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Report on wastewater disposal to Board of County Commissioners, Clark County Nevada

Clair N. Sawyer

REPORT
on
WASTEWATER DISPOSAL
to
BOARD OF COUNTY COMMISSIONERS
CLARK COUNTY NEVADA

PREPARED
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October 23, 1976

Board of County Commissioners
Clark County, Nevada
5857 East Flamingo Road
Las Vegas, Nevada 89122

Attention: Mr. Tom Wiesner, Chm.

Gentlemen:

Enclosed herewith is my report dealing with the problem of wastewater disposal from the BMI complex, Henderson, the City of Las Vegas and Clark County.

It has been my pleasure to serve you and I look forward to making my presentation before the Board on November 16.

Respectfully submitted,

Clair N. Sawyer

REPORT

CLAIR N. SAWYER

INTRODUCTION

This report is concerned with the management of wastewaters and subsurface drainage from the City of Las Vegas and its environs and the BMI complex, all in Clark County, Nevada. The prime objective is to recommend a plan of action which will utilize the natural resources of the area in the least costly manner and still protect Lake Mead for recreational purposes and use as a public water supply. At this writing, conditions in the upper Las Vegas arm of Boulder Basin are quite unsatisfactory for some recreational purposes due to the extensive blooms of algae which develop. Experience at other locations in the United States and elsewhere teaches us that these problems do not solve themselves, rather they grow worse as populations and wastewater flows increase.

Although the water supply of the Southern Nevada Water System (SNWS) has not been seriously affected up to the present time, it can be predicted that it will suffer from increased problems due to plankton and oxygen depletion, unless corrective measures are instituted. The water plant is particularly vulnerable to problems related to oxygen depletion because of its single intake structure.

The concepts developed in this report and the recommendations are based to a large extent upon a review of a number of reports[1] dealing with the limnology of Lake Mead and the character of the normal inflow from Las Vegas Wash (LVW). In addition, personal inspections were made on Lake Mead by U.S. Bureau of Reclamation boat in the area of the SNWS water intake at Saddle Island and all the way up Las Vegas Bay (LVB) to the point where waters from LVW enter. Shore line and near shore inspections were made at the

1) Discussions of the reports are given in the Appendix

following locations.

1. Temple Bar
2. Boulder Beach
3. Lake Mead Marina
4. Las Vegas Boat Harbor
5. Government Wash
6. Callville Bay
7. Echo Bay
9. Overton Beach

Valuable insight concerning the nature of treatment problems for producing a public water supply from Lake Mead was obtained during two visits to the SNWS plant and from visits to the Bureau of Reclamation offices in Boulder City and to the Boulder City Department of Public Works.

Information regarding Lake Powell and supplementary data on Lake Mead were supplied by the National Eutrophication Survey office of the U.S. EPA in Corvallis, Oregon.

In general, the information contained in many of the reports reviewed has been in good agreement with respect to my concepts of limnology and primary productivity (algal growths). This has been my first exposure to data on a deep subtropical lake. The negative heterograde oxygen profile which develops in the thermocline requires special consideration, otherwise the behavior is the same except that summer stratification persists until November or December, rather than September or October. The longer period of stratification has some significance and should be recognized.

Some mention of the change in philosophy of wastewater treatment and disposal which has occurred within the past three years should be made. This was stimulated by the people coming to realize that our energy resources are finite and rapidly dwindling. The Arab oil embargo served to shock us into a state of rational thinking. As a result, State and Federal regulatory agencies are again willing to consider utilizing natural purification processes under controlled conditions, and discussions of costs with respect to benefits can be conducted once again in a normal manner. A second factor which has had a great normalizing effect is the recent "discovery" by the regulatory authorities that there are "point" and "non point" sources of pollution. As will be shown in this report, there are also "multiple point" sources. Recent evaluations of "non point" sources have led to the consensus that some of the strict requirements made in the past are unreasonable in view of the magnitude of uncontrollable sources.

What may be considered by many to be a controllable source of pollution may not be unless undue pressure is exerted or legislation is passed to prohibit. Some 30 years ago, the writer proposed that the dairy farmers in the Madison, Wisconsin lakes area be prohibited from spreading animal manures during the winter months when the fields were covered with snow or the ground was frozen. With a State legislature controlled by farmers, nothing has happened to date.

REPORT

This report has been prepared with full recognition of the constraints imposed upon the discharge of wastewaters to Lake Mead and waters of the Lower Colorado River by the Nevada State Health Department with the approval of the appropriate Federal Agencies concerned with water pollution control. These constraints fall into three categories which are as follows:

1. "Minimum Quality Criteria" provide that interstate waters of the Colorado River shall be "free from materials attributable to domestic or industrial wastes or other controllable sources ----- in amounts sufficient to change the existing color, turbidity or other conditions in the receiving stream to such a degree as to create a public nuisance, or in amounts sufficient to interfere with any beneficial use of the water."

The last phrase of these requirements is one which is open to varied interpretation and debate.

2. Further, the Nevada water quality requirements include a "Basic Principle" that --- all identifiable sources of pollution will be managed and controlled to the maximum degree practicable with available technology, in order to provide water quality suitable for present and future uses of the (Colorado River) System's interstate waters.

3. Nevada State Board of Health Water Quality Standards for Las Vegas Wash as expressed in Table A-4, Appendix A of the U.S. Environmental Protection Agency's Report of December, 1971, concerning Lake Mead, Las Vegas Wash, and the Lower Colorado River.

After giving due consideration to the many aspects of the Lake Mead problem, it seems to this reviewer that the important issues can be described under the six categories listed below:

1. Salinity
2. Public Health
3. Water Supply
4. Recreation
5. Eutrophication
6. Las Vegas Wash

I shall now proceed to address each of these items.

Salinity

Calculations have shown that dissolved solids in current discharges of wastewaters in Las Vegas Valley increase the total dissolved solids (TDS) in Lake Mead by approximately 10 mg/L. According to U.S. Geological Survey (USGS) records for the water year 1975, TDS in the waters discharged from Lake Mead averaged 713 mg/L. The increase caused by LVW discharges amount to about 1.42 per cent of this total.

It is well known that a major part of the TDS carried in the LVW discharges are of industrial origin at BMI and can be excluded by diversion to evaporation ponds. If this is done, it can be predicted that the contributions of TDS from LVW will cause an increase of less than one percent. In order to provide some perspective on the salinity problem, it seems necessary to point out how salinity increases as the Colorado River progresses toward Hoover Dam.

TDS Data Colorado River
(USGS Water Year 1975)

Location	TDS, mg/L
Lee's Ferry	531
Grand Canyon	598
Below Hoover Dam	713

The great increase in TDS of 115 mg/L from Grand Canyon to Hoover Dam can not be totally ascribed to additions from tributary streams. One must take the effects of evaporation into consideration and also the compositing action of Lake Mead, as it has a detention of nearly two years. Waters leaving the lake in any given year, therefore, are not representative of those entering during the same period.

The TDS increase occurring in Lake Mead can be calculated with considerable accuracy. For example, at reservoir elevation 1170, the surface area is about 120,000 acres and the capacity of the reservoir is about 18,500,000 acre feet. Evaporative losses per year approximate 72 inches or 6 feet. This corresponds to 720,000 acre feet or 3.89 percent of the lake volume. If one assumes that water entering from the Colorado River has a TDS of 600 mg/L, the TDS will be increased by 24 mg/L/yr of detention. For the normal 2 year detention, the TDS would increase to about 650 mg/L through evaporation alone.

The principal argument advanced here is that the 10 mg/L increment due to LVW inflow is a relatively minor factor in the TDS build-up in Lake Mead. Also, it will become less significant as discharges from the BMI brought under control by diversion.

Further, it seems necessary because of the expensive schemes that have been proposed to reclaim the BMI discharges, to point out that such reclaimed water has to be considered solely as an additional increment to the supply of irrigation water and would have a corresponding value. For this reason the current plan to evaporate the high TDS wastewaters from the BMI complex in sealed ponds is the most practical.

Some consideration of the impact of TDS in future wastewater flows from Las Vegas and Clark County upon Lake Mead should be made. A gross approximation can be made from the 300,000 acre feet allotted to Nevada from Lake Mead. At the present time, the amount of water produced during the winter months at the SNWS is about 50 percent of the amount produced during the summer months. Winter production is a reasonable measure of the amount used for domestic purposes, since little is used for irrigation at that time. It seems reasonable to conclude, therefore, that approximately 2/3 rds of the total water available could find its way to the wastewater treatment plants and then back to Lake Mead. Human usage of waters normally increases the TDS by about 300 mg/L. The 200,000 acre feet of return water corresponds to 1.08 percent of the water in Lake Mead at reservoir elevation 1170. Thus, the return water would increase the TDS in Lake Mead by about 3.24 mg/L/yr of detention. In these calculations, the ground water supply has been ignored because domestic usage brings its TDS level up to about the same level as the waters in Lake Mead.

Public Health

Considerable effort has been expended to try to prove that the waters leaving LVW are or are not a threat to the Southern Nevada Water Supply System or those people using LVB for water sports. As would be expected, the counts of both fecal and total coliforms in LVW were very low, due to the practice of chlorinating the final effluent at both wastewater treatment plants and die-off under natural environmental conditions in the Wash. Very low counts were found in LVB at all stations. They were far below the levels normally considered acceptable in natural beach swimming areas.

The isolation of Salmonella in LVW has little or no epidemiological significance because such bacteria are known to be shed by mice and other rodents.

Examination of the Annual Reports of the Southern Nevada Water System has shown the raw water at the intake to be of relatively high quality with less than 30 coliforms/ 100 ml, except during July and August when higher counts are observed. This has been correlated with swimming activity at Boulder Beach and boating operations at the Lake Mead Marina. Although contamination by bathers is a distinct possibility, since there are no showering requirements, the significance of large numbers of ducks, geese and carp as excreters of coliforms in this area should not be overlooked.

The photo shown below gives some idea of the waterfowl problem as it exists at the Lake Mead Marina. Due to the proximity of the

water supply intake at Saddle Island, it appears that the high counts in the raw water during July and August are due in part to the waterfowl. The role of the carp is unknown but could be significant since they are bottom feeders and follow the waterfowl quite closely.

The role of animals and waterfowl, particularly sea-gulls and ducks, as carriers of coliform, enteric bacteria, and viruses has often been ignored, although knowledge of this characteristic has existed for many years. For example, Prescott, Winslow and McCrady drew attention to this hazard in their book "Water Bacteriology", published by John Wiley & Sons, in 1946. EXHIBIT "A" on the following page is a direct reproduction from their book. Rats and mice have long been recognized as a reservoir of Salmonella by those engaged in the food industry. See G.M. Dack's book "Food Poisoning", The University of Chicago Press, 1943. Contamination by animals and waterfowl can be classed as multiple point sources.

Water Supply

Lake Mead is the prime public source of water for the Southern Nevada area. From a review of annual reports of the SNWS and consultations with its treatment superintendent, the impression was gained that Lake Mead waters are reasonably satisfactory except for filtration problems related to blooms of diatoms, mainly Cyclotella, and taste and odor problems which develop in November and December. Coliform bacteria have never been a concern in the raw or finished waters.

The presence of phytoplankton and zooplankton must be expected in the raw waters at all plants having surface supplies. The numbers and types can vary widely from season to season. Diatoms

EXHIBIT "A"

Significance of the Occurrence in Animal Discharges of Organisms Pathogenic for Man. The danger to the consumer from drinking water moderately polluted by animals, such as birds, fowl, swine, horses, cows, wild or domestic, was for many years regarded as more or less negligible, if we except the possibility of infection due to ingestion of bovine tubercle bacilli. The expression, "subject to contamination only from cultivated fields," very commonly encountered in descriptions of surface waters considered of fair quality, despite the fact that such cultivated fields are usually manured, often with excrement from a variety of animals, is an evidence of this indifference toward animal pollution. The discovery of the multiplicity of *Salmonella* organisms common to man and animals, however, may change this attitude. Edwards and Bruner (1943) reported data showing that in their collection of *Salmonella* bacteria, isolated in the United States and possessions during a period of only a few years, some 30 types have been secured from both man and one or more animals such as fowl, horses, and so on. Although Mallmann, Ryff, and Matthews (1942) were unsuccessful in producing apparent disease in monkeys fed with cultures of various *Salmonella* types isolated from chickens, Edwards and Bruner stated that they possess unpublished data which "include a number of instances in which infection in man was traceable directly to animals." Brucellosis is another infection which conceivably might be transmitted by water polluted with discharges from animals. In addition to the danger from direct pollution by diseased animals there is the possibility of water being infected by fowls or other animals serving merely as vehicles of human pathogens. *E. typhosa*, for example, has been isolated from the feces of gulls which had apparently fed on material contaminated with typhoid organisms. It is quite probable that, as we learn more regarding the transmission to man of infectious diseases caused by animal discharges containing human pathogens, an increasing realization that animal pollution can be considerably more dangerous than heretofore suspected may dispel the measure of complacency with which such pollution has been regarded in the past.

are the predominant algae in oligotrophic or good quality water. The Lake Mead waters can be rated A-1 on this basis, also on the basis of coliforms.

The taste and odor problem which develops in November and December is related to the negative heterograde oxygen profile which develops in the thermocline during summer stratification of the lake. This has been shown to be caused by large populations of zooplankton which feast upon the phytoplankton that settle into the zone and, to some extent, the shad fry that enter to feast upon the zooplankton and algae. Both the zooplankton and shad use dissolved oxygen from the water and create the unusual oxygen profile. The dissimulatory actions brought about by these organisms in this zone is evidenced by the higher levels of inorganic phosphorus and nitrogen that occur.

The negative heterograde oxygen profile creates a serious situation at the water treatment plant because it drops deeper and deeper as the thermocline descends in the autumn. Because water for the Southern Nevada supply is taken at only one depth, elevation 1050, the bad water in the thermocline eventually reaches the intake and can not be avoided. Since the zone of water with the low dissolved oxygen is approximately 50 feet deep, some time passes before good water is available from the epilimnion. This condition will recur each year until such time that a multiple intake structure is provided at Saddle Island.

It is quite well established that oxygen depletion in the thermocline is consistently greater in Boulder Basin than in upper Lake Mead. Such data as are available from Lake Powell indicate that a negative heterograde oxygen profile develops there also, but it seems to be much less severe than in upper Lake Mead. This may be because Lake Powell is too young a body of water to develop normal characteristics.

The future of Lake Mead and its behavior are of prime concern. Although the primary productivity data, and even the dissolved oxygen data collected at the water treatment plant, indicate that Lake Mead is improving in quality, this is probably a result of the "toll" taken by Lake Powell in terms of algal nutrients and suspended matter. How long the benefits will continue is a matter of conjecture. It seems certain, however, that as long as wastewaters from Las Vegas and Clark County continue to increase in volume, any benefits due to Lake Powell will soon be overcome and Lake Mead will deteriorate, unless something is done to stem the entrance of the algal nutrients. If the situation should deteriorate to a point where anaerobic conditions develop in the thermocline, a change in the water intake structure will have to be made.

There are two puzzling aspects of the negative oxygen profile which bother me. 1. I do not understand why the low oxygen zone in the thermocline does not disappear through mixing action as the epilimnion thickens and the thermocline descends, and 2. The fact that the taste and odor problem occurs in spite of the presence of significant amounts of dissolved oxygen in the raw water is somewhat of a conundrum. I suspect that this is due to a situation in which the intake draws good and bad water simultaneously. This could give the taste and odor problem even in the presence of oxygen. Some study of the mixing phenomenon at the water intake seems in order. If this is the situation, it could be predicted that the problem will diminish as water taking increases due to greater mixing action.

Eutrophication

Lakes and reservoirs are not permanent features of the landscape. Geologically speaking, they are only water-filled natural or man-made depressions in the earth's crust that are destined to become filled with soil and organic deposits as time passes. Fundamentally, they are giant sedimentation basins which not only serve to remove suspended matter from tributary waters but also act as giant reaction vessels for biological phenomena involving production of both plants and animals.

Historically, young lakes are relatively barren bodies of water in terms of the amount of biological life they support. In this phase they are referred to as being oligotrophic. As aging progresses the materials retained by the lake gradually increase the bottom sediments and, through bacterial and other decomposition of the sediments, the lake waters become richer and richer in nutrient materials on which phytoplankton thrive.

With the increase in biological productivity of a lake, major changes occur in both the surface and deeper waters. The lake passes from the oligotrophic phase through the mesotrophic and finally into the eutrophic stage. It continues in this phase until deposits from biological activity, plus materials settled from tributary waters, fill the basin to the extent that rooted aquatic plants take command of the situation and gradually convert the area to marsh land. Eutrophication, therefore, may be considered synonomous with the aging process of lakes. Any materials added to the lake which speed up the aging process may be considered as contributing to its eutrophication. At the time Hoover Dam was planned, the life expectancy of Lake Mead was estimated to be 150 years, due to the heavy sediment load carried by the Colorado River. Creation of Lake Powell has intercepted a great deal of this load and has extended the life of Lake Mead, considerably.

The eutrophic or last stage in a lakes history is characterized by high biological productivity (plankton growths) in the euphotic zone and serious depletion of oxygen in the deeper waters, particularly in the hypolimnion of lakes deep enough to stratify. It has been well established by many investigators that domestic wastewaters and some industrial wastes contribute greatly to the eutrophication process, due largely to the nitrogen and phosphorus they carry.

The natural and accelerated eutrophication process due to fertilization from artificial or domestic sources is shown in EXHIBIT "B".on page 15.

There can be no question about the wastewater discharges currently reaching Lake Mead from LVW contributing to its eutrophication. One need only make a boat trip from Hoover Dam to the extremity of LVB to see the effect. To me, the effects in upper LVB were not as severe as I had anticipated based upon other experiences. This is due, undoubtedly, to the high specific gravity of the waters coming in from LVW that allow them to enter the lake as a density current, with minimal mixing with waters in the euphotic zone. Thus, algal growths are not as prolific as one would expect in the immediate area. Since the major part of the TDS that causes the density current originates from the BMI ponds, it can be predicted that their elimination will allow waters from LVW to enter the lake in a more normal manner and that conditions in upper LVB will be much more offensive than at present.

EXHIBIT "B"

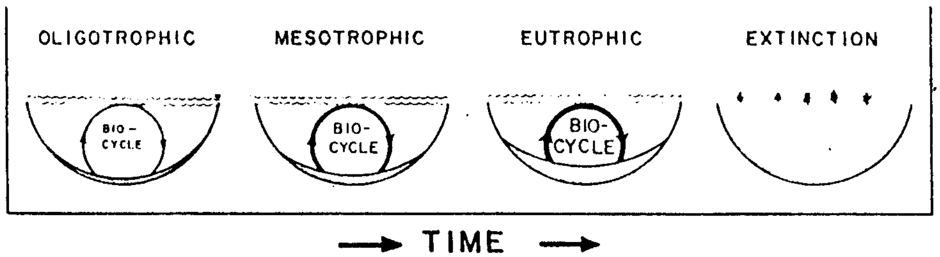

FIGURE 1.—Natural transition of a lake through various stages of productivity eventually resulting in extinction.

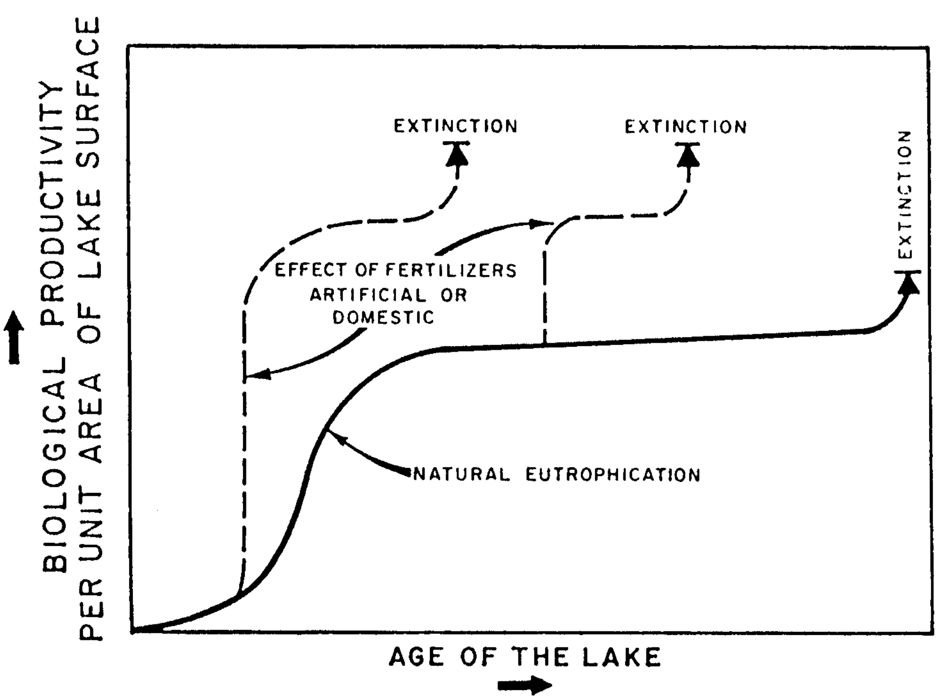

FIGURE 2.—Natural and induced eutrophication [from Hasler (3)].

The waters from LVW that flow away as a density current will exert their algal growth potential somewhere. They are, no doubt, the cause of greater growths in lower Boulder Basin as compared to upper Boulder Basin and Virgin Basin. This is evidenced by the more serious negative heterograde oxygen profile in the lower basin. A logical conclusion is that increased flows of wastewater from Las Vegas and Clark County will have serious effects in Boulder Basin by producing greater blooms of algae which will cause more serious depletion of oxygen in the thermocline. What is now a 50 foot band could easily be expanded to a 100 foot band. This could force the SNWS to take water from the epilimnion during a large part of the year.

There is evidence to indicate that the waters below Hoover Dam (headwaters of Lake Mohave) have a greater algal growth potential than the surface waters in lower Boulder Basin. This could be a result of the density current from LVW, with its high nutrient load, short-circuiting to some extent through the turbines at Hoover Dam. This has implications in terms of the rights of users of Lake Mohave. The black fly problem at Bull Head City could be associated with this enrichment, as is the case at Clear Lake in California.

In no way could I support the concepts of intercepting the flow in LVW and conducting it by underwater pipeline for some distance into Las Vegas Bay or transport the effluents across country for discharge to Lake Mohave below Hoover Dam. Either proposal, in my opinion, would be classed as avoidance of an ethical responsibility and would meet with litigation which would prevent progressive steps for many years.

The question must be asked: If the waters draining into LVB from LVW are contributing to the eutrophication of Lake Mead, can anything be done short of diversion of wastewaters out of the Valley to protect Lake Mead? This is a very difficult question to answer and any prognostication must be based upon quite limited data, namely that in Appendix I of Dr. Deacon's July 1976 report, other data available from the National Eutrophication Survey (NES), and the U.S. Geological Survey (USGS) as shown in EXHIBITS "C" and "D". Interpretation of these data can be "seasoned" to some degree by personal observations as recorded in EXHIBIT "E".

Dr. Deacon's data given in EXHIBIT "C" show that both dissolved phosphorus and inorganic nitrogen are reduced to very low levels by June 27 and continue so through October 16. Both may be considered limiting to phytoplankton growths during the summer growing season.

The data in EXHIBIT "D" were compiled from NES and USGS sources and span the Colorado River from upper Lake Powell to just below Hoover Dam. The data for Lake Powell show that significant levels of dissolved phosphorus and inorganic nitrogen exist in the waters through August, but the December data indicate that phosphorus becomes limiting in the late summer and autumn.

The USGS data for Lee's Ferry show significant dissolved phosphorus in April and December. Unfortunately, no data were available for August. The inorganic nitrogen remained high throughout the summer. This was probably related to water being taken at depths greater than 35 feet for the turbines. The USGS initiated nutrient analyses in Water Year 1975, so data are not available for prior years.

EXHIBIT "C"

ALGAL NUTRIENTS[1] IN LAKE MEAD - STA 6 - BOULDER BASIN

	Dissolved Phosphorus mg/L	Inorganic Nitrogen mg/L
Apr 28	.005	.30
May 16	.0065	.24
May 28	.005	.27
Jun 27	.0025	.08
Jul 31	.0055	.05
Aug 19	.003	.05
Aug 28	.003	.04
Sep 17	.004	.04
Oct 2	.0025	.03
Oct 16	.0065	.23
Oct 30	.004	.12
Nov 20	.0065	.23
Dec 22	.008	.30
Jan 29	.012	.34
Feb 19	.007	---

1) Dr. Deacon's data - per Appendix I - July 1976 Report
These are average data for the 0 and 10 foot depths.

EXHIBIT "D"

ALGAL NUTRIENTS[1] - COLORADO RIVER

	Dissolved-P, mg/L			Inorganic-N, mg/L		
	Apr	Aug	Dec	Apr	Aug	Dec
Lake Powell						
NES Sta. 09[2]	.019	.019	.003	.69	.27	.45
NES Sta. 10[3]	.008	.012	.002	.40	.13	.35
NES Sta. 19[4]	.011	.008	.002	.38	.26	.46
NES Sta. 02[5]	.012	.009	.002	.37	.17	.27
Lee's Ferry						
USGS Sta.	.01	----	.01	.50	.49	.35
Grand Canyon						
USGS Sta.	.01	.02	.00	.46	.45	.81
Lake Mead						
NES Sta. 08[6]	.005	.010	.008	.25	.06	.38
NES Sta. 04[7]	.013	.006	.009	.25	.02	.26
NES Sta. 03[8]	.011	.011	.010	.17	.05	.25
Hoover Dam						
NES Below Dam	.033	.015	.010	.27	.41	.45

Notes

1. Algal nutrients in upper 35 feet of water
2. NES (National Eutrophication Survey) Station upstream of Dirty Devil River
3. Sta. 10 Upstream of Eggnog tributary
4. Sta. 19 About 10 miles upstream of Glen Canyon Dam
5. Sta. 02 Above Glen Canyon Dam
6. Lake Mead Sta. 08 In upper Virgin Basin
7. Lake Mead Sta. 04 In upper Boulder Basin
8. Lake Mead Sta. 03 Immediately above Hoover Dam

EXHIBIT "E"

PERSONAL OBSERVATIONS OF CLAIR N. SAWYER

TEMPLE BAR - September 27, 1976

No algae growths visible to eye - water very clear - periphyton growths on rocks and bottom scarce.

BOULDER BEACH - September 27, 1976

Significant phytoplankton - enough to give green cast to water - no noticeable periphyton

LAKE MEAD MARINA - Sept. 27, 1976

Significant phytoplankton bloom - heavy periphyton growth on boat bottoms - many ducks and carp.

LAS VEGAS BOAT HARBOR - Sept. 27, 1976

Heavy growth of phytoplankton - heavy growths of periphyton, including some bright green - some ducks and carp

CALLVILLE BAY - Sept. 27, 1976

Significant phytoplanton - some periphyton - some ducks and carp

GOVERNMENT WASH - Sept. 27, 1976

Water very clear - excellent condition

OVERTON BEACH - Sept.28, 1976

Water quite clear - similar to Temple Bar - some periphyton, possibly a bit heavier than at Temple Bar

ECHO BAY - Sept. 28, 1976

Water reasonably clean - periphyton moderate - some rooted aquatic plants, possibly Milfoil - a few ducks and carp.

BOAT TRIP UP LAS VEGAS BAY - Sept. 3, 1976

Area of Saddle Island - water of very good quality - very few visible phytoplankton - periphyton growths on rocks fairly scant

Upper Las Vegas Bay - Significant increase in phytoplankton as we progressed up the Bay. Only a very few floating algae indicative of blue-greens - Algal growths in the upper Bay not nearly as heavy as anticipated - Periphyton growths fairly heavy and more greenish in color.

CLAIR N. SAWYER

At Grand Canyon the highest level of inorganic phosphorus was observed during August. This could be related to the peak tourist season and, if so, question can be raised as to the mode of handling domestic wastes at Grand Canyon.

According to the NES data on Lake Mead, there was adequate dissolved phosphorus for phytoplankton blooms at all seasons in Virgin and Boulder Basins. Inorganic nitrogen became limiting at all stations during August. The data collected on samples below Hoover Dam showed the water to be rich in both phosphorus and nitrogen at all seasons. During April the phosphorus value was excessively high.

On the basis of both Dr. Deacon's and the NES data, inorganic nitrogen is reduced to very low levels in the epilimnion of Lake Mead during the summer and autumn. It seems certain, therefore, that the growth of algae in Boulder Basin is limited by a shortage of inorganic nitrogen. With respect to dissolved phosphorus, the data are not in agreement. Dr. Deacon's data appear to indicate that phosphorus becomes a limiting factor, also. The NES data do not support such a conclusion.

Dr. Deacon's data definitely show that inorganic nitrogen serves as a limiting nutrient and that dissolved phosphorus is in excess in the upper reaches of LVB. This is a condition that could lead to the development of serious blooms of nitrogen fixing algae, as has been the case in Clear Lake, California and numerous other cases.

Conclusions - There is no question but what phosphorus contributions to Lake Mead must be severely limited if LVB is to be kept in a reasonable condition for recreational uses. On the basis of oxygen depletion in the thermocline and the relatively rich water passing through Boulder Dam, it would be wise to limit the amount of nitrogen entering Lake Mead to present levels, or even decrease them to some degree.

Las Vegas Wash

Las Vegas Wash is a valuable natural resource and it should be preserved in its present state or even expanded, if such can be done at reasonable cost. It serves as natural habitat for a wide variety of animals and birds, but its most important function in relation to Lake Mead is that it acts as a natural biological filter to remove large amounts of BOD, suspended solids, nitrogen and some phosphorus and prevent them from reaching Lake Mead. In addition it it serves as a nitrifying device which converts essentially all of the ammonia nitrogen in the wastewater treatment plant effluents to nitrates during a large part of the year. In my opinion, this mollifies the effect of the nitrogen loading on LVB in particular. It is well known that ammonia nitrogen is much more readily available to algae, and many authorities believe that it stimulates growths which have difficulty thriving on nitrates as a source of nitrogen.

The capability of Las Vegas Wash to retain algal nutrients has been the subject of considerable study by several investigators. The results of these investigations are summarized in Exhibit "F" as presented by their report on "Pollution Affecting Las Vegas Wash, Lake Mead and the Lower Colorado River", December 1971.

The data in Exhibit "F" indicate that the vegetation in LVW between Miles 9.3 and 6.0 is capable of removing from 1700 to 2100 pounds of nitrogen per day. Its capability below Mile 6.0

EXHIBIT "F"

ALGAL NUTRIENT CAPTURING CAPABILITY OF LAS VEGAS WASH

Location	Flow	Nitrogen			Phosphorus		
	mgd	mg/L	Lb/day	Lb Capt.	mg/L	Lb/day	Lb Capt.
			May 1966 FWPCA Study				
Mile 9.3	15.1	18.2	2300	-	12.0	1520	--
Mile 6.0	13.7	1.8	210	2090	9.3	1070	450
Mile 0.6	16.9	8.6	1210[a]	1090	4.9	690	830
			March 1968 Bureau of Reclamation Study				
Mile 6.0	18.1	3.5	530	-	12.8	1890	-
Mile 0.6	-	10.7	-	-	7.8	-	-
			July 1968 Tipton and Kalmbach Study				
Mile 6.0	10.0	3.9	330	-	16.5	1380	-
Mile 0.6	14.8	11.9	1480[a]	(1150)[a]	8.0	990	390
			December 1968 Boyle-CH_2M Study				
Mile 9.3	-	23.0	-	-	10.6	-	-
Mile 6.0	24.4	7.7	1560	-	7.0	1420	-
Mile 0.6	30.0	13.0	3250[a]	(1690)[a]	4.1	1025	395
			June-December 1970 Desert Research Institute				
Mile 9.3	25.3	13.6	2880	-	8.3	1760	-
Mile 6.0	26.9	5.1	1152	1728	6.1	1375	385
Mile 0.6	32.3	11.9	3210[a]	(330)[a]	3.0	808	952

a) Values are influenced by seepage from BMI ponds carrying high levels of nitrates

Mile 9.3 Below entrance of treatment plant effluents
Mile 6.0 USGS gaging station at Pabco Road
Mile 0.6 Sampling station at North Shore Road

is not subject to calculation because of the inflow of seepage from the BMI ponds that carry a high nitrate load. It is known that the BMI seepage is very low in phosphorus, however. It is also known that the inorganic nitrogen in the total flow at Mile 0.6, North Shore Road exists all most entirely as nitrate. Phosphorus removal between Mile 9.3 and 6.0 was about 400 pounds per day and ranged from 800 to 950 pounds per day over the entire span of the Wash.

The data in Exhibit "F" were collected during months of the year ranging from March to December and show a high degree of reliability on an annual basis. They also show that the capture holds up at highest flows investigated which is highly significant.

Water Quality - The water quality standards for discharge of effluents to Las Vegas Wash established by the Nevada State Board of Health are extremely strict in regard to BOD, suspended solids, total phosphorus and total nitrogen. In fact they are unrealistic in regard to total P and N because such levels are unobtainable except, perhaps, by reverse osmosis or other sophisticated means of treatment. The standards totally ignore the natural resource of Las Vegas Wash. If these standards are not challenged and brought into the realm of reality, then there is only one method of waste water disposal feasible and that is to export the waters out of the Valley to the Dry Lake north of the City, the same scheme as is used at Lake Tahoe. However, the wastewater should not be treated to drinking water quality before doing so.

CONCLUSIONS

The waters flowing into Lake Mead from Las Vegas Wash have a definite deteriorating effect upon the lake.

1. They stimulate extensive blooms of algae in the upper reaches of Las Vegas Bay which impair use of its waters for recreational purposes.
2. The biological productivity of Boulder Basin is increased to the point where serious oxygen depletion occurs in the thermocline and further degradation is bound to have serious consequences at the Southern Nevada Water System water treatment plant.
3. The waters discharged to the Lower Colorado River at Hoover Dam have an algal growth potential greater than the surface waters in Boulder Basin. This fact has interstate implications.
4. Presently, the inflow from Las Vegas Wash increases the TDS in Lake Mead by about 10 mg/L. This effect can be minimized by control of the high TDS wastes at BMI.

The waters entering Lake Mead via Las Vegas Wash come into the lake as a density current which seeks the bottom of the lake or deep waters having the same density. This is the result of the high TDS the waters in Las Vegas Wash carry. The high TDS is attributable mainly to seepage from the BMI ponds. The density current has beneficial and detrimental effects.

1. The beneficial effect concerns upper Las Vegas Bay. Because the inflow from Las Vegas Wash does not mix with Bay waters to any great extent, the nutrient load is limited and algal

growths in the upper bay are much less than would be expected. Thus, the density current is effective in distributing the nutrient load over a great area of Lake Mead and, thereby, minimizing local effects.

If the high TDS inflows to Las Vegas Wash are diverted, it can be expected that the inflows to the lake will enter in a normal manner and mix with the surface waters. This will cause extreme algal growth conditions unless upstream control of phosphorus and, possibly, nitrogen is practiced.

2. The detrimental effects of the density current are related to the fact that it distributes a considerable portion of the nutrient load into Boulder Basin. Here plankton growths are stimulated and settle into the thermocline where they are eaten by zooplankton and shad fry in a relatively narrow band of water. Their respiratory action depletes the dissolved oxygen in this zone severely. Each autumn, as the thermocline descends, the zone of low oxygen water intercepts the Southern Nevada Water System intake and creates serious taste and odor problems for a period of a month or more. It can be predicted that this condition will worsen as wastewater flows increase, unless some form of nutrient control is inaugurated.

Further, it seems quite certain that the density current plays a role in enriching the waters passing Hoover Dam. They serve to enrich the waters of Lake Mohave and it can be expected that complaints will be issued, if the word reaches the property owners on Lake Mohave.

Las Vegas Wash , through the extensive vegetation it supports downstream of the point of entry of the wastewater treatment plant effluents, is a valuable, natural biological purification device and has, undoubtedly, been a big factor in maintaining the integrity of Lake Mead for many years. The Wash acts in several roles and expansion of the area to increase its capacity at reasonable cost should be encouraged.

1. It serves to remove BOD and suspended solids carried in the treatment plant effluents. Also, it serves the same function for low run-off events due to small storms.
2. It serves as a nitrifying device to convert the large amounts of ammonia nitrogen carried in the treatment plant effluents to the more desirable nitrates.
3. It serves as a nutrient trap and removes large amounts of nitrogen and some phosphorus from the effluents.
4. It serves also as a place for natural die-off of coliforms, other enteric organisms and viruses to occur. Thus, it acts as a second line of defense between the chlorine contact chambers at the treatment plants and Las Vegas Bay.
5. The vegetative cover in the Wash is the home of a wide variety of birds and animals, consequently waters passing through it are subject to some degree of contamination and pollution.

The greatest threat to the use of Lake Mead as a source of public water supply is related to the taste and odor problem. This is mainly the result of the low dissolved oxygen levels that develop in the thermocline during summer stratification and the inability of the treatment plant operators to avoid the bad water layer as the thermocline descends, because of the single water intake.

The wastewater discharges in Las Vegas Valley as presently managed have no public health significance in Las Vegas Bay or to the Southern Nevada Water System. The presence of large numbers of waterfowl in the vicinity of the marinas and bathing beaches has two important aspects.

1. High coliform counts have been observed at Boulder Beach and Lake Mead Marina. Both of these locations are near the SNWS water intake at Saddle Island and have a recognized effect upon the coliform counts at the water intake during July and August.
2. The wastewater handling facilities at the marinas are not of fail-safe design. The normal coliform levels caused by waterfowl and other animals could obscure a failure or leakage in the sanitary system.

Inspections at Government Wash supported the contention that inflowing waters from undeveloped areas have little effect upon Lake Mead waters as far as enrichment with nitrogen and phosphorus is concerned.

Las Vegas Bay, Boulder Basin and Lake Mohave are affected by cultural contributions of algal nutrients in Las Vegas Valley. The only solution is to bring these under control so as to prevent the conditions now existing.

RECOMMENDATIONS

After careful and thoughtful consideration of all aspects of the wastewater disposal problem at BMI, Henderson, Las Vegas and Clark County, the following recommendations are presented.

1. All industrial waste streams at the BMI complex carrying total dissolved solids (TDS) values in excess of 2000 mg/L and/or waste streams containing in excess of 25 mg/L of inorganic nitrogen (ammonia plus nitrate nitrogen) should be isolated for disposal by evaporation in ponds sealed to prevent seepage.
2. The domestic wastes from Henderson and the sanitary wastes from the BMI complex should be treated by conventional secondary methods, the effluents chlorinated for disinfection and disposed of via the BMI ponds, where seepage through the soil will accomplish a high degree of phosphorus removal.

   The inorganic nitrogen in the effluents to the ponds should be accounted for and included in the permissible nitrogen budget for Las Vegas Wash.
3. Las Vegas and Clark County should continue to treat wastewaters by conventional secondary methods followed by chlorination of the effluents to accomplish a high degree of disinfection, as presently practiced.
4. Las Vegas Wash should be used to its maximum capability for removing nitrogen from wastewaters. A nitrogen budget should be established with due allowance for contributions from domestic wastes at Henderson and sanitary wastes from

the BMI complex. The wastewater flow admitted to Las Vegas Wash from the City of Las Vegas and Clark County treatment plants should be controlled to amounts within the nitrogen budget permitted for Las Vegas Wash. It is estimated that permissible flows will exceed 25 mgd.

5. The wastewater effluents from the Las Vegas and Clark County plants destined to flow to Las Vegas Wash should be treated, totally or partially, to remove phosphorus to the extent that they do not contain in excess of 800 pounds of total phosphorus per day.
6. Sludges produced in the removal of phosphorus should be returned to either the Clark County or Las Vegas treatment plants for disposal with other sludges or disposal with excess effluent as described under 8 below, unless cost-benefit ratios dictate otherwise.
7. Local use of excess effluent for irrigation and industrial purposes should be encouraged as in the past.
8. All excess effluent beyond that destined to flow to Las Vegas Wash or committed for second use in the Valley should be exported to Dry Lake north of Las Vegas for disposal by evaporation.

The plan proposed above makes no allowance for continued seepage of high TDS and nitrate waters from the mound of water existing under the BMI ponds. With the proposed plan these will gradually dissipate and have less and less significance.

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APPENDICES

APPENDIX A

WATER QUALITY STUDY OF LAKE MEAD - REPORT NO. CHE - 70

U.S. Dept. of Interior - Bureau of Reclamation (Nov. 1967)

The survey upon which this report was based was conducted subsequent to three other studies of L. Mead which led to release of reports in 1951, 1954, and 1965 dealing with chemistry and limnology. It was conducted primarily to determine the effect filling L. Powell had upon L. Mead. The studies were started in 1964 and completed in 1966. Pertinent facts developed which have been corroborated on subsubsequent surveys are as follows:

1. After stratification is well established in the summer, the lowest dissolved oxygen values are found in the thermocline.
2. Mineral content of water increases from upper to lower end of the lake.
3. Virgin and Muddy Rivers and Las Vegas wash are contributors of poor quality water.
4. Algae blooms have been reported and taste and odor problems have occurred in domestic supplies taken from the lake.

Specific information showed that the quality of water in L. Mead deteriorated considerably during the period L. Powell was being filled, in terms of dissolved solids, as measured by conductivity. Other parameters were not measureably affected.

Comments

The results of this study suffer from the fact that only 5 surveys were conducted: One each in the spring (April - May) of 1964, 65, and 66 and one each in the fall (Nov.) of 65 and 66. No information was obtained during the critical summer months of July, August and September.

A very limited amount of data was obtained on the algae nutrients - nitrogen and phosphorus - and on only one occasion in May 1966. Of these data, the ammonia and soluble phosphorus values appear inordinately high in the lake samples. The nitrogen data on the samples collected from LVW at North Shore Drive are obviously in error, particularily that for nitrates. No mention was made of the methods of analysis used.

The lowest dissolved oxygen values were found in the thermocline at depths of 100 to 150 feet. This great depth is a result of the season (Nov.). It is a well known fact that thermoclines develop at shallower depths, usually 40-50 feet in large deep lakes, and descend as the season progresses, particularily when night time temperatures allow significant cooling of the surface waters.

Although dissolved solids (TDS) increase was shown to be a major item of water quality deterioration in L. Mead and blame was placed upon entrance of poor quality water from LVW and Muddy and Virgin Rivers, no mention was made of the increase caused by the evaporative loss of about 6 ft/yr. This corresponds to about 3 per-cent of the lake volume. For a two year detention, calculations indicate that this factor alone causes an increase of about 50 mg/L. For a three year detention, the increase would be about 75 mg/L.

APPENDIX B

REPORT ON POLLUTION IN LAS VEGAS WASH AND LAS VEGAS BAY

Dept. of The Interior and Federal Water Pollution Control Administration

January 1967

This study was conducted during the latter half of May 1966 and was concerned solely with Las Vegas Wash, Las Vegas Bay, and the Boulder Beach area. Because of it's short duration, it can be classed as a "Quickie" investigation and the results obtained are probably typical of those in the early spring, only.

The parameters examined in the study were total and fecal coliforms, BOD, nitrogen, phosphorus, and heavy metals. Samples taken from LVB were restricted to the surface and 5 meter depths. Since the waters of Lake Mead are normally well stratified by the middle of May, the results obtained are, probably, indicative of those occurring in the epilimnion at that season.

At the time of the survey, sewage treatment plant effluent discharges to LVW were about 15.5 mgd, with about 4 mgd originating from the Clark County plant nad 11.5 mgd from the city of Las Vegas plant. These flows were supplemented by about 0.5 mgd cooling tower blowdown from the Sunrise and Clark power plants and an unknown underground flow from the BMI holding ponds.

The major results of this survey which are of current interest are as follows:

1. TDS in the sewage treatment plant effluents were:

Clark County	1055 mg/L
Las Vegas	783 mg/L

2. TDS in effluents from power plants were:

Clark Station	2843 mg/L
Sunrise	2832 mg/L

3. TDS in Las Vegas Wash below STP's 1135 mg/L
4. TDS in Las Vegas Wash at USGS gauge
   Flow 15.2 mgd 2400 mg/L
5. TDS in Las Vegas Wash at N. Shore Road
   Flow 17.0 mgd 2890 mg/L
6. A sample of ground water just north of BMI ponds 8140 mg/L
7. Bacteria - no comment needed here
8. Algae counts were greatest at the head-end of LVB and decreased with distance down the bay, with minimum values in Boulder Basin.
9. No correlation of algae growths and nitrogen could be established but a good correlation with total phosphorus was evident.
10. Signigicant levels of coliform organisms were present in the Boulder Beach area.

COMMENTS

The bacteriological data obtained in 1966 have little significance at the moment because of changed conditions. The isolation of *Salmonella* in LVW has no significance because rodents, particularly mice, are known to harbor these bacteria. The relatively high values at Boulder Beach are a concern of the Federal Government, not Las Vegas or Clark County.

The great increase in TDS of 1135 to 1890 between samples collected in the upper Wash, below known surface discharges and North Shore Road demonstrates serious degradation enroute. Some of this increase is due, undoubtedly, to water losses by evaporation and transpiration but, since flows at North Shore Road were greater than measured at the U.S.G.S.gauge upstream, the evidence is clear that ground water seepage is primarily responsible. The high TDS in the sample of groundwater taken just North of the BMI ponds makes them highly suspicious.

The observations that Algae counts were highest in the head-end of LVB comes as no surprise. It is logical that numbers would decrease down the Bay as dilution increases.

At the time of the year that the surveys were made (May), it would have been unexpected to find algae growths limited by either nitrogen or phosphorus.

The suggestion was made on P. 18 of the report that control of the Algae growths in LVB could be accomplished by limiting phosphorus in the sewage treatment plant effluents to 1.2 mg/L. No valid basis for this statement was made nor was mention made whether it pertained to 1966 flows or some greater flows at a date in the future.

In general, one can find little fault with the data given in this report, except the short time span over which it was collected and it failure to explore the deeper waters.

APPENDIX C

THE EFFECT OF LAS VEGAS WASH EFFLUENT UPON THE WATER QUALITY IN LAKE MEAD - BUREAU OF RECLAMATION REC-ERC-71-11

U.S. Dept. of the Interior, January 1971

This report was based upon surveys conducted in LVW, LVB, and the Boulder Basin of L. Mead during 1968. Reasons given for the study were three:

1. Poor quality water entering LVB from LVW.
2. Deteriorating water quality resulting in tastes and odors.
3. Reduction in attractiveness of LVB for recreation.

Four study periods were involved, - one each in March, May, August, and November, thus, spanning seasonal changes fairly well. Samples were collected at depths as low as 250 feet which allowed definition of stratification and conditions within the epilimnion, thermocline, and hypolimnion.

Pertinent data obtained concerned temperature, oxygen (DO), conductivity, pH, alkalinity, carbon dioxide, phosphorus, nitrogen, and various cations and anions.

COMMENTS

In this survey an effort was made to further define the source of extraneous TDS entering LVW by establishing sampling stations at the US gage, at a place called the dump, and at North Shore Road. The data obtained are summarized in the following table.

T.D.S. IN LVW in mg/L - 1968

	March	May	August	November
USGS Gage	3342	3136	4136	2808
Dump	-	-	6164	4544
North Shore Road	4778	5728	6068	4384

These data clearly indicate that major pollution with TDS occurs above the USGS gage and below it but above the dump. The report does not answer the question of where the extraneous TDS come from but suggests that they may come from the BMI ponds.

This study was the first attempt at what might be termed a limnological survey where an effort was made to obtain data from top to bottom and area wide. It suffered from the limited number of sampling stations established, only two is LVB and two in Boulder Basin. Participants in this survey were the first to discover the real nature of stratified conditions in L. Mead. The epilimnion is about 50 feet deep under summer conditions and the thermocline is unusually thick, being in the order of 50 feet, also. A strange phenomenon was discovered in relation to dissolved oxygen at various depths. It was found that lowest values were found in the thermocline, at depths of 100 to 150 feet, depending on the season. It was postulated that the low dissolved oxygen values were caused by algae that sank to such depths and created an unusual oxygen demand. This observation has been confirmed many times. Only the interpretation of the reason for the low DO values has changed.

The values for phosphorus and nitrogen in lake water samples reported are suspect. The analytical procedures were not well suited for determination of the low levels encountered. For example, the nitrate values at Station 4 in November appear outrageously high. All values of ammonia nitrogen (NH_3 -N) for lake samples in Table 11 appear very high. The method used for phosphorus was obviously not very sensitive. A method for ortho phosphate should be able to detect values in the range of 0.01 with ease. The total insoluble phosphate values are extremely low. It is recommended that very little significance be attached to the P and N data in this report.

Although one of the stated reasons for conducting this survey was "deteriorating water quality resulting in tastes and odors" it seems strange that a sampling station was not established near the water intake at Saddle Island. The nearest sampling station was Sta. 8 over two miles away.

APPENDIX D

EFFECTS OF WATER MANAGEMENT ON QUALITY OF GROUND AND SURFACE RECHARGE IN THE LAS VEGAS VALLEY

Annual Report 1971, Center for Water Resources Research
Desert Research Institute
University of Nevada - Las Vegas

As the title implies this report concerns an investigation designed to evaluate the impact of various waste-water discharges and waste-water reuse programs on ground water quality in LVW. The survey system consisted of 26 surface stations and 50 test wells located to determine the effect of waste-water disposal by percolation and waste-water reuse by irrigation.

A major concern is the increasing ground water elevation in the shallow aquifer downstream of Las Vegas. It is claimed that the level in this aquifer is increasing at the rate of 1.04 feet/yr, presumably from irrigation and seepage. As a result, leakage to LVW is increasing and such waters are of dubious quality, particularly in terms of TDS and nitrates.

The report indicates that the waste discharged to the BMI ponds is a major source of TDS in LVW. This confirms previous speculations by other investigators.

The self-purification capacity of LVW was defined by the study to some degree. For example, in the 3 mile reach between stations LW002 and LW003, the ammonia nitrogen level was reduced by 90%, due to green plant assimilation and oxidation to nitrate, and total nitrogen was decreased from 21 to 7.4 mg/L, a reduction of 64 percent. Phosphorus was decreased by only 14 percent, however.

Calculations derived from survey data indicate that discharges from the City of Las Vegas and Clark County ST P's contribute over 99% of the phosphorus, 81% of the nitrogen and 38% of the TDS loads to LVW by municipal and industrial sources.

A highly significant study was made in LVB. It was very simple and involved only conductivity studies. They showed that under conditions that existed on that day (May 8, 1970) that waters entering from LVW did not mix with the bay waters but flowed as a density current to the bottom of the bay. This was the first evidence reported of this phenomenon.

COMMENTS

There were several important factors developed by this study which seem highly pertinent and deserve further comment.

1. The significance of the seepage from the BMI ponds as a source of high TDS inflows to LVW was firmly established. No solution to the TDS problem can avoid this.
2. The significance of other ground water flows as a source of TDS was not well established.
3. The self-purification capacity of LVW was defined to some extent but requires further refinement as flows increase in the future.
4. The presentation of data on conductivity which indicates that waters in LVW enter LVB as a density current that seeks the bottom waters or waters of the same density was a major contribution to our knowledge of the behavior of LVB.

APPENDIX E

REPORT ON POLLUTION AFFECTING LAS VEGAS WASH, LAKE MEAD
AND
THE LOWER COLORADO RIVER

EPA, December 1971

This report alludes to various investigations conducted from 1966 to 1971 that have demonstrated that direct and indirect discharges of municipal and industrial wastes to LVW are causing interstate pollution of L. Mead and the lower Colorado R. which is deleterious to the health or welfare of persons living in Arizona, Calif., and Nevada, and are violating Federal-State water quality standards applicable to L. Mead and the Colorado R. It also states that practicable means exist for achieving region-wide abatement of pollution by municipal wastewaters.

Water quality in LVW is described.

Conditions in LVB are described and blamed to LVW discharges.

The statement is made that Lake Mead downstream from Las Vegas Bay (Presumably Boulder Basin) and the Colorado R. below Hoover Dam have a higher algae growth potential (AGP) than L. Mead has upstream from Las Vegas Bay.

Water quality standards applicable to L. Mead have been agreed upon by Az., NV and the Federal Government. They provide that the waters be "free from materials attributable to domestic or industrial wastes or other controllable sources ---in amounts sufficient to change the existing color, turbidity, or other conditions in the receiving stream to such a degree as to create a public nuisance, or in amounts sufficient to interfere with any beneficial use of the water".

Phosphorus and nitrogen are indicated as the prime cause of algae blooms in LVB and it is recommended that removal of all waste discharges be considered.

The following contributions of pollutants are given for the various sources in LV Valley.

	Nitrogen	Phosphorus	T D S
City of L V %	52.4	68.2	22.8
Clark C. %	29.0	31.4	15.0
B M I %	16.4	-	56.8
Total %	97.8	99.6	94.6

Two suggestions are made to correct the pollution problem in Lake Mead.

1. Collect and dispose all highly mineralized industrial wastes by evaporation in impermeable ponds.
2. Reduce nitrogen and phosphorus levels in municipal waste effluents. The statement is made, however, that available technology is not capable of meeting 1980 standards for LVW.

T D S and sulfate concentrations in L. Mead and the lower Colorado R. presently exceed the recommended limits specified by the Federal Drinking Water Standards.

The T D S discharged from LVW increase the T D S in the Colorado R. at Hoover Dam by 10 mg/L. Estimated detrimental effect or downstream users $670,000/yr.

A statement is made on P. 21 that Algae growth potential tests demonstrated that phosphate concentrations limited algae growths in Lake Mead and the Colorado R. throughout the year.

With respect to the lower Colorado R., the major concern seems to be T D S.

An interim regional treatment plan has been adopted by the State of Nevada and accepted by E P A. This plan includes valley-wide collection of municipal wastes, a regional waste treatment facility providing a high degree of nutrient removal, and discharge of treated effluent to the Colorado R. below Hoover Dam.

The T D S load imposed on LVW by BMI seepage averages about 300,000 pounds per day or about 57 percent of the total carried to L V B.

Cooling tower blowdown from the Sunrise and Clark power plants total about 0.5 mgd and carry about 3500 mg/L TDS.

The Nevada water quality standards for LVW (Table A-4) are in many respects more stringent than those for Lake Mead (Table A-1).

COMMENTS

The introduction to this report claims that municipal and industrial wastewater discharges to LVW are deleterious to the health or welfare of persons living in AZ., CA., and NV. This is a very far-fetched statement which has little foundation - in fact, except to those who use the upper reaches of LVB for recreational purposes. To my knowledge, no suits are pending in which CA. or AZ. are claiming damage of any sort due to drainage from LV Valley. Diversions at Parker are still being made to satisfy the thirst of Southern Californians and diversions are still being made at Imperial Dam to grow crops in Imperial Valley. With regard to Arizona, it still uses water from the Colorado for water supply and irrigation purposes at Yuma. In addition, the State of AZ. is pressing forward with construction of its Central Arizona Project to supplement agricultural supplies and public water supplies for Phoenix, Tucson, and other cities.

No evidence was presented to support the statement that waters downstream of Hoover Dam have a higher AGP than L. Mead has upstream of Las Vegas Bay. This is a definite possibility, however. A more profound statement would relate the AGP to that of the waters of Boulder Basin, or of Boulder Basin to upstream L. Mead.

The water quality standards for L. Mead agreed upon by AZ., NV., and the Federal Government are classical. As originally written they did not involve secondary effects such as Algae blooms. The last phrase - "in amounts sufficient to interfere with any beneficial use of the water" - is something upon which anyone can develop an argument. At the present time, it would appear that the upper LVB is the only area in which beneficial uses are impaired. The Las Vegas Valley Water

District System has been in service too short a time to establish any trends.

The recommendation that all wastewater discharges be isolated and diverted to some site for evaporation in impermeable holding ponds is, of course, the surest way of insuring that water quality conditions in LVW, LVB, and Lake Mead are met. Such a scheme, however, should be tied in with the greatest reuse of water possible in order to minimize the volume of water taken from L. Mead. This concept served as the basis of one of the early plans for disposal.

In any evaluation of the effects of wastewater discharges to LVW, one must recognize that over 80% of the nitrogen and over 99% of the phosphorus originates in municipal wastewater discharges and that over 56% of the TDS originates in seepage from the BMI holding ponds. An allied matter is the self-purification capacity of LVW this shows that the Wash serves as an important "trap" or "sink" for phosphorus and nitrogen, particularly the latter. See App. D. This is the natural way of accomplishing something useful and should be exploited to the fullest extent.

The report is somewhat contradictory. On page 3 the statement is made - "To provide maximum assurance that Algae growths in the Bay are not stimulated by waste discharges from LV Valley will require that essentially all waste discharges be eventually removed from LVB". On page 10, the recommendation is made - "Municipal wastes from the City of Las Vegas, the Clark County Sanitation District, the City of Henderson, and sanitary wastes from industrial sources be collected, treated, and discharged through a regional management system such that water quality standards for LVW, Lake Mead and the Lower Colorado R. are met". The recommendation also states that the facilities should be operated to accomplish a maximum practical removal of phosphorus and nitrogen in the waste effluent. Thus, it appears there are two choices.

On p.35 the statement has been made - "An interim regional waste treatment plant has been adopted by the State of Nevada and accepted by EPA ------This plan includes valley wide collection of municipal wastes, a regional waste treatment of facility providing a high degree of nutrient removal, and discharge of the treated effluent to the Colorado R. below Hoover Dam. Although this scheme would protect LVB and L. Mead, the introduction of such discharges into L. Mohave would cause the same problems that diversion would avoid in LVB. Such a diversion would certainly meet with strenuous legal objections from people interested in L. Mohave. Undoubtedly, their objection would be fortified by people from L. Havasu. Perhaps, even suits by CA. and AZ.

The statement is made that TDS and sulfates in L. Mead and the Colorado R. presently exceed the recommended limits specified by the Federal Drinking Water Standards. Although this is an undesirable situation it is in no way a hazardous one or an uncommon one. Wauwatosa, Wis., for example, has two wells in its system which exceed the standard. One has 754 TDS and 379 sulfate. The other has 837 TDS and 426 sulfate. There are numerous other instances: Little Rock, AK., Daytona Beach, Fl, Aurora, Ill., Galesburg, Ill with over 1000 TDS, Maywood, Ill., Kokomo, Ind., Hutchinson, KA., etc.

The statement was made that TDS discharged by LVW increases the TDS at Hoover Dam by 10 mg/L. The analysis should have gone two steps farther to state that removal of the BMI seepage would decrease the value to less than 5 mg/L and that, when corrections are made for the TDS in the water pumped from L. Mead, the actual increase would be about 2 mg/L. This is a very minor item when compared to the increase caused by evaporative losses of about 6 feet/yr from L. Mead, resulting in a 50 to 75 mg/L increase.

The statement made on p.21 that Algae growth potential tests demonstrate that phosphate concentrations limit Algae growths in L. Mead and the Colorado R. must be challenged. Experience elsewhere has shown that fertilization with domestic wastewaters always produces an excess of phosphorus. If this is not the case in L. Mead it must be because the inflowing waters from the Colorado are excessively rich in nitrogen. Data are needed on the quality of water leaving Lake Powell to prove this point.

With respect to the TDS problem in the lower Colorado R., we should not lose sight of the significance of concentration effects resulting from evaporative losses in L. Powell and L. Mead in any evaluation. This comment is not made to belittle efforts to control sources of high TDS waters such as those from the BMI ponds and similar point sources. This is standard practice in all parts of the world where salinity problems develop.

Cooling tower blowdowns from power generating plants are point sources with high TDS. Good practice involves isolation and evaporation from sealed ponds.

The Nevada water quality standards for LVW are extremely strict considering the fact that it serves very little use except as a wild life refuge. Presumably, the regulatory authorities have not been informed that the "old swimming hole" has been abandoned. New standards are necessary, if the self-purification capacity of this stream are to be utilized in a beneficial manner.

APPENDIX F

A MATHEMATICAL MODEL OF PRIMARY PRODUCTIVITY AND LIMNOLOGICAL PATTERNS IN LAKE MEAD

Technical Rpt. No. 13, Hydrology and Water Resources, Sept. 1972
University of Arizona, Tucson, AZ.

This report is essentially the doctoral dissertation of one Lorne G. Everett and suffers to some degree from the usual enthusiasm displayed by doctoral condidates. It attempts to apply mathematical precision to highly variable biological phenomena, employing biological productivity rates (ppr).

The report makes note of the great increase in TDS that has occurred in the Upper Colorado R. over the past several years. A summary of the data is as follows:

Average TDS Over 5-year Periods

	Green River	Lee Ferry	Grand Canyon	Hoover Dam
1960 - 64	308	715	778	692
1966 - 70	347	604	665	734

Figure 1 of this report shows major salt springs on the Little Colorado and Virgin Rivers, the former contributing 547,000 and the latter 133,000 tons/yr.

The Author contends that photosynthesis increases towards Hoover Dam in opposition to findings of other investigations.

The following data were presented to show sources of water flowing into Lake Mead.

	Colo. River	Virginia R.	Muddy R.	LVW
cfs	15,200	246	38	31
%	98	1.5	0.3	0.2

Sampling stations were established at 8 locations covering essentially the entire area of L. Mead. They were as follows:

Las Vegas Bay	Echo Bay
Bureau of Reclamation Raft	Overton Arm
Beacon Island	Temple Bar
Bonelli Landing	South Cove

Surveys were conducted on seven occasions starting in September 1970 and repeated at one or two month intervals through June of 1971, except for a final one in January 1972.

On p.62, the statement is made - "Chlorophyll samples at 5 and 30 meters were taken. Two milligrams of magnesium sulfate were added to 1,000 ml water ------".

Chemical analysis was performed on samples kept in dark bottles with no preservative. No mention made of time lapse.

Carbon 14 was used as a tracer employing the light and dark bottle technique, in situ.

On p.69, the following statement is made - "The temperature range was 10.1 to 28.4 deg. C, with November, January, and February temperature profiles showing the isothermous nature of the Lake during winter turnover. It is at this time that nutrients released in the anaerobic hypolimnetic layers of summer are brought to the surface.

During the September survey, the highest concentration of TDS was not supported by electrical conductivity data as given in Fig. 23.

"The ortho-phosphates found in L. Mead fall in the range of an oligiotrophic lake (0.1 to o.3 ppm)" p. 76.

"The nitrate values are much higher in September and November. There is no increase or decrease across the system; therefore, the Colorado R. is responsible for introducing these high levels. Excessive nitrogen is available at all times of the year."

"Sulfate levels consistantly increase by 60 ppm across L. Mead. This is a result of extensive chemical action in the reservoir".

On p. 93, the lake is classified on the basis of Keratella populations. He states - "The numbers present at Las Vegas Wash are extremely high when compared to the entire lake. In fact, the whole Basin including Beacon Island and the Bureau of Reclamation Raft show the effect LVW has on Boulder Basin." "These graphs may not prove that Boulder Basin is polluted but they do point out that the Basin is significantly more productive than the rest of the reservoir".

"Asterionella thrives very well in polluted waters. High numbers at South Cove tell us that Asterionella are taking full advantage of the nutrients flowing in from the Colorado R. Another population pulse at LVW is a result of enriched waters."

Data in Fig.45 shows peak Algae growth rates in Sept.

Two major sources of pollution were concluded from the ppr data. LVW was the major source of pollution to L. Mead. The 3 locations in Boulder Basin indicated that the pollution source at LVW had affected the whole Basin. In fact, the Bureau Raft, which is the station closest to Hoover Dam, shows ppr rates higher than Las Vegas Bay."

On page 136 - "All our data have shown that Boulder Basin is highly polluted and the rest of the L. is in an oligotrophic state". "There is strong evidence that HCO_3, SO_4 and PO_4 levels are the major elements controlling the ppr."

COMMENTS

The TDS shown for the Colorado R. From Green L., WY. to Hoover Dam are rather interesting. In the 5 year period prior to development of L. Powell, the data show a decrease from Lee Ferry to Hoover Dam. This is probably a result of the flashy flow then occurring and poor sampling. In a 5 year period following, a gradual increase occurred. The increase from Grand Canyon to Hoover Dam averaged 69 mg/L which is in agreement with anticipated increase from evaporation.

The data presented in Figure 1 showing major sources of salt to the Colorado R. is highly significant. The 547,000 tons/yr contributed by the Little Colorado R. and the 133,000 tons/yr from the Virgin R., for a total of 680,000 tons/yr make the 300,000 lb/da = 54,750 tons/yr from BMI seepage seem rather small, since it is only 8% of large upstream sources.

Before discussing the various technical aspects of this report it seems pertinent to point out that only 8 sampling stations were established in the entire L. Mead area of approximately 158,000 acres or 247 sq. mi. Only one of the stations was established in Las Vegas Bay and it was about 2.5 miles from the entrance of waters in LVW. With what is now known about the density current formed by LVW waters as they enter LVB, it seems quite certain that samples collected at Sta.1 in LVB were more typical of Boulder Basin Water than of the upper reaches of LVB. For this reason, generalizations made in the report concerning LVB and Boulder Basin Waters must be viewed with a good deal of skepticism.

Although the author was quite critical of the EPA for using Chlorophyll "a" as a parameter of biological productivity, he included it in his items of study. Details of methodology on p.62 indicate that samples for Chlorophyll "a" determination were collected at 5 and 30 meter depths and treated with 2 mg/L of magnesium sulfate. Just what benefit such a small amount of magnesium sulfate would have is not clear. Magnesium carbonate in much larger amounts, is normally used.

A serious limitation of the chemical data is related to the fact that the samples were not preserved. No mention is made as to whether the samples were iced or to the time span between sampling and analysis. The chemical analysis for many items is highly suspect.

Primary productivity rates (ppr) were determined using carbon 14 tracer technique in light and dark bottles. The light and dark bottle method is quite controversial but was the logical choice for the field studies in this case.

On p.69, mention is made of nutrients being brought to the surface waters from the anaerobic hypolimnion during the fall overturn. This statement is in error as the hypolimnion in L. Mead does not become anaerobic. The lowest oxygen tensions are found in the thermocline but seldom, if ever, does the oxygen level reach zero.

On p.76, the statement is made that ortho-phosphate levels (0.1 to 0.3 ppm) found in L. Mead fall in the range of an oligiotrophic lake. If such high levels occur the lake would be eutrophic Oligiotrophic lakes fall in the range of 0.01 to 0.03 mg/L. The data in Fig.27 confirm this. Thus, the original statement is in error.

Nitrate values were found to be much higher in September and November. This statement appears incongruous in view of the fact that September in particular is a month of maximum biological productivity. The statement is made that excessive nitrogen is available at all times of the year. Serious questions can be raised concerning the nitrate analyses because of the manner in which samples for chemical analyses were handled.

The statement is made that sulfates consistantly increase by 60 mg/L across L. Mead. The data in Figure 32 do not support such a conclusion. For example during Sept. 1970 the sulfate level was fairly uniform at all stations except Station H and was reasonably uniform at all stations during the Jan. 1971 survey except the upstream stations of Temple Bar and South Cove. The explanation offered that sulfates are generated in the lake is impossible by the mechanism suggested.

The author makes rather "sweeping" conclusions about the biological productivity of LVB and Boulder Basin based upon the numbers of a single zooplankter - the rotifer Keratella. This is the first time in my experience that anyone has ever used zooplankter as a"pollution" indicator. A summary of primary productivity rates as measured by C-14 studies is given in Fig.42. Two studies showed maximum productivity at Sta.1 in LVB, two showed maximum at Hoover Dam and on one occasion the rates were about the same. Again these data must consider the location of the LVB station. Had it been 2 miles farther upstream, the results could have been totally different.

Two major sources of pollution were concluded from the ppr studies: LVW and one in the vicinity of South Cove. LVW was claimed to affect all of Boulder Basin including the area around Beacon Island. On p.136, he states: "All our data have shown that Boulder Basin is highly polluted and the rest of the Lake is in an oligiotrophic state. There is strong evidence that HCO_3, SO_4 and PO_4 levels are the major elements controlling ppr". All it can say at this point is - if ppr leads to conclusions presented in this report, then we can be thankful we have eyes to see, noses to smell, ears to hear and, hopefully, some common sense for judgment.

APPENDIX G

"INTERRELATIONSHIP BETWEEN CHEMICAL, PHYSICAL AND BIOLOGICAL CONDITIONS OF THE WATERS OF LAS VEGAS BAY AND L. MEAD."

The University of Nevada-Las Vegas No date Rec. 5/11/73

The first 27 pages of this report deal with Methodology of sampling and counting of microorganisms and is highly acceptable.

Sixteen stations were established for this study: One in LVW at North Shore Bridge, fourteen in LVB and one in Boulder Basin near the water intake at Saddle Island.

WINTER SEASON

Studies conducted during Jan. and Feb. showed that the cold waters entering from LVW developed a density current which was readily detected thermally at Sta. 1 with a max. depth of 3 meters but was not at Sta. 2 at a depth of 13 meters. Oxygen data were essentially uniform with depth. A considerable variation in conductivity was found at various depths at some stations on some occasions but not on all sampling dates at the same station. A wide variety of phytoplankton consisting mainly of diatoms and green Algae were present in modest numbers. No chemical data.

SPRING SEASON March, April & May

The temperature profiles showed that a slight degree of stratification was evident on March 6 and was well developed by March 20 at about 20 feet. By May 30 the epilimnion was about 30 feet deep. There was definite evidence of some oxygen depletion in the thermocline. The conductivity data showed some variation at different depths but not nearly as radical as during Jan. & Feb. Again phytoplankton were quite diverse consisting, primarily, of diatoms and green Algae. Populations were very moderate.

SUMMER SEASON June, July, August, September

A negative heterograde oxygen profile developed during May and June, with oxygen concentrations lowest in the 20-30 meter region (60-100 ft). Degree of oxygen depletion appeared to be correlated with surface plankton populations and with fish (shad). On July 24, highest conductivities were found about mid-depth at Station 1, 2, and 3 in upper part of LVB but not at Sta. 4.

During June large populations of a colonial green Algae appeared. This was followed by blooms of Cyclotella and Anabaena, a blue-green Alga. Anabaena was first noted in the inner bay. The order of plankton succession is normal.

FALL SEASON October, November

By early November, the thermocline had descended from 10 to 15 meters in the summer to 35-45 meters. As the epilimnion descended, plankton counts decreased and the Bay took on the aspects of being oligiotrophic. For brief periods during the return to complete mixing, the sediment surface may show oxygen depletion as the lowering thermocline intercepts the bottom.

NUTRIENT ENRICHMENT

A series of studies were made with surface and bottom samples from LVB to determine what nutrients might be limiting to plankton growth. Nitrate was found to be the most limiting during the late spring, summer, and fall seasons.

Pigment analyses - Chlorophylls a, b, c and carotenoids - were made on samples from the inner, middle, and outer LVB. The data for Chlorophyll "a" showed much higher values for the inner bay and least in the outer bay.

The total phosphorus data in Table 33 appear entirely too low to have any validity.

A number of oxygen profiles were developed for Sta. 14 in LVB and and at a number of other widely scattered stations, including Overton Arm, Boulder Canyon, Virgin Basin, Temple Basin and Boulder Basin. In essentially all cases some oxygen depletion occurred in the thermocline. It was most serious, however, in LVB and Boulder Basin where values as low as 0.03 mg/L were observed.

Vertical distribution of nutrients is shown for Sta. 14 on Aug.22. These data, as do others, show low values of the prime nutrients, nitrogen and phosphorus, in the surface waters and maximum values at 20 meters when maximum depletion of oxygen occurred. Large populations of small shad were found at this depth. The shad "layer" followed the fall of the thermocline as it descended in late summer and fall.

The biological productivity of the inner, middle, and outer areas of LVB is illustrated very effectively in Fig. 56 for all seasons of the year.

The suggestion is made that inner LVB in eutrophic on the basis that it supports blooms of *Anabaena*, according to Hutchinson and Rawson, two accepted authorities.

On page 179, the statement is made - "Cessation of inflowing water from Las Vegas Wash will certainly mediate the entrophic character of the inner bay. Very probably the same result would come from dispersing the effluent farther into the Bay or into Boulder Basin".

COMMENTS

This study substantiates that inflow from LVW can enter LVB as a density current. It was readily detected at Sta. 1 but not at Sta. 2. This may have been because Sta. 2 was not directly over the old stream channel. A sonic depth finder would be required to locate the old stream bed.

COMMENTS

The conductivity data of January and February indicate that great masses of high conductivity waters occur at various depths and locations in the inner bay during the winter season. This seems like a very unlikely situation and confirmation is required.

The low populations of phytoplankton during the winter indicate a relatively low degree of fertilization.

The spring data are significant because they show that the pools of high conductivity waters have been well dispersed.

The summer season data are highly inportant because they show that oxygen depletion is greatest in the thermocline at a depth of 60 to 100 feet. It is important to note that this condition occurs at most locations throughout L. Mead. The condition does appear to be most serious in LVB and Boulder Basin, however. This has definite implication regarding inflow from LVW.

The presence of the blue-green Algae Anabaena has more than a little interest for three reasons: 1. It is a known tast and odor producer in water supplies. 2. It is capable of fixing nitrogen from dissolved nitrogen (air) in the water when sources of ammonia and nitrate become scarce in water. 3. Blue-green Algae, in general, are shunned by fish as food.

The report develops one concept that is not well understood by all limnologists. That concerns the declining depth of the thermocline during late summer and fall, as nights become cooler and surface waters are cooled. During this period, more and more deep water is brought into circulation in the epilimnion and, where the deep waters are nutrient rich, fall blooms of Algae are stimulated. Contact of waters in the thermocline devoid of oxygen with bottom deposits could create anaerobic conditions in the muds and result in release of large amounts of ammonia, phosphorus, iron and manganese. The latter would be a serious factor in water supplies.

be a serious factor in water supplies.

The studies on nutrient enrichment led to the conclusion that plankton growths in LVB are limited by the amount of nitrogen present. This is not unexpected because the waters entering from LVW are exceptionally rich in phosphorus as compared to nitrogen. This is not a serious matter, however, except in the presence of nitrogen fixing blue-green Algae. The presence of Anabaena is cause for alarm. Studies are needed to determine whether those in L. Mead have the capability of fixing nitrogen. Gleotrichia, Aphanizomenon and Nostoc are other blue-green Algae capable of nitrogen fixation. Fortunately, their presence has not been reported in L. Mead.

The pigment analyses for Chlorophyll "a" confirmed that plankton growths are most prolific in the inner LVB and growths decrease toward the outer bay. This result was not unexpected and substantiates what recreational users of the Bay have known for a long time. I would like to state that the headwaters of the Bay were in much better condition than I had anticipated on my visit, Sept.3, 1976. I am positive that the density current has a great modifying effect. In this regard the BMI seepage with its high TDS, most likely, has a beneficial effect by disappearing into the deep waters.

The total phosphorus data in Table 33 are much more indicative of soluble phosphorus levels. I can not accept them as representing true conditions. Determinations of phosphorus at the levels encountered in lake waters of reasonable quality are among our most difficult.

The presence of large numbers of very small shad in the low dissolved zone of the thermocline is an interesting observation. Such numbers as were found would have a considerable oxygen demand as they consumed phytoplankton coming within their reach.

Their activity, most likely, accounts for the high levels of ammonia and phosphorus found in this zone, as shown in Fig. 51.

No one can quarrel with the statement that "cessation of inflowing waters from LVW will certainly mediate the eutrophic character of the inner bay." But one can disagree with the statement: "The same effect could be brought about by dispersing the waters farther into the Bay or into Boulder Basin." Such an action would protect the inner bay at the expense of the rest of the lake. Certainly, the potential for producing Algae would not change. It would, however, exert its influence over a greater area and be less noticeable. Such a practice, if feasible, could have serious effects upon the local water supplies and cause increased problems in L. Mohave. It would postpone the date for needed correction but never solve it.

APPENDIX H

LAKE MEAD MONITORING PROGRAM

James E. Deacon, University of Nevada, Las Vegas - No date

This report, following an introduction and summary, consists of a series of twelve papers, some of which have no bearing upon the vital issues concerned with L. Mead. This report was superceded by one of the same title under date of July 1976. Since much of the material contained in this report is repetetive, my comments will be restricted to new information presented or changes in interpretation. The report is based upon 6 new stations as follows: 1. LVW, 2. Inner LVB, 3. Middle LVB, 4. Outer LVB, 5. Near water intake at Saddle Mt., 6. Boulder Basin.

SUMMARY

"Phytoplankton and Zooplankton respiration are the primary causative agents of the metalimnetic oxygen depletion". This is a change as previous reports had given shad credit.

"Although phosphorus and nitrogen loading has increased, phytoplankton numbers and biomass have decreased since 1972".

"The early summer pulse of Cyclotella has declined since 1972 and has been accompanied by an increase in the Anabaena population".

PHYSICAL AND CHEMICAL CHARACTERISTICS OF LAKE MEAD

Methods - Dissolved phosphorus was added to list of analyses. This is an important additive.

Conductivity - "Conductivity was generally constant at 1100 microhoms/cm and did not change vertically except in LVB Sta 2 & 3".
This is radically different from data discussed in my Appendix G.

EFFECTS OF LAS VEGAS WASH ON PHYTOPLANKTON POPULATIONS IN BOULDER BASIN, LAKE MEAD, NEVADA

Fig.4, p.34, shows definite decrease in phytoplankton from 1972 to 1975 as measured by Chlorophyll "a" and cell volume.

Mean daily primary productivity in L. Mead from April 1974 through March, 1975 showed marked differences between LVB and Boulder Basin stations as follows:

Station	Location	gc/m^2/day
2	Inner LVB	8.30
3	Middle LVB	5.34
4	Outer LVB	3.83
6-8	Boulder Basin	2.65

These results should be compared with those of Everett App.F.

The concept of nitrogen to phosphorus ratios is introduced on P.45 and in Table 10. The data in Table 10 show very low ratios at Sta.2 but gradually increasing values at Sta.3 , 4, and 6. These data would seem to indicate that nitrogen fixation by Anabaena would probably be limited to LVB.

ZOOPLANKTON COMMUNITY OF BOULDER BASIN

Peak zooplankton concentrations were found in the thermocline (metalimnion) of Boulder Basin. Rotatoria, Cladocera and Copepoda predominated. No special significance can be attached to the presence of these organisms other than that they feed upon Algae and the thermocline seemed to be a favorite place for that.

METALIMNETIC OXYGEN DEPLETION IN LAKE MEAD

High concentrations of copepods and cladocerans were always found in the zone of oxygen depletion and total numbers always declined below 30 meters.

"Oxygen transport and oxygen 'visibly' lost in the metalimnion during summer stratification were calculated from data presented in Table 18. Estimated zooplankton and phytoplankton respiration accounted for 57 to 94% of the total amount of oxygen lost during this period."
The latter statement makes no reference to shad as being a major factor.

"Echograms showed large concentrations of shad within the metalimnion during the early morning. The shad were dispersed throughout the epilimnion in the afternoon and were concentrated in a narrow band at the surface nocturnally. While these organisms were present within the metalimnion either in low numbers or for short periods of time, their respiration would result in further loss of oxygen from the area.

"Phytoplankton and zooplankton communities in L. Mead are not strikingly different from other eutrophic lakes. The primary factor resulting in the negative heterograde oxygen profile is the deep hypolimnion and minimal oxygen uptake of the mud water interface."

COLIFORM BACTERIA IN LAS VEGAS WASH AND LAS VEGAS BAY

"Samples collected in LVW from Sunrise Power Station to the convergence of LVW with LVB resulted in relatively low fecal and total coliform counts." The data demonstrate the benefits of natural die-off during travel in LVW. Numbers found in LVB were far below any normal standard for bathing beaches. They range from 1000 to 3000/100 ml in various parts of the country. Those coliforms present in LVB could easily be due to waterfowl excreta.

DISTRIBUTION OF ENTERIC BACTERIA IN LAS VEGAS BAY

"The results also provided an excellent picture of the enteric bacteria actually present, a result quite significant for a public health evaluation. For example, consider the high numbers of Klebsiella Pneumoniae, a known pathogen present in the wash. From a public health point of view it is fortunate that greater than 50% of these organisms are sedimented out at the convergence of LVW with LVB. Also it is equally important that large numbers of dysentary (Shigella) and enteric fever (Salmonella) bacteria were not found."

The persistent reference to the public health aspects of Klebsiella pneumoniae, Shigella and Salmonella is somewhat disturbing, since on p.101 a statement is made that K. Pneumoniae is found in association with root systems and as previously pointed out, Salmonella are known to be carried by rodents, particularly mice.

Because of the large numbers of birds and animals inhabiting LVW it seems pertinent to investigate the role they play in contributing enteric organisms to the waters. To assume that enteric organisms found in LVB are traceable to the domestic wastewater discharges from the LV and Clark Co. sewage treatment plants is extremely speculative and ignores basic knowledge of disinfection and die-off under natural environmental conditions.

IDENTIFICATION OF ENTERIC BACTERIA IN WATER SUPPLIES

No Comment.

WATER QUALITY STANDARDS NORTH SHORE ROAD

The establishment of water quality standards at North Shore Road seems rather incongruous for two reasons: 1. The station is so remote from the Las Vegas and Clark County STP'S dominat effect over which man has little control, except to provide channelized flow in the Wash. 2. The fecal coliform level is entirely too strict because of uncontrollable sources from animals in LVW and is far below any standard for bathing beaches.

APPENDICES

Some of the most important data presented in any of the reports reviewed is hidden in the Appendix to this report. This pertains to the data on dissolved phosphorus, ammonia nitrogen and oxidized nitrogen (NO_2 + NO_3) at the station in LVW, three stations in LVB and two in Boulder Basin. Samples were collected on 16 occasions from April 28 through February 19.

Station 1. This station was located in LVW. All samples were rich in dissolved P, highly variable in ammonia nitrogen, and generally rich in oxidized nitrogen. The samples are representative of the waters entering LVB, usually as a density current.

Station 2. This station is in inner LVB.

Samples were collected at 0 and 10 meter depths. In general, very adequate supplies of dissolved phosphorus were present to support any type of phytoplankton in the surface waters. On May 28 and, in general, until October 30, ammonia and oxidized nitrogen levels were sufficiently low to allow nitrogen fixation by blue-green Algae.

At the 10 meter depth, the dissolved phosphorus levels were more than adequate, with the exception of May 28, to support extensive blooms of all types of phytoplankton. The same was true for inorganic nitrogen (ammonia plus oxidized forms), except for the period of August 28 through October 30 when nitrogen could be considered limiting. During this period of Aug. 28 to Oct. 30, nitrogen fixing blue-greens could have prospered at the 10 meter level.

Station 3. Station 3 was located in middle LVB

Samples were collected at 0, 10, 20, 30, and 40 meters. Dissolved phosphorus supplies were more than adequate at the 0 and 10 meter depths on all occasions except May 28, Aug. 28, Sept. 10, Sept. 17 and Oct. 2. On these dates it could have exerted a limitation on Algae growths. At these depths, inorganic nitrogen could have exerted limiting effects from June 17 through October 30 with exception of Aug. 19. From this we can conclude that opportunity for nitrogen fixation was present through June, July and October.

The samples at depths greater than 10 meters were all rich in dissolved phosphorus and inorganic nitrogen until Oct. 30 when the epilimnion had descended past the 20 meter level. By December 22, dissolved phosphorus and inorganic nitrogen were quite uniform from 0 to 40 meters.

Station 4. Station 4 was located in the extreme outer fringe of LVB

Samples were collected at 0, 10, 20, 30, 40 and 90 meters Dissolved phosphorus could be considered limiting at all stations at the 0 and 10 meter depths, except on Apr. 28, Aug. 18, Sept. 17 and Jan. 29. Inorganic nitrogen could be considered limiting at both depths from June 27 through Nov. 20. There is some possibility that nitrogen fixing blue-greens could have grown during this period.

Station 5. Station 5 was located near the water intake at Saddle Island.

Samples were collected starting May 9 and continuing through Feb.19 at 0, 5, 10, 15, 20, 30 and 45 meters.

Dissolved phosphorus was very low in all samples collected at 0, 5 and 10 meters from Jan. 27 through Nov. 20. Inorganic nitrogen was also very low until Oct. 30. There is only a slight possibility that nitrogen fixing blue-greens could thrive at this station because of the very low dissolved phosphorus values during the entire summer and fall seasons.

In general, the deep water samples collected at this Station were quite low in dissolved phosphorus - June through October but oxidized nitrogen was in good supply at depths below 15 meters.

Station 6. Station 6 was located in Boulder Basin near Sentinel Island.

Samples were collected at 0, 10, 20, 30, 40, 90, and 130 meters.

Dissolved phosphorus levels were very low at all depths through 30 meters until Jan 29. Inorganic nitrogen levels were essentially depleted by June 27 down to 10 meters depth but were abundant at 20 meters and below until Oct. 30, when the epilimnion had penetrated below the 20 meter level. It is very questionable whether nitrogen fixing Algae can thrive in the region of Station 6 because of the low dissolved phosphorus levels.

COMMENTS

In my opinion, the most significant information of all the reports reviewed is contained in Appendix 1 of this report. The data show quite positively the fertilization effects of the inflowing waters of LVW upon L. Mead, particularly LVB.

The dissolved phosphorus and inorganic nitrogen data indicate that conditions in LVB, the inner and middle bays in particular, are conducive to the development of extensive blooms of Algae and, under summer and fall conditions, the potential exists for blooms of nitrogen fixing blue-greens. Since Anabaena blooms are claimed to be becoming more serious in L. Mead, it is quite likely that they are fixing nitrogen when phosphorus is available and available inorganic nitrogen reaches very low levels. Both conditions exist in the euphotic zone in LVB for extended periods in the summer and fall.

APPENDIX I

DR. DEACON'S PRESENTATION TO THE SEWAGE AND WASTEWATER ADVISORY COMMITTEE - JULY, 1976

On page 6, reference is made to Vollenweider"s system for calculating permissible nutrient loadings on lakes and from it draws the conclusion that 2000 lb/da of phosphorus could be "dumped" into Boulder Basin without harm. Even if this were true, it would not be desirable. At the present time, much smaller amounts are reaching LVB via LVW and are causing problems in LVB and, possibly elsewhere.

The point which Dr. Deacon makes on p.7 with reference to nitrogen to phosphorus ratio of 8 to 1 in living organisms is an important one. The ratio determines the type and nature of phytoplankton blooms as he discusses. The most important point is that, when the ratio falls below 8 to 1, phosphorus is present in excess and nitrogen fixing Algae can thrive. It is not correct to say that blue-green Algae are nitrogen fixers. Rather, a correct statement is that certain blue-green Algae are capable of fixing nitrogen when available nitrogen approaches zero.