

# MAIN REPORT

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1. DYB WORK
2. AMMONIA TOX. STUDY
3. CHE PRODUCTION IN WASH ??

4. CONTINUOUS PH  
TEMP } w/CURRENT  
DO. } MONITOR  
COND. }

W/2  
DO.

5. SAMPLES PERIOD END - fig. 30

Errata Sheet for ANALYSIS OF THE WATER-QUALITY STANDARDS PROPOSED BY  
THE NEVADA DIVISION OF ENVIRONMENTAL PROTECTION, Submitted by the  
City of Las Vegas, August 1987

<u>Page/Line</u>	<u>Change To:</u>
ii/27-28	Phosphorus Removal Has Cost \$170 Million
2/8	phosphorus. However, the wastewater-treatment plants operated
2/11	Although \$170 million (equivalent present value) has been spent on phosphorus removal,
7/9-12	Building and operating facilities for phosphorus removal have cost more than \$170 million so far (equivalent present value and operational costs).
12/7	also includes a study of algal ecology in the bay and of the
18/25	with relatively higher algal populations grow proportionately
37/9	upon much of the shallow lake bottom . . .
45/7	What effect did the decrease in phosphorus
48/14	or away from, the inner bay. In summary, although the
54/17	Las Vegas Bay is that when there are more algae, there are
58/9	increased to 1,660 pounds per day. (DEP 25 June 1986.)
59/4-7	<u>Phosphorus Removal Has Cost \$170 Million</u> Phosphorus removal is not cheap. As Figure 25 shows, the equivalent present-day costs so far of building and running the facilities add up to more than \$170 million.
64/18-19	In 1986 the fishery in Las Vegas Bay was as good as or better than it was in 1985 or 1984.
79/22	malfunctions--when it goes into overdrive and gets stuck
82/2	CONCLUSION: Scums result from the buoyant movement of the
85/3	In Panamá's Gatún Lake, the "maximum yearly chlorophyll
87/21	during the <u>Microcystis</u> bloom Paulson (1987) reported for
116/14	DEP asserts that "minimum dissolved oxygen concentrations
124/5	people who use it, than the mere suspicion that ammonia
128/2	in . . . the Clean Water Act, section
128/6	The criteria presented in this publica-

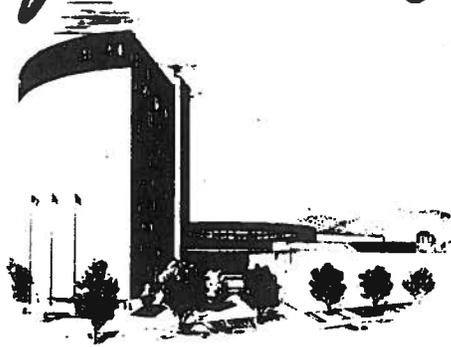
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131/1	value, 304 ug/l, is 760% higher than the proposed standard of
132/7	The lowest observed effect after seven
133/14	concluded that the temperature cap for Lake Mead
136/4	un-ionized ammonia around the clock at station 2 or anywhere
144/18	pull together people from various agencies to exchange

[1 September 1987]

# City of Las Vegas

RANDALL H. WALKER  
DEPUTY CITY MANAGER



August 24, 1987

Mr. Lewis H. Dodgion  
Administrator  
Nevada Division of Environmental Protection  
Acting Executive Secretary  
Nevada State Environmental Commission  
201 South Fall Street  
Carson City, Nevada 89710

Dear Mr. Dodgion:

We are enclosing our "Analysis Of Water-Quality Standards Proposed By The Nevada Division Of Environmental Protection", appendices to the analysis, and copies of the scientific literature cited.

This report is the result of a group process coordinated by Jerome Horowitz, the Environmental Officer of the City of Las Vegas. The conclusions and analyses set out in the report were developed through a long informal process of discussion and meetings among the City of Las Vegas, its consultants, other local governments and their consultants, and local agencies and organizations. Assistance in word processing, reproduction, preparation of figures, drafting, and editing was provided by Brobeck, Phleger & Harrison, CWC-HDR, Inc., and the City's consultants.

Mr. Horowitz is a specialist in water-pollution control and has more than 20 years of experience in the field. For many years he was a consultant to the U.S. Environmental Protection Agency, and during this time he was perhaps EPA's principal expert on water-quality standards and the effects of municipal discharges on water quality. He worked with EPA Headquarters and nearly all the regional offices, including Region IX in San Francisco and Region VIII in Denver. Mr. Horowitz is the principal author of several major reports on water-quality standards in California, Washington, Colorado, Missouri, Wisconsin, Ohio, Florida, New Jersey, and Massachusetts.

Mr. Lewis H. Dodgion  
August 24, 1987  
Page 2

These reports were written under contract to EPA and the U.S. National Science Foundation. Mr. Horowitz has also served as an environmental consultant to the U.S. Council on Environmental Quality, the U.S. General Accounting Office, the National Commission on Water Quality, Congressional Committees, and local governments.

In 1976, as the result of a nationwide study under contract to EPA, he reported that Advanced Wastewater Treatment (AWT) was not likely to correct the water-quality problems identified in any of the case studies. As a result of this study, Congress restricted federal grants to AWT projects.

Sincerely,

*Randy H. Walker / Rm*

Randall H. Walker  
Deputy City Manager

Enclosure

cc: Distribution list (letter, report, and appendices)

**ANALYSIS OF  
THE WATER-QUALITY STANDARDS  
PROPOSED BY  
THE NEVADA DIVISION OF ENVIRONMENTAL PROTECTION**

**Submitted by the City of Las Vegas**

**August 1987**

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## 1. SUMMARY

The Nevada Division of Environmental Protection (DEP) has proposed water-quality standards, applicable to Las Vegas Bay and Lake Mead, for (1) chlorophyll, (2) un-ionized ammonia, and (3) pH.

We have concluded that the proposed standards are unlikely to protect or improve water quality in Lake Mead.

The proposed chlorophyll standard:

- may harm the fishery. Lakes with more chlorophyll have greater fish production.
- will not improve clarity. Chlorophyll concentrations above 30 ug/l have little effect on clarity.
- will not protect against scums or dominance by blue-green algae. Lake Mead shows no consistent relationship between chlorophyll and scums or blue-green dominance.
- will not safeguard the drinking-water supply. Chlorophyll is irrelevant to the drinking-water supply.

The proposed standard for un-ionized ammonia depends on the assumption that a problem exists, but there is no evidence of any problem caused by un-ionized ammonia. If there is no problem, then the money spent "correcting" it will be wasted.

The proposed pH standard is unnecessary to protect any beneficial use. It is intended to prevent degradation of higher quality waters but, because of a statistical defect, it would be violated by random variations even if there were no degradation.

DEP expects to implement the proposed chlorophyll standard through restrictions on the municipal discharges of phosphorus. However, the wastewater-treatment plant operated by the Clark County Sanitation District and the City of Las Vegas have been removing phosphorus since 1981. Although \$170 million has been spent on phosphorus removal, it has failed to change chlorophyll concentrations in Lake Mead. The proposal now under consideration also appears to be headed for failure.

DEP also expects to impose restrictions on municipal discharges of ammonia. These phosphorus and ammonia restrictions are estimated to cost the taxpayers of Southern Nevada \$110 million (including construction costs plus the present value of operation and maintenance over the next 20 years).

The failure of municipal phosphorus removal may be compared to a field of grass. The height of the grass depends not only on the amount of fertilizer applied to the field, but also on the number of cows eating the grass. In the same way, the amount of chlorophyll in Lake Mead depends not only on the amount of phosphorus fertilizer added to the

lake, but on grazing and other ecological processes. DEP has ignored grazing and other ecological processes. It is an oversimplification to suggest, as DEP does, that phosphorus from wastewater discharges controls the amount of chlorophyll in the lake. The data show that there is no relationship between the two.

Moving the point at which Las Vegas Wash enters Lake Mead might be more effective than investing in wastewater-treatment facilities. DEP and the U.S. Environmental Protection Agency (EPA), among others, have endorsed the concept. Advocates say that moving the discharge will spread the inflowing wash water over a much greater area, thereby eliminating the peak concentrations found in the inner bay. However, not enough is known about mixing and ecology in the bay to determine where to move the discharge, or to be certain that it will succeed. A study is needed.

If the proposed standards are adopted now, the local governments and their consulting engineers may soon have to decide whether to add wastewater-treatment facilities or to move the discharge. Under these circumstances, they are likely to opt for more treatment facilities--there is simply not enough known about moving the discharge to make the commitment now.

We propose a Coordinated Lake Mead Study (CLAMS), financed by the local governments, to investigate moving the discharge and to determine whether there is any problem

caused by un-ionized ammonia. CLAMS is expected to last three years, of which two years will be spent collecting data and the third year analyzing and interpreting them. It is expected to cost several hundred thousand dollars per year.

We request that any decision on the proposed standards be deferred until the next triennial review, so that CLAMS can be completed before standards are established. Nothing in law or science requires the Commission to set standards now. EPA staff has suggested that once the proposed standards are established, they cannot be relaxed, even if CLAMS should prove that they are wasteful and unnecessary.

## 2. CONCLUSIONS

### The Proposed Standards Are The First Step In A Regulatory Process Leading To Phosphorus And Ammonia Restrictions On Wastewater Discharges

In June 1987, the Nevada Division of Environmental Protection (DEP) distributed a proposal for water-quality standards, including specific standards for chlorophyll, ammonia, and pH, applicable to Las Vegas Bay and Lake Mead. The document is entitled "Las Vegas Wash and Lake Mead Proposed Water Quality Standards Revisions and Rationale" (dated May 1987), and will be referred to as DEP's Proposal.

The proposed standards are designed to lead to restrictions on municipal discharges of phosphorus and ammonia. If adopted by the State Environmental Commission, the standards will trigger a complicated regulatory process that includes the following steps:

- "total maximum daily loads", often referred to as "TMDLs" (assessments of the amounts of phosphorus and ammonia that can be assimilated by Las Vegas Bay),
- "wasteload allocations" (apportionment of the TMDLs among dischargers),

- effluent limits (restrictions applicable to individual dischargers that are issued in NPDES discharge permits),
- facilities plans (engineering reports describing treatment facilities),
- plans and specifications, and finally
- construction of wastewater-treatment facilities.

DEP has suggested that new phosphorus restrictions could go into effect as soon as June 1988, and that facilities plans for ammonia removal could be required as soon as early 1989.

#### Phosphorus Removal Has Failed To Improve Water Quality

DEP first proposed a water-quality standard for phosphorus in the late 1960s, and has been advocating phosphorus removal ever since. DEP predicted that phosphorus removal would prevent algal nuisances in Las Vegas Bay, improve clarity, and eliminate the green color.

As a result, the Clark County Sanitation District and the City of Las Vegas added phosphorus-removal facilities at their wastewater-treatment plants. These facilities began operating by 1 July 1981, and have since complied with their phosphorus limits.

Six years have passed, and the results of this phosphorus-removal experiment are now in. They show beyond any doubt that phosphorus removal has not improved water quality in Las Vegas Bay. Chlorophyll concentrations in the

lake stayed the same after phosphorus removal. Clarity stayed the same. The green color has not been eliminated. Phosphorus removal did not prevent algal scums: In 1986, scums were reported in Las Vegas Bay for the first time. // \*

In short, DEP's predictions were wrong. Phosphorus removal has not improved clarity, eliminated the green color, or prevented algal scums in Las Vegas Bay.

#### Phosphorus Removal Cost The Public \$170 Million

Building and operating the facilities for phosphorus removal have cost ~~the taxpayers of Clark County and the City of Las Vegas~~ <sup>more than</sup> ~~the taxpayers of Clark County and the City of Las Vegas~~ <sup>\$ 265 million</sup> more than \$170 million so far (replacement value plus operational costs).

#### The Proposed Standards Are Likely To Lead To Another Failure

DEP continues to advocate phosphorus removal. It expects the proposed chlorophyll standard to lead to phosphorus-removal requirements, and believes that these phosphorus-removal requirements will ensure that Las Vegas Bay conforms to the proposed chlorophyll standard. The Proposal implies that the chlorophyll standard will eliminate algal scums, prevent blue-green algae from becoming dominant, improve clarity, improve dissolved oxygen, and improve the fishery. These are big claims, but they are not supported by the evidence.

Data collected from Lake Mead, as well as research reported in the scientific literature, lead to different conclusions. The data show no relationship between phosphorus from the treatment plants and chlorophyll in Las Vegas Bay. The data also show no relationships between phosphorus or chlorophyll and scums or dominance by blue-green algae. DEP's analysis suggests that clarity in Las Vegas Bay would remain about the same even if the proposed chlorophyll standard were less stringent. The fishery will not be improved by the proposed standard; it will be unaffected or harmed. In other words, the new proposal appears headed for another failure.

The proposed standard for un-ionized ammonia seems headed for failure too, since it depends on the assumption that a problem exists--even though there is no evidence of any problem caused by un-ionized ammonia. If there is no problem, then the money spent "correcting" it will be wasted.

#### The Proposal Will Cost The Public Another \$110 Million

The estimated cost of the proposed standards (expressed as construction costs plus the present value of operation and maintenance costs over the next 20 years) is \$110 million.

Conduct A Study Before Establishing Standards And Committing Public Money

Although DEP has the legal responsibility for studying water quality in Lake Mead, its budget is not sufficient for the kind of studies needed to determine whether the proposed standards are scientifically sound. Consequently, we propose to conduct a study, at local expense, of water quality in Las Vegas Bay. The proposed study, which is entitled the Coordinated Lake Mead Study (CLAMS), is expected to last three years, of which two years will be spent collecting data and the third analyzing and interpreting them. CLAMS will include investigations of the following questions:

- What prevents blue-green algae from forming scums in Las Vegas Bay?
- How could the fishery be improved?
- Are the ammonia discharges toxic to the fish?
- Would moving the discharge or restoring the wetlands be more effective than increasing wastewater treatment?

We recommend that the Commission defer consideration of the proposed standards until the next triennial review of water-quality standards. Before committing \$110 million to a program that appears headed for failure, it would be wise to conduct an adequate scientific study.

## Las Vegas Bay Is Not Well Understood

Many kinds of data on Las Vegas Bay (to our knowledge) have never been or are no longer collected, including data on hydrodynamics (water currents, surface waves, and mixing), algae (identification, count, and biovolume), and fish (residency, habitat preference, and range). Some data have not been collected from shore to shore or around the clock (which are necessary for assessing ammonia toxicity). Some data are collected but have not been considered by DEP, including data on the fishery (total catch and catch per angler), zooplankton (identification and abundance), and climate (wind speed and direction).

Given the inadequacies of the database, it is too much to expect anyone to come up with all the answers. Sometimes, however, DEP has gone beyond the data and arrived at conclusions for which there is no support. For example, DEP "unequivocally" concludes that processes such as erosion have caused changes in plume dynamics that in turn have affected the way phosphorus is distributed from the plume into the surface waters of the bay. No one has enough information to reach this conclusion, and DEP has not offered any evidence to support it.

## Establishing Standards Now May Prevent Moving The Discharge

Chlorophyll and ammonia standards, and the resulting investment in expensive wastewater-treatment facilities, are not the only choices available. Moving the discharge--

the point at which Las Vegas Wash enters Lake Mead--might do more to improve the lake. The wash now enters the lake in a narrow canyon extending from the mouth of the wash past station 3; the proponents of moving the discharge claim that this narrow canyon prevents adequate mixing, and nutrients from the wash are trapped there. There are too many algae in the canyon, they argue, and too few algae elsewhere in Las Vegas Bay and Boulder Basin. If the wash were piped to a place where the lake is wider and deeper, it might spread over a larger area and mix into a larger volume. Advocates maintain that mixing the wash discharge into a greater volume of water would benefit water quality throughout the bay:

- there would be very little chlorophyll in the inner bay
- there would be very little ammonia in the inner bay
- there would be better fish production throughout the bay

This is an attractive idea. It has been endorsed in concept by DEP, EPA, and the Southern Nevada Water System. Owing to the lack of data, however, no one can be certain that moving the discharge would improve the lake. If moving the discharge merely moves the peak concentrations

further out and spreads them over a greater area, many people would consider the idea a failure.

Careful study is required to assess the soundness of this idea. CLAMS includes a hydrodynamics investigation to assess whether water currents are sufficiently powerful and consistent to accomplish the necessary spreading. It also includes a study of algae <sup>Algae</sup> ecology in the bay and of the factors that tend to promote blooms of blue-green algae. These studies are expected to last three years, including two years for data collection and one for data analysis and development of a plan of action.

If the proposed standards are adopted now, the local governments and their consulting engineers may soon have to decide whether to add wastewater-treatment facilities or to move the discharge. Under the circumstances, they are likely to opt for more treatment facilities--there is simply not enough known about moving the discharge to make the commitment now.

Nothing Requires The Commission To Establish Standards Now

The Clean Water Act requires that each state "shall from time to time, (but at least once each three year period beginning with October 18, 1972) hold public hearings for the purpose of reviewing water quality standards and, as appropriate, modifying and adopting standards." (Clean Water Act, § 303(c)(1), 33 USCA § 1313(c)(1).) According to

this language, the first period began on 18 October 1972 and ended three years later; the second period ended three years after that, and so forth. The fourth period ended on 18 October 1984, and the fifth period will end 18 October 1987. The last public hearing, in 1982, fell within the fourth period; the next public hearing, which is scheduled for 9-10 September 1987, falls within the fifth--and current--period. Consequently, the scheduled hearings appear to be timely.

The regulations issued by EPA state that hearings must be held "at least once every three years". (40 CFR § 131.20.) EPA Region IX has suggested that, since the last public hearing held to review water-quality standards was nearly five years ago, Nevada is tardy. This interpretation may conflict with the statute, and when a regulation conflicts with a federal statute the regulation is invalid. However, no court has considered this issue and ruled on it.

Although the Commission is required to review the existing water-quality standards, it need not adopt new standards unless it decides that they are "appropriate". This report considers whether the proposed new standards are appropriate and concludes that they are not.

The results of the Commission's review must be submitted to EPA, which has authority to approve or disapprove the submission. The federal procedures for establishing standards, however, are stricter, more laborious, and more

time-consuming than Nevada procedures. It is much easier for EPA to pressure states than to establish standards on its own.

The proposal now before the Commission is unlikely to improve water quality in Las Vegas Bay; it cannot enhance the fishery and may harm it. Until a study is completed, there is no sound scientific foundation for determining appropriate water-quality standards or for relocating the Las Vegas Wash discharge into Lake Mead. Consequently, postpoing the establishment of standards for three years does not create a risk of harm to water quality or to the fishery and permits assessing a relocated discharge as an alternative to more wastewater treatment.

In short, neither law nor science requires the Commission to establish standards now. Postponing the decision until there is sufficient information to determine appropriate standards and appropriate programs to enhance Lake Mead is in the best interest of the citizens of the State of Nevada. It would not be in their financial interest to spend money on a problem that does not exist, and it would not be in their environmental interest to contribute to the deterioration of water quality and the fishery in Lake Mead.

Once Established, Water-Quality Standards May Be Impossible To Change

The establishment of water-quality standards triggers a planning process that leads to TMDLs, wasteload allocations, and revisions of discharge permits. Local governments, consulting engineers, and regulatory agencies devote a great deal of time and money to the planning process, which takes on a life of its own; it gains momentum as it proceeds, and soon becomes inevitable. Meritorious objections are often brushed aside without impartial, thorough consideration. Because of the complexity of the process and the amount of work required, it is difficult to begin anew when additional data are received. The decisions, once made, tend to stand, and once a project nears construction it may be impossible to stop.

Even if the Commission should decide in the future that the standards should be relaxed, EPA almost certainly will not allow it. EPA staff has suggested that once the proposed standards are established they cannot be relaxed, even if CLAMS should prove that they are wasteful and unnecessary. A standard that would be perfectly acceptable to EPA if there were none on the books will be completely unacceptable if there is a more stringent standard in effect.

Plainly, there is a risk in acting now: The establishment of the proposed standards will trigger a planning

process that may become irreversible, even if new information developed within the next three years establishes beyond any doubt that the proposed standards were inappropriate.

There Is Little Environmental Risk In Waiting Until The Next Triennial Review

Clark County Sanitation District and the City of Las Vegas are now complying with their phosphorus limits, and plan to comply with them until the next triennial review. There is little risk that phosphorus loads will make chlorophyll concentrations increase during the next three years. The data show that chlorophyll concentrations do not respond to the range of phosphorus loads expected during the next three years. Therefore, there is no need to establish chlorophyll standards now.

There is no need to establish ammonia standards now because (1) there is no evidence of any ammonia-related problem, and (2) no reason to believe that a problem will suddenly appear in the next three years. Surely it is better to determine whether there is a problem before committing tens of millions of dollars to "cure" it.

In 1985, in DEP's formal submission to EPA and to Congress, DEP reported that water quality in the inner bay was acceptable:

Conditions in the Inner Bay are overly-productive but these levels are acceptable due to:

- 1) its small area;
- 2) its importance as a nursery area for young fish;
- 3) its importance as a food base. [DEP 1985, p. 11.]

#### DEP's Proposal Is One-Sided

Judging from the Proposal alone, one might think that everyone agreed with the DEP's recommendations. Nowhere in the Proposal is there any mention of the objections that have been expressed to the arguments in the Proposal that DEP made public before June 1987.

Appendix B to the Proposal, entitled "Review Of Past Studies", is more noteworthy for what it excludes than for what it includes. It excludes all reports that took issue with DEP, especially those prepared within the last year. In particular, it excludes the report prepared by CH2M Hill on behalf of Clark County, and the four white papers prepared by the City of Las Vegas (all attached as appendices to this report). These reports provide the latest thinking by the city and county on water quality in Las Vegas Bay, and they include strong objections to the chlorophyll and ammonia proposals that DEP announced in June 1986. These objections are particularly relevant to the proposal now before the Commission, which is in many ways identical to the June 1986 proposal.

On the issue of water-quality standards for Lake Mead, DEP has not acted as a regulatory agency, but as a partisan. It has made no attempt to provide an objective and impartial review of available evidence for the Commission. The Proposal simply ignores all evidence that does not support DEP's position, rather than identifying all evidence, weighing it impartially, and making a balanced recommendation.

In short, DEP has not fully informed the Commission or the public.

#### DEP Did Not Adequately Consider Enhancing The Fishery

There is no dispute that the nutrients provided by wastewater discharges into Las Vegas Wash enhance the fishery in Las Vegas Bay. The nutrients feed the algae, which feed the zooplankton, which feed the forage fish, which feed the game fish.

The Proposal reported that Lake Mead is considered too unproductive to support a good sport fishery. It also reported that increased algal productivity leads to greater fish production. However, DEP did not consider whether the fishery might be enhanced by increasing chlorophyll concentrations in the inner bay, or by increasing the nutrient discharges from the treatment plants.

Published research provided by DEP shows that lakes with relatively higher algal production grow proportionately

*Err 1/6 Jan 88*

more fish. This research suggests that raising the proposed chlorophyll standards from 30 ug/l to 90 ug/l could more than triple fish production. Data on the fishery collected by the Nevada Department of Wildlife show that the fish catch in Las Vegas Bay was up in 1986, the year of high chlorophyll concentrations; this finding is consistent with the research DEP cited showing that chlorophyll is directly related to fish production.

DEP, however, did not review any of the data on the fishery in Las Vegas Bay or Lake Mead. It did not assess the relationship between algal productivity and fish productivity in Las Vegas Bay. Since the reported decline in the fishery appears to be an issue of great concern to the public, these are major oversights. DEP should have considered the beneficial effects of nutrients provided by wastewater discharges, and should have considered how to use them to enhance the fishery.

#### The Proposed Chlorophyll Standard Can Harm The Fishery

An important goal of the Proposal is decreasing algal productivity in Inner Las Vegas Bay. But if algal productivity is decreased, fish productivity is also likely to be decreased. Fewer, smaller fish in Las Vegas Bay is a logical consequence of DEP's Proposal. This proposal for a decrease in fish production is a degradation of the beneficial use of fishing.

Degradation of this kind may be restricted under the antidegradation policy required under the Clean Water Act. Whether or not the antidegradation policy applies, it is obvious that the proposed standards ought not to be adopted until there is an assessment of the damage they may cause to the fishery.

Furthermore, there is no evidence that the proposed chlorophyll standard can benefit the fishery.

#### The Proposed Chlorophyll Standard Will Not Improve Clarity

DEP has suggested that the proposed chlorophyll standard will protect or improve clarity in Inner Las Vegas Bay. However, DEP's data analysis shows that there is little change in clarity above chlorophyll concentrations of 30 ug/l; chlorophyll concentrations might be increased to 90 ug/l with little apparent change in clarity. Consequently, DEP's own analysis shows that the proposed standard will do little to improve clarity.

#### The Proposed Chlorophyll Standard Will Not Prevent Blooms Of Blue-Green Algae

DEP has suggested that the proposed chlorophyll standard will protect Las Vegas Bay against blooms of blue-green algae. However, reports published in the scientific literature show that blue-green dominance, and scums of blue-green algae are found in many lakes regardless of

chlorophyll concentration. Dominance by blue-green algae capable of forming scums has been reported in lakes with chlorophyll concentrations below 5 ug/l. Data from Lake Mead show that blue-green algae have often dominated in Boulder Basin, where chlorophyll is usually less than 5 ug/l. In short, the chlorophyll standard cannot protect Las Vegas Bay from scums or dominance by blue-green algae capable of forming scums.

The Proposed Chlorophyll Standard Is Irrelevant To Drinking Water

DEP has suggested that the proposed chlorophyll standard is necessary to protect drinking water taken from Lake Mead. However, drinking water is taken from Boulder Basin--not from Las Vegas Bay. Even during 1986, when there were occasionally extremely high chlorophyll values in the inner bay, chlorophyll did not increase in Boulder Basin. Furthermore, the Southern Nevada Water System (SNWS) has concluded that there is no relation between chlorophyll in Boulder Basin and anything affecting water treatment. The proposed standard does nothing to safeguard the drinking-water supply. According to SNWS, it is irrelevant.

### The Proposed Ammonia Standard Is Premature

The proposed ammonia standard is much too speculative. There are no reports of fishkills, of fish in distress, or of chronic toxicity caused by exposure to unionized ammonia.

The proposal for an ammonia standard grew out of chemical data on ammonia at station 2; EPA guidance suggested that the concentrations might cause chronic toxicity. However, the data collected at station 2 have since been shown to be severely biased, thereby invalidating the conclusions drawn from EPA guidance.

A study of ammonia and fish in Inner Las Vegas Bay is being proposed as part of this report. Until the study determines whether there actually are any problems attributable to ammonia, it would be premature to try to cure them.

### The Proposed pH Standard Is Statistically Defective

The proposed standard for pH is based on a statistical evaluation of past data, and is intended to prevent a trend for the worse in pH. There is no assertion that it will protect any beneficial use.

Unfortunately, the proposal is statistically defective because it ignores random variation. The problem is most easily explained in terms of flipping a coin. Although five out of ten tosses "ought to be" heads, sometimes only four of ten are heads, and sometimes six of ten are heads.

These results are caused by random variation, not because the odds change. However, the proposed standard would assume that each time someone reported six heads there was a change in odds--that is, a trend for the worse--and would record a violation of water-quality standards. Consequently, the proposed standard will produce apparent violations of water-quality standards even when there is no trend for the worse.

Because violations of water-quality standards trigger the regulatory process involving TMDLs, wasteload allocations, and so forth, the proposed pH standard is likely to lead to a great waste of time and resources, without providing any protection for any beneficial use in the lake.

#### There Is No Need For Haste

Decisions about water-quality standards start processes that last for decades. DEP's decision in the late 1960s to propose a water-quality standard for phosphorus led to wastewater-treatment facilities that were under construction in the late 1970s and went into operation in 1981. It is now six years later, DEP has proposed a phosphorus standard masked as a chlorophyll standard plus an ammonia standard, and the cycle is poised to begin again.

As DEP readily admitted in 1978, water quality was fine during the 1970s; there were no scums, or odors, or any interference with any beneficial use. By then, however,

construction had begun, and it was too late to retract the decision. If there had been time for reconsideration, \$170 million might have been saved.

The new Proposal, like the one in the 1960s, is undoubtedly motivated by concern over changes in water quality. The new, like the old, includes unrealistic predictions about improvements in water quality, and carries a hefty price tag of \$110 million.

Before starting the cycle again, the State of Nevada should carefully consider all reasonable choices, and the likelihood of success of each. A good study is imperative.

The study we propose centers on relocating the wash discharge farther out in the lake, where the nutrients may improve the fishery. A new discharge point may also lower chlorophyll and ammonia concentrations in the inner bay. Standards now would defeat the entire purpose of this study.

For these reasons, it is best to postpone the setting of new standards until the study results are in. There is much wisdom in the old tailor's adage: Measure twice, cut once.

### 3. SETTING

#### The Nation's Largest Reservoir

Lake Mead is the largest reservoir in the United States. When its surface is at an elevation of 1200 feet, the lake holds 30 million acre-feet (1.3 trillion gallons). (Brown & Caldwell 1982, figure 3-4.) In comparison, Lake Lahontan holds only 274 thousand acre-feet, or less than 1% of Lake Mead. (Martin & Hanson 1966, p. 66.)

Lake Mead was formed by damming the Colorado River, and nearly all the water in the lake comes from the Colorado. After passing through the Grand Canyon, water from the Colorado River enters Lake Mead at the eastern end, moves generally westward, and exits at Hoover Dam. The lake consists of several wide basins often connected by narrow canyons. See Figure 1.

Las Vegas Wash, a small stream that carries treated wastewater from Clark County and the City of Las Vegas, enters the lake at the western end of Las Vegas Bay. See Figure 2. Because the wash water is denser than lake water, it sinks as it enters the lake and becomes a density current (the so-called "plume") that flows at or near the bottom until it reaches water of similar density. See Figure 3.

Although the hydraulics are complicated and have never been comprehensively studied, it is clear that mixing works both ways: a small amount of plume water mixes into

the lake, and a great deal of lake water mixes into the plume, which becomes increasingly dilute as it moves away from the mouth of the wash. The plume disappears between station 5 and station 8.

Only a tiny fraction of the water in Lake Mead comes from Las Vegas Wash. During the summer of 1986, for example, Las Vegas Wash contributed less than half of one percent of the flow leaving the lake at Hoover Dam. See Figure 4.

Because of this disproportionate size, the effects of the wash--including increased productivity--are localized. They are most noticeable in the narrow canyon, sometimes called Inner Las Vegas Bay, that extends from the mouth of Las Vegas Wash past stations 2 and 3 and nearly to the Las Vegas Marina. The effects of the wash, like the plume, disappear by station 8.

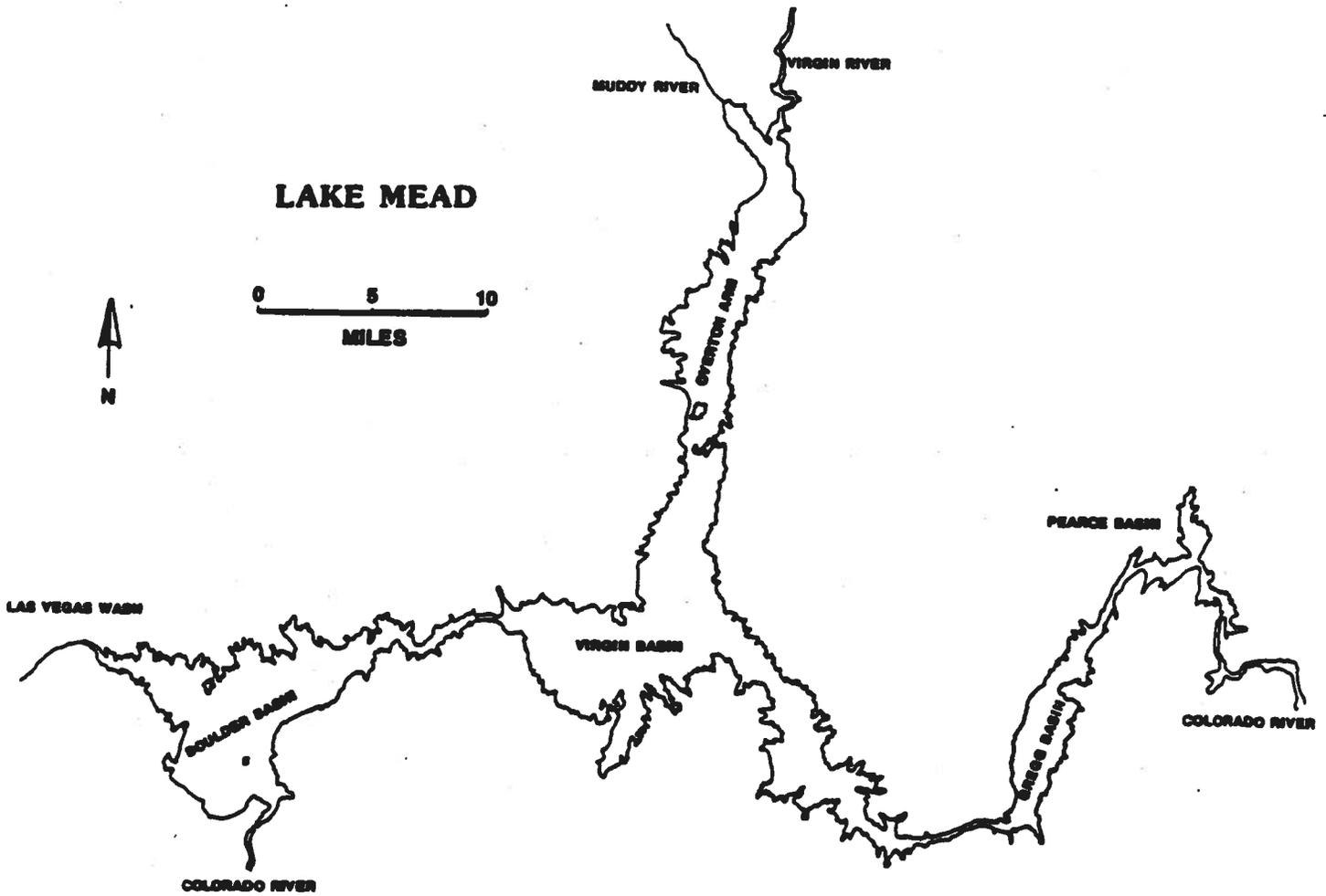
#### Inner Las Vegas Bay Is A Small Productive Area In A Huge Unproductive Lake

Lake Mead has been classified as unproductive. One sign of this lack of productivity is the sport fishery, which has reportedly been declining for the last two decades. (DEP May 1987, p. D.1.)

Inner Las Vegas Bay, in comparison, is relatively productive, but it includes only a small part of the lake. The inner bay covers less than 100 acres of surface area--

FIGURE 1

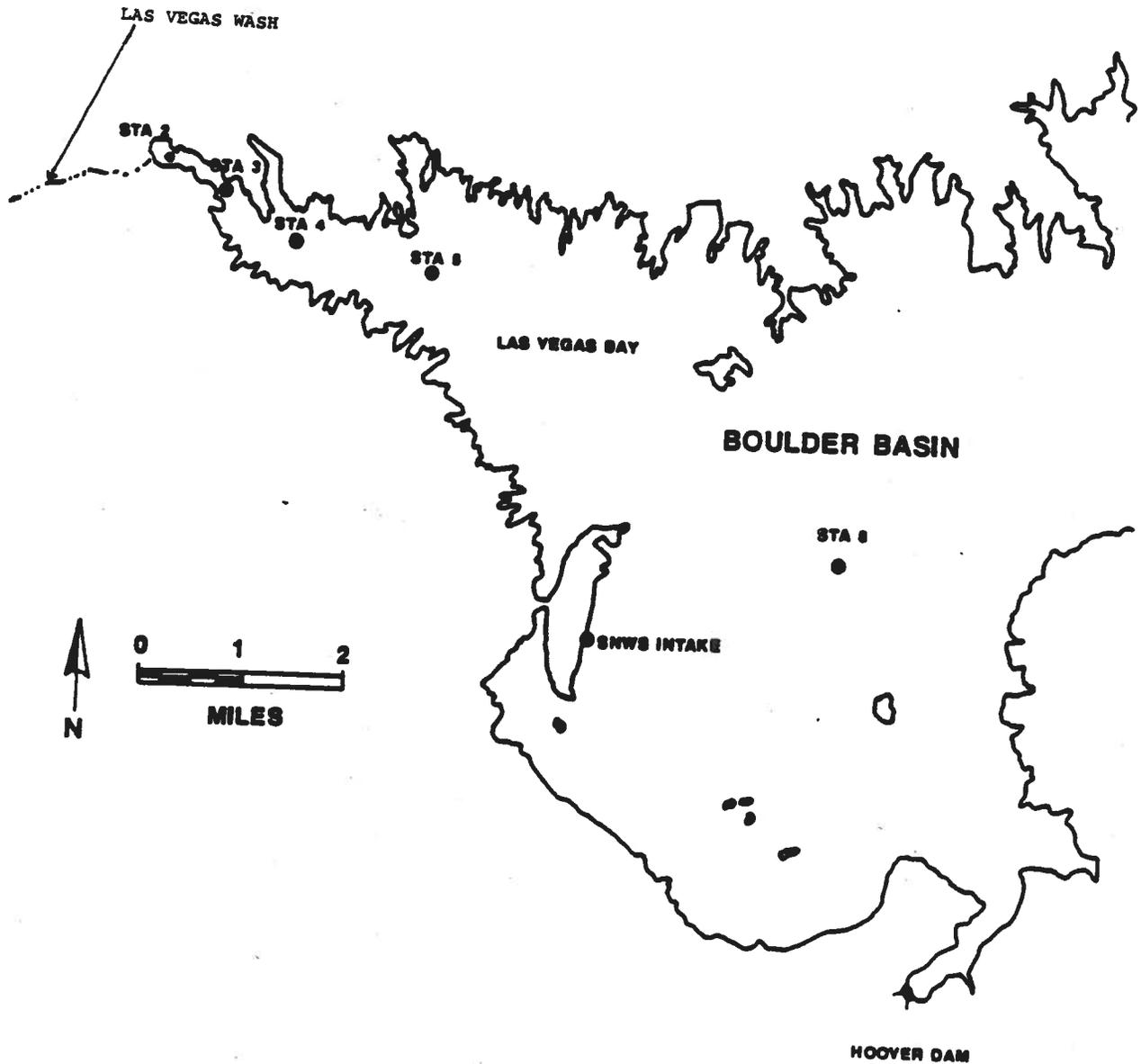
Map of Lake Mead



(Figure 1 from DEP's Proposal.)

FIGURE 2

Map of Las Vegas Bay and Boulder Basin

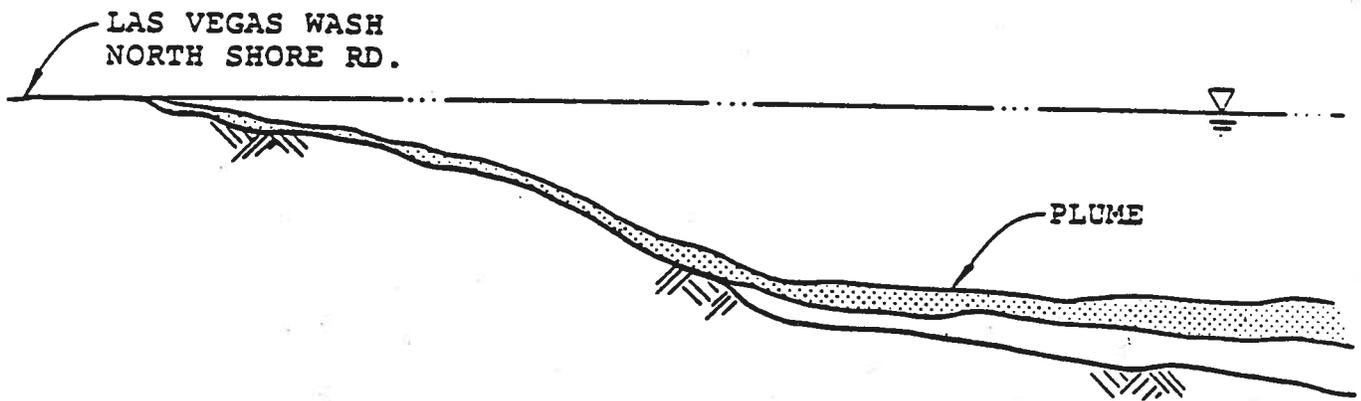


(Detail of Figure 2 from  
DEP's Proposal, slightly  
modified.)

FIGURE 3

## IDEALIZED PLUME PROCESS

### LAS VEGAS BAY PROFILE



(From CH<sub>2</sub>M Hill (January 1987). Elements of Water Quality Standards Review; Lake Mead--Las Vegas Bay.)

less than 0.1% of the 150,000 acres in the lake. It holds about 4,200 acre-feet of water, less than 0.02% of the 30 million acre-feet in the lake. (Brown & Caldwell 1982, figures 3-4 to 3-7 and accompanying text.)

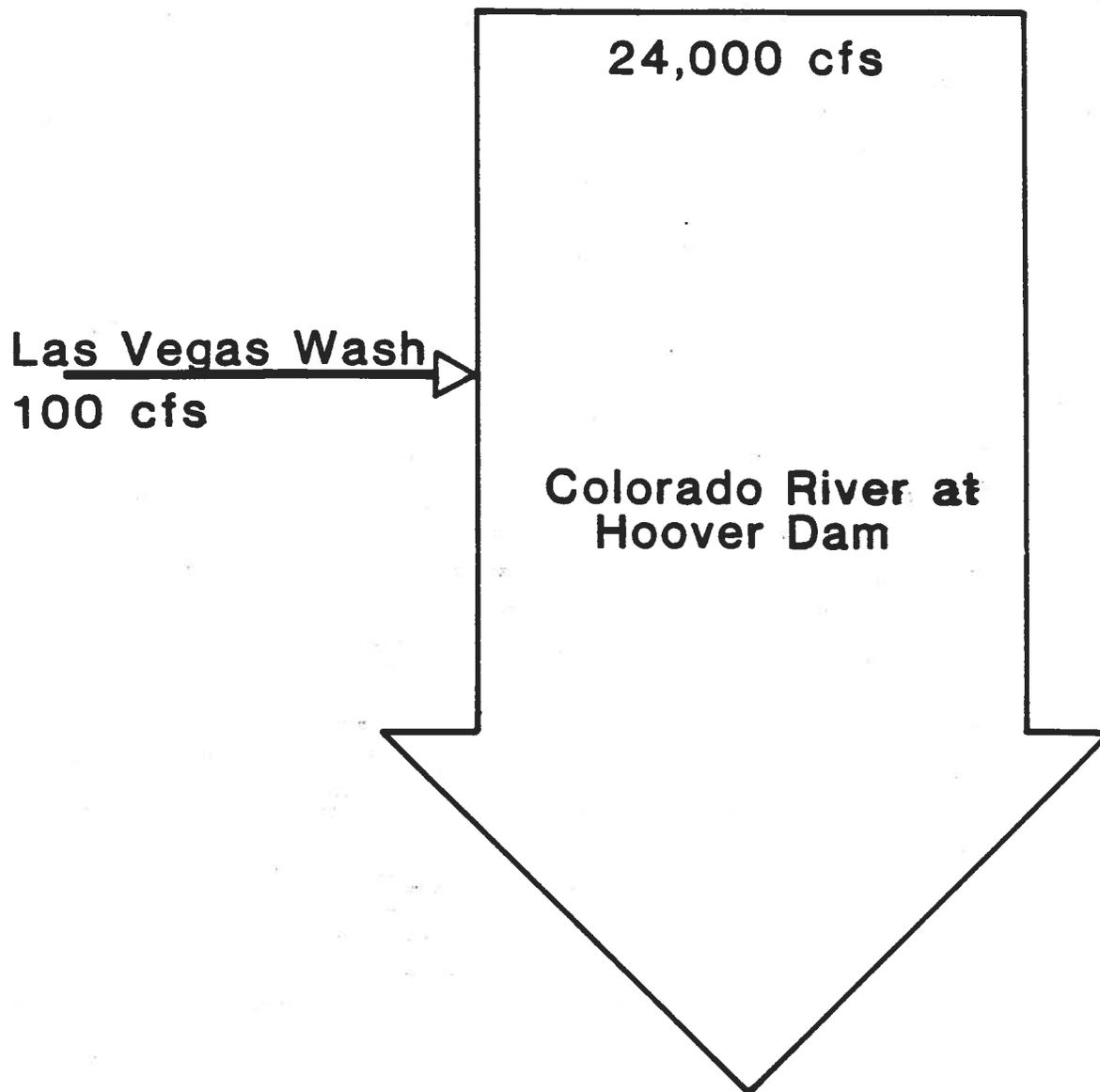
#### Municipal Wastewater Improves The Fishery In Las Vegas Bay

There is no dispute that municipal wastewater flowing into the inner bay from Las Vegas Wash contributes to the productivity of the area. Figure 5 shows, in simplified form, how the nutrients in wastewater help nourish and promote the fishery: sport fish eat smaller fish, which eat zooplankton (microscopic animals), which eat algae, which assimilate nutrients. Sometimes the pattern is slightly different; young striped bass may feed directly on zooplankton, for example, and shad may feed directly on algae.

Figure 5, however, can tell only part of the story. Like all plants, algae need light for photosynthesis, and so they tend to live in the top few meters of the lake, where sunlight can penetrate. This area of good light is called the euphotic zone. The plume, however, usually flows below the euphotic zone, and consequently most of the nutrients entering the lake from Las Vegas Wash may never reach the algae growing near the surface. One paper estimated that only about 10% of the plume mixed into the waters above

FIGURE 4

## Comparison of Flow During July - September, 1986



(Data from U.S. Geological Survey.)

**CONCLUSION:** Las Vegas Wash contributed less than half of one percent of the flow passing through Lake Mead.

it. (Fischer & Smith 1983.) The rest may simply dissipate in the vastness of outer Las Vegas Bay. See Figure 6.

Some algae may not depend on physical mixing of the plume to supply their nutrients. They may be able to sink down to the plume to obtain nutrients, and then rise to the euphotic zone to obtain light. Although this phenomenon has never been studied in Lake Mead, it is well documented in the scientific literature.

#### Water Quality In Lake Mead Is Usually Excellent

Owing to its enviable water quality, Lake Mead supports a National Recreational Area and is heavily used for fishing, pleasure boating, and swimming. It supplies most of the drinking water used in Las Vegas Valley: It also provides a wildlife habitat for migrating birds.

These uses are not perfectly in harmony. For example, high concentrations of fecal-coliform bacteria have been reported near the mouth of Las Vegas Wash; these bacteria are believed to come from the birds that are evident, often in great numbers, in the area. As a result, DEP has defined a special segment, between the mouth of Las Vegas Wash and the western end of the campground at the Las Vegas Wash marina, in which swimming is not designated as a beneficial use. (NAC 445.1352.) Wildlife habitat may be incompatible with swimming.

FIGURE 5

Simplified Diagram Of A Strand Of The Food Web  
In Lake Mead

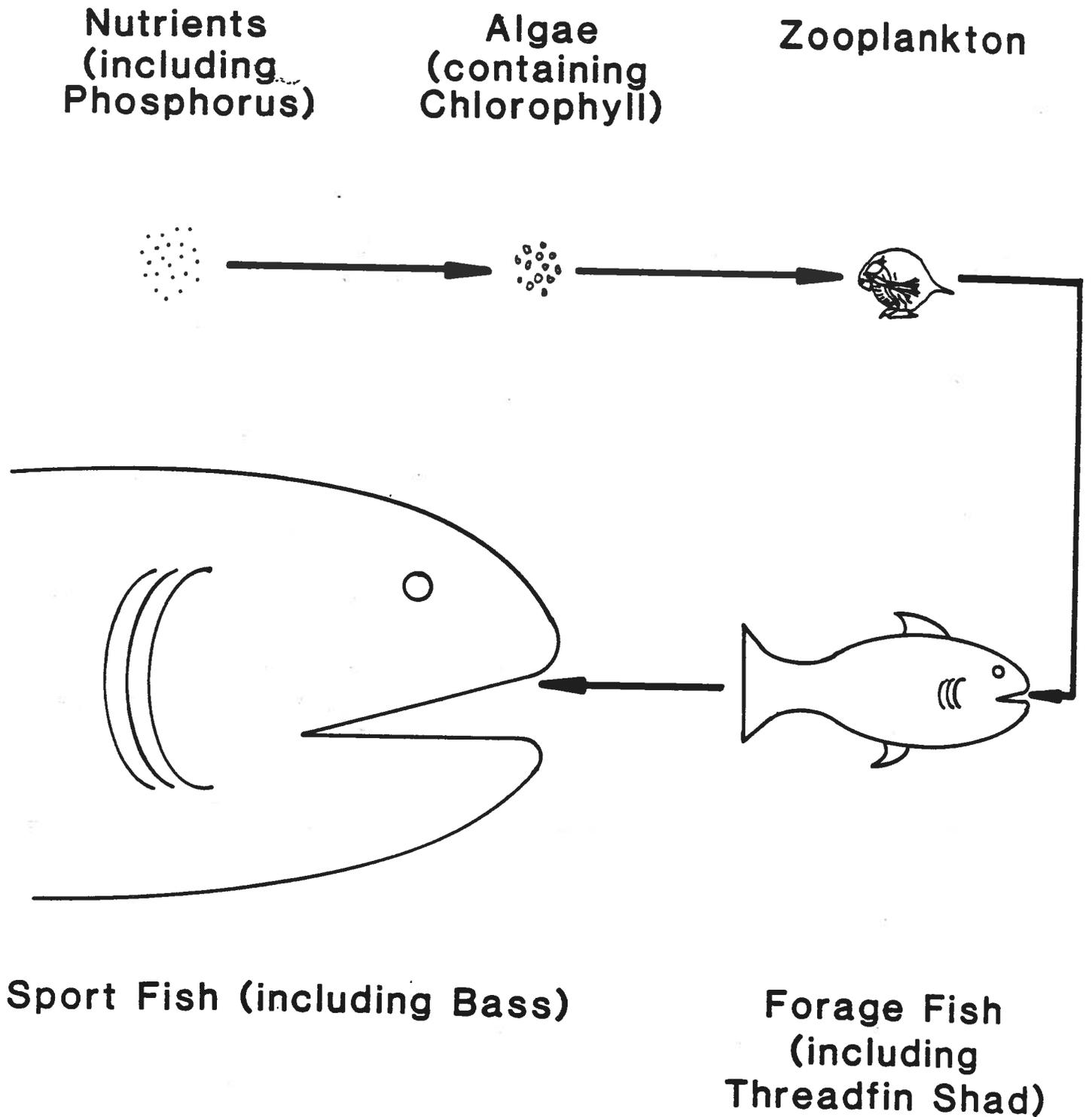
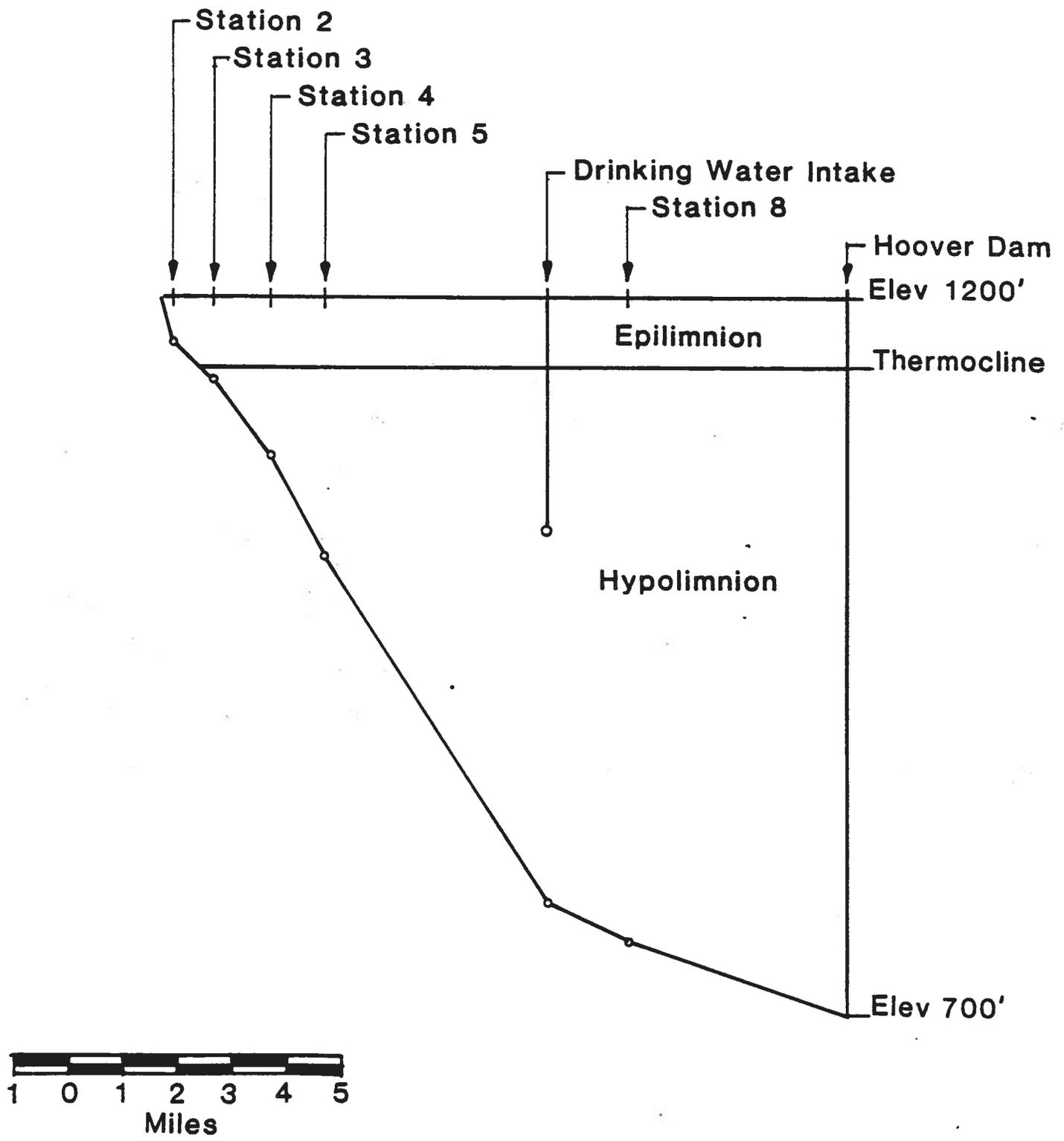


FIGURE 6

# Cross Section of Lake Mead Between Las Vegas Wash and Hoover Dam



Wetlands habitat for wildlife may also be incompatible with drinking-water supply. Because wetlands consume valuable water that might otherwise be available for people, the Colorado River Commission has objected to any attempt to restore the wetlands within Las Vegas Wash. (Colorado River Commission 1987.)

In other ways, the multiple uses of the lake can place conflicting demands on water quality. A good fishery, for example, requires a plentiful source of food. But the microscopic organisms on which fish feed--algae and zooplankton--reduce the clarity of water. Enhancing the fishery in Lake Mead may, in some places, decrease clarity. These are necessary trade-offs in balancing beneficial uses.

In general, water quality in Lake Mead is excellent. The U.S. National Park Service reports that "Both desert lakes [Mead and Mohave] are clear, clean, and ideal for swimming, snorkeling, and diving", and that "The lakes offer some of the best sport fishing in the country." (U.S. National Park Service, undated.)

DEP itself has concluded that water quality in Las Vegas Bay and even Inner Las Vegas Bay is usually appropriate for those areas. In the Proposal, for example, DEP asserted that water quality during 1981-1985 was exemplary, and that it would like to maintain the water quality observed during those years. (DEP May 1987, pp. D.34.-D.35.) DEP implied that water quality during the 1970s was

even better, at least so far as algae are concerned, since chlorophyll concentrations during 1974-1980 were generally lower than they were during 1981-1985. (Id., pp. D.15., D.17.) In fact, DEP identified only one year since 1974--the first year for which chlorophyll data are reported--in which water quality was not good. That year was 1986.

(Id., p. D.34.)

DEP has often testified that algae were not causing problems in Las Vegas Bay. In 1978, for example, DEP reported there had never been any interference with swimming or with any other beneficial use of Las Vegas Bay caused by suspended or floating algae. (Gregory 1978, pp. 78-79.) Although algae may have imparted a greenish color to the water that drew some comments in the 1960s, the color did not interfere with swimming or any other beneficial use of the water. (Id.) In 1983, DEP reported that there was no evidence of harm to any beneficial use during 1979-1982. (Anon. 1983, pp. 1075, 1077.)

From Time To Time, There Have Been Water-Quality Problems Throughout Lake Mead

Lake Mead is not perfect, no lake is. Various kinds of water-quality problems have been reported from time to time since the lake was created. These problems, which have not been confined to any one area of the lake, shared several common characteristics. They usually appeared far

from any wastewater discharge. Their causes, although sometimes investigated, were rarely discovered. They were not cured by human intervention; the problems simply disappeared after a while.

In the early 1950s, before Clark County and the City of Las Vegas began discharging wastewater to the lake, the lake was carpeted with blue-green algae:

. . . algae was found upon all shores and upon much of the shall lake bottom. . . . Generally, the filamentous and blue-green types were most commonly seen. Observations with the aid of aqua lungs revealed the presence of what appeared to be a blue-green lawn upon silt bottom at 20 to 25 feet depth. Murkiness of the water prevented this observation from the surface. The presence of a universal carpet of algae was the cause of this unusual sight. [¶] After periods of increased wind activity, a scum of dead and dying algae, which had been eroded from shallow lake bottom, was often found about windward shores. [Jones & Sumner 1954, p. 11.]

The list of algae identified by Jones & Sumner includes Anabaena, a filamentous blue-green alga capable of producing a potent mouse toxin under appropriate conditions.

During the early 1950s, there were also large algal blooms visible at the surface:

A large bloom which occurred during August and September, 1952 reduced visibility to within 3 feet of the surface. [Id., p. 19.]

During the late summer of 1953 a widespread bloom covered the upper Overton Arm. [Id., p. 27.]

Microcystis was identified as one of the common genera.

(Id.) There were also major fishkills:

During periods of peak inflow, large numbers of dead and dying game fish were observed in the upper reaches of the lake. In June of 1953 many channel catfish, crappie, and bass of all sizes were found in this condition. The area of highest frequency extended from the head of the lake to the lower end of Iceberg Canyon. Examination of many fish failed to find the cause of death. [Id., p. 19.]

Pollution was ruled out: "During the course of this study, no evidence of pollution of waters so as to be harmful to fishlife was found." (Id.) Jonez & Sumner, in short, found fishkills, scums, algal carpets, and large algal blooms in the early 1950s, before there were any wastewater discharges into Lake Mead.

In the mid-1960s, there may have been algal nuisances in Las Vegas Bay; the evidence is conflicting. Although DEP reports that there were complaints during the 1960s, it has not retained any documentation of any complaint. (Gregory 1978, p. 53.) DEP repeatedly investigated water quality in Las Vegas Bay in the 1960s but saw only a green color in the water and algae attached to boats; DEP did not see floating mats, scums, or slimes, and did not smell any offensive odors. (Id., p. 73.) The green color in the 1960s was approximately the same as the green color in 1978. (Id., pp. 74-75.) The color did not make the water undesirable for swimming. (Id., p. 77:) In 1965, the

decline was caused by a decrease in the number of shad, which was itself caused by overpredation by striped bass and a lack of nutrients in the lake. (Id., pp. 558-559.) They pointed out, however, that shad were still relatively plentiful in Las Vegas Bay because of the wastewater discharges. Apparently, the wastewater discharges helped maintain the striped-bass fishery during the decline.

Water quality, like weather, is better in some years than in others. These variations, like so many other things about water quality, have not been comprehensively studied and are not well understood. However, it is clear that variations in Lake Mead may be caused by natural perturbations--not by wastewater discharge--and may not be affected by changes in wastewater treatment. In these circumstances, expensive investments in wastewater treatment cannot pay off.

#### DEP Was Wrong About Phosphorus Removal

Clark County and the City of Las Vegas have invested, and continue to invest, millions of dollars of taxpayers' money in equipment and chemicals for phosphorus removal. Both the County and City began removing phosphorus more than six years ago, and both continue to remove phosphorus through the use of chemical treatment. DEP is responsible for phosphorus removal.

The campaign for phosphorus removal began in the late 1960s, when DEP proposed to limit the discharge of phosphorus from the County and City wastewater-treatment plants. (Gregory 1978, pp. 105, 132.) DEP has candidly admitted that it did not have authority to set effluent limits at the time, but circumvented this lack of authority by proposing water-quality standards that would apply three yards below sewage discharges into the wash. (Id., p. 162-163.) Phosphorus standards were intended to eliminate the green color attributable to algae in Las Vegas Bay. (Id., pp. 147-149.) DEP did not advance the proposal because it was under any legal obligation to eliminate the color, or because eliminating the color was necessary to improve water quality--on the contrary, DEP had determined that the color did not affect swimming or any other beneficial use of the water--but because it believed that some people found the color objectionable. (Id.)

During the 1970s, several consultants joined DEP in predicting improved algal conditions after phosphorus removal, but suggested different limits. The original proposal was modified, and in 1979 the County and City agreed to a 1 mg/l limit on phosphorus discharges. Facilities for chemical treatment were built and began operating by July 1981, and both the County and City have maintained their phosphorus concentrations well within the 1 mg/l limit since then. During this time, DEP continued to believe that

phosphorus limits would prevent algal nuisances in Lake Mead and would improve color and clarity. (McCurry 1981, p. 547.)

Six years have passed, and the results of the phosphorus-removal experiment are now in. They show beyond any doubt that phosphorus removal has not improved water quality in Las Vegas Bay.

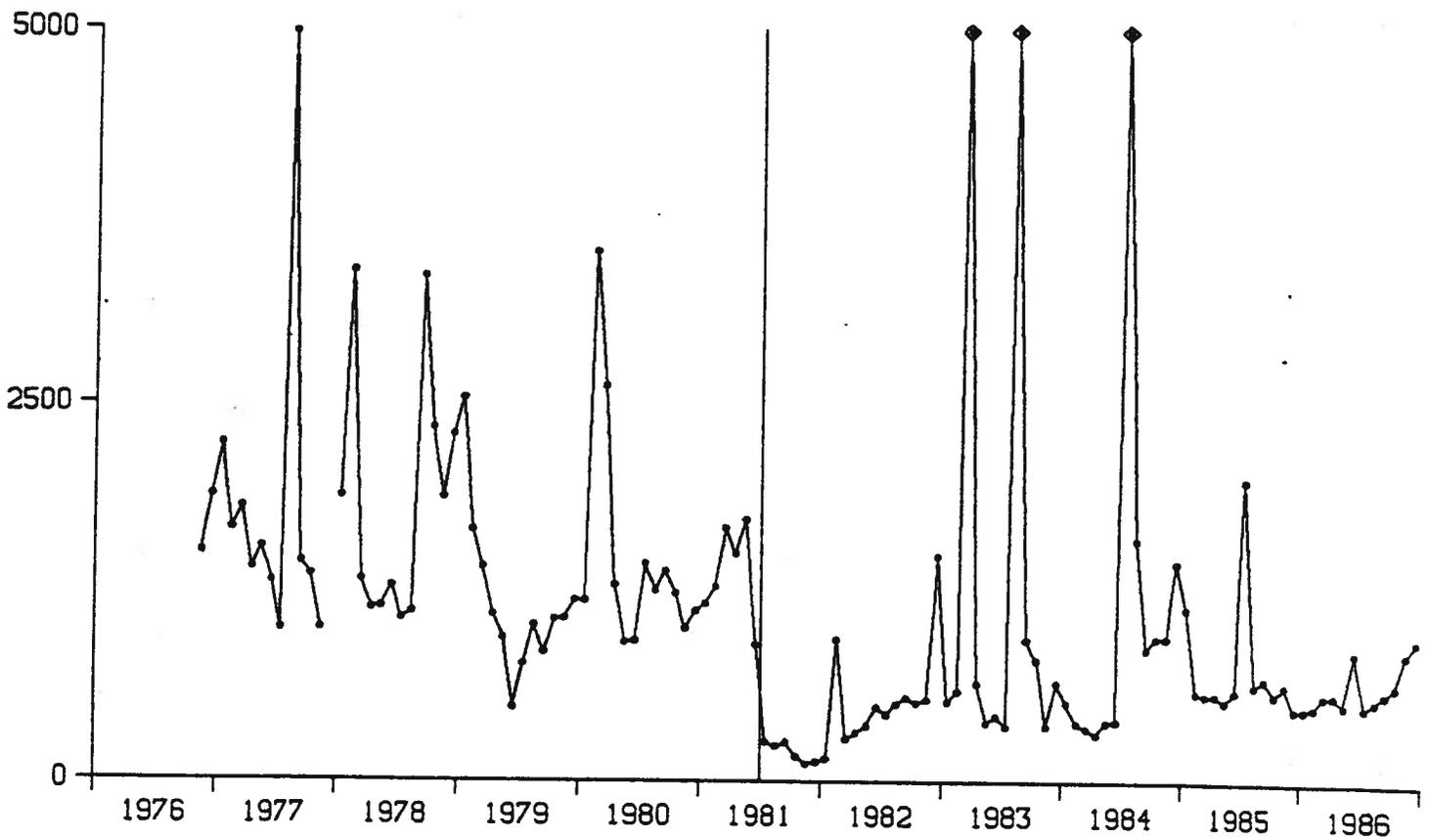
The phosphorus-removal facilities at the County and City plants performed as they were supposed to. Figure 7 shows that, except for intermittent peaks caused by floods, the phosphorus load entering the bay from Las Vegas Wash decreased substantially after July 1981. Phosphorus loads at Northshore Road, which is the monitoring station in Las Vegas Wash closest to the lake, fell from well over 1,000 pounds per day to several hundred pounds per day. Figure 8, which is DEP's graph of the same data, leads to the same conclusions.

Even a cursory glance shows that there is a remarkable difference between DEP's figure and the figure prepared for this report. Since the two figures supposedly include exactly the same data from 1977 through 1985, the diagrams for these years should be identical. Plainly, they are not identical. Inconsistencies within and among the various compilations of data have been a persistent problem for those who attempt to understand water quality in Las Vegas Bay, and more than a year of discussion and correspondence

FIGURE 7

# Total Phosphorus Loads at Northshore Road

monthly arithmetic averages, lbs/day as P  
diamond is off-scale, vertical line is July 1, 1981



**CONCLUSION:** Loads went down after the wastewater-treatment plants began removing phosphorus.

on this subject has only uncovered more inconsistencies. To cure this problem, this report includes a proposal for the creation of a clean database that would include only data transcribed directly from the original laboratory sheets and that would be proofread for transcription and other errors.

What effect did the ~~the~~ decrease in phosphorus loading have on algae in Las Vegas Bay? According to the data, none.

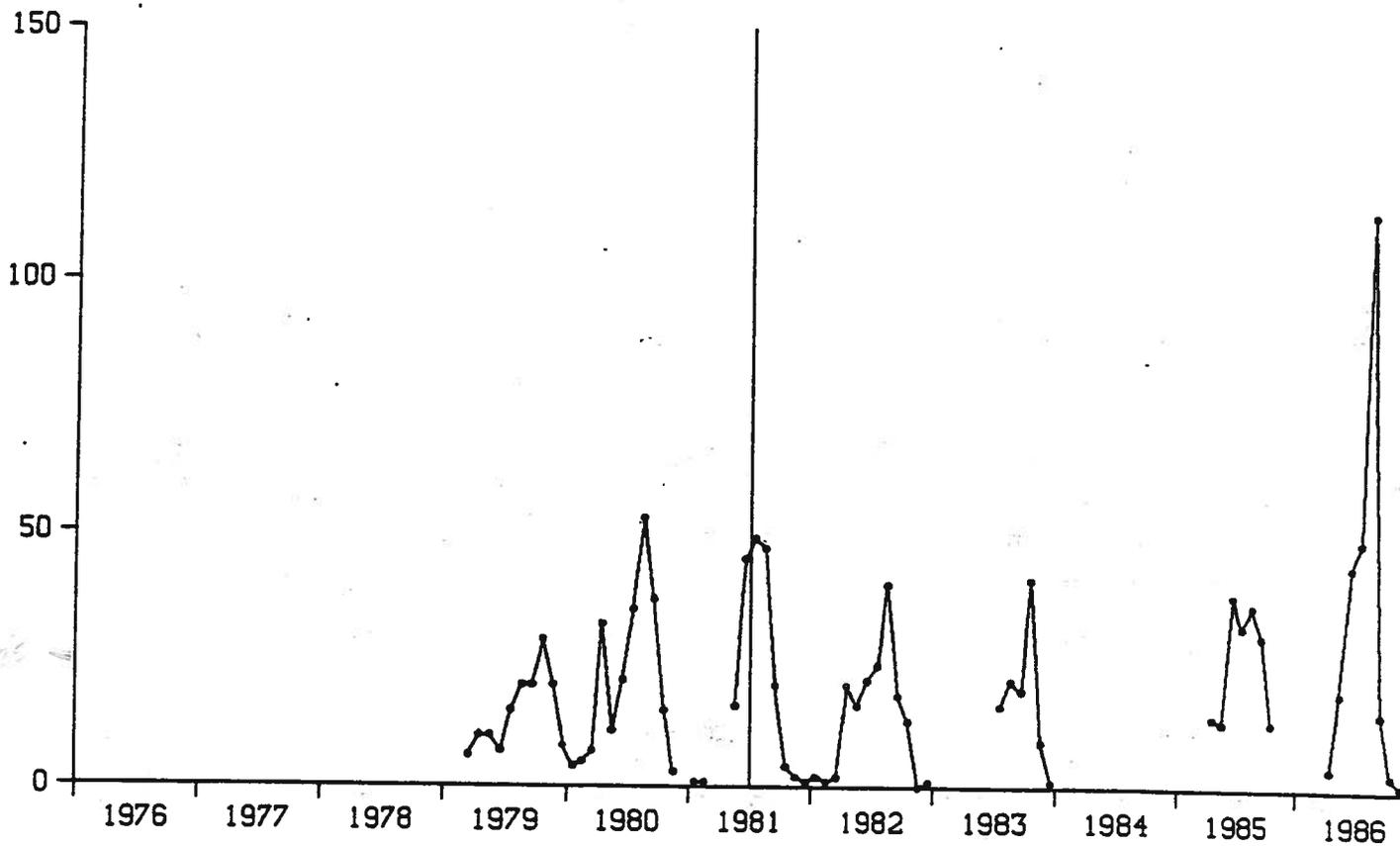
#### Chlorophyll Did Not Decrease After Phosphorus Removal

Algal species in Las Vegas Bay are not routinely identified and counted under a microscope, and algal biovolume is not calculated directly from cell counts. Instead, chlorophyll is used as an indirect measure of algal biomass. (This report will follow DEP's convention of using "chlorophyll" to mean chlorophyll a uncorrected for phaeophytins; however, chlorophyll concentrations reported in the scientific literature may be corrected.)

Figure 9 shows that chlorophyll at station 3 did not decrease after July 1981. The figure also shows that there is a strong seasonal trend in chlorophyll: Concentrations decrease to nearly zero in the winter, and peak in the summer. The unusually high chlorophyll concentration in 1986, incidentally, was caused by a single extraordinary

FIGURE 9

Chlorophyll at Station 3  
monthly arithmetic averages, total (ppb)



Conclusion: Chlorophyll concentrations in the lake stayed the same after phosphorus removal

reading; without that reading, 1986 is almost identical to 1981.

Station 3 was chosen for the figure because DEP's proposed chlorophyll standard is to be monitored at station 3. However, none of the other stations shows a substantial decrease in chlorophyll after 1981. In fact, Figure 10, which was prepared by DEP, shows that chlorophyll at station 2 was higher after 1981 than it had been in the 1970s. However, that figure mixes chlorophyll data collected before 1979 with data collected afterwards. Very different collection methods and perhaps laboratory methods were used before 1979, and consequently it is impossible to say how much of the apparent increase in chlorophyll after 1978 is merely an artifact of the procedures used for sampling and analysis. Figures and calculations prepared for this report do not mix water-quality data collected from the lake before 1979 with lake data collected during and after 1979.

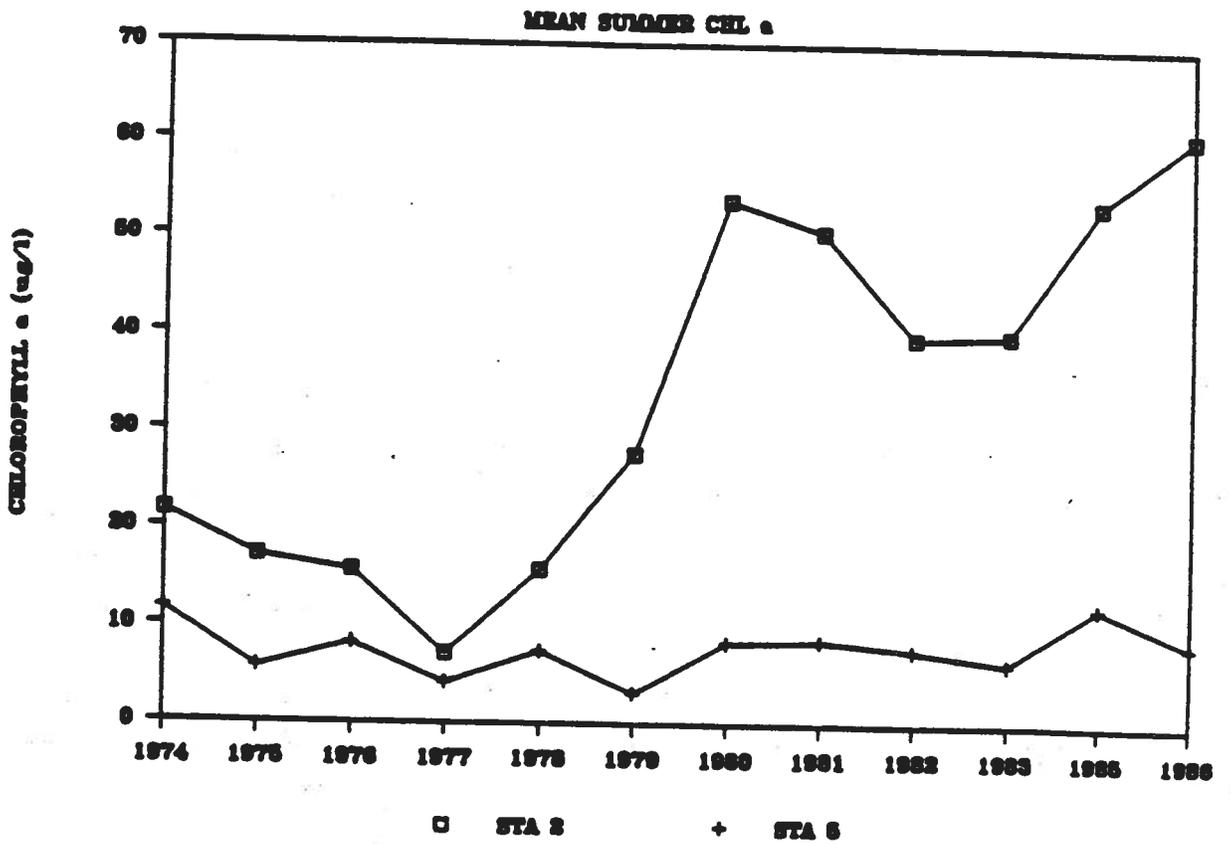
In summary, the data clearly show that phosphorus removal by the County and City plants did not result in any substantial decrease in chlorophyll concentrations in Las Vegas Bay.

### Clarity Did Not Improve After Phosphorus Removal

Although phosphorus removal may have been intended to eliminate a green color in the water, no one has measured how green the water was or is, and consequently there is no way of knowing whether water color has changed since the 1960s. However, DEP has reported that there was no apparent change in color between the 1960s and 1978, when chlorophyll concentrations were very low. (Gregory 1978, pp. 147-148; see Figure 10.) During the tour of the lake conducted in June 1987 for the benefit of the State Environmental Commission, there were several comments about the color of the water, although there seemed to be a difference in opinion about whether the water became greener as one moved towards, or away from, the inner bay. In summary, although the ~~the~~ green color in the water has apparently not been eliminated, the lack of data prevents anyone from knowing whether the great expense of phosphorus removal resulted in any color change whatsoever.

Clarity is routinely measured in Las Vegas Bay using a procedure known as "Secchi depth". As part of its Proposal, DEP calculated summertime averages for all stations routinely monitored (stations 2, 3, 4, 5, and 8); no station shows any consistent improvement in clarity after July 1981. (DEP May 1987, p. D.21.) Figure 11, which is a detail of DEP's figure, shows that Secchi depth at station 3 after phosphorus removal is not consistently better or worse

FIGURE 10



(Figure 13 from DEP's Proposal.)

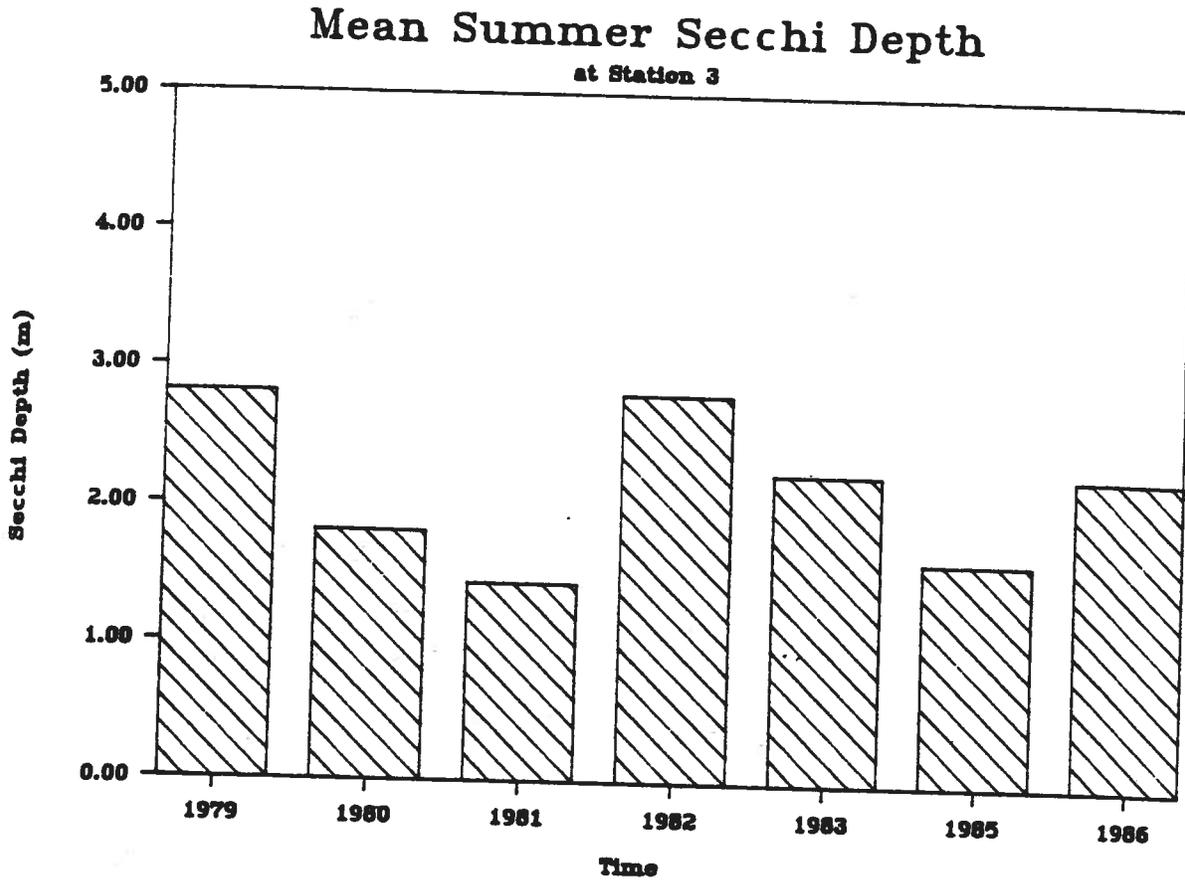
than Secchi depth before. In short, the great expense of phosphorus removal did not consistently improve clarity anywhere in Lake Mead.

Now that six years have passed since the County and City began removing phosphorus, there are abundant data available to assess whether the program accomplished its objectives. There is no doubt that the wastewater-treatment plants accomplished their task, and that phosphorus loadings into the lake decreased substantially. However, the data do not show any consistent improvement in the lake. The green color has not been eliminated. Chlorophyll concentrations remain roughly what they were before phosphorus removal began. Secchi depth shows no consistent improvement. No one has presented any data, or advanced any argument, to show any improvement in the algal quality of Las Vegas Bay since phosphorus removal began. One can only conclude that phosphorus removal was a failure.

#### There Is No Relationship Between Phosphorus Discharges And Chlorophyll

Undoubtedly, those who recommended phosphorus removal believed that there was a direct relationship between phosphorus discharges from the County and City and chlorophyll in the lake. If there were a direct relationship, the decrease in phosphorus loading might have caused a corresponding decrease in chlorophyll.

FIGURE 11

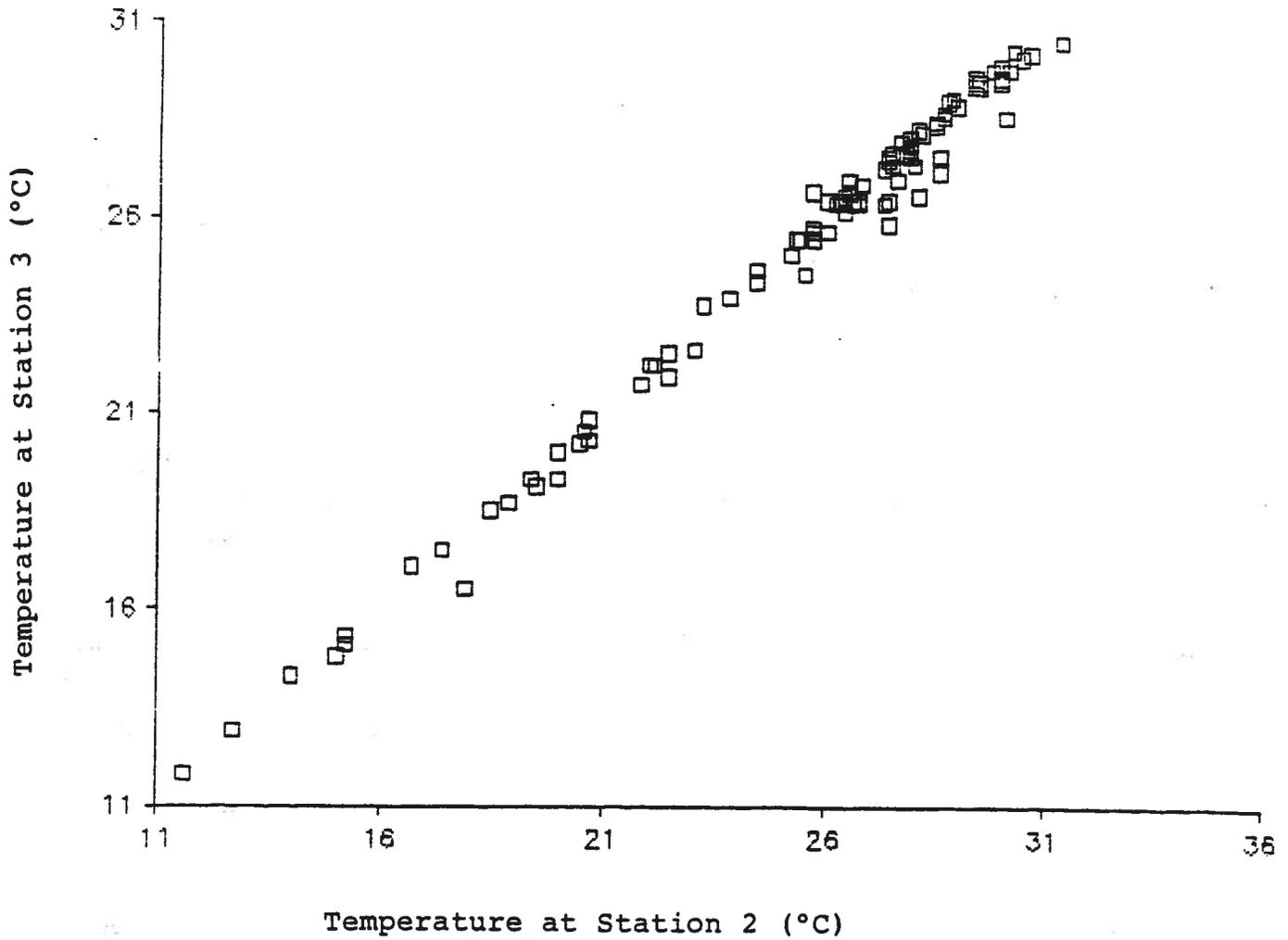


(Detail of Figure 18 from DEP's Proposal.)

CONCLUSION: Secchi depth did not consistently improve after phosphorus removal.

FIGURE 12

Water Temperature at Stations 2 and 3  
Integrated Samples, 1979-1986



(Data From STORET.)

**CONCLUSION:** There is a strong relationship between temperatures at the two stations.

This relationship may exist in some lakes, and there has been a great deal of discussion in the scientific literature about the possibility of decreasing algae by phosphorus removal. The literature, not surprisingly, includes a great diversity of opinions on the subject. Phosphorus removal has a checkered history, and there have been notable failures.

To test for a relationship, statisticians produce graphs (called "scatter diagrams" or "scatterplots") such as Figure 12, which illustrates a strong relationship between the water temperature at station 2 and the water temperature at station 3. When there is a strong relationship between the two variables, (i.e. the two kinds of measurements being plotted), the points on the graph line up nicely, without much scatter. When there is no relationship between the two, the points are widely scattered about the graph.

Figure 13 is a systematic analysis of the relationship, if any, between phosphorus loading at Northshore Road and chlorophyll concentrations at station 3. The figure shows that there is no relationship between the two. It also shows that although phosphorus loading at Northshore Road decreased after July 1981--the pluses (after phosphorus removal) are between 0 and 1,000 pounds per day, whereas the circles (before phosphorus removal) are mostly between 1,000 and 2,000 pounds per day--chlorophyll concentrations remained between roughly 0 and 50 ug/l. Figure 13

establishes the failure of phosphorus removal and proves that the hoped-for relationship between phosphorus discharges and chlorophyll does not exist in Las Vegas Bay.

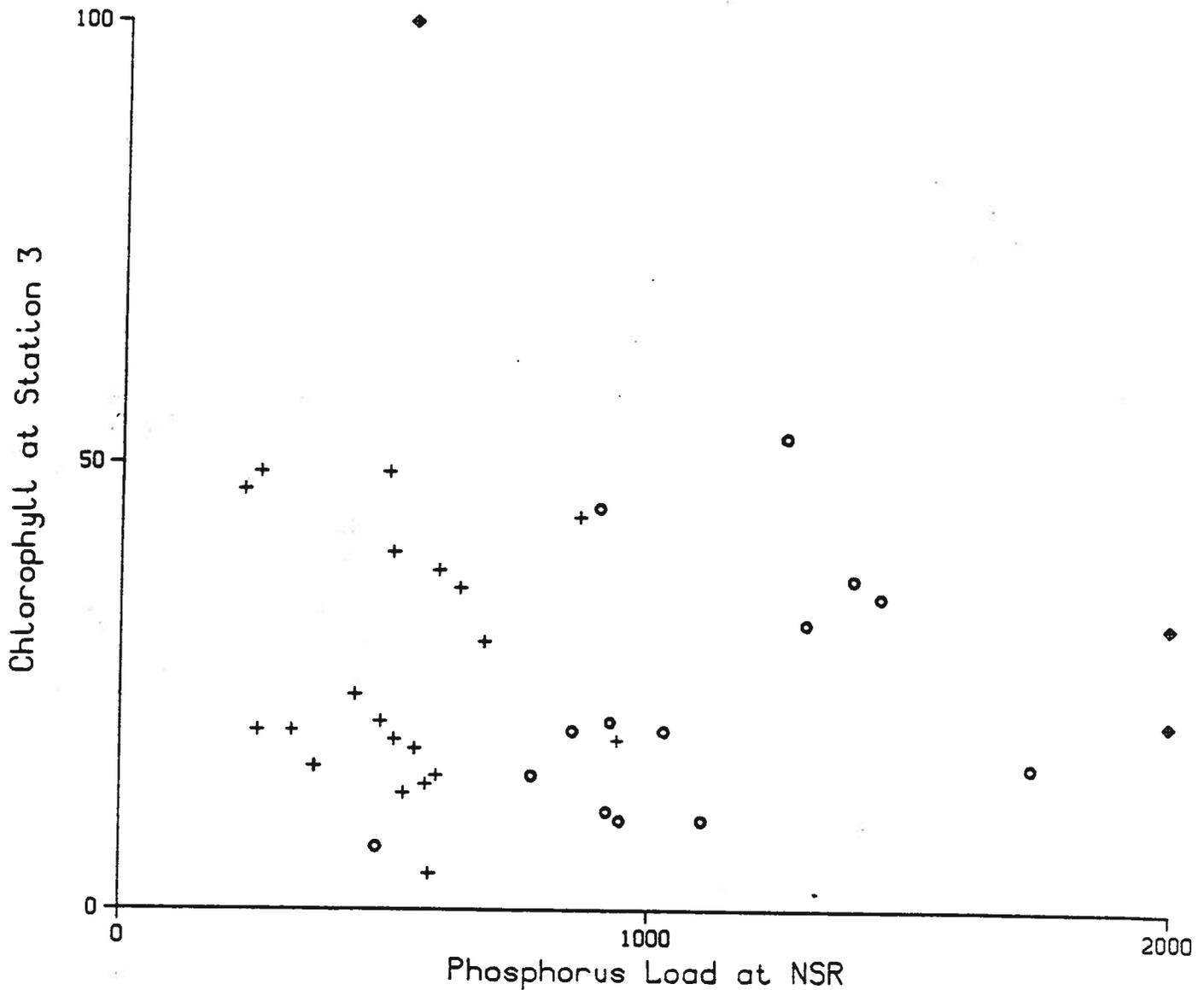
In the past, DEP has attempted to show a relationship between phosphorus and chlorophyll by plotting total phosphorus at a lake station against chlorophyll at the same lake station. However, DEP did not seem to recognize that chlorophyll and most of the phosphorus are in the same algal cells. Here is a simple analogy. Suppose DEP went from city to city counting tires and headlights; it would surely find that the number of headlights increased in proportion to the number of tires, because both are contained in the same motor vehicles. This finding in no way shows that tires cause headlights, or that headlights cause tires; it merely shows that both are normal components of motor vehicles. Similarly, all one can legitimately conclude in Las Vegas Bay is that when there are more algae, there ~~is~~ <sup>are</sup> more chlorophyll and more phosphorus. One cannot legitimately conclude that more phosphorus causes more chlorophyll. 26/40-2

Figure 14 shows that if one plots dissolved orthophosphorus--which is not contained in the algal cells--against chlorophyll, there is no relationship. The figure also shows that the concentrations of dissolved orthophosphorus at station 3 decreased after July 1981, and that chlorophyll did not. This analysis suggests that decreasing

FIGURE 13

### Chlorophyll at Station 3 Phosphorus Loads at Northshore Road

total chlorophyll (ppb), total phosphorus as P (lbs/day)  
monthly arithmetic averages, April through September  
o before, + after July 1, 1981, diamond = off-scale

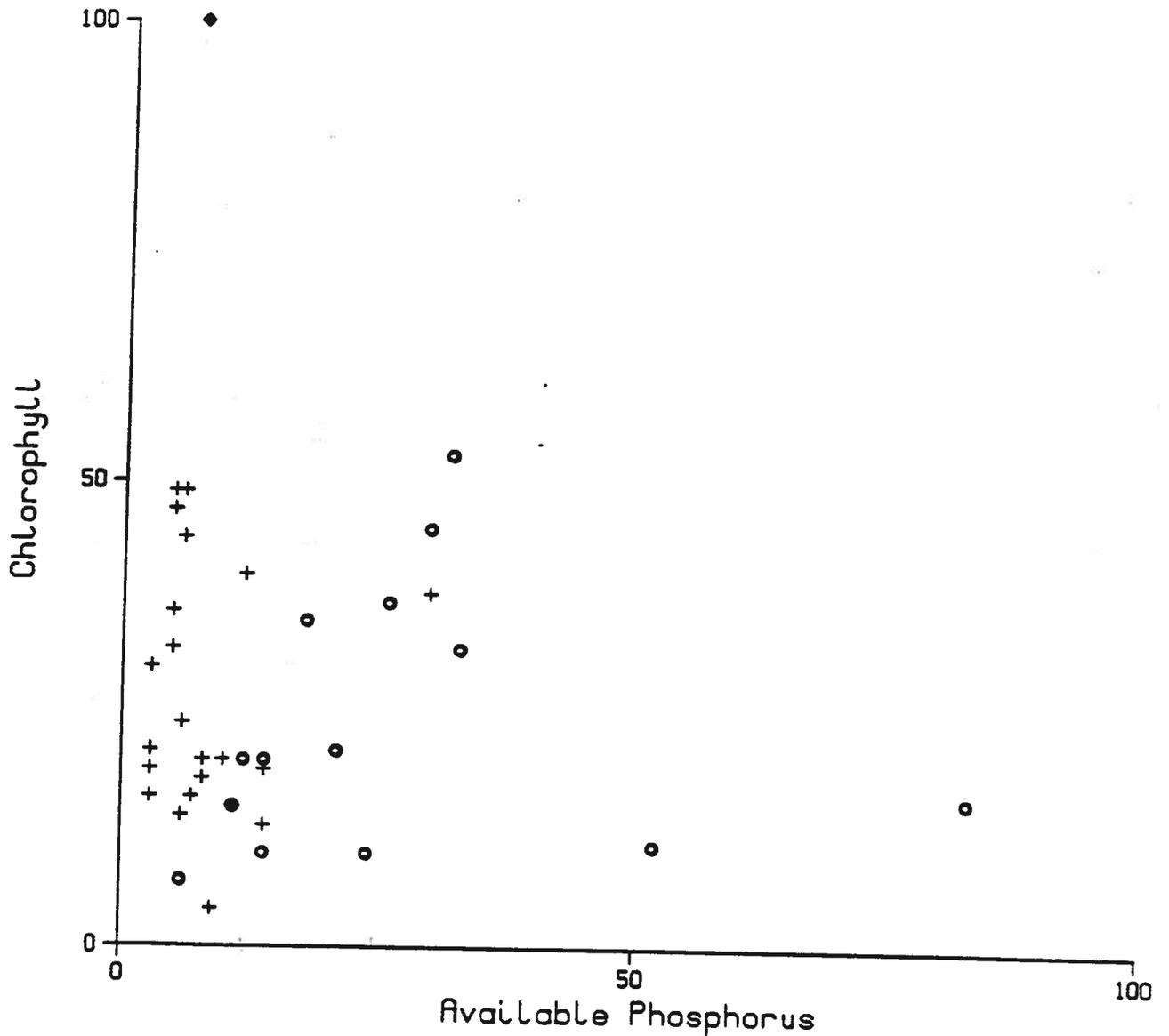


Conclusion: The data show no relationship between chlorophyll in the lake and phosphorus loads at Northshore road

FIGURE 14

# Chlorophyll and Available Phosphorus at Station 3

total chlorophyll, diss ortho P as P, ppb  
monthly arithmetic averages, April through September  
o before, + after July 1, 1981, diamond = off-scale



Conclusion: The data show no relationship between chlorophyll and available phosphorus in the lake

the available phosphorus at a station does not decrease chlorophyll concentrations at that station.

These conclusions about the lack of a relationship between phosphorus and chlorophyll are important because DEP continues to suggest that phosphorus removal can and should be used to regulate chlorophyll concentrations in Las Vegas Bay. Unless DEP comes to grips with the past failure of phosphorus removal, it is doomed to repeat the failure in the future.

#### Water-Quality Standards Lead Directly To TMDLs

DEP's proposals for water-quality standards, now before the State Environmental Commission, are part of a larger design to establish phosphorus and ammonia limits for Clark County and the City of Las Vegas. DEP's first proposal for chlorophyll and ammonia standards, in early 1986, was accompanied by proposals for total maximum daily loads (TMDLs). (DEP 8 May 1986.) Although the TMDLs originally proposed have been modified, DEP has consistently expressed its desire to have TMDLs established.

Once established, TMDLs must be divided into maximum loads for individual dischargers; these individual load limits are known as wasteload allocations. (40 CFR § 130.2.) Wasteload allocations, in turn, are incorporated into discharge permits.

The first phosphorus TMDL proposed by DEP was apparently 645 pounds per day, although numbers between 640 and 660 were mentioned. (DEP 8 May 1986.) In June 1986, it was increased to 692 pounds per day. (DEP 25 June 1986.) In December 1986, however, DEP suggested that the number was 637 pounds per day. (DEP 9 December 1986.)

The first ammonia TMDL proposed by DEP was for 855 pounds per day. (DEP 8 May 1986.) In June 1986, it was increased to 1,660 pounds per day in June 1986. (DEP 25 June 1986.) In October 1986, it was increased to 1,698 pounds per day. (DEP 24 October 1986.)

In a draft schedule distributed in May 1987, DEP suggested that TMDLs should be developed in the fall of 1987. It also suggested that a phosphorus TMDL should go into effect on June 1, 1988--less than a year from now--and that the County and City, by early 1989, should either (1) prepare a facilities plan for ammonia-removal facilities or (2) submit studies showing that the ammonia standard and TMDL ought to be modified. (DEP 1 May 1987.)

The problem with this draft schedule is that it does not leave enough time for proper studies, which will require at least two years for data collection plus time for data analysis. The schedule also does not leave time for the evaluation of alternative proposals, including restoring the wetlands and moving the point at which wastewater enters Las Vegas Bay. Neither of these proposals can be adequately

evaluated with existing data. If the schedule is enforced, the County and City will be forced to add units to the existing wastewater-treatment plants.

Phosphorus Removal Has Cost The County And City \$170 Million

Phosphorus removal is not cheap. As Figure 15 shows, the costs so far of building and running the facilities add up to more than \$170 million.

DEP's New Proposal Would Cost Another \$110 Million

As discussed above, DEP's proposal for new chlorophyll and ammonia standards would force the County and City to add units to the existing wastewater-treatment plants, and to increase the budgets for operation and maintenance. As Figure 15 shows, the cost of building and the present value of running the facilities over the next 20 years would be approximately \$110 million.

FIGURE 15

COSTS OF PHOSPHORUS REMOVAL AND AMMONIA REMOVAL  
 (Estimated for Clark County and  
 City of Las Vegas, 1987 dollars)

PAST COSTS

Phosphorus Removal

Capital <sup>1</sup>	\$149 million
Operation and <sup>2</sup> Maintenance	<u>23 million</u>
Total	<u>\$172 million</u>

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TOTAL PAST COSTS	\$172 million
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=====

COSTS FOR NEXT 20 YEARS

	<u>Phosphorus Removal</u>	<u>Ammonia Removal</u>
Capital	\$12 million <sup>3</sup>	\$33 million <sup>4</sup>
Operation and <sup>5</sup> Maintenance	<u>41 million</u>	<u>26 million</u>
Total	<u>\$53 million</u>	<u>\$59 million</u>

=====

TOTAL COSTS FOR NEXT 20 YEARS	\$112 million
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- 
- 1 Replacement value, AWT plant and City plant modifications for removal.
  - 2 Costs for operation 1981-1987.
  - 3 Filtration facilities at City plant.
  - 4 Nitrification at City plant; ammonia stripping at County plant.
  - 5 Operation 6 months per year, 20 years, present worth.

#### 4. CHLOROPHYLL

##### DEP Has Proposed Five Chlorophyll Standards

DEP has proposed three chlorophyll standards applicable to station 3 and two applicable to Boulder Basin and other areas in Lake Mead. For station 3, DEP is proposing the following standards:

- the four-year average of the July-September averages shall not exceed 30 ug/l
- no July-September average shall exceed 40 ug/l
- only one monthly average per year may exceed 45 ug/l.

For Boulder Basin and other parts of the lake, DEP is proposing the following standards:

- the average for April through September shall not exceed 5 ug/l
- 90% of the chlorophyll measurements must be less than 10 ug/l.

##### Chlorophyll Is Food For Fish

We agree with DEP that the ability of a lake to grow fish is related to its ability to grow algae. As DEP asserts, "Empirically derived relationships indicate that increased phytoplankton production does lead to greater fish production." (DEP May 1987, p. D.33.) In support of this

proposition, DEP provides three literature references, one of which is Oglesby (1977).

Oglesby reports that fish harvests increase dramatically with increasing chlorophyll concentrations. He examined several environmental variables and concluded that:

"For the variables tested, the highest correlation of fish yield was that with CHL [chlorophyll concentration]. Lakes represented in this regression range from oligotrophic to highly eutrophic, small to very large in area, and very shallow to very deep. [p. 2278]"

In a wide range of lakes, therefore, the single best predictor of fish yield was found to be chlorophyll concentration.

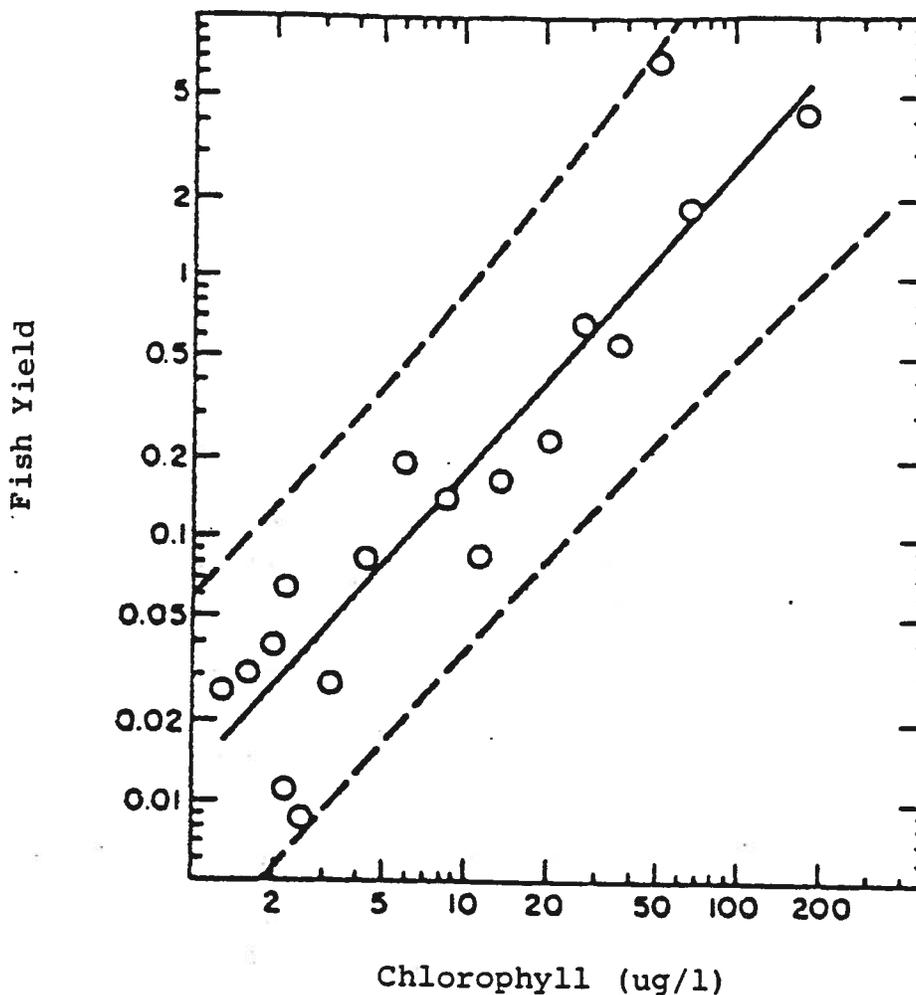
Figure 16, which is taken from Oglesby, shows that the fish yield of lakes increases proportionately with their chlorophyll concentrations. For example, lakes with 90 ug/l yield three times as much fish as lakes with 30 ug/l, and lakes with 200 ug/l yield seven to eight times as much fish as lakes with 30 ug/l.

Why not establish a chlorophyll standard at 90 ug/l, or at 200 ug/l? Why not establish a minimum requirement for chlorophyll instead of a maximum? These are not idle questions. If Nevada's water-quality standards are to provide for the protection and propagation of fish, as they must to be in conformity with the Clean Water Act, then a proposed standard must be carefully reviewed to determine whether it truly enhances the fishery. Even a cursory

FIGURE 16

CLAIM: Empirically derived relationships indicate that increased phytoplankton production does lead to greater fish production. (Page D. 33.)

SUPPORT:



(Figure from Oglesby, cited in DEP Proposal.)

CONCLUSION: We agree with DEP's literature references that the fish yield of lakes increases with their chlorophyll concentrations. For example, lakes with 90 ug/l yield three times as much fish as lakes with 30 ug/l, and lakes with 200 ug/l of chlorophyll yield seven to eight times as much fish as lakes with 30 ug/l.

review of the scientific literature suggests that a higher chlorophyll standard would be more likely to enhance the fishery.

Chlorophyll is an ingredient of algae, and algae, either directly or indirectly, are food for fish. The more the fish have to eat, the bigger they can grow and the more they can reproduce. In a place like Lake Mead, where the shortage of fish food has been widely publicized, it is not surprising that an area with more algae would grow more fish.

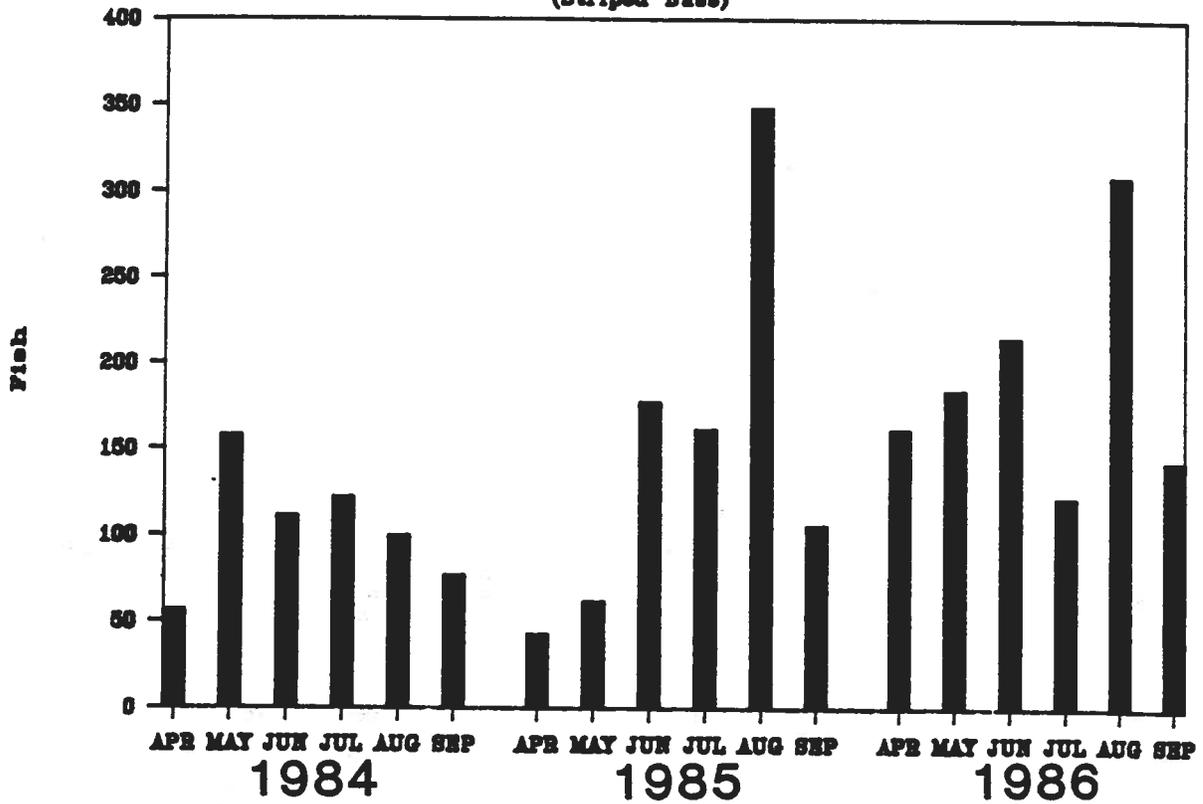
DEP did not explain why it is proposing a standard likely to be detrimental to the fishery. However, it asserts that water quality during 1986, the year of peak chlorophyll concentrations, was "degrading" to the fishery. (DEP May 1987, p. D.34.) However, DEP does not attempt to support its assertion with data from Lake Mead.

Data from Lake Mead contradict DEP's assertion. The fishery in Las Vegas Bay was as good or better in 1986 than it was in 1985 or 1984. The catches of striped bass and total fish were both up in 1986 (see Figures 17 and 18), without decreasing the catch per angler (see Figures 19 and 20). In short, 1986 was a good year for the fishery in Las Vegas Bay.

In summary, research reported in the scientific literature suggests that increasing the chlorophyll in Las

FIGURE 17

Fish Harvest in Las Vegas Bay  
(Striped Bass)



(Data from Nevada Department of Wildlife.  
Data collected before 1984 were not used  
because they are not directly comparable.)

CONCLUSION: The number of striped bass caught in Las Vegas Bay has increased since 1984.

FIGURE 18

Fish Harvest in Las Vegas Bay  
(Total Fish)

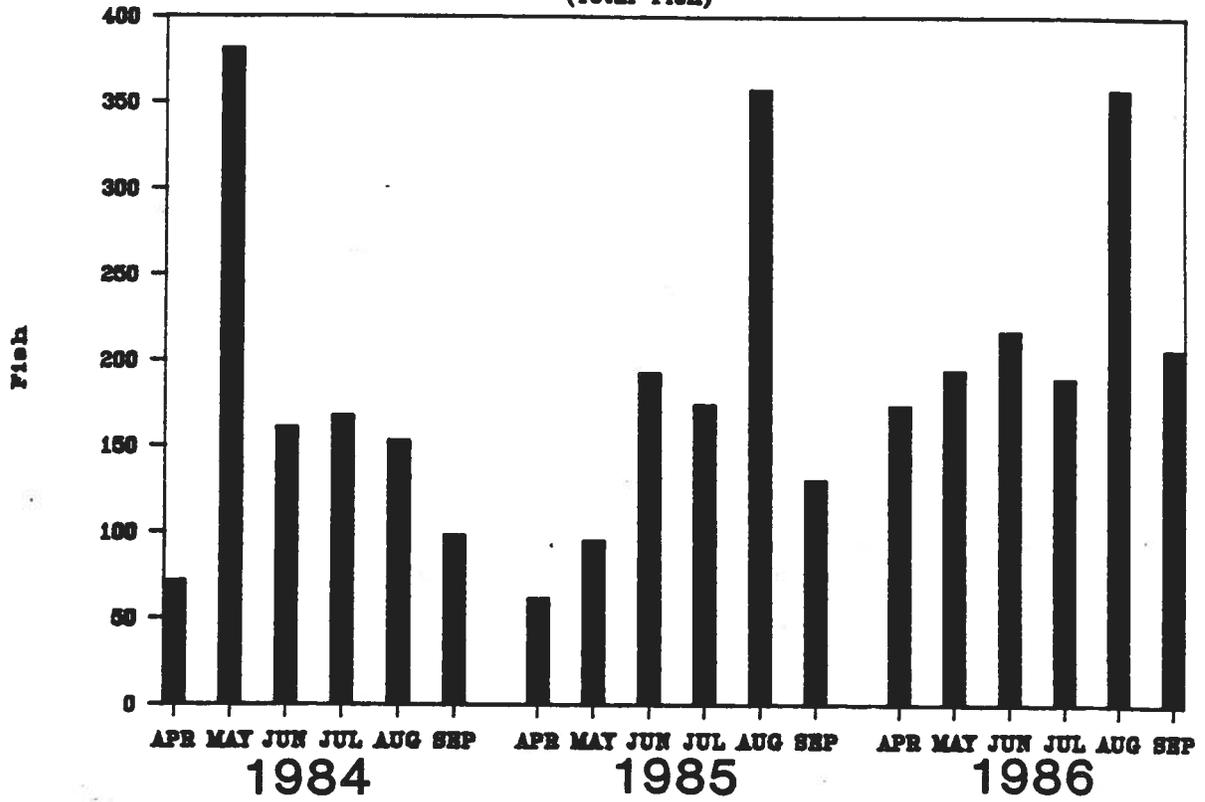


FIGURE 19

Fish Harvest in Las Vegas Bay  
(Striped Bass Per Angler)

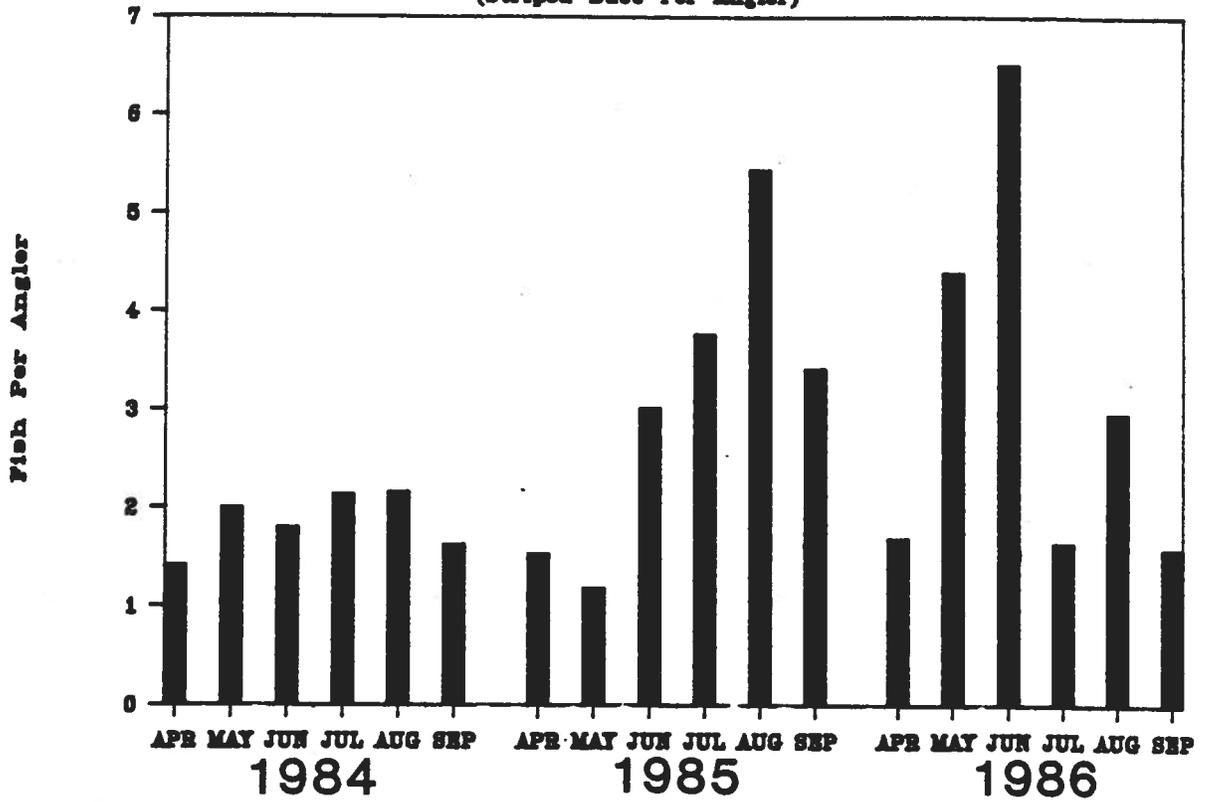
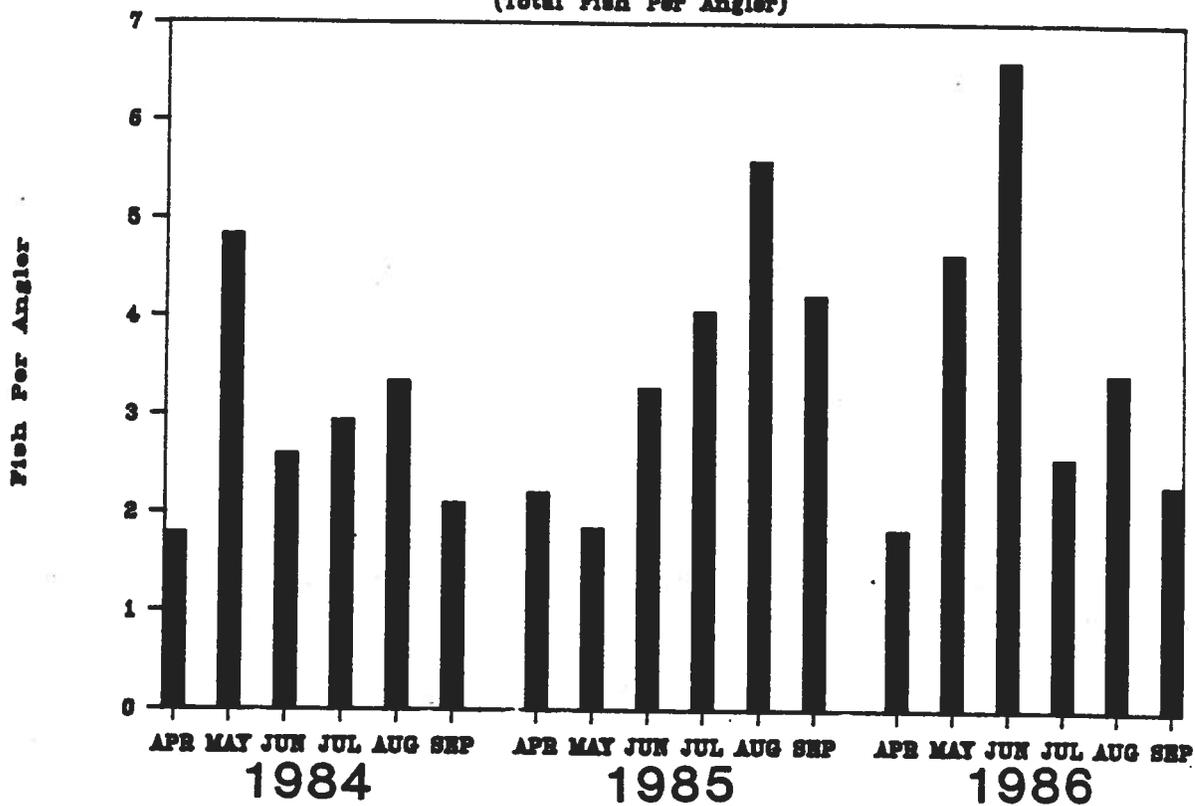


FIGURE 20

### Fish Harvest in Las Vegas Bay (Total Fish Per Angler)



Vegas Bay might produce a corresponding increase in fish production. The data for Las Vegas Bay, although limited, support the conclusion. Consequently, the proposed chlorophyll standard is plainly inappropriate for Las Vegas Bay. The proposed standard cannot protect or enhance the fishery; on the contrary, it can only harm the fishery.

DEP's Arguments About Phosphorus And Chlorophyll Are Ecological Oversimplifications

Although phosphorus loading is widely thought to control chlorophyll levels and trophic state in lakes, Welch (1984) reports that "Of the 23 eutrophic lakes examined only 10 showed an improvement to either mesotrophy or oligotrophy following diversion" of all sewage discharges out of the lakes. "In general [Welch reports], definite improvements were noticed in about one [lake] in three." Lake Mead is just one of many lakes where phosphorous removal--and even complete diversion of all wastewater discharges--has failed.

DEP's chlorophyll analysis identifies only one determinant of chlorophyll levels: phosphorus discharges from the wash. The data do not support this conclusion: they show inexplicable scatter, not a clear, consistent relation between phosphorus discharge and chlorophyll (see Figure 13). Clearly, chlorophyll levels in the bay respond to more factors than just phosphorus discharges. Among the factors DEP overlooks are food relationships and

dependencies. Chlorophyll levels are affected by grazing, not just by phosphorus inputs (see Figure 5). When grazing is intense, chlorophyll levels may drop.

The makeup of fish populations in Lake Mead has changed dramatically over the years, especially since the introduction of threadfin shad (1954) and striped bass (1969). Striped bass are voracious predators; as stripers increase, they feed on forage fish (like threadfin shad) and zooplankton that graze the algae. More stripers, fewer zooplankton and forage fish, more algae, more chlorophyll--this is the overall ecological pattern.

It is an ecological oversimplification to ignore the effect of changing fish populations on chlorophyll levels. The Nevada Department of Wildlife reports that Las Vegas Bay is a productive striper fishery, and the striper catch has increased steadily since 1984 (Figure 19). The scatter in the relation between chlorophyll and phosphorus discharges may be traced in part to changing patterns of grazing pressure as striper populations have increased.

Obviously, grazing cannot be ignored. A parallel with sheep farming comes to mind. The height of grass in a sheep pasture (the amount of chlorophyll, if you will) is not solely determined by the amount of fertilizer applied to the pasture; it is also determined by how many sheep graze on it and by how much the sheep eat. Even if the grass

should grow luxuriantly, its height will depend on the intensity of grazing as well as on the amount of fertilizer applied. When wolves devour the sheep, the grass can grow long again because grazing no longer keeps its length in check. Striped bass, like wolves, are voracious predators. When stripers abound, grazers are devoured and chlorophyll levels may increase.

#### Chlorophyll, Zooplankton, And Fish: Vital Interactions

One of the great proponents of phosphorus controls, Professor J. Shapiro, is also a proponent of the need for more biology and ecology in understanding lakes. He points out, for example, that "biological phenomena within lakes can result in at least fivefold variations in average chlorophyll concentrations at the same phosphorus level", that "small changes in productivity can cause large changes in herbivore [zooplankton] populations", and that "changes in predator fish can effect changes in planktivorous fish and in herbivores." (Shapiro 1978/1979.)

Many investigators have shown that changes in fish populations can greatly affect the quantity and type of algae. Zooplankton and planktivorous fish eat algae; but if the population of carnivorous fish increases, algal concentrations will increase too because there will be fewer "grazers" to keep the algae in check. Striped bass are voracious carnivores (Setzler et al., 1980); they were

introduced into Lake Mead in 1969. Baker & Paulson (1983) report that as the population of stripers became established, threadfin shad and zooplankton populations fell, although these events may not be causally linked. Whatever the reason, when organisms that eat algae become scarce, algal populations and chlorophyll levels can increase.

Lynch & Shapiro (1981) tested this hypothesis in Pleasant Pond, Minnesota:

The significance of grazing and enrichment to the Pleasant Pond phytoplankton community was examined through a series of enclosure experiments. The addition of planktivorous fish led to the removal of large herbivores and to an order-of-magnitude increase in total phytoplankton biomass. This was a result of the appearance of several new algal species as well as the increase of most initial resident species . . . . In the most highly enriched lakes, the phytoplankton community will be much more sensitive to changes in predators than to changes in nutrient levels.

Cryer et al. (1986) report that zooplankton populations fall when fish production rises:

When [fish] fry were abundant . . . the summer zooplankton became sparse. . . . In years of good recruitment [production of fish fry], as each of the preferred [zooplankton] prey species entered the diet of underyearling [fish], its density dropped dramatically.

Vanni (1987), like Lynch & Shapiro (1981), has used experimental enclosures to assess the interactions among nutrients, zooplankton, and fish. In one of his experiments, "total phytoplankton density was significantly lower

in the fishless enclosures (where zooplankton were larger and grazing rates presumably higher), at a given nutrient level." He concluded that:

It is likely that both direct and secondary effects of zooplankton grazing are important in determining phytoplankton community structure. Whatever the particular mechanisms, it is clear that alterations in zooplankton size structure within small species, such as those caused by fluctuating levels of fish predation, can influence substantially the structure of phytoplankton communities.

In oligotrophic Lake George (New York), the introduction of a new species of fish has been associated with a dramatic shift in algal populations. Siegfried (1984/1985) recounts this remarkable species shift:

The phytoplankton community of Lake George, N.Y., has recently undergone a dramatic shift in composition. Prior to 1977, the phytoplankton community of south Lake George was dominated by diatoms . . . . Beginning in 1977 and continuing through 1982 the phytoplankton community has been dominated by coccoid blue-greens: Anacystis incerta and Aphanothece nidulans. The shift to a blue-green-algae-dominated phytoplankton community in an oligotrophic lake such as Lake George is unusual, especially since no increases in nutrient concentrations or inputs have been documented during this time period . . . . The establishment of the rainbow smelt, Osmerus mordax, in Lake George coincides with the historical shift to blue-green dominance. The introduction has resulted in significant differences in the abundance of large-bodied crustacea and appears to have contributed to the changes in phytoplankton community structure.

## Phosphorus Loads And The Ecology Of Lake Mead

Lake Mead has been subjected to enormous changes since it was formed. The changes include:

- the introduction of dozens of exotic fish, including threadfin shad and striped bass
- great fluctuations in lake level, especially when Lake Powell was formed
- changing phosphorus loads associated with the formation of Lake Powell and the construction of phosphorus-removal facilities at the sewage plants in Greater Las Vegas (see Figures 7 and 8)
- record floods in the Colorado River in 1983 and large floods in Las Vegas Wash, particularly in 1975 and 1984
- changes in ammonia loading from Las Vegas Wash, with large increases in the late 1970s, sharp declines in the early 1980s, and sharp increases since 1985
- changes in its temperature structure following the formation of Lake Powell
- changes in its conductivity and salt content since the record floods of the Colorado River in 1983

Amid all these changes, DEP has concentrated its attention on just one: phosphorus loads from Las Vegas

Wash. But the lake has not responded in any simple way to these changes in phosphorus loads, and given all the other changes going on, there is no particular reason why it should have.

In an effort to improve chlorophyll levels and fish production in Boulder basin, DEP has proposed increasing wintertime phosphorus loads from Las Vegas Wash. But there is no evidence that chlorophyll concentrations in Boulder Basin respond to high wintertime phosphorus loads from Las Vegas Wash. Chlorophyll concentrations are reliably low in Boulder Basin, not just in winter (when chlorophyll concentrations are low everywhere in the lake), but in the spring and summer too. They were low before phosphorus removal began in 1981, and they are low now.

Chlorophyll concentrations in Las Vegas Bay have not responded consistently to the AWT facilities for phosphorus removal, which began operating in July 1981. Median chlorophyll concentrations at Station 3, for example, have remained at  $30 \pm 10$  ug/l since 1979. (DEP May 1987, p. D.38.) Even chlorophyll maxima at Station 3 have not responded to phosphorus removal: The maximum was much lower in 1979 (about 30 ug/l) than in any subsequent year. The maximum chlorophyll in 1985 was more than double the 1979 maximum, even though phosphorus loads were much lower in 1985 (see id., p. D.10.) In 1986 the chlorophyll maximum was more than 10 times what it was in 1979, although the

2-10-86  
104-3-3  
North Shore  
Boulder Basin  
1981

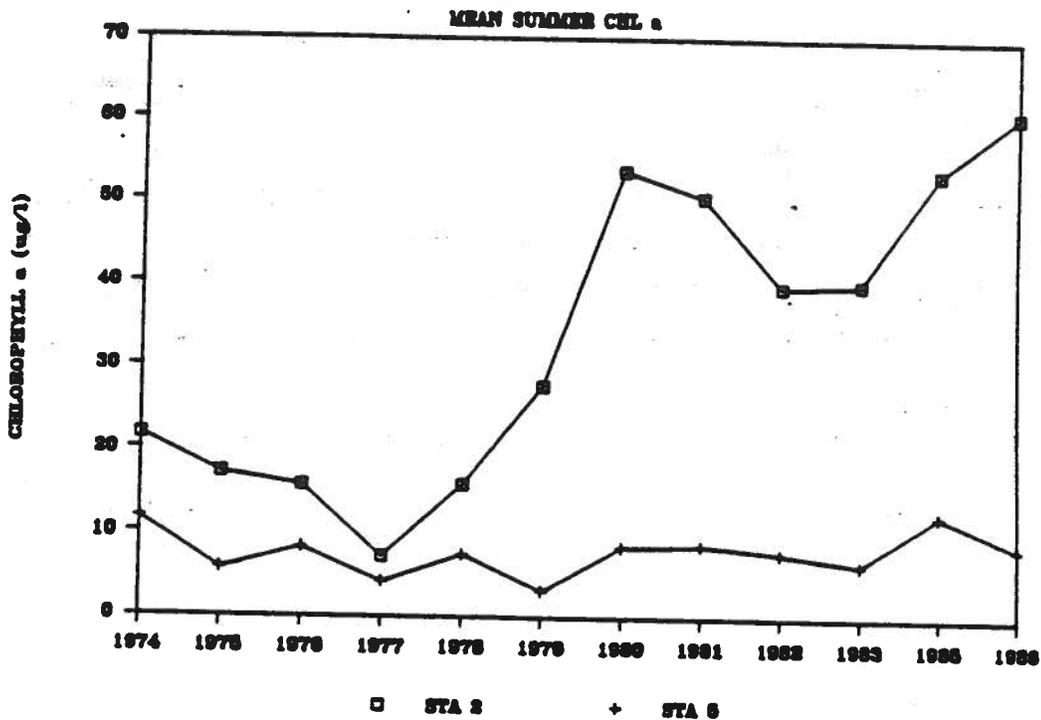
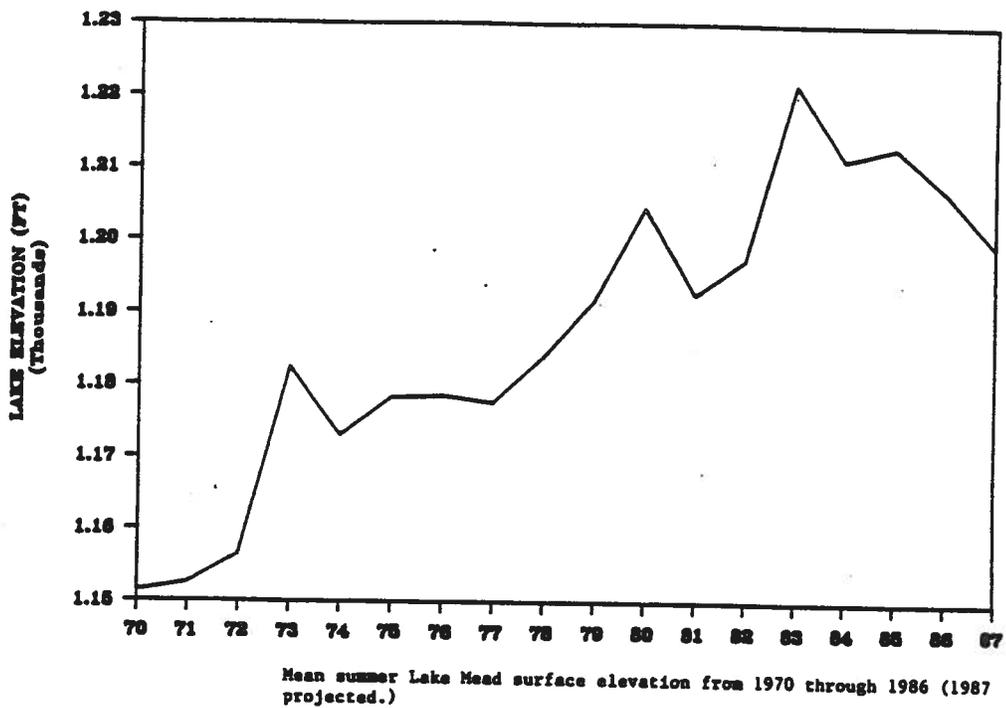
phosphorus load was lower. Paradoxically, one of the principal arguments in favor of AWT was to control algal blooms as evidenced by high chlorophyll concentrations. Clearly, neither median nor maximum chlorophyll concentrations at Station 3 have fulfilled the promises and expectations of the AWT proponents. Phosphorus controls--even very drastic controls like total diversion of sewage discharges--too often fail to produce the promised results (Welch 1984).

So far as the valuable fishery in Lake Mead is concerned, it is just as well that chlorophyll levels have not responded to phosphorus controls. Oglesby (1977) has reported that the single best predictor of fish production is chlorophyll. If Oglesby is right, fish production should decline with declining chlorophyll levels.

#### Chlorophyll Levels Did Not Decrease When Lake Levels Rose

DEP has suggested that rising lake levels may decrease chlorophyll levels through simple dilution. (DEP May 1987, p. D.22.) Figure 21, however, shows that since the 1970s both lake levels and chlorophyll levels have generally been rising. According to DEP, either rising lake level or declining phosphorus discharges should have lowered chlorophyll levels. However, chlorophyll at station 2 has not behaved this way: it has not consistently fallen.

FIGURE 21



(Figures 13 and 19 from DEP's Proposal.)

CONCLUSION: Chlorophyll has not decreased as lake levels have increased.

DEP's Proposed Chlorophyll Standards Will Not Protect  
Against Blue-Green Dominance Or Algal Scums

On 26 June 1986, UNLV's field crew noted "a dense surface bloom of granular algae. . . . Granular scum very distinct but patchy, out to Marina @ [Station] 4." The dominant alga in this scum was reported as Microcystis. The total chlorophyll concentration that day was 377.8 ug/l at Station 2, 88.4 ug/l at Station 3, where the field sheet reports "surface streaks of algae, real green." On 7 August 1986, the total chlorophyll concentration at Station 3 hit an all-time high of 331.5 ug/l, and at Station 2 it was a near-record 202.1 ug/l; but the field notes for that day make no mention of scums, green color, or algae. The field sheets for both Stations 2 and 3 read identically, as follows: "clear, wind south 5-10 mph." There was evidently no consistent relation between chlorophyll concentrations in Las Vegas Bay and the algal scum, which "peaked in late June and early July." (Paulson 1987.)

Aside from the 1986 reports for inner Las Vegas Bay, we have found only one other mention of algal scums in Lake Mead. Jonez & Sumner (1954) reported widespread algal blooms and scums of dying algae in the Overton Arm in 1952 and 1953. If there were algal scums between 1953 and 1986, no one made any record of them that we can find. Yet types of algae capable of forming scums had been consistently reported throughout Lake Mead in dozens of reports and data

sets during the intervening 32 years (see below). Whatever the explanation may be, scum formation clearly had nothing to do with phosphorus loads from Las Vegas Wash, because phosphorus loads were higher before July 1981 than in 1986, and there were no phosphorus loads from the wash in 1952 and 1953.

#### How Algal Scums Form

Reynolds (1984) and Reynolds & Walsby (1975) have identified the conditions for and the mechanisms of bloom formation. The following paragraphs summarize their findings.

Alone among the algae, blue-greens possess gas vesicles or vacuoles to regulate their buoyancy, thereby controlling their vertical movement. Blue-greens require light, but not too much; their nutritional requirements do not differ greatly from those of other algae. By expanding and collapsing their gas vacuoles, they adjust their position in the water column, rising or sinking as necessary to control their exposure to light and their access to food. Scums form only in windless weather, when the water is calm, and when the buoyancy-control apparatus of the algae malfunction--when it goes into overdrive and gets stuck there. Scums result from the buoyant movement of the existing blue-green population, not from a significant population increase during scum formation. Instead, algal material,

hitherto distributed over a substantial depth, becomes telescoped into a thin layer immediately beneath the water surface. Buoyancy control malfunctions when the blue-greens are in poor physiological condition, especially when they are nutrient-deficient. Reynolds & Walsby relate large increases in buoyancy to deficiencies in intracellular nitrogen and phosphorus:

The genera [of blue-greens] which most commonly form blooms . . . are those which, under appropriate conditions, float most rapidly through water. . . . Water blooms occur because the buoyancy-control mechanism becomes "tricked" into compensating for sub-optimal photic exposure. . . . If turbulent motion [i.e. good vertical mixing of the water by wind action] subsides abruptly, many of these algae may float to the surface before they can reduce buoyancy sufficiently. Moreover, some populations may be incapable of reversing overbuoyancy. Under these circumstances, sudden reduction in turbulence leads to the formation of a surface bloom. . . . It is [the] buoyant behavior [of these blue-greens] which leads to an exaggerated view of their abundance in lakes, whereas maximal populations[s] of other algae, which remain dispersed, are frequently tolerated; blue-green algal blooms, even when they represent a modest fraction of the whole plankton, are often regarded as unacceptable. We believe that the occurrence of surface blooms may have often led to quite unjustified claims about the extent of algal growth in some of the world's lakes. [Reynolds & Walsby (1975)]

Reynolds & Walsby give two clear examples of the sequence of events in scum formation in Crose Mere (England). A Microcystis scum developed within 15 hours,

although the chlorophyll concentration in the 0-5 meter water column was less than 12 ug/l:

Within a period of 15 h, 87% of the [Microcystis] population, formerly distributed over a depth of up to 5 m, accumulated in the top 1 m, and 56% within the top 0.1 m; the surface scum became intense during the last 6 h. Although the standing population was small (less than 12 mg Chl a per cubic meter in the 0-5 m column), the eventual bloom was relatively intense (326 mg per cubic meter in the top 0.1 m).

Scums need not form quickly: an Anabaena scum in Crose Mere gradually developed over a week (21 June-2 July 1968). On 21 June the algae were uniformly distributed through the water column (see Figure 22). By 28 June all the algae had risen into the top 4 meters. By 2 July nearly all the algae were at the surface.

Scum formation gives the algae no biological advantage. On the contrary, over-exposure to strong sunlight is often a fatal consequence of a regulatory mechanism (buoyancy control) gone wild.

In summary, scums can form whenever three conditions are met:

- calm warm weather and quiet water
- a population of blue-greens capable of forming scums (e.g. Anabaena, Microcystis, Oscillatoria)
- a breakdown in the buoyancy-control mechanisms of these algae.

FIGURE 22

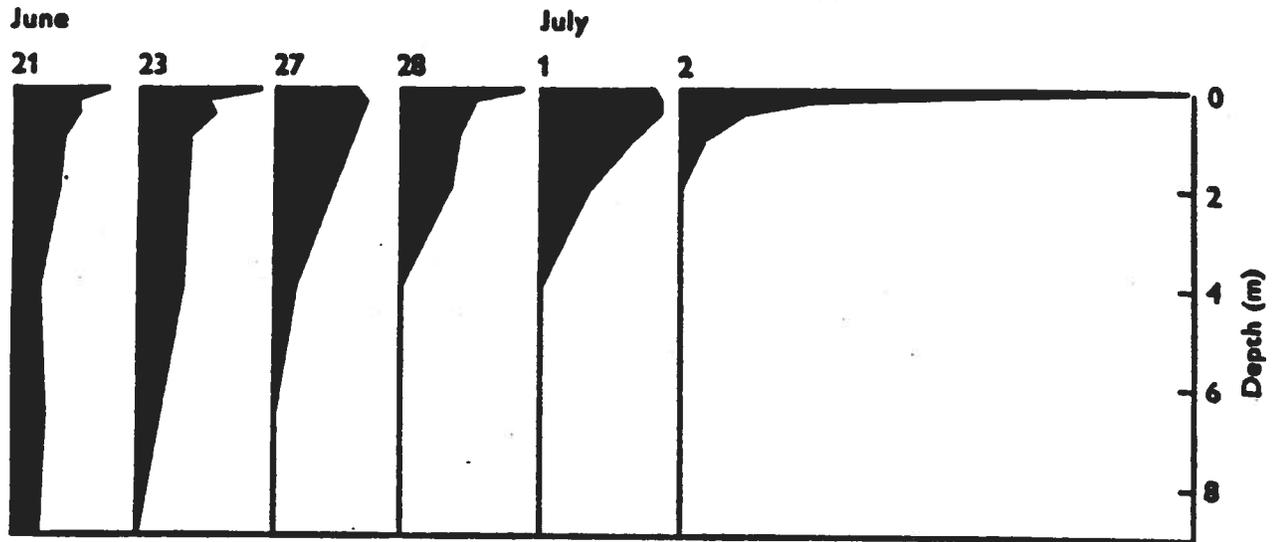


Fig. 7. Vertical distribution diagrams of *Anabaena circinalis* in Crose Mere, Shropshire, during 1968. Re-drawn from Reynolds (1971, fig. 7).

(From Reynolds & Walsby 1975.)

CONCLUSION: Scums results from the buoyant movement of the existing blue-green population, not from a significant population increase during scum formation. On 21 June the algae were uniformly distributed through the water column. By 28 June all the algae had risen into the top 4 meters. By 2 July nearly all the algae were at the surface.

Chlorophyll concentrations in a 0-5 meter sample really have no bearing on any of these conditions. Blue-greens capable of forming scums when the weather is calm and when their buoyancy-control mechanisms malfunction have been reported in Lake Mead for over 30 years. Jonez & Sumner found Anabaena and Microcystis in the early 1950s; these and other possible scum-formers have been widely reported since then, and they were sometimes dominant. There have certainly been long stretches of calm weather since the early 1950s. But for reasons as yet unknown, the buoyancy-control mechanisms of the possible scum-formers have not malfunctioned sufficiently to cause scums. Those reasons merit careful study. DEP's proposed standards for chlorophyll and management objectives for Las Vegas Bay are no help in understanding or controlling algal scums. Only a serious study of Lake Mead can provide the answers we need to control them.

#### The Proposed Chlorophyll Standards Cannot Prevent Blue-Green Dominance

Dominance by blue-greens capable of forming scums has been widely reported at chlorophyll concentrations much lower than DEP's proposed standards. We have already given an example of a Microcystis bloom in Crose Mere when the

chlorophyll concentration was less than 12 ug/l. Other instances are equally telling.

The cleanup of Lake Washington (in Seattle) is one of the most celebrated instances of lake restoration in the world. It was accomplished by diverting all sewage discharges from the lake between 1963 and 1968. The summer plankton was dominated by Oscillatoria rubescens and related Oscillatoria spp. (notorious for the red scums they have produced in Swiss lakes) from the mid-1960s through 1972 (when it still accounted for 89 percent of the algae). But in 1972 the average summertime chlorophyll was 7.2 ug/l; in 1971 it was 6.1 ug/l; in 1970 it was 8.8 ug/l. (Edmonson 1975/1977; Edmonson & Lehman 1981.) Clearly, blue-greens dominated in Lake Washington at average chlorophyll concentrations lower than even the lowest chlorophyll standard DEP is proposing for Las Vegas Bay.

In the Mondsee, a deep lake in the alpine foothills of Austria, "Oscillatoria rubescens D.C. and Microcystis aeruginosa Kuetz. dominated [in the] summer and early autumn" of 1982. During these months, the chlorophyll a concentration never exceeded 10 ug/l at any depth, and the average concentration was much lower (approximately 5 ug/l in the top 5 meters). (Dokulil & Skolaut 1986.) Oscillatoria rubescens and Microcystis aeruginosa are both notorious scum-formers. They dominated the phytoplankton

despite the extremely low chlorophyll concentrations during their dominance.

In Panamá's Gatún Lake, the maximum yearly chlorophyll a concentration is 4.1 ug/l." Yet the phytoplankton assemblage includes Anabaena, Anacystis, Microcystis, and Oscillatoria, and at the beginning of the dry season "Microcystis may appear in unusually large densities." (Zaret 1984.)

Las Vegas Bay itself offers clear examples of the unrelatedness of chlorophyll to scum-formers. No algal scums were reported during 1979-1980, but blue-greens were prevalent throughout the bay and at the SNWS intake in Boulder Basin. Here are several revealing examples from STORET data for Station 5 (the middle bay):

- On 7 August 1979 the blue-green count was 3,200,000 per liter and the total phytoplankton count was 4,500,000 per liter; but the chlorophyll a concentration that day was only 6 ug/l. Blue-greens dominated, despite the low chlorophyll concentration.
- On 20 August 1980 the blue-green count was much higher: 18,900,000 per liter. The total phytoplankton count was 28,900,000 per liter, and the chlorophyll a concentration was 8 ug/l. ✓

- On 11 September 1980 the blue-green count was higher still: 36,200,000 per liter, and the total phytoplankton count was 50,100,000 per liter. But the chlorophyll a concentration was 14 ug/l.

These examples show that there is no necessary connection between chlorophyll and the dominance of scum-formers. Even when algae capable of forming scums under appropriate conditions are present in high numbers, scums may not form, regardless of the chlorophyll concentration (e.g. Lake Mead from the early 1950s until 1986). Even at very high chlorophyll concentrations (e.g. Las Vegas Bay on 7 August 1986), no scums may be reported. Conversely, scums have been reported at very low concentrations of chlorophyll (e.g. Crose Mere in England).

There is no necessary connection between scums and chlorophyll because scums can form only when buoyancy-control mechanisms of blue-green algae break down, regardless of the kind of algae present and regardless of the chlorophyll concentration. Reynolds & Walsby report that the nutritional requirements of scum-formers "are not significantly higher than those of other algal groups." They also point out that "blue-green algae frequently become dominant in lakes at about the same time that [nutrient] concentrations reach their seasonal minima."

Lake Mead during the 1970s confirms that the dominance of scum-forming genera of algae is unrelated to chlorophyll concentrations. Anabaena was dominant much more often in middle and outer Las Vegas Bay and in Boulder Basin than in the inner bay, where chlorophyll concentrations are always much higher.

In 1986, the dominant algae cannot be identified in Las Vegas Bay because the total population of algae was not enumerated. When an alga is dominant, it must account for at least half of (1) the total cell count, (2) the total algal biovolume, or (3) the total algal biomass. Not one of these three items is available for Las Vegas Bay in 1986.

Data on surface waters of Boulder Basin at the SNWS intake are available for the total cell count and total algal biomass. In 1986 Microcystis (which SNWS often combines with Anacystis--algal taxonomy is fluid) dominated the cell count on five days but never accounted for more than six percent of the biomass. All blue-greens together never accounted for more than 19.4 percent of the biomass (4 April); from then on it stayed below six percent, even during the Microcystis biomass Paulson (1987) reported for May through July.

Why did Anacystis/Microcystis never dominate the biomass? Because the cells are small ("micro" comes from the Greek word meaning "small"). Algae, like mammals, vary greatly in size and weight. Mice are smaller than men;

Microcystis aeruginosa cells occupy a volume of 30-100 cubic microns, but Ceratium hirundinella is 41,000 to 70,000 cubic microns. (Reynolds 1984, pp. 20-23.)

Although SNWS routinely counts algal cells in the surface waters near the drinking-water intake, DEP reports only one of these measurements: On 2 May 1986, Anacystis/Microcystis dominated the cell count (29,000 cells/ml). DEP has exaggerated this finding out of proportion. Because Anacystis/Microcystis are so small, the cell count gives a distorted idea of the relative importance of this organism in the algal assemblage. The 29,000 cells/ml accounted for only one percent of the biomass; all blue-greens together accounted for only 1.4 percent of the biomass.

When there were 29,000 cells/ml of Anacystis/Microcystis, were chlorophyll concentrations high? Not at all. Although SNWS took no chlorophyll measurements, UNLV measured it the day before. In Boulder Basin (Station 8) total chlorophyll was 3 ug/l; in middle Las Vegas Bay (Station 5) it was 5.6 ug/l.

SNWS data show that although Anacystis/Microcystis occasionally dominated the cell count, it never accounted for much of the biomass. In 1983, however, blue-greens dominated the biomass twice, during mid-August and late October, despite low chlorophyll levels in Las Vegas Bay and record high lake levels.

SNWS takes its samples right at the surface; UNLV's samples for chlorophyll and nutrient analysis are depth-integrated, extending down to 5 meters in Boulder Basin. The data from these two sets are not strictly comparable, but UNLV has never found much chlorophyll in Boulder Basin. In 1983-1986 (the years when SNWS data allow computation of algal dominance), all UNLV chlorophyll measurements in Boulder Basin were less than 6 ug/l.

DEP's management objectives for Las Vegas Bay specify that algae capable of forming surface scums must not be dominant. The chlorophyll objectives DEP is proposing offer no protection against occasional dominance by possible scum-formers, as SNWS data show. Dominance by scum-formers has been repeatedly documented in lakes exhibiting very low summertime chlorophyll concentrations, and Lake Mead itself is ample proof that algal scums are rare, even when chlorophyll concentrations are relatively high.

#### Blue-Green Dominance In Lake Mead Since 1952

There is a long history of blue-green dominance in Lake Mead, which suggests that blue-greens are normal denizens of the lake. Blue-green dominance has not been confined to Las Vegas Bay either. In report after report, blue-green dominance has been identified at many locations in the lake.

Jonez and Sumner (1954) reported dramatic blue-green dominance in the early 1950s. Their sampling stations were located in the Overton Arm, Virgin Basin, and near the mouth of the Moapa River (Jonez & Sumner 1954, p. 23); evidently no observations were made in Las Vegas Bay and Boulder Basin, but there were certainly plenty of blue-green algae at the places they looked for it:

During warmer months, May to October, a gradual increase in abundance of algae was found. At these times, algae was found upon all shores and upon much of the shallow lake bottom . . . . Generally the filamentous and blue-green types were most commonly seen. Observations made with the aid of aqua lungs revealed the presence of what appeared to be a blue-green lawn upon silt bottom. Murkiness of the water prevented this observation from the surface. The presence of a universal carpet of algae was the cause of this unusual sight. [¶] After periods of increased wind activity, a scum of dead and dying algae, which had been eroded from shallow lake bottom, was often found about windward shores. [P. 11.]

High winds often caused a turbid condition about dirt shores and silt covered shallow areas, such as the upper Overton Arm. More rarely light penetration was reduced by phytoplankton blooms. A large bloom which occurred during August and early September, 1952 reduced visibility to within 3 feet of the surface. [Id. p. 19.]

During warm months large blooms of phytoplankton were occasionally found about the lake. During the late summer of 1953 a widespread bloom covered the upper Overton Arm. The lack of any wind for 6 weeks undoubtedly encouraged this condition. [Id. p. 27.]

Algal scums are caused only by blue-greens; scums can develop only when the water is calm, generally in windless weather. (Reynolds & Walsby 1975.) Among the algae Jonez & Sumner identified, four are blue-greens, and two of them are scum-formers: Anabaena and Microcystis. (Jonez & Sumner, pp. 27 & 181; Reynolds & Walsby, p. 439.)

On 4-8 June 1965 the U.S. Public Health Service reported high algal counts and dominance by another scum-former, Oscillatoria, in Las Vegas Bay:

Surface algal counts exceeding 9,000/ml occurred for a distance of three miles out from the mouth [of Las Vegas Wash]; surface counts exceeding 2,000/ml extended out six miles. In the main body of Lake Mead the surface counts were less than 2,000/ml. The principal alga in the 9,000/ml area was Oscillatoria sp. which, in many cases, comprised 50% of the total phytoplankton population. [U.S. Public Health Service 1965, p. 1.]

This finding was repeated verbatim in several federal reports in the late 1960s.

Throughout the 1970s, UNLV consistently reported blue-green dominance throughout Lake Mead. In 1972, Anabaena was reported to be the dominant alga in inner, middle, and outer Las Vegas Bay. (Deacon & Tew 1973, see p. 172.) Anabaena dominance continued throughout the warm months of 1974:

Blue-green algae (Anabaena) were prominent in the inner bay during the summer and fall but became dominant only in early August in 1972 and in late

September 1974. The genus became proportionately more important farther out in the Bay and in Boulder Basin. Frequently during July, August, September and October in 1972 and 1974, Anabaena was the dominant phytoplankton organism in the outer bay and in Boulder Basin. [Deacon 1975, p. 4.]

Nine genera of blue-greens were collected in Boulder Basin in 1974; five of them (Anabaena, Coelosphaerium, Microcystis, Oscillatoria, and Spirulina) commonly cause surface scums. (Reynolds & Walsby, p. 439.)

Anabaena became even more dominant in 1975: "Anabaena, has become increasingly more dominant since 1972 and was completely dominant throughout the summer (July-September)" in middle Las Vegas Bay, outer Las Vegas Bay, and Boulder Basin (but not in the inner bay). Anabaena accounted for up to 50 percent of the biomass. (Deacon 1976, pp. 36, 45.)

On 21 September 1976, Goldman reported 10 genera of blue-greens in Las Vegas Bay and Boulder Basin, including possible scum-formers such as Anabaena, Microcystis, Anabaenopsis, and Oscillatoria. Blue-greens dominated over all other algal types in middle and outer Las Vegas Bay (but not in the inner bay) and everywhere in Boulder Basin. (Goldman 1976, pp. 64-65.)

Throughout the autumn of 1976 and again in May 1977, UNLV again reported blue-green dominance in middle Las Vegas Bay, outer Las Vegas Bay, and Boulder Basin; because

no samples were taken during the summer months, blue-green dominance may be considerably understated in these two years. (Deacon 1977.)

In 1978 UNLV reported blue-green dominance at Temple Bar, Boulder Basin, Boulder Canyon, and middle Las Vegas Bay. It is important to note that Temple Bar, where Microcystis dominated, is entirely unaffected by Las Vegas Wash. In addition to Microcystis, the dominant genera included Anabaenopsis, another possible scum-former. (Paulson et al. 1980, p. 124.)

Algal samples collected by UNLV during 1979-1980 are on file in EPA's STORET data bank. A STORET retrieval prepared for the City of Las Vegas by EPA Region IX on 21 February 1987 showed that blue-greens were often dominant in inner and middle Las Vegas Bay. EPA's retrieval inexplicably omitted algal data for Boulder Basin. Nonetheless, even in the middle bay (Station 5), where chlorophyll concentrations never exceeded 25 ug/l in 1979-1980, blue-greens often exceeded a million per liter; on 20 August 1980 the blue-green count was 18,900,000, and on 11 September 1980 it was 36,200,000. There are no algal data in STORET for any year after 1980, and we do not know of any other algal enumeration data in published or computerized form.

The Southern Nevada Water System (SNWS) has monitored algae in surface waters near its intake in Boulder Basin; these data are not published or computerized, but

SNWS kindly sent us copies of the original laboratory sheets. For sampling dates before October 1982, it is not possible to identify dominant organisms in this data set, owing to the methods of enumeration and reporting; however, these data may be used in a qualitative way to identify the presence or absence of important algal types. The data collected before October 1982 show that blue-greens were often present, including such possible scum-formers as Anabaena, Anacystis, Microcystis, Oscillatoria, and Spirulina. Since October 1982, SNWS data show blue-green dominance (counts greater than 50 percent of total phytoplankton) in October and November 1982; February, April, May, August, October and December 1983; August and September 1984; January, June, July, August, September and October 1985; and April, May, June, July, August, November and December 1986. The dominant genera often include such possible scum-formers as Microcystis, Anacystis, and Oscillatoria.

Large numbers of blue-greens, accounting for as much as 25 percent of the phytoplankton biomass, were reported in Lake Powell in May 1981. (Janik 1984, p. 38.) There are essentially no sewage discharges into Lake Powell.

In summary, blue-green algae (including many types of possible scum-formers) have been consistently identified throughout the lake since the early 1950s. Blue-green dominance has been reported at many sites far removed from Las

Vegas Wash. Within Las Vegas Bay, blue-green dominance was reported as early as 1965; in Boulder Basin, blue-green dominance has been consistently reported in summertime samples since 1972. The widespread occurrence of blue-greens throughout Lake Mead since the early 1950s--often blue-greens that can form surface scums when the conditions are right--casts doubt on the attainability of DEP's first management objective for Las Vegas Bay: "The dominant algae shall be of the non-surface scum forming variety." (DEP May 1987, p. D.34.)

#### Blue-green Algae Are A Good Food Source For Zooplankton And Fish

DEP's rationale contends with no reservation of any kind that blue-green algae are not a ready source of food in the ecosystem:

Studies have shown that blue-green algae are not readily ingested or digested by zooplankton, and therefore do not represent a good food source (Lefevre 1950; Burns 1968; Schindler 1971; Hayward and Gallup 1976). Lack of grazing on the algae by the zooplankton leads to high concentrations of blue-greens commonly observed during a bloom. Due to the fact that zooplankton do not feed well on blue-green algae, a block in the food chain is created that effects [sic] the entire bioenergetics of the system on which the ecosystem depends. This phenomenon will have an adverse effect on all organisms within the food chain including the sport fish. [DEP May 1987, p. D.18.]

Blue-green algae predominate from time to time in lakes sustaining excellent fisheries; this is a commonplace of limnology. Highly productive lakes are those where many forms of life flourish, and blue-green algae are common in them.

It is well known that productive lakes typically produce successive "waves" of algae, and that blue-greens are commonly in the "wave" that crests in summer (see, for example, Reynolds 1984, chap. 8).

Describing the extremely productive lakes of the Chang Jiang (Yangtze River) basin, Liu (1984) reported that: (1) fish yields (in kg/ha) increased from 84.75 to 546.0 between 1970 and 1978; (2) blue-greens, and especially blue-greens such as Anabaena, Aphanizomenon, and Microcystis, became increasingly predominant during this interval, accounting for more than 50 percent of the algal cell count and an even greater percentage of the biovolume; and (3) "neither feeds nor fertilizers are applied to the lake for the stocked fish; the stocked fingerlings, just like the wild population, feed solely on the food organisms naturally present."

DEP cited four authorities (none more recent than 1976) to support the argument that zooplankton do not feed on blue-greens. Many authorities, however, have reported that zooplankton and fish do feed on blue-greens. It is astonishing that DEP failed to take note of important work

in this field at UNLV, where Starkweather and his colleagues have reported that zooplankton do indeed feed on blue-greens, even strains of blue-greens toxic to mice. For example, Starkweather & Kellar (1983) reported that the zooplankton Brachionus calyciflorus exhibited "normal population growth on a strain of A[nabaena] flos-aquae (NRC-44-1) reported to be one of the most toxic cyanobacteria yet isolated". They concluded that "blue-greens, such as Anabaena flos-aquae, should now be included in the inventory of possible foods for planktonic rotifers and must be evaluated as representing positive nutritional contributions to the group." More surprising still, they reported that zooplankton fed on a 1:1 mixture of toxic Anabaena flos-aquae and the standard laboratory food organism Euglena gracilis exhibited "significantly greater fecundity and population growth rates" than zooplankton deprived of Anabaena in their diets. Finally, Starkweather & Kellar (1983) reported that blue-greens and filamentous algae probably serve as a food source for zooplankton under a wide variety of conditions:

Despite the remarkable capacity of suspension-feeding rotifers to select or reject individual food items (Starkweather 1980), the animals "choose" to feed on Anabaena. Thus, consumption of blue-green cells and filaments seems likely to occur not only under transient bloom conditions, but at times of greater sestonic diversity as well.

The UNLV group under Starkweather has shown that blue-greens are an important food source under laboratory conditions, but many prominent investigators have concluded that blue-greens are an important food source in lakes all over the world. Caron et al. (1985), for example, have reported finding blue-greens in the food vacuoles of heterotrophic microflagellates and in the guts of rotifers from Lake Ontario; they concluded that chroococcoid blue-greens (a large component of the algae in Lake Ontario) "may be an important food source" and may "play an important role in the food webs of freshwater plankton communities" in other lakes.

One of the seminal papers on blue-greens as a food source established that both fish and zooplankton ate, digested, and assimilated nutrients from the dominant blue-greens (principally Microcystis and Anabaena) in Lake George, Uganda (Moriarty et al., 1973). They showed that the fish fed directly on the dominant blue-greens and could assimilate an astonishing 70 to 80 percent of ingested carbon from Microcystis, but only about 50 percent from the green alga Chlorella. Zooplankton assimilated 35 to 58 percent of the ingested carbon from Microcystis. The genera of blue-greens grazed by fish and zooplankton included Microcystis, Anabaena, Lyngbya, and Aphanocapsa.

Reporting on Lake Valencia (Venezuela), de Infante (1982) found that resident zooplankton ate and digested as

much as 97 percent of the filamentous blue-green Lyngbya limnetica.

Gunn et al. (1977) reported that the filamentous blue-green alga Anabaena flos-aquae was an important food source in the Ottawa River for the brown bullhead (Ictalurus nebulosus, a close relative of the channel catfish, Ictalurus punctatus, common in Lake Mead). "Isotopic and caloric techniques showed that about 23% of the carbon from Spirogyra [a green alga] and 67% of the carbon from Anabaena flos-aquae was assimilated by the fish within 24 h of ingestion." Once again, this work established that blue-greens were a better food source than green algae; the carbon assimilation rate from the blue-greens was nearly 300 percent of the assimilation rate from the green algae.

In studies of Crystal Lake (Ohio), Schoenberg & Carlson (1984) reported that the cladoceran zooplankter Daphnia greatly reduced chlorophyll concentrations and the biomass of Microcystis:

The Daphnia enclosures yielded a 5-fold lower total cell volume . . . and 3-fold lower chlorophyll a [than] . . . the control enclosure and the lake. Furthermore, a concomitant decline in gross primary productivity occurred [where] Daphnia populations developed . . . The principal difference in biomass and relative abundance is a decrease in the large, extensively sheathed blue-green alga Microcystis when Daphnia was present. . . . A significantly greater relative abundance of presumably more edible green algae (primarily Scenedesmus) was observed in the Daphnia enclosures

despite the apparent increase in grazing intensity. . . . Our observations that Daphnia galeata mendotae grazed the colonial blue-green alga Microcystis conflicts with previous laboratory feeding studies where it was utilized at the lowest rates of all algae examined. . . . Our studies indicate no such invulnerability to grazing for the Microcystis from Crystal Lake. . . . [T]he ingestion rate by D[aphnia] longispina when fed Microcystis was still 57% of that for Ankistrodesmus, considered an ideal food (Schindler 1971). Reynolds et al. (1982) have reported that colonies smaller than 60 um could be ingested and observed an instance in which 97% of a Microcystis population was decimated by Daphnia grazing. Since the specific productivity of Microcystis in nature is rather low (Reynolds 1973), even a small increase in grazing losses could bring about a very significant reduction in standing stock.

Working with ostracod zooplankton from Louisiana rice paddies, Grant et al. (1983) found that these ostracods fed voraciously on such filamentous blue-greens as Tolypothrix, Nostoc, and Anabaena; ostracods starved for 24 hours grazed at more than double the rate of ostracods continuously fed.

Lewis (1979) found that two types of zooplankton, cyclopoids and rotifers, exhibited strong affinities for blue-greens in Lake Lanao (the Philippines). He commented on these strong affinities as follows:

Strong association of herbivore production with the abundance of bluegreen algae is . . . surprising, since the bluegreen algae are often considered to provide an inferior food source for herbivores. . . . Since the peak abundances of bluegreen algae are entirely out of phase with peak abundances of diatoms and cryptomonads, it would be unlikely

that an association of major zooplankton herbivore production with the production of bluegreen algae could occur by spurious correlation through some other variable. Occurrence of high herbivore production in connection with the high levels of bluegreen algal biomass could scarcely be explained by a mechanism other than the use of bluegreen algal biomass as food, since significant amounts of alternative food sources are not available when bluegreen algae occur in great numbers. [p. 112, text references omitted.]

Carlson & Schoenberg (1982/1983) have commented at length on the inconsistent reports of blue-greens as a food source:

The common belief is that zooplankton cannot control blue-green algae because blue-green algae themselves are too large, indigestible, or toxic, or that the densities of zooplankton during the summer months are too low to effect any significant control. . . . A review of the literature, however, reveals a disturbing number of inconsistencies. All too often the same blue-green species is reported noningestible or toxic by one author, yet another author finds it to be a totally acceptable food. . . . In conclusion, the evidence that blue-green algae are either too large to be ingested, undigestible because of gelatinous sheaths, or toxic is inconclusive and often contradictory.

The importance of size and sheath was investigated by McNaught et al. (1978/1980) in the ecology of Lake Huron:

[C]ladocerans, which are typically warm-water inhabitants, have become abundant in the shoreward regions of Lake Huron and may constitute up to 85% of inshore populations. We have pictured them as generalists with regard to diet (they eat more blue-greens) and particularly with

regard to size-selective feeding (they consume a broader range of sizes). . . . Seven common herbivorous crustaceans, including five adult stages (Diaptomus sicilis, Cyclops bicuspidatus, Cyclops vernalis, Tropocyclops prasinus, and Eubosmina coregoni) and two of their larval stages (copepod nauplii and cyclopod copepodites), were fed mixtures containing 50% by volume of one of two blue-green algae (Gloeocapsa sp., Anacystis nidulans) and one of three green algae (Scenedesmus quadricaudata, Ankistrodesmus falcatus, and Pediastrum sp.). . . . Most crustacean zooplankters were not highly selective feeders. . . . Thus the predominant conclusion is that food selectivity is not a characteristic of these important herbivores; they took both sheathed and unsheathed blue-greens of a variety of sizes. However, two dominant forms (adult D. sicilis and cyclopoid copepodites) were highly selective. . . . Diaptomus selected the small, sheathed [blue-green] Gloeocapsa over the large, plain [green] Pediastrum. . . . Similarly the cyclopoid copepodites selected [blue-green] Gloeocapsa over [green] Scenedesmus. . . . Thus the small sheathed blue-green was always selected.

Food preferences of the dominant zooplankton of Lake Huron were clearly not dictated by algal type (green versus blue-green). Most ate greens and blue-greens unselectively, and the others always preferred small sheathed blue-greens to green algae.

This sampling of recent work on the diets of zooplankton shows that DEP's claim that "blue-green algae are not readily ingested or digested by zooplankton" is out of date. Although it was once believed that blue-greens are not nutritious, work that DEP failed to cite has established

beyond any doubt that blue-greens, even strains very toxic to mice, can be highly nutritious for a wide variety of zooplankton and fish. Some of this work has established that zooplankton often prefer blue-greens to the supposedly tastier, more appealing green algae and derive greater nutritional benefit from blue-greens than from green algae.

#### More Chlorophyll Will Have Little Effect On Water Clarity

DEP may have created the impression that the proposed chlorophyll standard is needed to ensure clarity in Las Vegas Bay. As one of its management objectives, DEP asserts that "Water clarity will be maintained at desirable levels (e.g. Secchi depth: sta 3, 1.6 m . . .)". (DEP May 1987, p. D.34.) However, data from Lake Mead and from other lakes show that chlorophyll values above approximately 30 ug/l have little effect on clarity.

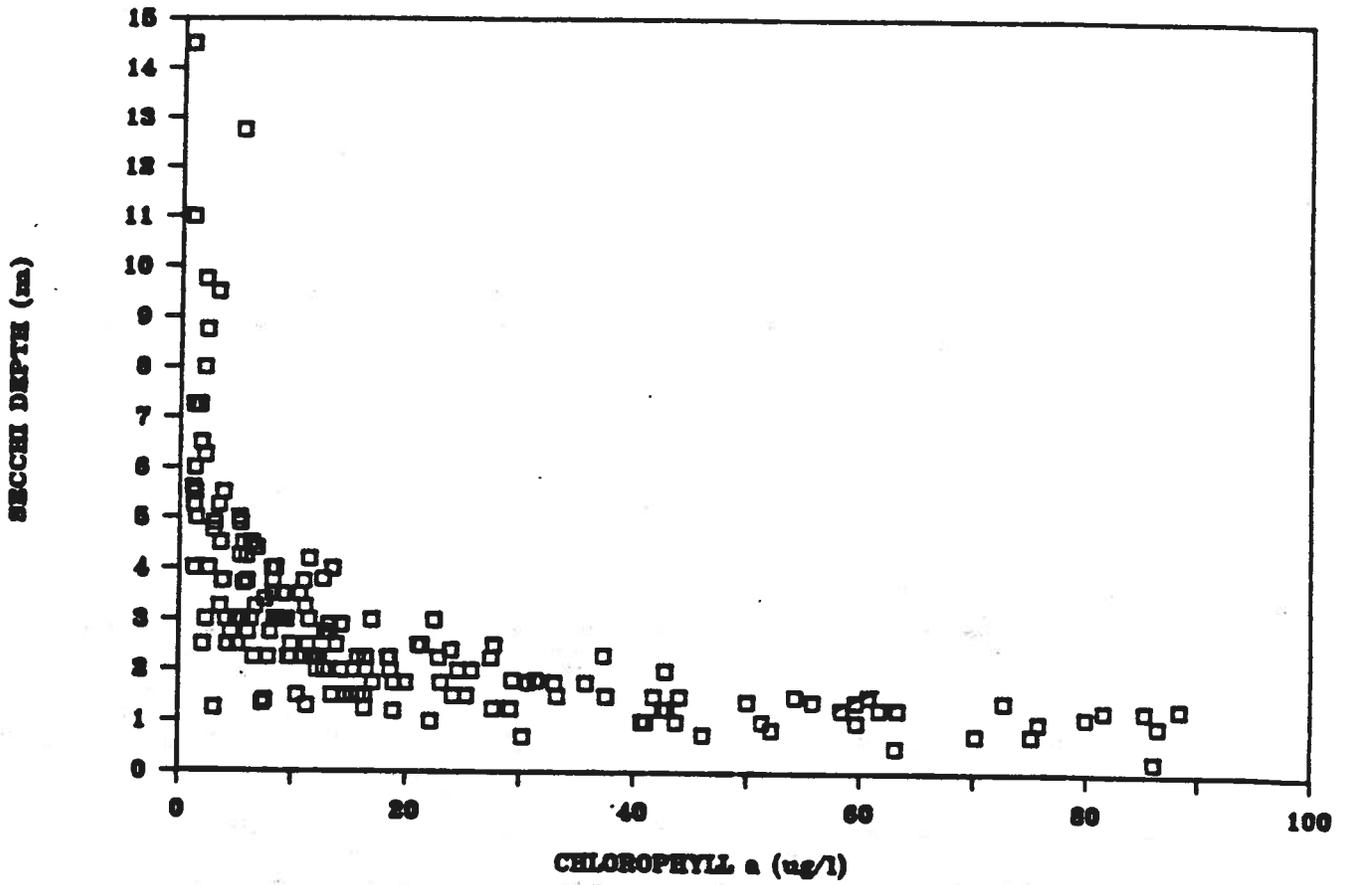
Megard et al. (1980) examined the relation between chlorophyll and Secchi depth in several quite different lakes and found that high chlorophyll concentrations had little effect on Secchi depth. They concluded that "the Secchi depth becomes insensitive to changes of chlorophyll at concentrations greater than 30 [ug/L]. . . ." Lind (1986) has recently substantiated the ideas of Megard et al.; he also found that

There was no Secchi depth to chlorophyll  
a relationship observed for Waco Reser-  
voir in either study or for Stillhouse

Reservoir. An unexpected negative relationship was found for reciprocal Secchi depth with chlorophyll a content in Sam Rayburn Reservoir. . . .

DEP has portrayed the relationship between Secchi depth and chlorophyll in Las Vegas Bay (DEP May 1987, p. D.21). See Figure 23. This figure shows that at very low chlorophyll concentrations, Secchi depths scattered

FIGURE 23



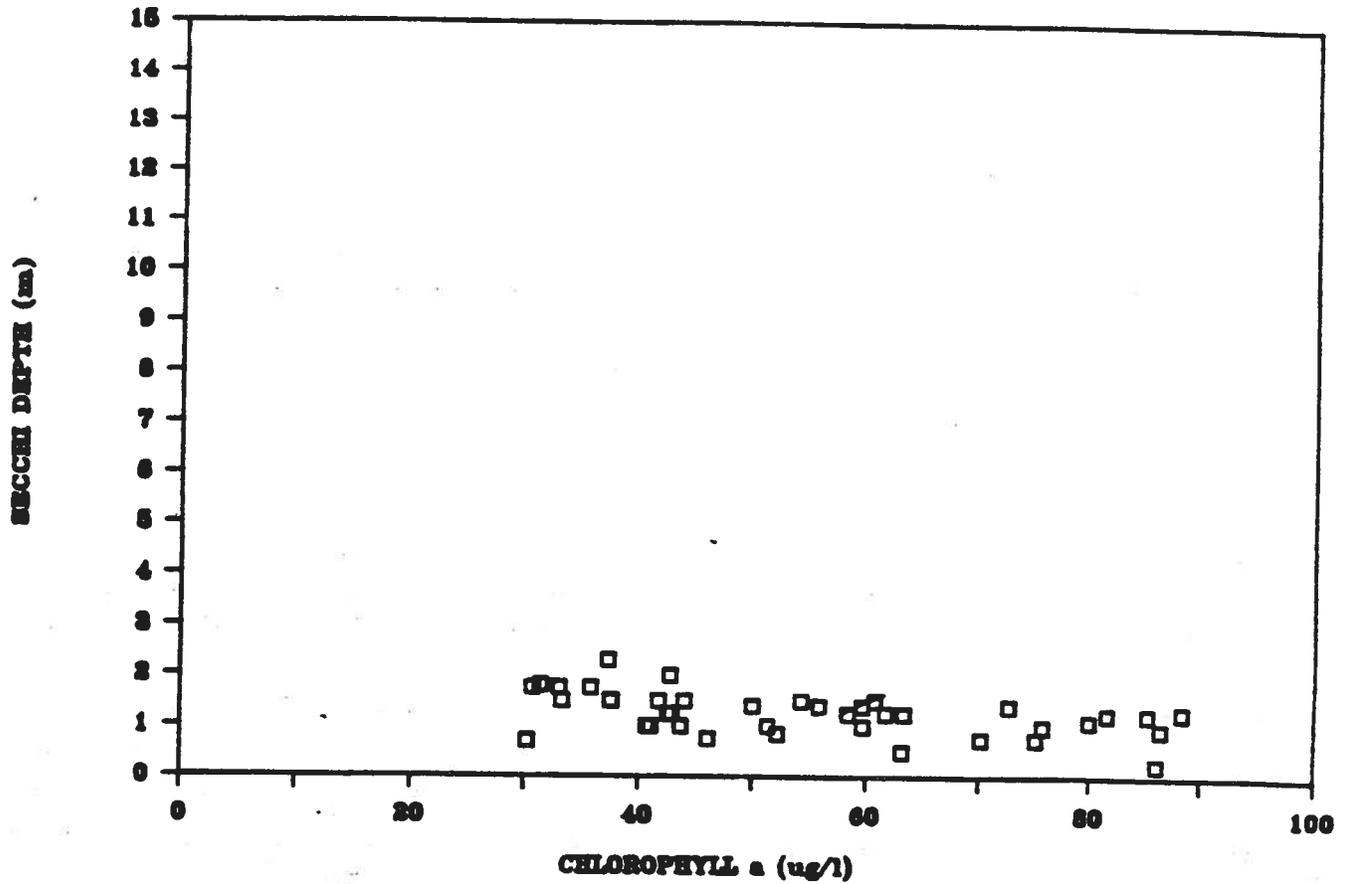
Relationships between Secchi depth and chlorophyll a in Las Vegas Bay.

(Figure 17 from DEP's Proposal.)

FIGURE 24

CLAIM: DEP claims that Secchi depth (clarity) decreases as chlorophyll increases.

SUPPORT:



(Detail of Figure 17 from DEP's Proposal.)

CONCLUSION: According to DEP's own figure, there is only a small decrease in clarity as chlorophyll increases from 30  $\mu\text{g/l}$  to 90  $\mu\text{g/l}$ .

erratically between 1 and 15 meters; at concentrations above 20-30 ug/l, Secchi depths changed very little. See Figure 24. The pattern DEP shows substantiates the conclusion of Megard et al. that Secchi depths are insensitive to chlorophyll concentrations above 30 ug/l.

It also substantiates Lind's finding that Secchi depth varies greatly at low chlorophyll concentrations: "Any small variation (real, or as an error in measurement) in chlorophyll a concentration, when the concentration is low, will produce a large variation in Secchi depth." In other words, low chlorophyll concentrations produce higher average Secchi depths, but there will still be days when clarity is relatively low.

Edmondson (1980) explains that Secchi depth is related to the number of particles scattering light, rather than to the absolute chlorophyll concentration:

I have demonstrated this to my limnology class by showing a flask of tapwater with a small piece of chalk in it; it looks clear. Then I grind the chalk up and have what looks like milk; the mass of chalk has not changed. (Maybe I should use green chalk to relate more closely to phytoplankton).

Monitoring data for Las Vegas Bay in 1986 confirm that Secchi depth does not respond sensitively to high chlorophyll concentrations. Paulson (1987) reports that "chlorophyll a concentrations in the inner Las Vegas Bay were considerably higher during summer (June-August) 1986 than in

previous years . . . and averaged 147.8 ug/L in June, 63.3 ug/L in July and 100.7 ug/L in August at [Station] 2." The average Secchi depths for Station 2 in those three months were 1.0, 1.3, and 1.0 meters, respectively. In 1985, the average chlorophyll concentrations were much lower, 53-63 ug/l between June and August; but the monthly average Secchi depths were about the same: 1.0 in June, 1.2 in July, and 1.0 in August. The higher chlorophyll concentrations in 1986 had no effect on Secchi depths, which remained nearly identical to their values in 1985.

Extreme week-to-week changes in chlorophyll didn't consistently affect Secchi depth in the inner bay. In August 1986, Station 3 hit new records for maximum and for average chlorophyll. Here are all the data on chlorophyll and Secchi depth for Station 3 in August 1986:

<u>August</u>	<u>Chlorophyll (ug/l)</u>	<u>Secchi depth (m)</u>
7	331.5	1.25
15	15.3	1.50
21	86.5	0.95
28	22.2	1.0

Between 7 and 15 August the chlorophyll concentration plummeted from 331 to 15 ug/l; scarcely 5 percent of the chlorophyll remained. But the crash in chlorophyll produced hardly a quiver in Secchi depth, which never deviated much from its monthly average of 1.2 meters.

DEP proposes to restrict chlorophyll concentrations at Station 3 to 30 ug/l. However, Lake Mead (like other lakes) shows that high chlorophyll values above 30 ug/l have little effect on Secchi depths. Figure 24, derived from DEP's own analysis, shows that there is very little change in Secchi depth as chlorophyll increases from 30 to 90 ug/l.

#### The Chlorophyll Standard Does Not Protect Against Low Dissolved Oxygen

DEP suggests that the proposed chlorophyll standards will protect Lake Mead from low dissolved oxygen (DO) values. (DEP May 1987, pp. D.27-D.32.) Data on parts of Lake Mead remote from Las Vegas Wash, on Lake Powell, and on Flaming Gorge Reservoir prove beyond any doubt that low DO values are widespread in reservoirs of the Colorado River system and are unrelated to phosphorus and sewage discharges. No data we know of support the proposition that chlorophyll concentrations have anything to do with these widespread low DO values; since most of the low DO values reported for Lake Mead are in waters commonly classified as oligotrophic, chlorophyll is not a likely explanation.

#### Low Dissolved Oxygen In Lake Powell

Monitoring data for Lake Powell assembled by UNLV show that DO values below 2 mg/L were widespread during 1981-82. Johnson & Page (1980) reported a layer of low-DO

water running the entire 175-mile length of the reservoir; this layer was frequently anaerobic during the summer. Anoxic conditions (DO values less than 1 mg/L) recur "year-after-year within a given bay and bay-after-bay in a given year" (Johnson & Page). "The bottom waters of Lake Powell are commonly oxygen-poor (3-5 mg/L) throughout the winter." (Id.)

Lake Powell receives essentially no sewage discharges. To our knowledge, neither sewage nor chlorophyll has been offered as a plausible explanation of the gigantic deoxygenation of Lake Powell. Whatever the causes may be, they must account for (1) the 175-mile anoxic layer at the metalimnion, (2) anoxia in the principal bays, year after year, and (3) hypolimnetic DO depression in the bottom waters throughout the winter.

#### Low Dissolved Oxygen In Flaming Gorge Reservoir

Much further upriver, at the Utah-Wyoming State line, Flaming Gorge has large areas of low DO (Bolke 1979):

Depletion of dissolved oxygen occurred simultaneously in the bottom waters of both tributary arms [bays] in the upstream part of the reservoir and was due to reservoir stratification. Anaerobic conditions in the bottom water during summer stratification eventually results in a metalimnetic oxygen minimum in the reservoir. [p. 1]

[I]n the deepest part of Flaming Gorge Reservoir, which is near the dam, there is a chemically stable zone where the dissolved-oxygen content is nil. [p. 11]

The minimum dissolved-oxygen concentration decreased from about 5 mg/L in June to less than 1 mg/L in July . . . . The metalimnetic minimum cannot be explained on the basis of analysis of water samples for phytoplankton . . . nor can it be explained on the basis of analysis of water samples for seston that were taken during this study, but it might be due to flow characteristics of the reservoir. The most probable cause for the metalimnetic oxygen minimum is an interflowing current in the reservoir. [p. 24]

The movement of water currents through the reservoir--not chlorophyll concentrations--is identified as the probable cause of the metalimnetic DO depression. Phytoplankton (algae) were ruled out as a possible cause. The interflowing current in Flaming Gorge bears several striking similarities to the Las Vegas Wash density current in Las Vegas Bay.

#### History And Extent Of Low Dissolved Oxygen In Lake Mead

Low DO values were reported throughout the lake in 1964, 1965, and 1966. (Hoffman et al. 1967/1970; 1971.) Although DO had been occasionally measured here and there earlier, the surveys of the mid-1960s conducted by the Bureau of Reclamation were the first extensive chemical analysis of the lake.

Low DO values in the newer reservoirs upriver suggest that low DO values may have been even more extensive in Lake Mead before the mid-1960s. Deacon (1976) suggests that "low metalimnetic oxygen levels probably have occurred since the formation of the lake." (P. 26)

During BuRec's surveys of the mid-sixties, DO values below 5 mg/L were reported at Hoover Dam, at several sites in Boulder Basin, in the Narrows (Boulder Canyon), Las Vegas Bay, Virgin Basin, the Overton Arm, Virgin Canyon, and Gregg Basin. See Figure 25. Chlorophyll concentrations were not measured in Lake Mead until the 1970s, but it is unlikely that chlorophyll can explain the widespread oxygen depression in Lake Mead. In any event, sewage discharges and phosphorus certainly had nothing to do with low DO in lake waters remote from Las Vegas Wash.

In the early 1970s, low DO values were again reported at sites remote from Las Vegas Wash. In addition to Las Vegas Bay, low DO values were recorded in Black Canyon near Hoover Dam, near Saddle Island, and in the Overton Arm. (Deacon 1976, pp. 13, 22-27.) Paulson et al. (1980) reported low DO at Hoover Dam, Boulder Basin, and Echo Bay in 1977 and 1978.

During the 1970s, DO measurements were most commonly taken in Las Vegas Bay and Boulder Basin; low values were often found and much was made of them--rather too much, perhaps. In 1981-82, however, UNLV regularly monitored DO

at lake stations remote from Las Vegas Wash and frequently found very low values. For example, in Grand Wash, anoxic conditions (values less than 1 mg/L) began in May and persisted into September both years. DO values well below 5 mg/L were measured in Iceberg Canyon, Gregg Basin, Fish Island (in the Overton Arm), Temple Bar, Echo Bay, and Black Canyon. All these sites are in areas of the lake commonly classified as oligotrophic; chlorophyll concentrations are therefore not likely explanations for these numerous instances of DO depression.

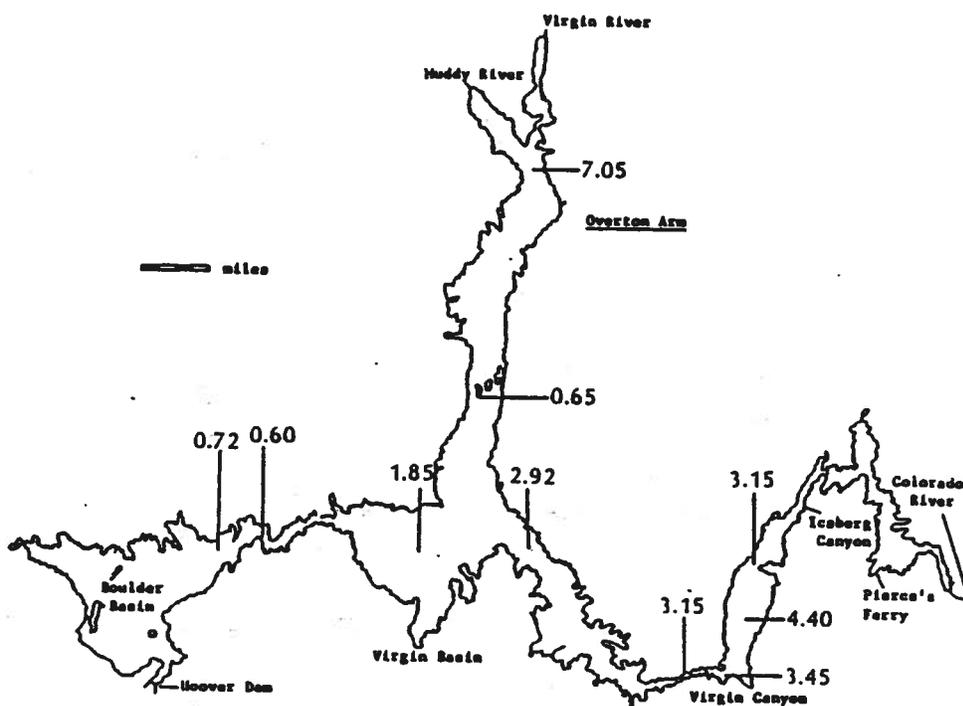
#### Dissolved Oxygen Patterns In Las Vegas Bay

DEP argues that DO patterns in Las Vegas Bay are unique in several ways. Most of DEP's assertions are disproved by actual data on the lake.

DEP asserts that Las Vegas Bay is unique in that DO values there (1) extend into the hypolimnion, (2) are often less than 5 mg/L, and (3) are very low by late summer:

Most parts of Lake Mead experience a metalimnetic oxygen depression, which . . . in the major portions of Lake Mead begin[s] in late April and becomes more extensive as the summer progresses. Dissolved oxygen levels only occasionally drop below 5 mg/L and this depletion is limited to the metalimnion only . . . . However, due to the higher oxygen demanding substances, the inner and middle Las Vegas Bay zone of oxygen depletion extends into the hypolimnion [down] to the lake bottom and by late summer becomes quite severe. [p. D.27.]

FIGURE 25



MINIMUM D.O. VALUES (mg/l) FOR NOVEMBER 1965 AS REPORTED BY HOFFMAN, et al.,  
WATER QUALITY STUDY OF LAKE MEAD  
November 1967

**CONCLUSION:** Concentrations of dissolved oxygen have fallen below 5 mg/l in nearly every part of Lake Mead, and have even approached zero. None of these areas is near any wastewater discharge.

DO patterns in Las Vegas Bay are not unique. Where Grand Wash enters upper Lake Mead, for example, the DO depression (1) extends into the hypolimnion by mid-April, (2) drops to concentrations less than 1 mg/L by May, and (3) is therefore "quite severe" by May. DEP offers no proof of the assertion that "higher oxygen demanding substances" account for DO patterns in Las Vegas Bay. To our knowledge there are no sewage discharges into Grand Wash or upper Lake Mead; nonetheless, very low DO values begin earlier there than in Las Vegas Bay. Neither sewage, nor "higher oxygen demanding substances," nor phosphorus, nor chlorophyll can explain the severe deoxygenation of Lake Mead near Grand Wash.

Although severe oxygen depletion at Grand Wash begins very early and extends through the hypolimnion to the lake bed by May, other stations in upper Lake Mead can show marked oxygen depression by early summer: Iceberg Canyon, Gregg Basin (where the oxygen depression extends all the way through the hypolimnion to the lake bottom), Fish Island in the upper Overton Arm (where the oxygen depression also extends through the hypolimnion to the lake bottom).

By September, hypolimnetic oxygen depression extending to the lake bottom has been observed at Temple Basin, Virgin Basin, Echo Bay, and Black Canyon.

Autumnal hypolimnetic DO depression extending down to the lake bottom has also been reported for Station 8 in Boulder Basin and for Bonnelli Bay.

DEP is wrong in asserting that only in Las Vegas Bay can we find DO values regularly less than 5 mg/L and hypolimnetic oxygen depression. DEP's explanation that oxygen-demanding substances account for the DO patterns in Las Vegas Bay is entirely unsupported. How does DEP explain low DO values and hypolimnetic oxygen depression at so many other sites in Lake Mead (not to mention Lake Powell and Flaming Gorge)? Whatever the explanations may be, they cannot depend on sewage discharges and phosphorus loads at Northshore Road.

DEP asserts that "minimum dissolved concentrations increase with increasing distance from Las Vegas Wash likely as a function of BOD and hypolimnetic volume "(DEP May 1987, p. D.28.) The factual assertion is plainly false. During 1986, for example, the minimum DO at Station 4 was lower than the minimum DO at Station 3 on 17 April, 1 and 15 May, 5 June, 17 and 24 July, 25 September, 16 and 29 October, and 13 November. Minimum DO at Station 5 was lower than minimum DO at Station 4 throughout September and October. The speculations about BOD are entirely unfounded, since BOD is almost never measured in Las Vegas Bay. The speculations about hypolimnetic volume are quashed by the fact that the minimum DO at Station 4 is often lower than the minimum DO

at Station 3, despite the larger hypolimnetic volume at Station 4.

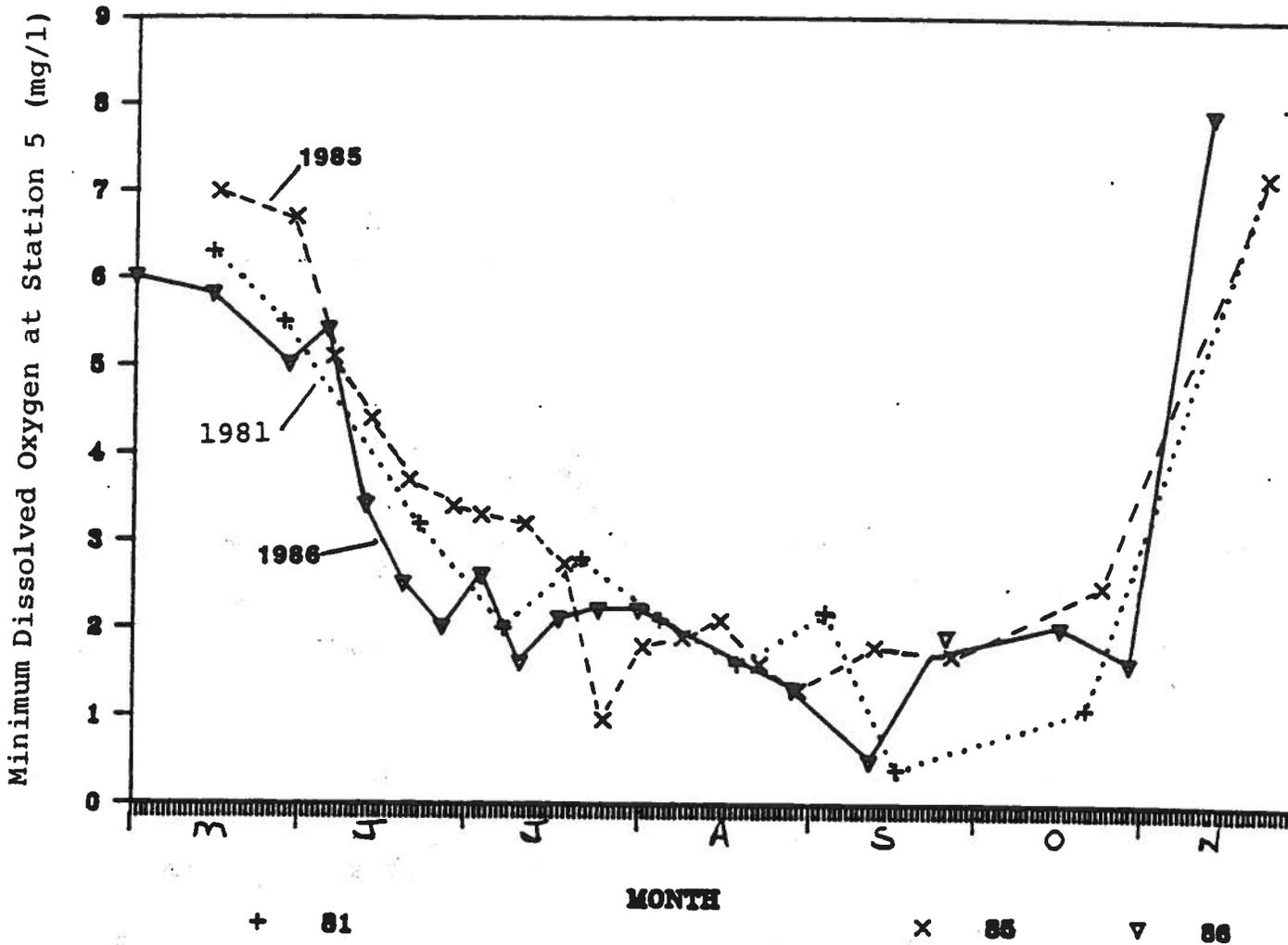
DEP argues that the pattern of minimum DO values at Station 5 was worse in 1985 and 1986 than in previous years; DEP contends that in 1985-86 low DO values started sooner and "remained lower throughout the season than in previous years" (DEP May 1987, p. D.28). Figure 26 shows that 1985 and 1986 were nearly identical to 1981. Figure 27, which is DEP's figure unchanged, shows that three of the lowest DO values were measured in 1980, 1981, and 1983. It would not be fair to conclude, from Figures 26 and 27, that DO is getting worse at station 5.

In Lake Mead as in other lakes, very low DO values are commonly recorded near the head of a bay where water flows in; but the greatest volume of deoxygenated water is found not at the narrow head of the bay, but rather nearer its wide mouth. The high chlorophyll values in Las Vegas Bay are at the narrow end; the greatest volume of deoxygenated water is at the wide end. Similar DO patterns have been reported for both Lake Powell and Flaming Gorge Reservoir (Johnson & Page; Bolke), where chlorophyll has not to our knowledge been identified as a correlate of the DO patterns.

FIGURE 26

CLAIM: DEP claims that dissolved oxygen at station 5 is worsening.

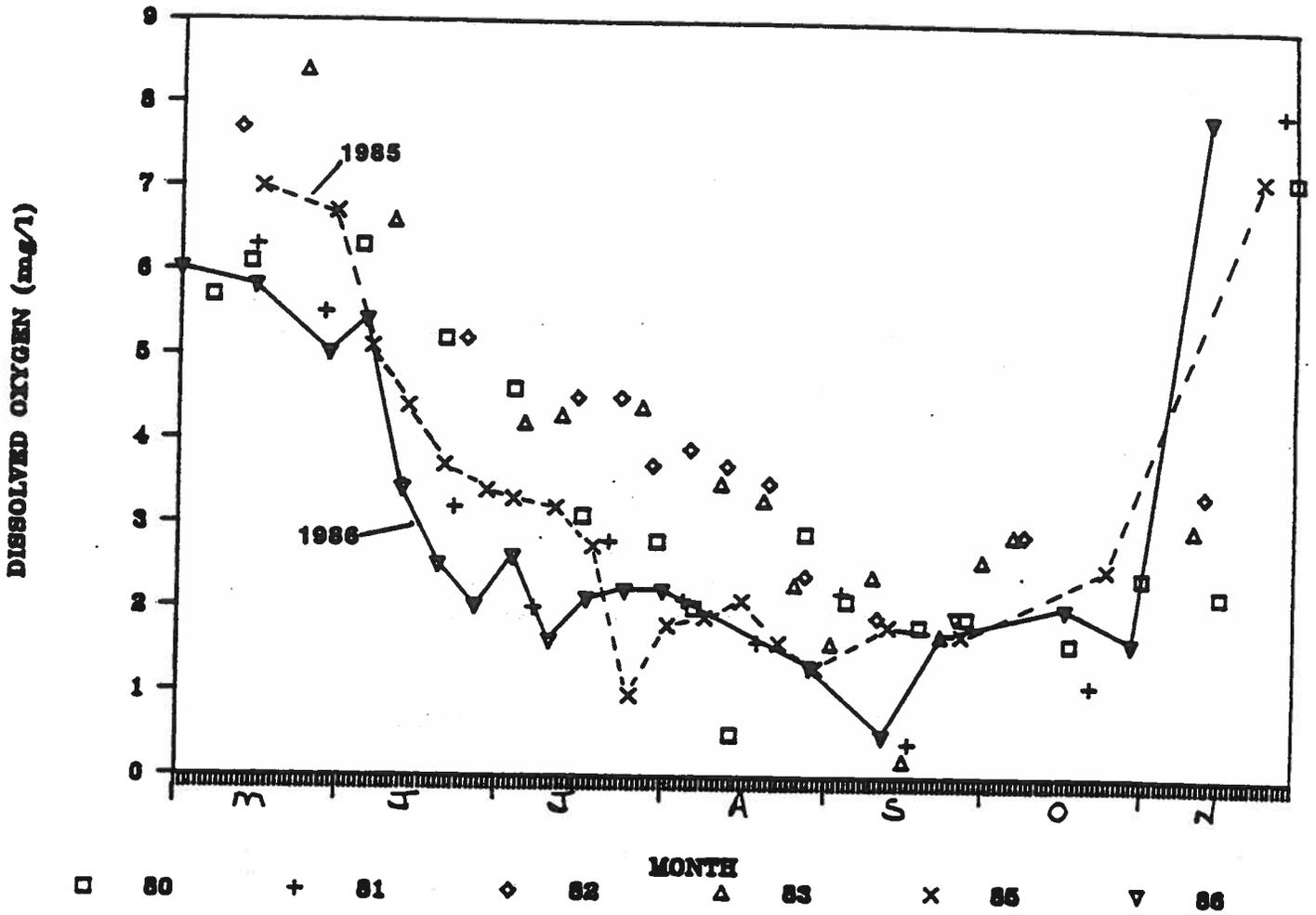
SUPPORT:



(Detail of Figure 24 from DEP's Proposal.)

CONCLUSION: 1985 and 1986 look about like 1981. There is no consistent time trend in these data, according to DEP's own figure.

FIGURE 27



Minimum water column dissolved oxygen concentration during the growing season at station 5 from 1980 through 1986.

(Figure 24 from DEP's Proposal.)

Low Dissolved Oxygen And High Temperature Have Not Excluded  
Striped Bass From Las Vegas Bay

DEP argues that striped bass may avoid Las Vegas Bay because the near-surface waters are too warm and the deeper waters are deficient in oxygen. This argument fails on two counts: (1) the harvest of stripers in Las Vegas Bay is steadily increasing, and (2) there are reports from another reservoir where stripers flourish despite warm waters near the surface and low DO values at depth where the water is cooler.

Figures 17 through 20 show the improving fish harvests in Las Vegas Bay since 1984; data on the fish harvest for Las Vegas Bay are not available before 1984. Records of the Nevada Department of Wildlife show that Las Vegas Bay is one of the most productive striper fisheries in all of Lake Mead. Even in late summer and early fall (August-September), when DEP most fears that conditions in Las Vegas Bay will exclude stripers, data from the Department of Wildlife show that Las Vegas Bay has yielded a large percent of all the stripers caught in the entire lake: 56 percent in August 1985, 33 percent in September 1985, 43 percent in August 1986, 35 percent in September 1986. Clearly, stripers are flourishing in Las Vegas Bay, despite DEP's fears about high water temperatures and low DO.

DEP cites Coutant (1977) to support their contention that stripers prefer water temperatures less than

23° C. Coutant's data were derived from small Tennessee lakes. In a large Oklahoma-Texas reservoir, however, Matthews et al. (1985) reported that stripers flourished despite high temperatures in near-surface waters (28.5° C) and DO concentrations less than 2 mg/L in deeper, cooler waters:

[F]ish were concentrated immediately above the chemocline (8-12 m deep) where water temperature was 28.5 C . . . . This concentration of fish included sub-adult and adult striped bass Morone saxatilis, which are known to congregate in the main basin of Lake Texoma during the summer. Despite the high temperatures in the epilimnion and low oxygen conditions in the hypolimnion, no mortality of adult striped bass was observed. Although the available data indicate that a temperature-oxygen "squeeze" is typical in Lake Texoma in numerous summers, the reservoir has a large population of striped bass with many individuals larger than 5 kg. [p. 84]

From 8 July until at least 7 September [1982], the entire water column of the main basin, where adult striped bass congregate in summer, was either above 25 C or had dissolved oxygen less than 2.0 mg/liter . . . . Despite our evidence that adult striped bass were subjected for much of the summer to conditions considered unacceptable by Coutant, we found no evidence of summer die-off of striped bass . . . . Adults that we have examined in late winter and early spring of those years [1982 - 1984] have been robust, with well-developed ovaries and testes. Catch of numerous, apparently age-I, striped bass in our gill nets in the last 3 years suggests that spawning has been successful despite the late summer exposure of adult fish to conditions suggested by Coutant to possibly

lower fecundity or prevent reproduction. [¶] Lake Texoma has had for a decade a thriving population of striped bass, despite the evidence that exposure to high temperatures is typical for fish in the reservoir in most summers. [p. 90; text references omitted]

In summary, data from Lake Mead itself show that stripers are thriving in Las Vegas Bay, despite the temperature and DO patterns there; and data from another large southern reservoir (Lake Texoma) show that stripers flourish and reproduce successfully there too, despite temperature and DO patterns remarkably similar to those that DEP fears may exclude stripers from Las Vegas Bay.

## 5. AMMONIA

DEP has proposed two water-quality standards for un-ionized ammonia: (1) an instantaneous limit of 450 ug/l intended to prevent acute toxicity, and (2) a four-day average of 40 ug/l intended to prevent chronic toxicity. (DEP May 1987, p. E.8.) These proposals are derived from national guidance published by EPA, not from studies conducted in Las Vegas Bay.

### The Ammonia Issue Has Been Blown Out Of Proportion

Even if DEP's worst fears were true, and this is unlikely, the area DEP is concerned about is very small -- substantially smaller than the area affected by algal blooms. Toxic concentrations of ammonia, if they exist at all, would occur in a small area around the plume at station 2; away from this point, ammonia concentrations fall off rapidly.

In comparison, the fishery is declining throughout the lake, according to DEP, and the decline has been consistently attributed to a lack of food for the fish. Chronic starvation may not be considered a kind of toxicity, but it certainly affects growth and reproduction. Malnutrition may weaken the fish, rendering them more susceptible to infection and disease. Plainly, depriving the declining fishery of food may lead to effects just as severe as any

conjectured ammonia toxicity, only spread throughout the bay.

Plainly, the decline of the fishery throughout the lake is of much greater importance to Lake Mead, and to the people who use it than the mere suspicion that ammonia concentrations in a small area at station 2 might be exerting a toxic effect too subtle to be noticed. The question under consideration should be how the nutrients available from wastewater-treatment plants can best be used to promote and enhance the fishery.

#### No Evidence Of Acute Or Chronic Toxicity In Lake Mead

No one has presented any evidence of ammonia toxicity in Lake Mead, either acute or chronic. DEP's concerns derive from EPA guidance, not from biological evidence that ammonia ever harmed any fish in Inner Las Vegas Bay. Although we have repeatedly asked for any biological evidence of harm, DEP has not produced any reports of fishkills or of fish in distress in the inner bay. It has not presented any evidence that the fish in the inner bay are smaller or reproduce less than fish elsewhere in the lake. It has not shipped fish from the inner bay to a pathology laboratory for an assessment of organ or tissue damage. In short, DEP has not presented any evidence of any kind that fish in Inner Las Vegas Bay have been harmed by ammonia or anything else.

DEP reports that concentrations of un-ionized ammonia are at levels that EPA guidance says may be harmful. However, harm is assessed by examining the fish, not by looking at ammonia concentrations.

It is generally agreed that no fish in Lake Mead have been subjected to acute ammonia toxicity. At a workshop on ammonia toxicity held by DEP in September 1986, EPA staff asserted that the reported concentrations of un-ionized ammonia were too low to cause acute toxicity. DEP now agrees that the proposed standard has never been exceeded. (Id., corrected p. E.3.)

Chronic toxicity does not suddenly exterminate a population of fish. It may cause a slow decline in a fishery owing to poor reproduction or retarded growth. However, there is no evidence that the fish in Inner Las Vegas Bay are smaller or reproduce less than fish in the rest of the lake. The only information available shows that the fishery in Las Vegas Bay improved during 1985 and 1986, when ammonia concentrations were reported to be highest. The striped-bass fishery was particularly productive, both in total stripers caught (see Figure 17) and stripers per angler (see Figure 19). In short, chronic ammonia toxicity is mere suspicion.

### Mere Suspicion Does Not Justify An Ammonia Standard

A suspicion of chronic toxicity should properly lead to a study, in which investigators can assess the available evidence, collect more if necessary, and determine whether there is any sound scientific foundation for the suspicion. DEP, however, is not proposing a study; it is proposing a water-quality standard that will lead directly to the expenditure of tens of millions of dollars. We submit that mere suspicion does not justify an ammonia standard when there is no real evidence of a toxicity problem, and when there is a real risk that tens of millions of dollars of public money will be wasted on a problem that does not exist.

### Neither DEP Nor The State Environmental Commission Is Legally Bound By EPA Guidance

DEP has suggested that it is legally bound by EPA's guidance on ammonia, and that the State of Nevada has no choice but to follow EPA guidance. In one context, DEP has asserted that "the national guidance requires"; in another, it contended that "this requirement is imposed by EPA . . . , not [by] the State of Nevada". (DEP 9 December 1986, p. 6.) Neither suggestion is legally correct.

There are three questions related to an ammonia standard:

- Is Nevada required to establish an ammonia standard?
- Is Nevada required to use the criteria recommended by EPA?
- Is Nevada required to follow the procedures recommended by EPA?

The answer to all three is no.

EPA has not required that ammonia standards must be established for every body of water, and the great majority undoubtedly do not have ammonia standards. Ammonia standards are not required for Las Vegas Bay because (1) there is no credible evidence of a problem, and (2) there is a bona fide proposal to study whether a problem exists. Consequently, DEP is not required to propose an ammonia standard, and the State of Nevada is not required to establish one.

Nevada is not required to use EPA's recommended criteria and is not required to follow EPA's recommended procedures because EPA's recommendations are in a guidance document, not in an official regulation. There is an essential difference between guidance and regulations: Regulations have the force of law, but guidance does not. Because EPA's recommendations on ammonia are in the form of guidance, they are not binding. The guidance document itself clearly says that it is "non-regulatory ":

The term "water quality criteria" is used in . . . of the Clean Water Act, section 304(a)(1) . . . . In section 304, the term represents a non-regulatory, scientific assessment of ecological effects. The criteria presented in this publication are such scientific assessments. . . . [I]n many situations States may want to adjust water quality criteria developed under section 304 to reflect local environmental conditions and human exposure patterns before incorporation into water quality standards. It is not until their adoption as part of the State water quality standards that the criteria become regulatory. [EPA 1985, p. iii, emphasis added.]

Nothing in the guidance document is sacrosanct:

Whenever adequately justified, a national criterion may be replaced by a site-specific criterion, which may include not only site-specific concentrations, but also site-specific durations of averaging periods and site-specific frequencies of allowable exceedances. [Id., p. 6, citations omitted.]

Plainly, the Commission may adopt any ammonia standard that is reasonable, or none at all.

#### Nevada Law Encourages A Study Of Las Vegas Bay

Nevada law invites the Commission to rely on studies such as the one that the City of Las Vegas is proposing:

The commission may establish water quality standards . . . which vary from standards based on recognized criteria if such variations are justified by the circumstances pertaining to particular places, as determined by biological monitoring or other appropriate studies. (NRS 445.244(3).)

tank and constant for the duration of the test. The test fish have no way of avoiding the uniformly high concentrations.

Un-ionized ammonia concentrations are not uniform throughout the inner bay. They are probably highest near the surface in a narrow strip running down the center of the bay. The fish are not confined to this narrow strip; they can swim to the right, to the left, and beneath it. Even within the strip, un-ionized ammonia concentrations fall rapidly with increasing distance from Las Vegas Wash. The fish can swim towards or away from the wash. They are free to move at will.

Un-ionized ammonia concentrations in the bay are higher by day than by night. Even if the fish should stay in one place all the time, they would not be exposed to a constant concentration of ammonia, because the concentration would rise during the day and fall during the night.

In laboratory tests, the concentrations are uniform in space and time, and the fish are confined. In Inner Las Vegas Bay, the concentrations are not uniform in either space or time, and the fish are free to move at will.

Although zooplankton do not have the mobility of fish, they are less sensitive to chronic ammonia toxicity. According to EPA, zooplankton do not begin to be affected by chronic toxicity until un-ionized ammonia is in the range of 304 ug/l to 1,200 ug/l. (Id.) Even the lowest reported

value, 304 ug/l, is 760% higher than the proposed standard of 40 ug/l. There is no evidence that sustained concentrations reach 304 ug/l anywhere in Lake Mead.

Evidence That The Proposed Standard Is Much Too Stringent

The number 40 ug/l is too stringent for two reasons: (1) the number comes from thirty-day tests, and DEP is applying it to a four-day test, and (2) data from Lake Mead show that concentrations of 262 ug/l produced no toxic effects.

The chronic-toxicity standard proposed by DEP applies to four-day-average concentrations. However, four-day laboratory tests measure acute toxicity; most chronic-toxicity tests last thirty days or more. EPA has also reported on many four-day tests of ammonia toxicity, and the numbers developed from these four-day tests are much higher than 40 ug/l -- more than ten times higher.

At first, on the advice of Mr. Willingham of EPA Region VIII, DEP proposed a thirty-day standard; the number proposed was 40 ug/l. Now DEP is proposing a four-day standard, but the concentration DEP recommends is still 40 ug/l. The number 40 ug/l is properly associated with a thirty-day standard. If DEP wants to set a four-day standard, it should select a much higher number.

EPA Region VIII recently ran seven-day toxicity tests with water from Boulder Basin. In these tests, there were no toxic effects observed on the test fish at 262 ug/l;

for zooplankton, there were no toxic effects observed at 849 ug/l. (EPA May 1987, pp. 29, 32, 34.)

In short, the test fish were safe at 262 ug/l -- more than 650% higher than DEP's proposed standard. This study provides evidence that the proposed standard is much too stringent.

In short, the lowest observed effect after seven days was at 499 ug/l, nearly 1250% higher than the proposed four-day average of 40 ug/l. This study provides evidence that the proposed standard is much too low.

#### EPA Strongly Suggests "Site-Specific Criteria Development"

In the guidance document for ammonia, EPA reported many studies showing that fish become more resistant to acute toxicity as water temperature increases. (EPA 1985, p. 38.) See Figure 28. However, EPA found no data on how temperature affected chronic toxicity (*id.*, p. 61) and consequently recommended that site-specific studies should be performed before chronic-toxicity standards are established: "Site-specific criteria development is strongly suggested at temperatures above 20[°] C because of the limited data available to generate the criteria recommendation" (*id.*, p. 97).

At Lake Mead, where air temperatures frequently exceed 100°F, it is not surprising that the water temperature at station 2 is often well above 20°C (68°F) during spring

and summer, and sometimes above 30°C (86°F). Plainly, EPA's recommendation applies to Lake Mead.

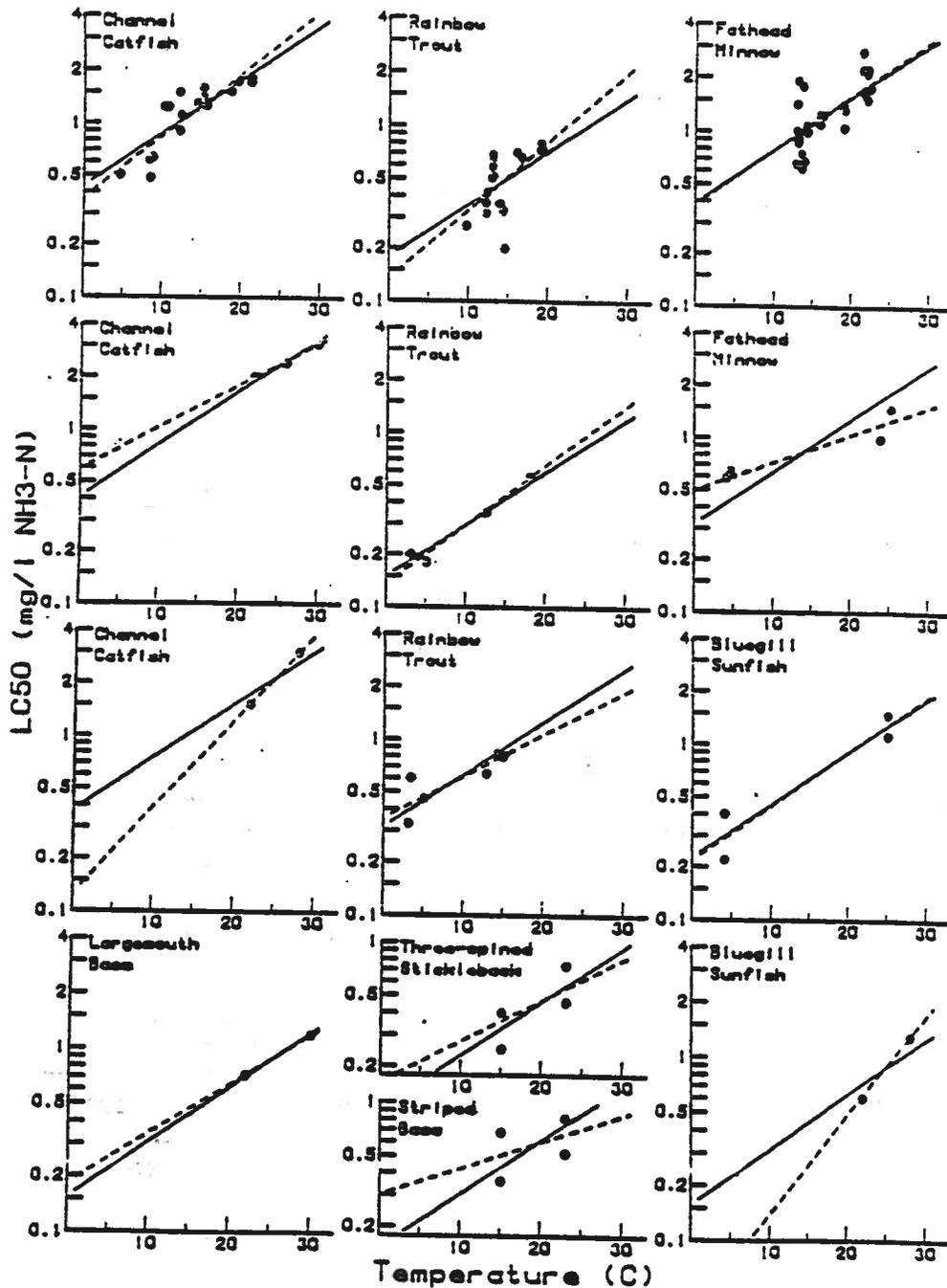
DEP used a "recalculation procedure" to adjust EPA guidance to temperature conditions in Lake Mead. (DEP May 1987, p. E.5.; DEP 25 June 1986.) However, the recalculation procedure used has a temperature cap (a "TCAP", in EPA jargon) at 20°C. (DEP 25 June 1986.) Consequently, this procedure has not properly adjusted the proposed standard to actual temperatures in Lake Mead.

EPA guidance specifies that "The [temperature] cap may be raised in a site-specific analysis as warranted by the species present." (EPA 1985, p. 65.) At the ammonia workshop in September 1986, Dr. Erickson of EPA Duluth concluded that the degree 5 year temperature cap for Lake Mead could be raised at least to 25°C. A site-specific study is warranted.

Other objections to the use of the recalculation procedure are explained in Appendix A, pp. 5-9.

In short, the City's proposal for a toxicity study in Las Vegas Bay is fully in accord with EPA guidance.

FIGURE 28



Acute NH<sub>3</sub> toxicity at different temperatures (data from Cary 1976, Thurston and Russe 1983, Thurston et al. 1983, Colt and Tchobanoulous 1976, Ministry of Technology 1968, Reinbold and Pescitelli 1982, Roseboom and Richey 1977, Hazel et al. 1971). Dashed lines indicate individual regressions; solid lines indicate pooled regression.

(EPA 1985, p. 38.)

CONCLUSION: All the graph lines rise steeply. This shows that fish become more resistant to ammonia as temperature increases.

Lake Mead Data Cannot Be Compared With EPA Guidance Because  
The Lake Data Are Biased

EPA guidance cannot be directly applied to Las Vegas Bay because the data from the inner bay are distorted by two kinds of biases: time bias and location bias.

Time Bias

Ammonia mixed with water exists in both an ionized and an un-ionized form. The percentage of each form depends largely on pH and temperature: As temperature and pH increase, the nontoxic form of ammonia (ionized ammonia) is converted into the toxic form (un-ionized ammonia). For obvious reasons, the water temperature at station 2 tends to be higher in the afternoon than at night. The pH also tends to be higher in the afternoon because sunlight promotes algal photosynthesis, and photosynthesis raises the pH. One expects to find more un-ionized ammonia at station 2 during mid-afternoon than late at night.

The University of Nevada, Las Vegas (UNLV) collects samples at station 2 during midday or afternoon, when concentrations of un-ionized ammonia are likely to be near their highest. During three days in 1986, however, UNLV measured pH and temperature at station 2 during both morning and afternoon. These data confirmed the existence of a time bias: The percentage of ammonia in the toxic un-ionized form was about 400-500% higher in the afternoon. See Fig-

ure 29. The bias could be substantially greater, because the lowest percentage should theoretically be found before dawn. Unfortunately, no one has reported measuring un-ionized ammonia around the clock at stations 2 or anywhere else in Lake Mead.

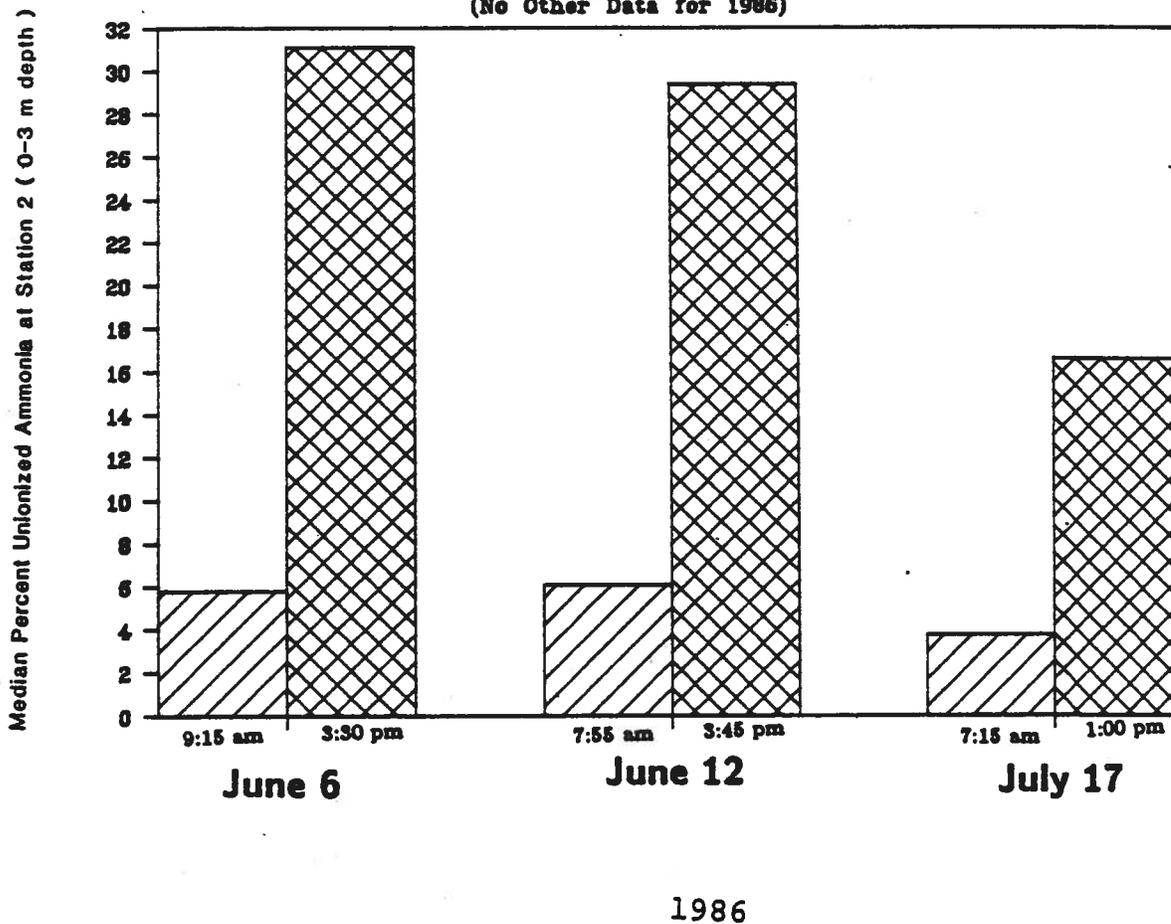
Time bias has been extensively discussed in two reports previously prepared by the City of Las Vegas (Appendix C; Appendix B, pp. 7-8) and by CH2M Hill (Appendix A).

As a result of time bias, existing data do not represent daily average concentrations at station 2. Averages of the existing data are also distorted by the bias, and do not represent true four-day, monthly, or seasonal averages. Because the reports on un-ionized ammonia toxicity in the scientific literature are based on unbiased average conditions, literature values cannot be directly compared to the biased data collected from station 2 (or any station in Las Vegas Bay). Furthermore, figures that purport to show average conditions, such as DEP's Figure 1 on page E.3. in DEP May 1987 (both the original and "corrected" versions), are not correct. The true averages must have been much lower.

FIGURE 29

### Comparison of Percent Unionized Ammonia During Morning and Afternoon

(No Other Data for 1986)



(Data from University of Nevada, Las Vegas.)

**CONCLUSION:** The percentage of ammonia in the toxic un-ionized form was much greater in the afternoon than in the morning.

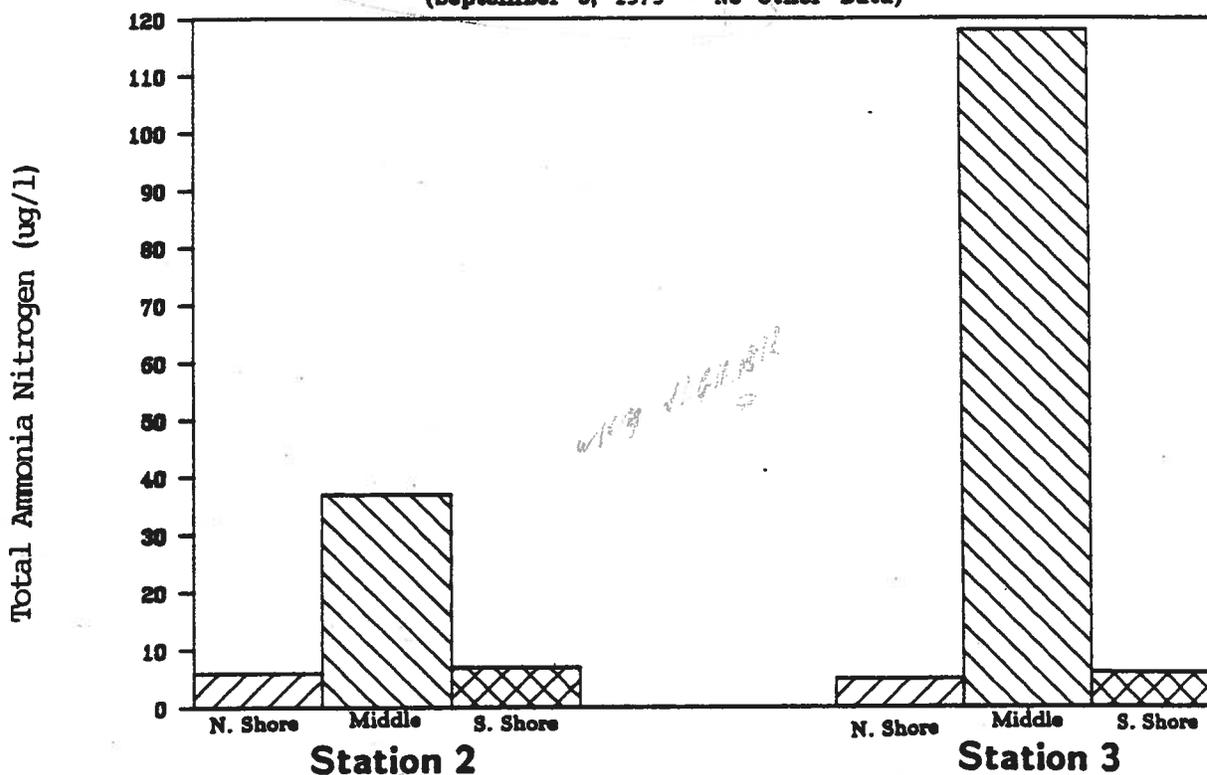
### Location Bias

Concentrations of ammonia in Inner Las Vegas Bay are higher midchannel than they are near the north and south shores. In 1979, UNLV measured concentrations midchannel and at both of the shores, and found that concentrations midchannel were 500% to 2,400% higher midchannel at stations 2 and 3. See Figure 30. Location bias has been discussed in reports prepared by CH2M Hill (Appendix A) and the City of Las Vegas (Appendix B, pp. 4-5).

FIGURE 30

**Comparison of Ammonia Concentrations Near the Shore  
and in the Middle of the Channel**

(September 6, 1979 - No Other Data)



(Data from STORET.)

**CONCLUSION:** Ammonia concentrations were much higher at midchannel than at the north and south shores.

### If The Biases Were Corrected, Averages Would Be Much Lower

The biases are multiplicative. If, for example, the time bias produces results that are 3 times too high, and the location bias produces results that are 4 times too high, the combined bias produces results that are 12 times too high. Although existing data are insufficient to determine the true correction factor, it could be a 10 or more. Figure 31 shows the effect of a correction factor of 10: averages that once appeared to be substantially above the proposed standard of 40 ug/l are seen to be substantially below the proposed standard. In short, time and location biases have made existing conditions seem much worse than they are.

### The Number 450 ug/l Appears To Be A Mistake

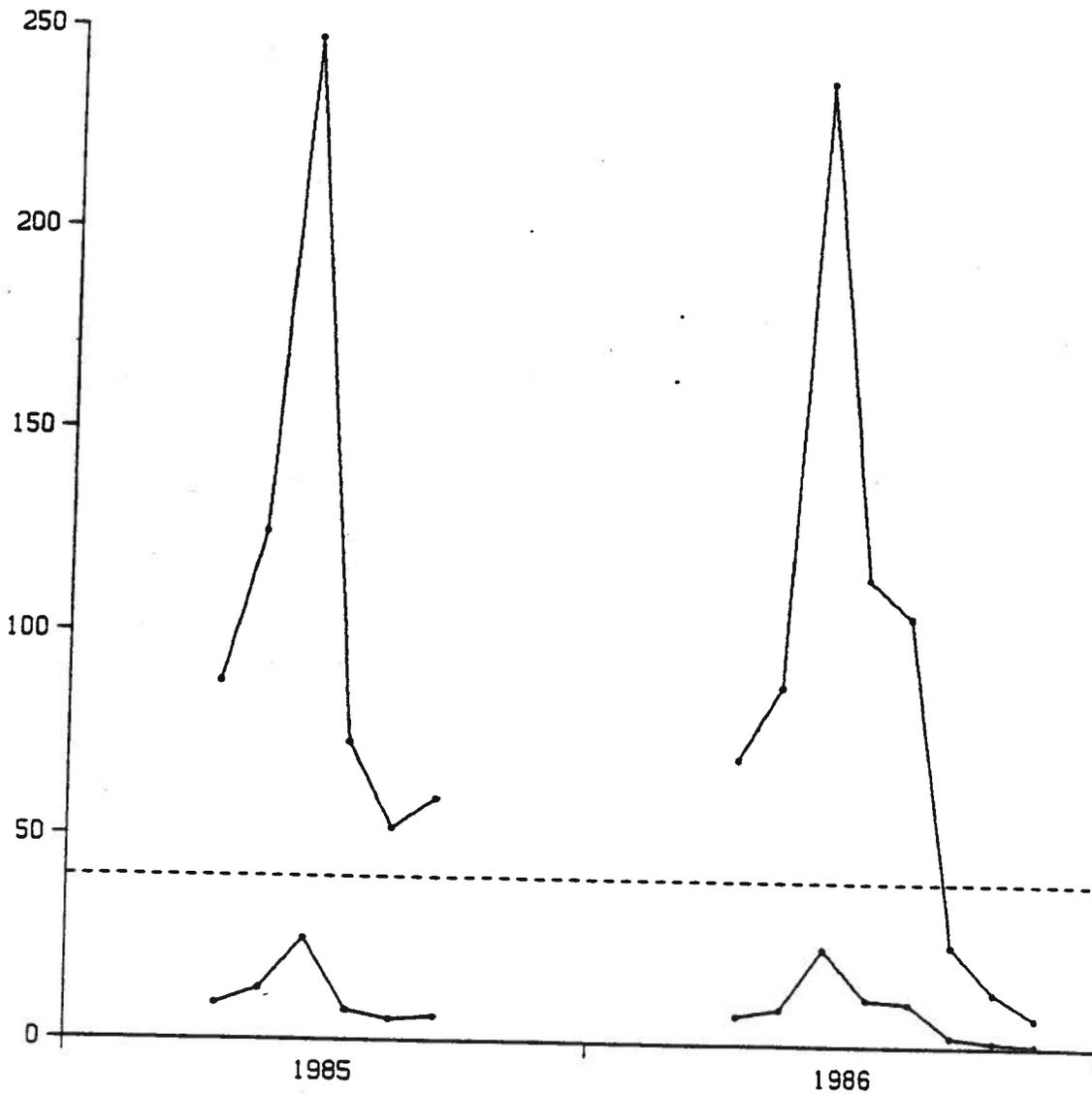
A standard for acute ammonia toxicity appears to be unnecessary for three reasons: (1) there is no evidence of acute ammonia toxicity in Las Vegas Bay, (2) EPA staff have concluded that concentrations are too low for acute toxicity, and (3) a study of actual conditions in the inner bay should precede the establishment of standards. There are also some objections to the proposed standard itself. For example, the number 450 ug/l appears to be a mistake. According to DEP's printout, 480 ug/l is the result of its recalculation procedure. (DEP 8 May 1986; Appendix A, p. 6.) Furthermore, if the temperature cap were raised to

30° C, the result of the recalculation procedure would be  
680 ug/l.

FIGURE 31

Un-ionized Ammonia at Station 2  
UNLV Data; Same Data with Biases Removed

monthly geometric averages, ppb as N  
bias correction is illustrative



## 6. PROPOSED STUDY

### Coordinated Lake Mead Study (CLAMS)

The City of Las Vegas is proposing a practical study of Las Vegas Bay centering on a new discharge point for Las Vegas Wash. The nutrients from the wash represent a resource for a lake that is starved for nutrients. One way of controlling the resource may be to move the discharge.

Many people have suggested that the relatively high concentrations of chlorophyll and ammonia found in Inner Las Vegas Bay are the result of geography: Nutrients entering the lake from the wash cannot adequately disperse because they are trapped in the narrow canyon extending from the mouth of the wash past station 3. If the point of discharge were diverted past station 3, they argue, nutrients might be spread out across a much greater area, or mixed into a greater volume.

The idea of moving the point of discharge has been widely endorsed. DEP called it "a conceptual solution to the water quality problems in the inner Bay", but noted that additional studies would be required. (DEP 8 December 1986.) Staff at EPA Region 9 commented that dispersal "sounds like a reasonable alternative". (EPA March 1987.) The Southern Nevada Water System, which operates the drinking-water plant, concluded that "If it is truly desirable to fertilize Lake Mead, then every effort should be made to

disperse the current concentration of nutrients which exists in the Las Vegas Bay portion of the lake." (Monoscovitz 1987.)

Advocates maintain that mixing the wash discharge into a greater volume of water would benefit water quality throughout the bay:

- there would be very little chlorophyll in the inner bay
- there would be very little ammonia in the inner bay
- there would be better fish production throughout the bay

Relocating the discharge is an attractive alternative to more wastewater treatment. The proposed study will give decision makers the facts to make an informed choice.

First, the proposed study will pull together existing data now scattered throughout many agencies. It will pull together people from various agencies and exchange ideas and information. It will study mixing processes in the bay with state-of-the art instrumentation. It will study ammonia toxicity in the inner bay.

#### Collect Information That Is Now Scattered

The City of Las Vegas proposes to develop and implement a coordinated study of Lake Mead and is soliciting

the participation of Clark County, Henderson, and North Las Vegas.

Several state and federal agencies, as well as other organizations, collect data on water quality and beneficial uses in Lake Mead, and people within those agencies have developed knowledge and expertise related to water quality and beneficial uses. For example:

- The Nevada Department of Wildlife collects data on the fishery throughout Lake Mead.
- The Southern Nevada Water System collects data on water quality and algae in Boulder Basin.
- The U.S. Bureau of Reclamation collects data on stageheights and water quality in Lake Mead, flow at Hoover Dam, and water quality and vegetation in Las Vegas Wash.
- The U.S. Geological Survey collects data on water quality, riverflow, and erosion in Las Vegas Wash.
- The University of Nevada, Las Vegas, collects data on water quality for the Nevada Division of Environmental Protection and the U.S. Bureau of Reclamation.

These agencies generously provided copies of their data and information about how the data were collected and should be interpreted.

The Clark County Sanitation District (CCSD) and the Cities of Henderson and Las Vegas collect data on their wastewater discharges; CCSD also collects data on water quality in Las Vegas Wash. The City of Las Vegas hopes to begin collecting data on Lake Mead in 1988.

CLAMS is an attempt to bring together people from these agencies and organizations, to arrange for the sharing of data and ideas, and to supplement existing programs with specific studies. The goal is to develop a comprehensive understanding of the physical, chemical, and biological processes that affect water quality and beneficial uses. CLAMS will be financed with local money, although it will try to obtain grants when available.

We propose to invite representatives from the agencies and organizations named above, plus the Nevada Division of Environmental Protection and the U.S. Environmental Protection Agency, to form a coordination council. The council should meet regularly, receive study plans, suggest improvements to the plans, receive briefings on the status of study elements, and discuss unexpected difficulties and unforeseen needs. It should be responsible for ensuring that the study is adequately comprehensive and scientifically sound.

### Improve Information Flow Among Agencies

No one has ever assembled, integrated, and analyzed all the existing kinds of data that are being collected from Lake Mead. As a result, one agency may not consider relevant data collected by another agency, and basic assumptions may never be tested against available data. CLAMS would develop an integrated database that would make the full range of information on Las Vegas Bay readily accessible to everyone working on the bay.

In its Proposal, for example, DEP assumed that water quality during 1986 was bad for the fishery in Las Vegas Bay--without testing the assumption against the data on the fishery collected by the Department of Wildlife. DEP also assumed that the costs of water treatment increase as the amount of plankton biomass increase, without testing the assumption against data from the Southern Nevada Water System. An integrated process for collecting and analyzing data would help agencies test assumptions against available data.

### Disadvantages Of Establishing Water-Quality Standards Before A Study Is Completed

If the proposed water-quality standards are established this year, there will not be sufficient time to investigate lake mixing and hydrodynamics. Establishing the proposed standards will trigger a process that will require consulting engineers to make decisions long before the

results of the studies are in. Consequently, the engineers will be forced to rely on proven technology, and will design process units, to be added to the wastewater-treatment plants, for removing more phosphorus and ammonia.

"Proven technology", however, means only that the engineers can design wastewater-treatment facilities for removing phosphorus and ammonia. It does not mean that these wastewater-treatment facilities, even if they function as designed, will improve the lake. The facilities may not be necessary to eliminate a hypothetical ammonia-toxicity problem, and they may not be sufficient to prevent scums of blue-green algae. Additional wastewater-treatment facilities may be neither necessary nor sufficient.

Would Moving The Discharge Be More Effective Than Increasing Wastewater Treatment?

CLAMS includes study elements to provide information to decision makers so that they can evaluate the competing claims and relative merits of additional wastewater-treatment facilities and a relocated discharge from the wash. One of these elements is a study of mixing processes in Las Vegas Bay. The precise details of the measurement program will be finalized in meetings of the coordination council proposed herein to guide CLAMS. In its preliminary design, this measurement program consists of seven sets of monitoring stations, each with sensors at two or three

depths, spread out over 12 kilometers between the mouth of Las Vegas Wash and Boulder Basin.

A preliminary proposal by ECO-Systems Management Associates, Inc., a California company having 22 years experience in monitoring hydrodynamics is attached as Appendix F. ECO-Systems offers to conduct the instrumentation portion of the hydraulic study for approximately \$350,000. This proposal does not include many of the costs associated with maintaining the monitoring instruments in the field (e.g. SCUBA divers to clean and service the instruments every week or so). Additional instruments for monitoring vertical currents and perhaps pH may later be recommended by the coordination council, and these recommendations may change the costs considerably.

In addition, Dr. Gabriel T. Csanady has been retained by the City of Las Vegas for advice on mathematical modeling of the hydrodynamics of Las Vegas Bay. Dr. Csanady, formerly Senior Scientist at the Woods Hole Oceanographic Institution and now Professor of Oceanography at Old Dominion University in Virginia, is internationally recognized for his outstanding contributions to engineering, meteorology, limnology, and oceanography.

Are Ammonia Discharges Toxic To Fish In Inner Las Vegas Bay?

Existing data are inadequate for determining whether the fish in the inner bay are being affected by

chronic toxicity. CLAMS recommends three kinds of studies designed to remedy these inadequacies:

- In-situ studies of un-ionized-ammonia concentrations,
- In-situ studies of the exposed fishery, and
- Bioassays designed to assess the sensitivity of resident fish to un-ionized ammonia.

In addition, to determine how concentrations of un-ionized ammonia fluctuate from hour to hour and from place to place, a series of continuous monitors would be installed to measure temperature, pH, and conductance (from which concentrations of un-ionized ammonia are calculated). Routine and special intensive studies would also be conducted to assess diurnal and lateral variations in ammonia concentrations. Fishery studies might include tagging studies to determine residency, habitat preference, and range, as well as population estimates. Bioassays will be designed to assess the sensitivity of resident fish to concentrations of un-ionized ammonia under actual lake conditions. For this purpose, CH2M Hill has recommended that a laboratory trailer devoted to bioassays be set up on the shore of the bay so that actual bay water can be used for the tests.

CH2M Hill's proposal for a study of ammonia toxicity in Las Vegas Bay is attached as Appendix G. The total cost of CH2M Hill's proposal (which includes other tasks) is about \$400,000. In addition, Professor Robert V. Thurston

has volunteered to help design a study tailored to Las Vegas Bay. The final design and implementation will be decided after consultation with the coordination council as a whole, and especially with experts and staff from DEP and EPA.

#### What Prevents Blue-Green Algae From Forming Scums?

CLAMS includes an algal study consisting of three parts: collection of data, review of historical data, and analysis of data. Data collection will not be limited to algal data (e.g. algal identification, enumeration, and bio-volume), but will include an assessment of processes that may limit algal growth or blue-green dominance (e.g. zooplankton grazing, fish grazing, turbulence and wind mixing, temperature, light and shading, nutrient supply). The historical review will assemble data collected in Las Vegas Bay--some algal data were collected in years past--and in Boulder Basin. In addition, existing data on weather collected at McCarran Airport will be assembled. All data will be analyzed and interpreted.

#### How Could The Fishery Be Improved?

In its Proposal, DEP suggests that the fishery can be improved by maintaining chlorophyll concentrations below certain levels. CLAMS proposes to collect and analyze existing data on the fishery, and to augment these data with additional studies, including population estimates as well

as tagging studies to determine residency, habitat preference, and range. The relationships among chlorophyll, zooplankton, and fish production will be investigated, as well as the relationships among discharges from Las Vegas Wash, algae, and zooplankton.

#### Coordination And Quality Control

Several agencies and organizations now collect data, often using different techniques for sampling and laboratory analysis, from Las Vegas Bay and Lake Mead. These data may not be comparable, and apparent changes for better or worse may be no more than a change in sampling or laboratory technique.

To remedy these inconsistencies and ensure that all data are comparable, CLAMS includes a program for quality control. This program will arrange for coordinated sampling times as well as sampling techniques, cross-calibration among laboratories and equipment, and resolution of disparate results.

#### Database Management And Statistical Analyses

The data that have been collected over the years are stored among many agencies, in many places, and in many forms. The data are not readily available to users, and there is no centralized process for providing updates as more data are collected. Even STORET, the computerized

storage-and-retrieval system run by EPA, has not been able to provide complete information in a timely manner. Moreover, STORET does not check its data for errors or multiple entries; it does not police its files for inconsistent and obviously incorrect data.

CLAMS includes a program for database management and statistical analyses. This program will gather existing data (copies of the original laboratory sheets and field notebooks, if available), arrange for updates as more data are collected, encode the data and check them for errors, and make available copies of a clean computerized database. It will also provide computer services, including the calculation of time trends and statistical analyses.

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