LAKE MEAD LIMNOLOGICAL RESEARCH CENTER

Evaluation of Impacts Associated with Reregulation of Water Levels in Lake Mohave

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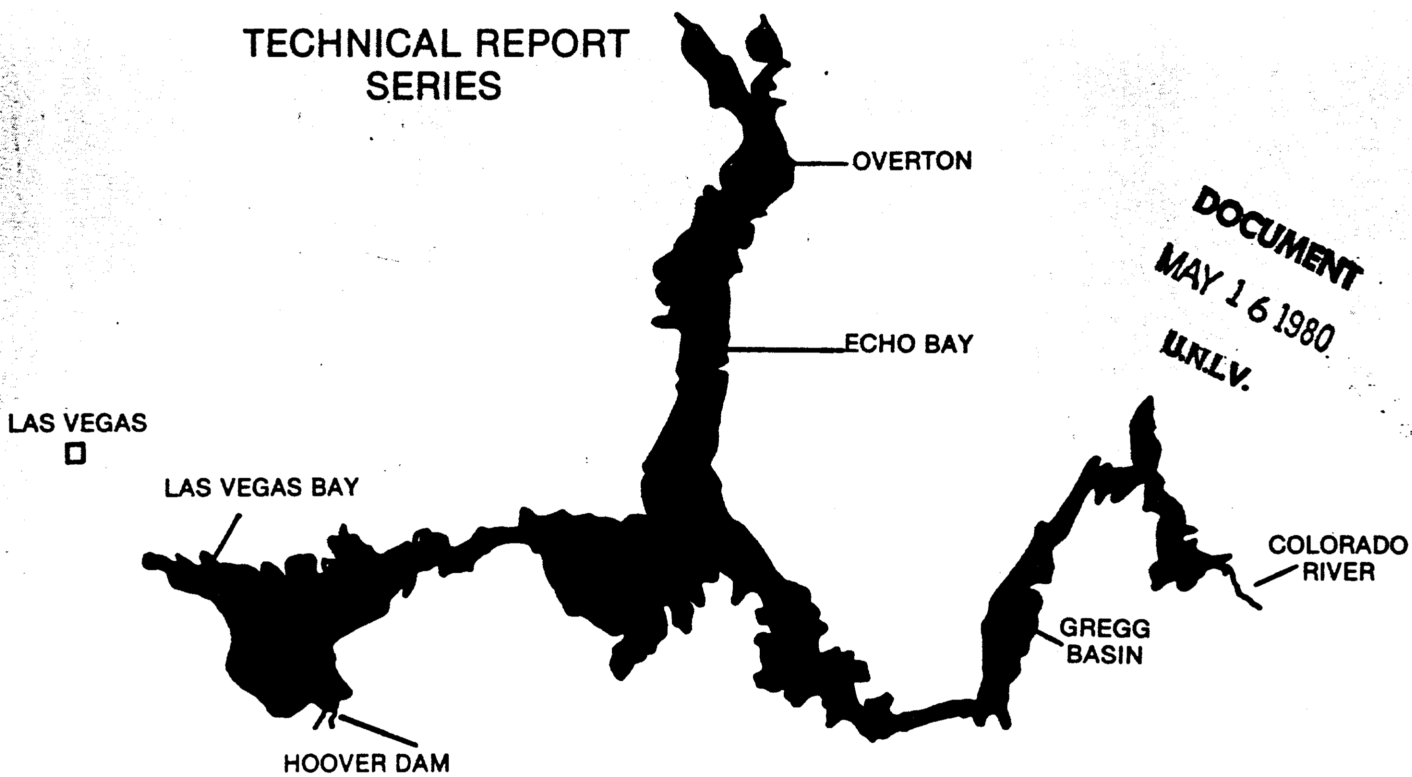

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1.0 INTRODUCTION

The U.S. Water and Power Resources Service is considering reregulating Lake Mohave water levels to increase the net power benefit from Hoover Dam. Reregulation will not increase the generation capacity of the Hoover powerplant but it will enable the plant operation to be increased when the energy has greater monetary value. Energy generated at different times of the year has different market value, the highest being in January-March and July-September. By generating more power during these periods more net monetary benefit can be drived from Hoover Dam. The total volume of water released from Hoover Dam over an annual period must remain unchanged due to downstream water requirements for irrigation. To obtain this power benefit, therefore, less water for generation would be discharged during the low market value periods to enable higher discharges during the high market value periods. The discharge regime at Davis Dam would also remain unchanged in order to meet downstream water requirements. Therefore more extreme fluctuations in Lake Mohave water levels would result in order to accommodate changes in the Hoover Dam discharge regime.

Water levels in Lake Mohave presently fluctuate from a maximum elevation of about 647 ft. in February-April to a minimum of 630.5 ft. in September-November (Fig. 1). The minimum elevation has been maintained to accommodate the marinas on the lake. To optimize power generation from Hoover Dam, water levels in Lake Mohave will fluctuate from elevations of 600 to 640 ft. as shown in Figure 1 (alternatives A-C). The greatest power benefit would be derived from decreased Hoover Dam discharge in April-June and October-December and increased discharge in January-March and July-September (alternative A lake elevations, Fig. 1). Alternative B would have higher Hoover Dam discharge occurring in March-May to maintain a steady elevation (less than a 2 ft.

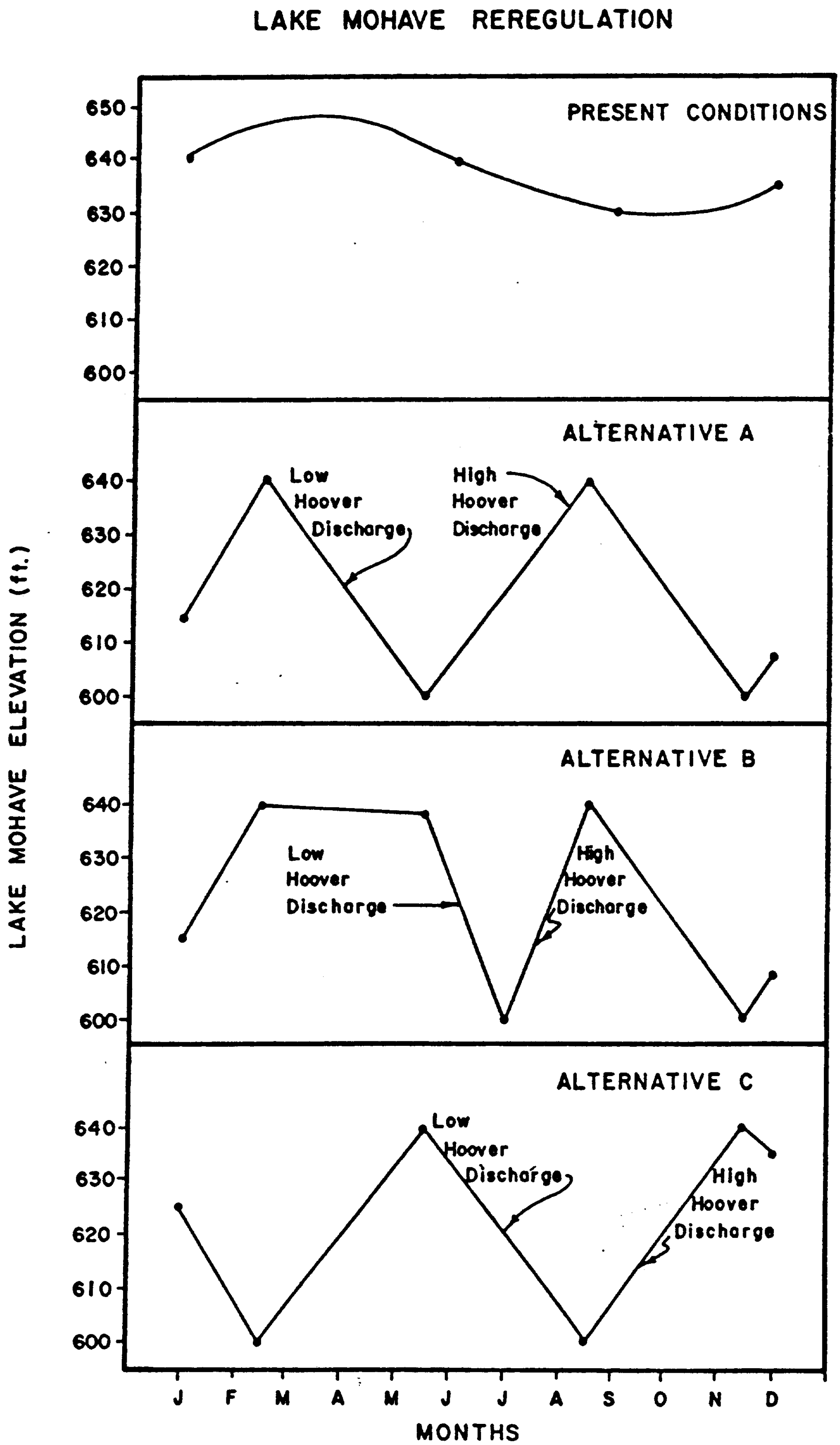

Figure 1 Existing and proposed reregulated water levels in Lake Mohave.

decrease) during spring. Alternative C, the least beneficial, is similar to A but is out-of-phase with increased discharge in February-May and August-December.

The proposed reregulation alternatives will alter environmental conditions in Lake Mohave because of the extreme variations in water level. The U.S. Water and Power Resources Service initiated this investigation to determine to what extent reregulation would affect limnological conditions and fisheries in Lake Mohave.

2.0 EXISTING LIMNOLOGICAL CONDITIONS IN LAKE MOHAVE*

Lake Mohave was formed in 1950 by the construction of Davis Dam on the Colorado River below Hoover Dam (Fig. 2). It is long and narrow and is best described as a "run of the river reservoir" having a very short retention time of 0.24 years (Table 1). There are four major areas: a river section approximately 18 miles long below Hoover Dam, Eldorado Basin, Little Basin, and Cottonwood Basin.

Discharge from Hoover Dam is the only significant input to Lake Mohave. A few springs and the Willow Beach Trout Hatchery are located in the river section below Hoover Dam. Inflow from these sources are minor compared to the total river flow.

Hypolimnetic discharge from Hoover Dam releases cold water (11-13°C) throughout the year. This cold water discharge forms an obvious interface with warmer Lake Mohave water during thermal stratification. At the interface, the colder river water, because of its greater density, flows under the warmer Lake Mohave water. The location of the interface depends on Hoover Dam discharge and Lake Mohave water level and has been observed from just

*For a complete description of limnological conditions see Paulson, Baker and Deacon (1980). All data were taken from that report.

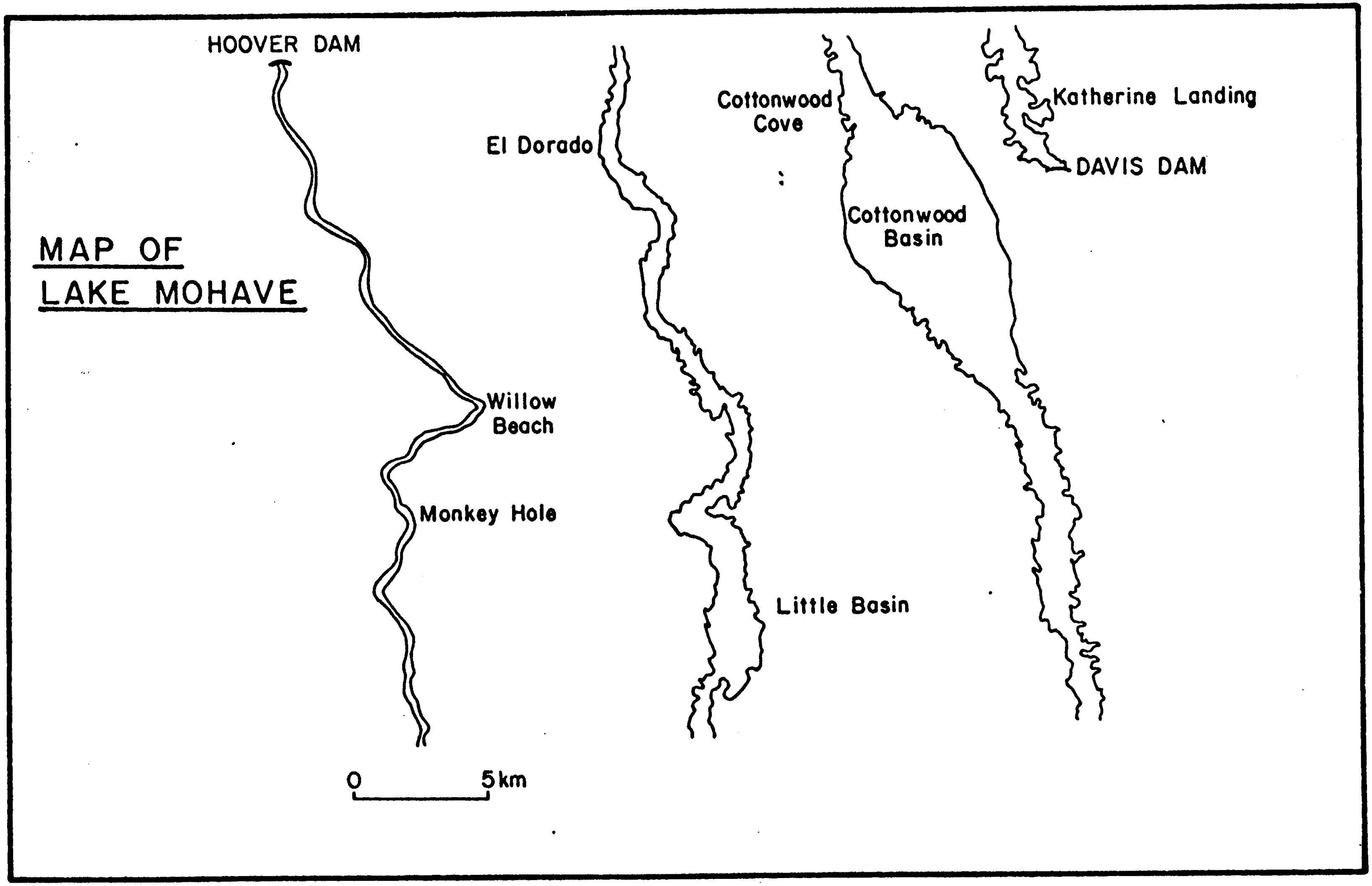

Figure 2 Map of Lake Mohave. (From Paulson et al. 1980)

Table 1. Morphometric characteristics of Lake Mohave. [From Paulson et al. (1978)].

Parameter	Lake Mohave
Maximum operating level (m)	197.0
Maximum depth (m)	42.0
Mean depth (m)	19.5
Surface area (km^2)	115.0
Volume ($m^3 \times 10^9$)	2.3
Maximum length (km)	108.0
Maximum width (km)	6.4
Shoreline development*	3.0
Discharge depth (m)	42.0
Annual discharge (1977) $m^3 \times 10^9$	9.3
Replacement time of maximum operation level (years)	0.24

*Unitless parameter to measure regularity of shoreline value; of 1 is equivalent to a lake shaped in a perfect circle.

below Willow Beach (mile 12.5) to Eldorado landing (mile 24). The interface is pushed down-lake at high discharge and recedes up-stream at low discharge; it extends further up-stream at high Lake Mohave elevations and recedes further down-lake at low lake elevations.

The cold river water forms an underflow throughout most of the year creating circulations patterns during thermal stratification as illustrated in Figure 3. During high discharge from Hoover Dam the thermocline is elevated as the larger volume of cold water forces warmer lake water upward. A reverse up-lake circulation cell develops due to the combined effects of entrainment of surface water by the underflow and the flow of the hypolimnetic water mass down lake. During low discharge from Hoover Dam, the thermocline returns to its original position resulting in a seiche produced by the up-lake flow of eplimnion water. The down-lake flow of the hypolimnion water mass also causes an upwelling at Davis Dam as it collides with the dam. The fluctuating high and low discharge of cold-water from Hoover Dam, therefore, creates a great deal of temperature instability in Lake Mohave.

Typical winter and summer thermal structures in Lake Mohave are shown in Figures 4 and 5, respectively. Water temperatures are generally isothermal during winter ranging from 12-13°C. Thermal stratification begins to develop in May and lasts through October. During mid-summer the thermocline is located at 10-15 m in Cottonwood Basin. In Eldorado Basin, the location of the thermocline varies from a depth of 3. to 10 m with varying Hoover Dam discharges.

A clinograde oxygen profile usually occurs in Lake Mohave with the lowest xygen concentrations occurring in the hypolimnion at Davis Dam. Hovever, hypolimnetic oxygen concentrations remain relatively high (Table 2) because of the river underflow and rapid flushing of the hypolimnion.

Phytoplankton productivity ranges from 21-2976 mg $C \cdot m^{-2} \cdot day^{-1}$ from

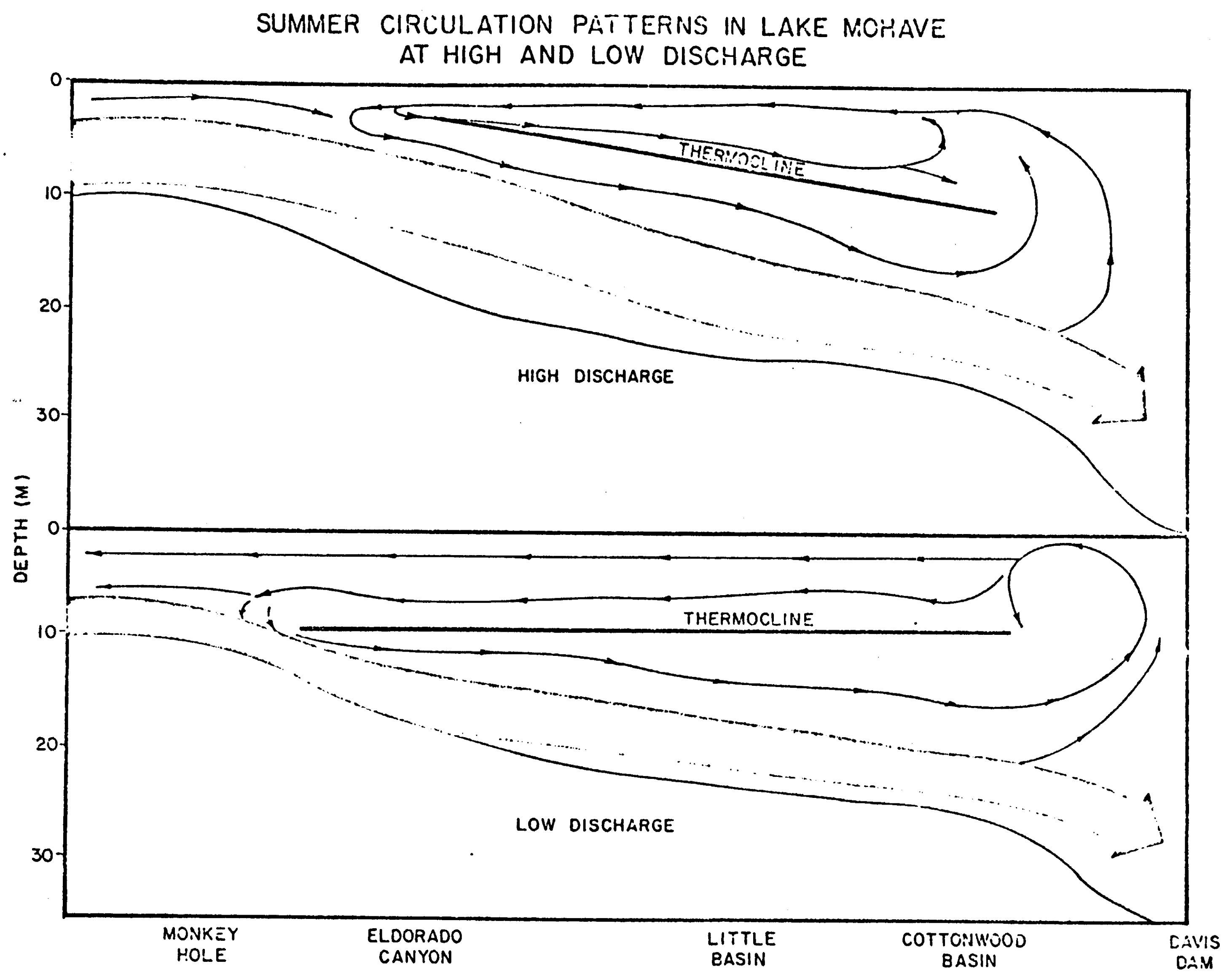

Figure 3 Summer circulation patterns for high and low discharge in Lake Mohave. (From Paulson et al. 1980)

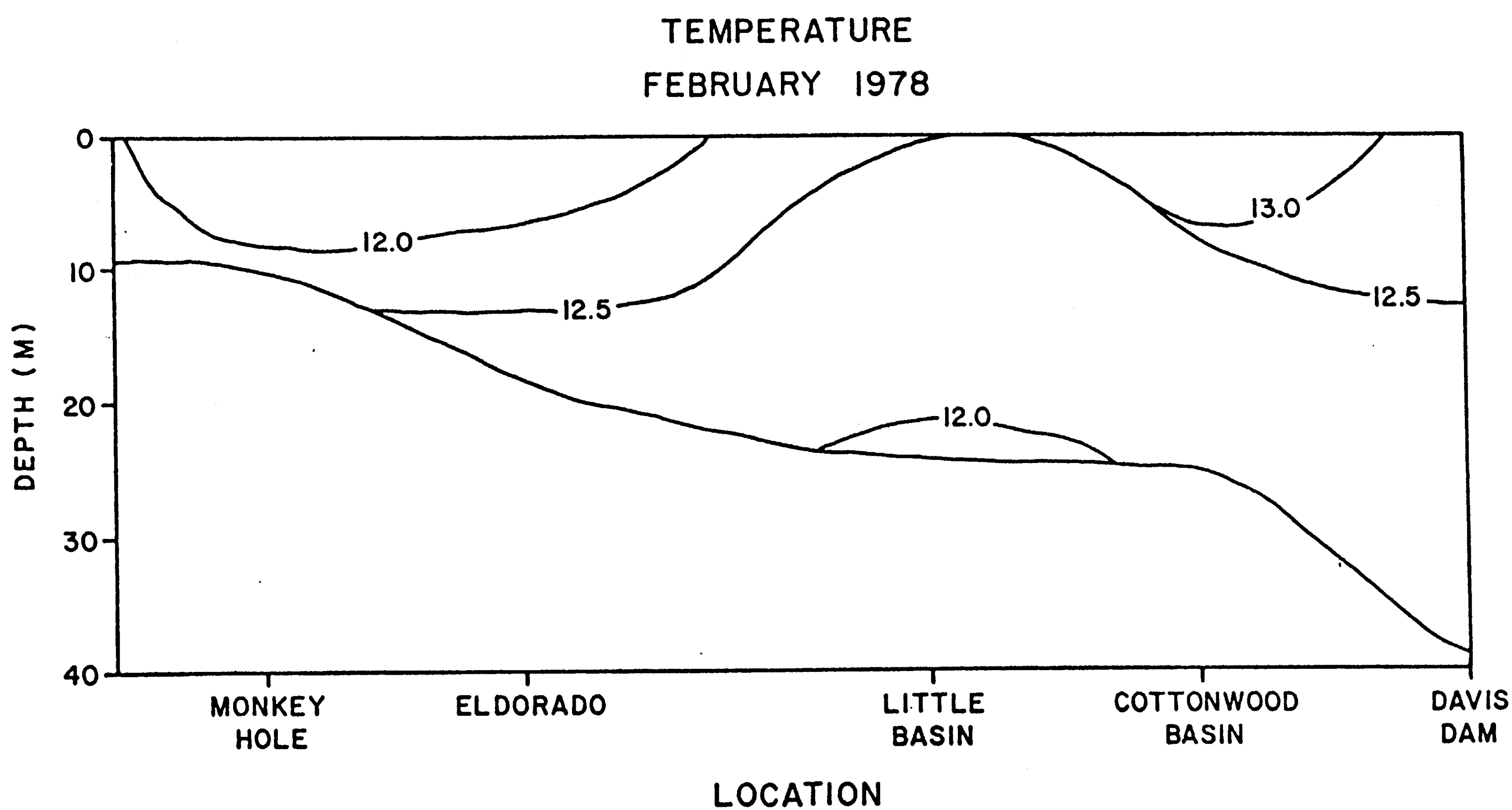

Figure 4 Temperature isotherms for Colorado river channel stations, Lake Mohave in February, 1978. (From Paulson et al. 1980)

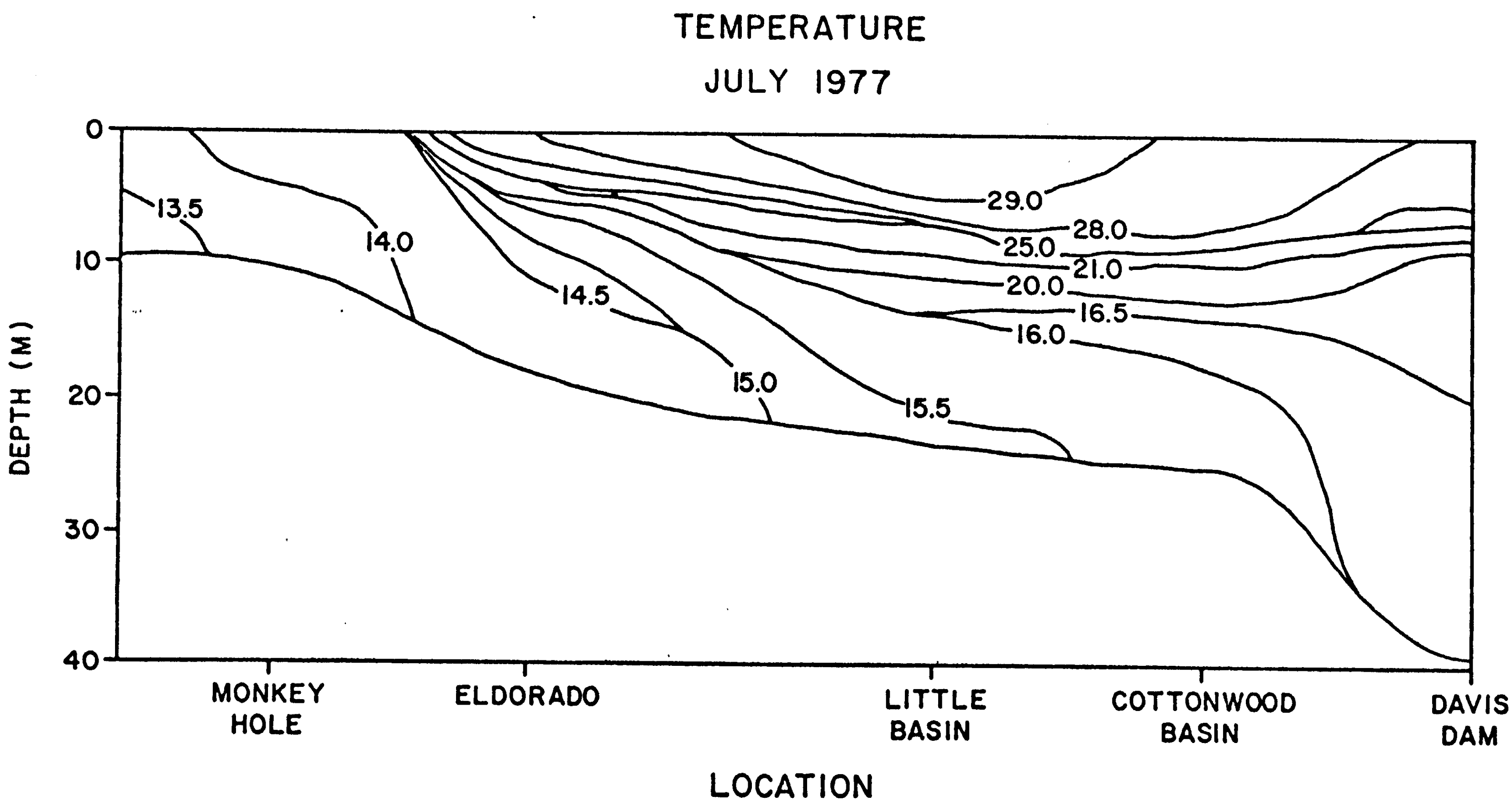

Figure 5 Temperature isotherms for Colorado River channel stations, Lake Mohave in July, 1977. (From Paulson et al. 1980)

Table 2 Minimum oxygen concentrations in the hypolimnion of Lake Mohave, 1977. [From Paulson et al. (1980)]

	STATIONS			
	Davis Dam	Cottonwood Cove	Little Basin	Eldorado Canyon
June	6.5	6.9	7.9	9.6
July	4.9	6.9	8.4	8.5
August	4.4	7.2	8.2	9.5
September	4.6	5.3	5.9	10.0
October	3.4	5.0	8.5	8.3
November	8.4	4.3	6.2	9.0

April 1977 through May 1978 (Fig. 6). A general seasonal pattern in productivity is evident with high productivity in the spring-summer period (March-September) declining in the fall (October-November) and remaining low during winter. Productivity is very low in Eldorado Basin in winter apparently due to increased turbulence and mixing of the river inflow when the lake destratifies. Eldorado Canyon has the highest spring-summer productivity due to higher nutrient concentrations (Fig. 6) from partial mixing of the river inflow from Hoover Dam. Productivity decreases at the down-lake stations in response to lower nutrient concentrations. The lowest average daily productivity occurs at Davis Dam.

3.0 REREGULATION EFFECTS

3.1 Thermal Stratification

Reregulation of Lake Mohave water levels will have a marked effect on thermal stratification because of reduced lake volume and depth at the lower lake elevations. At an elevation of 640 ft., the capacity of Lake Mohave is 1626 x 10^3 acre-feet (Table 3). At an elevation of 600 ft., the capacity is reduced to 702 x 10^3 acre-feet, less than one half the volume at 640 ft. As a result of reduced volume, river conditions and colder water will extend further down-lake, decreasing the area that becomes thermally stratifies.

Mid-summer thermal structure in Lake Mohave in our 1977 study was used to estimate conditions that will occur at an elevation of 600 ft. In shifting temperatures isopleths down-lake to an elevation of 600 ft. adjustments were made for changes in depth, bottom contour and the up-welling at Davis Dam. Figure 7 illustrates the thermal structure in Lake Mohave that will probably occur at an elevation of 600 ft. River conditions will extend into Little Basin resulting in water temperatures of 14-16°C. Water surface profiles, with a Lake Mohave elevation of 600 ft., also indicate that river conditions

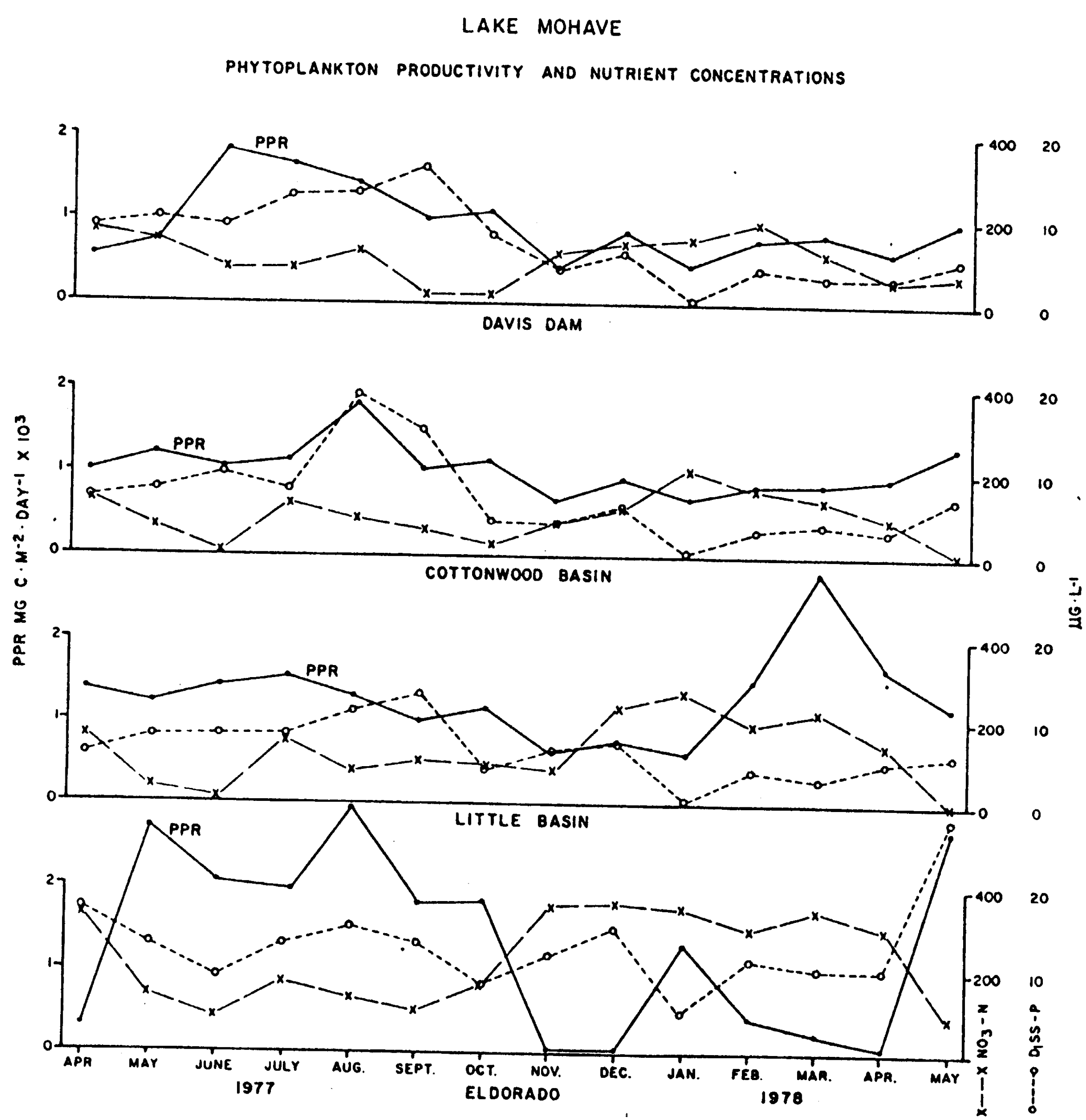

Figure 6 Areal phytoplankton productivity and nutrients in Lake Mohave. (From Paulson et al. 1980)

Table 3. Lake Mohave area and Capacity at elevations 600-647 ft.
(U.S. W.P.R.S. Data)

Lake Elevation Meters	Area Acres x10^3	Capacity Acre·Feet x10^3
600	19.2	702.1
610	21.2	904.4
620	23.2	1125.2
630	25.2	1367.1
640	26.7	1626.0
647	28.8	1818.3

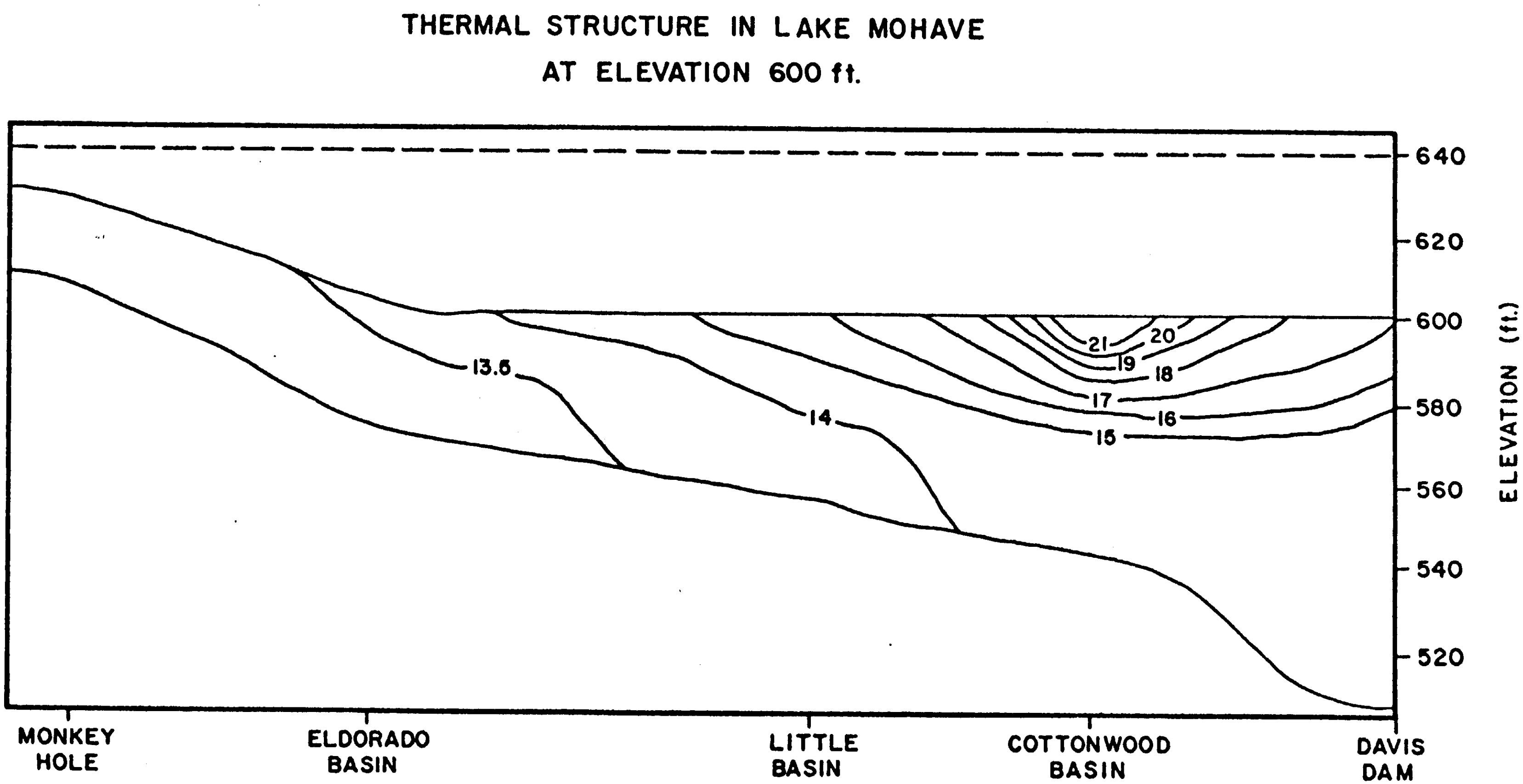

Figure 7 Temperatures isotherms in Lake Mohave at an elevation of 600 ft. (Paulson et al. 1980)

will occur to about mile 35, 2 miles above Little Basin (Fig. 8). The higher elevations (greater than 600 ft.) in Figure 8 are due to the incoming river water. The location of the interface will occur at the point where the water surface profiles become level (mile 35). Weak thermal stratification will develop in Little Basin but relatively warm surface waters (greater than 20°C) will occur only in Cottonwood Basin. Up-welling at Davis Dam will be amplified, resulting in weak thermal stratification in the canyon area up-lake of Davis Dam (Fig. 7).

The greatest effect on thermal stratification will occur when lake elevations are low (600 ft.) and when there is a shift from low to high daily Hoover Dam discharges (Fig. 1). This will be especially pronounced if Hoover Dam peak discharges are increased from 30,000 to 60,000 or 76,000 $ft^3 \cdot sec^{-1}$, as a result of Hoover Dam modifications. The higher peak discharge will tend to push the interface and the cold water wedge further down-lake as illustrated by the water surface profile for a discharge of 76,000 $ft^3 \cdot sec^{-1}$ (Fig. 8). The upwelling at Davis Dam with higher Hoover Dam discharge, will be enhanced because of the greater velocity and volume of the hypolimnetic flow colliding with Davis Dam. At the lower lake elevations and peak discharges of 60,000-76,000 $ft^3 \cdot sec^{-1}$, thermal stratification above Davis Dam may be completely disrupted. The time period when this will occur will shift from early summer (alternative A) to late summer (alternative C) (Fig. 1), but each of the alternatives will have the same overall effect on thermal stratification.

3.2 Phytoplankton Production

Phytoplankton production in Lake Mohave will decline with all proposed water level alternatives. The total surface area and volume of Lake Mohave will be reduced with the low summer lake elevations, a period when phytoplankton production is generally highest. The decrease in surface area and volume will

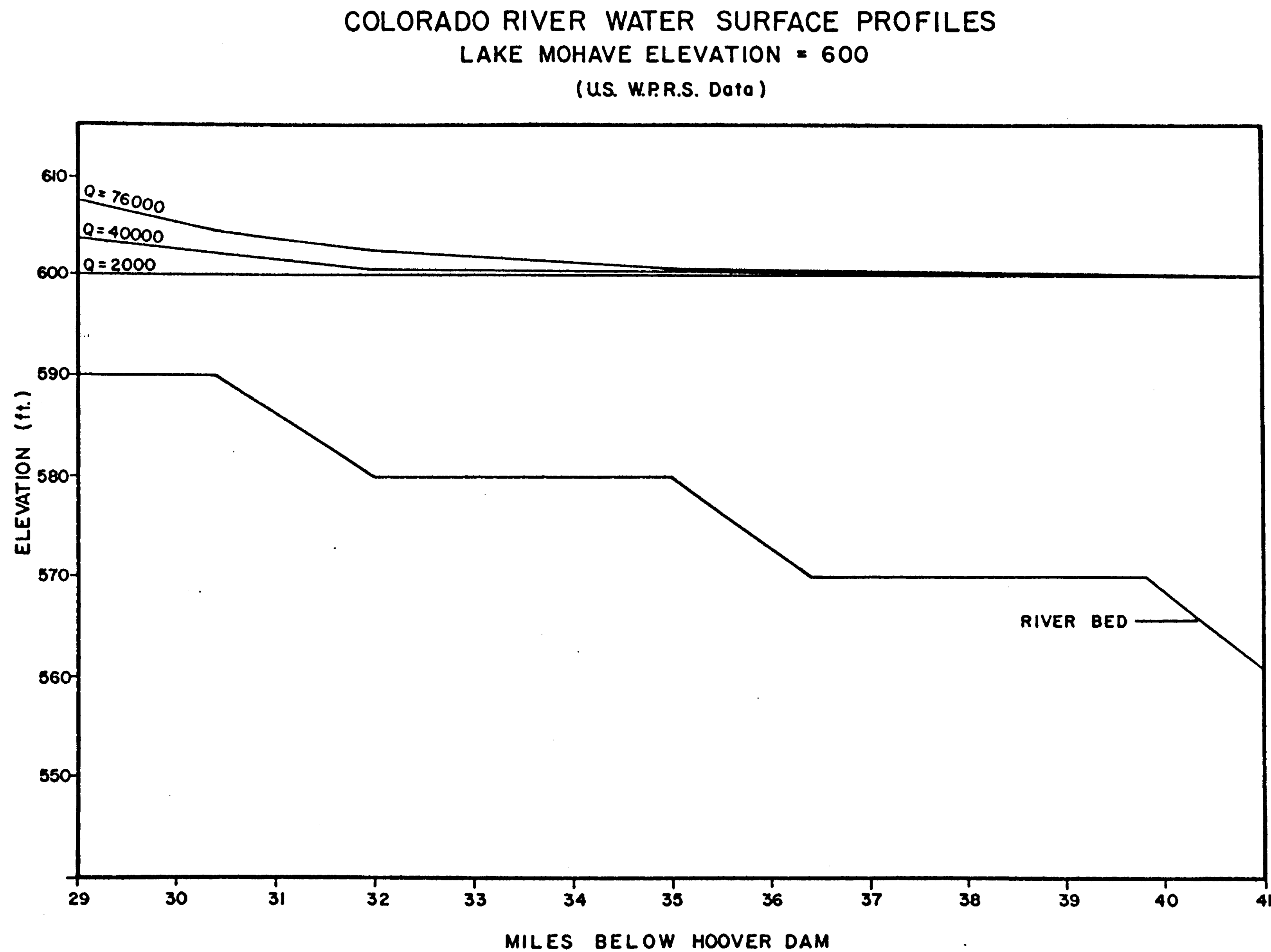

Figure 8 Water surface profiles in Lake Mohave (mile 29-41) at Hoover Dam discahrges of 76,000, 40,000 and 2000 $ft^3 \cdot sec^{-3}$.

reduce the effective region for phytoplankton production, which will be lower at the lower lake elevations than at the higher lake elevations. Assuming annual productivity rates measured in 1977-78 (Paulson, Baker and Deacon 1980) are representative of productivity rates at the various proposed water levels, the average annual productivity of Lake Mohave will decline about 10-18% (Table 4) with reregulation.

Phytoplankton production is controlled by a number of various environmental factors; therefore the rates measured in 1977-78 may not reflect those that will occur with the proposed changes in Lake Mohave water elevations. At lower Lake Mohave elevations and higher Hoover Dam discharge, there will be an increase in mixing of the incoming river water and Lake Mohave surface water. This will increase nutrient availability for phytoplankton production but it will also decrease water temperatures and increase turbulence. Although we are not able to predict what effect these changes will have, it appears that the increased instability and decreased water temperatures will tend to decrease phytoplankton production. Therefore, water quality problems such as nuisance algal blooms should not develop with reregulation.

It is also difficult to predict to what extent this decrease in phytoplankton production will affect the higher trophic levels (zooplankton and fish). A large percentage of the total production in Lake Mohave is flushed down-stream because of the short retention time and shallow depth. This is reflected in nutrient budget for Lake Mohave. Only 2.8% and 3.9% of the annual input of phosphorus and nitrogen respectively, are retained in the reservoir (Priscu 1978). Nutrient retention will be reduced even further with the proposed reregulated water levels due to the lower lake elevations resulting in greater flushing. The low nutrient retention is partially due to the downstream flushing of organic material through Davis Dam. This was evident from the large numbers

Table 4 Total areal primary production in Lake Mohave for the proposed reregulated water levels. Values are based on data collected in 1977-78 (Paulson at al. 1980)

		mg C·day^{-1} x 10^{10}		
Month	Present Conditions	Alternative A	Alternative B	Alternative C
Apr.	10.1	8.9	9.8	6.4
May	13.5	11.4	13.1	11.2
Jun.	14.8	11.3	13.2	14.8
July	14.6	12.1	10.8	12.4
Aug.	17.7	15.7	14.9	15.2
Sept.	10.2	11.7	11.4	9.7
Oct.	11.3	10.6	10.6	10.6
Nov.	5.8	4.0	4.0	6.8
Dec.	7.8	6.0	6.0	8.1
Jan.	7.3	6.4	6.4	6.0
Feb.	10.3	9.3	9.3	5.3
Mar.	13.4	12.9	12.9	5.8
$\bar{x}$	11.4	10.0	10.2	9.4

of zooplankton that we found being discharged from Davis Dam (unpublish data). Consequently, as a result of the greater flushing with the proposed reregulated water levels a greater amount of the organic production in Lake Mohave will be lost downstream. This will tend to decrease food availability for fish.

3.3 Lake Mohave Fisheries

Based on creel census data taken by the Nevada Department of Wildlife rainbow trout (*Salmo gairdneri*) and largemouth bass (*Micropterus salmoides*) are the two most important game fish in Lake Mohave making up over 75% of the harvest. Other gamefish include channel catfish (*Ictaluris lacustris*), bluegill (*Lepomis macrochirus*), and black crappie (*Promoxis nigromaculatus*). There is very little or no natural reproduction of rainbow trout in Lake Mohave, this fishery being maintained by periodic stocking. Largemouth bass and the other game fish have naturally reproducing populations.

Reregulation of Lake Mohave water levels will have the greatest impact on largemouth bass. The extreme drop in water level in February-June (app. 0.5 $ft \cdot day^{-1}$) as in alternative A (Fig. 1) will be very detrimental to largemouth bass reproduction. The spawning period for largemouth bass in Lake Mohave begins in April and extends into late May (Beckstrand 1979; Jonez and Sumner 1954). Poor spawning success has been associated with declining water levels in Lake Mead (Romero and Allen 1976) and in other reservoirs (Aggus and Elliott 1976; von Geldern 1971). In April 1979, the water level in Lake Mohave dropped 3 ft. over a period of a week during which bass nesting was completely disrupted (personal communication Kraig Beckstrand, Nevada Department of Wildlife). This 3 ft. decrease is less than the water level decline that will occur with reregulation in alternative A. Therefore, largemouth bass nesting success can be expected to be dramatically reduced.

Maintaining more or less constant water levels in March-June (Alternative

B Fig. 1) would be less detrimental than Alternative A to nesting success. However increasing water levels during nesting generally enhances spawning success and survival (Aggus and Elliott 1975; Romero and Allen 1975; von Geldern 1971). Alternative C, with increasing water levels in May and June, would thus be more ideal; however because of the concurrent loss of habitat, spawning success and survival would be poorer than with the present Lake Mohave water level regime. The prime littoral area for spawning in Lake Mohave is comprised of inundated saltcedar (Tamarais sp.) which occurs along the shoreline down to an elevation of about 639 ft. This elevation is considered the bottom of the preferred bass spawning habitat (personnel communication Kraig Beckstand). With the present regime water levels in the spring are at 647 ft., inundating large areas of saltcedar. With the proposed reregulation, water levels will only reach 640 ft., the bottom of the preferred saltcedar habitat. This will greatly reduce the prime spawning area and spawning success in Lake Mohave. New vegetation below the 639 ft. elevation will probably not develop because of the extreme fluctuation in water and more frequent inundation of the shore area below 640 ft.

Survival of largemouth bass fry will also be adversely affected by the reregulated water levels due to the loss of cover vegetation. Aggus and Elliott (1975) and Romero and Allen (1975) have shown that vegetation cover is important in reducing predation on bass fry. With the present water level regime, the inundated saltcedar in May and June, provides the most effective bass cover. As previously mentioned, this habitat extends only to an elevation of 639 ft. and will be eliminated in May and June with alternatives A and B because of low lake elevations (Fig. 1). This will occur only temporarily with alternative C. Submergent vegetation (Potomogeton sp. and Najas sp.) growing at depths from 5-20 ft. provides some additional cover (personel communication Kraig Beckstrand), but development of this vegetation will be eliminated with the extreme water level fluctuations, further reducing bass cover. Therefore, reregulation will not only hinder spawning success, but will markedly affect fry survival due to loss of adequate cover.

The reduced area of warm stratified water will also limit the largemouth bass population. Largemouth bass prefer warmer water up to about 27°C (Coutant 1975). Under the present water level regime warm stratified water extends beyond Eldorado Basin. During the low summer water levels (600 ft.) with reregulation, water temperatures above 20°C will occur only in Cottonwood Basin and possibly in the canyon area below Cottonwood Basin depending on the magnitude of the upwelling at Davis Dam. Therefore, lower temperatures will greatly reduce the suitable area for largemouth bass. This is also true for threadfin shad (Dorosoma pentenense) which selectively inhabit the warmer waters. Threadfin shad are the primary forage fish for both largemouth bass and rainbow trout; a reduction in the threadfin shad population, therefore will affect all game fish.

The overall effects of reregulation on rainbow trout will be less severe. Rainbow trout inhabit the colder water and will be unaffected by destratification in the upper areas of Lake Mohave with the lower reregulated lake levels. No natural reproduction in Lake Mohave occurs so fluctuating water levels will not affect spawning success. Even though these factors will not affect the rainbow trout populations, reregulation will tend to reduce their numbers. Again, at the lower lake elevation (600 ft.), the total volume in Lake Mohave is only about one half the volume at the higher water levels occurring with the present water level regime. The reduced volume will decrease the total carrying capacity of Lake Mohave for rainbow trout. Food availability may also limit rainbow trout if the threadfin shad population is substantially reduced by the cooler water temperatures.

4.0 DISCUSSION

The proposed reregulated water levels will have dramatic environmental impacts. All of the proposed alternatives will increase the instability of Lake Mohave which, in turn, will affect every component of the biota. Although many of these impacts cannot be quantified, it is reasonably certain that the largemouth bass fishery will decline as a result of the reregulated water levels. The extreme drop in water levels in April and May (alternative A) will result in a marked decline in spawning success and survival. Maintenance of steady water levels (alternative B) or increasing water levels (alternative C) in the spring would be more conducive for bass spawning, but due to the loss of cover vegetation fry survival will be poor. With reregulation, the lower water will also tend to reduce the total carrying capacity of Lake Mohave for all types of fisheries.

Fluctuating water levels and high Hoover Dam discharges, during low Lake Mohave water levels, will increase the instability in Lake Mohave, resulting in partial destratification and cooler water temperatures. This instability will produce changes in the plankton communities, but nuisance conditions will probably not occur due to increased turbulence and lower water temperatures. Cooler water temperatures can be considered a water quality problem because the total area in Lake Mohave available for water contact sports will be reduced. Therefore, reregulation of Lake Mohave water levels will result in a net monetary power benefit from Hoover Dam, but at the expense of the beneficial uses of Lake Mohave. The value of these uses should be evaluated in relation to the cost effectiveness of reregulating Lake Mohave water levels.

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