impacts to shrimp may occur: lower absolute cyst production, lower cyst quality and higher susceptibility to disease and poor nutrition, among others. All of these impacts can occur from the inter-relationships of food abundance/quality, predation, water chemistry and other habitat-related constraints.

Given the increasing attention to salinity-related issues, DNR believes it is important to know the locations and amounts of salts. Some locations may hold relatively small quantities. An accounting of all salts in the lake, regardless of where they are, will serve as a baseline for future studies and/or inventories. DFFSL will consult with affected landowners and mineral operators regarding the approach to accounting for salts.

2.3 Other water chemistry topics

A better understanding of lake chemistry will provide the fundamental information necessary to understand and optimize the many uses of the lake now and in the future.

UGS currently has a brine-chemistry database which was started in 1966 and continues to the present time. Parameters include major ions (sodium, potassium, magnesium, calcium, chloride and sulfate) and minor elements (lithium, bromine and boron). Other parameters include field and lab densities, temperature and secchi-disk readings. These elements/metals are of interest to the mineral extraction industries. In addition to these data, DWQ, in cooperation with the Health Department, has analyzed the lake brines for nutrients, metals and other components. The state has a good database on the salinity, chemistry and other parameters of the lake.

Many of the trace component distributions and concentrations are somewhat unknown and available data is limited. These components are often paramount to the overall water quality, bioconcentrate and have profound effects on various life forms at every level in an aquatic system. These components include iron, zinc, copper, fluoride,

iodide, cadmium, dissolved and colloidal aluminum, strontium, rubidium and hydrogen sulfide.

The state does not know how much bioconcentration has been or is currently taking place. The state is not aware of any studies that compare present levels of heavy metals in GSL brine shrimp eggs as compared to archive samples, or compare the levels of heavy metals in GSL brine shrimp eggs to those from other harvesting locations throughout the world. GSL brine shrimp eggs must meet the market's approval or they would not be in such demand.

It has been the goal of UGS to establish a baseline chemical database for the lake for the major ions (Na, K, Mg, Ca, Cl and SO_4) and the minor elements (Li, Br and B). To meet this goal, sampling has been done since 1966. The Utah Department of Health has created a record of lake metals and nutrients since the late 1970s. Beyond these sources of analytical information there is very little other publicly-available information. A more intense effort to obtain additional chemical data is limited by funding.

The disappearance of brine shrimp may not be caused by the changing salinity, but could be due to a change of the composition of chemicals that make up salinity, mainly caused by the discharge of nutrients, causing eutrophication. Although in the past phosphorus was considered the limiting factor, ecologists worldwide now acknowledge that nitrogen is limiting in salt water.

Very little change in the overall chemistry has been noted since 1966, though there has been a decrease in the non-sodium and chloride ions in the north arm. It is very doubtful that this is the cause for the disappearance of the shrimp in the north arm.

No problems with nutrients in the lake have been identified and therefore this has not been a high priority for DWQ. Also guidelines for nitrogen and phosphorous are site specific (various salinities, different areas of the lake, seasonal, etc.) and the state would need to show thorough scientific evidence that there is a problem. If a problem was identified it would be cost prohibitive to remove nitrogen and phosphorous from all the tributaries entering the lake. The best science available would be essential to ensure an accurate determination of need for such measures.

Manganese is the proper ion name associated with magnesium.

Manganese is a separate element, atomic no. 25, with an atomic weight of 54.93, compared with magnesium (the proper ion name), atomic no. 12, with an atomic weight of 24.312.

3.0 WATER QUALITY

3.1 Develop a strategy to ensure water quality protection for GSL ecosystem

Many individuals supported development of numerical water quality standards for the lake. Very few respondents supported alternatives A and C. Over 27 percent of the respondents had an opinion on this topic.

The ability of a terminal basin to maintain consistent water quality is compromised. This is even more evident as anthropogenic influences have affected its movement and chemistry. The bioconcentration of trace elements in an aquatic system might have profound effect.

Developing numerical water quality standards requires initiating research now or it will not be reasonable to adopt numerical standards in the future, because there will never be a basis for such standards. It would then become prohibitively expensive or even logistically impossible.

Numerical standards delineate compliance standards, limit misinterpretation and ensure against challenges on the judgement of inspectors, inequities of regulation and enforcement. Numerical standards may be more difficult and costly, but over the long run they will be a more effective tool.

Data should be collected to establish the "chemical discharge" into the lake from natural and human activities. Sewage treatment plant discharges, ammonia toxicity and total dissolved solids are very high.

Water quality and quantity are important variables to maintain a healthy GSL biotic ecosystem. They depend on flow restrictions, diversions, contaminants and sediment loads of the sub-basins entering into the lake. These should be measured where they enter the wetlands within fresh and salt water marshes which provide a protective natural filter as well as essential habitat for birds and wildlife.

Gigantic quantities of micronutrient inflows, especially nitrogen loading (from wastewater treatment plants, agricultural, animal feed lots and fossil fuel combustion by automobiles and trucks) are carried into the air and return to this terminal basin.

GSL and its wetlands are incredibly productive areas for invertebrates which are essential to many of the birds that use the lake. Yet little is known about the potentially harmful effects of heavy metals and other pollutants on the lake's invertebrates and the rest of the food chain. We should know more about heavy metals and other pollutants in the lake.

This is a terminal lake and continual discharge into the lake will lead to an increase in concentration of those constituents in the lake. Fluctuations in lake levels and weakening of the chemocline allows for full mixing of the lake so indefinite storage of potentially harmful constituents in lake bottom sediments is unrealistic.

Narrative standards do not appear sufficient for addressing the cumulative long-term effects of discharge of potentially dangerous constituents into GSL. DEQ should develop a comprehensive plan to evaluate the need for numeric criteria to protect brine shrimp, brine flies, dominant algal species and bird life on GSL.

This plan should compile, summarize and evaluate existing water quality information on the lake and identify data gaps.

An analysis of lake contaminants, concentrations and loading should be conducted. Metals and other pollutants should be prioritized, bioassays should be collected across a matrix of contaminant concentrations and salinity gradients. This will identify if acute and chronic concentration criteria are needed for the lake.

Development on the flood plain needs to be restricted to enterprises that expect to be abandoned by flooding or to take the responsibility for their own relocation or diking and pumping.

The studies listed above would require significant time and funding resources. It would be unwise not to take a proactive approach and investigate the need for defensible numeric water quality criteria for the lake.

Magcorp's waste ponds located below 4212 feet were damaged extensively during the 1980 flood years, resulting in the mixing of discharge-laden water with dioxin and other wastes with GSL waters. This is an oversight and should be investigated since it is inevitable that it will occur again.

Water quality standards should be established, approved by EPA, monitored and enforced. Also, we recommend development of more comprehensive designation of beneficial use to include at least all current uses and the appropriate definition of aquatic wildlife. Management decisions that affect the lake should be evaluated for impacts on water quality and a very conservative and protective approach taken.

If the water quality and chemistry of the lake is disrupted to the extent that remediation is required it will take longer and be much more expensive.

The local, national and international importance of the lake should help acquire partners to participate in development of water quality standards. The state should be a leader in such an effort and attempt this in this planning effort.

We recommend 3C and 3D numeric water quality standards be used for most constituents. All tributaries to the lake should have numeric standards with a minimum of 3C and 3D and the appropriate TMDL should be developed and enforced. If the state continues with the narrative standards, new policy and implementation procedures will be needed to ensure appropriate application.

How the chemistry of GSL has changed since before 1966 (when UGS began its brine-chemistry monitoring program) is not really known. Before this time, there are only spotty chemical analyses which were not of the current quality, accuracy and

consistency and did not include all the parameters that are, or can be, measured currently.

Since the causeway was constructed, and after 1966 when UGS began its chemical monitoring program, there has not been great change noted in the lake's chemistry. There has been a slight decline in potassium, magnesium and sulfate over time, but this is probably more attributable to the dissolution of sodium chloride from earlier precipitated sodium chloride than anything else.

From 1966 (and probably from 1959-60 when the causeway was first constructed), the south arm of the lake was density-stratified. The lower layer of brine was of greater density than the upper layer. It was also dirty and contained considerable dissolved hydrogen sulfide gas. Because of this, heavy metals such as copper, iron, lead etc. that entered the lower, dense layer of brine were precipitated as metal sulfides. Because of this condition, the heavy-metal content of the lake remained very low during the above period of time. The lake was "self-cleaning" with respect to heavy metals. After disappearing in 1991 the dense layer is forming again.

The ability to accurately determine the concentration of heavy metals in the highly-saline waters of GSL is a problem. One of the first real attempts to do this was reported by Tayler, Hutchinson and Muir of KCC in 1977. The only other public analyses that have been done are by the Utah Health Department, using standard analytical methods. Whether these methods are accurate for the high salinities found in GSL is questionable, especially for those analyses done years ago.

Selenium bioconcentrates and could pose biological concerns for some GSL organisms. More information is needed about lake chemistry and the effects of trace elements in this unique aquatic system.

DWQ does not see any water quality problems in GSL. Financial resources to establish numerical water quality standards are very limited, since available resources must be focused on high priority problems where impairments to stream uses are known, and ameliorations are required by law and funded. Also, many variables would need to be considered due to the chemically complex nature of the lake. Funding with partners and assistance from the Legislature would be necessary to initiate this effort. However, DNR would like to see research continue and will coordinate with DWQ and others in conducting research to better understand and monitor impacts to the lake and its resources.

Numerical standards would help with enforcement and would also be effective in protecting water quality.

Sewage treatment facilities are heavily controlled except for nitrogen and phosphorous. These nutrients would need to impair a beneficial use to require their costly removal from effluent. Since this issue is site-specific, much monitoring would be required. Best science would be needed to convince industry that removal would be necessary. There are no current problems. Ammonia toxicity is controlled and total dissolved solids is not a concern at this time.

Water quality and quantity are important in maintaining GSL ecosystems. These variables are considered on a case-by-case basis. Several state, county and federal water quality monitoring projects are ongoing in and around GSL. Davis and Weber Counties are monitoring inflows to GSL as close to the lake as possible. DEQ is also monitoring water quality in several locations. TMDLs will be completed for impaired high priority waters including the Jordan River in the future. It is uncertain if or when TMDLs will be completed for the lake.

All dischargers upstream and those entering into the lake must be permitted. There are limits on heavy metal discharges upstream. No problems have been identified. Existing controls appear to be adequate and there is no indication that further controls are needed. More information would help better identify water quality concerns.

Several nonpoint source water quality projects are conducted upstream and efforts are slow to reduce all the problems associated with these sources. The cumulative impacts of these sources are unknown. However DWQ and DAQ are continually working on improving air and water quality along the Wasatch Front.

We know very little regarding the harmful effects of heavy metals and other pollutants on lake invertebrates and the rest of the food chain.

See R317-2-7.2 of the Utah State Code. The current narrative provides a level of protection. The team will consider recommending research on water quality impacts on GSL organisms. Funding partners and legislative support would be needed.

Studies are ongoing regarding Magcorp contaminants near GSL. Low levels of toxins have been identified. The planning team will consider problems associated with flooding of dikes.

DWQ and DNR need more clearly defined suggestions in regard to a "more comprehensive designation of beneficial use" and how the "definition of aquatic wildlife" should be changed. These definitions have been written broadly to capture all of the potential impairments to the resource and includes all uses, even some specific uses. The water quality standards are reviewed every three years, providing an opportunity for comment.

DNR is interested in specific concerns regarding water quality and chemistry problems related to the resources that DNR has jurisdiction over, including wildlife.

Additional information is needed to consider changing water quality classifications and upgrading numerical standards for tributary inflows to the lake.

3.2 Determine GSL wetland policy

The public supports DNR in developing GSL protection strategies. Only 6 percent of the respondents had an opinion on this topic. Most of the concerns related to wetlands include nutrient loading, contamination and wetland protection for wildlife and water quality. The planning team developed this alternative to respond to scoping comments and to improve resource management.

Nutrient enrichment could be responsible for pfiesteria in east coast estuaries, cholera in GSL wetlands and other related issues.

There is a strong need to establish a policy that would promote interaction with other land managers and provide a basis for asserting interests on lands the state does not own that may affect the water quality of the lake.

A wetland policy should also provide a mechanism to regulate discharge permits and address spill containment and other contamination incidents affecting this ecosystem. The state should work closely with DEQ in developing MOUs for a wetland policy to more effectively manage the biological resources of the ecosystem.

The state should educate the public about the role of wetlands in maintaining and enhancing water quality. Protection of wetlands associated with the lake and its tributaries should also include considering their importance as wildlife habitat.

The COE only regulates "jurisdictional wetlands" and already requires mitigation for wetland losses no matter where they occur. The state should consider "no loss of wetland value and function" in the GSL flood plain and its tributaries.

The wetland policy under the preferred alternative would pertain to subjects not presently addressed in the federal regulatory framework, e.g., non-jurisdictional wetlands and activities other than placement of fill. The policy would take into account the state wetland management strategy and would set guidelines for mitigation of projects in wetlands on DNR lands. DNR's influence above meander will be limited to review and comment of proposals on other lands.

As has been recognized, DNR has initiated several programs to educate the public about values of wetlands and water quality. Several DNR divisions are participating with USU, URMCC, GOPB and others to develop wetland management strategies.

The state will consider new strategies to protect wetland value and function below meander line. Considering the entire flood plain and GSL tributaries is beyond the scope of this planning effort, but may be part of future coordination efforts.

3.3 Other water quality topics

Faulty application of pollution testing and failure of the Clean Water Act to address water quality concerns.

DWQ stated that there is no faulty application of pollution testing and appropriate procedures are followed.

Public health impacts from lowered salinity levels or a reduction in water circulation could have dramatic consequences. Sewage pollution and toxic heavy metals released from sediments in Farmington Bay could produce bioavailable metals, large algal blooms and offensive odors.

This is a recurring issue in Farmington Bay. Freshening would need to continue and this has not been a serious problem to date. However DWQ agrees with DNR that a large freshwater embayment would not be recommended for these and other reasons.

The preferred alternative should include more specific measurements and standards for chemical, nutrient and sediment loading in the rivers which enter this terminal basin.

The planning team recognizes the importance of all of the sub-drainage basins contributing to the lake in regard to water quality protection of the lake. We gathered water quality information about each of the sub-basins to gain some background understanding. However this planning effort is focusing below meander line and this issue is beyond the scope of this project. It may be dealt with in the future through coordination with state, local and other interest parties.

The description of IMC's discharge permit is unclear, old and needs to be revised.

This discharge permit was under revision when the planning team released the SCCT document. Corrections are in progress.

4.0 AIR QUALITY

4.1 Protect public trust resources

The preferred alternative was well supported by the majority of the respondents. The public also suggested that DNR should actively coordinate and help evaluate air pollution impacts on aquatic organisms and the rest of the ecosystem. There was also concern regarding potential industry air and water contamination and the effect that this has on the ecosystem, particularly for aquatic wildlife.

We need to institute significant oversight and regulation of all industrial sources of pollution that could be impacting the lake (like Magcorp).

Improved coordination with DAQ is wise and we support the preferred alternative. Data collection could be improved through coordination with other agencies and stakeholders to prevent duplication and optimize resources.

Magcorp is a probable major source of dioxin, furans and other endocrine disruptors (the equivalent of an uncontrolled producer of a stew of pesticides, herbicides, PCBs, PAHs and other organochlorine compounds). Contamination is released through air, water and solid materials. None of these contaminants are understood or even well investigated.

More detail is needed in the draft plan to evaluate these alternatives.

Have there been any studies conducted on the impacts of emissions on GSL other than those recently at Magcorp? DNR should determine whether the implications of these emissions should be studied. DNR should coordinate with DEQ to evaluate whether this operation is impacting this ecosystem and determine whether any mitigative actions are necessary.

The brown cloud of smog (sulfur) that covers the lake could pose some air quality problems in regard to management of aquatic organisms and other wildlife. This requires further study and coordination with USGS and EPA.

Data should be shared between agencies and with industry. For instance meteorological data collection should be coordinated between the agencies and possible the brine shrimp industry who work on the lake. Toxicology data and studies should be coordinated between the agencies and other entities who might want to collect the data including citizen's groups and industry.

Oversight and regulation of releases of pollution to air, water and soil are under the jurisdiction of EPA and DEQ. Significant oversight of industrial air pollution sources near GSL is part of DAQ continuing operations. DAQ's Compliance Section visits KUC and Magcorp on a regular basis. During these visits, it is determined whether these industries are running their plants in accordance with their legal operating permits which specify amounts of pollution allowable for daily operations. DAQ also evaluates potential health problems associated with air pollution from these and other sources. Operating permits are designed to protect the environment and public health and to set allowable pollution levels based on engineering, computer models of pollution dispersion in the air, known health effects of air-borne pollutants and public comment which is taken at hearings before an operating permit is granted. The DAQ Air Pollution Inventory Group evaluates the overall impact of air pollution emissions from industries and cars, and EPA reviews the data from DAQ to determine whether additional regulation is required to protect the environment and public health.

It is not clear what the term "significant oversight" is intended to mean in the above comment. DAQ believes significant oversight already exists, at least from the standpoint of EPA and DEQ. If, however, "significant oversight" means that DNR should seek regulatory jurisdiction in addition to EPA and DEQ, that is a matter for federal and state lawmakers. If the comment is suggesting that DNR should routinely review EPA and DEQ regulations and actions taken, DEQ will keep DNR informed of its actions.

DAQ is willing to cooperate with the planning team and DNR. The specific nature of that cooperation is yet to be defined.

Tests conducted on samples taken from a waste-water drainage ditch and holding pond last September confirmed that dioxins and furans are produced in Magcorp operations. DAQ and Magcorp are engaged in an aggressive study to determine whether, or to what extent, the dioxins produced in the manufacture of magnesium contaminate water and sediments in GSL.

Tests on samples of soil, water and lake sediments taken since September confirm that dioxins have not contaminated soils beyond the drainage ditch and holding ponds and there is no dioxin contamination in solid wastes or commercial products. Dioxins do not dissolve in water to any significant extent, but they can become attached to dirt particles that are carried in water. We now know that the principle dioxin pathway at

the Magcorp operation is dioxin-contaminated particles in wastewater which is released into the drainage ditch that carries the waste water to the holding pond; both the drainage ditch and the holding pond are on Magcorp property. The company and DAQ believe that the waste water can be successfully filtered to eliminate future release of dioxin contamination to the drainage ditch and holding pond. This, in turn, will also eliminate additional deposits of dioxin in areas of the company's property that could be inundated by water from the lake.

The most recent test results show that dioxins from the plant have entered the lake in past years, most likely when lake waters inundated the waste water holding ponds in 1983-84. To protect against high lake water inundation, Magcorp relocated their waste-water holding pond after the 1983-84 incident, moving it farther from the shore line. The new holding pond is also behind a dike that provides further protection against high lake levels.

While the levels of dioxin in lake sediments near Magcorp are numerically higher than normal background levels in the lake, these levels are ten times lower than those considered harmful by EPA, the Center for Disease Control and Prevention and the Agency for Toxic Substances and Disease Registry. The lake sediment dioxin levels measured near the plant are below levels requiring additional action or study by these agencies, and they are also lower than background levels in most cities, including Salt Lake City. Even though the current test results from lake sediments are low, DAQ will do additional testing this summer to determine if there is any evidence of dioxin accumulation in brine shrimp, brine flies and birds.

Magcorp and DAQ will also be doing testing of the smokestack this summer to determine whether dioxins are being released directly to the air. These tests have not been done earlier due to the lack of a smokestack test calibrated for high chlorine conditions that exist in the Magcorp stack.

DAQ will keep DNR and the planning team informed of future work and invite DNR's participation.

It is the intent of the preferred alternative to improve coordination between agencies, industry and other interested entities.

5.0 BIOLOGY

5.1 Identify strategies to preserve and maintain wildlife and habitats on GSL to preserve the integrity of this ecosystem

The public almost equally supported alternatives A and B. There was no support for alternative C. Over 25 percent of respondents commented on this topic, most of whom strongly supported the idea that wildlife should have primacy over other multiple uses and that more habitat should be formally protected.

Protection of the 39 townships designated for wildlife and recreation use should continue.

All of the 23-21-5 lands should become WMAs.

The state should formally protect more wildlife habitat with wildlife primacy for the 39 townships. Multiple-use does not necessarily need to be ruled out if the state holds optimal biological productivity as a priority.

Wildlife and habitat should take primacy over other multiple uses which advocates formal protection of additional habitat. There are many significant high value wetlands below meander line that are not currently associated with state WMAs, BRMBR or other specially designated areas. These wetlands need consideration and protection in the planning process. The state should take an active role in county wetland planning and make a commitment to help fulfill their wetland protection goals.

DWR and the GSLEP will coordinate an effort to examine wildlife values of lands identified within these 39 townships. A formal recommendation will be made to the Wildlife Board regarding designation.

Many acres of valuable wildlife habitat around the lake currently are not included in WMAs, the BRMBR or other areas of special designation. Alternative 6.1 addresses a mechanism to recognize more of these important habitats, especially those around the east side of the lake which have tremendous wildlife value.

5.2 Other biology topics

Why is the brine shrimp harvesting COR revision process going through the RAC process rather than being considered within this planning process?

The Utah Wildlife Board has the legal authority to set policy for DWR and issue rules and proclamations which govern the issuing of CORs and rules which govern the harvesting of brine shrimp. This plan is intended to coordinate management activities of DNR divisions and provide for a collaborative process to ensure sound management decisions are made to protect the lake. The plan and the process cannot supersede the legally required mandates of the divisions and their boards. Therefore such issues as COR distribution, harvesting season opening/closing and COR fees are legally addressed by the Utah Wildlife Board.

Why would the team not designate certain areas on the west side of the lake as protected? If we are looking at the whole GSL ecosystem, protecting the east side and not the west does not make any sense. Could the west side become more ecological productive with a different salinity regime?

The Legislature defined what lands could be considered for special wildlife uses. Other lands around the lake are available for multiple uses. Wildlife will be given consideration during the planning and permitting of development activities. Wildlife impacts will be avoided or mitigated where possible.

Consider supporting the creation of the South Shore Wetlands Ecological Reserve of GSL by helping restore freshwater inflow to the delta of the Jordan River.

Water rights of the Jordan River are legally governed and administered by DWRi. Providing water for the South Shore Wetlands Ecological Reserve would necessitate acquiring waters rights and changing the points of existing diversion. The owners of the reserve can work with the State Engineer to understand how water rights can be acquired and points of diversion changed to deliver water to this area. The water rights would need to be purchased from the existing owners, and/or appropriated by DWRi.

Locomotive Springs WMA should be supported in its plans to expand to include protection of playas for Snowy plover habitat.

This decision will be made by the Wildlife Board concurrent with or following approval of this plan.

A reference is needed to substantiate that GSL supplies the largest quantity and quality of brine shrimp cysts in the world, if this statement is true. It is not stated if Gary Belovsky's brine shrimp population model takes into account different lake levels which affect salinity.

Historically the GSL provided the largest quantity and quality of cysts available. In the last two years the quantity of cysts provided by GSL may have decreased. Quality is a judgement made by the buyer. The brine shrimp population model will predict the performance of the shrimp population. Input parameters to the model can relate to changes in salinity.

Claiming that the difference between north and south arm salinity is increasing is contrary to UGS data. There is no evidence to support that salinity in the south arm could diminish to the point where "the brine shrimp population becomes stressed and is reduced, while salinity in the north arm continues at concentrations high enough to prevent the establishment of a viable brine shrimp population." Gunnison Bay should not be considered biologically "dead."

The trend in salinities between 1996 and 1999 in both arms of the lake compared with brine shrimp population parameters do suggest the brine shrimp population in the south arm has been impacted. This was empirically observed in the late 1980s when the south arm salinities decreased. There is no meaningful brine shrimp population in the north arm today. It is too saline in the north arm of the lake. The north arm is indeed not dead. The high salinity level there precludes the diversity and abundance of algal, brine shrimp and wildlife species, relative to the south arm.

Elevation of dikes at Harold Crane and Howard Slough WMAs needs to be included in the text.

See the SCCT section of this document.

When acreage of habitat is described, it is necessary to give the associated lake level at which these measurements are taken.

The data were extracted from "Evaluation of Existing Wetland Habitat in Utah," by F.C. Jensen. Utah DWR 74-17. The evaluation was completed in 1974; the acreages are estimates. The lake elevation was 4201 feet in 1974.

Claims of international significance of GSL in a migration corridor for water birds should be substantiated. A discussion on how birds have adapted to changes in lake salinity should be included.

The lake was recognized as a Western Hemispheric Shorebird Reserve. Refer to "Biology," "International, Hemispheric and National Significance of the GSL" section in the planning document. There are 74 species of water birds that utilize the lake. Each of these birds has a different adaptive evolution and strategies that help them deal with salinity. It is not the intent of this planning document to reiterate biological history of all lake water birds.

The relationship between brine flies as a food source for birds should be better understood.

A comprehensive plan should include protection of the brine fly and studies should be supported which clearly define the role of the brine fly on the lake.

Brine flies are a very important food item to many birds and other types of wildlife found around GSL. This fact will be considered when any activities that could negatively impact the flies are proposed. There is currently a research project underway associated with the GSLEP to understand the importance of brine shrimp/eggs as a food item for birds. This is a priority because brine shrimp populations are being impacted by low salinities and are being commercially harvested. The project anticipates that brine flies will be studied in the future to understand the their importance to avian population sustainability.

Dangerously low salinity in the south arm has dramatically altered primary production (shift in the food chain) and has resulted in poor food availability, reduced brine shrimp productivity and is impacting the entire ecosystem.

If the salinity continues to decrease in the south arm of the lake, it is anticipated that brine shrimp will potentially decrease to the extent that birds dependent upon them as forage and commercial harvesting of brine shrimp will be progressively negatively affected.

Research has suggested that as the lake salinity decreases the preferred forage species for brine shrimp becomes less abundant. As a result, brine shrimp production decreases substantially.

Research is continuing and suggests changes in salinity result in different algal species abundance in the lake. Some species seem to be more beneficial to brine shrimp as forage, so when changes occur it can negatively affect brine shrimp populations. This circumstance has also occurred in the north arm of the lake, although salinity levels

there are too high for brine shrimp to physically tolerate and allow the existence of abundant populations.

It is imperative for us to recognize major impacts on the future of the lake because of its critical importance to migratory bird populations (irreplaceable and unmitigable). This should take priority over other values or in addressing management situations of potential conflict (recreation, development, industry, etc.).

Consideration of wildlife needs while making decisions about facilities and recreation impacts is important. Whenever possible, these impacts will be minimized.

It is recognized that allowing use or developments can have impacts upon wildlife species. DWR currently closes most areas within their WMAs to protect wildlife populations at the appropriate times of the year and makes recommendations to do the same on lands not under their jurisdiction.

There should be a comprehensive look at the various families of insects and effects of mosquito abatement chemicals to improve our understanding of the impacts of mosquito abatement on GSL wildlife.

The chemicals used by Mosquito Abatement Districts are licensed and controlled. Their impact to other non-target species and how that relates to the environment have been considered in the authorization process. There have been no problems associated with this concern noted around the lake. Should problems be discovered, considerations will be given at that time.

There is a need to identify high priority restoration opportunities on the lake.

Future management plans will identify priority problems and opportunities that may exist.

The draft shorebird management plan should be considered when developing a plan for GSL. There should be a mechanism for including this shorebird management plan in management decisions about the lake.

It is recognized that a shorebird management plan is being prepared for the lake. When the plan is finished it is the intent of DWR to use the information contained in the plan to guide management decisions and recommendations for the conservation of lake shorebirds.

Collectively, the quality and abundance of GSL wildlife habitat has probably declined compared to pre-settlement conditions resulting from human impacts and encroachment on GSL. Considering alternative C is clearly inappropriate and would increase this decline.

Alternative C would allow continued degradation of wildlife and habitats around the lake. Alternative B suggests the opposite, that wildlife would have primacy over other multiple uses and therefore would protect habitat. The alternative which is ultimately

selected should provide for the long-term sustainability of lake resources without prematurely eliminating options.

Much of the past habitat management strategies have emphasized diking and water augmentation and control. We have lost much of the natural dynamic of GSL wetlands particularly saline, shallow water areas that are only wet on a seasonal basis. The management philosophy should recognize the importance of these saline playas and wet meadows. Non-game species are as deserving as game species in regard to habitat protection and management.

The presence of a continuously changing shoreline of GSL due to changes in water levels provides for the habitat needs of many bird species. Therefore, consideration of this phenomenon and its impact upon avian species is recognized by DWR.

To ensure sustainable resource use, managers must realize the need to balance short-term economic gains with long-term maintenance of lake dependent revenue streams.

DNR welcomes reasoned critique of the preferred alternative from this perspective.

Ensuring sustainability of the resources can only be accomplished by restoring the natural range of variation that shaped this ecosystem. Restoring the natural flow of brines is the first step and the most obvious. Ecological restoration of other areas, avoidance and minimization of any future impacts to the system should follow in order to restore balance in this ecosystem.

It is clearly important to analyze the impacts of differences in salinity in the various bays of the lake. The north arm is so saline that only bacteria exist in the water in meaningful abundance. Brine shrimp and the birds that feed upon them do not currently exist in the north arm, except for isolated circumstances. Degradation of wildlife habitat values by development has resulted in negative impacts to lake wildlife, such as birds. Wise planning and management decisions can preclude or lessen these impacts.

Ensuring sustainable use of the lake requires research and monitoring. How can we manage something, when we don't really know how it works? The draft alternatives contain no provisions for maintaining or increasing the scope and intensity of research effort on GSL. Once effects are known it is possible to alter management activities to better meet the goal of long-term ecological sustainability.

DWR established the GSLEP in 1996 to study and manage wildlife resources of the lake. Several research projects are currently under way. Findings will be used to improve management and direct future research needs. Caution will be exercised when making decisions so the resource receives the benefit of doubt.

The ability of GSL wetlands to maintain viable wildlife populations and support large migratory bird flyways should be emphasized and carefully considered during project planning.

Acknowledgment of the lake's importance for migratory birds is part of the preferred alternative. There are many uses which the Legislature has mandated for the lake. DNR believes the management direction in the CMP provides a reasonable mix of uses thereby satisfying public trust obligations.

6.0 LAND

6.1 Determine the appropriate mix of sovereign land classifications on GSL

The majority of respondents supported alternative B and stated that this should be determined to ensure public trust resource protection. Very few respondents commented on this issue.

There should not be a split of the south shore GSL Park since we have a proposal in this area that should be managed for wildlife.

There is a need to identify high priority restoration opportunities on GSL (such as acquiring Fremont Island, watershed/ecosystem protection through coordinated initiatives and opportunities for priority site identification, restoration options, costs and implementation strategies).

Sovereign lands should be managed in a manner compatible with the protection and conservation of its wetland and wildlife values.

The old GSL State Park included sovereign land between the Goggin Drain on the north and Black Rock on the south. When DPR decided that most of this sovereign land was not needed for park purposes, DFFSL and DWR agreed that, pending completion of this CMP, land north of old Saltair would not be developed. The development classification (Class 2) remained in place for the rest of the old state park. The proposal for a south shore educational center and its competing applications will be addressed by DFFSL in a ROD (Record of Decision) which will be subject to appeal to DNR.

Opportunities for restoration below meander will be considered in the context of WMA plans subsequent to this CMP. Restoration opportunities above meander will be considered as they arise in conjunction with other planning efforts such as Legacy Parkway and Inland Sea Shorebird Reserve.

The multiple-use framework in the legislative policy for the lake includes uses which are not compatible with yielding to wildlife values at every conflict. Through allocation of resources to wildlife conservation, acknowledgment of the importance of wildlife values, and imposition of mitigative actions, DNR believes a reasonable mix of uses is proposed in this CMP.

6.2 Consider geologic hazards in all sovereign land-use decisions

The planning team received only support in the alternative of incorporating geologic hazard identification and analysis in all sovereign land-use decisions.

6.3 BRMBR expansion

The public supported alternative B to allow for BRMBR expansion without conditions. The majority of those who commented suggested that this would allow more flexibility for DNR and USFWS to better manage this area and optimize migratory bird conservation. Only one respondent suggested no change in present management.

Assisting USFWS in expanding the size of the refuge is a good idea, except the refuge should be allowed some flexibility in establishing closed areas and imposing other restrictions consistent with state WMAs.

The bird refuge should be expanded without conditions.

The state should reserve the right to impose restrictions on a case-by-case basis. This should include a blanket policy of not making sovereign land available or by imposing the restriction suggested by A, limiting the flexibility of both the state and USFWS to consider land transactions and best tailor the conditions associated with them.

Sovereign lands would contribute toward achieving the migratory bird conservation objectives of BRMBR and should be managed by USFWS consistent with the acts and authorities governing USFWS refuges.

Sovereign lands of the state may be leased to the BRMBR, but the title to these lands will remain with the state. The intent of the alternative is to ensure that hunting continues on these lands because the state recognizes hunting as an appropriate use of wildlife. The lease stipulations of the lands can ensure the state's interests are protected. DWR will work with the DFFSL and USFWS to facilitate these needs.

Expansion of BRMBR was identified through scoping as a concern to be addressed in the CMP. At this time DNR and the USFWS are reviewing ownership records in preparation for negotiating the appropriate land use authorization. Compliance with state law and loss of some recreational activities if sovereign land is included in the refuge are among the concerns to be addressed in the negotiation. Claimed private property interests notwithstanding, sovereign land in the expansion area is open to recreational pursuits that the refuge may seek to curtail.

6.4 Diking Policy

The public supported requiring an assessment of wetland, lake level, water quality, navigation and other impacts for each diking proposal. Over 70 percent of the respondents supported alternative A and less than 30 percent suggested no change in present management. Industry and wildlife management concerns were identified in this area of concern.

We agree with the proposed approach, but would add that any diking must be consistent with ecosystem management principles and the protection of public trust resources.

Alternatives A and B are most consistent with the multiple-use charter of sovereign lands and the emerging recognition of diking impacts on this ecosystem.

Many diking proposals and studies have not demonstrated a benefit to the lake or the ecosystem and have posed more damage to other resource extraction industries than is economically justified.

Impacts on wildlife (brine shrimp populations) and tourism (problem beaches) have not been figured into the economic calculations of causeways and extractive industry so far. An assessment of many issues must be required, off site impacts and the effect on optimal productivity should be accurately addressed.

Diking should be evaluated on a case-by-case basis with a strong emphasis on avoiding or minimizing the use of dikes to manage the lake or to protect infrastructure. Remove at-risk structures to a safe location and do not permit infrastructure where it might subsequently require protection.

The intent of the proposed diking policy is to provide assessments of impacts for consideration in the permitting process. Ecosystem-related impacts will be considered. The preferred alternative would require assessment of wetland, wildlife habitat, lake level, water quality, navigation and other management impacts for diking proposals on DNR lands. This would include cumulative impact assessment.

The adverse impacts of previous diking are evident, but not all impacts are negative. Even though the salinity of Farmington Bay and Bear River Bay is affected by dikes and causeways, the habitats which have resulted and their use by wildlife are very beneficial.

Further economic analysis is planned and efforts are made to utilize all practical knowledge when making resource decisions.

On other lands, infrastructure siting and building permits are the responsibility of local government. DNR's influence on other lands will be limited to review and comment if given the opportunity.

6.5 Other land topics

There are significant archeological sites on the west side of the lake. Will these sites be protected?

Archeological sites beyond the meander line are outside the scope of this planning effort but may be considered in future coordination.

The state should buy Fremont Island or it could be bought by out-of-state or foreign interests.

The state appreciates notice of the likely sale of Fremont Island. Given legislative and administrative constraints on land acquisition, DNR has developed criteria for acquisitions. At this time, Fremont Island does not satisfy enough of the criteria to warrant acquisition.

Existing contractual obligations should be taken into account in allocating public trust resources.

All contractual obligations are subject to consistency with public trust obligations.

Under the preferred alternative the Wildlife Board will be asked to determine which of the 23-21-5 lands will be designated WMAs. In the interim most of the land included in 23-21-5 should be managed to protect potential resource preservation options.

DFFSL currently has offered protection to these lands to ensure their suitability as wildlife habitat.

7.0 MINERALS AND HYDROCARBONS

7.1 Review mineral leasing plan zones

The public did not strongly support any of the proposed alternatives, but did support more resource protection and had a strong interest in utilizing the 1996 MLP recommendations since this process had a good public involvement process and balances multiple uses. This issue received quite a bit attention in this comment period. The public requested more detail and information on this topic to better understand the implications and reasoning supporting these alternatives.

While oil and gas development certainly can be done in sensitive areas without environmental damage, as a practical matter unacceptable damage is the norm unless the development is carefully supervised by outsiders. There is no one with the time and capability to provide such supervision.

Areas allowing OGH leases should not be expanded beyond the areas indicated in the MLP. Accidents and spills pose a threat. Little experience in doing OGH exploration here and no operations are currently in production.

We are strongly opposed to any change in the MLP that would open new areas in the lake for oil and gas leasing. This is not consistent with the Wildlife Board's and DWR's authority and management responsibilities (23-21-5 and 23-21-2.1) and would frustrate legislative policy by making it more difficult to establish WMAs in the future. Also, it would be impermissible to open WMAs to oil and gas leasing.

Changes to the MLP categories should require an additional public process. This is an example that the overarching management objectives were not addressed. Highly sensitive wildlife habitat should not be opened for OGH leasing. What new information has surfaced since the 1996 MLP and public scoping in developing this alternative? The preferred alternative is not balanced, unreasonable and would not be considered careful planning for a public trust resource. The draft plan should provide background information supporting this change. There was not a significant interest in opening up these areas just three years ago. The 1996 MLP had a thorough review and public comment process. There has been no additional information forthcoming to demonstrate the desirability or need to open up additional areas for OGH leasing.

There have been no known significant hydrocarbon resources in the areas east of Fremont and Antelope Islands.

The history of oil leasing on the lake demonstrates that there have been inadequate controls placed on offshore wells.

The Utah Code has set aside a reasonable portion of the lake for the priority of wildlife management.

The lake is an international bird resource that is in significant jeopardy from all kinds of threats, including water quality and increasing human population pressures. There is no reason to allow even more risk to these resources for what appears to be unnecessary speculation to open up additional areas for OGH leasing. There is a documented decline in bird species worldwide, including shorebird species.

To proceed with this preferred alternative indicates the significance of wildlife resources is not clearly understood, nor does sovereign land always have to be all things to all people.

Alternative B is the best option of this topic however alternative C is clearly incompatible with the current multiple-use mission of sovereign lands.

The potentially catastrophic impacts associated with large-scale OGH spills into the lake warrant the removal of such activities from the array of alternatives. Oil and gas industry has no place on or in GSL under the public trust doctrine management responsibilities.

There is a world wide glut of gas and oil, prices are low and there is extensive oil and gas development in other areas around the state. The local economy is strong and unemployment is low. We recommend a moratorium on oil and gas leasing for this planning period.

Mineral leasing in or around the lake should be closely scrutinized for need and impacts due to the irreplaceable importance of the lake for migratory birds. We recommend a moratorium period on OGH leasing on the lake to be evaluated in depth with public input.

Determine impacts on the lake (individually and cumulatively for disturbance, access, infrastructure, etc.). Determine impacts related to abandonment of mineral development facilities. Establish the appropriate bonding requirements to prevent abandonment and future contamination. Develop stipulations and requirements of technology that would guarantee no spills or leakage, immediate containment and cleanup in case of accidents or emergencies.

DOGM has staff to supervise such activities. They supervised clean up at Rozel Point.

Amoco drilled 13 wells in GSL discovering one field at West Rozel and oil and gas shows in eight wells. UGS published a paper entitled "Engineering Problems of GSL,

UT-Marine Drilling Operations" by R. J. Woodhall (Bull. 116, 1980) addressing some of these issues.

People may disagree over the adequacy of the oil and gas regulatory framework. If oil and gas operations were to be conducted within the 39 townships it likely would follow the imposition of stipulations at two stages-the initial lease offering and a hearing before the Board of DOGM. The imposition of stipulations would afford the greatest practicable level of protection for other resources.

No changes in the MLP are recommended in the preferred alternative. DNR's interpretation of the management implications of Section 23-21-5 is presented under "Land Uses on Sovereign Land" in this document. DNR agency management responsibilities will be clarified in a MOU following approval of this plan. Title is not affected by the 23-21-5 designation. WMA plans will be reviewed for OGH leasing implications to be considered in alternative presented in the final CMP.

The MLP went through a thorough process; however there has been some interest in changing existing OGH leasing categories.

Farmington gas field (just off of Farmington Bay in Davis County) produced 150,000 MCI of gas.

Some wells located at Rozel Point have leaked (they were drilled onshore when the lake level was low). No documented problems are associated with offshore wells. There are some natural oil seeps in the lake such as Rozel Point.

DFFSL statutory code requires that many multiple-use activities be considered in planning and management of the lakes resources.

Decreases in bird populations are not directly related to oil and gas drilling.

UGS receives several inquires per year by companies interested in the OGH potential of the lake.

The expansion of sovereign land available for OGH leasing under alternative C resulted from a review of the alternatives for consistency with DNR policy on OGH leasing. That policy is oriented toward minimizing the land area that is declared off limits to OGH leasing without first considering the stipulations that could be placed on leasing in order to protect other resources. It is possible that lease stipulations may be so onerous that OGH development is rendered economically infeasible.

The Board and DOGM have for some time recognized the ecological value of GSL, and other values that are enumerated in the GSL management plan. To ensure oil and gas extractive operations are compatible with established and future uses of GSL, the Board (nearly 20 years ago) promulgated special rules governing oil and gas operational practices in GSL. These rules are found at R649-3-33, Utah Code of Administrative Rules.

Oil and gas drilling operations have been successfully conducted in GSL without concomitant environmental degradation. There are special regulatory provisions already in place to cover future oil and gas operations in GSL. This notwithstanding, any future oil and gas operations proposed for GSL will be afforded an opportunity for comment through the RDCC process prior to approval of an application for permit to drill. When lease proposals are submitted to RDCC for review, DFFSL trusts that interested persons will comment regarding any assessments that need to be made and stipulations that should be included in lease offerings.

The assertion that unemployment is low and the economy on the Wasatch Front is strong does not tie to the world oil glut. In addition the oil from GSL fields is very unusual. Among other things, it is chemically similar to ichtyol, a rare substance used for medical purposes. Several companies are looking at the oils for various products.

The statement that (because) there is oil and gas development in the Uinta Basin and in the Price area, none should be considered for the GSL, ignores the inevitable realities of depletion of established resources in those areas through time. This comment does not consider that favorable geologic environment for oil and gas development shares a similarity to wildlife habitat, neither are randomly created and both accrue as a result of certain unique circumstances. Accordingly, at some time in the future it may be desirable to explore for oil and gas in GSL. At that time, the special environmental protection provisions already in place in the DOGM's regulations, plus others that may be developed by then, will ensure minimization of environmental risk from drilling and producing operations.

There is no mineral leasing moratorium. The MLP guides mineral activity while the CMP is being prepared. The request for a moratorium on oil and gas leasing for the duration of this planning period is not supported and does not consider that we are currently experiencing a worldwide oil glut. Under this circumstance a *de facto* moratorium has been imposed by the law of supply and demand, and no further action is needed.

7.2 Review MLP policies

The public supported alternative B which is nearly the same as the current situation and suggested using the 1996 MLP policies in conjunction with cleaning up Rozel Point and suggested including additional wildlife and recreation protection stipulations in leases.

Refer to Utah code 23-21-5. Using the optimal biological productivity of the lake would determine this management consideration.

Mineral leasing policies should include an in-depth evaluation and public process and the following issues should be addressed: 1) mineral development impacts on the lake, individually and cumulative (disturbance, requirements for access, infrastructure, etc.); 2) impacts regarding lake spills and/or abandonment of mineral development facilities; 3) stipulations and requirements of technology that would guarantee no spills or leakage and would provide for immediate containment and cleanup in case of accidents or emergencies; and 4) appropriate bonding or other means to ensure that developers

do not abandon developments that prove uneconomic or mitigated if they occur and properly mothballed so that there are no remaining contamination problems.

Section 65A-10-8 must also be taken into account. The existing mineral lease procedures provide for these and other factors to be addressed prior to the time a lease is offered.

7.3 Other mineral leasing topics

Rework the royalty fee structure and pursue receiving fair compensation for development and extraction of the lakes various resources. A royalty of less than half a percent ad valorem is ridiculous. It is a good time to end legal theft of resources of this state.

The royalty schedule is reviewed periodically for consistency with industry standards. DFFSL pursues opportunities to adjust royalty rates as they arise. For some of the older leases on the lake there is little opportunity to adjust royalty rates.

Litigation has been settled regarding increased royalties and could the team consider updating this information in the document.

The royalty section has been updated.

8.0 RECREATION AND TOURISM - WATER

8.1 Provide additional recreational opportunities

The public's comments were fairly balanced in regard to this array of alternatives. Slightly more individuals supported allowing additional boating access and facilities in the north and south arms of the lake. Very few respondents mentioned this area of concern.

There are very few access sites on the lake that have deep water and public access to construct a marina. We should acquire access to these potential areas. Consider adding more boat launches at the existing marinas, particularly at AISP to accommodate air-boat users.

We support the preferred alternative with additional public involvement in determining the type and level of development that would occur at Black Rock.

Access to bird nesting and foraging areas should be restricted during critical periods. Management should be sensitive to access disturbance, increasing vulnerability to predation or potential habitat degradation. Facilities and opportunities should be managed to provide for solitude with wildlife and to experience natural environments.

The sites identified in the final plan will be available to the brine shrimp industry. Development of harbors will be the responsibility of the industry under appropriate land use authorization.

As noted in the appendix, the lease for the commercial harbor at Black Rock has been issued.

Policy should dictate whether navigation throughout the entire lake, particularly accessability to the north arm, is advisable or not, considering the bird rookeries on the north-arm islands.

DWR currently manages WMAs by limiting access at critical times and recommends that other land owners do likewise. Activities on sovereign lands are reviewed by DWR and recommendations are made to DFFSL.

8.2 Navigability of GSL

Those who commented supported alternative C which proposed that the state should allow for unlimited access through causeways. Some noted the public trust responsibility involved in this decision and others were interested in the benefits related to recreation and commercial activities by having a completely navigable body of water. Over 25 percent of the respondents had some comment on navigation on the lake.

The preferred alternative should allow for unlimited access/navigation through the causeway by reducing or altering existing dikes and causeways. The northern railroad causeway limits navigation for the benefit of private interests and constitutes a breach of the public trust doctrine. Navigation is critical to safety, search and rescue, research and data collection, monitoring, recreation and commercial activity on the lake; at a minimum a marina for public access in the north arm of the lake. The plan must consider the risk associated with loss of ownership due to failure to maintain navigation since sovereign lands are deeded to the state on this basis. Consider the existing salinity difference between the north and south arms of the lake in this decision.

Limited recreational and commercial boating access into the north arm of the GSL is available through the northern railroad causeway breach near Lakeside, Utah. At current lake levels, navigational access is open to vessels under 25 feet in width, 15 feet in height above the water's surface, drawing less than 5 feet of water. Although the northern railroad causeway breach acts to restrict, through size limitations, the number of vessels capable of navigating into the north arm, sensitive ecological interests are buffered by the reduced access. The small islands located in the north arm of the lake provide critical habitat and nesting grounds for American white pelicans and other shorebirds. Gunnison Island hosts one of the three largest nesting colonies of American white pelicans in North America. The pelicans and other shorebirds rely heavily upon the habitat provided on these isolated islands during the annual nesting season, and significant human presence has been shown to disrupt them to the point that they move off the island to less productive habitat.

Despite the waterbird disruption concerns associated with the increased boating traffic in the north arm, the GSL CMP presents alternatives for increased boating access in the north arm. The plan advances three possible alternatives with respect to navigability on GSL: 1) continue the status quo which allows limited navigation through the existing breach in the northern causeway; 2) alter the existing causeway to increase navigability;

or 3) breach or eliminate the causeway to allow unlimited navigation into the north arm. The plan further presents an additional alternative to enhance navigation on the lake through developing marinas and boat ramps in the north arm.

Any effort to breach the northern railroad causeway to facilitate full navigational access from the south arm to the north arm and vise versa will be very costly whether the state bears the cost of the breach or attempts to legally compel the railroad to bear the cost. Full navigational access through the causeway can be accomplished in one of two ways: 1) breach the causeway and construct a bridge that will accommodate high vessel passage; or 2) breach the causeway and abandon railroad traffic across it.

Any breach in the causeway designed to fully accommodate navigational access to the north arm without disrupting railroad traffic will need to occur in water depths sufficient for deep keel boat passage. The bridge system spanning the breach must not only allow railroad traffic across the causeway, but also have sufficient height or mobility to allow passage of sailboats with tall masts. The geology of the lake bed in the deeper waters is such that engineering and constructing such a bridge will be extremely expensive, if not impossible. The second scenario for full navigational access to the north arm from the south arm circumvents the geological and engineering impediments associated with constructing a bridge, but requires the railroad to abandon the causeway and re-route the displaced train traffic. This alternative is obviously very damaging and costly to the railroad and those that use rail transport.

In light of the leases held by the railroad for this causeway, it is highly unlikely that they will voluntarily bear the cost associated with building a bridge or abandoning the causeway. While brine shrimp harvesting companies and mineral extraction operations in the south arm of the lake would likely support breaches in the northern railroad causeway in anticipation of the resulting higher salinity levels in the south arm, mineral extraction companies in the north arm and the railroad would vigorously oppose it. The north arm mineral extraction operations currently enjoy near saturation salinity levels in the water which makes evaporative extraction processes very productive. Breaches in the causeway will reduce salinity levels, resulting in decreased mineral extraction productivity in the north arm. Some of these operations have also invested significant amounts of money in lake bed canal systems designed to channel dense brine solution to locations where the brine can be pumped into evaporation impoundments. The head differential between the north and south arms will create strong currents when the causeway is breached which may damage or destroy these lake bed canal systems. This problem was experienced in 1984 when 300 feet of causeway was breached immediately East of Lakeside, Utah. The state was subsequently sued in court and required to compensate the canal owner for the damages that resulted from the water currents generated by the breach.

Administrative access including search and rescue to the Little Valley Harbor under agreement with the upland owner provides reasonable access to the north arm.

9.0 RECREATION AND TOURISM - LAND

9.1 Develop opportunities for OHV use

The majority of the respondents supported alternative B which proposed not to allow OHV use on sovereign lands. The planning team received minimal support in allowing limited access for OHV recreation activities in particular selected areas around the lake. OHV activity, law enforcement, trespass, ecosystem impacts and public trust conflicts were the concerns most often mentioned in these comments.

We oppose OHV use on sovereign lands and state WMAs. I have seen numerous tracks on the south shore between the C-7 ditch and the Antelope Island Southern Causeway. OHV users are often using sovereign lands to trespass onto privately owned properties in this area and interfering with wildlife enhancement goals of these property owners (duck clubs, Gillmor Sanctuary, etc.). There is no identified need to open sovereign lands to OHVs. The state should focus its efforts on adequately enforcing current OHV closure areas instead of opening new areas to OHV use. OHV use degrades, destroys habitats and creates noise pollution shattering the character of remote areas. These impacts affect all non-OHV users for the benefit of a few people. This should be eliminated based on the public trust doctrine of prioritizing uses for preserving the long-term purpose of the resource. OHV use is prohibited by statute on sovereign lands of GSL. We support this prohibition since this type of recreation is indiscriminate and damaging to the ecosystem and requires strict law enforcement, a resource that DFFSL is lacking.

A thorough analysis of recreational demands on the lake should be completed before any permitting of additional recreational activities. A more thorough recreation plan should be developed that would identify recreational users, level of use, impacts, monitoring, infrastructure, resources in question and current and future demands on the resource.

DWR should be responsible for determining OHV use restrictions on sovereign lands/WMAs to manage for the protection of migratory birds during nesting and other sensitive time periods. OHV use should be monitored to avoid or minimize degradation of essential habitat for birds and other wildlife.

Under administrative rule (R652-110-200) all sovereign lands are closed to OHV use pending formal evaluation through a planning process. The preferred alternative allows for OHV use to be considered in WMA planning. Under this alternative sovereign lands will be closed to OHV use unless WMA planning or other planning process, such as the west Box Elder access management plan, opens sovereign land to OHV use. Monitoring of OHV activity is a component of the west Box Elder plan. Monitoring will occur if other areas are opened to OHV use.

Recreational opportunities should not conflict or disturb critical habitat areas. Recreation should be managed to minimize impact upon wildlife. Not doing so breaks the linkage between recreation (i.e. wildlife viewing) and the resource that the recreation activity is based upon. This highlights the need for thorough analysis of recreational impacts in the planning phase as well as the need to ensure that facilities

are congruent with surrounding resource needs. This also highlights the need for increased education and interpretation activities to help heighten public awareness and the avoidance of these conflicts.

DNR is not aware of any statutory prohibition.

The points raised about the need for planning regarding OHV use, interpretation and education activities are well taken. It is good policy to conduct thorough research of recreational demands in the development of any broad-based plan. Further, future recreational planning efforts specific to GSL-related state parks concerning *all* proposed recreational activities will be coordinated with the GSL planning team and will be in accordance with the recommendations made by that body. We also agree that any opportunity to couple interpretation/education with various recreation activities should be capitalized upon as such efforts help increase awareness of the multi-faceted uses and impacts upon the GSL. Areas open to OHV activity will be monitored.

9.2 Improve recreational opportunities and access

The public supported the preferred alternative which recommended providing additional recreational opportunities and access. The public identified considerable tourism and recreation potential but also insisted on a more fully developed recreation plan with an additional public involvement process to best address this issue.

A road around the lake would encourage more people in these areas, resulting in more impacts on wildlife, flora, air quality and wilderness quality of the lake. More access should be provided at specific points like Rozel or a short distance along the west side of the lake, but not a general automobile route around the lake. This is a more development-oriented option. An automobile route around GSL is unnecessary. Current routes exist and public access issues should be resolved. A new road would be expensive to build and maintain. Funds would be better spent on other access and interpretive facilities and opportunities. Automobile access should be limited and more opportunities for nonconsumptive wildlife-based recreation and education should be explored.

A route around the lake could be developed as a international magnet to bicycle touring and increase access to the west side of the lake. The scenery, wildlife and uniqueness of this resource could be an attractive option for some tourists.

Increase access to Stansbury Island.

Lake level, access, safety and equipment needs should be considered in long-term planning of lake access related to brine shrimp harbors.

Additional access to GSL sovereign lands is needed, but it should only be achieved where the goals of adjacent land owners are considered.

More people almost always means more impact; proper planning and management can reduce these impacts. The automobile route mentioned in the alternatives would use

existing public roads. The only segment currently not available to the public lies between Hogup Ridge and Lakeside.

DPR acknowledges the abundant opportunities available around the lake for recreational activities such as bicycle touring. DPR actively plans for and promotes this type of recreational activity within its parks adjacent to the lake or on nearby land or corridors that fall under divisional stewardship. While a bike path encompassing the lake has not been previously considered and is not currently included in any division-specific planning effort, the division would be open to a more in-depth examination of the feasibility of such a trail.

As noted in the SCCT, concerns about trespass on private land and a management strategy for recreation on the island will have to be addressed before additional access is pursued, but the recreation potential is mentioned.

The additional recreational opportunities associated with the preferred alternative are primarily located where public access is available or planned by other agencies or persons. DNR supports recreational development by other entities and may offer financial and/or technical assistance in this regard. The possibility that improved access may lead to trespass was a factor in choosing among alternatives.

9.2 a Other recreational opportunity and access topics
The visitor fee at AISP should be lower to bring more people out on the lake.

DPR believes that the current entry fee at AISP is appropriate. The annual costs required to operate and maintain the park typically exceed the annual revenues received from entry fees. Given the already high annual visitation rates to the park, it is questionable that lower fees would be significantly elastic to lead to additional revenue gains that would match or exceed current revenues or associated increases in operations and other associated maintenance costs.

Current access also includes boat access for brine sampling and measurement of the lake bottom by the state and extraction industries.

See the SCCT section of this plan.

9.3 Improve education and interpretation opportunities
The majority of the respondents supported the preferred alternative, to improve existing and develop new education and interpretation opportunities on the lake. Most of the respondents supported the preferred and only one person who commented preferred alternative C and one agreed with the current situation.

We support the preferred alternative and suggest looking for opportunities to pair recreation and education in our discussions.

Recreation and education opportunities should be considered together.

9.4 Hunting conflicts on sovereign lands

The public mainly agreed with the preferred alternative to reduce hunting related conflicts. Some individuals who commented also recommended no change from the current situation. The planning team was addressing scoping comment concerns regarding user conflicts.

The one-mile buffer is too large but the 100-yard buffer is acceptable.

DPR currently has a 100-yard hunting buffer around the island. This policy is expected to continue in the future and will remain intact with implementation of the GSL plan. Establishment of this buffer zone would be limited to the area north of Fielding Garr Ranch at AISP around to Elephant Head.

9.4 a Other hunting topics

Management of the BRMBR boundary line along the sovereign land involves conflicts between USFWS interpretation of the boundary and air boaters utilizing these areas where there are no boundary markers. This access corridor between Willard Bay and the refuge to open water is difficult to navigate and the hunting on open water is not good.

The BRMBR is a national migratory bird refuge managed and operated by USFWS. The state does not control or oversee enforcement of the refuge's boundaries or regulations, hunting or management regulations specific to the refuge, or boundary markings.

Consider limiting hunting in proximity of the marina. Boat owners are finding buckshot on their boats.

Posting the area appears to have resolved this issue.

A request to correct a land ownership discrepancy identified as below meander line on the map to reduce trespass (hunting) and to ensure the proper authority by the landowner.

The correction has been made.

10.0 COMMERCIAL AND INDUSTRIAL

10.1 Determine the acceptable mix of DNR's statutory requirements regarding commercial & industrial use of the lake's resources

The public equally supported alternatives A and B. There was indication that an overarching principle and more clarification would assist in evaluating these alternatives more effectively.

A planning framework is required to give a meaningful response to the preferred alternative.

The 1995 plan recommendations regarding sovereign land classifications should be used and develop standards to respond to new proposals based on optimizing biological productivity.

More specific information is needed here. The draft plan should provide specific examples of land uses which conflict with other trust resources. The lake is experiencing tremendous pressure as population growth further constrains the lake ecosystem. I support reducing those pressures on sovereign lands.

Commercial and industrial uses should be evaluated in light of their impacts to lake resources. Alternatives A and B should be combined to support current status or less development (i.e. acreage increases in salt removal categories causes decreased wildlife habitat and railroad causeway causing concentrations near saturation).

To the extent that optimizing biological productivity can be achieved within the context of the multiple-use mandate, the preferred alternative differs little from the 1995 plan.

Identifying every specific conflict around the lake would be an enormous task that would serve little purpose. The proposed land classifications were developed with existing and potential general conflicts in mind. The classifications are a guide to be supplemented through additional planning in response to specific proposals.

A range of alternatives have been identified to allow decision-makers to consider a variety of scenarios.

10.2 Open specific areas of the lake for commercial harbors for the brine shrimp industry

This entire array of alternatives received support, however the preferred did have a little additional public acceptance and would involve opening specific areas of the lake for commercial harbors.

Since it is possible that commercial use of the Antelope Island Marina could be disallowed sometime in the future due to an increase in recreational boat use, could a provision to allow commercial boaters to access the lake via the Davis County Causeway or another location close to the existing marina be considered. In low lake level years it is one of the only places deep enough to facilitate the launching of boats.

Today several harbors are accessible, but during low lake level years some harbors would dry up and others would have to be dredged to be utilized.

Large boats that the industry now uses require easy access for trucks to service and unload the vessels. The brine shrimp industry needs fairly large and protected harbors.

North arm potential harbor sites include Black Mountain (small harbor accessed through desert land and could not handle many boats without further development), Rozel Point (limited area, navigational hazards and would require a breakwater for adequate protection), Little Valley Harbor (best harbor on the north arm and every

effort should be made to gain public access to it) and next to the northern railroad causeway at Lakeside (second best harbor option).

South arm potential harbor sites include Lakeside and Magcorp (already taken by private companies), Promontory Point (good potential but needs public access), Stansbury Island (privately controlled) and Black Rock Harbor (development helps, but is limited).

AISP Marina is an excellent location for commercial use (easy access, good location) and additional opportunities for harbor development in the north and south are critical to the long-term health and viability of the brine shrimp industry. There is very little recreational use of AISP Marina during the brine shrimp season and this harbor should be kept available for as long as possible since it provides good revenue for the state. Every effort should be made to increase the availability of this marina. If industry cannot use this marina, we should already have the permits ready to build another harbor at this location.

In developing brine shrimp harbors, managers must consider fairness, access and sustainability of the resource.

In 1995, DPR modified its policies to allow commercial access to its marina at AISP on an emergency basis to serve as an interim facility while a commercial boat launch facility is constructed. It is important to stress that the current commercial status is temporary. Since the marina was designated for recreational purposes, it will revert back to its "recreation only" status once a commercial facility is in place.

The construction of a new harbor facility off the Davis County Causeway is a possibility when and if the facility is needed.

The draft GSL plan identifies potential areas where sovereign land will be made available for brine shrimp harbors. Development of the harbor sites will be the responsibility of lessees. The utility of the sites at various lake levels will have to be managed by the lessees. At this time DFFSL does not anticipate any problem with granting the easements required to dredge harbor channels at low lake levels. DNR will assert rights of public access where DNR believes such rights exist.

10.4 Other commercial and industrial topics

The brine shrimp royalty for raw product is very low.

The brine shrimp royalty rate was determined by the Utah Tax Commission in partnership with the brine shrimp harvesters. DNR did not set this rate.

DWR should be granted permission by the Wildlife Board to re-open the brine shrimp harvesting season.

The Utah Wildlife Board has the legal authority to set policy for DWR and issue rules and proclamations which govern the issuing of CORs and rules which govern the

harvesting of brine shrimp. This plan cannot supersede the legally required mandates of the various divisions and their boards. Therefore such issues as COR distribution, harvesting season opening/closing and COR fees are legally addressed by the Utah Wildlife Board.

The significant decline of GSL brine shrimp cysts as a proportion of the world's supply; GSL used to supply 90 percent and that number has recently declined to 40 percent for a number of reasons.

Due to the variability of the proportion of world supply harvested off GSL, this statement has been changed in the document. It now reads that cysts harvested from GSL provide "a significant but declining proportion of the world's supply of cysts..."

Brine shrimp and mineral industry employment estimates are low in the document. Make any necessary corrections or better explain your sources.

After checking again with Utah Workforce Services, the following numbers were given for minimum employment on the lake: 1,127 employees in mineral extraction and 177 employees in brine shrimp harvesting. This number should be considered a minimum because data on employment at all companies are not available. Specific employment numbers for the recreation sector on the lake were not ascertained. This information has been noted in the text under the "Commercial and Industrial Uses" section.

A suggestion to eliminate the brine shrimp royalty and increase the cost of CORs.

The brine shrimp royalty tax was established by the Legislature and would need to be repealed by that body. The cost of a COR funds research, management and law enforcement activities. Royalties on natural resources compensate the state for a partial value of the resource. The Legislature then decides how to allocate those funds.

The length of the brine shrimp season has been so short that the COR is not worth what is being paid for it.

The COR revenues are used for research, management and law enforcement activities on the lake. Those endeavors must continue irrespective of season length. If economic factors dictate that a COR is not worthwhile, the purchaser will make that decision.

Has a contingent or nonmarket valuation of the lake's resources been considered?

In the plan, we identify areas in need of future research. Contingent valuation and other types of nonmarket valuation of the lake's resources would help to ascertain other values of the resources, in addition to market values. A study such as this is recommended for future work on the lake under the "Commercial and Industrial Uses" section as time, human resources and funding permit.

Some brine shrimpers have concerns that the biological data currently collected on brine shrimp have not been considered in decision-making, implementation and in determining when to close the season.

DWR has met with the brine shrimp industry in public meetings and explained why brine shrimp harvesting season was closed. Data collected and analyzed are reviewed and the decision to close the season was explained at those meetings.

The mineral extraction graph does not reflect quantities of minerals extracted nor does it account for inflation.

The minerals extraction graph is not meant to reflect the quantity of minerals extracted. The data for this graph are from DFFSL, which requires that the data be reported. Companies report value of production to DFFSL in current dollar form, without adjusting for inflation. A footnote has been added to this graph to clarify that inflation is included in the data presented.

10.3 Policy regarding unauthorized construction below meander line for the development of harbors, ramps or any other structures

The planning team received strong support regarding the preferred alternative to link specific enforceable penalties to other DNR permits, licenses and applications. Very few comments were received in this area of concern.

Inappropriate building or commercial activity within the active flood plain should be avoided.

Regulation on DNR land is DNR's responsibility; elsewhere local government controls development.

11.0 AGRICULTURE

11.1 Grazing on sovereign land

Grazing on sovereign lands around GSL is minimal but the team received interest in considering changes in grazing management and policy. The public supported the preferred alternative, however some individuals recommended that no grazing should be allowed on sovereign land and that DNR should terminate existing grazing permits.

We support the preferred alternative because it has been proven that grazing is a wildlife management tool in other locations around the lake.

Grazing should at least be guided by DWR and tightly prescribed with a target vegetative grazing plan.

Grazing on arid and unproductive (biomass), as well as most of the uplands surrounding GSL, is inherently inconsistent with the public trust doctrine. Wetlands are more productive and are critical habitat for wildlife and aquatic environments within a desert landscape and should not be grazed.

Grazing levels should be compatible with nesting migratory birds.

Grazing can be compatible with other multiple-use management objectives.

Grazing by domestic livestock on sovereign lands around the lake will be considered after determining the affect on wildlife and habitats. Grazing can have a negative impact on birds, especially during the nesting and brooding seasons. In other habitat types experience has demonstrated that appropriate grazing needs to comply with a plan containing objectives and stipulations so that other resource values are not adversely impacted

12.0 TRANSPORTATION

12.1 Designate roads, causeways and utility corridors

The preferred alternative received support from the majority of the respondents. Respondents agreed that the state should keep using existing corridors and not to support the AISP South Causeway. The few that supported alternative C had a strong interest in intra-lake transportation proposals.

"Legacy Parkway" could be built on a causeway from the area northwest of the SLCIA out to Antelope Island, along the eastern side and then to Fremont Island on to Promontory Point following the peninsula to Thiokol and Tremonton.

Roads and fills across GSL have water quality impacts due to restricting water circulation and resulting changes in salinity. The southern causeway fill to AISP should not be considered.

The state should close any further discussion of the southern causeway fill to AISP and justify it with the ultimate consideration being given to the optimal biological productivity of the lake.

We agree with the state in not supporting the southern causeway fill for the following reasons:

-Access only through one causeway makes AISP a more highly treasured, more attractive destination as well as more easily managed.

-Tourism entities in Davis County as well as numerous conservation groups are supportive of this recommendation.

-A variety of activities could make the south shore of the lake a more educational and desirable place to visit.

-A roadway to AISP from the south would directly conflict with National Audubon's Gillmor Sanctuary property unless it was built on sovereign lands from I-80. Impacts on sovereign lands would be costly and unacceptable in regard to public trust resource protection. We are strongly opposed to this unnecessary and damaging proposed roadway.

Measures to balance north and south arm salinity should be also considered with the transportation alternatives in this document.

The recommendation to convey fresher flow to the north arm of the lake, either by a canal from the east side of the lake or by a canal from the Bear River, has been investigated by DWRe in the past and found to be much more expensive than other possible solutions to the present salinity problem and much more disruptive to the overall salinity and exchange throughout the lake.

The southern causeway fill to AISP is considered in the alternatives. Whether or not the causeway serves as a transportation route, the effect of the causeway on biology and salinity will be considered in subsequent management actions.

The preferred alternative does not support the AISP southern causeway fill.

DPR does not support development of a south causeway to AISP as an alternate public access. However, the division will continue to access the southern corridor to provide emergency access to AISP in the event of wildfires, search and rescue activities or for other similar contingencies. Access must also be maintained for existing structures owned by FAA. The division does not oppose development of potential recreational activities (e.g., bicycle or foot trails, etc.) along the corridor. Nor does it oppose the associated development of interpretation/education activities. Again, the type of recreational activity allowed on the causeway must be in harmony with the recommendations put forth in the GSL plan and future planning processes. This would require coordination with private landowners.

The preferred alternative does not call for any new routes across the lake. Salinity-related impacts of transportation developments will be taken into account.

13.0 LAW ENFORCEMENT

13.1 Identify the meander line for law enforcement purposes

The public supported the preferred alternative to identify the meander line on the ground for law enforcement purposes. Some respondents were concerned about possible constraints to navigation or problems related to flooding if markers were utilized to identify the meander line.

Marking the meander line will cause grief to landowners and people trespassing where private property exists below meander.

General land status maps are not intended to display up-to-date land ownership. County records and agency files must be used for this purpose. Nonetheless, Map 1 has been revised to show private ownership below meander. Whatever graphic systems (e.g. maps and GPS coordinates) are used to identify the meander line, private ownership below meander will be shown. In very few instances on-the-ground markers may be necessary.

14.0 SEARCH AND RESCUE

14.1 Improve search and rescue

The public supported the preferred alternative to improve search and rescue access and operations. Stakeholders were interested in supporting search and rescue operations particularly industry and boating recreationists that are out on the lake on a regular basis.

Improved access to the north arm of the lake would be beneficial for search and rescue on the lake.

There is a need for a breach in the causeway to allow unlimited access between the north and south arms of the lake. This is a safety concern due to limited access.

The document should acknowledge the importance and valuable role of the brine shrimp industry in assisting with search and rescue operations and other emergency situations (during the season and for research, data collection and monitoring outside of the season enable prompt response for search and rescue).

Air boaters would be willing to provide additional assistance with search and rescue operations on the lake.

Entities such as the brine shrimp industry, recreational boaters, air boaters as well as other "participants" are a valuable resource in search and rescue operations. The voluntary services rendered with search and rescue operations and other emergency situations are indeed a great service to our agencies and to the general public.

We appreciate the willingness of these groups to provide such valuable assistance. This is consistent with the DPR effort to secure volunteer assistance in managing state parks and other DNR resources in Utah.

15.0 RAMSAR

15.1 Ramsar recognition of GSL

The planning team received considerable input on this issue. The public supported a Ramsar designation for at least the 39 townships identified by the Legislature for wildlife management. Over 9 percent of the respondents supported alternative B. There was some confusion about why alternative A suggested no designation at this time.

The state should embrace this designation for the GSL ecosystem. A Ramsar designation does not preclude the state's management regime.

At a North American Wetland Conservation Act grants meeting, it was mentioned that in competitive bidding for monies a Ramsar designation receives additional scoring points. A grant for $1,000,000 was approved for GSL wetlands. This designation means the chance to bring additional money to Utah for state and private project enhancement.

We strongly support a Ramsar designation for the 39 townships identified by the state Legislature for wildlife management.

In addition all WMAs, BRMBR, TNC's Nature Preserve and National Audubon's Society's Gillmor Sanctuary

All or selected portions based on international importance of GSL for migratory birds

Ramsar is urgently needed to educate the public and protect critical parts of the lake from proposed development and highway projects. This is a very unique ecosystem with complex biogeochemical and biological dynamics and the important role that it plays in supporting millions of migratory shorebirds and waterfowl each year makes this designation eminently appropriate.

Ramsar indicates that there should be "wise use" promotion of an area and does not interfere with any management decisions. DNR should be interested in promoting wise use of an area, while still protecting the resource. This would be consistent with the need to manage the resource for its long-term protection and conservation.

The implications, responsibilities and other required activities which are associated with this designation are currently unknown as they relate to DNR's public trust responsibilities. Therefore DNR recommends taking a thorough look at the possible consequences involved with a Ramsar designation for GSL wetlands. Recommending further research on this issue does not mean the opportunity will be lost in the future.

The Ramsar "Identification of Benefits to the Current U.S. Listed Sites" survey was conducted by USFWS and state natural resource agencies and it indicates that a Ramsar designation brings additional funding to these sites to help with studies, mitigation and other conservation measures. It increases recognition of important wetlands and raises the visibility of the resource in regard to tourism, public education and other consequences of a high profile wetland.

It is a more viable option to recommend particular areas for this designation of a wetland of international importance. Particular areas around the lake have a wildlife and habitat protection or conservation priority and lend themselves to a Ramsar designation. This would require coordination with the entities mentioned above and with local land owners to ensure compatibility with this designation.

According to the Ramsar survey, an Alaskan National Wildlife Refuge and State Game Area claims that it has "heightened the level of scrutiny it places on various forms of recreational and commercial use currently ongoing or proposed for the area." DNR is concerned that a Ramsar designation will be used to limit DNR's ability to accommodate changing needs of the public trust. Also, some flexibility is necessary to balance all the diverse management interests and responsibilities mentioned in 65A-10-8 of the Utah Code. This is a unique system with complex dynamics and plays an important role in supporting wildlife.

DNR is interested in promoting wise use of an area while still sustaining and protecting the resource. Ramsar requires "wise use" of wetlands and their support systems. Ramsar defines "wise use" as "the wise use of wetlands is their sustainable utilization for the benefit of humankind in a way compatible with the maintenance of the natural properties of the ecosystem."

Ramsar requires that contracting parties complete a full assessment of environmental concerns in planning (wetland and upstream) that might affect the wetland and possibly impact associated benefits and values. Other required actions include continued evaluation during planning project implementation and the full implementation of necessary environmental measures. Also, in cases where there is insufficient evidence to prove a direct link between activities and resulting wetland degradation, a "precautionary principle" should govern determination of appropriate activities for a wetland.

These requirements would be difficult to meet since funding and other resources are limited. We do not know exactly how this dynamic ecosystem works and what impacts particular activities have on these resources. According to Ramsar's "Identification of Benefits to the Current U.S. Listed Sites" survey, a Ramsar designation has not changed or shifted the type of management or land-use practice. However, nearly all of the Ramsar sites listed have a clear natural resource management focus— to mainly protect wildlife and habitat values. The state is required to balance multiple-use and protect sustainability of the lake and its resources. According to Ramsar's web site, a Ramsar designation has prevented development in several cases. This may be inconsistent with our public trust responsibility and existing mandates for managing the lake.

16.0 OPEN SPACE/CRITICAL LANDS

16.1 Protect open space and critical lands

The public supported the preferred alternative to acquire additional property or conservation easements for open space and critical land protection. Some individuals suggested that the preferred alternative was consistent with several other management objectives.

A *Ramsar designation would be consistent with acquiring additional property or conservation easements in support of DNR's goal to work towards protecting open space and identifying critical lands policies. It would also have the potential to help prioritize the lake as an area to acquire additional habitat or conservation easements on a willing seller basis.*

The consideration of Ramsar must be fully investigated and determined not to conflict with other public trust responsibilities. It would be consistent if it did not conflict with the reasons for acquiring a particular parcel. A decision to acquire a property with a willing seller would be based on several criteria and some of these activities may conflict with a Ramsar designation.

16.2 Protect the viewshed and visual aesthetics

The majority agreed with the preferred alternative to protect the visual aesthetics of GSL. One respondent recommended no change in current management.

Managing for the preservation of this asset makes good sense. Zoning which designates viewshed in near and far categories and considering this in permits, leases and mitigation strategies is wise.

The lake environs and wildlife provide an outstanding aesthetic experience. Efforts to enhance and protect the aesthetics of the lake should be encouraged through sensitive placement of power lines, boating facilities and other infrastructure.

Black Rock Brine Shrimp Harbor is a visual resource concern. Tourism and other visual quality activities should consider site activities and near and far viewshed issues.

The lake provides an outstanding aesthetic experience. These concerns may be addressed in a viewshed protection plan. This will be a potential implementation recommendation in this planning process. DNR divisions will coordinate in developing a plan for viewshed protection. Near and far visual resource categories will be considered and likely applied to permits, leases and mitigation strategies.

This visual resource concern was addressed in the ROD for the Black Rock Brine Shrimp Harbor. A copy of this is available upon request from DFFSL.

17.0 PROCESS AND STRUCTURE COMMENTS

These planning process and structure concerns were diverse and considered the development of the management alternatives, implementation and decision-making. Some focused particularly on the use of the GSLTT, establishing an overarching management framework and the validity of the science used in the SCCT and in alternative generation. The public also indicated some concern regarding the balancing of multiple uses and how management issues would be resolved.

The planning process is lacking an overarching vision, principles and framework/goals for management of the lake, such as "protect and sustain the trust resources of the lake." This illustrates the problem of addressing specific management issues without first establishing a basic planning framework.

The overarching management objective for public trust lands is discussed in the introduction to this plan as "..to protect and sustain the trust resources of the GSL, and to provide for reasonable beneficial uses of these resources, consistent with their long-term protection and conservation." Legislative and administrative policy for management of the lake must be implemented within the context of this overarching management objective. DNR welcomes critique of the preferred alternative in this same context. Through resource allocation, including allocation to non-extractive and non-consumptive uses, DNR believes GSL is large enough to accommodate legislative policy and public demand for resource use and enjoyment.

Request to provide an opportunity to voice comments (orally) and to provide more background information on why the team chose a particular alternative. What information was utilized (scoping comments, alternatives comments or other information)?

Why was the public meeting presentation on the alternatives so short? Why did you not provide any additional information?

While preparing for public meetings it was obvious that, due to the complexity of the GSL Planning Project, it would be impossible within time constraints to present background and reasoning for each of the alternatives presented and provide for a dialogue with those attending. As presented, the alternatives encompassed 16 major categories and 34 individual resource management concerns. Each of those concerns required a statement of its current status and three possible management alternatives. A conservative estimation of the time required to conduct a presentation as suggested is three hours, which does not include any opportunity for those attending to ask questions or make comments to the planning team. As presented, the alternatives required approximately 40 minutes, providing an overview of the alternatives, which then left at least two hours at each meeting for interested individuals to discuss them in detail with planning team members. Planning team members were prepared to provide necessary background information and the reasoning behind the choice of a particular alternative. This structure also afforded those attending the opportunity to skip any area in which they had little or no interest, while guaranteeing that those who wished a detailed discussion on all the alternatives could do so.

Alternative B seems to be in direct conflict with most of the other B "amenity" choices and appears to be more like a development alternative.

This alternative could be characterized differently by different people. In this case additional access is perceived to enhance recreational use of sovereign land.

The GSLTT included representatives of the five counties surrounding the lake, state and federal agencies and interested parties. How will this group be utilized in the future? Why was a planning team selected consisting of employees of DNR utilized and not the GSLTT? The GSLTT should assist in the development of this management plan for the lake or the process is inadequate. The GSLTT wants to meet in a larger group and utilizing the GSLTT would assist and improve conflict resolution.

The planning team recognizes the role the GSLTT played in the past and acknowledges the statutory provision encouraging continued use of the GSLTT. See the "Planning Process and Implementation" section of this plan.

A proposal to open vast new wildlife sensitive areas including WMAs should first be based on the future framework for resource planning on the lake.

The draft GSL management alternatives do not acknowledge the errors of the SCCT that we identified. By not addressing these errors the state now proposes solutions to problems for which they do not have documentation to support.

No corrections have been incorporated based on public comment. Some of the conditions are not current, conjecture is often used instead of measurement, faulty application of actual data and claims are made without credible sources.

The planning team has made every attempt where necessary to acknowledge and incorporate changes to the SCCT. The state will also have a scientific review of the SCCT and continue to meet with stakeholders to resolve these and other concerns.

There should be a discussion of policy and procedure changes in DNR to ensure the forthcoming plan will be implemented.

See the "Planning Process and Implementation" section of this plan. The proposed GSL CMP Decision Process should address this concern.

Management decisions should be based upon whether or not they will first of all "protect and sustain the trust resources of GSL" and secondly, will they "provide for reasonable beneficial uses of those resources consistent with their long-term protection and conservation."

The alternatives are insufficiently developed in regard to issue resolution which is related to the lack of articulated overarching management objectives.

The public trust doctrine "requires that those benefits that best preserve the purpose of the public trust under the circumstances should be given a higher priority." The ultimate circumstances should be one of long-term sustainability which would protect even the long-term commodity values of the lake. How can we manage something when we really don't know how it works. Ensuring sustainablility requires research and monitoring.

Alternatives have been more fully developed. See the "GSL Management Alternatives Narrative" section of this plan. Research and monitoring needs will be addressed and discussed in the final plan.

The Enlibra process involves resolving polarized issues and bring all parties to the table to discuss and resolve differences. This planning process does not necessarily have only polarized issues nor was there any attempt by the team to bring all interested parties together to develop alternatives according to an Enlibra process. Enlibra has to be a process, if it is to exist.

The Enlibra principles will be utilized in subsequent public involvement activities.

There is a lack of a "no action" alternative for each issue. Alternatives are not fully developed and are not always mutually exclusive.

The current situation alternative, in many cases, represents the "no action" alternative.

How are scoping comments addressed and considered in the development of these alternatives? This knowledge would be helpful in participating effectively in this planning process.

Scoping comments were incorporated in the SCCT where possible (see newsletter for the brief summary). Not all scoping comments were put into alternatives. However comments were summarized into one document. All scoping comments have received consideration.

The public needs to know how the state views this resource in the long-term. What is the balance between economic potential and biological productivity?

The planning process is offered in context with the statutory direction. See the SCCT section in this plan. Our planning horizon deals with a ten-year time frame.

The management options were severely limited and are confusing without an adequate context and management philosophy. The management objective should be to manage this ecosystem, to first optimize the biological productivity and allow for sustainable use of the lake's resources.

The planning purposes are discussed in the "Introduction" section of this document.

If the goal is to "strive for sustainable resource management of the lake," then the biological productivity should be used as the limiting factor. These are lands held in the public trust. This doctrine does not mandate that managers make money from the lake or try to accommodate everyone. Isn't this the distinction between sovereign land and school trust lands?

The "trust duty" receives consideration throughout the planning document.

This general planning document is not the place to resolve some of these issues (BRMBR expansion, acquiring water rights for Locomotive Springs WMA).

The planning team disagrees. The planning team considered all scoping comments regardless of the specificity of the concern.

The functional link among water quality, water chemistry, hydrology, changing lake levels, topography and biological systems is the ecosystem itself. The planning team should tie all of these disciplines back together to reconnect all of these dynamic processes that form the basis of this astonishingly rich and biologically productive ecosystem.

Research is underway to understand some of these relationships. Findings will be incorporated to improve management. Further research will answer more questions.

The final GSL CMP statement will attempt to integrate all planning segments.

Under what framework of inquiry represented in this process will population growth, air and water pollution and other impacts be analyzed? How will the multiplication of these impacts be understood?

The state's execution of its public trust responsibility is described in the plan. As these factors influence resource management, appropriate changes will be made in plan amendments and subsequent plans. This is a dynamic plan and revisions will be accomplished as needed or required.

Impacts on this watershed and region of global climate change should be acknowledged and incorporated into any discussion about the lake's future.

The GSL planning process only deals with impact within the state's jurisdiction of the lake.

The management alternatives do not discuss who will oversee and implement the various alternatives in the future. Who will be resolving division conflicts regarding management responsibilities?

See the "Planning Process and Implementation" section of this plan. The proposed GSL CMP Decision Process should address this concern.

Given the broad scope of managing an ever changing lake and the increasing knowledge about this resources, how will additional information be utilized and changes in management be made in the future?

See the "Planning Process and Implementation" section of this plan.

The lack of adequate detail regarding the logic and background information used to develop these management alternatives makes it very difficult to formulate constructive comments. This information is essential to formulating good public comment.

See the "Introduction" and SCCT sections of this document. The planning team believes that all alternatives are legitimate in the context of public trust management. The team also believes identifying the alternatives in relative terms is sufficient.

Propose the preferred management alternatives based on the best solution for each issue instead of selecting one particular alternative. The issues are too complex to use a simplified process.

This planning process allows for mixing of alternatives to occur. The final plan may include a mix of actions rather than adhering to a straight (proposed) alternative.

The labels "Enlibra," "amenity" and "commodity" are vague descriptors and the management circumstances are not well defined.

Circumstances regarding the background for the alternatives are described in the SCCT.

The commodity alternative doesn't seem to take into account the commodity value of the recreation and ecotourism industry, only extractive resource industries (1.6, 2.1, 1.3 C).

Areas in need of further research are identified in the GSL management plan. Contingent valuation and other types of nonmarket valuation of the lake's resources would help to ascertain other values of the resources, in addition to market values. A study such as this is recommended for future work on the lake under the "Commercial and Industrial Uses" section as time, human resources and funding permit.

Comment Contributors

Comments to Scoping

Scoping issue ideas were received from the following persons, groups or at the following meetings (note, not all scoping issues came from comments directly received by the GSL Planning Team):

Adler, Robert W.
Anderson, Russell J. (Salt Creek, Inc.)
Battle, Cullen (Farmington Bay Advocates)
Begue, Tim (Prime Artemia Incorporated)
Borigone, Joe (DEQ/DAQ)
Brindley, William A. (Utah State University)
Bureau of Land Management
Carter, Kevin (SITLA)
Ciak, Penny L. (Great Salt Lake Audubon)
Cole, David W. (Salt Creek, Inc.)
Cole, Don P. (Salt Creek, Inc.)
Cook, F. Grant
Corey, Gerald and Rosemary
Covey, Owen Kent (New State Inc./Jordan Fur & Reclamation Co.)
De Freitas, Lynn (Friends of Great Salt Lake)
Department of Community & Economic Development
    Division of State History
Department of Environmental Quality:
    Division of Air Quality
    Division of Drinking Water
    Division of Water Quality
Department of Natural Resources:
    Administration and DNR Planners
    Division of Forestry, Fire & State Lands
    Division of Parks and Recreation
    Division of Water Resources
    Division of Wildlife Resources
    Division of Water Rights
    Utah Geological Survey
Edwards, Gerald (Union Pacific Railroad Company)
Friends of Great Salt Lake

Funk, Tim (Hawkwatch International)
Great Salt Lake Minerals
Great Salt Lake Technical Team
Green, Bill (Salt Creek, Inc.)
Gygi, Janice (The League of Women Voters of Utah)
Hahl, Daniel C.
Hansen, Carl (Davis County Public Works)
Harja, John A. (for Brad T. Barber) (GOPB)
Harris, Reed E. (USFWS)
Hoffman, Stephen W. (Hawkwatch International)
Hutchings, Sherry (Salt Creek, Inc.)
Hyde, Lacy B.
Ingley, Mark D. (Salt Creek, Inc.)
Jones, Nathan (Bonneville Artemia International, Inc.)
Lichfield, Water and Wilma B.
Livermore, Dave (The Nature Conservancy of Utah)
Marden, Brad (Avocet Artemia, Inc.)
Martinson, Wayne (National Audubon Society)
Matheson, Norma (The Nature Conservancy of Utah)
McCandless, Allen G. (Salt Lake City Airport Authority)
McDougal, Mark R. (Artemia Brine Company, Inc.)
McDougal, Richard
Morgan, Max G. (Utah Wildlife Board)
Mihamou, Lou H. (Salt Creek, Inc.)
Milliken, John W. (The Nature Conservancy of Utah)
Nangle, Joseph (Prime Artemia Incorporated)
Nelson, DeVon (Weber County Public Land Advisory Council)
O'Connell, Ann
Olsen, Halvor M.
Olwell, W.H. (Utah Wetlands Foundation)
Ostler, Don A. (DEQ/DWQ)
Ottley, Robyn (Salt Creek, Inc.)
Pearce, Maunsel B. (The Nature Conservancy and Utah Wetlands Foundation)
Peterson, Joel M. (The Nature Conservancy)
Public Scoping Meetings:
- Box Elder County
- Davis County
- Salt Lake County
- Tooele County
- Weber County

Raymond, Bert J.
Sanders, Gail C.
Second Great Salt Lake Issues Forum
Sorensen, Ella (Gillmor Sanctuary and National Audubon Society)
Stock, Valon E.
Storrs, Gordon (Poplar Grove Community Council)
Tadje, James B. (Department of the Air Force)
Testa, Thomas K. (Salt Creek, Inc.)

Trevithick, Bill
U.S. Fish & Wildlife Service
Valentine, Bob (Utah Wetlands Foundation)
Weber, Ivan
Weber River Basin Steering Committee
Wilcox, Richard B. (SITLA)
Willener, John A. (J.A.W. Brine Shrimping, Inc.)

Comments to Current Trends and Conditions

Atwood, Genevieve (Atwood & Mabey, Inc.)
Barry, John E. Sr.
Berger, Randy
Covey, Owen Kent (New State Inc./Jordan Fur & Reclamation Co.)
Dalton, Mike
Denton, Richard (DEQ)
Dolling, Justin
Green, Terry (Utah Division of Parks and Recreation)
Gwynn, Wally (UGS)
Herbst, David B. (Sierra Nevada Aquatic Research Laboratory, University o f California)
Howe, Frank (Utah Division of Wildlife Resources)
Isaacson, Alan E. (Bureau of Economic and Business Research)
Jehl, J.R. Jr.
Kuehn, David W. (Sanders Brine Shrimp Company, L.C.)
Landis, Kevin
Lichfield, Walter
Mabey, Don R. (Atwood & Mabey, Inc.)
Marden, Brad (Avocet Artemia, Inc.)
Martinson, Wayne (National Audubon Society)
May, J.C. (Antioch Living System Collective)
Milne, Corey R. (IMC Kalium)
Peterson, Joel M. (The Nature Conservancy)
Pitkin, Jay
Rushforth, Sam (Brigham Young University)
Smith, Dan
Stephens, D. (USGS)
Tadje, James B. (Department of the Air Force, Hill Air Force Base)
Talbot, Sheldon (CUWCD)
Wurtsbaugh, Wayne (Utah State University)
Zucker, Michael (DEQ, Division of Environmental Response & Remediation)

Comments to Alternatives

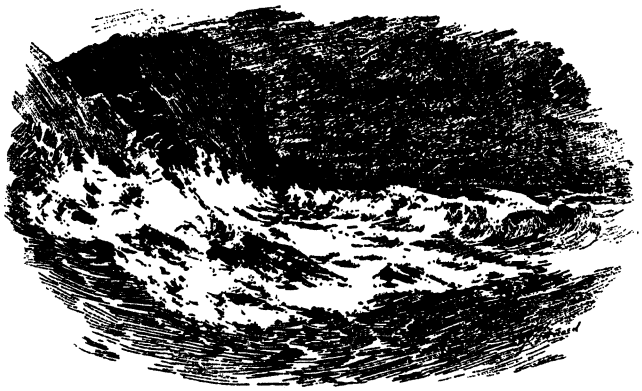
Carl A. Nelson	ENC Laboratories
Dave Kuehn	Sanders Brine Shrimp Company, L.C.
Bert Thomas Clark	Mineral Exploration Mining Property Evaluation
Kathy Van Dame	Wasatch Clean Air Coalition
J.C. May	Antioch Living Systems Collective

Ken Warnick	IMC Kalium Ogden Corp.
Peter Erickson	Salt Creek, Inc.
Lyndon T. Jones	Cargill Salt
Lynn de Freitas	Friends of Great Salt Lake
Wayne Martinson	National Audubon, Utah Wetlands
Reed E. Harris	U.S. Fish & Wildlife Service-Utah Field Supervisor
Teryl Hunsaker	Tooele County Commission
Donald C. Griffin	
Cheryl Owen	
Richard E. Stephens	
Owen Kent Covey	
Halvor M. Olsen	
Peter Maier, Ph.D., PE	
Gail Duering	
William M. Stokes	
Matthew C. Lindon P.E.	
John A. Willener	
Wim Tackert	
Steve Barrowes, Ph.D.	
Ivan Weber	
Howard Gross	
R. Spencer Martin	
Bob Valentine	Utah Wetlands Foundation
Stephen W. Hoffman	Hawk Watch
Dave Livermore	The Nature Conservancy of Utah
Ella Sorenson	Gillmor Sanctuary, National Audubon Society
Joel Peterson	The Nature Conservancy
Maunsel B. Pearce	The Nature Conservancy, Utah Wetlands Foundation
Robert W. Adler	University of Utah College of Law
W. H. Olwell	Utah Wetlands Foundation
Cullen Battle	Farmington Bay Advocates
Chris Montague	The Nature Conservancy
Kathlyn Collins	Friends of Great Salt Lake
Ran McDonald	Division of Air Quality
Steve Packham	Division of Air Quality
Jay Pitkin	Division of Water Quality
Steve McNeal	Division of Water Quality
Judy W. Watanabe	Division of Comprehensive Emergency Management
Michael Schwinn	U.S. Army Corps of Engineers

Utah Artemia Association
Great Salt Lake Coalition

Appendix D

Literature Cited



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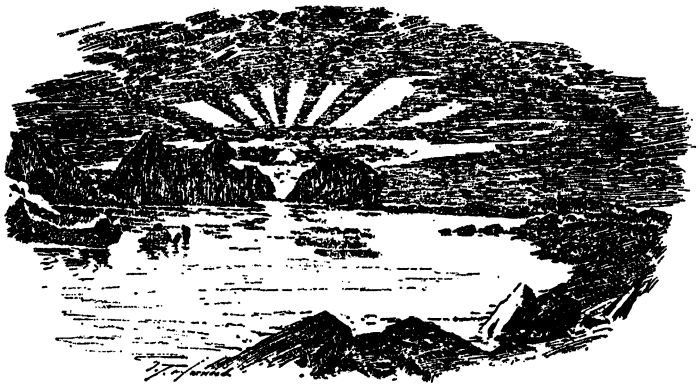
Appendix E

Acronyms and Abbreviations



Acronyms and Abbreviations

AADT	Annual Average Daily Traffic
af/yr	acre-feet per year
AISP	Antelope Island State Park
Amoco	Amoco Oil Company
BDA	Beneficial Development Area
BLM	Bureau of Land Management
BOD	Biological Oxygen Demand
BRMBR	Bear River Migratory Bird Refuge
CMP	Comprehensive Management Plan
COE	U.S. Army Corps of Engineers
COR	Certificate of Registration
CUP	Central Utah Project
DAQ	Division of Air Quality
DCEM	Division of Comprehensive Emergency Management
DERR	Division of Environmental Response and Remediation
DEQ	Department of Environmental Quality
DFFSL	Division of Forestry, Fire and State Lands
DGSL	Division of Great Salt Lake
DNR	Department of Natural Resources
DOGM	Division of Oil, Gas and Mining
DPR	Division of Parks and Recreation
DSLF	Division of Sovereign Lands and Forestry
DWQ	Division of Water Quality
DWR	Division of Wildlife Resources
DWRe	Division of Water Resources
DWRi	Division of Water Rights
E	east
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Authority
FTE	Full-time Employee
FTE	Full-time employee
GAP	Geographic Approach to Planning for Biological Diversity
GIS	Geographic Information System
GOPB	Governor's Office of Planning and Budget
GSL	Great Salt Lake
GSLAC	Great Salt Lake Advisory Council
GSLEP	Great Salt Lake Ecosystem Project
GSLTT	Great Salt Lake Technical Team
HAFB	Hill Air Force Base
I-80	Interstate 80
IMC	IMC Kalium Ogden Corp
KUC	Kennecott Utah Copper
M&I	Municipal and Industrial
Magcorp	Magnesium Corporation of America

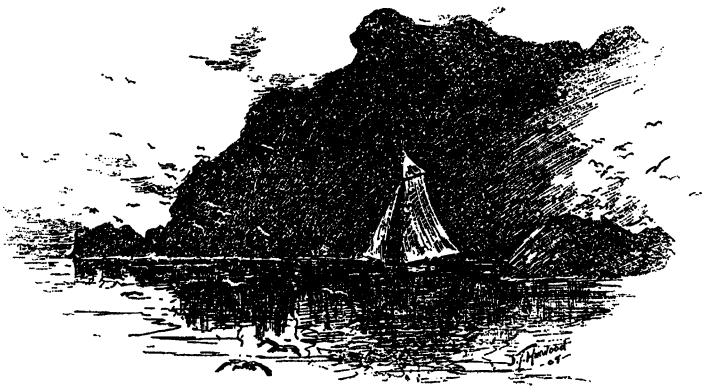
MLP	Mineral Leasing Plan (for Great Salt Lake, Division of Forestry, Fire and State Lands)
MOU	Memorandum of Understanding
N	north
NA	Not Applicable
NAAQS	National Ambient Air Quality Standards
NaCl	Sodium chloride or table salt
NAGPRA	Native American Graves Protection and Repatriation Act
NAWQA	National Water Quality Assessment
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
NRC	National Response Center
OERP	Office of Energy and Resource Planning
OGH	Oil, gas and hydrocarbon
OHV	Off highway vehicle
PD	Planning Document (internal review draft)
ppm	parts per million
Pt.	Point
RAC	Regional Advisory Council
RDCC	Resource Development Coordinating Committee (State Information Clearinghouse)
RMP	Resource Management Plan
ROD	Record of Decision
RR	Railroad
S	south
SCCT	Statement of Current Conditions and Trends (Great Salt Lake Planning Project, 1998)
SIP	State Implementation Plan
SLAC	Sovereign Lands Advisory Council
SLB&M	Salt Lake Base and Meridian
SLC	Salt Lake City
SLCIA	Salt Lake City International Airport
SPRR	Southern Pacific Railroad
SPTC	Southern Pacific Transportation Company
SRC	Scientific Review Committee
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
TSS	Total Suspended Solids
UDOT	Utah Department of Transportation
UGS	Utah Geological Survey
UPDES	Utah Pollutant Discharge Elimination System
URMCC	Utah Reclamation Mitigation and Conservation Commission
USAF	U.S. Air Force
USDA	United States Department of Agriculture
USFWS	U.S. Fish & Wildlife Service
USGS	U.S. Geological Survey
USU	Utah State University
UWRL	Utah Water Research Laboratory

VRM	Visual resource management
W	west
WDPP	West Desert Pumping Project
WFRC	Wasatch Front Regional Council
WHSRN	Western Hemisphere Shorebird Reserve Network
WMA	State managed waterfowl or wildlife management areas depending upon the context
WWTS	Waste water treatment system

Notes:

Appendix F

Glossary of Terms



Glossary of Terms

10th degree polynomial fit: Power equation curve fitting (statistical fit)

ad valorem: Imposed at a rate percent of value.

amenity: Environmental values

anaerobic: In the absence of oxygen.

anthropogenic: Of, relating to or resulting from the influence of human beings on nature.

anticline: Arch of stratified rock in which the layers bent downward in opposite directions from the crest.

appropriation: Authorization of the use of a quantity of water

aquaculture: Science and business of cultivating food fish or shellfish.

aquifer: Underground geological formations or group of formations containing usable amounts of groundwater that can supply wells and springs.

avian botulism: Bird disease that results in death.

avifauna: Birds of a specified region or time.

basalt: A dark, tough extrusive volcanic rock

beneficial use: Use of water for one or more of the recognized beneficial uses including but not limited to, domestic, municipal, irrigation, hydropower generation, industrial, commercial, recreation, fish propagation and stock watering; it is the basis, measure and limit of a water right.

bi-directional flow: Two-way stratified flow through a causeway resulting from differing densities between water bodies on either side of the causeway.

bioavailability: Capability of an element or compound to be accumulated in an organism.

biodiversity: Composition of species in a given area at a given period of time.

bioherm: Deposits of calcium carbonate deposited over time by cyanobacteria. The metabolic activity of these bacteria change carbon dioxide into calcium carbonate. These deposits can form large rock or reef like formations on the bottom of the lake. They are also known as stromatoliths.

biological oxygen demand: Amount of oxygen required by aerobic biological processes to break down the organic matter in water. It is a measure of the polluting strength of biodegradable waste in dissolved oxygen in water.

biomass: All product harvested by brine shrimpers.

bitterns: Bitter water solution of salts that remains after sodium chloride and other salts have crystallized out of a brine.

breach: Opening or breakthrough in a dam or dike.

brine: Water saturated with or containing large amounts of salts.

buffering: Something that serves as a protective barrier.

by-catch: Portion of biomass that does not include brine shrimp eggs.

calcareous: Of, like or containing calcium carbonate, calcium or lime.

causeway: Raised way across wet ground or water; a large dike.

chemical homogeneity: Well mixed chemically; uniform throughout chemically.

coliform: Organisms like or normally found in the colon, often used as an indicator of fecal contamination of water supplies.

commodity: Commercial or development values

contaminant: Any physical, chemical, biological or radiological substance in water.

copepod: Any of the class Copepoda of small, sometimes parasitic, crustaceans living in either salt or fresh water.

cysts: Brine shrimp's eggs that have a hard shell that enables survival during harsh conditions.

DDT: Powerful insecticide effective upon contact: its use is restricted by law due to damaging environmental effects.

depletion: Loss to the hydrologic system. Withdrawal or loss of water from a water source (river, stream or basin) at a rate greater than its natural rate of recharge as a result of consumption.

design wave: Calculated, designed or modeled wave which is the average of the highest one-third of all waves.

detritus: Accumulation of disintegrated material or debris.

diffusion: Process whereby particles of liquids, gases or solids intermingle or disperse into air or water.

dikes: Embankment to confine or control water.

dioxin: Chemical that can build up in the environment.

discharge: Addition of any pollutant to any waters of the state.

diurnal: Occurring during the daytime.

diversion: Transfer of water from a stream, lake, aquifer or other source of water by a canal, pipe, well or other conduit to another watercourse or to the land; turning aside or alternation of the natural course of a flow of water, normally considered physically to leave the natural channel.:

drainage basin: Drainage system that consists of a surface stream or body of impounded surface water together with all tributary surface streams and bodies of impounded surface water.

ecosystem: Community of animals and plants and the physical environment in which they live.

end member: Brines that are on opposite ends of a brine chemical composition scale.

effluent: Wastewater, treated or untreated, that flows out of a treatment plant sewer or industrial outfall. Generally refers to wastes discharged into surface waters.

embayment: Confined body of water by a dame, dike or other barrier.

emergent marshes: Marsh consisting of rooted plants in shallow water and having most of the growth above the water.

Enlibra: Balance between commodity and amenity values; promotes stewardship

environs: Adjoining area or space surrounding a particular area; in the vicinity.

ephemeral pool: Pool of water that exists in direct response to precipitation or other favorable climatic conditions.

errant hardware: Military ordinance or other abandoned materials that have strayed outside the proper path.

exotics: Nonnative species of plants or animals.

eutrophic: Designating or of a body of water, esp. a lake or pond, rich in nutrients which cause excessive growth of aquatic plants, esp. algae: the resulting bacteria consume nearly all the oxygen, esp. during warm weather.

fauna: Animals of a specified region or time.

fetch: Distance a wind blows unobstructed over water, esp. as a factor affecting the buildup of waves.

flood plain: Area bordering a stream or water body that may be overflowed or flooded during times of high water.

flora: Plants of a specified region or time.

flux: Continued flow or continuous moving on or passing by of a stream; a substance used to promote fusion of metals or minerals.

food chain: Sequence of organisms in a community in which each member of the chain feeds on the member below it.

forbs: Broad-leaved herbaceous plant, as distinguished from the grasses, sedges, shrubs and trees.

freeboard: Vertical distance from the maximum water level in the lake to the top of the causeway slope protection.

furans: Chemical compounds that result from the incomplete combustion of hydrocarbons

Jersey barriers: Concrete barriers used to separate lanes in a road or to prevent flooding.

Gilbert Bay: The south arm of Great Salt Lake; the main body of Great Salt Lake

groundwater: Underground water stored in aquifers. Groundwater is created by rain which soaks into the ground and flows down until it collects above an impervious zone.

Gunnison Bay: The north arm of Great Salt Lake

halophytic: Ability for a plant to grow in either salty or alkaline soil.

hatch out: Portion of brine shrimp eggs that hatch in a given quantity.

head differential: Difference in lake level elevations between the north and south arms.

heavy metals: Metals that have high specific gravity and high atomic mass, such as lead, cadmium, zinc, copper, silver and mercury. In sufficient concentrations, these metals are toxic to humans and aquatic wildlife.

historically: Period from 1847 to the present.

Holocene: The present epoch of the Quaternary Period, extending from the close of the Pleistocene

hydrograph: Map of oceans, lakes and rivers, esp. with reference to their navigational and commercial uses.

hydrology: Science dealing with properties, distribution and circulation of water on the surface of the land in the soil and underlying rocks and in the atmosphere.

hydrosalinity model: Hydrologic model of water and salinity balance. It incorporates inflow, outflow, causeway permeability and other hydrologic factors plus the movement of

dissolved salts, precipitated salts and salts removed from this closed system.

hypersaline: Highly saline water.

hydrostatic: Pressure and equilibrium of water and other liquids.

hysteresis: Used to explain the northward movement of dissolved salts through the SPRR causeway during rising lake conditions and the reverse of southward movement during periods of declining lake level.

Indicator species: Organism or ecological community so strictly associated with particular environmental conditions that its presence is indicative of the existence of these conditions.

infrastructure: Permanent structures used to provide for transportation, commerce and which support other community needs (such as roads, utilities, parking, etc.).

inter-island: Occurring between islands.

intermittent: Coming and going at intervals, not continuous.

inversion: Cooling of the atmosphere near the Earth's surface. Occurs at a much faster rate than away from the surface creating a stable layer of air. Low wind speeds limit the transport and diffusion of pollutants.

ions: Atom or group of atoms that carry a positive or negative electrical charge as a result of have lost or gained one or more electrons.

jetty: Structure extending into a sea, lake or river.

Jurassic: The second period of the Mesozoic Era, characterized by the dominance of dinosaurs and the appearance of flying reptiles and birds

jurisdiction: Limits of administrative authority of a federal, state or local government agency.

keystone species: Species that other species or associated thing depend upon for support.

limnology: Study of physical, chemical, meteorological and biological conditions in water bodies like lakes.

liquefaction: Act or process of making or becoming liquid; sudden loss of strength of a soil resulting from a dynamic loading as from a earthquake.

littoral zone: Region along the shore of a non-flowing body of water, such as a lake.

meander line: The line run in surveying particular portions of the public lands which border on navigable waters as a means of ascertaining the quantity of land subject to sale.

mitigation: Action designed to lessen or reduce adverse impacts.

mudflats: Flat, low lying areas with a thick layer of fine soils with a high clay content found around water bodies and other low lands occasionally covered by water.

multiple-use: Coordinated management of various surface and subsurface resources, without impairment of the land, that will best meet the present and future needs of the people.

municipal & industrial use: Water supplied for municipal and industrial uses provided through a municipal distribution system.

nauplius: First larval stage in the development of brine shrimp.

nonattainment area: Areas that are not meeting federal health standards for certain criteria pollutants. These areas must develop comprehensive state plans to reduce pollutant concentrations to a safe level.

nonpoint source: Sources of water pollution not associated with a distinct discharge source: includes rainwater, erosion, runoff from roads, farms and parking lots and seepage from soil-based wastewater disposal systems.

north arm: That part of Great Salt Lake north of the northern railroad causeway and west of the Promontory Mountains.

nutrients: Simple dissolved inorganic ions (nitrate, nitrite, phosphate, ammonia, etc. along with other dissolved forms of nitrogen and phosphorous); a minor substance in water bodies that is required for growth, promotes growth and may limit growth in an aquatic system. Nutrients may be the result of natural processes or by human wastes, agriculture, runoff and other sources.

oolites: Sands with almost spherical grains

outfall: Place where a stream discharges; outlet or structure through which reclaimed water or treated effluent is discharged.

ozone: Unstable, pale-blue gas with a penetrating odor. Secondary pollutant formed in the atmosphere as a result of a chemical reaction. It is formed by the complex series of reactions between nitrogen dioxide and volatile organic compounds in the presence of light.

panaeid shrimp: Type of shrimp raised in hatcheries in Asia for human consumption. Recipients of the majority of Great Salt Lake brine shrimp cysts harvested.

passerine: Pertaining to an order of small or medium-sized, chiefly perching songbirds having grasping feet with the first toe directed backward. More than half of all birds are included.

pelagic: Of or relating to or living or occurring in open water.

perennial: Vegetation that persists with new herbaceous growth for several years.

perfected water right: Water right that has been certificated; is considered real property.

permeability: Rate at which a soil transmits water when saturated.

pH: A symbol for the degree of acidity or alkalinity of a solution; it varies from 0 to 7 for acidic and 7 to 14 for alkaline

piscivorous: Fish-eating.

playa: Flat-floored bottom of an undrained desert basin that becomes at times a shallow lake or ephemeral pool.

Pleistocene: The first epoch of the Quaternary Period in the Cenozoic Era, characterized by the spreading and recession of continental ice sheets and by the appearance of modern humans.

PM10: Particulate matter with a diameter of 10 microns or less. Particles of this size settle slowly and stay suspended in the air.

pod: Group of animals.

point of diversion: Point specified in a water right from which water is diverted from a source.

point source: Specific discharge that is traceable to a distinct source (pipe, ditch, container, well, etc.) such as those from wastewater treatment plants or industrial facilities.

pollutant: Contaminant that adversely alters the physical, chemical, or biological properties of the environment. The term includes toxic metals, carcinogens, pathogens, oxygen-demanding material, heat and all other harmful substances, contaminants or impurities.

pollution: Any introduction into water of microorganisms, chemicals, wastes or wastewater in a concentrate that makes the water unfit for its intended use.

Public Trust Doctrine: The Public Trust Doctrine provides that public trust lands (e.g. beds of navigable waters), water and living resources in a State are held by the State in trust for the benefit of all of the people, and establishes the right of the public to fully enjoy public trust lands, waters and living resources for a wide variety of recognized public uses.

pupa: Insect in the nonfeeding stage of development between the last larval and adult forms, characterized by many anatomical changes and, often, by enclosure in a cell or cocoon.

pupal casings: Outside covering of a pupal or intermediate stage of an insects development.

recession: Ceding back.

reliction: Gradual recession of water leaving land permanently uncovered.

riparian: Of, on or pertaining to the banks of a stream, river or lake.

river basin: Land area drained by a river and its tributaries.

runoff: Rainfall or other precipitation that is not absorbed by the soil, but drains off the land into streams, rivers and other receiving waters.

saline: Waters containing salts or dissolved solids.

salinity: Grams per kilogram of dissolved salts in brine.

salt budget: Balance of salt in a system; where salt is in solution, deposited or removed from a system.

salt crust: Precipitated layer of salt on the bottom of a lake, depression or soil.

salt water intrusion: Saline groundwater entering into an area where fresh ground water has been depleted or withdrawn.

scoping: Early and open process for determining the scope of issues to be addressed and fore identifying the significant issues related to a proposed action.
Section 404: The *Clean Water Act*, Section 404 (b) (1) guidelines establish a refutable presumption that a nonwater dependent project does not need to be located in a wetland to fulfill its basic project purpose. To issue a permit, the COE must determine that impact to waters of the United States, including wetlands, have been avoided and minimized to the maximum extent practicable.

seiche: Large-scale oscillation of the surface of a land-locked body of water that varies in period from a few minutes to several hours; back and forth movements of water in a lake.

seismically: Formed by earthquake or earth vibration.

seral stage: Of or related to an ecological stage of development; each transitory community.

sewage: Waste and wastewater produced by residential and commercial sources and discharged into water.

siltation: Deposition of finely divided soil and rock particles upon the bottom of a stream, river, reservoir or lake.

sodium chloride: Salt

south arm: All of Great Salt Lake except the north arm. (In some cases the text of this plan distinguishes the south arm from Bear River Bay and Farmington Bay.)

sovereign lands: Lands lying below the ordinary high water mark of navigable bodies of water at the date of statehood and owned by the state by virtue of its sovereignty.

standard deviation: Statistical term describing the measure of the dispersion of a frequency distribution and how a probability or density function is centered around its mean.

streak: Aggregation of brine shrimp eggs, brine shrimp and biomass which can be observed on or near the lake's surface.

sub-basin: Drainage basin that is located within much larger drainage basin.

succession: Slow, regular sequence of changes in the regional development of communities of plants and associated animals, culminating in a climax characteristic of a specific geographical environment.

tailings: Residue or unusable material of the ore and an unavoidable and non-economic by-product of the extraction of economic minerals from ore.

taxonomy: System of naming and arranging animals and plants into related groups based on some factor common to each.

total maximum daily load: Total pollutant loading that a water body can assimilate while still maintaining its water quality classification and standards to avoid impairment of beneficial uses.

total dissolved solids: Total amount, in milligrams, of solid material dissolved in one liter or water. It is determined by weighing the solid residue after evaporation and heating to 180 degrees Celsius.

total suspended solids: Concentration of all substances suspended in water (solids remaining after filtering of a water sample).

tributary: Stream that joins another stream or body of water.

tri-linear plot: Three sided plot that uses percentages to depict composition. (Anion, cation and summary percentages are used in lake chemistry tri-linear plots.)

turbid: Water containing suspended matter that interferes with the passage of light through the water or which visual depth is restricted.

upland: High land located some distance from a body of water where there is a noticeable change in vegetation.

wastewater: Sewage, industrial waste or other liquid substances which might cause pollution of water.

water budget: Water balance in a system; the amount of water entering, exiting and existing a basin through inflow, groundwater, precipitation and other means and exiting via evaporation, diversions, etc.

water right: Right to use water occurring in a water supply and putting it to beneficial use.

watershed: Geographic area in which water, sediment and dissolved materials drain to a common outlet such as a point on a larger stream, a lake, an underlying aquifer and estuary or and ocean.

water table: The top of the saturated ground

weir: Device for determining and controlling the quantity of water released or flowing over it.

West Pond: Created on the west side of Great Salt Lake by the removal of water from GSL by the WDPP. Creation of the pond expands the surface area of the lake by approximately 26 percent.

wetland: Areas inundated or saturated by surface or groundwater at a frequency and duration to support and that, under normal circumstances, do support, a prevalence of vegetation typically adapted for life in saturated soil conditions; vegetative communities that exhibit wetland hydrology, hydric soils and hydrophytic vegetation.

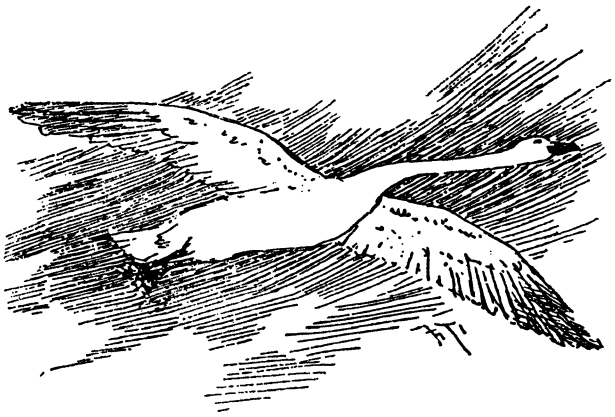
wind setup: Sustained winds blowing across the surface of a body of water which results in tilting of the water surface caused by the movement of water toward the downwind shore.

windrows: Quantity swept together by wind.

wing wall: Sides of a structure used to prevent sloughing of embankment material which prevent sediment obstruction or deposition.

Appendix G

Maps



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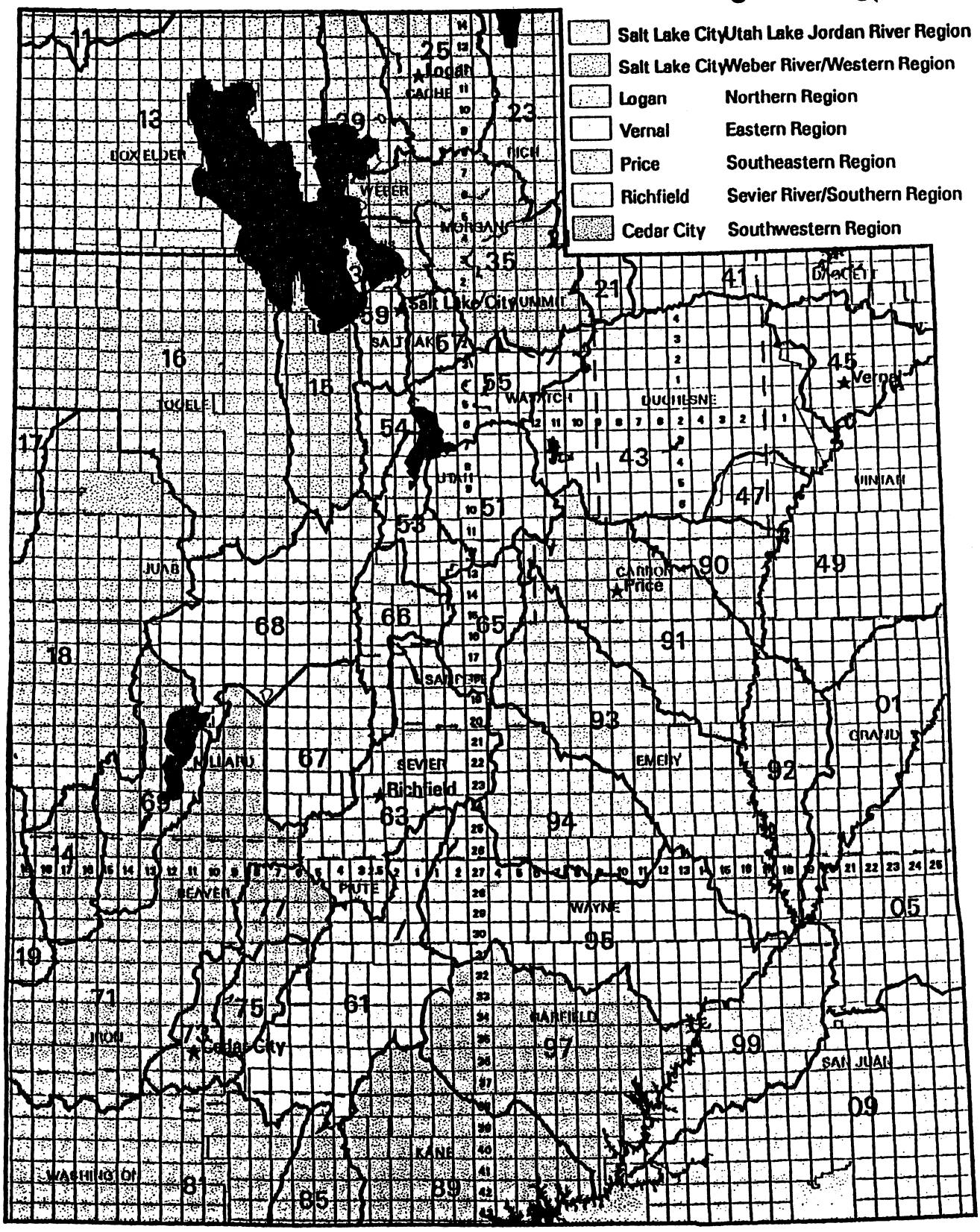
Map 1

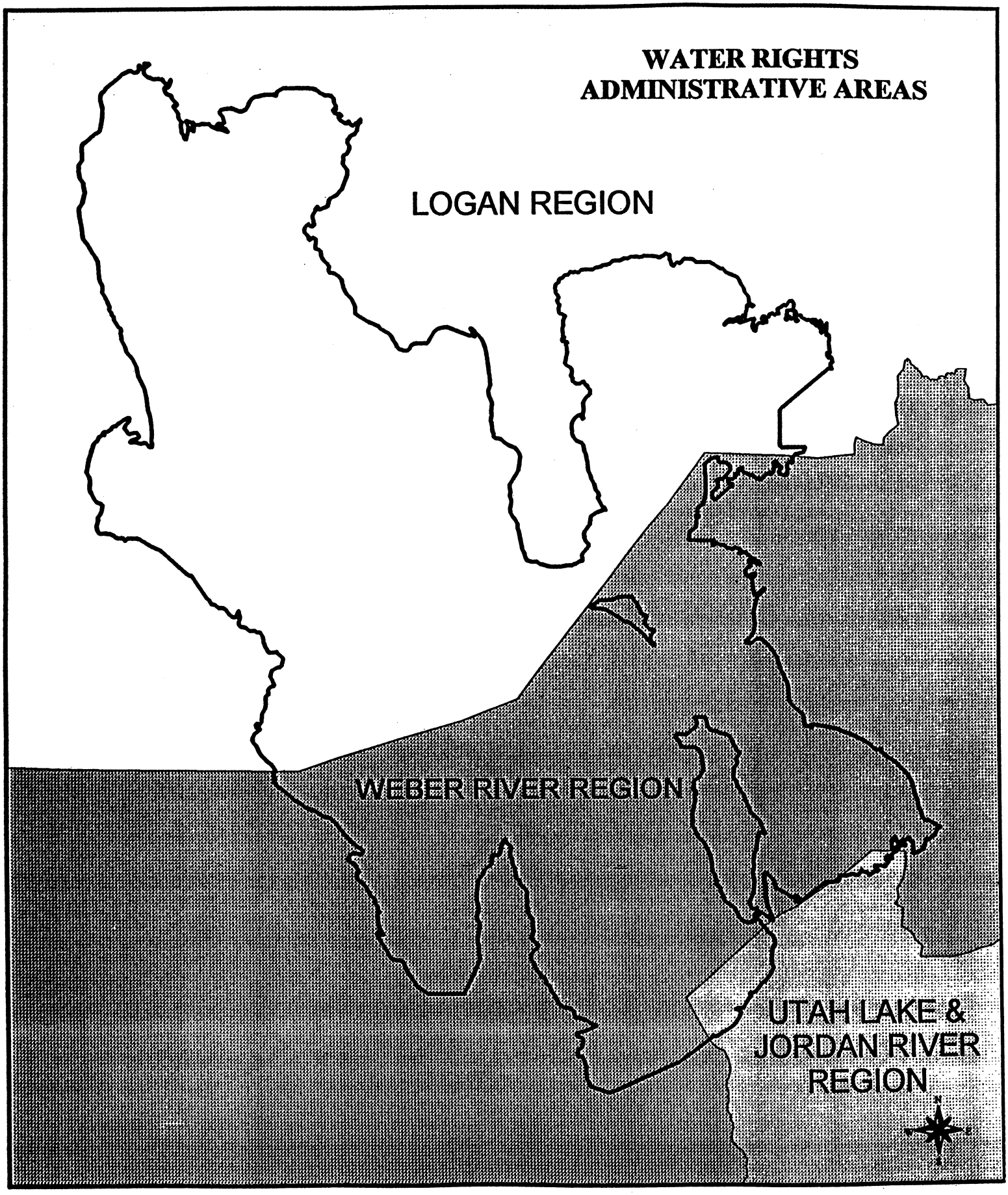
State of Utah
DEPARTMENT OF NATURAL RESOURCES

Water Rights Regions



Map 2

State of Utah
DEPARTMENT OF NATURAL RESOURCES

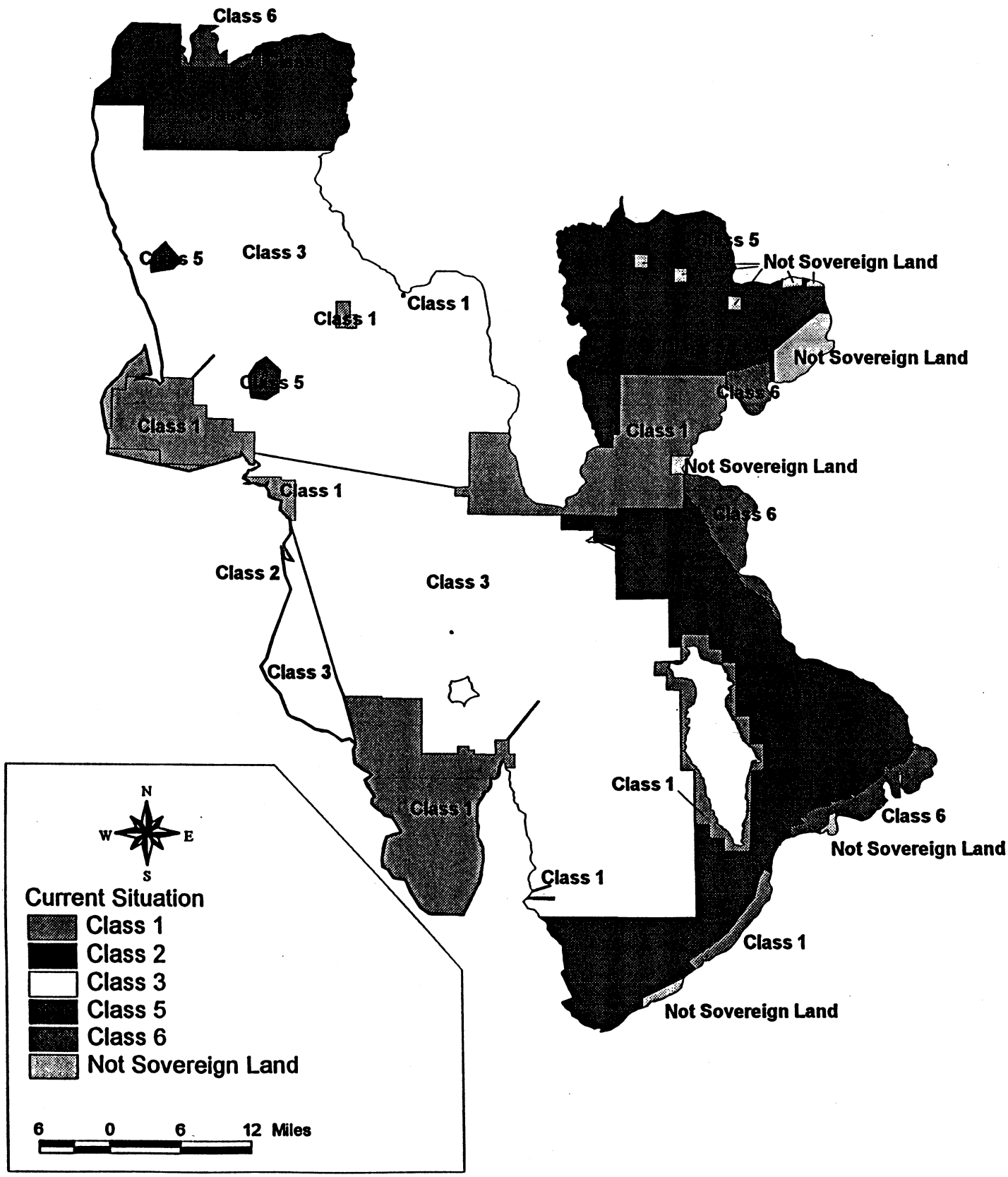


Map 3

State of Utah
DEPARTMENT OF NATURAL RESOURCES

SOVEREIGN LAND CLASSIFICATIONS

Current Situation

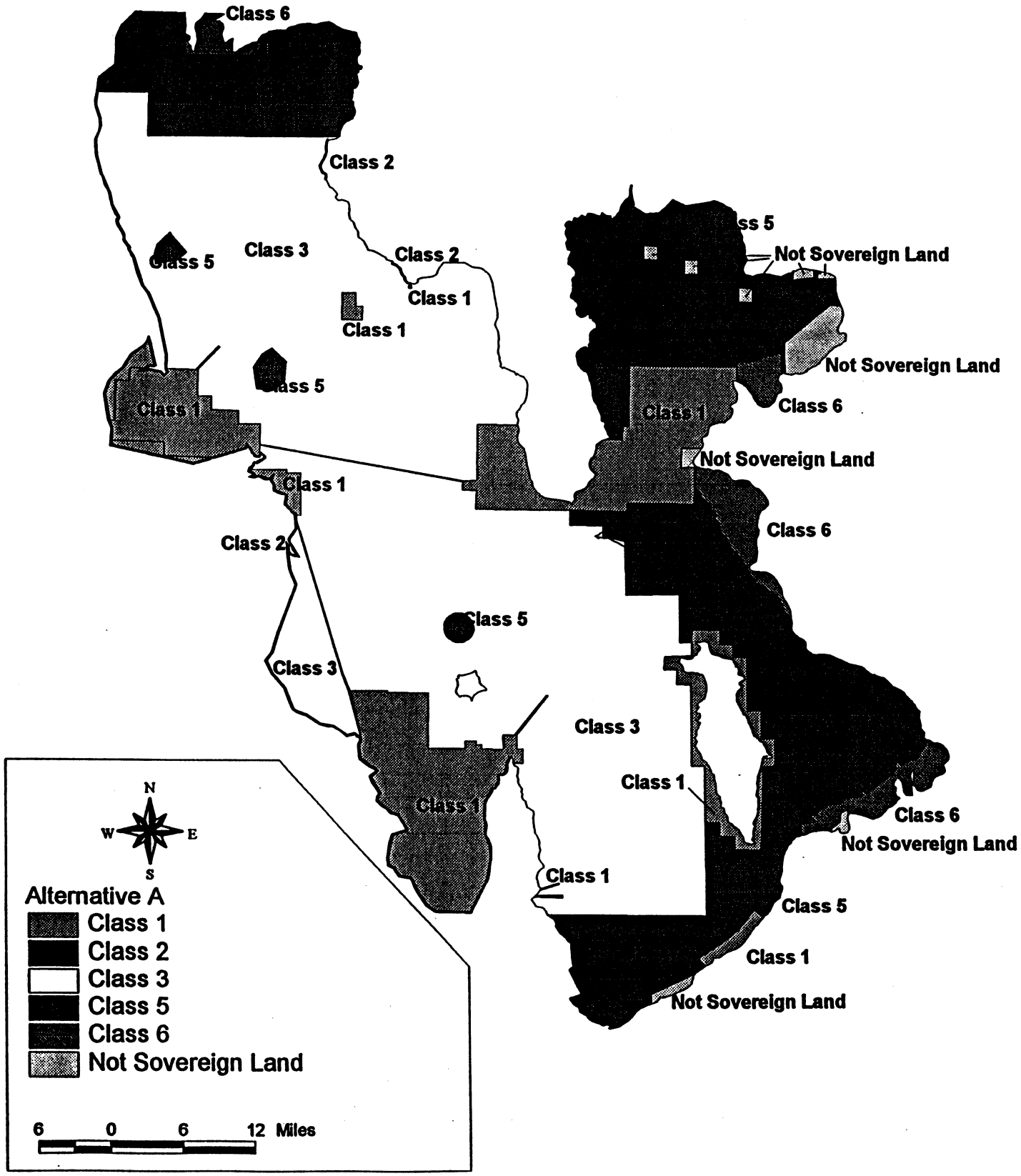


Map 4

State of Utah
DEPARTMENT OF NATURAL RESOURCES

SOVEREIGN LAND CLASSIFICATIONS

Alternative A

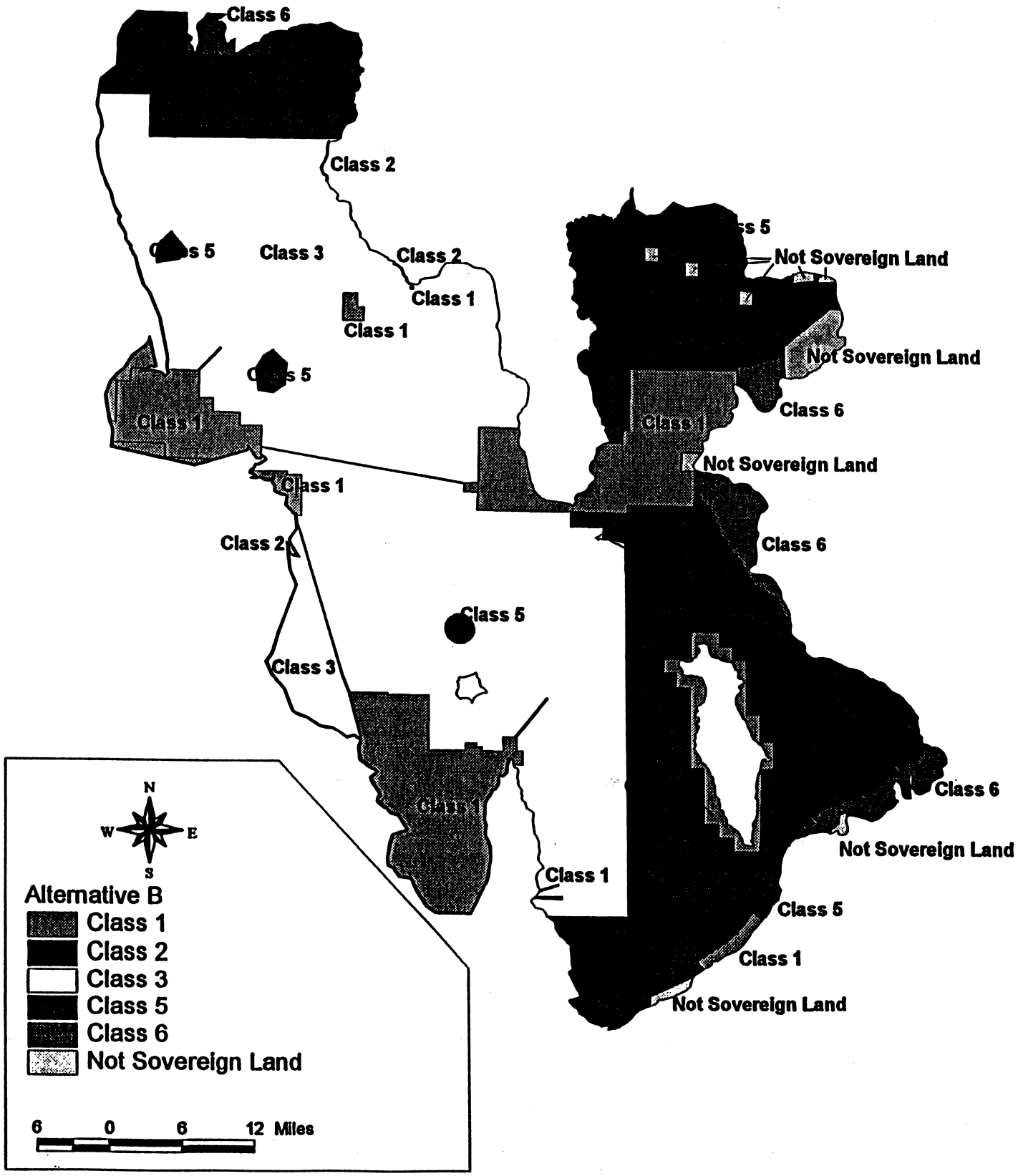


Map 5

State of Utah
DEPARTMENT OF NATURAL RESOURCES

SOVEREIGN LAND CLASSIFICATIONS

Alternative B

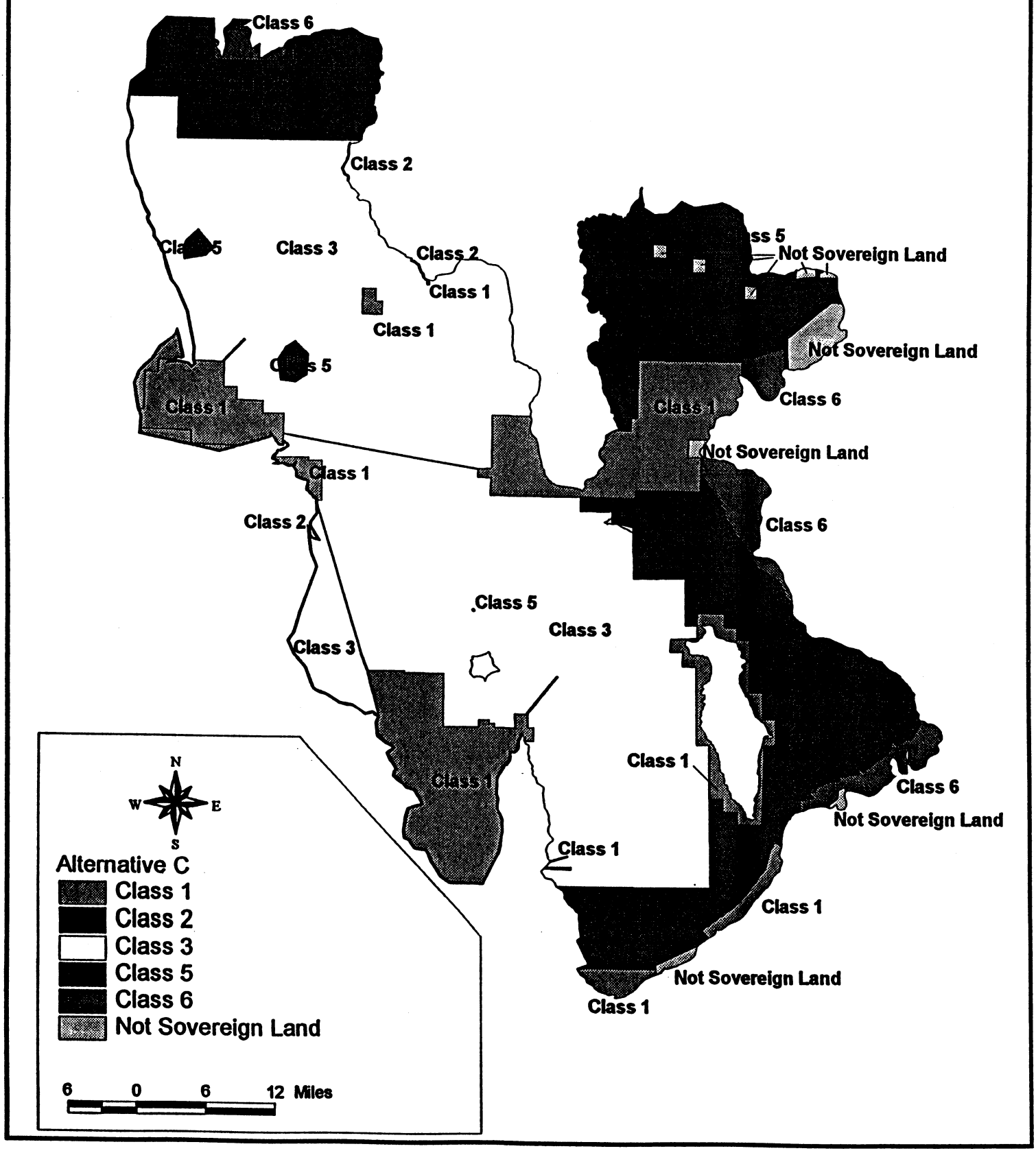


Map 6

State of Utah
DEPARTMENT OF NATURAL RESOURCES

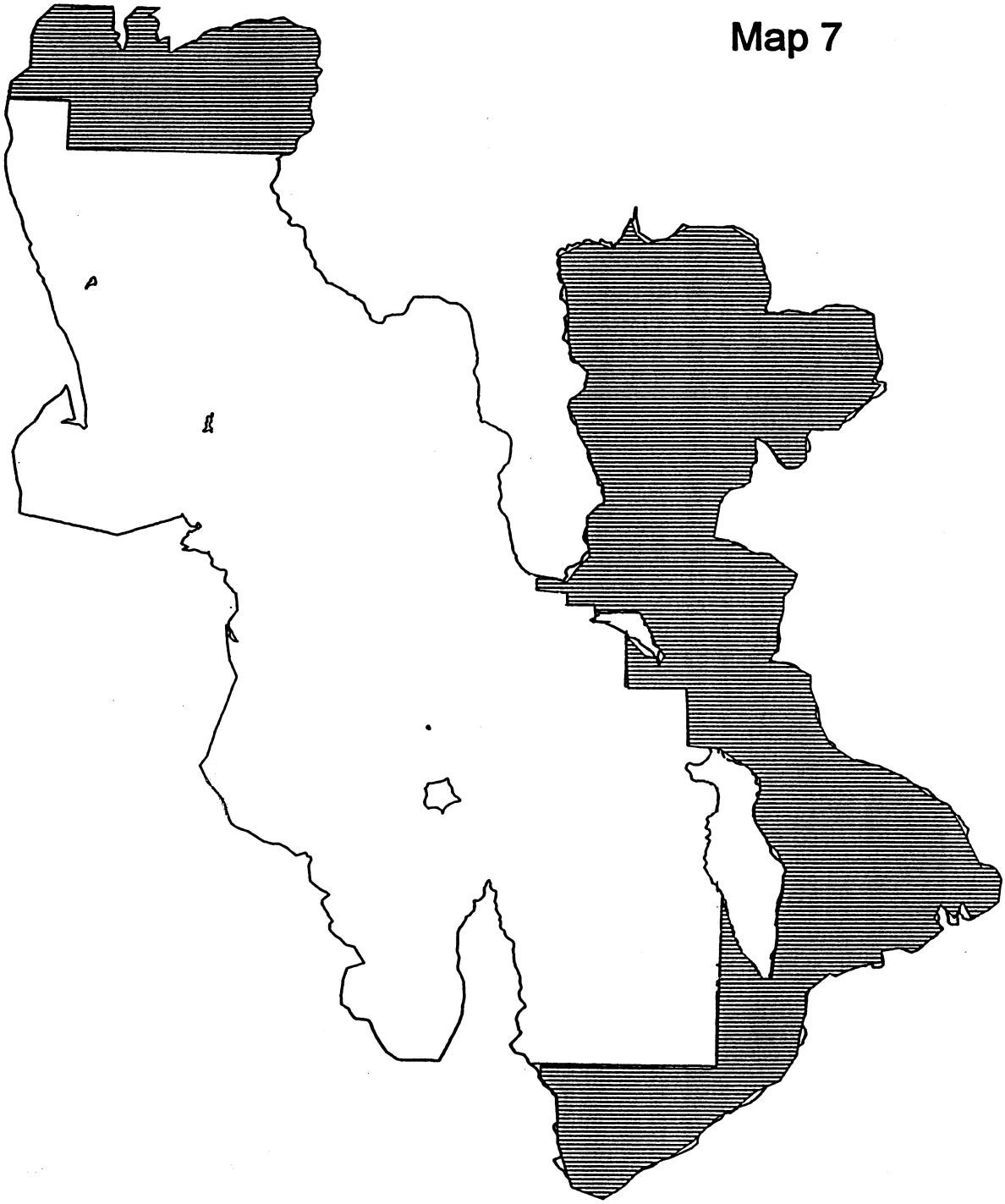
SOVEREIGN LAND CLASSIFICATIONS

Alternative C

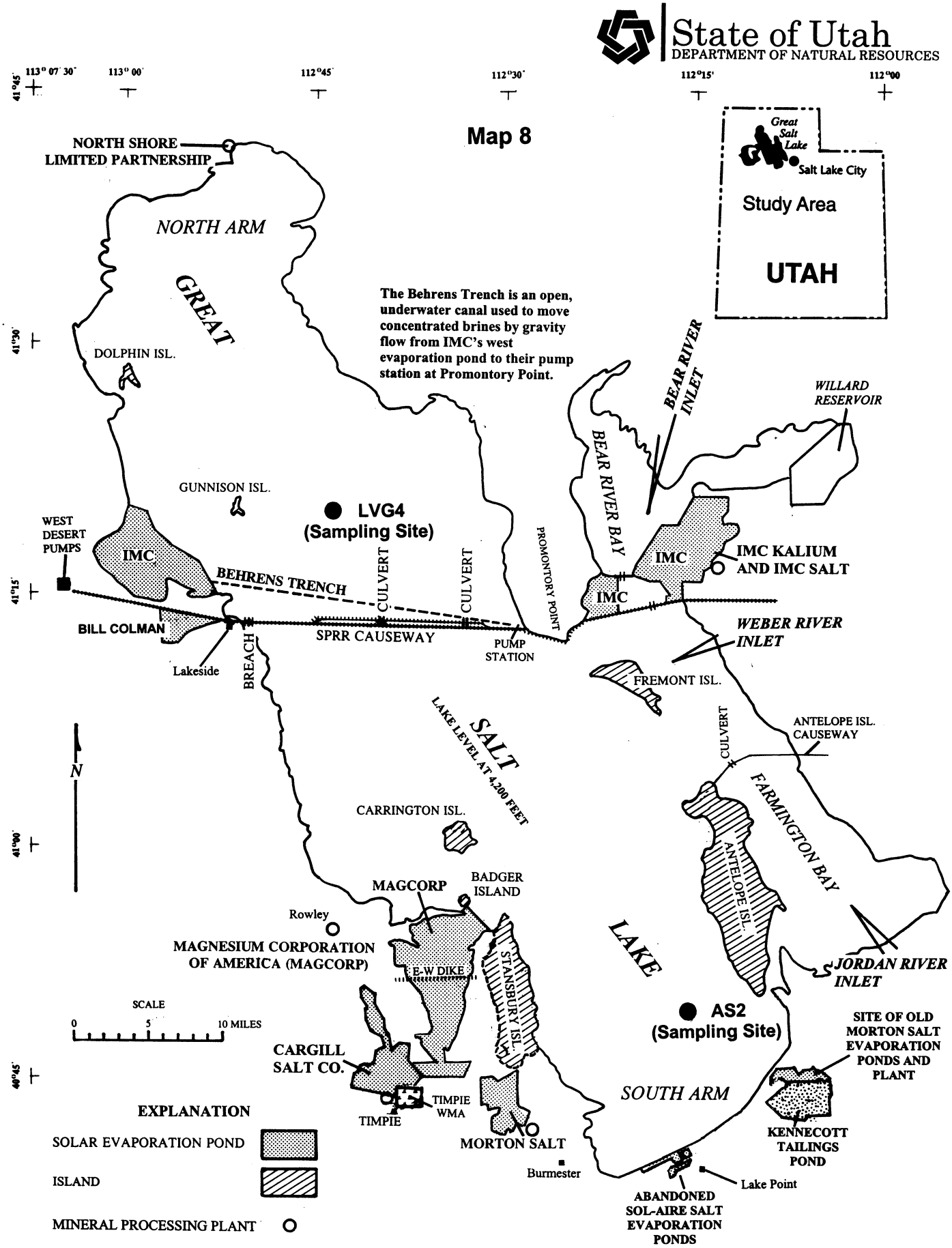


State of Utah
DEPARTMENT OF NATURAL RESOURCES

Map 7



Sovereign lands which the legislature has authorized the Division of Wildlife Resources to use for the creation, operation, maintenance and management of wildlife management areas, fishing waters and other recreational activities.



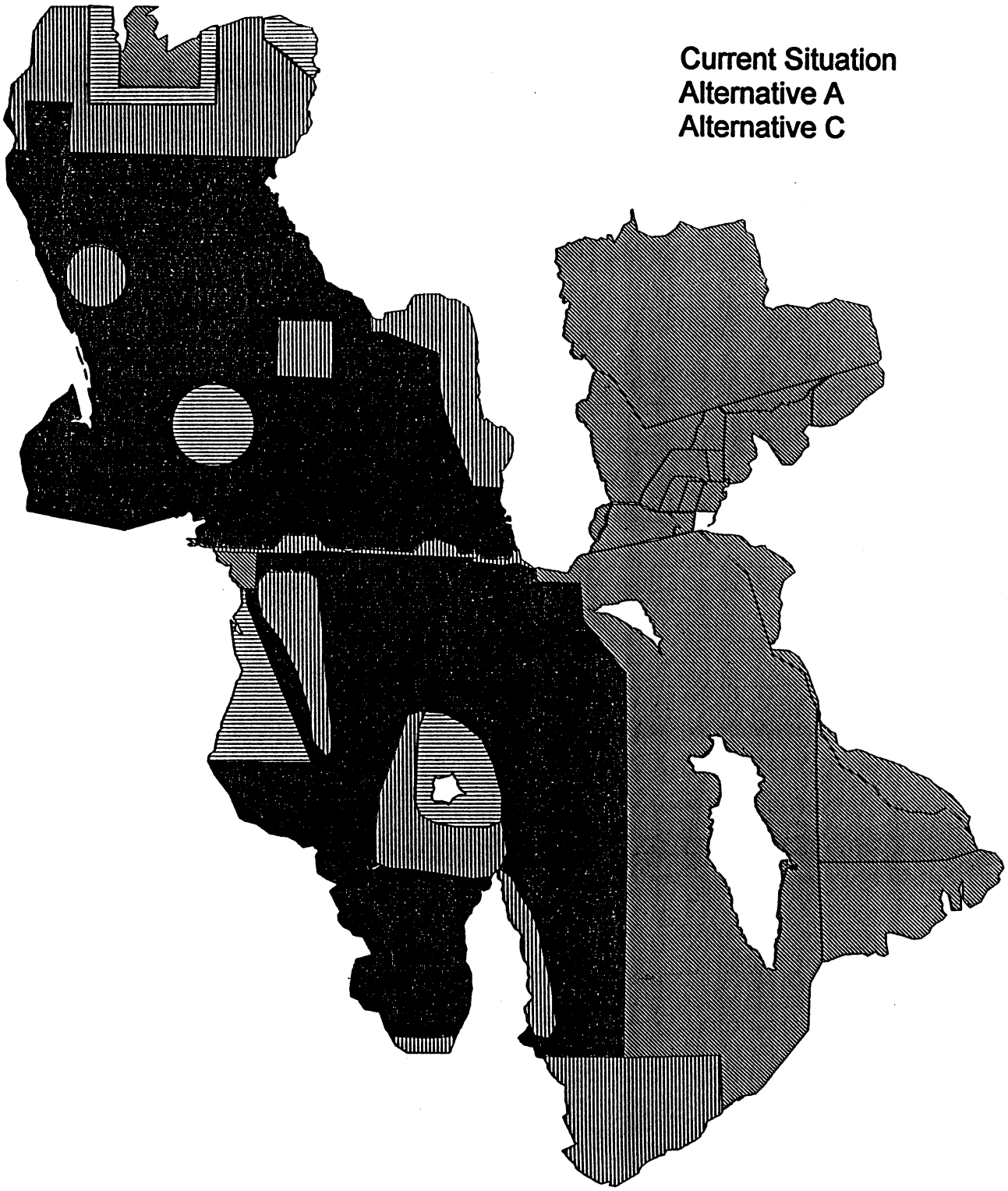
Locations of Great Salt Lake mineral-extraction industries, the SPRR causeway, the Behrens Trench, and brine-density and chemistry-measurement sites.

Map 9

State of Utah
DEPARTMENT OF NATURAL RESOURCES

Mineral Salts

Current Situation
Alternative A
Alternative C



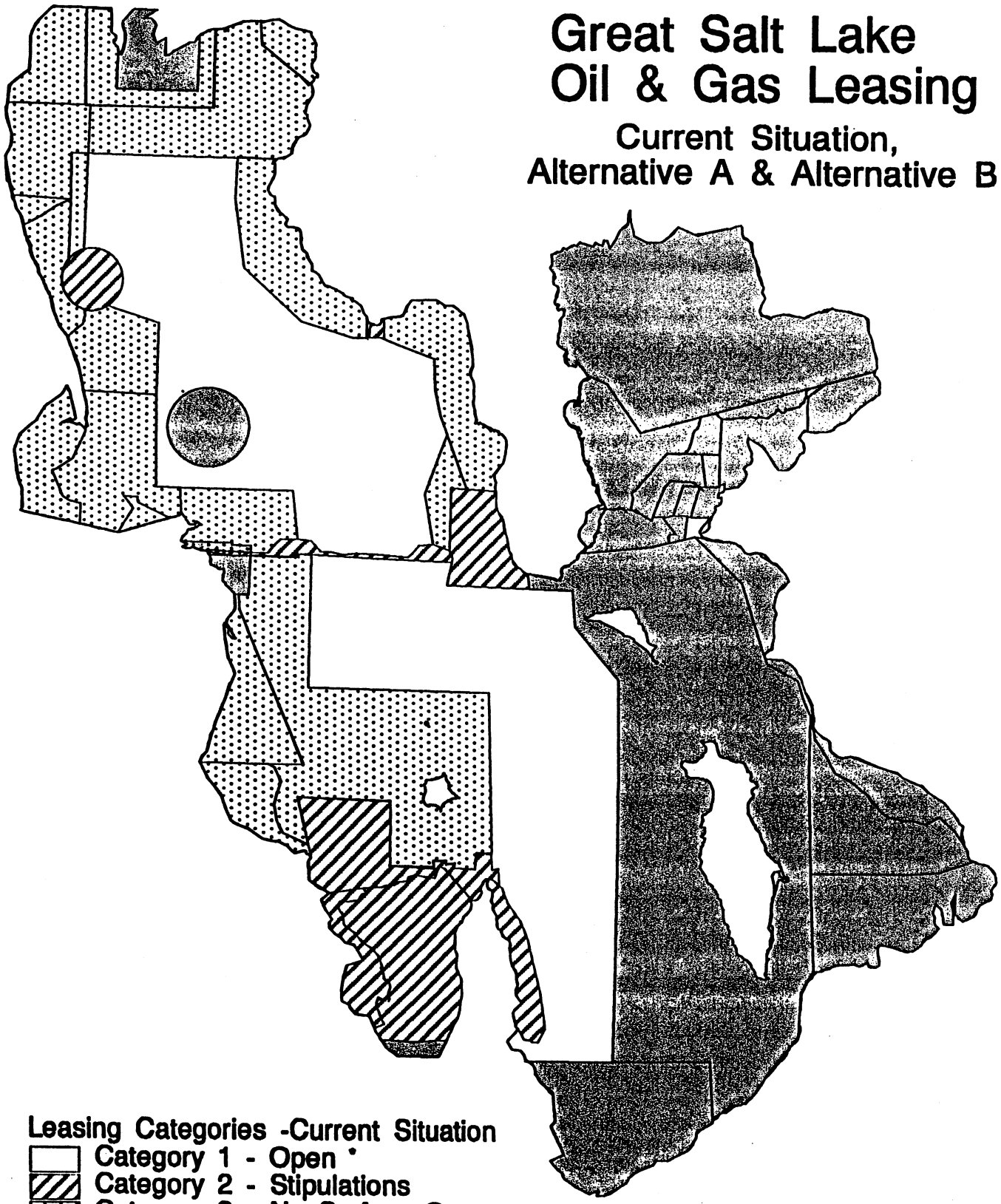
Leasing Categories
- Category 1 - Open
- Category 2 - Stipulations
- Category 3 - Brines Only
- Category 4 - No New Leasing

Map 10

State of Utah
DEPARTMENT OF NATURAL RESOURCES

Great Salt Lake Oil & Gas Leasing

Current Situation, Alternative A & Alternative B



Leasing Categories -Current Situation

- Category 1 - Open *
- Category 2 - Stipulations
- Category 3 - No Surface Occupa
- Category 4 - No New Leasing
- Meander Line

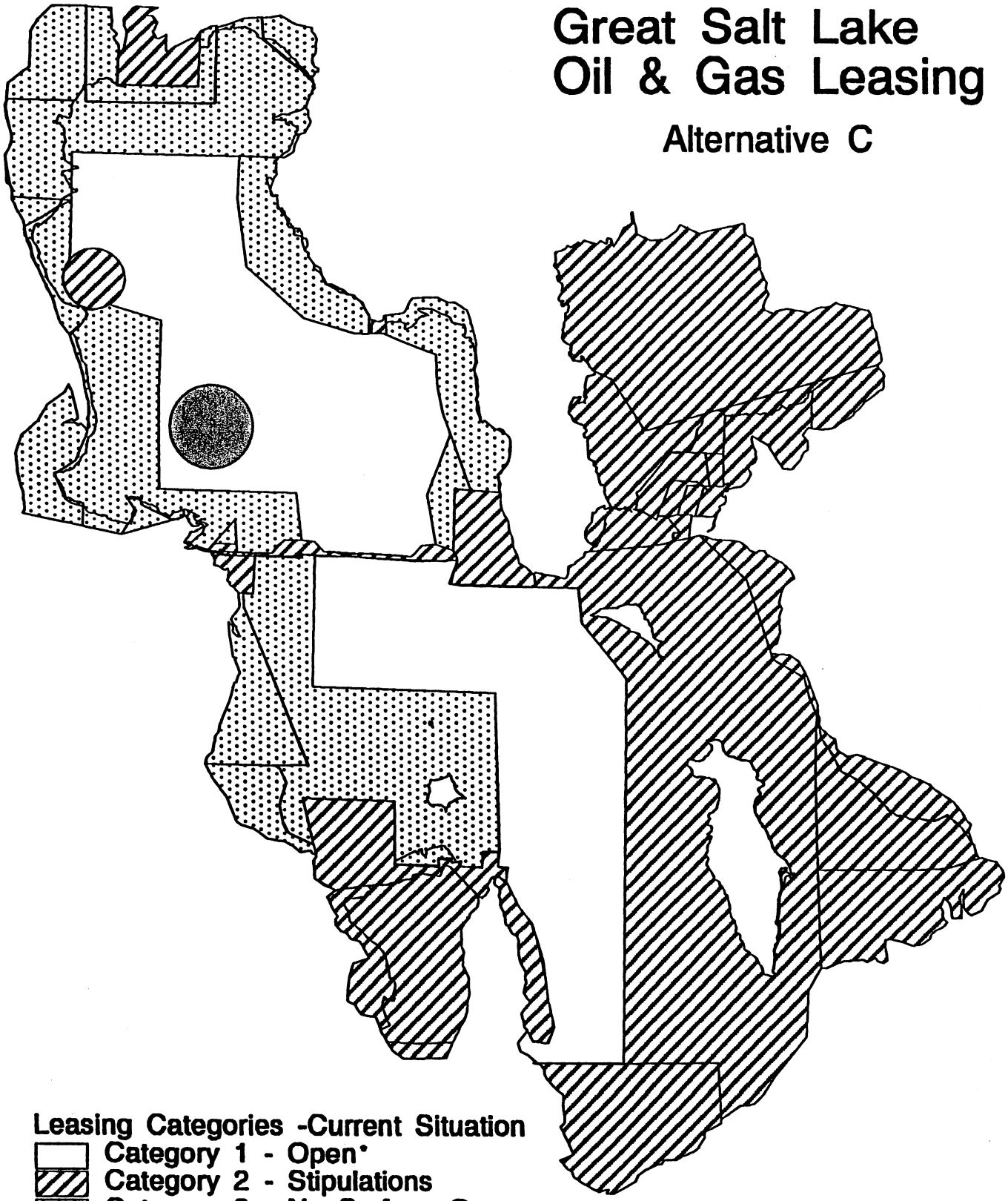
* Except Antelope Island and non-state lands

Map 11

State of Utah
DEPARTMENT OF NATURAL RESOURCES

Great Salt Lake Oil & Gas Leasing

Alternative C



Leasing Categories -Current Situation

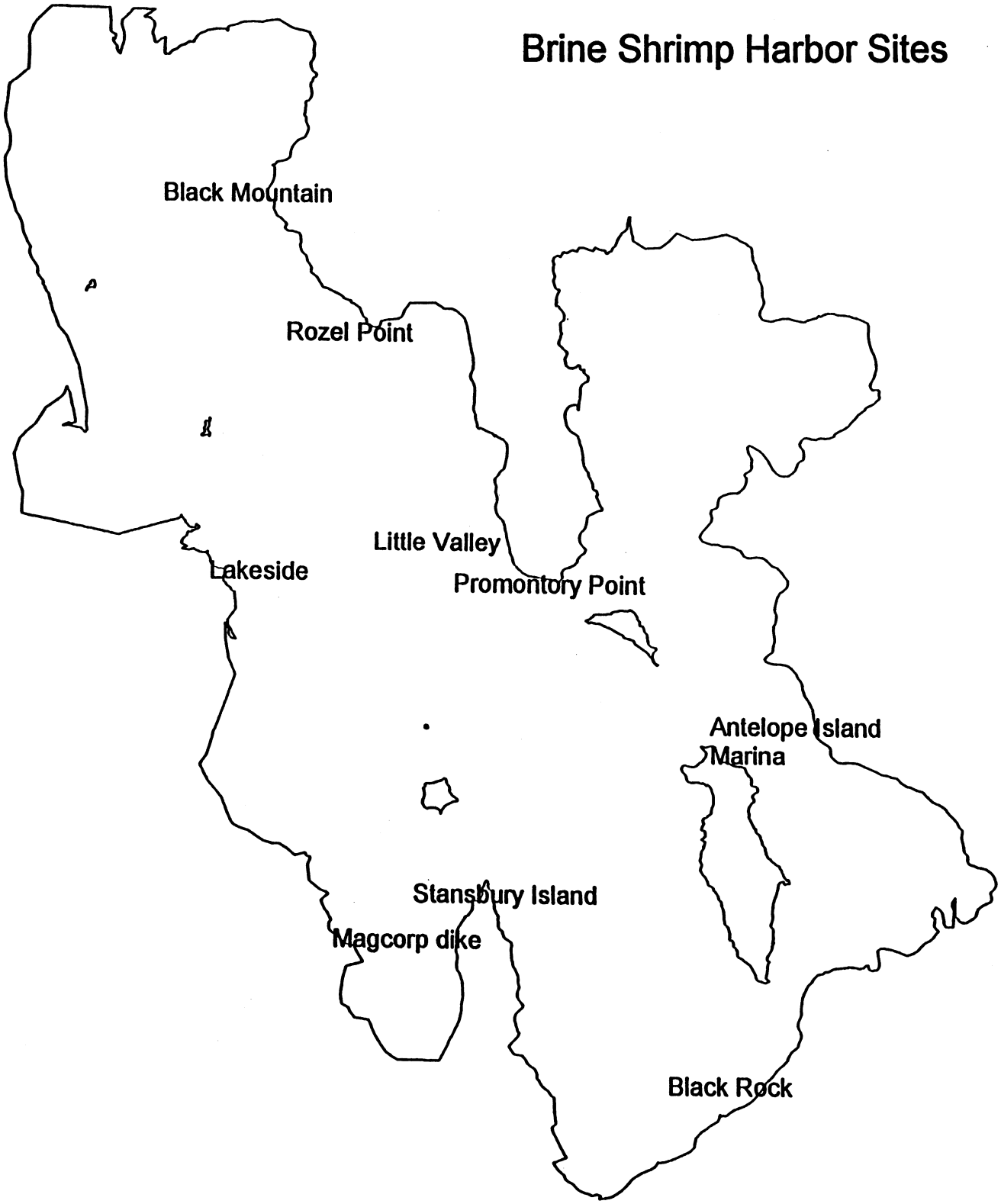
- Category 1 - Open*
- Category 2 - Stipulations
- Category 3 - No Surface Occupa
- Category 4 - No New Leasing
- Meander Line

* Except Antelope Island and non-state lands

Map 12

State of Utah
DEPARTMENT OF NATURAL RESOURCES

Brine Shrimp Harbor Sites



Notes:

Appendix H

Modeling Great Salt Lake Salinity

Modeling Great Salt Lake Salinity

by
Craig W. Miller, P.E., Norman E. Stauffer, Jr., Ph.D., and Kidd M. Waddell

USGS and DNR have have worked together for many years to help analyze and solve GSL problems involving flooding and salinity. USGS created a model to simulate the dynamic hydrologic and hydraulic processes of the GSL. The current version of the model will be fully described in a USGS report which accounts for the the mass balance of water and salt in the north arm and the south arm, flow through the causeway fill, culverts, and breach; and pumping to the West Pond. The latest version was calibrated for the period from 1987 to 1999 and produces results that agree with historical records.

The first model version created by the USGS for this purpose was documented by Waddell et. al. (1973). Schematics showing the general operation of the water and salt budget budgets calculated by the model are shown in figures 1 and 2.

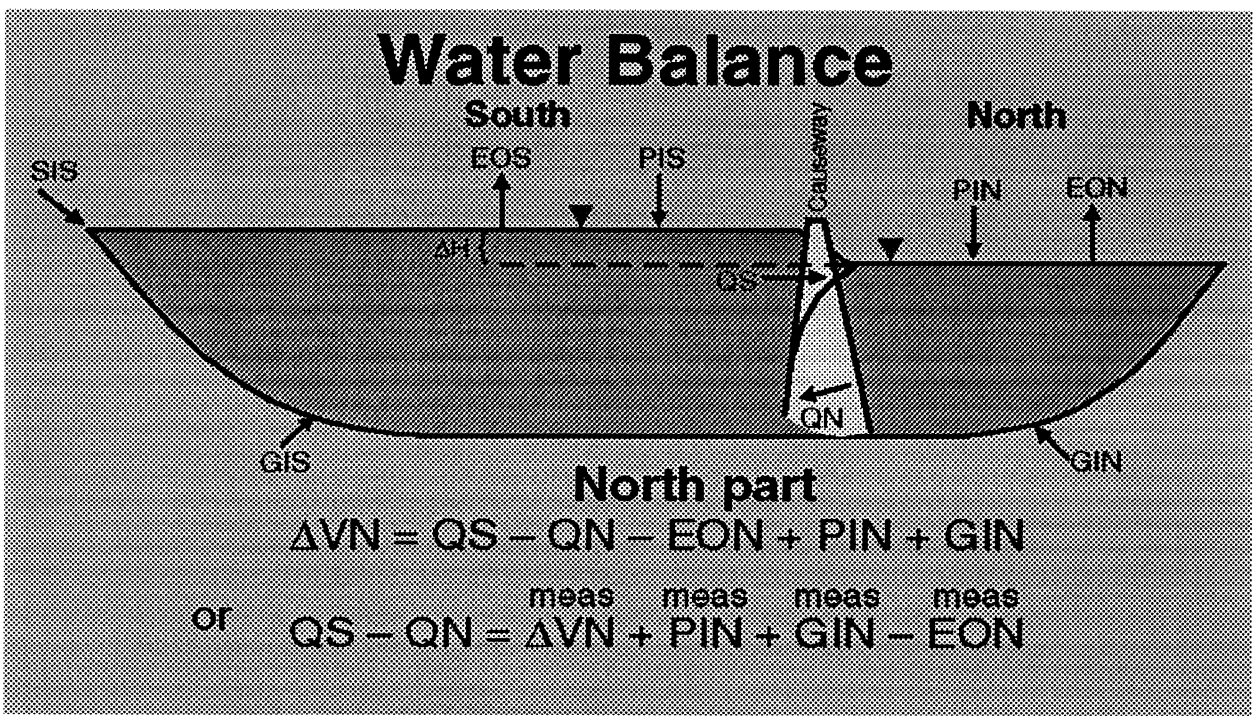


Figure 1. Great Salt Lake water balance.

Almost all surface inflows entering Great Salt Lake, SIS in the graphic above, flow directly into the south arm. Surface flow entering the north arm is mostly unmeasured and requires estimation. After surface inflow, the next largest source of water for the lake is precipitation, followed by groundwater flow. The model also considers lake precipitation and evaporation.

The original model considered the north and south arms of the lake as two well-mixed, separate bodies of water hydraulically connected by culverts and a permeable causeway fill. This first model assumed a deep, dense layer of brine on the bottom of the south arm, and a layer of salt precipitate in the north arm that could form or dissolve depending upon the salinity of the north arm. (See figure 2.) To simulate the flow through the causeway, the permeability of the fill was estimated with dye tests. A fill flow model developed by Pinder and Cooper (1970) was used to develop a matrix of flows for various head and density differentials across the causeway for estimation of north-south and south-north flows through the causeway fill. Flows through the culverts were estimated with a theoretical and empirical method. The model calibration period was conducted for two water years (1971 and 1972), and the calibrated model was then used to predict results from the 1965 to 1972 period.

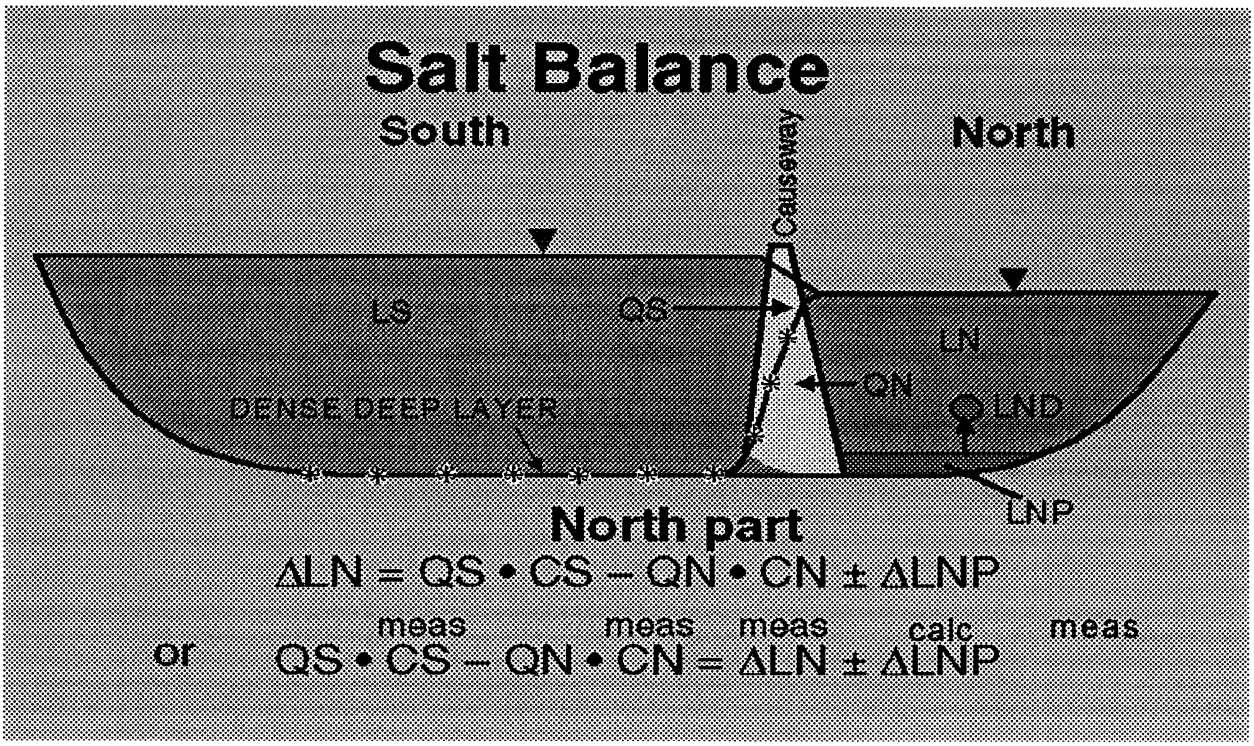


Figure 2. Great Salt Lake salt balance.

DWRe, Stauffer (1977), used the version described in Waddell, et. al. (1973) to design the causeway breach, finished in 1984. Thirty runs were analyzed for breach invert elevations of 4175, 4180, and 4195 feet. A graph of results for the selected elevation of 4195 feet is shown in figure 3. The breach was actually constructed with an invert elevation of about 4199.5 feet above mean sea level. Modifications have since reduced the invert elevation to approximately 4198 feet above mean sea level. Salinity levels of the south arm shown in the graph are higher than present lake salinity because of plugged culverts and lower causeway fill permeability.

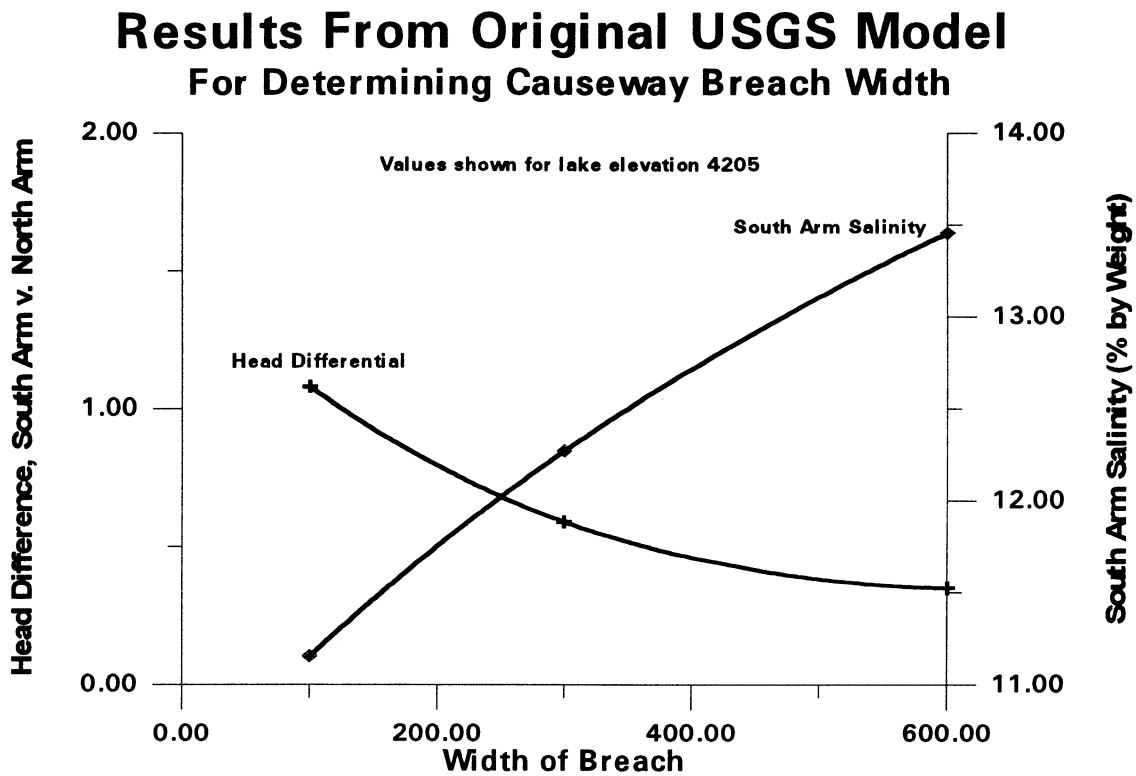


Figure 3. Results from original USGS model used to size the causeway breach.

Holley et. al. (1976) modified the model to solve for culvert flows using the equations of motion governing two layer flow. Critical flow at each end of the culvert is defined by the equation:

$$F_1^2 + F_2^2 - \varepsilon F_1^2 F_2^2 - 1 = 0 \quad \ldots\ldots (1)$$

where:

$$F_i = \frac{u_i}{\sqrt{\varepsilon g a_i}} \quad \ldots\ldots (2)$$

F = densimetric Froude number
i = layer number
u = velocity, flow divided by the cross-sectional area
g = gravity
a = layer thickness
ρ = fluid density

$$\varepsilon = \frac{\rho_2 - \rho_1}{\rho_2} \quad \ldots\ldots (3)$$

The model identifies the proper flow condition and adjusts Q_1, and upper layer thickness at the north end, a_{1N}, iteratively until boundary conditions are satisfied. In the following illustration , "H" refers to the depth of the north or south arm, "u" is velocity and "a" is the depth of the upper or lower layers for either the north or south, and "ρ" is the fluid density of either upper or lower layers. Entrance losses are distributed evenly along side walls and the bi-directional flow interface from upstream critical section to the downstream critical section. It was also assumed also that ρ_2 is greater than ρ_1 and that H_N is less than H_S. Holley, et. al. (1976) assumed a free upper water surface and did not consider submergence in his derivations

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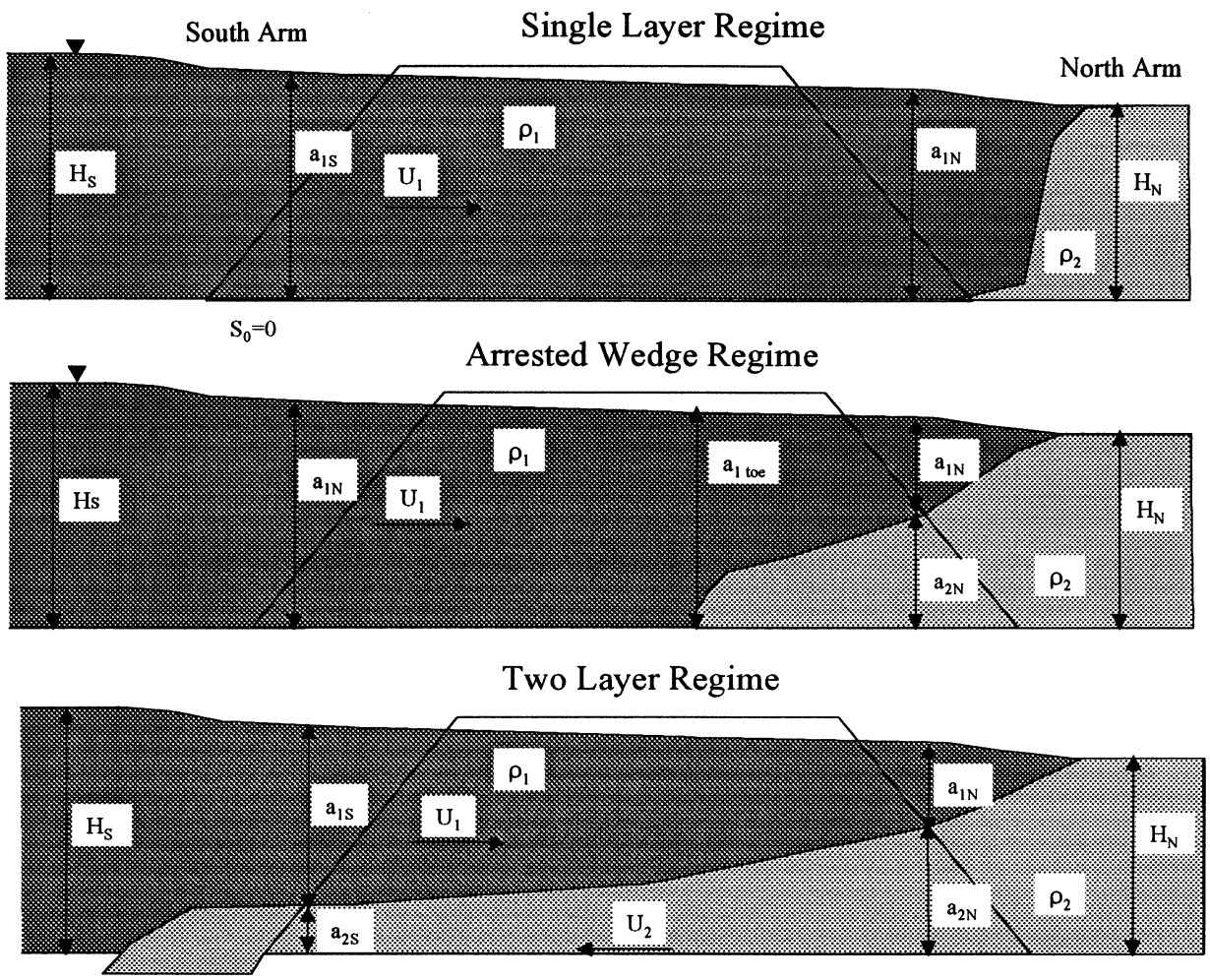


Figure 4. Flow regimes modeled with Holley, et al. (1976) revisions.

Wold, et. al. (1996), used the model modified by Holly and added a very wide and shallow culvert to simulate the 1984 causeway breach. The model was calibrated to simulate water movements during the period from 1980 to 1986. It was discovered that the fill flow for the period of calibration was about 40 percent with equivalent head and density difference in the previous calibration. To accommodate this difference calculated fill flows were multiplied by a constant to reduce them to equivalent present condition flows. As lake

levels increased the culverts were both submerged and wave action plugged them with .5 to 1.5 inch gravel. Since submergence and culvert plugging seemed to occur together, this was simulated by code in the model which set culvert flows to zero and bypassed culvert subroutines whenever submergence was predicted. Another change in GSL from 1986 to 1987 was the pumping of brines from the north arm of GSL to the Newfoundland Evaporation Basin for flood control. It was estimated that this pumping left a total of 600 million tons of salt in the Newfoundland Evaporation Basin, decreasing the total salt in GSL from 4.9 to 4.3 billion tons.

In the most recent study of GSL water and salt balance by USGS for the period from 1987 to 1999, it was discovered through model calibration that the causeway dike has tightened further to twenty percent of the 1973 study permeability. The more recently constructed portion of the dike above elevation 4200 feet is approximately 80 percent as permeable as the 1973 dike hydraulic conductivity values.

As a result of the plugging of the causeway culverts and tightening of the causeway fill, higher salinity north arm brines have not been able to adequately replenish the dissolved solids load of the south arm. Brine shrimp populations, which require a salinity range somewhere between 13-19 percent salinity to thrive, have plummeted and harvests of eggs have been disappointing. South arm salt industries are now seeing the lowest south arm salinity since the 1986-87 period when lake elevation reached record highs. The importance of the causeway culverts has become apparent since they were designed to return north arm brines to the south and now were plugged and inoperative. DWRe and USGS began to see the need of modeling free-flowing culverts to see if the answer to the lake's salinity problems could be found in keeping the culverts cleaned.

Studying the submerged culverts was difficult with the model modified by Holley, et. al. (1976) since it could only model flow regimes with a free upper surface. Dr. Edward Holly was again commissioned by USGS in 1998, this time to derive the equations governing submerged culvert flow. These newly derived equations were incorporated into water-salt balance model subroutines by Craig Miller of DWRe in 1999 and used to study the effect that the free-flowing submerged culverts might have on the salt balance of the lake.

Dr. Holly determined that the equation for critical flow under submerged conditions remained the same as equation (1) above. From the general equation for momentum and the boundary conditions of a submerged culvert, Dr. Holly derived the equations for the depth of the culvert versus distance along the barrel to be as follows:

$$\frac{dx}{da_1} = \frac{\phi}{\alpha + (1 - F_2^2)\left[\dfrac{\alpha + \beta - \phi\, dD/dx}{\kappa}\right]} \quad \ldots\ldots (4)$$

$$\frac{dx}{da_2} = \frac{\phi}{\beta - (1 - \varepsilon)F_1^2\left[\dfrac{\alpha + \beta - \phi\, dD/dx}{\kappa}\right]} \quad \ldots\ldots (5)$$

where:

$$\phi = F_1^2 + F_2^2 - \varepsilon F_1^2 F_2^2 - 1 \quad \ldots\ldots (7)$$

$$\alpha = \left(\frac{1}{\varepsilon} - F_2^2\right)T_1 - T_2/\varepsilon + F_2^2 S_0 \quad \ldots\ldots (8)$$

$$\beta = \left(1 - \frac{1}{\varepsilon}\right)T_1 + \left(\frac{1}{\varepsilon} - F_1^2\right)T_2 + (F_1^2 - 1)S_0 \quad \ldots\ldots (9)$$

$$T_1 = \frac{2a_1(E_1 + W_1) + B(2E_1 + I_1 + S_1)}{g\rho_1 a_1 B} \quad \ldots\ldots (10)$$

$$T_2 = \frac{2a_2(E_2 + W_2) + B(I_2 + Z + 2E_2)}{g\rho_2 a_2 B} \quad \ldots\ldots (11)$$

B = Culvert width
D = Culvert depth
E = Entrance losses expressed as a force per square foot
I = Interfacial losses expressed as a force per square foot
W = Wall losses expressed as a force per square foot
x = distance in the horizontal direction

With the submerged flow equations incorporated in the model, the additional flow regimes shown in figure 4 could now be analyzed. In previous studies submerged flow was approximated by assuming that the culverts had no top. It was believed that lower layer flows would not be significantly influenced by submergence and that upper layer flows would be inaccurate but small with respect to breach flows that would begin when submergence occurred. The model with the new subroutines indicated that when free-surface flows are calculated for an unconfined culvert that lower layer flows will be higher than would be predicted for submerged flows, but sometimes close enough to be within the accuracy of the method.

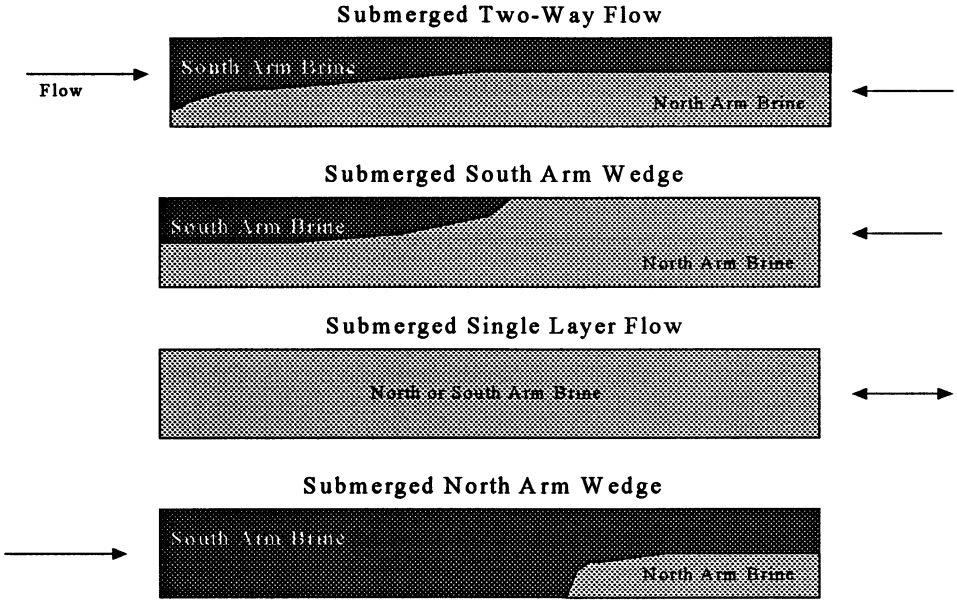
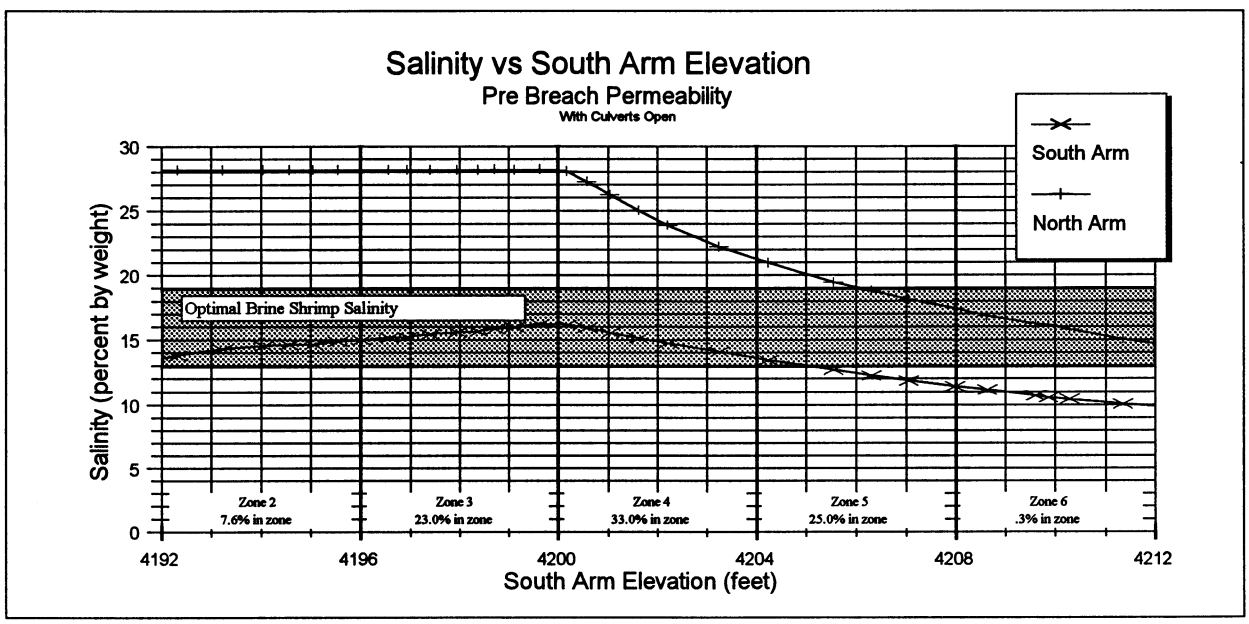


Figure 4. Submerged flow regimes.

The following chart shows model results for pre-breach causeway permeability and pre-1986 GSL salt loads. Salinity for GSL is charted against south arm lake elevation. Each point on the graph indicates equilibrium salinity for the lake with a constant inflow, precipitation and evaporation over a long period of time (30+ years).



Note: This model run assumes a pre-1986 salt load of 4.9 billion tons.

Figure 5. Pre-breach water-salt balance model simulation results.

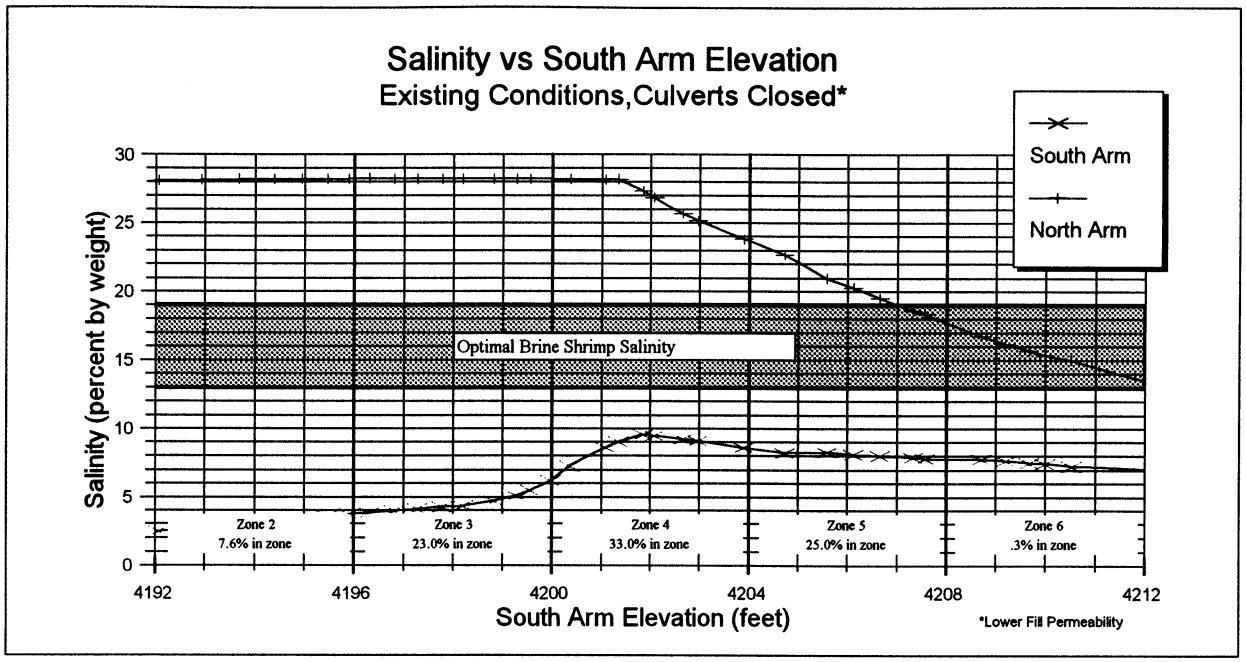


Figure 6. Water-salt balance model simulation results with present conditions.

Simulation results for present conditions show a very different picture. North arm salinity remains near saturation to south arm elevation 4201 feet while south arm salinity varies from about ocean salinity of three percent at an elevation of 4192 feet to a peak of nearly ten percent at 4202 feet. This simulation assumed that the culverts were completely plugged and that the salt load of the present lake is 600 million tons less than that for the simulation of figure 5. The causeway modeled in this run has about twenty percent of the permeability of the simulation in figure 5 for water level elevations 4200 and about eighty percent of the permeability above that point.

The model results tell us that while the culverts are significant to the salt balance of the lake, that they alone are not adequate to provide the circulation necessary for a properly functioning lake. Figure 7 shows the simulation of present conditions but with the culverts cleaned. Note that south arm salinity is somewhat higher, but never reaches the range that is typically associated with ideal brine shrimp production. The extreme freshening of the lake shown in figure 6 at lower lake elevations was not evident in this simulation.

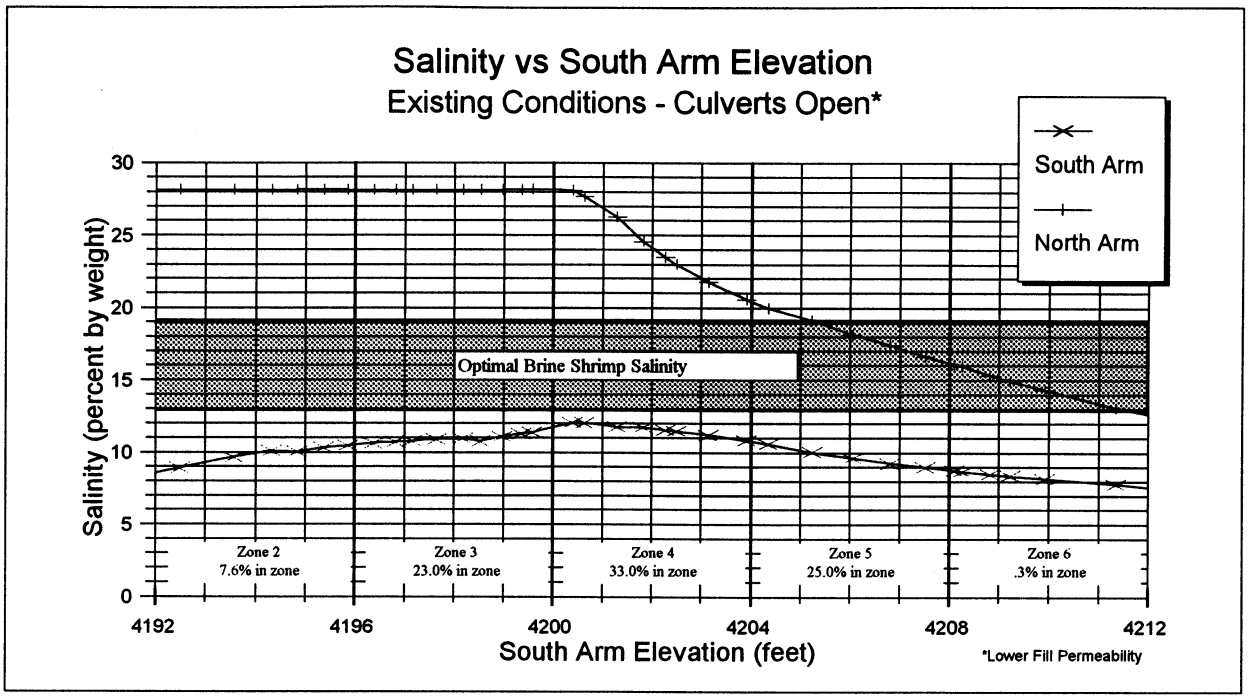


Figure 7. Existing conditions with culverts maintained in a free-flowing condition.

The model is now being used to create alternatives for solving the problem of salinity imbalance. For example, a new breach, 400 feet wide could produce the scenario shown in figure 8. This figure reveals salinity levels in the south arm close to what was experienced in the 1960s and 1970s allowing brine shrimp to flourish during periods of drought and flood.

In conclusion, tools such as the current GSL model can help us come closer to a fair and equitable solution for recent salinity imbalances. We believe it also help us analyze future issues as well.

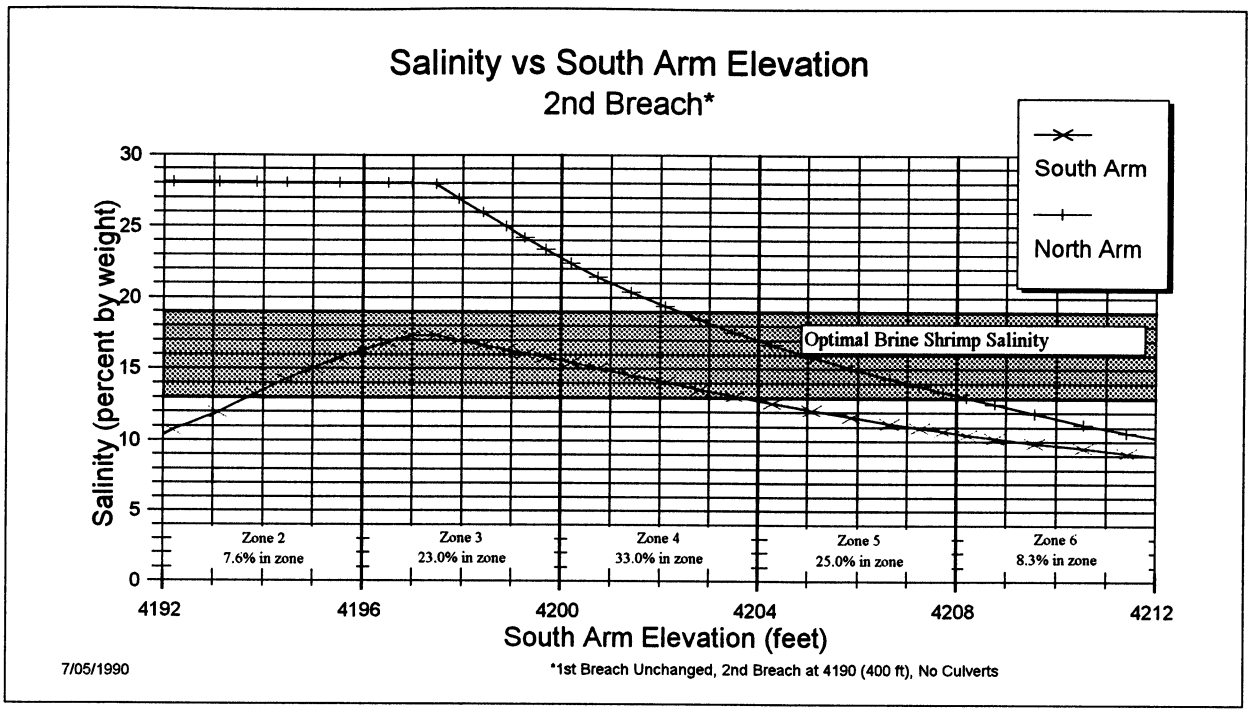


Figure 8. A new 400 foot wide breach with a bottom elevation of 4190 feet.

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Symbol Definition

a - Layer depth. First subscript refers to layer number, 1 or 2. Second subscript refers to critical depth for either the north or south end of the culvert.
B - Culvert width
CN - Salt concentration in north arm
CS - Salt concentration in south arm
D - Culvert depth
E - Entrance losses expressed as a force per square foot
EON - Evaporation from north arm
EOS - Evaporation from south arm
ϵ - $\frac{\rho_2 - \rho_2}{\rho_2}$
F - Densimetric Froude number or $\frac{u_i}{\sqrt{\varepsilon g a_i}}$
g - Gravity constant
GIN - Groundwater inflow to north arm
GIS - Groundwater inflow to south arm
H - Elevation head. Subscript S means south arm, N means north arm.
I - Interfacial losses expressed as a force per square foot
LN - Salt load in north arm
LS - Salt load in south arm
LND - Salt dissolution/precipitation in north arm
LNP - Precipitated salt load in north arm
ρ - Density. Subscript refers to layer number, 1 or 2.
PIN - Precipitation into north arm
PIS - Precipitation into south arm.
QN - Flow from the north arm to the south arm
QS - Flow from south arm to the north arm
SIS - Surface inflow to south arm
U,u - Velocity
VN - Volume for north arm
W - Wall losses expressed as a force per square foot
x - Distance in the horizontal direction

Notes:

Appendix I

Supplement to Salinity, Chemistry and Water Issues

Preliminary Draft - Subject to Revision

Supplement to Salinity, Chemistry, and Water Issues

by

J. Wallace Gwynn
Utah Geological Survey
September 23, 1999

INTRODUCTION

During the SRC's review of the GSL CMP-PD, questions were raised concerning the adequacy of the information contained in the sections on salinity, chemistry and other water issues. This draft appendix provide additional information on these topics.

ISSUES

Effect of the Breach

A 300-foot opening was breached in the western Rambo Fill portion of the SPRR causeway near Lakeside; it was opened on August 1, 1984. The purpose of the breach was to help reduce flooding on the south arm of the lake by reducing the head differential of nearly four feet that had developed between the south arm (higher elevation) and the north arm (lower elevation). The obvious effect of the breach was that within about two months, the head differential was reduced to less than a foot.

In addition to reducing the head differential, the breach allowed a major redistribution of the salinity and salt loads between the south and north arms. Large volumes of south-arm brine (lower salinity) flowed into the north arm as the head differential was reduced. South-to-north flow continued through the breach opening until the level of the south arm reached the breach-bottom elevation of 4195-4200 in about 1994. These large volumes of lower-salinity water helped to reduce the salinity of the higher-density north-arm brines (Gwynn and Sturm, 1987).

During the same period of time, higher-salinity north-arm brine moved through the depths of the breach opening, as return flow into the bottom of the south arm. This movement of north-arm brine, which ceased about December 1988, (1) further reduced the overall salinity (and salt load) of the north arm, and (2) increased the overall salinity (and salt load) of the south arm.

From 1988 until 1999, only south-to-north flow occurred through the breach opening (though there was little or no flow in either direction during the 1994 to 1997 period). North-to-south return flow resumed in 1999 (USGS breach-flow measurement records)

as the lake level increased, deepening the water in the breach, and as the head differential has been reduced.

Causeway Permeability

GSL brine can flow not only through the breach and culverts in the causeway but also through the porous crushed-rock fill of the causeway itself. The permeability of the SPRR causeway fill material is a major factor in determining the rate at which water moves either south-to-north or north-to-south through the causeway. This rate is also influenced by the head differential across the causeway, and to a lesser degree by the viscosities of the different saline waters. Under a given head differential, the greater the causeway permeability, the greater the rate of flow.

The causeway's permeability is controlled by the size and number of the interconnected openings within the fill material, and the length of the fill path the water has to travel. For a given interconnected opening size and number, the overall permeability near the narrow top of the causeway is greater than at the wide bottom.

Within a narrow lake-elevation range, and similar causeway-permeability conditions, the head differential across the causeway should be similar as the net inflow into the south arm is balanced by flow through the causeway. Somewhat higher head differential can be expected during a rising lake scenario than during stable- or dropping-lake conditions. If the permeability decreases under the given conditions, the head differential will increase to compensate for the change. The increase in head differential provides a greater south-to-north driving force.

It is believed that the permeability of the SPRR causeway was decreased during the 1980s high-water years as shown by a comparison of the two pre-breach head-differential groups and the post-breach group shown in figure A. The time periods of the three groups, plotted on a south-arm hydrograph are shown in figure B, and the head differentials between the south and north arms across the causeway, over time, are shown in figure C. Lake-elevation data used in figures A and B are USGS provisional lake-level data; south-arm data are corrected using Wold/Waddell corrections developed for the lake-salinity model.

Pre-Causeway Salinity Conditions

It is assumed that the entire lake was relatively well mixed vertically as well as laterally prior to the construction of the SPRR causeway as there is little or no evidence to the contrary based on north/south or top/bottom brine densities observed at the same time. Figure D shows the relationship between lake level and wt% salt in the brine from about 1850 to about 1965, or just after the construction of the SPRR causeway. Data for the pre-causeway plot came from a number of early publications. For comparisons, the lake level-wt% salt in brine plots for the post-causeway south and north arms of the lake are also given for the 1966 to 1987 period of time. Data for the south and north-arm data are from UGS GSL brine chemistry database.

Salt-Load Balance Through Time

South- and north-arm salt-load data obtained from the USGS, prepared for their salt balance model (in progress), are presented in figures E and F for the south- and north-arms of GSL over the 1963-1998 time period. 10th-degree polynomial fit lines are drawn through the data points just to illustrate the general trends of the data, and notations are given to explain the rise and fall of the salt loads in each arm. As of the end of 1998, it can be seen that the south arm of the lake is declining in its dissolved salt load while the north arm is increasing. More complete information, including the total salt load over time, and the amounts of precipitated salt can be obtained from the USGS and from Appendix H.

Lake "Hysteresis"

The term hysteresis has been used to explain the northward movement of dissolved salts through the SPRR causeway during rising lake conditions, and the reverse or southward movement of salts during declining lake conditions. From the time of the causeway's construction in 1959-1960, this principle was apparently operating as can be seen by the long, solid, upper lines on both figures G and H. This concept is supported, as the south and north-arm lake levels have increased and declined throughout this time period, they have not deviated greatly from these paths. With the breaching of the causeway and the additional of more fill to increase the height of the causeway during the lake's 1980s high water years, however, the causeway's long-standing physical parameters have changed. Most notable are the free flow of brine through the breach opening above an elevation of about 4199.5 to 4200 feet, and an apparent reduction in the permeability of the causeway fill below the breach-bottom elevation. Graphical evidence for the reduction in the causeway's permeability is given in figure A, and the associated discussion.

With the breaching of the causeway in 1984, there was a significant redistribution of the dissolved salt loads between the south and north arms of the lake (Gwynn and Sturm, 1987) and a dramatic departure from the pre-breach "hysteresis patterns in the two arms of the lake, as seen in figures G and H. In the south arm, starting in 1987, the salinity first increased above the 1966-1987 path, due to influx of north-arm return-flow brine through the breach opening, and then from about 1989 to late 1994, a reduction in its salinity below the 1966-1987 path. This reduction in salinity was brought about by a net loss of salt to the north arm due to nearly-exclusive south-to-north flow. From late 1994 to the present there has been a continued net loss of salt from the south arm to the north arm (figures E and F) as south-to-north flows through the breach opening have increased due to rising lake levels, and little or no north-arm return flow until 1999.

In the north arm, starting with the breaching of the causeway in 1984, the salinity was initially greatly reduced by the large influx of dilute south-arm brine. This occurred as the head differential across the causeway was reduced. Even during the rapid decline in lake level from 1987 to 1995, the path of the north arm was below the 1966-1987 path due to the continued influx of south-arm brine until 1994-95. The north-arm's path during this time period was well below the 1966-1987 path. Through the 1994-1997

low (figure B), there was greatly reduced south-to-north flow, and the north-arm salinity was increasing due to evaporation. Thus, the overall 1995 to 1998 path is still below that of the 1966-1987 path.

For both the south and north arms (figures G and H) the change in wt% salt per foot of elevation change is shown adjacent to a dashed line which approximates the slope of the different paths within the 4198 to 4202 elevation range. For the south arm (figure G), curve "a", representing the 1966-1987 path of the lake, changes at the rate of about 0.77 wt%/foot of elevation change. Curves "b" and "c", with values of 1.22 wt%/ft., and 1.2 wt%/ft., respectively, both show a greater change in the lake's wt%/ft of elevation change. This increase is due to the south-arms increase in overall salinity brought about by the large influx of dense, north-arm brine when the breach was opened in 1984.

For the north arm (figure H), curve "a" represents the 1966-1987 path of the lake, and changes at the rate of about 0.47 wt%/ft of elevation change. Curve "b", with a value of 0.93 wt%/ft of elevation change, represents the lake between 1987 and 1995, as it was dropping rapidly, and being diluted by south-arm brines after the causeway was breached. It also represents the loss of high-salinity brines to the south through return flow through the end of 1998. Curve "c", with a value of 0.38 wt%/ft of elevation change, represents the lake's path from 1995 into 1999. This time period represents a gain of salt through nearly-exclusive south-to-north flow of south-arm brine through the breach opening until 1999 when north-to-south return flow was again observed.

South-Arm Deep Brine Layer

Stratified-brine conditions in GS: (where a low-density brine overlies a brine of greater density) were first observed in the south arm during the early 1960s (Hahl and Handy, 1969, and UGS brine data files). These conditions were observed until mid-1991, near the end of the high-water period, at which time the lake became vertically mixed. During 1999, the lake appears to be showing signs of restratification.

Published (Hahl and Handy, 1969, Mason, 1970, Spencer and others, 1985, and Whelan, 1973) discuss a possibly significant difference in the chemistries of the pre-1991 north arm of GSL, and the deep-brine layer in the south arm. The brines in the main southern body of the south arm and in the northwest portion of the south arm are separated by a low topographic ridge on the lake's bottom between Promontory Point and Carrington Island.

Tri-linear plots using chemical data from Hahl and Handy (1969), the Utah Department of Health, and the UGS were used to evaluate and compare the chemistries of the north-arm brines, and brines from the two areas in the south arm. Brines analyses from the 1960s suggest that there was a change from lower sodium-chloride north-arm brines to higher sodium-chloride main-body south arm brines (as end members) as precipitated salt was dissolved. Brines in the northwest portion of the south arm had an intermediate sodium-chloride content (on a dry-weight-percent basis). Tri-linear plots of more recent brines (1978 to 1984 Department of Health data, and pre-1991 UGS data) from the

three parts of the lake suggest that there has been a homogenization of the lake's chemistry, though salinity differences still exist between the south and north arms.

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FIGURE CAPTIONS

Figure A. Plot of head differential versus time-in-years showing two pre-breach head-differential groups and one post-breach group which illustrate possible changes in the permeability of the SPRR causeway.

Figure B. Hydrograph of south arm of GSL showing breach-bottom elevation range, and elevation range and time periods of head differential comparisons.

Figure C. Head differentials measured between south and north arms of GSL from 1966 to 1999.

Figure D. Pre-causeway (entire lake) and north and south-arm post causeway lake-level versus Wt.% salt-in-brine plots.

Figure E. Plot of south-arm salt load versus time in years, with polynomial-fit line to illustrate general trends.

Figure F. Plot of north-arm salt load versus time in years, with polynomial-fit line to illustrate general trends.

Figure G. Plot of south arm elevation versus Wt.% total dissolved solids in brine, broken into 1966-1987, 1987-1995, and 1995-1999 time periods to show the different paths the lake has taken during these time periods.

Figure H. Plot of north arm elevation versus Wt.% total dissolved solids in brine, broken into 1966-1987, 1987-1995, and 1995-1999 time periods to show the different paths the lake has taken during these time periods.

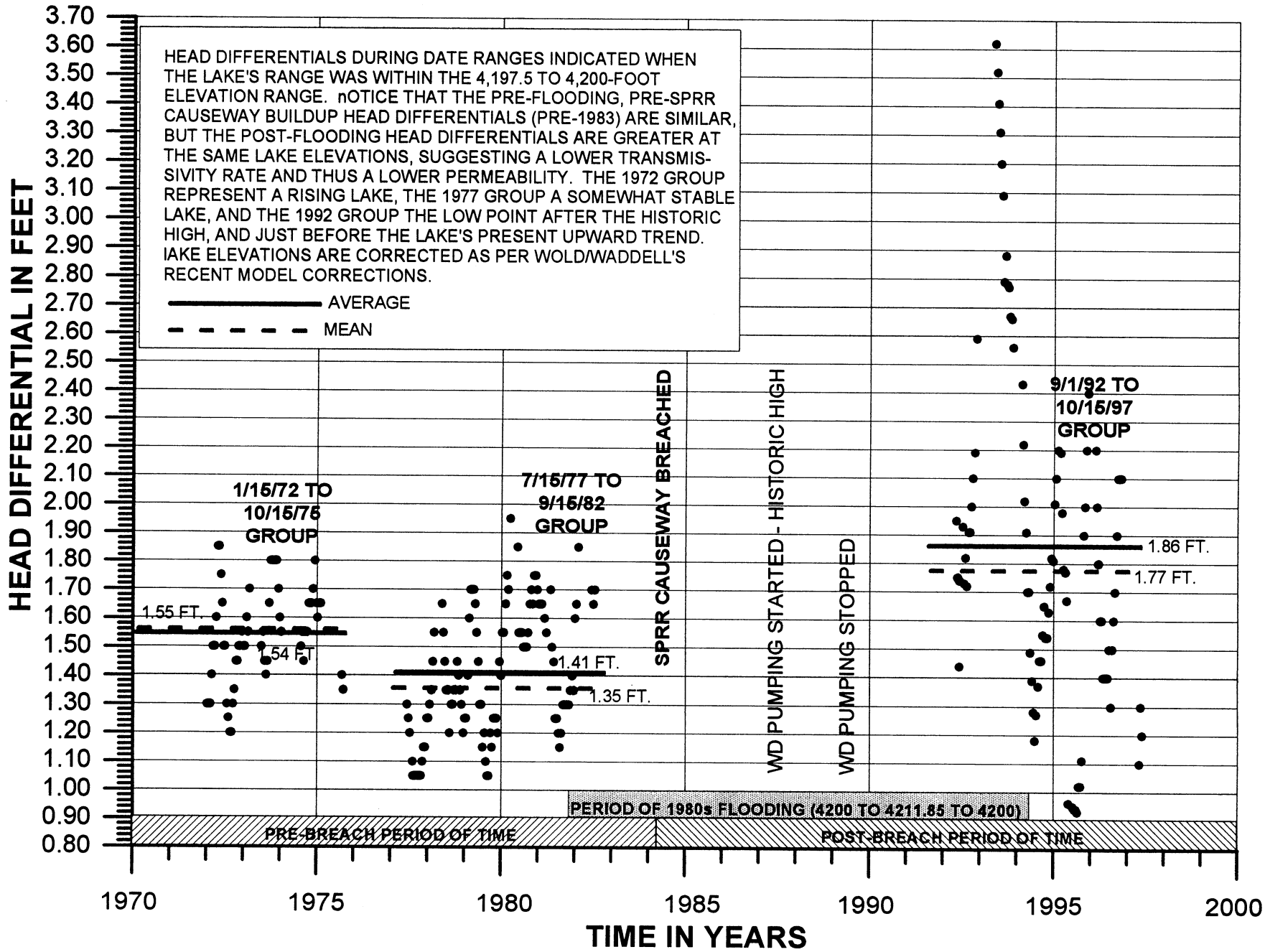


Figure A. Plot of head differential versus time-in-years showing two pre-breach head-differential groups and one post-breach group which illustrate possible changes in the permeability of the SPRR causeway.

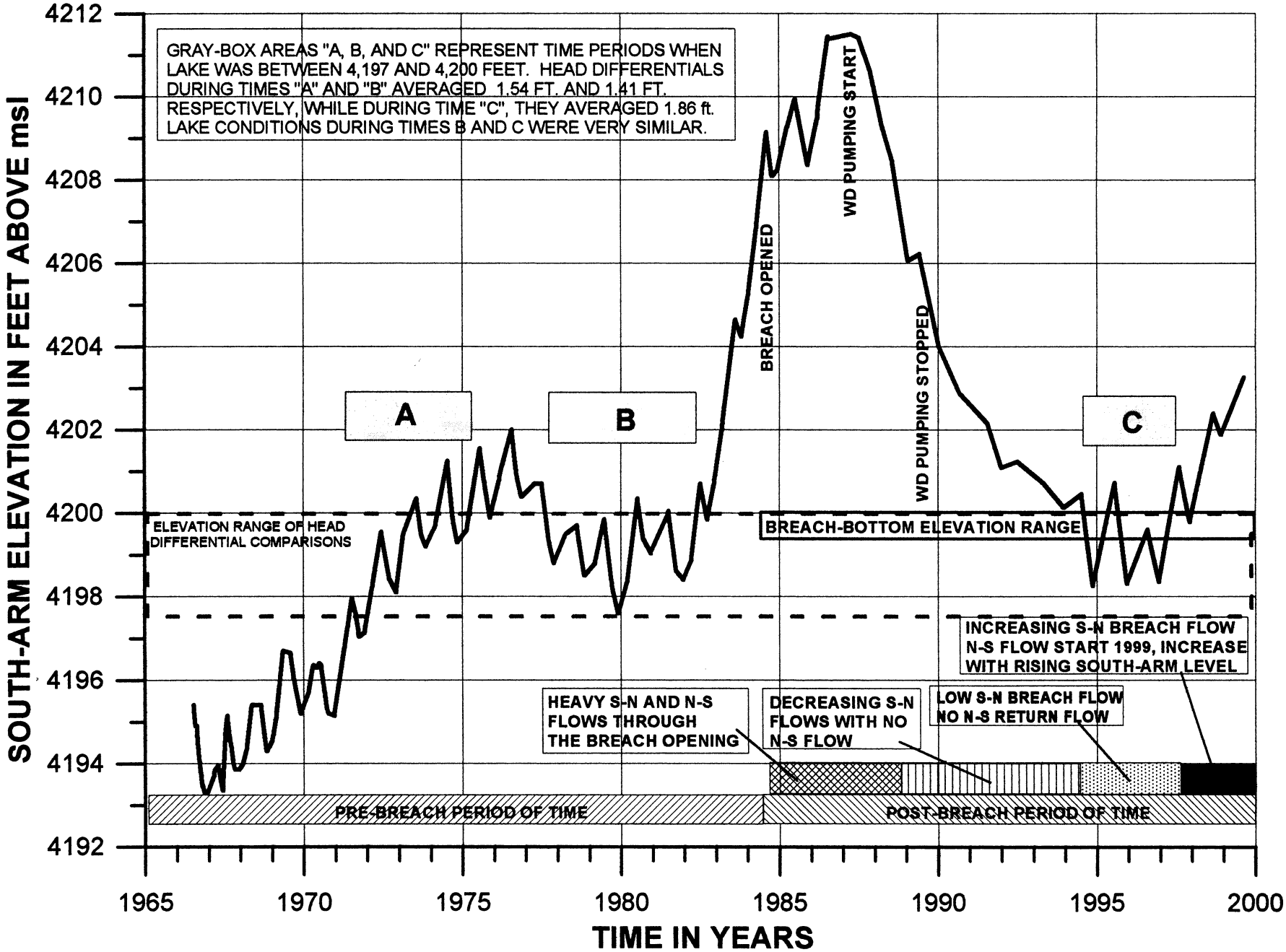
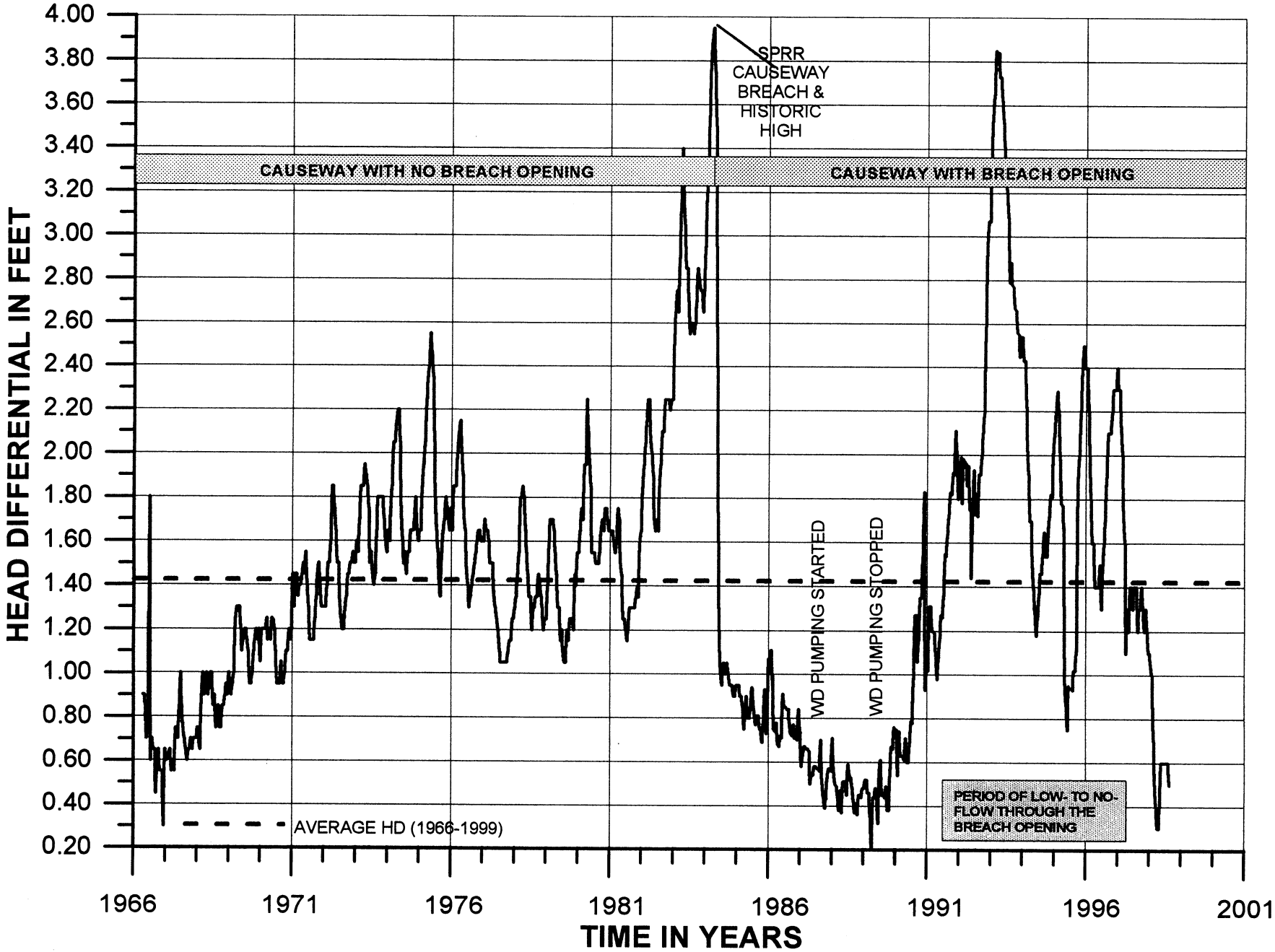


Figure B. Hydrograph of south arm of Great Salt Lake showing breach-bottom elevation range, and elevation range and time periods of head differential comparisons.



HEAD_DIF.GRF

Figure C. Head differentials measured between south and north arms of Great Salt Lake from 1966 to 1999.

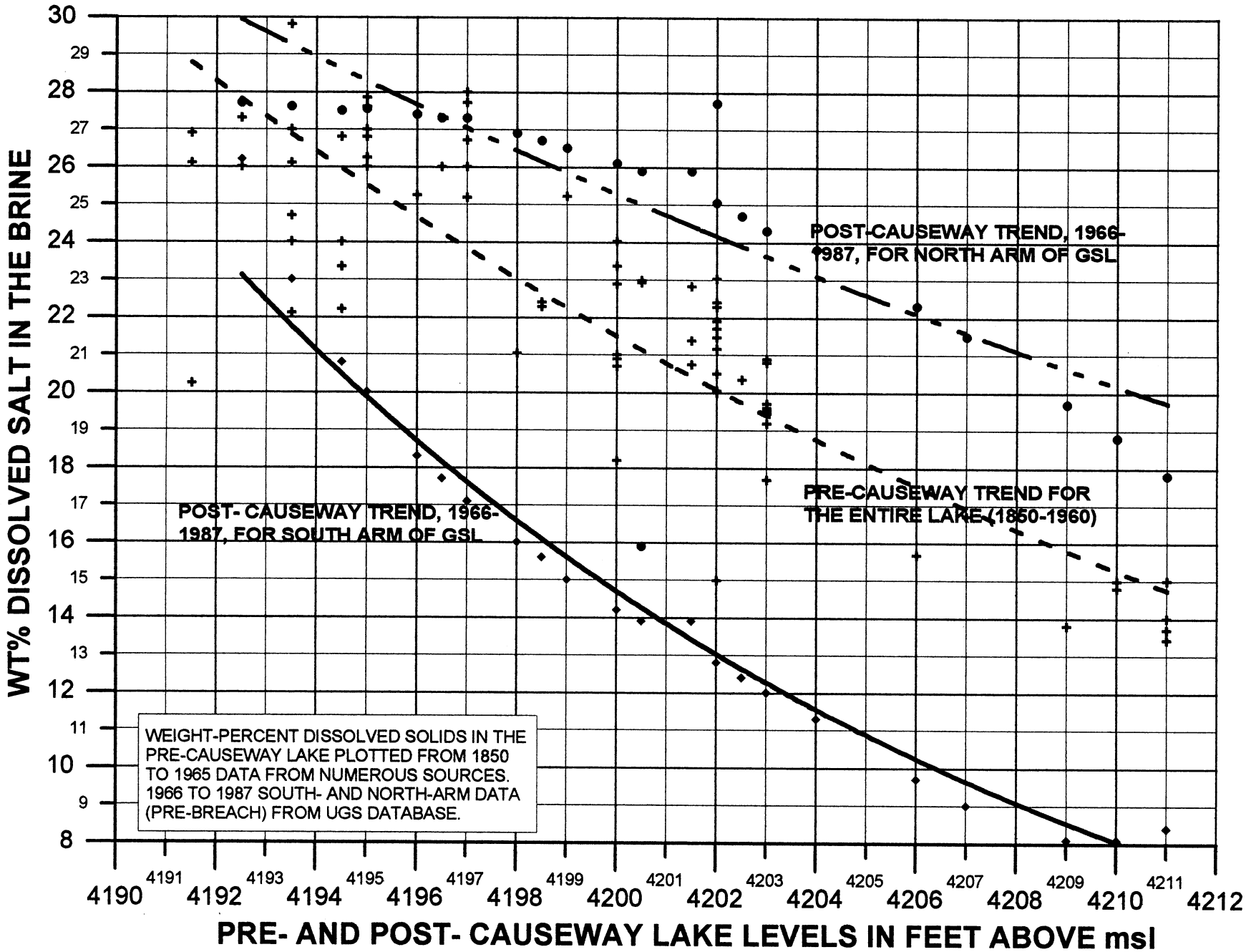
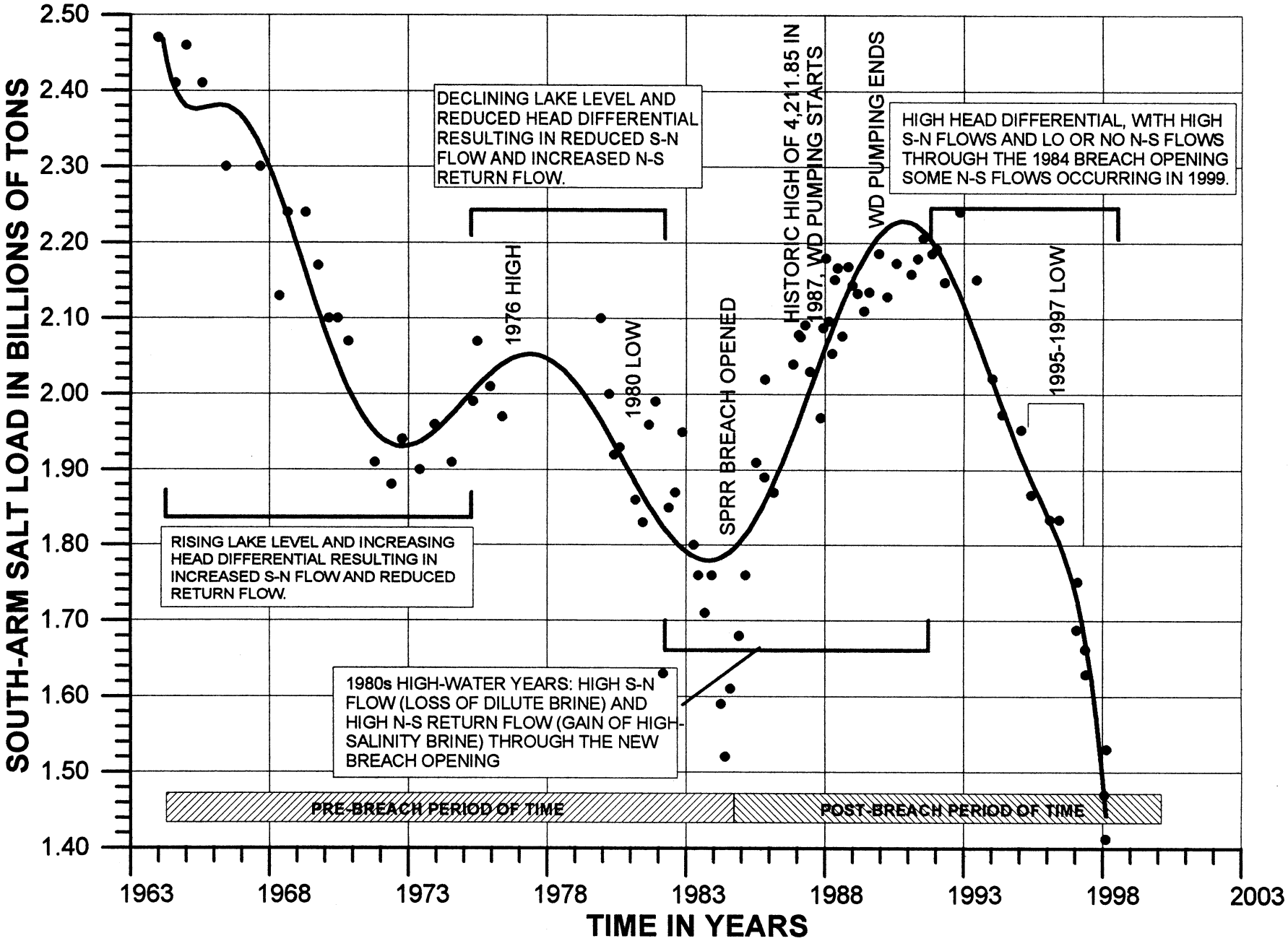
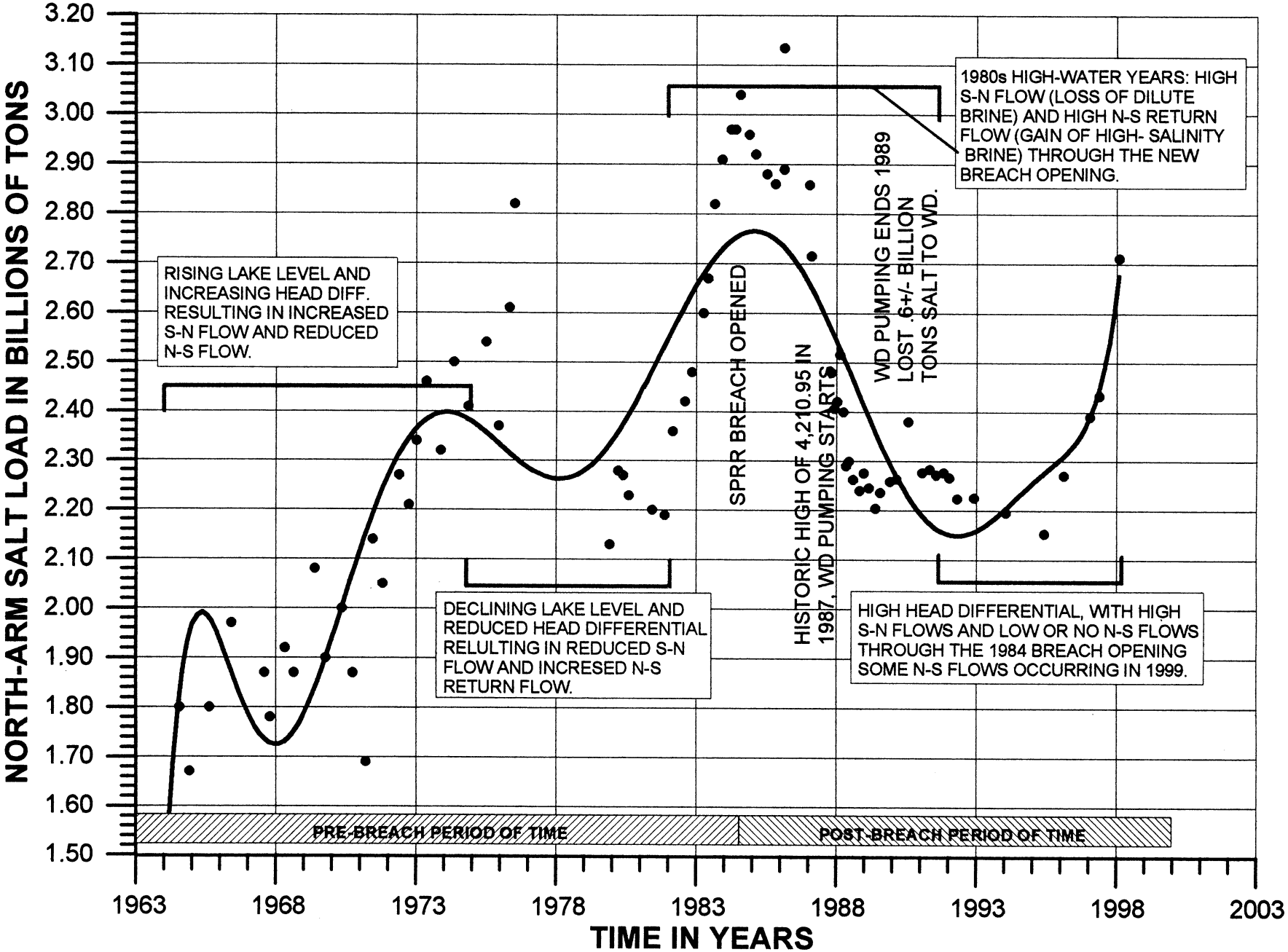


Figure D. Pre-causeway (entire lake) and north and south-arm post causeway lake-level versus Wt.% salt-in-brine plots.



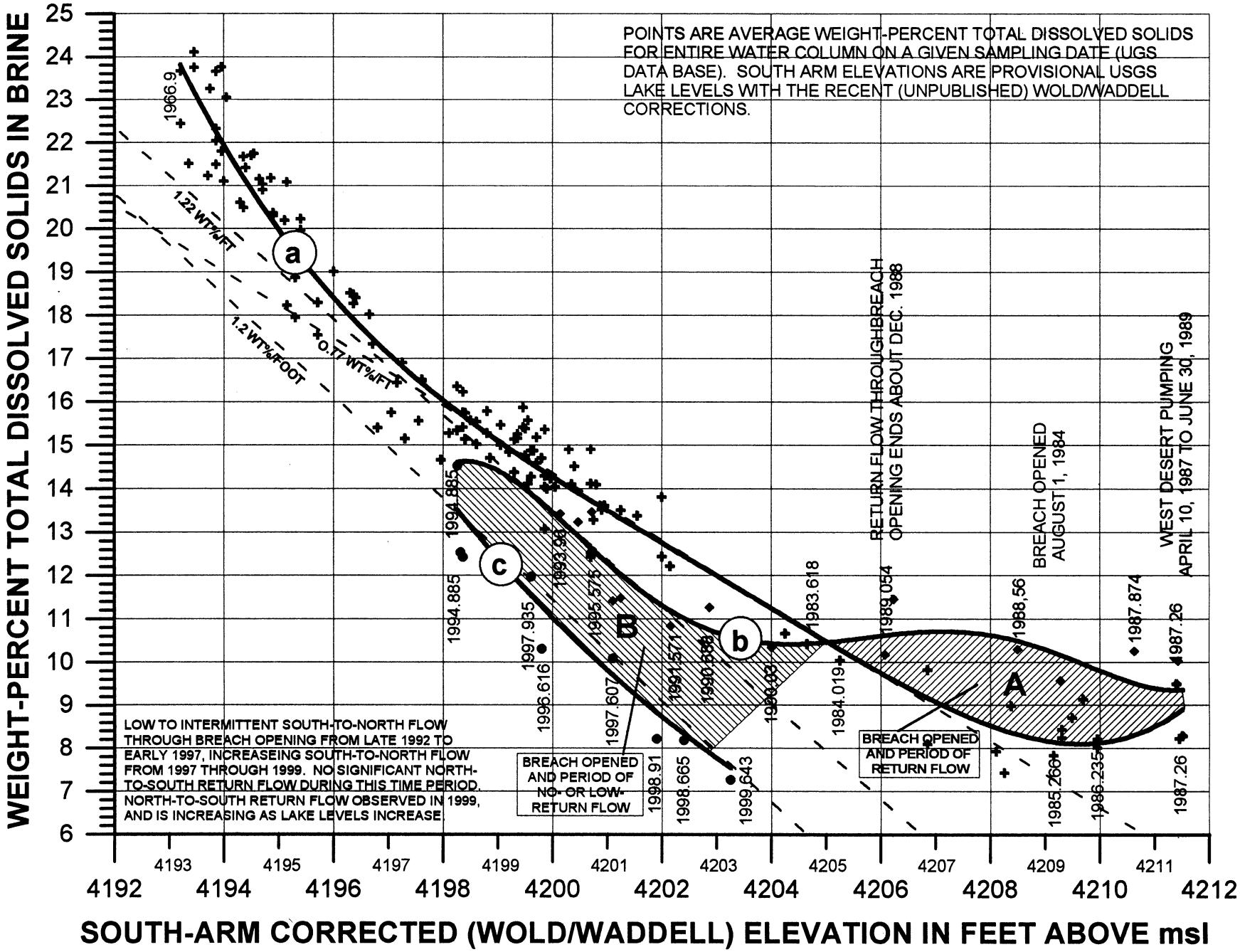
SO_LOAD.GRF

Figure E. Plot of south-arm salt load versus time in years, with polynomial-fit line to illustrate general trends.



NO_LOAD.GRF

Figure F. Plot of north-arm salt load versus time in years, with polynomial-fit line to illustrate general trends.



latestw%.grf
as2a.dat

Figure G. Plot of south arm elevation versus Wt.% total dissolved solids in brine, broken into 1966-1987, 1987-1995, and 1995-1999 time periods to show the different paths the lake has taken during these time periods.

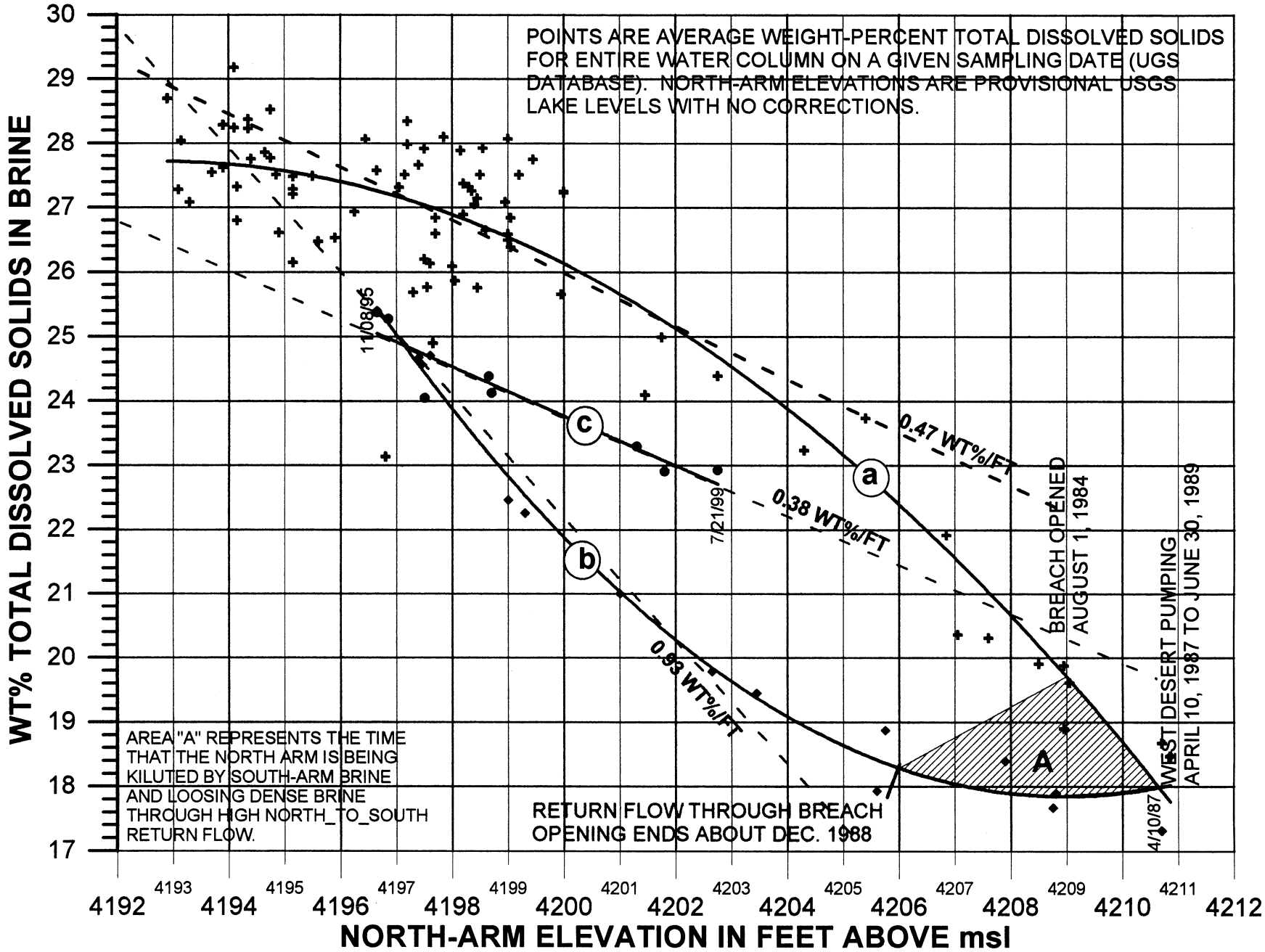


Figure H. Plot of north arm elevation versus Wt.% total dissolved solids in brine, broken into 1966-1987, 1987-1995, and 1995-1999 time periods to show the different paths the lake has taken during these time periods.

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