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REPORT OF THE PENSACOLA DAM IMPOUNDMENT OF THE GRAND RIVER WITH SPECIAL REFERENCE TO FISHERY PROBLEMS IN THE COMPLETED RESERVOIR

by

M. M. Ellis

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This is the fourth in a series of mimeographed Special Scientific Reports, published in limited quantities for the official use of Federal offices and cooperating agencies. Previous reports in this series are as follows:

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REPORT ON THE PENSACOLA DAM IMPOUNDMENT OF THE GRAND RIVER WITH SPECIAL REFERENCE TO FISHERY PROBLEMS IN THE COMPLETED RESERVOIR

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INTRODUCTION

The surveys of the area to be flooded by the impoundment back of the Pensacola Dam now under construction across the Grand River near Disney, Oklahoma, and of the various streams tributary to this reservoir, as reported here had three objectives concerning fisheries developments in the completed impoundment, namely, the determination of (1) the character of the waters which will be impounded, (2) the water conditions which may be expected within the reservoir, and (3) the most feasible methods for offsetting the rapid decline in fish productivity which usually occurs in such impoundments 3 to 7 years after the reservoir is filled for the first time.

The field studies supplying the data for this report were made during April, May, June, and early part of September, 1939, by three field parties (seven observers in all) from the U. S. Bureau of Fisheries Laboratories at Columbia, Missouri. These groups using laboratory trucks carrying equipment for the necessary field analyses followed the Neosho River and its tributaries south from Emporia, Kansas, Spring River west and south from the Joplin district in southwestern Missouri, and the headwaters of Sycamore and Elk Creeks west from southern Missouri into the area to be covered by the impoundment. All of the small streams and creeks entering this area were surveyed at points which will be near the shoreline of the complete reservoir.

Large numbers of samples were returned to the Columbia (Mo.) laboratories for assays and analyses which could not be made in the field and the entire project has been supported by supplementary data on the streams of this region, collected at various seasons throughout the year during the past 5 years by the Columbia (Mo.) field unit of the U. S. Bureau of Fisheries as part of the stream pollution studies conducted by this unit in the Joplin (Mo.) -- Miami (Okla.) district.

The principal base stations at which the major studies were conducted during this survey of the Pensacola Dam impoundment are listed in table 1. From these base stations field parties worked out into the surrounding territory covering all of the larger tributary waters.

Table 1. Base stations of the U. S. Bureau of Fisheries survey of the Pensacola Dam (Okla.) impoundment area.

I. Neosho and Grand Rivers.

1. Neosho River near Emporia, Kans.
2. " " " Burlington, Kans.
3. " " " Iola, Kans.
4. " " " Chanute, Kans.
5. " " " South Mound, Kans.
6. " " " Oswego, Kans.
7. Labette Creek, south of Oswego, Kans.
8. Neosho River near Chetopa, Kans.
9. " " just south of Miami, Okla.
10. Grand River 9 miles north of Bernice, Okla.
11. " " tributaries 1 mile east of Bernice, Okla.
12. " " east of Fairland, Okla.
13. " " at Ketchum Ferry, Okla.
14. " " at Pensacola Dam near Disney, Okla.

II. Spring River.

15. Center Creek west of Carthage, Mo.
16. Chat drainage east of Dunweg, Mo.
17. " " north of Galena, Kans.
18. Spring River east of Baxter Springs, Kans.
19. Chat drainage south of Baxter Springs, Kans.
20. Spring River northeast of Baxter Springs, Kans.
21. " " east of Miami, Okla.
22. Tributary of Spring River near Quapaw, Okla.

III. East side of impoundment.

23. Lost Creek near Wyandotte, Okla.
24. Sycamore Creek south of Wyandotte, Okla.
25. Elk River between Grove and Wyandotte, Okla.
26. Honey Creek south of Grove, Okla.

WATERS TRIBUTARY TO THE IMPOUNDMENT

The waters flowing into the impoundment which will be created by the Pensacola Dam can be divided into four groups on the basis of chemical and physical characteristics, namely, (1) wet weather run-off waters entering the impoundment largely from the west (see fig. 1) between the Dam and Wyandotte, Okla.; (2) permanent streams drawing their waters from the Ozark height of land in southwestern Missouri and northwestern Arkansas either directly or via springs, and entering the east side of the reservoir between the dam and Wyandotte, Okla.; (3) Spring River which drains through its tributaries portions of southern Missouri, southeastern Kansas and northeastern Oklahoma north and northeast of Wyandotte, Oklahoma including the chat fields of the Joplin-Miami district; and (4) the Neosho River which drains an agricultural district in southeastern Kansas north of Miami, Okla.

As there are no permanent streams entering the west side of the impoundment run-off, waters from storms and snows will be poured into the reservoir from the west in an unmixed condition, that is, these run-off waters will not be diluted by stream waters. Consequently the run-off waters will vary from clear trickles following the gradual melting of snows to sudden inrushes of very muddy water sweeping down the gullies and draws during and immediately after heavy storms. Analyses of such waters show that a turbidity of 4,000 p.p.m. (parts per million) or greater may be expected at times in these run-off waters. Because of the nature of the soils in the Vinita-Miami (Okla.) area these waters also may carry some salts (chiefly sulphates of magnesium and sodium and calcium carbonate) and will have a relative acidity (pH) definitely on the alkaline side of neutrality ranging from pH 7.4 to pH 8.4.

These run-off waters will not greatly disturb conditions in the main impoundment because the volume of run-off water expected will not be large (excepting unusual storms) and the salt loads and alkalinity of these waters will be within ranges tolerated by warm-water fishes. However, the run-off waters will present definite hazards to fish life in the two large arms on the west side of the impoundment between the dam and Fairland, as there will be little current in these arms except that produced by the draw-down. Sudden inflows of muddy water into these arms, therefore, will greatly increase the turbidity of those portions of the reservoir with all of the attendant effects on aquatic life and will increase the silt deposits on the bottom of these arms to the detriment of bottom animals (an important item of fish food) and such fish nesting grounds as may be developed in these lateral portions of the impoundment.

The physical and chemical characteristics of the waters flowing into the impoundment from the permanent sources have been reviewed together for the sake of comparisons. The dissolved oxygen in the waters of the flowing portions of the Neosho, Spring and Elk Rivers, and in Honey and

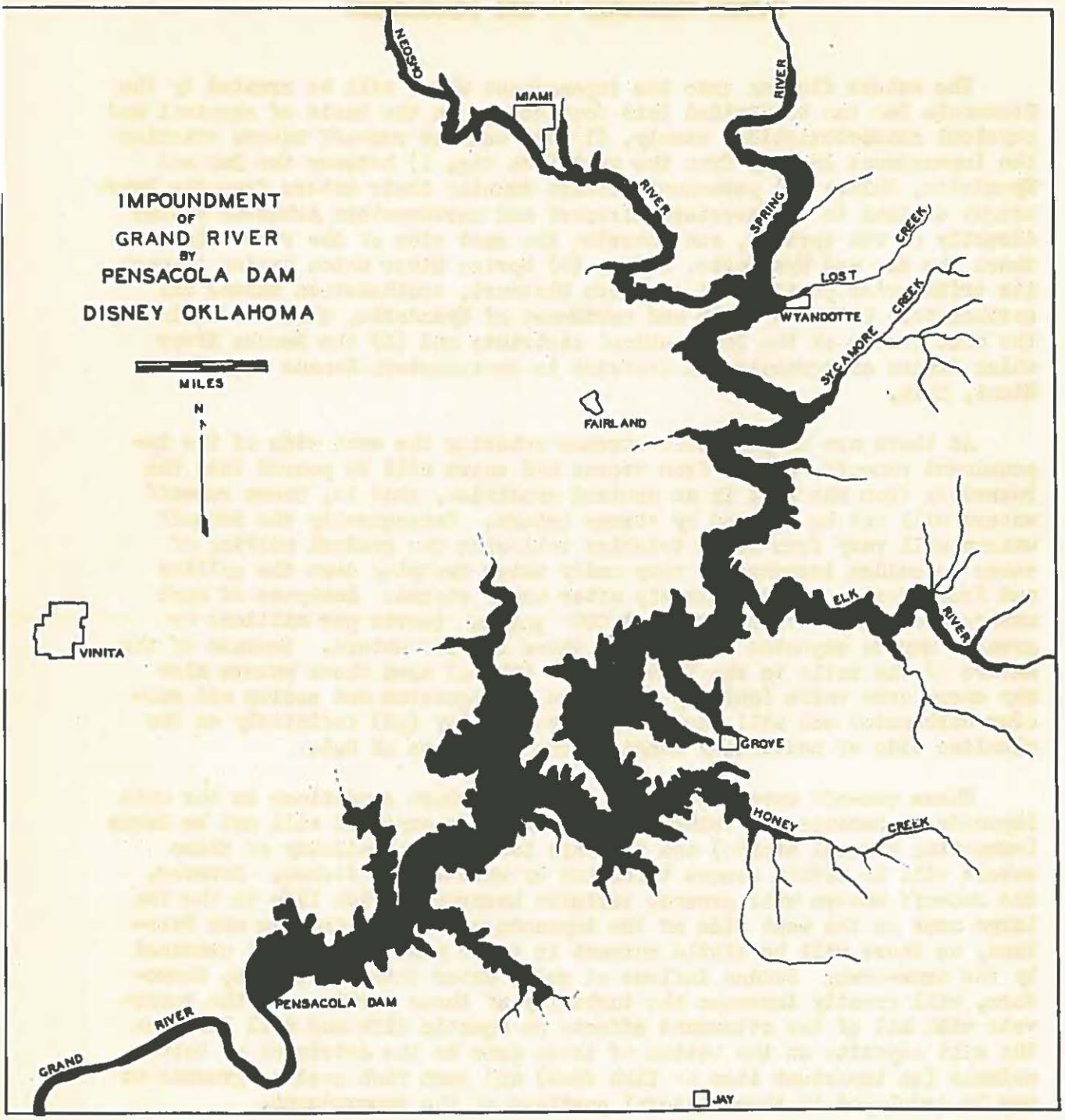

Figure 1. - Map of the water-impoundment areas created by the construction of Pensacola Dam.

Sycamore Creeks was found to be greater than 5 p.p.m. in the winter, spring and early summer samples, and 5 p.p.m. dissolved oxygen are adequate to support a good fish fauna, (Ellis, 1937; National Resources Committee, 1939).

During mid-summer the dissolved oxygen in the Neosho River, the waters of which become quite warm, falls below 5 p.p.m. in the deeper and slower parts of the stream. Values below 4 p.p.m. were found at various points in the Neosho River including the station between Miami and Wyandotte, Oklahoma, which station will be near the upper reaches of the impoundment when it is filled.

These values for dissolved oxygen show that during the warm summer months the Neosho River will bring into the reservoir barely enough oxygen to support a desirable fish fauna for as the dissolved oxygen content of water drops from 5 p.p.m. to 3 p.p.m. conditions rapidly become unfavorable to hazardous for even warm-water fishes.

The load of organic matter of natural origin, i.e., plant and animal detritus -- not sewage -- carried by the Neosho River in southeastern Kansas is moderately high for a flowing stream, approaching pond or small lake values, but without, however, any excessive oxygen demand. This organic matter will be an asset in the completed impoundment as it will contribute to the production of plankton by supplying some nitrogenous material and small quantities of phosphates. However, in view of the rather low amount of dissolved oxygen carried by the Neosho River during mid-summer the organic load of this river can not be greatly increased without depleting the supply of available dissolved oxygen.

As long as the present balance of organic matter is maintained the dissolved oxygen contributed by the Neosho River to the Pensacola impoundment should remain above the critical low level of 3 p.p.m. However, should additional sewage or organic wastes either municipal or industrial be poured into the Neosho River from Emporia, Kans., southward (i.e., from Emporia, Burlington, Iola and Chetopa, Kans. and Miami, Okla.) serious conditions as regards fisheries in the completed impoundment could easily arise, as the present differential between the oxygen demand and the amount of dissolved oxygen carried by the waters of the Neosho River in mid-summer is very small.

The seasonal variations in the dissolved oxygen carried by the waters of Spring River, Sycamore Creek, Elk River and Honey Creek showed that these waters will reach the impoundment in satisfactory condition as regards dissolved oxygen, since the flowing portions of these streams when undisturbed by other factors carry in general 5 p.p.m. or more dissolved oxygen throughout the year.

The dissolved oxygen carried by the present Grand River between Wyandotte, Okla. and the Pensacola Dam (not closed when the samples were

taken) varied over much the same range as the Neosho River, although the dissolved oxygen began to drop as early as April in the Grand River where values as low as 3.8 to 5.3 p.p.m. were noted in the deeper and slower portions south of Fairland, Okla. These findings in the portion of the Grand River which is to become the main basin of the deep reservoir suggest that the higher oxygen content of the waters from the east side of the impoundment and from Spring River, when that stream is flowing normally, do not offset the oxygen demand produced by the organic matter contributed by the Neosho River.

In table 2 the summarized findings on relative acidity (pH), specific conductance (dissolved ionizable material) and methyl orange alkalinity (essentially total carbonates) are presented because the study of these

Table 2. Summarized values giving range of certain water characteristics of the major streams tributary to the Pensacola, Oklahoma, impoundment as found during U. S. Bureau of Fisheries surveys, 1939. All values are for flowing waters under average conditions.

Stream	Relative acidity (pH)	Specific conductance in mho x 10^{-6} at 25° C.	Carbonate as CO_3 parts per million (methyl orange alkalinity
Neosho River	7.6-8.4	600-700	24-50
Spring River	7.6-8.1	200-300	24-33
Chat pool waters	3.8-6.2	1150-1300	None
Sycamore Creek	7.8-8.2	180-210	42-58
Elk River	7.6-8.1	180-250	40-50
Grand River	7.7-8.2	300-420	24-36

characteristics brought out one of the major hazards to fish and other aquatic life which will develop when the impoundment is completed.

The relative acidity, dissolved ionizable material and carbonates of these permanent tributary waters are all within ranges tolerated by warm-water fishes and the values are of magnitudes expected for streams of this region. Specifically these data show slightly to mildly alkaline water with a relatively small load of salts and buffer substances. The Neosho waters carry the largest quantities of total salts and the east-side streams the largest quantities of carbonates.

The figures in table 2 take on greater significance as regards conditions which can develop in the completed impoundment when compared with the summarized data (third line of table 2) on the waters from the chat pools in the mine areas north and northeast of Miami, Okla.

Throughout the Joplin-Miami district there are many piles of chat and other rock wastes from the lead and zinc mines of this region. Some of these piles of waste are of huge proportions being comparable to small hills. In this discussion the term "chat" has been applied to these piles of mine waste because chat is a conspicuous component of these rock heaps, and not because "chat" as such is the most dangerous component of these rock wastes. In addition to the chat which is essentially a dolomitic limestone these waste piles contain varying quantities of several metallic sulphides particularly those of iron, lead and zinc, and the various break-down products of these sulphides which form when such sulphides are exposed to the combined action of air, water and weathering.

Consequently, melting snows and slow rains leach from these piles a variety of substances which accumulate in surface pools. To these waters are added the mine waters pumped from some of the active mines, and the combined mixture ultimately finds its way into the Spring River. Heavy rains flush large quantities of these "chat-pool waters" into the Spring River and on one occasion, for example in June 1939, one of the field parties noted an abrupt change in the composition of the waters of Spring River east of Miami following a heavy rain in the chat areas the night before. The total load of dissolved ionizable material rose from a conductivity of 210 mho x 10^{-6} at 25°C. to nearly 700 mho in spite of the greater volume of stream flow which the flood waters produced, and the pH changed from definitely alkaline pH 8.2, to definitely acid, pH 6.0.

In table 2 it may be seen that the pH of the waters in some of the chat pools was below pH 4.0 which is sufficient acidic in itself to kill warm-water fishes. Several small streams in the vicinity of Quapaw, Okla., tributary to the Spring River were found to have running water, draining from the chat areas, with pH 4.6 to pH 6.0. These streams contained no fish, were very low in dissolved oxygen, less than 3 p.p.m., and along the shore margins were fouled with blue-green algae; plants characteristic of many polluted waters. Laboratory tests showed that in addition to the high

acidity (due to sulphurous, hydrosulphurous and sulphuric acids) these chat-pool waters carried other ingredients toxic to fish life.

From a practical standpoint the mine-field wastes, entering the Pensacola impoundment via Spring River constitute perhaps the greatest single potential pollution hazard to fish and other aquatic life in the completed reservoir.

There is no doubt concerning the toxic nature of these chat-pool waters, both through the action of the contained acid ingredients and salts of various metals which are also present in varying quantities. Dilution and neutralization attendant on stream flow can and will eliminate large portions of these hazards under average conditions but sudden rains after long dry seasons can readily flood into the impoundment via Spring River sufficient quantities of these materials from the mine-waste fields to produce serious catastrophes in the impoundment at any time and particularly in mid-summer when the waters of the reservoir will be warm, low in dissolved oxygen, and moving slowly.

In view of findings at Elephant Butte Reservoir (Ellis, in press), Norris Reservoir (Wiebe, 1938) and Lake Mead (National Research Council, 1938) it is not at all improbable that sudden changes in the flow of Spring River will produce density currents in the Pensacola reservoir and these slugs of water from the chat fields could easily move the entire length of the reservoir on occasion with disastrous results to the fish and aquatic life of the impoundment.

EXPECTED WATER CONDITIONS IN THE COMPLETED IMPOUNDMENT.

From the studies of the water supplies, the configuration of the impoundment and the depth of the reservoir, the water conditions within the completed impoundment can be predicted with a considerable degree of certainty barring two disturbing factors, namely, (1) abrupt additions of large quantities of water from the mine fields, and (2) abrupt changes in the draw-down program at the power plant.

Assuming a rather steady and constant outflow at the Dam and no sudden movements of water into the Reservoir from Spring River and the chat fields, the impounded waters in the Pensacola reservoir will be fairly rich in carbonates, i.e., "hard" according to the classification of Birge and Juday (1911) or not much below that standard. They will range in pH (surface zone or epilimnion) from pH 7.4 to pH 8.4 in mid-summer and there will be very marked thermal and dissolved-oxygen stratification in mid-summer with a large volume of the water (below 25 to 40 feet) very low in dissolved oxygen. The draw-off currents will probably be evident as far up the lake as the first large arm on the east side (now known as Drowning Creek) or possibly up to the mouth of the Honey Creek arm; upstream in the main reservoir from Drowning Creek as far as Wyandotte, Oklahoma, much relatively dead water with low dissolved oxygen may be expected. As previously pointed out, the west side arms

also will be very sluggish and probably low in dissolved oxygen below surface zone. Marked silting in, with its attendant effects on bottom fauna and on the dissolved oxygen content of the upper portion of the reservoir during mid-summer, may be expected from the waters brought in by the Neosho River.

Collectively, these predictions for the waters of the Pensacola Reservoir define an impoundment similar in general water characteristics to many others in the United States but specifically describe a reservoir in which during mid-summer an increase in the load of organic material (sewage and organic wastes) in the intake waters, or sudden fluctuations in water level, or abrupt additions of mine waters from the Joplin-Miami area would produce serious catastrophes for fish life.

Excepting such catastrophes and even in spite of some such disasters, the fish productivity of this impoundment will be high for the first few years, probably for 5 years or more, if the history of nearby impoundments such as the Lake of the Ozarks be significant. However, the natural food supply will decline sooner or later and poor fishing will follow. Such a decline which was predicted several years ago is now actually in progress in the Lake of the Ozarks in Missouri.

This decline in light of our present knowledge can not be prevented, but fishing can be maintained at a fairly good level after the initial high productivity period has passed by combining a good restocking program with provisions for nesting sites and food for both young and adult fish. It must be remembered that merely restocking the lake after its peak of productivity has passed will not bring back fishing.

Impoundments like the Pensacola Reservoir are limited in fish food production by sheer banks in many parts of the impoundment and by the draw-down which changes water levels in lateral areas where food would naturally develop if the water level were properly maintained. To meet these conditions several plans have been proposed all more or less costly and each with its limitations. In the following section specific recommendations are made which will be helpful if the expense is justifiable to those concerned.

RECOMMENDATIONS

1. Floating nests and floating submerged brush shelters should be installed in the arms on the west side of the impoundment, in the Drowning Creek arm and possibly near the mouths of Honey Creek, Sycamore Creek and Elk River. These devices have been used with varying success at Lake Tacao in Georgia and at Elephant Butte Reservoir in New Mexico. However, they have biological limitations and require some attention from a trained fish-culturist so that both the initial construction and the subsequent maintenance must be considered in their cost. However, devices of this type are the only means which

can be recommended at present for the improvement of fisheries on the west side of the Pensacola impoundment. Whether the cost would be justified by the increased production of fish can not be stated here. Some reports on these devices are very favorable and very encouraging, others are not. Experimental tests of these devices in the Grand River impoundment might be undertaken by state authorities or by local sportsmen's clubs.

2. Low lateral dams across Honey Creek, Elk River and Sycamore Creek should be constructed near the high-water level of the reservoir to provide shallow lateral areas in which both submerged and emergent vegetation would become established free from the disturbances of the draw-off. Such areas would provide food, shelter and nesting sites for large numbers of fish, and could be developed in cooperation with the U. S. Bureau of Biological Survey as bird refuges. Lateral dams across the tributary streams on the east shore can be made productive if properly constructed and supervised. The supervision will consist not only in the stocking of these areas with proper plants and fish by a competent fishery biologist, but also in the regulation of fishing in these areas so that the productivity of the lateral impoundments may contribute to the productivity of the reservoir as a whole. The exact sites for the lateral dams should be determined by a fishery biologist and the construction should be included in the program before the reservoir is flooded. In general, as has been described elsewhere, these lateral dams should be located below, that is, on the reservoir side of the average expected high-water level of the reservoir and should impound several acres or more behind each dam. The lateral dams should not be more than 10 ft. high at the most, and depending upon local conditions probably not more than 6 ft. high. The dams should close only permanent tributary streams.

3. Restocking can play a part in the maintenance of fisheries of nearly all impoundments. However, local conditions near the impoundment are not always suitable for a hatchery. In addition, the hatchery and the restocking which it will make possible, will not solve all of the problems of the fishery-management program in the Pensacola impoundment. If a hatchery is to be built it should be constructed preferably on Elk Creek and Grand River below the dam would be an acceptable second choice. A hatchery is not recommended for the Pensacola impoundment.

4. The draw-off for power purposes should be made as near the botton of the reservoir as possible since low dissolved oxygen in the waters of this reservoir during mid-summer is indicated by the studies of the Grand and Neosho Rivers. Any mass of water below the level of the draw-off will certainly be depleted of its dissolved oxygen during the warm summer months. (Although the preceding statements cover the problem, construction already has progressed so far that the cost of changing the outlet openings would be great. It seems very probably that there will be an unusually large amount of stagnant water in the Pensacola impoundment for reasons set forth in the report. Any adjustment which will bring well-aerated water from the surface to the lower levels in the impoundment would prove beneficial to fish life, especially during the warm mid-summer months. Because of water conditions in the main tributary streams -- Neosho and Spring Rivers -- and

the pollution hazards from oil wells, chat piles, municipalities, and industrial plants in the large area draining into the Pensacola Dam, predictions for moderate to poor fishing after the initial first period of high productivity has passed seem justified. It is, therefore, a serious question whether the experiments for an extensive program of fish management will be justified in the Pensacola impoundment.)

5. Spill water, that is, water not needed for power purposes which is released for the maintenance of the Grand River below the dam, should be drawn from the bottom of the reservoir. Thus oxygen - deficient and polluted waters in the lower strata of the impoundment could be removed. (The improbability of following this recommendation was set forth in the comments under No. 4.)

6. Appropriate action should be taken now to prevent further pollution of the Neosho River by municipal or industrial wastes from Emporia, Kans., southward. Additional pollution of this river could readily result in lasting and highly undesirable conditions in the Pensacola impoundment.

7. Immediate measures should be sought that will keep all chat-field and mine-waste waters out of Spring River for these sources of contamination present perhaps the greatest potential hazard to fish life in the Pensacola reservoir.

(The question of interstate pollution of streams which arises in connection with the Pensacola impoundment is not only one of special importance to that impoundment through a variety of contacts including public health and recreational interests as well as fisheries, but is a basic problem to be considered by those in authority for the many impoundments now contemplated. In the case of the Pensacola impoundment the agency empowered to act with reference to the pollution problems should first be designated and then should take immediate action if pollution catastrophes are to be averted. The expense of rectifying existing conditions that result in pollution hazards to Pensacola Dam waters, whether from mines, municipalities, or industries, will be great and perhaps prohibitive. Future impoundments should be safeguarded with reference to pollution before their construction is authorized.)

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LITERATURE CITED

BIRGE, E. A. and C. JUDAY, 1911.

The inland lakes of Wisconsin. The dissolved gases of the water and their biological significance. Bulletin, Wisconsin Geological and Natural History Survey, No. 22, pp. 1-259.

ELLIS, M. M., 1937.

Detection and measurement of stream pollution. Bulletin, U. S. Bureau of Fisheries, Vol. 48, pp. 365-437.

ELLIS, M. M. (in press)

Water conditions affecting aquatic life in Elephant Butte Reservoir Bulletin, U. S. Bureau of Fisheries.

NATIONAL RESEARCH COUNCIL, 1938.

Report of the Interdivisional Committee on Density Currents. April 30, 1938. Appendix E, p. 12.

NATIONAL RESOURCES COMMITTEE, 1939.

Water Pollution in the United States. 3rd Report of Special Advisory Committee on Water Pollution. p. 165.

WIEBE, A. H., 1938.

Limnological observations on Norris Reservoir with special reference to dissolved oxygen and temperature. Transactions, 3rd N. American Wildlife Conference, pp. 440-457.