# The Rising Level of the Great Salt Lake: Impacts and Adjustments

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## Abstract

Societal responses to climatic fluctuations can be difficult and costly. The recent case of the rising level of the Great Salt Lake indicates that resource managers are often unprepared to respond to climate related impacts, except in an ad hoc and costly fashion. Precipitation in the Great Salt Lake drainage basin between 1982 and 1986 averaged 134 percent of normal, resulting in a rise in the level of the Great Salt Lake of 3.66 m (12 ft) to a new historic record high level of 1283.77 m (4211.85 ft). This rise in the level of the lake has had widespread adverse impacts, forcing resource managers to implement costly emergency flood mitigation measures. Policymakers, however, have been unwilling to implement long-term policies aimed at adapting to fluctuating lake levels, relying instead on crisis management while hoping that the lake will soon recede. The water level of the Great Salt Lake, its impacts and adjustments, and an assessment of the long-term adjustment options are discussed.

## 1. Introduction

Scientists and policymakers alike have become increasingly aware of the impact that fluctuations in climate have on sensitive social and economic systems. The growing literature on climate impacts offers both conceptual and methodological frameworks for understanding climate and society interactions (e.g., Kates et al., 1985). Recent case studies have demonstrated how sensitive modern society can be to fluctuations in climate (Riebsame, 1988), and might be to the potential impacts from a trace-gas induced global warming (Glantz, 1988). However, societal responses to climatic fluctuations can be difficult and costly. For example, recent cases of lake-level rise and flooding have indicated that policymakers and resource managers are often unprepared to respond, except in an ad hoc and costly fashion; long-term policy adjustments have been lacking (see Changnon, 1987; Morrisette, 1988).

Changnon (1987) discussed the difficult problems that have confronted policymakers in Illinois and the Great Lakes region as a result of record high lake levels on the Great Lakes. Societal adjustment has been difficult because of the diverse impacts, and the fact that both interstate and international jurisdictions are involved. While resource managers have been searching for solutions, they have been forced to rely on local structural adjustments. Changnon (1987) argues, however, that effective policy solutions will likely require resolution at the regional level.

The Great Lakes are not the only lakes in North America that have experienced record high levels this decade. Several of the closed basin lakes in the western United States have been at or near modern-day record high levels in the past several years, most notably Utah's Great Salt Lake (Federal Emergency Management Agency, 1986a). The Great Salt Lake has risen 3.66 m (12 ft) since 1982, setting a new historic high record of 1283.77 m (4211.85 ft). This rapid rise in the level of the lake has been directly tied to increased precipitation in the lake's drainage basin. The resulting flood from the rising lake has had widespread adverse impacts on public and private facilities and on activities along the shore of the lake. This flooding has forced resource managers and policymakers to implement emergency mitigation measures and to investigate the possible implementation of large-scale adjustment strategies.

Decision makers, however, have been unwilling to implement flexible long-term adjustments, relying instead on short-term structural alternatives (see Morrisette, 1988). It took the record high lake level of 1986 to force the state legislature to fund the west desert pumping project that is designed to slow the rate of rise. Policymakers have adopted a wait-and-see approach with respect to lake-level rise. Ad hoc adjustments have been made only as rising lake levels have forced a response. However, as with the Great Lakes, effective adjustment will likely require a long-term regional policy. While this has been proposed in the form of designating a special development zone around the lake, no such action has yet been taken. The problem of the rising level of the Great Salt Lake, including impacts and adjustments, and an assessment of long-term adjustment options are given here. The Great Salt Lake case clearly illustrates the difficulty that resource management institutions have in adjusting to climatic fluctuations.

## 2. Lake-level and climate fluctuations

The Great Salt Lake is a terminal saline lake located in an enclosed drainage basin in northern Utah (Fig. 1). The modern-day lake is a remnant of Pleistocene Lake Bonneville that began forming about 30 000 years ago, reaching a peak elevation of 1551.43 m (5090 ft) (the rim of the enclosed basin) about 16 000 years ago, and then declining to 1295.40 m (4250 ft) about 10 000 years ago. The Great Salt Lake, as the Holocene remnant of Lake Bonneville, has also fluctuated markedly between nearly dry conditions and levels between 1285.34 and 1292.35 m (4217 and 4240 ft). Recent research has indicated that the lake has reached an elevation of 1285.34 m (4217 ft) as many as five times in the past 500 years (Mckenzie and Eberli, 1985). The estimated "normal" level of the present-day lake, defined as the historic average (based on a 140-year record from 1847 to the present), is approximately 1280.16 m (4200 ft) (Arnow, 1984).

Because the lake is located in a shallow basin, a small change in lake level can have a substantial impact on the shape of the shoreline and the surface area of the lake. The nearly 3.66-m (12-ft) rise in the level of the lake since 1982 has resulted in

[1] Sponsored by the National Science Foundation.

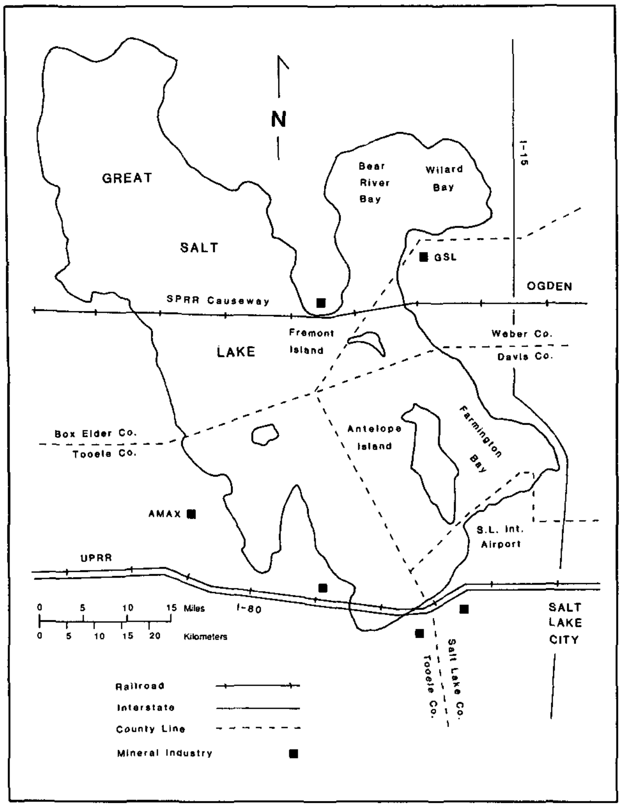


FIG. 1. Great Salt Lake drainage basin (from Arnow, 1984).

significant flooding of shoreline property. In 1982, with the lake at an elevation of 1280.16 m (4200 ft), it covered approximately 4403 km$^2$ (1700 square miles); however, in 1986 with the lake at 1283.77 m (4211.85 ft), the surface area was approximately 6475 km$^2$ (2500 square miles), an increase of 47 percent. In addition, the terrain of the basin is an important factor influencing lake-level rise. For example, if the lake reaches an elevation between 1284.43 and 1284.73 m (4214 and 4215 ft) it will cross the first of three topographic thresholds between 1284.43 and 1285.34 m (4214 and 4217 ft) that will allow the lake to flow into successively larger basins to the west and south of the present lake, greatly increasing the size of the lake (Atwood, 1986).

The level of the Great Salt Lake is maintained by a balance between precipitation, runoff, and evaporation. Runoff is the largest source of inflow into the Great Salt Lake, accounting for 66 percent of the lake's average annual inflow. The Bear, Weber, and Jordan rivers are the lake's principal tributaries, with the Bear River accounting for 59 percent of all runoff. Precipitation directly on the lake accounts for 31 percent of the average annual inflow, and groundwater contributes the remaining 3 percent. Under equilibrium conditions, the combination of precipitation, runoff, and evaporation should maintain a stable lake level within .3 to .6 m (1 to 2 ft) (Arnow, 1984). However, the level of the Great Salt Lake during the period of historic record has been anything but stable (Fig. 2).

During the past 140 years the Great Salt Lake has fluctuated more than 6.10 m (20 ft) between high and low lake levels. In June 1986, as a result of a prolonged period of increased precipitation over northern Utah, the Great Salt Lake reached an historic high of 1283.77 m (4211.85 ft), surpassing the old record of 1283.70 m (4211.6 ft) reached in 1873. The historic record low level for the lake of 1277.52 m (4191.35 ft) occurred in 1963, and since 1963 the lake has risen 6.25 m (20.5 ft). The lake rose steadily between 1963 and 1976, reaching a level of 1280.77 m (4202 ft) for the first time since the 1920s, before declining again. However, since the fall of 1982 the lake has risen over 3.54 m (12 ft). This included rises of 1.55 m (5.1 ft) in 1983, 1.52 m (5.0 ft) in 1984, and 1.07 m (3.5 ft) in 1986—the three largest single-season rises in the historic record. In 1987, as a result of a dry winter, the lake just reached the previous year's record level of 1283.77 m (4211.85 ft) and fell to a low of 1283.04 m (4209.45 ft). Part of this decline was due to the recently implemented west desert pumping project.

Recent research on the climate of northern Utah shows a direct relationship between precipitation in the Great Salt Lake drainage basin and lake-level rise (Karl and Young, 1986; Kay and Diaz, 1985b; Williams, 1985; Arnow, 1984). The climate record indicates that the Great Salt Lake Basin has been in a wet period for some years, with the last several years being the wettest on record. Figure 3 shows, for ten index stations, the percent of normal precipitation in the Great Salt Lake Basin from 1951 to 1986.[2] Since 1963, precipitation has been above normal for 18 of the last 25 years. Precipitation as a percent of normal for the period 1980 to 1986 has been 129, 112, 150, 180, 133, 107, and 129 percent of normal, respectively. Karl and Young (1986), using a record for the Great Salt Lake drainage basin from 1864 to 1984, identified the wet spell of 1981 to 1984 as the most extreme period on record, and Eischeid et al. (1985), using 90 years of record, identified 1983 as the wettest year on record. Similarly, runoff into the Great Salt Lake has been 265, 330, 190, and 300 percent of normal for the water years 1983 to 1986, respectively.

Individual weather events over the past several years have been as anomalous as the annual precipitation and runoff totals. For example, on 27 September 1982, Salt Lake City International Airport recorded 5.77 cm of rain (2.27 in), the most it ever recorded in a single day. The 17.88 cm (7.04 in) of precipitation for September 1982 was also a record for a single month. In addition, monthly records for precipitation have been set at many stations throughout the basin in 1982, 1983, 1984, and 1986, and the late spring snowpack in the Wasatch Mountains has been as much as 500 percent of normal. This increased precipitation over the past several years has affected more than just the level of the Great Salt Lake. Extensive stream flooding, mudflows, and landslides occurred along the Wasatch Front in the spring of 1983 and 1984. The floods and landslides of the spring of 1983 were the most severe on record (Utah Division of Comprehensive Emergency Management, 1985).

Two questions that have been raised by policymakers are whether the climate is changing and what might future climate and lake-level trends be. Karl and Young (1986) argue that while the increased precipitation of the last several years is highly anomalous, it is not unprecedented in the long-term climate record of the region. Using the extended record for the

[2] *Normal* is defined as the 1951–1980 30-year average at these stateous of 45.47 cm (17.9 in).

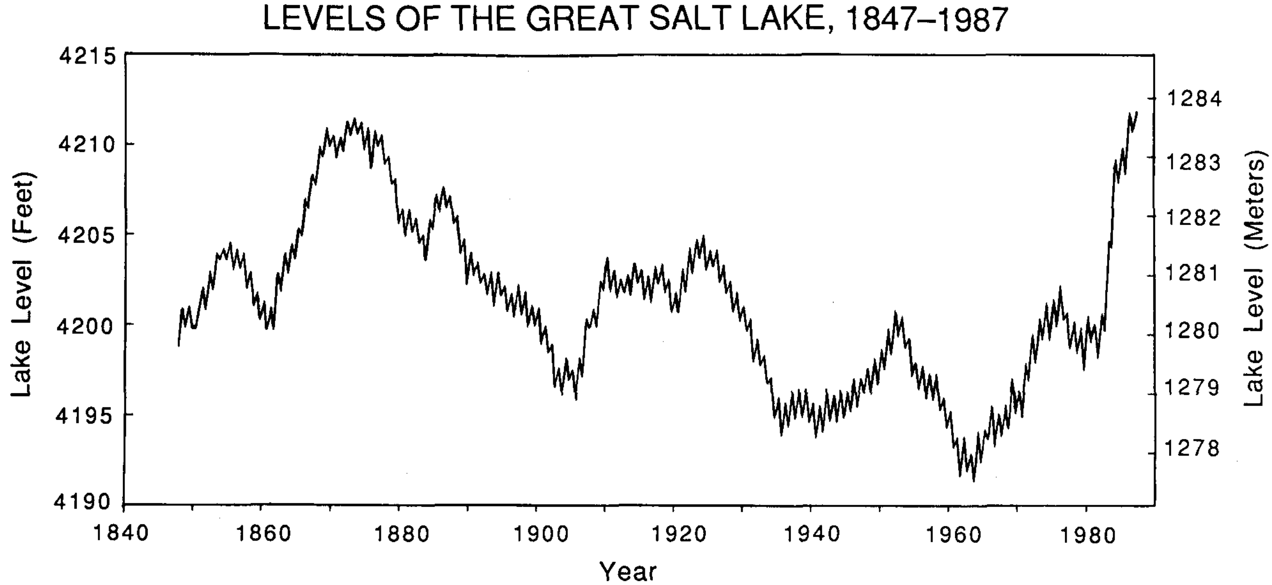


FIG. 2. Historical lake-level record for the Great Salt Lake (data from USGS).

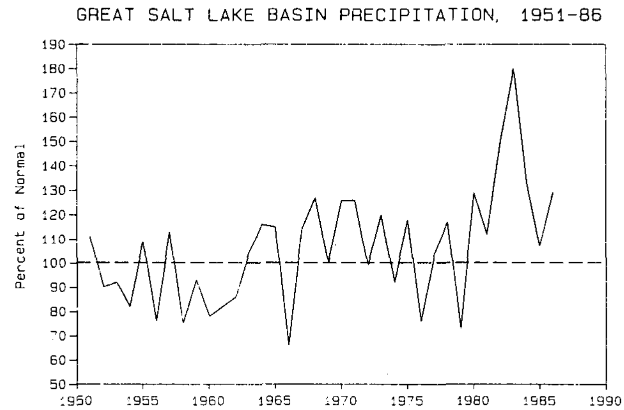


FIG. 3. Percent of normal precipitation in Great Salt Lake Basin, 1951–1986.

Great Salt Lake drainage, they estimated the return period for the record wet period of 1981 to 1984 to be 118 years. They also argue that there is a 50 percent chance of having a similar wet spell in any given 100-year period. Karl and Young (1986, p. 357) conclude that the record "tends to suport the hypothesis that the time series contains climate fluctuations, but the evidence for a 'runaway' change in climate in recent years is not convincing." It is likely, therefore, that the recent lake-level rise occurred as a result of normal climatic variability, rather than from a change in long-term climatic conditions.

Predicting future lake-level and climate trends has proven to be an uncertain and risky task. Past efforts have not met with much success. In response to the current crisis, a conference entitled "Problems of and Prospects for Predicting Great Salt Lake Levels" was held in Salt Lake City in March 1985. Predictions from participants attending the conference were qualified and relatively conservative, calling for the lake to continue to rise for several more years, perhaps to a level of 1285.34 m (4217 ft), before declining (Kay and Diaz, 1985a).

With a dry year in 1987, the lake has at least temporarily leveled off. With the existence of drier conditions in the basin during the winter and spring of 1988, prospects for the lake declining in 1988 look good. However, even if the lake begins to recede, it will probably take 10 years or more for the lake to fall to 1280.16 m (4200 ft). A return to wetter conditions during this period would likely result in the lake's level rising once again.

## 3. Impacts and mitigation efforts

The rising level of the Great Salt Lake has resulted in widespread impacts on public and private facilities, and on activities along the shore of the lake. Most notable have been the impacts on mineral and industrial operations, highways and railroads, and wildlife and recreation areas. Each of these impacts has resulted in mitigation efforts. To date, the costs of impacts and adjustments has exceeded $300 million.

Solar pond mining operations along the shore of the lake have been particularly vulnerable to rising lake levels. Through 1986, mineral companies had invested $84.7 million to protect their property and maintain their operations in the face of rising lake levels (US Army Corps of Engineers, 1986). However, their operations still remain vulnerable, and it is uncertain at which lake level these companies will be forced to close completely.

Flood damage to major highways and railroads that pass near or over the Great Salt Lake has been significant (Utah Department of Transportation, 1986). The most seriously threatened routes have been Interstate 80 and the Union Pacific Railroad, which pass to the south of the lake, and the Southern Pacific Railroad causeway, which divides the north and south arms of the lake (Fig. 4). The raising and diking of highways and railroads have been among the most visible of all flood mitigation efforts. For example, sections of Interstate 80 have been raised to an elevation between 1284.43 and 1284.73 m

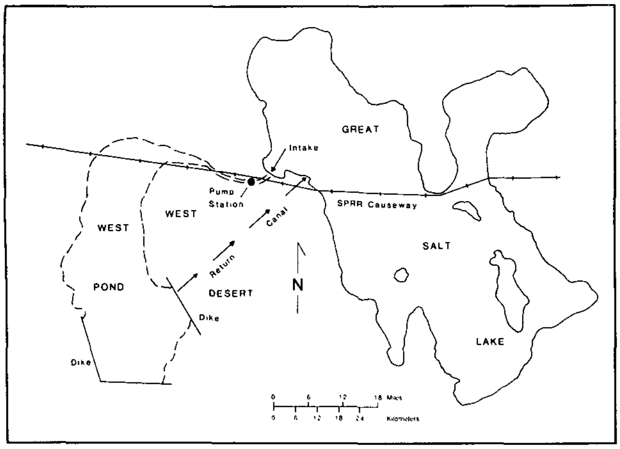


FIG. 4. Map of Great Salt Lake and vicinity showing facilities affected by rising lake levels.

(4214 and 4215 ft) at a cost of over $25 million. However, for structual reasons, the interstate could not be raised further, and it was forced to close for short periods of time during the spring of 1986 because of storm surges and high waves. Other state and local roads have also experienced flooding, including the north and south causeways to Antelope Island, which are under ten feet of water.

Damage to the Union Pacific Railroad and to the Southern Pacific Railroad has likewise been significant (Utah Department of Transportation, 1986; Utah Division of Comprehensive Emergency Management, 1985). The Union Pacific Railroad has raised its tracks along the southern shore of the lake four times at a total cost of over $23 million, and the Southern Pacific Railroad has invested $70 million to raise and protect its causeway. The causeway can currently withstand a lake level of only 1283.70 m (4211.6 ft), and it was forced to close for several months in the summer of 1986 after being severely damaged by waves during a storm. The Southern Pacific Railroad cannot raise its tracks further because the lake bed cannot support the additional weight. It is also unlikely that the Union Pacific will raise its tracks further.

Waterfowl refuges, state parks and other recreation areas, and agricultural lands adjacent to the lake have also been flooded. Other public facilities that have been impacted by the rising level of the lake include wastewater treatment plants, landfills, underground telephone lines, and overhead electrical power lines. Although most of these immediately threatened public facilities (e.g., wastewater treatment plants and landfills) have been protected by dikes, major residential and industrial-commercial areas in Salt Lake, Davis, and Weber counties, and Salt Lake City International Airport would be threatened if the lake continues to rise.

In addition to the numerous direct impacts from the rising level of the Great Salt Lake, there are also potential long-term, indirect impacts that include serious disruptions in highway, rail, and even air transportation, and losses of both jobs and tax revenue. Major disruptions in transportation have already occurred. For example, the Southern Pacific Railroad has been forced to close its causeway and reroute traffic for extended periods of time. Interstate 80 has been forced to close during storms. If the lake continues to rise, the Southern Pacific Railroad would be forced to permanently close the causeway. In addition, Interstate 80 and the Union Pacific Railroad would both have to be rerouted south of the lake at substantial cost. Such disruptions in transportation would have a widespread impact on the economy of Utah. Also threatened, if the lake continues to rise, are the jobs and tax revenues generated by large companies such as AMAX, Great Salt Lake Minerals, and the Southern Pacific Railroad. While these companies have been able to maintain their operations despite the 3.66-m (12 foot) rise in the level of the lake, it is questionable whether they would remain in operation if the lake were to rise much above 1283.82 m (4212 feet).

Damages and capital investments from the 3.66-m (12-ft) rise in the level of the Great Salt Lake since 1982 have been substantial and widespread. They are likely to increase at an accelerated rate if the lake continues to rise. In terms of impacts, the lake is at or near a threshold at which critical facilities such as highways and railroads will be lost, and heavily developed residential and commercial areas are threatened if the lake should continue to rise at rates similar to those of the last few years. Mitigation efforts, however, have been directed primarily toward protecting isolated facilities and offsetting impending crises, rather than toward implementing long-term adjustment strategies.

## 4. Efforts at large-scale adjustments

The rapid rise in the level of the Great Salt Lake over the past several years and the resulting impacts have forced resource managers and policymakers to respond. This response has been in two forms: first, the implementation of emergency flood mitigation efforts to protect immediately threatened facilities (discussed in the preceding section), and second, the investigation of larger scale lake-level control and flood mitigation efforts and the review of potential long-term planning strategies. While the state has been forced to dike and protect threatened public facilities or lose them, it has been less willing to tackle the larger issue of how to adjust in the long-run to a rising lake. The state, however, has investigated an array of structural lake-level control strategies, and has recently started pumping water from the lake into the desert west of the lake. Yet even this decision was based more on the need to offset an impending crisis (the rapidly rising lake in 1986), rather than on the basis of the need for implementing long-term adjustments.

Much of the difficulty the state has had in adjusting to the current crisis is due to the fact that it was completely unprepared to deal with the problem of rising lake levels. Past experience (prior to 1982) with managing the lake, and models of the lake's hydrologic system that were developed in the 1970s, suggested that lake levels above 1280.77 m (4202 ft) were highly unlikely and a lake level of 1283.77 m (4211.85 ft) was widely perceived to be impossible (Morrisette, 1988). The lake was at record low levels in the early 1960s and had not been above 1280.77 m (4202 ft) since the 1920s. Discussions of lake-level control and floodplain management had surfaced in the 1970s when the lake reached a peak of 1280.77 m (4202 ft) (Utah Division of Great Salt Lake, 1976); however, the lake soon receded and so did efforts at planning for lake-level variability. Even as the lake began rising rapidly in the early 1980s, the widely held belief was that it would soon recede. In the past, policymakers and resource managers have been most concerned with developing the lake for economic and recreational benefits, and not with managing it as a variable resource that someday might represent a serious hazard. With the continual rise of the lake since 1982, the state of Utah has reluctantly been forced to deal with the lake-level rise problem. Large-scale efforts at lake-level control and flood mitigation were beyond the means and authority of local governments, and the federal government has ruled that existing authorities did not allow its involvement in any lake-level control project (Utah Division of Comprehensive Emergency Management, 1985; Federal Emergency Management Agency, 1986b). However, some federal assistance has been provided through FEMA and the U.S. Army Corps of Engineers. In responding to the lake-level rise problem, the state has essentially adopted a wait-and-see approach, doing only what is immediately necessary and hoping that the lake will soon recede. It was not until May 1986, with the lake at a record high level, that decision makers, who were faced with the prospect of even more-severe flooding, finally committed themselves to a major structural adjustment—the west desert pumping project.

*a. Structural adjustments: efforts at lake-level control*

The first measure taken by the state to attempt to control the level of the Great Salt Lake was the breaching of the Southern Pacific Railroad causeway in the summer of 1984 (Utah Division of Comprehensive Emergency Management, 1985). The railroad causeway divides the lake into a northern arm and a larger southern arm. Because most of the inflow occurs in the southern arm of the lake, the effect of the causeway had been to create higher brine concentrations in the northern arm of the lake and a higher lake level in the southern arm. However, the causeway breach was a relatively small project. It cost $3.7 million, and had only a one-time effect on the lake, lowering the south arm by 30.48 cm (1 ft). Yet at the time the project was being debated, it was highly controversial. Many politicians, for example, questioned whether the project was necessary, and one of the larger mineral companies and the Southern Pacific Railroad were initially opposed for economic reasons.

The state also investigated several larger structural lake-level control projects (Utah Division of Water Resources, 1984, 1986a; US Army Corps of Engineers, 1986). Included among these were plans to increase upstream storage on the Bear River (the lake's principal tributary), and the diversion of water from the Bear River into the Snake River in Idaho. Increased storage on the Bear River, however, would have only a minimal effect on lake levels, and the diversion of Bear River water would be costly and would face serious institutional and legal constraints (Utah Division of Water Resources, 1986a). A third proposal involved the construction of protective dikes along the shore of the lake; however, this was seen as being too costly to be effective (Utah Division of Water Resources, 1986a).

Two different plans to create eastshore embayments were also proposed (Utah Division of Water Resources, 1986a; US Army Corps of Engineers, 1986). The larger and more popular of these two plans, inter-island diking, involved the construction of a series of deep water dikes that would connect the south shore of the lake with Antelope Island, Freemont Island, and the north shore of the lake at Promontory Point. The idea was to separate the east shore of the lake from the main body of the lake by creating a fresh water embayment in which the water level could be controlled by pumping into the main lake. The project, however, would do nothing to protect the south and west shores of the lake, and in fact, would leave these areas more vulnerable to future lake-level fluctuations. In addition, serious questions remain concerning the technical feasibility of creating a fresh water embayment (US Army Corps of Engineers, 1986; Utah Division of Water Resources, 1986a). Nevertheless, it remains a popular idea because of the potential economic and recreation benefits associated with a fresh water embayment. In fact, the political motivation behind the project is more to encourage lake development than to control the lake-level. The project has long been popular among east shore community leaders and politicians for this reason.

While the state has investigated numerous large-scale structural adjustments, it has been reluctant to follow through on any of these projects, hoping instead that the lake would recede naturally. In early 1985, however, after two years of record lake-level rise, the state legislature passed Senate Bill 97 that authorized $96 million for flood mitigation and lake-level control (Utah Code 73-10e). Twenty-million dollars was allocated immediately for flood mitigation measures. The remaining funds were to be allocated during a special session of the Legislature later that spring. However, during the spring of 1985 it became clear that the lake would peak far below its predicted level due to drier than anticipated conditions in the basin. The legislature, thinking that the lake-level rise problem was over, decided not to hold a special session in order to allocate the remaining funds it had authorized for flood mitigation and lake-level control.

In 1986, however, the lake began rising rapidly again, and the state was confronted with another crisis. While diking public facilities and raising highways had worked in the past, the lake was reaching a level at which such adjustments would no longer work. Policymakers were finally forced to consider a larger solution. The legislature opted for the west desert pumping project because it was determined to be the most practical and cost effective of the many alternatives investigated (US Army Corps of Engineers, 1986) and it could be implemented in a relatively short period of time. The decision to fund the west desert pumping project was made during a special session of the Utah Legislature in May 1986. This decision was not without political controversy. For example, many legislators favored inter-island diking because of its potential economic benefits, and still others were concerned about the need for the project and about funding. However, perhaps most important was the general opposition to funding a $60-million project that was designed specifically to remove water from the lake, when the lake could start to recede naturally making the project unnecessary. This has, in fact, happened as drier conditions have prevailed over northern Utah since 1987.

The idea behind the $60-million west desert pumping project is to increase the rate of evaporation by artificially increasing the size of the lake (Utah Division of Water Resources, 1986b; US Army Corps of Engineers, 1986). The project utilizes three large diesel pumps to carry water from the lake into a large evaporation pond located in the desert west of the lake (Fig. 5). A return canal brings highly concentrated brine back to the lake to be used by mineral companies. It is estimated that the project will increase evaporation by $1011.47 \times 10^6$ $m^3$ (820,000 acre-ft) annually, and under normal climatic conditions, reduce the level of the lake by 32.51 cm (12.8 in) during the first year of operation and 16.76 cm (6.6 in) in each additional year of

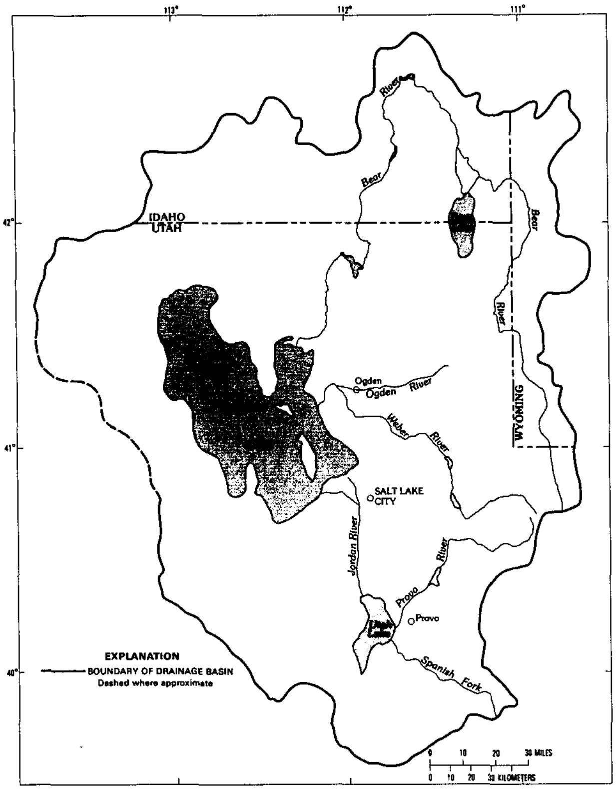


FIG. 5. West desert pumping project (after Utah Division of Water Resources, 1986a).

operation. Construction on the project began in the summer of 1986, and it became operational in the late spring of 1987. Approximately 30.48 cm (1 ft) of the 1987 decline in the level of the lake has been attributed to the pumping project.

West desert pumping, however, cannot be considered a final solution to the lake-level rise problem. To begin with, the design of the project and the natural rate of evaporation limit the amount of water that can be removed. For example, if input into the lake is above 200 percent of normal, the lake will continue to rise (input was at or above 200 percent of normal from 1983–1986). The project is only operational with lake level below 1284.73 m (4215 ft), at which point the lake begins to flow into a series of basins west of the lake (including, eventually, the basin used for west desert pumping). Thus, while west desert pumping will help to alleviate the problem, the fact remains that if the precipitation pattern of the recent past persists, the lake will continue to rise.

*b. Non-structural adjustments*[3]

In addition to west desert pumping and the other structural measures discussed above, the state also investigated one non-structural approach to the lake-level rise problem. This approach was based on designating the lake's floodplain as a Beneficial Development Area or BDA (Utah Division of Comprehensive Emergency Management, 1985; Federal Emergency Management Agency, 1986b). The BDA was first proposed by FEMA in its hazard mitigation reports, and FEMA has since tied future federal funding to the implementation of the BDA concept (Federal Emergency Management Agency, 1986b). The BDA concept is based on restricting development within the floodplain by implementing flexible land-use policies that would allow for only those developments that can withstand damages from high lake levels. The BDA would include all shoreland between the lake and 1285.34 m (4217 ft). The 1285.34 m (4217 ft) level was chosen based on recommendations from the scientific conference held in March 1985, and on the fact that it had been identified as relatively stable high level for the lake during the past 500 years (Utah Division of Comprehensive Emergency Management, 1985). While the BDA would do little to mitigate the existing problem, it could curtail potential future losses from rising lake levels. Thus the BDA could be used as the foundation of a long-term program for lake management and development, and in fact, it has been endorsed by most of the state's resource management agencies for this purpose.

However, the BDA has not been implemented. While local governments have implemented some zoning restrictions, they are reluctant to surrender their authority over land use. In addition, some at the local and state government levels feel that the BDA is being forced on them by FEMA. There is also opposition to restricting development on valuable industrial lands adjacent to the lake. The BDA has also received little support from the governor or the legislature. Both would prefer to support a structural solution to the problem rather than restrict development around the lake. The hope is that the lake will soon recede either naturally, or with the aid of west desert pumping, or both.

*c. Crisis decision making*

Decision makers in Utah have had much difficulty in dealing with the rising level of the Great Salt Lake. Policymakers have been making decisions on a wait-and-see basis by responding only to impending crises, and relying on short-term structural solutions. The raising of the interstate, breaching the Southern Pacific Railroad causeway, and even the west desert pumping project were ad hoc responses to crisis conditions and not part of a rational plan for dealing with rising lake levels. This is not to say that these projects were not necessary; however, it does point to the lack of coordinated long-term planning. Decisions have been based on a hope that the lake will soon recede thus making further action unnecessary.

Given this crisis decision-making process, it has been nearly impossible to address the long-term problem of lake-level variability. Although the state has investigated the option of designating a special development zone around the lake, it has not done so. Even traditional structural measures such as the west desert pumping project have been difficult to justify given the short-term and crisis nature of the decision-making process. In 1986, the state turned to west desert pumping to mitigate what at that time was perceived to be a serious crisis. However, with the onset of drier conditions in 1987 and 1988, the west desert pumping project has attracted much criticism. The present concern centers on whether the project was necessary. Clearly, concern about the lake comes and goes as the lake level rises and falls.

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[3] Much of the information in this section and the following section was derived from structured interviews with key Utah policymakers conducted during the summer 1986. For a complete description and documentation of these interviews see Morrisette (1987).

The short-term crisis nature of the decision-making process for the Great Salt Lake has not been well suited to making rational long-term management decisions. While the state has been able to weather the current crisis, it has done little to prepare for lake-level rise problems in the future. Thus, despite the 3.66 m (12-ft) rise in the level of the lake and the extensive flooding of lakeshore facilities and property since 1982, Utah continues to remain vulnerable to the rising and fluctuating level of the Great Salt Lake. A flexible long-term approach to the problem of varying lake levels not only needs to include structural measures such as those already implemented, but it also needs to be based on a planning process that recognizes the potential for future lake-level fluctuations. This second point is crucial and points to the need for decision makers to implement coordinated comprehensive planning for the lake, rather than relying on short-term crisis management if they want to reduce societal vulnerability to a fluctuating Great Salt Lake.

## 5. Summary

The rapid rise in the level of the Great Salt Lake since 1982 has been due to a prolonged period of increased precipitation over northern Utah. Eighteen of the past twenty-three years have had above normal precipitation, and precipitation for the period 1980–1986 averaged 134 percent of normal. In the past six years, the Great Salt Lake has risen to record levels. The 1.52 m (5-ft) rises in the level of the lake in 1983 and again in 1984 were unprecedented in the 140-year historical record. The rising lake has flooded valuable lakeshore property and threatened major transportation routes. Impacts and resulting mitigation efforts have exceeded $300 million. If the lake rises above levels reached in 1986 and 1987, additional damages would be significant, including the loss of major railroads and highways.

Existing policies and resource management institutions have not been able to easily deal with a rapid rise in the level of the Great Salt Lake. Decision makers have adopted a wait-and-see approach, and crisis management has become the mode of decision making. Policymakers have only been willing to take those actions that have been immediately necessary to protect threatened facilities. Initially, this involved diking public facilities and raising threatened highways. More recently, it has involved controlling the level of the lake and the rate of rise through west desert pumping. While the state has investigated long-term adjustments such as the proposed BDA, none have been implemented. However, effective adjustment to the fluctuating level of the Great Salt Lake will likely require a flexible long-term policy for managing and developing the lake.

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