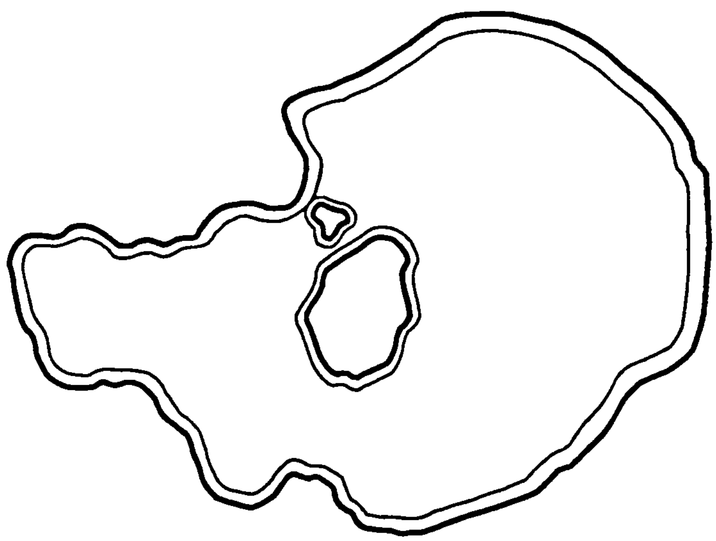
An Auxiliary Report
Prepared for the

MONO BASIN WATER RIGHTS EIR

Historic and Modern Distribution of Shore-Fringing Wetlands, Mono Lake, California



Prepared under the Direction of:

California State Water
Resources Control Board
Division of Water Rights
P.O. Box 2000
Sacramento, CA 95810

Prepared With Funding from:

Los Angeles Department of
Water and Power
Aqueduct Division
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Mono Basin EIR Auxiliary Report No. 21

An Auxiliary Report
Prepared for the
Mono Basin Water Rights EIR Project

This auxiliary report was prepared to support the environmental impact report (EIR) on the amendment of appropriative water rights for water diversions by the City of Los Angeles Department of Water and Power (LADWP) in the Mono Lake Basin. Jones & Stokes Associates is preparing the EIR under the technical direction of the California State Water Resources Control Board (SWRCB). EIR preparation is funded by LADWP.

SWRCB is considering revisions to LADWP's appropriative water rights on four streams tributary to Mono Lake, Lee Vining Creek, Rush Creek, Parker Creek, and Walker Creek. LADWP has diverted water from these creeks since 1941 for power generation and municipal water supply. Since the diversions began, the water level in Mono Lake has fallen by 40 feet.

The Mono Basin water rights EIR examines the environmental effects of maintaining Mono Lake at various elevations and the effects of possible reduced diversions of water from Mono Basin to Owens Valley and the City of Los Angeles. Flows in the four tributary creeks to Mono Lake and water levels in Mono Lake are interrelated. SWRCB's decision on amendments to LADWP's water rights will consider both minimum streamflows to maintain fish populations in good condition and minimum lake levels to protect public trust values.

This report is one of a series of auxiliary reports for the EIR prepared by subcontractors to Jones & Stokes Associates, the EIR consultant, and contractors to LADWP. Information and data presented in these auxiliary reports are used by Jones & Stokes Associates and SWRCB, the EIR lead agency, in describing environmental conditions and conducting the impact analyses for the EIR. Information from these reports used in the EIR is subject to interpretation and integration with other information by Jones & Stokes Associates and SWRCB in preparing the EIR.

The information and conclusions presented in this auxiliary report are solely the responsibility of the author.

Copies of this auxiliary report may be obtained at the cost of reproduction by writing to Jim Canaday, Environmental Specialist, State Water Resources Control Board, Division of Water Rights, P.O. Box 2000, Sacramento, CA 95810.

Historic and Modern Distribution of Shore-Fringing Wetlands, Mono Lake, California

A report to

The California State Water Resources Control Board
and
Jones and Stokes, Associates, Sacramento

February, 1993

Prepared by

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Please cite thusly: Stine, Scott, 1993. Distribution of substrate types at Mono Lake, California. Report to the California State Water Resources Control Board, and Jones and Stokes Associates, Sacramento, 23 pp.

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Historic and Modern Distribution of Shore-Fringing Wetlands, Mono Lake, California*

A report to

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1. Introduction

Mono Lake is a saline/alkaline water body that abuts the eastern escarpment of California's Sierra Nevada (Figure 1). Under natural conditions the level of this hydrographically closed lake fluctuates widely in response to changes in the relationship between inflow and evaporative loss. Since 1940, inflow to the lake has diminished due to water diversions by the Los Angeles Department of Water and Power (DWP). These diversions have forced the lake to drop 45 vertical feet--from an elevation of 6417 ft above sea level in 1940, to 6372 ft in 1982 (Figure 2).

Prior to diversions, the lake was in many places fringed with wetlands of three general types--freshwater marshlands (dense concentrations of rushes, grasses, sedges, and other marsh vegetation growing in standing water); wet meadows (luxuriant stands of graminoid vegetation growing from moist, but

* A copy of this report has been placed in the Water Resources Center Archives, U.C. Berkeley.

Cite thusly: Stine, Scott, 1992. Historic and modern distribution of shore-fringing wetlands, Mono Lake, California. Report to the California State Water Resources Control Board, and Jones and Stokes Associates, Sacramento, 59 pp.

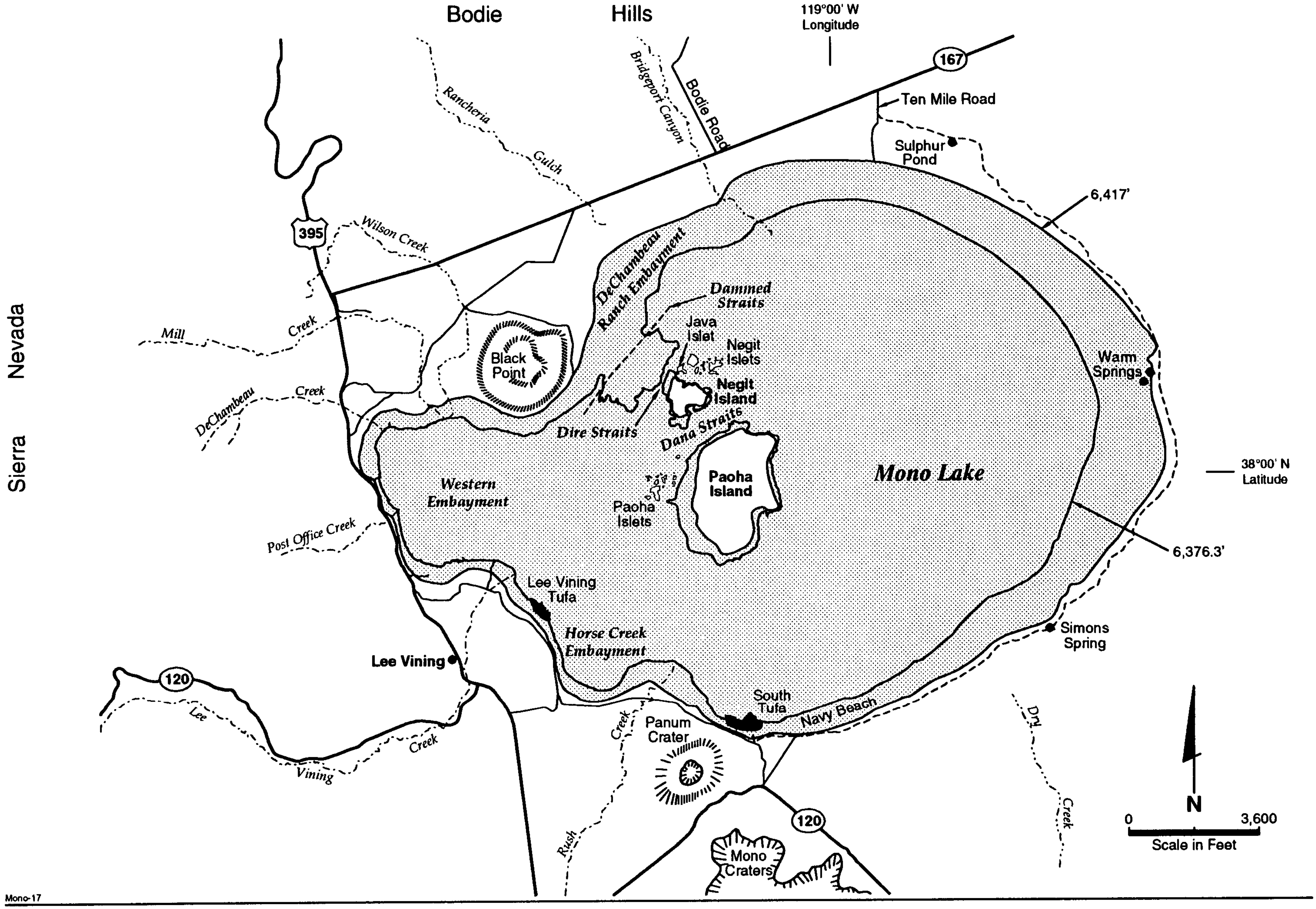


Figure 1.
Index Map of Mono Lake

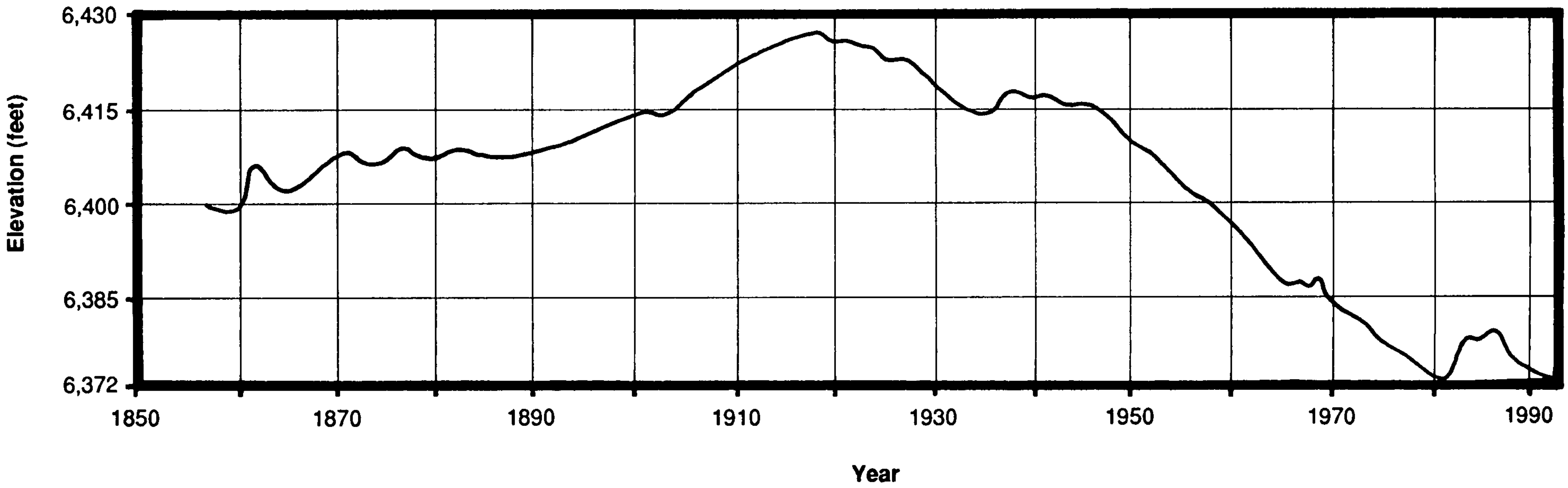


Figure 2.
Historical Fluctuations of Mono Lake

not flooded, ground); and lagoons (fresh- to brackish-water ponds typically separated from the lake by a bar, berm, or other embankment constructed by waves and longshore currents). (These definitions, rather than the U.S. Fish and Wildlife Service definition of wetlands, are used throughout this report). In most cases these wetlands were natural, though a few owed their existence to, or had been modified by, human manipulation of the hydrography (through either irrigation, excavation, or impoundment).

The drop in lake level induced by the DWP's operations altered the hydrology and geomorphology of the Mono shorelands. These alterations, in turn, caused changes in the nature, distribution, and extent of the lake-marginal wetlands. Some wetlands were lost, while others were enlarged or newly created. This report documents these changes, and other hydrology-related changes in lake-marginal phenomena, that coincided with the drop in lake level between 1940 and 1982. The report is based on written and anecdotal historical accounts, maps, and aerial photographs of the Mono Basin. The nature and distribution of wetlands in 1940 and 1982 are shown on Plate 1. The Fairchild Aviation aerial photographs of 1930, the U.S. Forest Service aerial photos of 1940, the U.S. Forest Service aerial photos of 1982, and the provisional U.S. Geological Survey topographic maps (1:12,500-scale) of 1986 (based on aerial photos of 1982), provided the basis for the polygons shown on Plate 1. To explain the changes that occurred between 1930-40 and 1982, other aerial photos were used. These included sets from 1952, 1956, 1964, 1968, 1972, 1973, and 1974.

2. Background

The Historic Fluctuations of Mono Lake

The period from 1885 to 1919 brought relatively high precipitation and runoff to the east-central Sierra Nevada, forcing Mono Lake to rise ~24 vertical feet. In July of 1919 the lake attained its "Historical High Stand" of 6428 feet (Figure 2).

Mono Lake remained near its historic high stand until 1924, then began to fall in response to the low runoff of the Dust Bowl years. By December of 1929 and January of 1930, when Fairchild Aviation of Los Angeles produced the first complete aerial photographic coverage of Mono Lake and its shorelands, the lake had declined 9 feet to an elevation of 6421 feet. The lake continued to fall through 1934, then rose slightly in response to the return of wetter conditions. In June of 1940, when the United States Forest Service produced their earliest set of aerial photographs of the Mono Basin, the lake stood at an elevation of 6417 feet.

Five months later, in November of 1940, the DWP began to operate its diversion system. By 1952 (a wet year in which Mono Lake rose approximately 1.5 feet) the lake surface stood at ~6409 feet; in 1958 (another wet year characterized by a ~1.2-foot rise in lake level) it stood at ~6402 feet; and by the end of 1966 the lake had declined to ~6387 feet.

Monumental runoff in 1967 and 1969 forced the lake to rise 3.3 feet, to a level of ~6390 feet. (As described below, this transgression, as well as the transgression of 1952, proved important in altering the hydrology of the shorelands.) Over the next dozen years the lake fell an additional 18 feet, reaching its "historical low stand" of 6372 feet early in 1982. (The U.S. Forest Service produced aerial photos of the basin shortly after the lake attained this low stand.) Abnormally high runoff between 1982 and '86 instigated a 9-foot transgression. (This transgression, too, altered the shorelands in a hydrologically significant way.) With the exception of some minor seasonal fluctuations, the lake has been falling since 1986, and currently stands at ~6374 feet (Figure 2).

Climatic Context

The wetlands that fringe Mono Lake are sustained by surface- and/or groundwater that originates as precipitation in the surrounding hills and mountains, distant from the lake margin. At none of the wetland sites is the vegetation or the standing water maintained solely by on-site rain- or snowfall. Average annual precipitation totals in the immediate vicinity of the lake are meager, decreasing from approximately 12 inches along the west shore, to just ~6 inches in the northeast quadrant. Interannual variations in runoff are high, ranging from 25% to 220% of normal (Vorster, 1985). Climatic conditions had been abnormally dry for several years prior to 1929-30, when Fairchild Aviation produced the first aerial photographs of the basin. Conditions had been relatively wet for several years prior to 1940, when the first Forest Service photographs were taken, and prior to 1982, when the Forest Service produced the photos depicting the historic low stand.

Geologic Context

Over the past several million years, the mountains that encircle the Mono Basin have shed sediments from their slopes, partially filling the depression with perhaps 5000 feet or more of debris. Mono Lake and its shorelands occupy this basin-fill.

Toward the middle of the basin the fill is composed primarily of lacustrine silts and clays; near the basin margins these fine lake sediments interfinger with coarser alluvium, and with littoral sands and gravels. In a general sense, the fine sediments of the lake bottom (and former lake bottom) constitute aquitards that trap and impede the flow of water, while the coarser materials act as aquifers that convey water. Complications to this generalized scheme of groundwater conveyance and impedance do occur. A single lacustrine unit, for instance, may contain layers of airfall tephra that are capable of translating substantial amounts of water.

Hydrographic Context

Under natural conditions, five perennial streams feed Mono Lake. The three largest of these, Rush, Mill, and Lee Vining creeks, flow from their Sierran sources across glaciated bedrock, then through canyons cut into their highstanding, late Pleistocene deltas, then finally across their Holocene deltas, before reaching Mono Lake. The other perennial streams--Dechambeau and Post Office creeks--are relatively small. They flow from unglaciated bedrock canyons, then across alluvial fans, to the lake. Upon leaving the bedrock, all five of these streams loose a portion of their flow to the permeable alluvium that constitutes the walls and floors of their channels.

A number of other streams--most notably Wilson, Bridgeport, Rancheria, Rattlesnake, and Cottonwood creeks, but including other, unnamed, streams--flow ephemerally toward Mono Lake. Typically they wither into their permeable alluvial fans some distance above the lake, and so seldom reach the shoreline. A portion of the water lost to the ground by both the perennial and the ephemeral streams reappears as it nears the lake margin, creating wetlands (see below). The shorelands in the immediate vicinity of the creeks, particularly along the margins of the late Pleistocene deltas of Rush, Mill, and Lee Vining creeks, are thus particularly prone to groundwater flow.[1]

The water that sustains Mono Lake's wetlands comes not only from streams, but from diffuse runoff that enters the basin's alluvial fill from the surrounding mountains, and from the relatively minor amount of precipitation that falls directly on the fill. These groundwater sources sustain a high water table, if not actual wetlands, around much of the lake.

Geomorphic Context

While the climate and hydrography produce and deliver the water to the basin fill, and while the geology and stratigraphy dictate how the water is translated lakeward, it is the geomorphology (landforms, faults, shoreland gradients, etc.) that determines the nature, location, and size of the individual wetlands around the lake. A discussion of the different geomorphic factors that, individually or in tandem, influence the distribution of the Mono Lake wetlands, follows.

Shoreland gradients. The gradient of the shorelands that encircle Mono Lake plays an important role in the distribution, and particularly in the size, of the lake's marshlands and wet meadows. This is so for two primary reasons: First, to sustain such wetlands, the lands must not drain at a rate faster than the water can be supplied. Because steeply sloping lands tend to be readily and rapidly drained, freshwater marshes are most likely to form on gently sloping lands. Secondly, because the groundwater table typically rises toward the ground surface in the lakeward direction, and reaches the surface at or immediately upslope from the lake margin, low-gradient lands will produce a band of wet ground wider than that produced on steep lands, all other conditions remaining equal.

With the exception of a few sites (see below), the gradient of the lands that surround Mono Lake decreases in the lakeward direction. On the southern margin of the lake (specifically, at South Tufa), for example, the gradient of lands lying between elevations of 6420 feet and 6415 feet (that is, within the elevation interval occupied by the shoreline between the years 1938 and 1947), is approximately 56 feet per mile; it decreases to around 25 feet per mile in the elevation interval 6395-6400 feet (the interval occupied by the shoreline between 1959 and 1962), and to 12 feet per mile in the interval 6372-6375 feet (near the historical low stand of 1981-82, and where the lake stands today). These same intervals on the eastern side of the lake (at Warm Springs) are characterized by gradients of 42 feet per mile, 16 feet per mile, and 12 feet per mile, respectively; on the northern shorelands (near Bridgeport Creek) they decline from 14 feet per mile, to 12 feet per mile, to 6 feet per mile, respectively; and on the western shorelands (near the old County Marina) they decrease from 250 feet per mile, to 125 feet per mile, to 23 feet per mile, respectively. Thus, in a general sense, formation and maintenance of wetlands that owe their existence to a high water table (as opposed to, say, the ponding of surface water) have been favored as the lake has fallen to lower elevations in modern time (Stine, 1987).

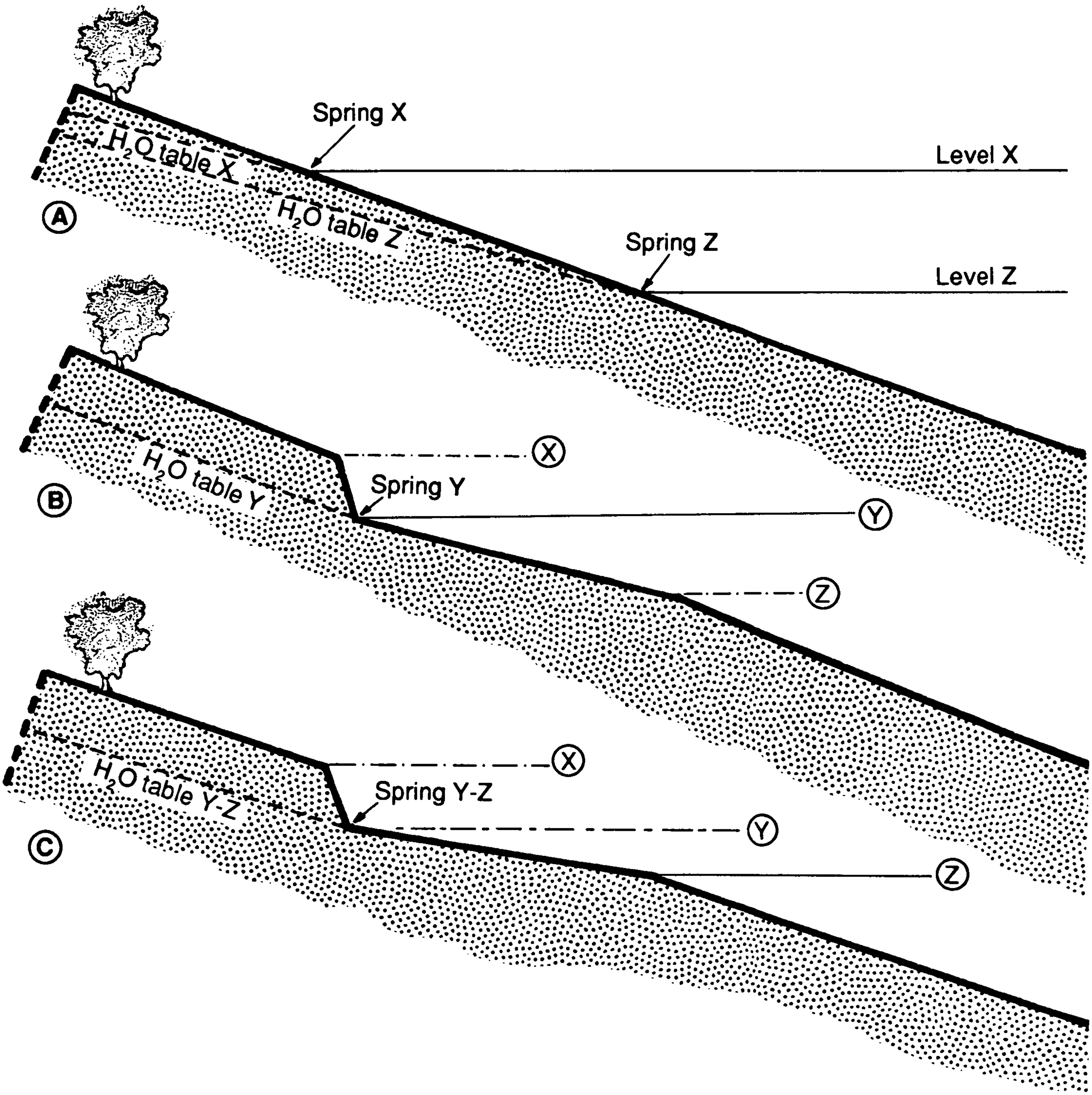
Delta gradients. The Mono deltas represent exceptions to the above-described generalization that shorelands flatten in the lakeward direction. Each of the main deltas (i.e. on Rush, Mill, and Lee Vining creeks) is characterized by a relatively low gradient (~1%) surface (the "delta plain") that extends lakeward to an elevation of ~6400 feet. At that level each delta plain gives way to steep (from ~8% to ~20%) surface (the "delta front") that extends deep into the lake. As long as the lake surface occupies the gently sloping delta plains, these features can maintain a high water table and support marshlands and lagoons. When the lake surface drops below the level of the delta plains, in contrast, the delta wetlands disappear, not only because the lake-supported water table follows the receding shoreline, but because the drop in lake level causes the streams to incise, creating a "delta trench" that saps the groundwater from both sides of the newly deepened channel (Stine, 1987).

Formation and Distribution of "Littoral Springlines". Energy exerted at the shoreline of a lake by waves and long-shore (littoral) currents is expended through the erosion, or the transportation/deposition, of sediment (littoral drift). Through either erosion or deposition, the shorelands over time assume a gradient that permits the most efficient transport of the given supply of littoral drift. Shorelands that are either at, or less than, the equilibrium gradient, and that are choked with drift, tend to be characterized by depositional processes. These result in the formation of berms and bars and, locally, the consequent development of lagoons (see below). Steeply inclined shorelands, and shorelands swept by "sediment-starved" currents, in contrast, tend to be characterized by erosional processes. In ways described in the following paragraphs, such erosion can give rise to "littoral springlines".

The amount of littoral erosion that occurs at the shoreline depends on, among other factors, whether the lake is rising or falling. A receding shoreline is capable of eroding only a narrow wave-cut platform, and thus, only a minor cliff. Width of the platform is limited because, as waves move across it toward shore, they expend their energy as frictional drag on its surface. Once the platform reaches some critical width, insufficient wave energy remains at shoreline to accomplish further backwearing of the cliff, and widening of the platform ceases. When the lake rises, in contrast, waves lose contact with the existing platform and batter the cliff, causing its retreat. The waves of a rising lake thus create a relatively broad platform that, depending on the erodibility of the substrate, may widen until the transgression ceases (Stine, 1987).

As shown schematically on Figure 3, erosion of a platform during a rise in lake level can result in the distal truncation of one or more water-bearing strata, thus creating springs or seeps at the cliffline. Where found at Mono Lake, littoral springlines can extend for thousands of feet along a contour. They are found, discontinuously, at five distinct elevations around the Mono shorelands. Each corresponds to a cliffline cut during a recent rise in lake level. The highest and most prominent of the five clifflines lies at 6428 feet, and was cut as the lake rose to its Historical High Stand of AD 1919. The second of the prominent clifflines (elevation ~6409 feet) was formed during the 1.5-foot transgression of 1952; the third (at 6402 feet) owes its existence to the 1.3-foot lake transgression of 1958; the fourth (at 6390 feet) to the 3.3-foot lake transgression of 1967-69; and the fifth and lowest of the prominent clifflines lies at an elevation of 6381 feet. It was cut during the transgression of 1982-86.[2] Littoral springlines characterize (or have historically characterized) each of these prominent clifflines over a substantial portion of their length.

Formation and Distribution of Faultline Seeps and Springs. The Mono shorelands are bisected in numerous places by faults. For two different reasons, the faults tend to be areas of springs and seeps. First, they can act as conduits along which water from deep lying, otherwise confined, aquifers can rise to the ground surface. Secondly, displacement along the fault can



Notes: In Block A, the lake, standing at Level X (and supporting H_2O table X and Spring X), falls to level Z (forcing a drop in both the water table and the spring). In Block B, the lake rises from Level Z to Level Y, carving a wave-cut platform and a cliffline. This raises the water table and the associated springline to H_2O table Y. When the lake again falls to Level Z, neither the water table nor the springline falls with it, since the cliffline continues to intercept the groundwater at Level Y.

Figure 3.
Creation of Clifflines and Springlines

result in the disruption of aquifer continuity, resulting in the "damming" of water-bearing strata at depth. This can cause springs to form not only along the ground break itself, but dozens or even hundreds of feet to either side of the break.

Along some of the shoreland faults, water issues from (or from near) the trace as a seep or spring. At others there is no apparent surface flow, though a band of relatively luxurient vegetation coinciding with the trace evidences the presence of abundant water.

Many of the shoreland faults are solitary features, constituting a single linear break; this type includes the ~dozen north-trending breaks that lie between the South Tufa Grove and Warm Springs along the lake's southern shore. Other faults occur in tightly packed groups that run parallel, and/or at an oblique angle, to one another (e.g. in the vicinity of the Lee Vining Tufa Grove).

In general, the springs that issue from the faults of the Mono shorelands are characterized by moderate temperatures. At a few sites (e.g. Warm Springs on the northeast shore, Hot-spring Cove on Paoha Island, and Hot Tower Spring on the north shore), warm- to hot water emanates from the faults.

Formation and Distribution of Lagoons. On relatively low-gradient shorelands around Mono Lake there is a tendency for wave- and current-transported sediments to accumulate at, and immediately above, the shoreline as elongate "littoral embankments" (e.g. hooks, barrier bars, and berms). Such embankments can impound water on their landward side, creating lagoons--ponds lying adjacent to, and typically in hydrostatic equilibrium with, the lake.

Deposition of littoral embankments is favored within particular elevation intervals, and in certain sectors, of the Mono shorelands. They are particularly well developed along the lake's northern shore, where the prevailing clockwise longshore currents transport massive amounts of gravel and sand eroded from the flanks of the Black Point cinder cone. These berms of Black Point cinder are restricted to elevations above 6400 feet (the elevation at which a declining Mono Lake withdraws from the flank of Black Point, thus cutting off the supply of volcanic sand and gravel to the longshore currents), and below 6436 feet (the elevation at which the Mono shoreline, immediately down-current from Black Point, takes an abrupt northward bend, forcing the longshore current to drop its load of cinder). It is behind these berms of the northern shorelands that Mono Lake's largest lagoons have historically occurred.

Smaller lagoons have formed historically on the plains of the Rush, Mill, and Lee Vining creek deltas. The impounding berms are composed of cobbles, gravels, and sands that were transported to the shoreline by the streams, then reworked by waves and longshore currents. At an elevation of 6400 feet, the low-gradient delta plains give way to high-gradient delta fronts, which are too steep to promote the formation of large littoral embankments. Berm formation on the deltas at elevations below 6400 feet is restricted to a small area at the stream mouth.

Littoral embankments (and thus lagoons) are relatively rare along other portions of the lake shore. Where they do occur, they are small, shallow, and highly ephemeral features, persisting only hours or days. Formation of berms in these other areas is hindered by steeply sloping shorelands, and/or feeble longshore currents, and/or a dearth of sediment supply (Stine, 1987).

3. Shoreline-Fringing Wetlands at Mono Lake, 1930-1982

Introduction

During the latter stages of the transgression that culminated in the Historical High Stand, the lake flooded lands that had not been inundated for three centuries (Stine, 1990a). The rising saline/alkaline waters quickly killed all newly flooded shoreland vegetation. By July of 1919, when the lake attained its high stand, a well-defined vegetation trimline encircled the lake, with trees, shrubs, or herbaceous growth standing landward of the shoreline, and bare ground (or at least ground devoid of living vegetation) to the lakeward. These barren grounds became exposed as the lake withdrew from its Historical High Stand.

In 1930 and 1940, the times depicted on the earliest aerial photos of Mono Lake, the newly exposed lands were being colonized locally by wetland vegetation. Also in evidence were extensive lagoons. In ways described below, these different wetland environments over the next half-century would change markedly in both extent and distribution. The following sections detail the history of the wetlands around Mono Lake.

Lagoons

Lagoons of the Northern Mono Shorelands. Early maps and photos of the Mono Basin show clearly that the lake's northern shore, from Rancheria Gulch to a point ~2 miles southeast of Sulphur Pond, was characterized by a discontinuous chain of lagoons dammed by a berm on their lakeward side. These lagoons fluctuated in size, growing during lake transgressions (and merging with the lake when the shoreline exceeded an elevation of 6436 feet, an event that has not occurred within historic time), and shrinking during lake recessions (and ultimately desiccating when the lake dropped below ~6405 feet). These lagoons were used extensively by waterfowl (Eldon Vestal, Wes Johnson, Don Banta, pers. comm., 1991).

The berm that impounds these north-shore lagoons has existed in its present form for at least 300 years, ever since Mono Lake withdrew from its "Clover Ranch High Stand" of ~1650 AD (Stine, 1987, 1990a). In all likelihood, another similar berm preceded the existing one in approximately the same location.

The confining berm has a crestal elevation of ~6436 feet. Its back (landward) flank is steep, and intercepts the low-gradient shoreland surface (the lagoon floor) at elevation ~6405 feet. Still farther landward, the ground again rises, this time onto the flanks of sand dunes (the "Generation-2 dunes" of Stine, 1987). The lagoons are thus "enclosed" by two highly permeable barriers--dune sand on the landward side, and littoral sands and gravels to the lakeward. This permits the lagoons to receive water from the landward direction, and, if the lake is above 6405 feet, from the lakeward as well. The water in the lagoons thus represents a brackish mixture of groundwater and lake water, a characteristic that is confirmed by early scientific reports,[3] and by the presence of brackish-water diatoms in the bottom sediments of the lagoonal depressions (P. Bradbury, USGS, pers. comm., 1991). The permeability of the confining walls also permits the lagoons to stay in rough equilibrium with the level of the lake.

The north-shore lagoons are shown on W.D. Johnson's topographic maps of the Mono Basin, produced during the Russell (1889) expedition of 1883 (lake level 6410 feet). They also appear on the United States Geological Survey topographic maps (1:125,000-scale) of 1898 (lake level ~6414 feet). The inner walls of the lagoonal depressions are inscribed with a subtle strandline at ~6428 feet, indicating that they, like Mono Lake itself, rose to that level in July, 1919. The lagoons are prominent features on the aerial photographs of 1929-30 (lake level 6421 feet) and 1940 (lake level 6418 feet)--years in which they constituted ~200 acres of standing water. These photographs were used as the basis for depicting the lagoons on Plate 1.

A steady decline in the size of the lagoons accompanied the artificially induced lake regression after 1940. By 1956 (lake level 6402 feet), when the USGS produced aerial photographs of the basin, the lagoons had desiccated. Since that time, they have existed only ephemerally, and as small and shallow water bodies, during the spring and early summer of high-runoff years.[4] To restore these lagoons of Mono Lake's northern shore to large and permanant features would require raising the lake to an elevation above ~6405 feet.

The "Dechambeau Lagoon". Approximately 1 mile northeast of Black Point (and approximately 1 mile southeast of the Dechambeau Hot Ponds) is another north-shore lagoon that differs in many ways from those described above. This lagoon (the "Dechambeau Lagoon") is impounded on all sides by berms and hooks. Its floor lies at ~6400 feet (and so becomes non-lagoonal when Mono Lake drops below that level), and it joins Mono Lake to create an embayment at a lake level of ~6412 feet. Von Schmidt (Stine, 1981, 1987) mapped this feature as a lagoon during his cadastral survey of the Mono Basin in 1857 (lake level ~6407 feet). W.D. Johnson did likewise in 1883 (lake level 6410 feet). During the late 1940s, following a period of inundation during which the lake rose to its Historical High Stand, the Dechambeau Lagoon reemerged. It remained lagoonal until the late 1950s, when the lake fell below the level of its floor.

Since 1960 this once-lagoonal depression has ephemerally held one to three small (~1 to 5-acre) ponds fed by precipitation and by seepage from the landward. This seepage may be at least partially artificial, resulting from the irrigation of the Dechambeau Ranch by water taken from the northeastern (artificial) distributary of Wilson Creek.

Restoration of the Dechambeau Lagoon would require raising the surface of Mono Lake to an elevation of between ~6400 and ~6412 feet.

Lagoons of the Mono Lake Deltas. Berms and bars were common features of the Mono deltas, though these embankments were far smaller in size (both in height and length) than their counterparts on the northern shore. The lagoons that these embankments confined on their landward flanks were therefore relatively small, and persisted for only a short period of time as the lake rose and fell. They also differed from the lagoons of the northern shore in that they were composed of fresh, rather than brackish water, being fed by the streams and by stream-induced groundwater (Lee, unpublished).

The aerial photographs of June, 1940 (lake level ~6418 feet) show actively building barrier bars impounding lagoons at or near the mouths of all the main tributary streams (Rush, Mill, Lee Vining, Wilson, and Post Office creeks). These particular features (see Plate 1) were exceptional for their size, reflecting the persistence of the lake at one elevation (6417-6418 feet) for a prolonged period of time. These same delta lagoons presumably continued to exist until 1947, when the lake began to fall in response to full-scale water diversions by the DWP. A series of lagoons formed on the deltas as the lake receded to 6400 feet, though these were smaller and less persistent than the lagoons at 6417 feet. The bars that enclosed the lagoons can still be seen on the deltas today.

By the late 1940s, the lagoons of the Rush Creek delta differed from those of the other deltas in that they had been artificially modified to provide duck-hunting grounds. According to Walter Dombrowski (unpublished notes and maps), who operated the hunting grounds, 12-and-a-half acres of artificially modified freshwater ponds lay on the delta to the west of Rush Creek, while 22 acres (plus an additional ~15 acres that he mapped, but for which he provided no areal estimate) lay to the east of the stream. These were fed by ditches that tapped Rush Creek. Areal extent and depth of the ponds were managed using a system of crude gates and spillways, a few of which can still be seen today on the delta.

Around 1960, Mono Lake fell to below 6400 feet. Both the recession itself, and the stream incision instigated by the recession, forced a drop in the water table on the deltas, thus draining the lagoons. Restoration of the delta lagoons would require raising the lake to an elevation above 6400 feet, thus elevating the shoreline onto the delta plains. Even if this were to occur, the lagoons would take many decades or centuries to reform, since the stream sediment required to build the confining bars would, for a prolonged period of time, collect in the newly embayed delta trench (the canyon cut into the delta by the incised stream), rather than being spread onto the delta plain as an embankment of drift. (Between 1982 and 1986, as Mono Lake rose 9 feet in response to abnormally high inflow, the lake embayed the mouths of the delta trenches. On Rush Creek, small bay-mouth bars formed across the stream mouth, creating a lagoon-like feature at the lower end of the trench. While such features will likely form at the stream mouths during future rises in lake level, they can be expected to be short-lived, filling with stream sediment within a few months or years.)

Wetlands in the Southeastern Quadrant of the Mono Shorelands

Introduction. The southeastern quadrant of the Mono shorelands, stretching from the 119th meridian in the south to the 38th parallel in the east, is characterized by numerous springs and seeps associated with a system of roughly 12 north- to northeast-trending faults, the best known of which is the "Simon's Springs Fault" (Plate 1). In some areas, water from the springs and seeps drains into shallow depressions (creating ponds), and/or becomes dammed behind berms (creating lagoons), and/or drains only slowly off low-gradient shorelands (creating conditions conducive to the formation of wet-meadows, alkali meadows, or marshlands). Such wetlands have characterized the southeastern quadrant of the Mono shorelands throughout historic time, though their size and configuration has changed markedly in response to the fluctuations of Mono Lake.

The source of the water that emanates from springs along the southeastern shore seems to be the precipitation that falls on the region between the Mono Craters and the Cowtrack Mountains. This water moves underground though the sediments that blanket the region, and reappears at fault- and cliffline-related seeps and springs. Sinclair (1988), based on limited data, noted a general correspondence between the height of the water table at Simon's Springs and the occurrence of local precipitation, suggesting, at least, a direct and simple link between the two.

The best known of the southeastern springs is "Sammonn's Spring", later called Sammon's Spring, later called Samman's Spring, now called Simon's Spring, located immediately west of the Simon's Springs Fault at a point just south of the north boundary of Section 7, T1N R28E. Its orifice stands immediately above the cliffline coinciding with the Historical High Stand of 1919 (elevation 6428 feet). In the discussions that follow, "Simon's Spring" is used in reference to this one spring orifice; "the greater Simon's Springs area" refers to the shorelands that lie within ~1 mile to the northeast of the Simon's Springs Fault, and within ~1.5 miles to the southwest of that fault (this latter area includes several individual springs, ubiquitous seeps, and, depending on the lake level, persistent and extensive wetlands.) Both these areas are included in the yet larger "southeastern quadrant" (see above).

Sediment-supply conditions along the lake's southeastern quadrant dictate that the prevailing counterclockwise long-shore currents erode in some areas (typically up-current of the fault traces) and deposit in other areas (down-current of the fault traces). As a generalization, erosional processes (i.e. cliff-cutting) dominates the southeastern quadrant; deposition prevails only locally, most notably at elevations below about 6400 feet in the small embayment that lies immediately southwest of the Simon's Springs Fault.

The earliest description of the southeastern quadrant appears in the unpublished survey notes of Von Schmidt. In 1856 (lake level ~6407 feet) he noted "grass and willows" at what was to become known as Simon's

Spring, and marked the position of the orifice on his survey plats with the word "spring". Russell (1889), in 1883, described and mapped the springs at "Sammonn's", and mapped three other concentrations of springs along the southwestern shoreline--one of them to the northeast (just east of the Simon's Spring Fault, and thus within the greater Simon's Springs area), and two to the southwest (the most southwesterly of which has come to be called "Willow Spring").

The southeastern quadrant in 1930-40. The lake transgression that culminated in the Historical High Stand (6428 feet) in 1919 submerged nearly all of the wetlands that have been known to exist historically in Mono Lake's southeastern quadrant. These lands reemerged during the following decades. By April of 1934 (lake level 6417 feet), when C.H. Lee (unpublished notes) visited this portion of the lake shore, Simon's Spring had been artificially modified to concentrate the flow and direct it to ponds excavated for duck hunting. He described Simon's Spring, and other springs and wetlands of the southeastern quadrant, thusly:

> Large flow from trench dug back into bank [the cliffline]. 10+ M.I. [miner's inches] flow.[5] Much water cress. Green grass below. Wide strip of grass all along lake shore here for some distance and several lagoons. Also a few tufa crags. Springs all along lake shore to [south]west for 3/4 mi. issuing in zone between 1919 lake shore [6428 feet] and present level [6416.6 feet]. Also scattered small springs and tufa crags beyond [southwest of] this for 1/2 mile.

True to Lee's account, the aerial photographs of 1930 and 1940 depict a narrow, discontinuous band of wetlands along the southeastern quadrant of the Mono shorelands (Plate 1). These consisted primarily of marshlands and vegetation-choked lagoons ponded behind one or more of the bars that had been deposited as the lake fell from its Historical High Stand. The wetlands were best developed immediately northeast of, and slightly southwest of, the Simon's Springs Fault (that is, in the greater Simon's Springs area), though a thin, discontinuous strand of marshland trailed toward the southwest within a few yards of the shoreline. While some of the water that fed these wetlands came from Simon's Spring proper, much of it appears to have flowed from the cliffline at 6428 feet.

Changes between 1940 and 1982. According to long-time residents of the Mono Basin, the Simon's Springs area was characterized by an extensive lagoon during the 1940s and early 1950s (Don Banta, pers. comm., 1991). This was likely ponded behind the berm that formed at the elevationally stable shoreline of 1938-1947 (elevation 6417 feet). This berm, no longer impounding a lagoon, persists today.

Aerial photographs show that by 1968 (lake level ~6387.5 feet) the distribution of wetlands along the southeastern quadrant had changed markedly. Most notably, the marshlands and lagoons present in 1930-40 have, by 1968, largely reverted to dry-meadow vegetation. Also absent on the 1968 photos is any sign of the littoral springline that had previously existed along the cliffline at the Historical High Stand.

Even more conspicuous on the 1968 photos are the new wetlands, far more extensive than those of the pre-1940 period, that had formed on the recently relicted shorelands along nearly the entire length of the southeastern quadrant. The upper (landward) boundary of these new wetlands is abrupt, and coincides with the cliffline that was cut at 6409 feet during the transgression of 1952. Clearly, the erosion that produced that cliffline truncated an aquifer, creating a littoral springline. This springline supported a wide (typically 500 feet, but up to 3000 feet) band of marshland that stretched continuously from Warm Springs south- and westward to near Dry Creek; from there it extended discontinuously southwestward for ~1.5 miles. Henceforth this will be referred to as the springline of 1952.

The 1968 photos also depict a second recently-formed vegetation band lying lakeward of the first. This lower band, the upper boundary of which corresponds with the cliffline cut at 6402 feet during the 1.3-foot transgression of 1958, is limited to the area immediately southwest of the Simon's Springs Fault. It likely formed due to the creation of a littoral springline at the newly cut cliff. It is referred to as the springline of 1958.

The aerial photographs of August, 1973 reveal further notable changes in the wetlands of the southeastern quadrant. Most importantly, the 3.3-foot rise in lake level that occurred between 1967 and 1969 had left a blatant strandline at an elevation of 6390 feet around much of the lake, including the entire length of the southeastern quadrant. In the small embayment immediately southwest of the Simon's Springs Fault the transgression is marked by a ~1- to 2-foot-high berm that impounded (and continues to impound) water to the landward. Elsewhere along the southeastern quadrant, the strandline at 6390 feet takes the form of a bold cliffline. On the 1973 photos, seeps can be seen emanating from this cliffline along much of its length. Hereafter, this feature is referred to as the 1969 strandline (also, as appropriate, the 1969 cliffline, or the 1969 berm).

In early October of 1982 (lake level 6372.7 feet) the U.S. Forest Service produced yet another set of aerial photographs of Mono Lake. These can be taken to represent the condition of the shorelands at the time of the lake's historic low stand (6372.0 feet in January of 1982). These aerial photos, in combination with the USGS provisional Mono Mills Quadrangle (1:24,000), were used in the preparation of Plate 1 to delineate the 1982 wetland boundaries of the southeastern shorelands.

By 1982 the lake margin had retreated far from the 1969 strandline, greatly increasing the amount of relicted shoreland along the southeastern quadrant. These lands are of extremely low gradient (as low as 0.1%). Active springs emit water from several orifices, and water stands at high levels in duck-blind pits, indicating a high water table.

Despite the many years that wetland vegetation had had to colonize these newly relicted lands, and despite an abundance of standing water, vegetation is lacking over much of the newly exposed acreage, particularly at the lowest elevations. The reason for this may well be that these extremely low-gradient, lake-marginal lands are wicking lake water, creating soil salinities and alkalinities too high to support plant life. The presence of an ephemeral salt crust on much of these lands supports this hypothesis.

The 1982 photos also show changes in those wetlands that had developed during previous decades. Most notably, the band of marshland that formed at the base of the 1952 cliffline had, over most of its length, reverted to dry meadow by 1982. Only in the greater Simon's Springs area, and at a few highly locally sites along the base of the 1952 cliffline, did wetland persist in 1982.

Changes between 1930-40 and 1982: Summary and conclusions. The southeastern quadrant of the Mono shorelands is a geomorphologically and hydrologically complex area that has a complicated modern history. In order to draw generalizations and distil tenets from the information presented above, it is advantageous to separate the Greater Simon's Springs area from the southeastern shorelands that lie to its northeast and southwest. Regarding these other shorelands:

1. Except in the immediate vicinity of fault-related springs, the falling lake exposed lands that were not readily colonized by marshland vegetation. Only when the overall regression was punctuated by minor rises that created platforms and clifflines (thus, littoral springlines), were areas created that were condusive to colonization by marshland vegetation.

2. Marshlands that formed at high elevations on the newly relicted shorelands desiccated as the lake fell to lower elevations. In all likelihood, this was due to one (or both) of two factors:

a. The drop in lake level forced the water table to drop to deeper levels, thus resulting in the desiccation of the wetlands;

b. Each individual springline continued to issue water only as long as it was the highest springline. The cutting of a second cliffline (thus, a second springline) at an elevation lower than the first sapped the higher springline, and any marshland it supported, of water.

3. On extremely low-gradient lands such as those lying below an elevation of ~6380 feet, marshland formation at most sites appears to be precluded by high salinities/alkalinities that, it seems, result from the wicking of lake water by the sediments. Only where springs actively emit freshwater in amounts that can flush the solubles do vegetated wetlands form.

Regarding the changes in the wetlands at the Greater Simon's Springs area:

1. Because of an abundance of water in the Greater Simon's Springs area, relicted lands were more readily colonized by vegetation as the lake fell.

2. Despite the abundance of water, wetlands on the high-gradient lands above ~6408 feet did, with local exceptions, desiccate as the lake fell. This was likely due, in large part, to a lake-regression-induced drop in the water table; sapping of upland water by cliffline formation may also have played a role in this desiccation.

3. In general, conditions in the Greater Simon's Springs area are most condusive to wetland formation and maintenance on lands lying between ~6408 feet and ~6378 feet. In this area shoreland gradients are moderately low (favoring the retention of standing water), and spring sites are abundant.

4. In general, lands lying between elevations of ~6378 feet and ~6372 feet are characterized by very low gradients, and are colonized only at sites where freshwater is abundant. Elsewhere within that elevational band, vegetation colonization proceeds slowly if at all, perhaps because of high soil salinities and alkalinities.

Wetlands in the "Greater Warm Springs Area"

The "Greater Warm Springs area", as used here, constitutes those eastern shorelands of Mono Lake that lie between latitudes of 38° and 38° 2' 42". It encompasses several sites that, throughout historical times, have supported wetlands. Like the Greater Simon's Springs area, the abundance of springs and seeps at the Greater Warm Springs area is in general due to the presence of a fault system (the Warm Springs Fault--see Plate 1). Like the Simon's Springs area, the seep- and springwater seems to be derived from local precipitation. Water table fluctuations bear a general correspondence to local precipitation occurrences (Sinclair, 1988).

In 1856 (lake level ~6407 feet), Von Schmidt (unpublished) mapped springs, ponds, and willows at several sites along this section of shore. Russell (1889) described Warm Springs in 1883 (lake level 6410 ft), and provided a chemical analysis, a temperature estimate (80° to 90° F), and an estimate of discharge (10 gal/min). When Charles Lee (unpublished) visited the site in 1933 (lake level 6417.5 feet) the shoreline had regressed ~10.5 vertical feet from its Historical High Stand. He found "numerous small springs and seepages of fresh water issuing from 1 to 5 feet above lake level".

The wetlands of the Greater Warm Springs area that appear on the aerial photos of 1930 and 1940 are shown on Plate 1. During that decade they were restricted to a narrow band that lay between the Historical High Stand (6428 feet) and the existing shoreline (6417-6421 feet). The largest of these wetlands centered immediately north of the Warm Springs Fault. It occupied a shallow embayment that was isolated from Mono Lake by a succession of bay-mouth berms that were deposited as the lake fell from its historic high stand. The water that fed this marshland seems to have emanated from the base of the cliffline that coincides with that high stand. To both the north and south of this marshland other, smaller, wetlands (apparently marshlands) were forming immediately upslope of berms in 1940.

Changes between 1940 and 1982. The evolution of the wetlands in the Greater Warm Springs area is in many ways similar to that of the Greater Simon's Springs area. Clifflines with associated springlines were formed during the brief lake rises of 1952 (at 6409 feet), 1958 (at 6402 feet), and 1967-69 (at 6390 feet). Marshland vegetation colonized (and in many places still persists) at each of these springlines. There has been an overall tendency of the higher marshlands to partly or wholly desiccate as the lake fell to lower elevations, either because of a recession-induced drop in water table, or because of sapping of existing springs by a lower, newly formed springline.

By 1982, wetlands in the Greater Warm Springs area were as depicted on

Plate 1. While most of the marshlands that had been present in 1940 had reverted to meadow by 1982, wetland area had, overall, increased by a factor of perhaps 15.

Another characteristic shared with the Greater Simon's Springs area is the near absence of wetland vegetation on the low-gradient lands that lie lakeward of the 1967-69 cliffline. Only immediately below that cliffline, where an abundance of springwater is available to flush the saline/alkaline compounds, and at a handful of small (<1.5 acre) highly localized sites flushed by springs, had wetland vegetation in 1982 colonized the low-gradient lands below 6390 feet.

The North-Mono Shorelands

The "North-Mono shorelands", as defined here, constitutes the ~12-mile stretch of relicted shoreland that extends from the Greater Warm Springs area in the east, to Rancheria Creek in the west. It is along this stretch that the clockwise littoral currents of the northwest Mono shore collide with the counterclockwise currents of the northeast shore. At any given point along the north-Mono shorelands the currents vary through time from clockwise to counterclockwise.

As previously noted, the North-Mono Shorelands were characterized by extensive lagoons that formed on the landward side of high berms above ~6400 feet. In 1930-40 no other wetlands were found on this stretch of shore (Plate 1).

Aerial photos show that by August of 1973 several individual marshlands had formed on the newly exposed lands of the northern shore. Predictably, each of these lay at the base of one of the three conspicuous clifflines/ springlines (at 6409, 6402, and 6390 feet). Most were concentrated near the western extremity of the North-Mono Shorelands, in the vicinity of Bridgeport, Cottonwood, and Rancheria creeks. It is suspected that subsurface flow associated with these ephemeral, withering streams accounts for the presence of these wetlands.

During the ensuing 9 years, the distribution and configuration of the wetlands along the North-Mono Shorelands changed little, though some areas that were previously marshland may have reverted to seasonally wet meadow. Thus, by 1982 (Plate 1), there had been no further colonization by wetland vegetation on the hundreds of acres of newly exposed northern shorelands. While springs and seeps (typically associated with the above-noted littoral springlines) are abundant on these lands, they support little vegetation, perhaps because of the salinity and alkalinity of the groundwater along the central and eastern portions of the north shore (Sinclair, 1988).

Wetlands of the Dechambeau Ranch Embayment

Immediately northeast of Black Point, the shoreline of Mono Lake describes a subtle embayment. This "Dechambeau Ranch Embayment" is a down-dropped block bounded on both its eastern and western sides by faults. The western of these faults runs through, and is the conduit for, the thermal springs that feed the artificially created "Dechambeau Hot Ponds"; the eastern fault coincides with the lower portions of Rancheria Gulch. During the decade prior to water diversions by the DWP, the shorelands at the mouth of the Dechambeau Ranch Embayment appear on aerial photos to have been devoid of wetlands. While it seems likely that seepage occurred along a narrow band immediately upslope of the shoreline, the relatively steep gradients of the shorelands, and the highly porous volcanic cinder that composed them, precluded any significant development of wetland vegetation.

The aerial photos of September, 1956 (lake level 6402.5 feet) show a discontinuous band of marshland or wet meadow along the shorelands of the Dechambeau Ranch Embayment that coincide with a cliffline/springline at approximately 6409 feet (the strandline cut during the lake transgression of 1952). These wetlands persisted through 1968 (as evidenced on the aerial photos of that year), though they appear to have remained narrow, and not grown downslope as Mono Lake fell.

The lake transgression of 1969 created another cliffline and springline along the Dechambeau Ranch Embayment. The aerial photos of 1982 show clearly that as of that year, this lowest springline, as well as several individual spring orifices below the springline, continued to issue water and support wetland vegetation. As of 1982, portions of the linear wet meadow that had earlier characterized the cliffline at 6409 feet had reverted to dry meadow, presumably due to a lake-regression-induced drop in water table, or to sapping of groundwater by cliff formation to the lakeward. As at most places around the northern and eastern sides of Mono Lake, the wetlands in 1982 did not extend to the lake margin. The low gradient lands below approximately 6380 feet, characterized by a crust of salts, supported vegetation only in the immediate vicinity of individual spring orifices.

The presence of wetlands in the Dechambeau Ranch Embayment may well be due largely to irrigation of the lands in the vicinity of Dechambeau Ranch. Since before the 1880s, water from Wilson Creek (a stream made artificially large by the addition of Mill and Virginia creek water--see below) has been diverted down an artificial channel to the east of Black Point and spread onto the porous sediments of the ranch lands. It seems likely that the wetlands of the Dechambeau Ranch Embayment would be far smaller in the absence of the irrigation.

The Wilson Creek Wetlands

Under natural conditions, Wilson Creek was a small, ephemeral stream that drained the Bodie Hills. In the mid-1850s it entered Mono Lake immediately west of Black Point (Von Schmidt platts and notes; see also Clayton's "Map of Esmeralda and Mono" in Stine, 1981 and 1987). By the early 1880s at least a portion of the Wilson Creek flow had been diverted to the north and east of Black Point for irrigation (Russell, 1889). In what follows, the term "Wilson Creek" is used only in reference to the stream's natural course west of Black Point.

During the early decades of the 20th century, and perhaps even earlier, Wilson Creek was artificially enlarged by the addition of water from Mill and Virginia creeks. This augmentation, perhaps in concert with the lowering of Mono Lake, caused Wilson Creek to incise dramatically. Whereas the aerial photographs of 1930 show the natural course of Wilson Creek to be perhaps 5-8 feet deep and crossable by car (a road transects the channel), by the early 1960s it had been incised to a depth of more than 40 feet (the old road can still be seen in the field today, terminating at the shear, 40-foot-high cliff on either side of the canyon). The sediment excavated during this episode of incision is spread over the Mono shorelands to the lakeward, and to either side, of Wilson Creek. It constitutes a lobe of coarse, permeable deltaic alluvium that varies from one to several feet in thickness.[7]

In 1883 Russell visited, studied, and photographed the shorelands in the vicinity of the Wilson Creek mouth. He apparently found no springs or seeps above the shoreline (then 6410 feet) in this vicinity, though he described plumes of spring water rising to, and roiling, the lake surface offshore. To the extent that springs were indeed absent above 6410 feet in 1883, as inferred from the Russell account, the series of aerial photos taken between 1930 and 1982 would suggest that springflow has increased during modern time, perhaps due to the artificial augmentation of Wilson Creek. As described below, these photos show that wetland vegetation formed over much of the Wilson Creek shorelands as the lake dropped from its 1940 position to the Historical Low Stand.

By the time the aerial photos of June 1940 (lake level 6417 feet) were taken, a narrow band of willows and other wetland vegetation had become established near the mouth of Wilson Creek at the cliffline coinciding with Mono Lake's Historical High Stand (6428 feet). By 1956, not only had this band of vegetation widened, thickened, and lengthened, but lands further lakeward, newly exposed by the ongoing drop in lake level, had been colonized by wetland vegetation. To the east of Wilson Creek these new wetlands appear to have been marshland. Their landwardmost extent was the cliffline (and coinciding springline) associated with the lake transgression of 1952. To the west, they were either marshland or wet meadow, or a combination of the two. These west-side wetlands extended upslope to the cliffline at 6428 feet.

During the ensuing two-and-a-half decades, wetland formation on the newly relicted lands at the mouth of Wilson Creek continued as the lake fell to lower elevation. It was checked, however, by the ongoing deposition of coarse deltaic alluvium at the mouth of the stream. This alluvium composed a substrate unfavorable to colonization by wetland vegetation. Only beyond the eastern and western margins of this blanket of coarse sediment could wetlands of significant size become established.

The distribution of wetland vegetation that existed at the mouth of Wilson Creek in 1982, shortly after the lake attained its historic low stand, is shown on Plate 1. Note that, close to the creek mouth, it extends nearly to the lake shore, suggesting the presence of water in amounts sufficient to leach the soluble compounds that preclude vegetation colonization elsewhere.

Wetlands of the Western Embayment

The Western Embayment constitutes the westernmost shore of Mono Lake, stretching from Dechambeau Creek in the north to the area around the now-stranded Mono County Boat Launch in the south. The strong waves and currents that control depositional and erosional processes around most of the Mono shorelands are rare in this sheltered sector of the lake, making wave cut- and wave-deposited shoreline features much less prevalent than elsewhere.

The area is watered by several named and unnamed streams that drain the Sierra Nevada. For ease of discussion, the Western Embayment is divided into three areas: the Dechambeau Creek wetlands, the wetlands of the Sierran escarpment, and the wetlands of the County Marina.

The Dechambeau Creek wetlands. The Dechambeau Creek wetlands lie adjacent to the northwesternmost corner of Mono Lake. Dated tufa towers aligned along faults that run roughly parallel to the shoreline provide evidence that springs have been active in this sector for nearly 1000 years (Stine, 1987). Under natural conditions the source of water for these springs is likely Dechambeau Creek, a small perennial stream that drains a largely unglaciated watershed on the Sierra's eastern flank. Because the stream's drainage basin was not stripped of its alluvial and colluvial cover by ice during latest Pleistocene time, streamflow varies relatively little through the year.

Since the middle of the 19th century farmers have spread Dechambeau Creek water over the lands adjacent to the northwesternmost corner of Mono Lake (the lands long called the "Thompson Ranch"). Since early in this venture, Dechambeau Creek has been supplemented by water from Mill Creek. As a result of this artificial manipulation, then, surface water (and likely groundwater as well) in the northwesternmost shorelands of Mono Lake has historically been in greater abundance, and more widespread, that was the case under natural conditions.

Aerial photographs from 1930 and 1940 show that the narrow band of land exposed as Mono Lake dropped from its Historical High Stand was quickly colonized by marshland and wet meadow. This same pattern--rapid colonization by wetland vegetation of newly relicted lands--is evident on aerial photos from 1955, '56, 68, '72, '77, and 1982. To an extent greater than at most other sites on the Mono shorelands, there seems at the Dechambeau Creek wetlands to be little lag between the time lands are relicted and the time that they are colonized by vegetation. The vegetation pattern evident at the Dechambeau Creek wetlands in 1982 is shown on Plate 1.

<u>Wetlands of the Sierran escarpment</u>. Between Dechambeau Creek and the County Boat Launch the Sierran escarpment is cut by a half dozen deep ravines that, ephemerally or perennially, feed water to Mono Lake. Each of

these bedrock ravines looses some or all of its surface flow to the porous alluvial fan that lies at the canyon toe. A portion of this lost water reemerges near the lake shore as springflow, and supports a band of wetland vegetation. Unlike many other sites along the western shorelands of Mono Lake, the hydrology of the escarpment lands described here remains in a natural to virtually natural state, unaffected by agricultural or municipal water diversions.

As the lake receded from its Historical High Stand (6428 feet) after 1919, the zone of shoreline seepage along the relicted portion of the escarpment spread further lakeward, fostering wetland development in many areas. Locally, however, colonization by wetland vegetation during these early years was precluded by the formation of beachrock--coarse sediments (often cobbles and boulders) that, because of their immobility, become cemented with a matrix of tufa, forming a thick, concrete-like slab (Stine, 1992a). A narrow, vegetation-free band of beachrock characterizes the steeper portions of the escarpment between elevations of 6428 feet and approximately 6385-90 feet. Below that level the sediments are finer, a factor that permits them to be agitated by waves, thus preventing beachrock formation. On these high-gradient lands, then, wetland vegetation is largely restricted to lands lying below ~6385 or 6390 feet.

On the flatter portions of the relicted lands of the escarpment (e.g. immediately west and south of Dechambeau Creek) beachrock developed only locally during the early stages of the modern lake regression. As a result, the wetland pattern is the opposite of that on the steeper lands: vegetation has colonized the higher elevations (above ~6400 feet), and is largely absent on the lower, generally flatter lands, presumably due to high salinities and alkalinities. Only on the immediate margins of the small streams that traverse these lowest-gradient lands has wetland vegetation found a hospitable habitat.

The aerial photos of 1930 and 1940 show that, where beachrock was absent, wet-meadow- and marshland vegetation was quick to colonize the newly relicted lands of the Sierran escarpment. The same rapid colonization is evident on the photos of August, 1954 and July, 1968. The wetlands that existed in October of 1982 are shown on Plate 1.

Wetlands of the "County Marina". The steep and narrow relicted lands of the Sierran escarpment flare to the southward beginning at the Mono County Boat Launch, creating a broader, generally flatter area referred to as the "County Marina". Since before 1898 the lands immediately above the Historical High Stand in this area were irrigated with Lee Vining Creek water by way of the "Ney Ditch" (Stine, 1991; USGS 1:125,000-scale Mt. Lyell Quadrangle, 1898). On aerial photos of 1930 and 1940 the newly relicted shorelands are covered with wetland vegetation everywhere except where beachrock has developed. How much of the non-beachrock land would have been wetland in the absence of the irrigation is not known, though much of it reverted to scrub and dry grass shortly after irrigation of the Ney-ditch lands ceased in 1952. Thus, by the time aerial photos were taken in August, 1954 (lake level 6406 feet), only small patches of wetland were evident, and these were restricted to the far eastern, and west-central portions of the marina lands. Between 1954 and 1968 (lake level 6387.5 feet) these two patches had grown lakeward slightly, and several new springs, having recently emerged from the lake, were were supporting small patches of wetland vegetation. There appears on aerial photos to have been little lakeward spread of any of these patches between 1972 (lake level 6385.5 feet) and 1975 (lake level 6379.5 feet). Indeed, the largest patch of wetland (the previously mentioned patch near the center of the Marina) appears somewhat desiccated on the photos of 1975. By 1982 this largest patch of former wetland is covered by dense, but dry, meadow.

Colonization by wetland vegetation of lands that emerged between 1968 and 1982 was restricted to highly localized sites, with wetland vegetation covering tiny patches totaling perhaps 5% or less of the newly relicted ground. The distribution of wetlands in 1982 is mapped on Plate 1 (no attempt was made to map the tiny wetland patches that appeared between 1968 and 1982).

Non-Lagoonal Wetlands of the Lee Vining Creek Delta

Aerial photos from 1930 and 1940 show that on portions of the Lee Vining delta--specifically the area immediately north and west of lowermost 2000 feet of channel--the stream's delta was covered by wet meadow or marshland. At least a portion of this land was watered by a small, unnamed irrigation canal that bifurcated from Lee Vining Creek near its mouth.

The dewatering of the stream, and the cessation of irrigation diversions, quickly eliminated this wetland--it is not evident on photos taken during or after August of 1954. This was presumably due to a lowering of the water table due to the elimination of groundwater recharge. The water table was further lowered due to the incision of Lee Vining Creek in the late 1960s and early 1980s.

Wetlands of the Lee Vining Tufa Grove

The Lee Vining Tufa Grove, as defined here, occupies the shorelands between the mouth of Lee Vining Creek and the Horse Creek Embayment. The existence of tufa towers as old as 900 years along this portion of the shore indicates that it has long been an area of groundwater emergence. The springs and seeps are concentrated along the more than one dozen faults that cut the shorelands in this area. Under natural conditions the likely source of the spring water is the upper alluvial reaches of Lee Vining Creek. Irrigation of lands near the present-day airport, underway by late last century, continued through 1970. This irrigation may have temorarily increased the flow of the springs at the Lee Vining Tufa Grove.

Russell's maps (1889) indicate that springs were flowing at the then-shoreline (~6410 feet) in the Lee Vining Tufa Area in 1883. The aerial photos of 1930, 1940, and 1954, taken during the early stages of the modern regression, show that most places on the narrow strip of newly exposed lands had been quickly colonized by wet meadow as the lake fell.

This same pattern continued through 1968, though an increasing percentage of newly exposed lands was covered by tufa and was thus incapable of supporting wetland vegetation.

It is clear from the aerial photos that by 1972 (also evident on the photos of 1973 and 1975) the wetlands were growing lakeward onto newly exposed lands at the expense of previously existing wetlands at higher elevations. Thus, whereas the upper edge of wetland vegetation extended to somewhere between 6417 feet and 6428 feet in 1954, its highest edge stood at approximately 6390-6400 feet by 1975. Continued lakeward expansion of wetlands on newly relicted lands, and transformation of previously existing wetlands to dry meadow and scrubland at higher elevations, continued through 1982. The wetlands that existed in 1982 are shown on Plate 1.

Wetlands of the "Horse Creek Embayment"

The Horse Creek Embayment is the ~2-mile-long bight in the Mono shoreline that lies between the Lee Vining and Rush Creek deltas. The ephemeral "Horse Creek" reaches Mono Lake at the center of the embayment.

By late last century the drainage basin of Horse Creek (called "Gibbs Creek", or "Gibbs Canyon Creek" on some old land-use maps) had been hydrographically modified to irrigate nearby lands.[6] Lee Vining Creek water was conveyed to the Horse Creek basin by way of "H-ditch", which fed both the "Roger's ditch" (thus irrigating lands near the present-day airport) and the "Cremasco-Mattly ditch" (irrigating the Mattly lands at ~6800 feet in the Horse Creek Embayment, and the Cremasco lands farther lakeward). Because of the H-ditch diversion, the Horse Creek Embayment was wetter, and the shoreland wetlands were likely more widespread, than would have been the case under natural conditions. Indeed, as discussed below, the discontinuation of H-ditch diversions in 1970 seems to have coincided with the disappearance of most of the previously existing wetlands.

The 1930 and 1940 aerial photos show that, particularly in its western half, where beachrock was rare, the Horse Creek Embayment below an elevation of 6455 feet (the "Clover Ranch High Stand" of Stine, 1990a) was dominated by wet meadow or marshland. Wetland seems to have been less well developed in the eastern half of the embayment, though it still dominated the ground cover.

In addition to this more or less continuous cover of low-lying wetland vegetation were two dense stands of trees and shrubs (which, based on modern examination, were likely dominated by willows and buffalo berry) that grew in association with springs in the western and central portions of the embayment. According to eyewitness accounts (Dondero and Banta, pers. comm., 1991) flow from these springs was "vigorous" and "copious". Lakeward-flowing rills associated with the springs can be seen on the 1930 photos.

In the course of the 30-foot lake regression that occurred between 1940 and 1968, beachrock formation prevented the lakeward spread of wetland vegetation onto newly relicted lands of the Horse Creek Embayment. The previously existing wetlands continued to thrive, however, as did the previously existing springs and spring-fed woodlands. This condition is evident not only on the aerial photos of 1968, but on the intervening photos of 1951, 1954, and 1956 as well.

In 1970, as the DWP began operating their "second aqueduct barrel", diversion of Lee Vining Creek water into the Horse Creek Embayment by way of H-ditch ceased. According to long-time residents of the Mono Basin, it was at this time that the once-vigorous springs of the embayment stopped flowing (Dondero and Banta, pers. comm., 1991). Aerial photos from 1972, '73, and '75 seem to show an overall decline in the distribution of wetland vegetation, with dry meadow or shrubs expanding at the expense of the more hydrophytic species.

The 1973 and '75 photos show the beginnings of a strip of wetland vegetation forming at the shoreline (the upper edge of this vegetation follows a contour at elevation ~6384 feet). The reason for the formation of wet meadow at this elevation is not known, though it may be related to a decrease in the size of the long-shore drift, and thus in a cessation of beach-rock formation. Wetland vegetation continued to colonize this newly relicted strip through 1982. It is mapped on Plate 1.

Non-Lagoonal Wetlands of the Rush Creek Delta

The history of the non-lagoonal wetlands of the Rush Creek delta closely parallels that of Lee Vining Creek, except that the wetlands at Rush Creek may have persisted somewhat longer before being transformed to shrublands. Naturally occurring wetlands are evident not only on the 1930 and 1940 photos, but, in a somewhat diminished state, on the photos of 1951 and 1954 as well. By the time the aerial photos of 1968 were taken, the water table on the Rush Creek delta had been lowered dramatically due to the stream incision of the previous year. Those photos show a delta surface that appears nearly barren of vegetation. By 1982 shrubs covered the delta surface.

Wetlands of the South Tufa Area

The "South Tufa Area", as defined here, encompasses not only the associated grove of tufa towers (the "South Tufa Grove"), but also the marshlands, springs, and wet meadows that lie within a half-mile to the east, and a quarter mile to the west, of the grove.

The South Tufa Grove is peculiar in that, unlike most of the existing tufa groves around the lake, there is little or no water emanating from the bases of most of the tufa towers. Given that the towers are shallow-rooted and exceptionally young (having apparently formed near the beginning of this century), and that the springs that must have existed at the base of the towers are now extinguished, it seems reasonable to suggest that the springflow that instigated tower formation was an artifact of irrigation of the Pumice Valley lands by A-ditch and B-ditch (Stine, 1992b). These diversions began early in this century. They were curtailed in the late 1940s, then reestablished at a much reduced rate in the early 1950s, only to be permanently abandoned in the late 1960s. Groundwater flow to the South Tufa Area may thus have varied markedly during the period from 1930 to the present.

Neither the von Schmidt platts nor the Russell maps indicate spring activity in the South Tufa Area. Similarly, the 1930 aerial photos show no evidence of wetlands in the area, though littoral and sublacustrine springs may well have been active at this time. On aerial photos from 1940 (lake level 6418 feet), 1951, and 1954 (lake level 6405.5) a series of small bars constrain narrow wetlands at the site. Bars do form in this vicinity, it it may be that lagoons charaterized the area.

The lake transgression of 1967-69 cut a cliffline at the South Tufa Area. While this feature was small, and seems to have exerted little influence on wetland formation at the South Tufa Area itself, it did create a springline immediately east of the area, where, for at least several years, wet meadow covered the site. That strip of wetland has reverted to dry meadow, presumably in response to the continued lowering of Mono Lake.

The photos of 1968, 1972, 1973, and 1975 show growth (due to the emergence) of the peninsula that is made up of the main concentration of towers at the South Tufa Area. While there seems to be no wetlands associated with the peninsula itself, the small embayments to both its east and west appear to be supporting an increasing area and density of wetland vegetation. Locally at least, these wetlands persisted and grew through 1982 (Plate 1), fed by local seeps and springs. Particularly to the west of the main concentration of towers, the wetlands are conditioned by the low berms that act as dams, confining the water to a greater extent than would be the case in their absence.

Wetlands of Paoha Island

Unlike Negit Island, which is essentially waterless,[8] Paoha Island has been characterized historically by wetlands at several different sites. These wetlands include ponds that occupy slump scars on the island's western flank ("slump ponds"), ponds that occupy the bottom of volcanically induced depressions on the island's northeastern and south-central flanks ("volcano ponds"), and marshlands and wet meadows that developed above "Hot Spring Cove" on the island's southeastern flank.

Slump ponds of Paoha Island. A half-dozen small depressions on Paoha Island's western flank have held water at times since 1930. The largest of these lies at a level just above the Historical High Stand (6428 feet). It seems to have been in hydrostatic equilibrium with Mono Lake when Mono stood at high levels. Thus, even during dry times (e.g. January of 1930, when the Fairchild aerial photos were taken) the pond contained water. As Mono Lake fell during subsequent decades, the pond was no longer supported by the lake, and, like all of the other slump ponds on the island, it became an ephemeral feature, holding water only during times of high precipitation and runoff (e.g. during 1982).[9]

Volcano ponds of Paoha Island. The northeastern corner of Paoha Island is made up of a complex of coalescing cinder cones. Aerial photos show that three of these features held small ponds until sometime between 1956 and 1968. Like the largest of the slump ponds described above, these volcano ponds were supported by, and in fact were composed of water from, Mono Lake. Desiccation of these volcano ponds occurred when Mono Lake fell below an elevation of approximately 6395 feet (thus, around 1961). Since that time, surface water has not collected in the cones, presumably due to the high permeability of the cinder that composes the cone floors.

An additional volcano pond characterized the south-central flank of Paoha Island. It differed from the others in that it occupied the bottom of a solitary explosion crater, rather than the floor of a cinder cone. The history of this solitary feature closely parallels that of the "cinder ponds": it remained inundated as long as Mono Lake stood above a critical elevation (in this case, approximately 6412 $\pm$6 feet), and desiccated when the lake fell below that level.

The wetlands of Hot Springs Cove. The transgression of Mono Lake that culminated in the Historic High Stand (6428 feet) of 1919 carved a well-defined platform and cliffline onto the flanks of Paoha Island. In the vicinity of Hot Spring Cove, that cliffline has remained an active springline since 1919, supporting a widening band of wet- and dry meadow and marshland on the relicted platform. The lake transgression of 1967-69 carved a new platform and cliffline/springline at the foot of the old platform, so that by 1982 the shorelands in the vicinity of Hot Springs Cove were composed of two steps, both of which had an active springline at their upper edge.

The history of colonization of the Hot Springs Cove platforms by vegetation can be reconstructed from aerial photos. This reconstruction is limited, however, because it is difficult to differentiate between wet meadow and dense dry meadow on most of the photos. The history proceeded as follows: By 1940 (lake level 6418 feet) there are hints of wetland(?) vegetation along the very thin strip of relicted land. This band of vegetation widened, but did not keep pace with the declining shoreline, between 1940 and 1954 (lake level 6406 feet). Over the next decade the lag between lakeward migration of the shoreline and lakeward migration of the vegetation decreased, so that in 1964 (lake level 6390 feet) the southern half of the platform at Hot Spring Cove was colonized by graminoid vegetation clear to the shore, while at most places on the northern half it stretched more than three-quarters of the way to the shore. By 1968 the vegetation has gained on the falling shoreline to an even greater degree, extending to the lake in most places. (This is probably due, in part though not entirely, to the lake having risen to the existing vegetation in 1967.)

The cutting of the new cliffline in 1967 and 1969 (with most of the erosion occuring during the greater rise of the latter year) created a new springline at an elevation of 6391 feet. This may have diminished the amount of water available to the upper terrace due to sapping at its base. Thus, while graminoid vegetation continued to be widespread on both the upper and lower terraces in 1982, true wetlands (interpretation based on false-color infrared photos of 1982) appear to be most prevalent immediately below the two cliffines. A drier-type vegetation (presumably dry meadow) seems to dominate on the middle portions of the platforms (Plate 1).

4. Conclusions

The regression of Mono Lake from its Historic High Stand of 1919 AD has resulted in marked changes in the nature and distribution of lake-fringing wetlands. The fresh- and brackish-water lagoons of the deltas and the northern shore have disappeared. Overall, marshlands and wet meadows have expanded, despite the loss of formerly extensive tracts on the Rush Creek, Lee Vining Creek, and Mill Creek deltas, and in the Horse Creek Embayment.

The history of the expansion of marshlands and wet meadows is complex, with details varying from site to site depending on geology, hydrology, geomorphology, and land-use practices. Perhaps the simplest case is to be found in the vicinity of Dechambeau Creek, where surface- and groundwater is abundant and the shorelands are of moderate gradient. There, marshland and wet meadow have rapidly and completely colonized newly relicted lands. The landward margin of the wetlands has remained stationary through time, with the result that the band of wetlands has become ever wider as the lake has fallen. At the other extreme of complexity is the Greater Simon's Springs Area, where the vegetation spread lakeward not as an ever-widening strip with a stable upper boundary, but rather as a migrating band that, while expanding lakewardly on its downslope margin, was contracting lakewardly on its upslope margin. Furthermore, while wetland vegetation rapidly colonized newly-relicted shorelands of moderate to moderately high gradient in the Simon's Springs Area, it has been slow to colonize (if it has colonized at all) the low-gradient lands closer to the lake. Colonization by wetland vegetation on the low-gradient lands here and at other sites around the lake lags reliction by at least many years, and perhaps even by decades or centuries.

Complexities such as these, as well as others (including beachrock formation, possible lowering of groundwater levels due to erosion-induced sapping, and changes in land-use practices) make it difficult to predict how the future fluctuations of Mono Lake will affect the growth and shrinkage of shore-fringing wetlands. Any attempt to make such predictions must take the following factors into account:

1. Restoration of the Dechambeau Lagoon would require raising the lake to levels above approximately 6400 feet; restoration of the lagoons of the northern shore would require raising the lake to levels above approximately 6405 feet; restoration of the lagoons on the Rush Creek, Mill Creek, and Lee Vining Creek deltas would require raising the lake to levels above

approximately 6400 feet, though much time would be required to "heal" the delta trench, a process that would be required before berms could again be built on the delta plains.

2. While the greatest potential acreage of relicted land within a ten-foot vertical band lies between elevations of 6370 and 6380 feet (potential relicted land = 8320 acres), this interval supports substantially less wet meadow and marshland than the vertical interval 6380-6390 (potential relicted land = 4290 acres). This seems to be due to the flatter shoreland gradient, and consequent tendency to precipitate a crust of alkaline salts, within the lower interval. With this in mind, any attempt to equate future amounts of relicted land with future acreages of wetland should be done on an elevation-interval by elevation-interval basis.

3. The past response of wetlands to the drop in Mono Lake is the key to understanding the future response only insofar as the past hydrologic, geomorphic, and geologic conditions continue to prevail. Short of a volcanically induced ash-fall or a marked shift in climate, future changes in these parameters should be minor, as long as the surface of Mono Lake remains above the topographic "nick point" that encircles the lake at an elevation of 6368 feet (Stine, 1990b). Should the lake drop below that level, the water table beneath much of the lake-marginal wetlands will fall, due not only to a loss of sub-surface hydrostatic support, but to local incision by the rills that drain the lands. The consequences of such an event would be irreversible, since, during a subsequent rise in lake level, the lake surface

would not simply regain the gently sloping platform above the nickpoint. Rather, the rising lake would cut a new platform at the expense of the old one, forcing the nickpoint (the instigator of rill incision) to higher and higher levels. If lake-marginal wetlands are to be preserved, the surface of Mono Lake should be prevented from falling to 6368 feet.

Footnotes

1 The LADWP (1987), following the then-unpublished conclusions of Pelagos (1987), suggested that Rush Creek is too far west to be related to the springs that created the South Tufa Grove. Seeking an explanation that tied Rush Creek to the tufa grove, they argued that the stream must have previously occupied a position farther east, at the present site of Panum Dome, and that the creation of the dome by volcanic eruption 600 years ago must have forced the stream to change positions and cut its present canyon. To bolster their argument, the DWP and Pelagos cited the existence of a narrow, high-gradient, sublacustrine canyon ("Pelagos Canyon") that bisects the lake floor near South Tufa Grove between elevations of 6365 feet (9 feet below the present lake surface) and 6275 feet. Their contentions regarding the origin of "Pelagos Canyon", as well as those regarding the history of Rush Creek and the South Tufa Grove, are unfounded, and their arguments are untenable, for the following reasons:

A. Between about 12,000 and 10,000 years ago, as Mono Lake fell from its late Pleistocene high stand of 7070 feet, the lake's tributary streams were forced to incise their deltas. The drop in lake level did not occur at a steady rate. Rather, the lake surface staggered downward, stabilizing at several intermediate elevations in the coarse of the overall regression. The stream canyons of Mill and Lee Vining creeks record this stagger as canyon-wall terraces that were cut as the stream planed laterally during the still-stands. Expectedly, both of these streams display the same sequence of terraces (graded to the same base levels). The canyon of Rush Creek likewise displays this same sequence of terraces. The only plausible explanation for this coincidence is that between 12,000 and 10,000 years ago, during the late Pleistocene regression of Mono Lake, Rush Creek occupied its present-day canyon.

B. The canyon that Rush Creek cut into its delta is not a minor topographic feature. It reaches a depth of over 300 feet, and a width of more than 2000 feet. Any former canyon of Rush Creek would have to have been of roughly similar dimension. Had Rush Creek formerly occupied a position different than that of the present day, this former canyon would have to be in evidence today. No such remnant stream canyon (indeed, no abandoned stream canyon of any kind) characterizes the Rush Creek drainage.

C. "Pelagos Canyon" is far too steep to have been cut by a stream. Whereas the other streams that flow to the lake over unconsolidated, easily erodible sediments have gradients of between 22 and 30 per 1000, the gradient of "Pelagos Canyon" is in places greater than 100 per 1000. Had a stream actually flowed down this canyon, it would have flattened the gradient by a factor of 3 to 4 in short (weeks to months) order.

D. It has been demonstrated (Stine, 1987, 1990a) that Mono Lake has not been low enough since Panum Dome erupted 600 years ago--indeed, it has not been low enough during at least 4000 years--to have allowed a stream to flow overland to even the highest reaches of "Pelagos Canyon".

E. There is no delta associated with the mouth (or any other part, for that matter) of "Pelagos Canyon". A delta would have to be expected if the canyon was stream-cut.

F. The tufa towers that the DWP cite as evidence of former large-scale spring activity at South Tufa Grove more than 600 years ago have been shown to post-date, rather than pre-date, the Mono Craters eruption of 600 yrs BP (Stine, 1992b).

In light of the overwhelming evidence against a fluvial origin of "Pelagos Canyon", it is well to consider an alternative origin. The canyon coincides with a fault that runs northeastward from Panum Dome into Mono Lake. At the mouth of the canyon is a widespreading splay deposit of the type that would be expected to form in a subaqueous environment following a slump-induced turbidity flow. It is therefore hypothesized that "Pelagos Canyon" is a slump scar (one of many that are known to exist on the lake floor) that formed in association with the tectonic activity that accompanied, or followed, the emplacement of Panum Dome ~600 years ago.

2 Sinclair (1988) attributed the springlines at 6381 feet and 6390 feet along the lake's south shore to "seeps . . . issuing from tephra layers where they intercept the sloping beach." This interpretation is incorrect. The tephras from the most recent Mono Craters eruptions, as well as those from the Paoha Island eruptions, do not intersect the surface of the southern shorelands. The ash beds are oriented parallel to the shoreland surface, and lie at depths of from ~1 foot to ~5 feet below ground level. The springlines always run along a contour, a situation that would be most unlikely if they owed their existence to a slope/stratum intersection. Furthermore, the shorelands along the lake's southern margin are composed virtually entirely of littorally reworked tephra sands that originated from the most recent eruption of the Mono Craters. These sands are neither more nor less capable of conveying groundwater than the airfall tephra units that are intercallated within them. The springlines are clearly related to topographic nickpoints created during the above-mentioned transgressions of Mono Lake, rather than to any slope/tephra intersection.

3 On March 23, 1934 (lake level 6416.7 feet), hydrologist Charles Lee described the two lagoons on the lake margin near Bridgeport Creek, and another 2 in the vicinity of Cottonwood Creek, as being brackish. In both cases he observed "numerous small seeps" of cold, fresh water entering the lagoons from the landward side. He estimated the area of lagoon surface to be 52 acres on Bridgeport Creek, and 199 acres on Cottonwood Creek.

4 Two small spring-fed ponds along the northern shore--Sulphur Pond, and a tiny pond ~2500 feet to its southeast--remain in existence. They do not occupy lagoonal depressions, but rather interdunal areas of the Generation-2 dunefield of Stine (1987, 1990a).

5 "Miner's inch" is a measure of water flow dating from the California Gold Rush. It has different cubic feet per second (cfs) equivalents, depending on whether it conforms to the northern California definition (1 cfs = 40 M.I. with 6" of pressure head), or southern California definition (1 cfs = 50 M.I. with 4" of pressure head). It is not known which

definition Lee used in describing Simon's Spring.

6 It appears that, under natural conditions, Gibbs Creek played a major role in watering the "Horse Creek" drainage. Russell's map of 1883 shows Gibbs Creek flowing through the Horse Creek embayment to Mono Lake. He also shows shoreline springs emanating from the embayment. On the USGS map of 1898 Gibbs Creek is shown bifurcating at an elevation of ~8500 feet, with the ephemeral branch (thus, presumably, the overflow waters) flowing into the Lee Vining Creek drainage (joining it upstream of the present-day Forest Service Compound) and the perennial branch (thus, presumably, the main branch) flowing down Horse Creek canyon. Shortly thereafter, a system of diversions was established near the point of bifurcation. It was intended to regulate the flow of Gibbs Creek water between the Horse Creek embayment and the Lee Vining Creek drainage. The degree to which this diversion sent more water to Lee Vining Creek than was previously the case is not known.

7 The gravels excavated by the artificially induced incision of Wilson Creek bury lands that might otherwise support wetlands.

8 While Negit Island harbors no freshwater, one of its flows traps lake water between pressure ridges at low lake levels (~6373-6378 feet). This creates a narrow, arcuate pond of water that, because of evaporation, is more saline than the lake. This saline pond is shown on Plate 1.

9 Plate 1 shows that the slump pond that was present in 1930 remains in 1982, suggesting that no change had occurred. It should be realized the the presence of the pond in 1982 is largely a matter of chance (being related to the wet year and the rains of the days immediately before the photos were taken), and that while the pond of 1930 was a permanent feature, it was ephemeral by 1982.

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