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COASTAL RIVERS INVESTIGATION

INFORMATION REPORT 69-2

COASTAL LAKES AS POSSIBLE WATER SOURCES FOR A COHO HATCHERY

by
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INTRODUCTION

Recent successes of hatcheries in producing coho salmon have stimulated searches for additional hatchery locations in coastal watersheds. In the past hatcheries were designed with gravity flow water supplies, but in more recent years pumping the water has proven feasible. Because of the acceptance of pumping, naturally impounded waters are now potential hatchery water supplies.

The purpose of this report is to review the present information about 11 coastal lakes to determine if they would provide suitable water supplies and to consider other factors which might influence the location of a hatchery. The water quality criteria were that there must be a minimum of 17 cfs with a maximum temperature of 65 F. Other factors investigated were (1) sites for a hatchery, (2) access roads, (3) power availability, (4) fish passage for juveniles and adults, and (5) diseases of native fish.

METHODS

The data for this report were extracted from Oregon Game Commission and Oregon Fish Commission reports and from raw data files of personnel from both agencies.

The quantity and quality of limnological data varied between lakes, but in all cases sufficient information on water volumes and temperatures were available or could be calculated.

Summer temperature profiles were drawn for those lakes that stratified.

Depth-volume relationships were calculated by using a polar planimeter to measure areas between contour intervals of existing bathymetric maps. The volume between contours was calculated as one-half the area between contours plus the area of the deeper contour times the contour interval.

Temperature-volume relationships were calculated by determining the depth range of each degree of temperature and relating it to the volume within the same depth range.

Pumping schedules were established based upon a constant flow of 17 cfs (33.66 acre feet per day). During periods when the surface water temperature was 63 F or less, it was assumed that all water would be pumped from the epilimnion. During periods when epilimnion temperatures exceeded 63 F, I programmed mixing variable quantities of the coldest hypolimnetic water with surface water to provide the 17 cfs of water at 63 F. This was to allow for some heating in the hatchery distribution system without violating the criterion of having water 65 F or less.

RESULTS

The initial review of the data from coastal lakes indicated that none had minimum discharges approaching our criterion of 17 cfs. The only way that lake water could be used would be to cycle it through the hatchery and return it to the lake to maintain the water level. The data also indicated that, with the exception of Floras Lake, summer surface temperatures exceeded 65 F. This means that only Floras Lake and those lakes which had cooler subsurface water would have any potential for a hatchery.

Of the 11 lakes included in the study, four were eliminated because they were homothermous with maximum temperatures exceeding 65 F (Table 1). Mercer and Woahink lakes were also eliminated since their hypolimnetic temperatures varied from year to year (Figures 1 and 2). The volumes and temperatures of their hypolimnions would not provide sufficient cooling water in some years. The variability of the hypolimnetic temperature indicated the temperature and time of the beginning of stratification might vary more widely than records showed in previous years.

Clear, Floras, Loon, Munsel, and Triangle lakes have water that could be developed to provide the necessary volume of controlled temperature water. Since more is known of the limnology of Munsel Lake, it will be considered in detail and the other lakes will be compared to it.

Table 1. Coastal lakes with maximum temperatures above acceptable levels

Lake	Homothermous with excessive temperatures	Stratified with insufficient cooling water
Devils	X	
Mercer		X
Siltcoos	X	
Tahkenitch	X	
Tenmile	X	
Woahink		X

Munsel Lake

Physiography--Munsel Lake is the last in a chain of four lakes formed between the coastal sand dunes and a north-south ridge extending from Herman Peak to Siuslaw Bay. The lake is 103 acres, is 75 feet deep, and has a volume of 3,200 acre feet (Figure 3).

The north, east, and south slopes of the basin are quite steep both above and below lake surface level. The west side is flatter with a gently sloping lake bottom; patches of water shield, bullrush and water

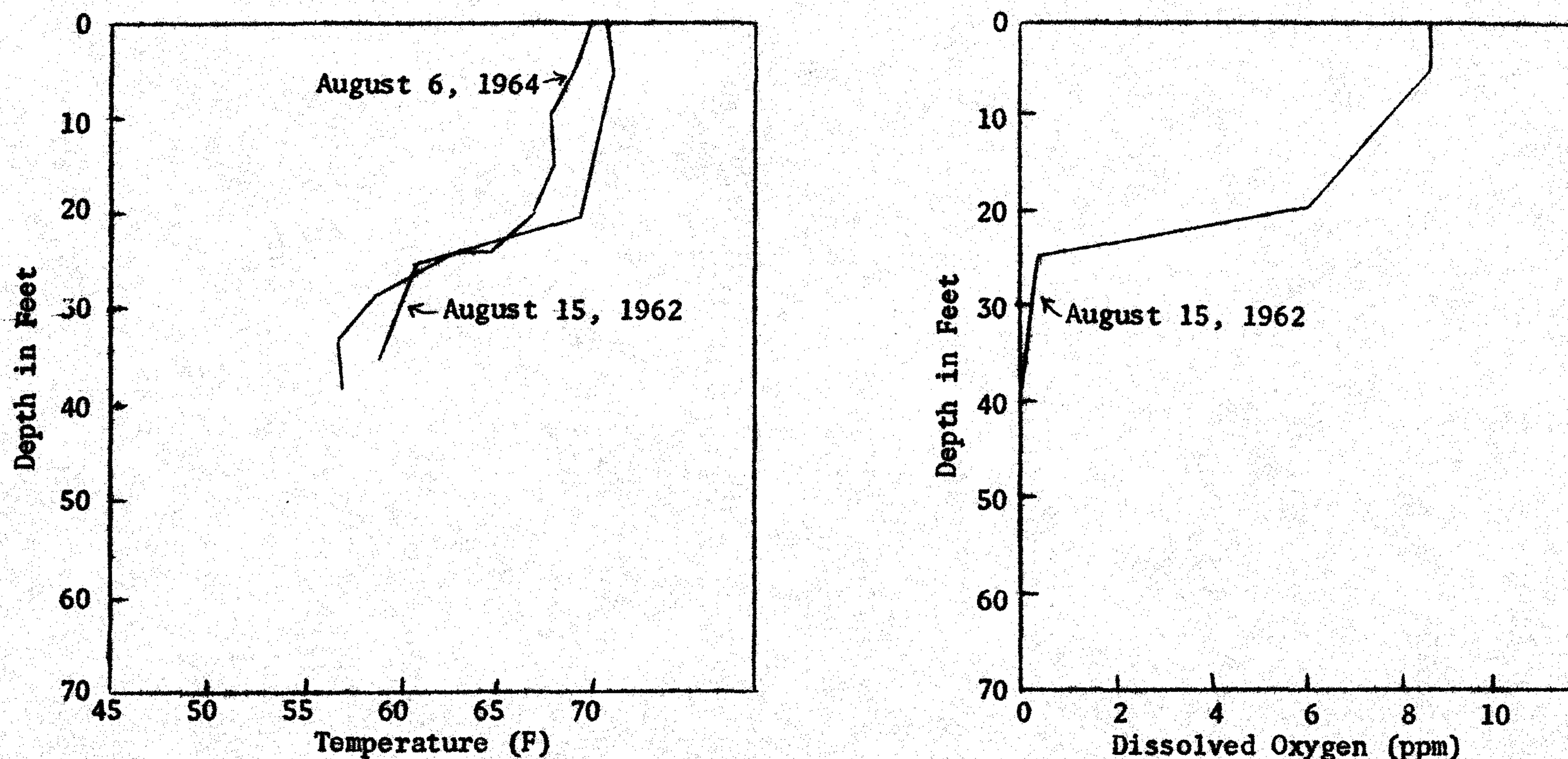

Figure 1. Temperature and Oxygen Profiles in Mercer Lake. (Data from Oakley, 1962, and W. Saltzman, personal communication, 1964)

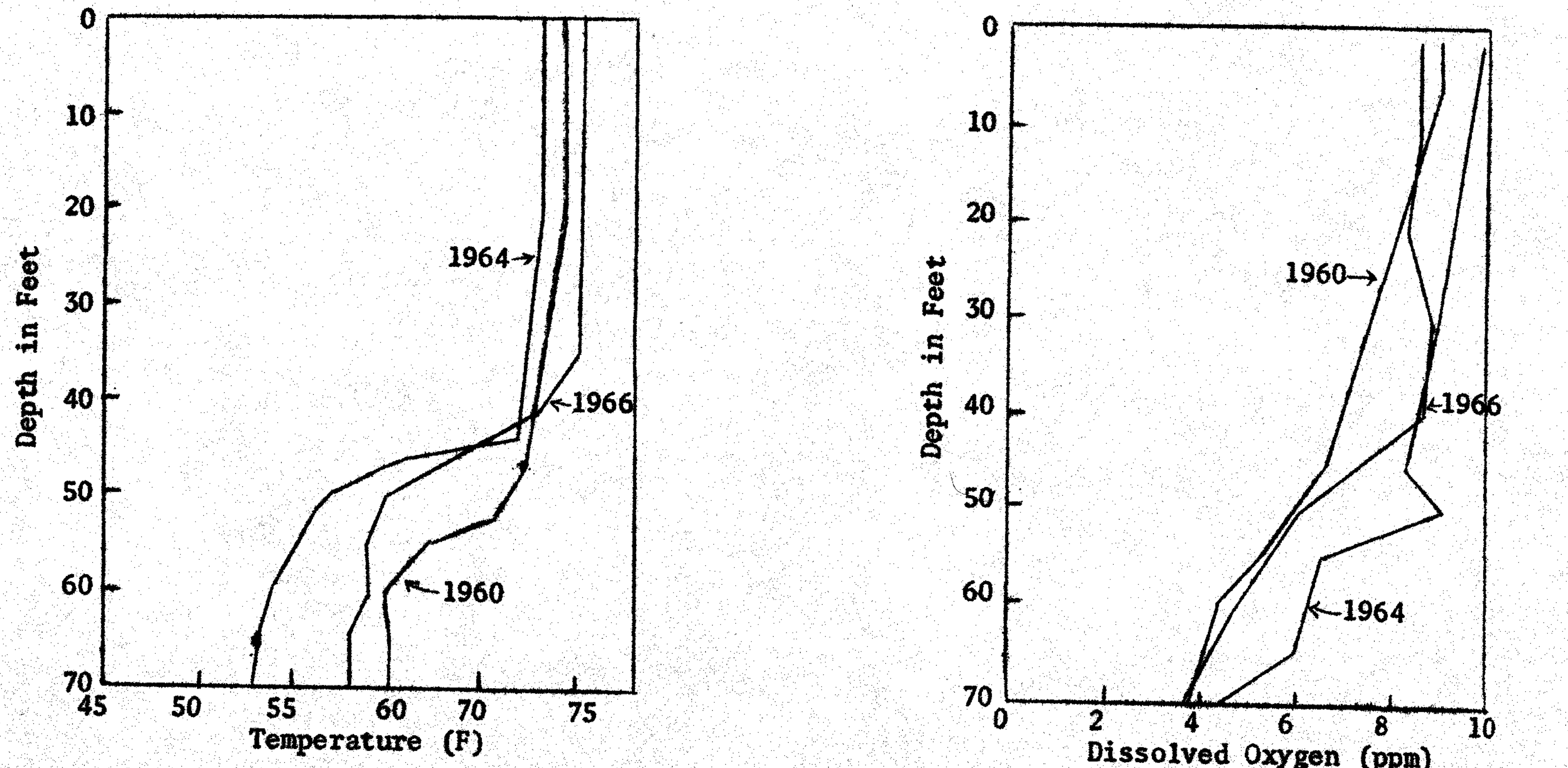

Figure 2. Temperature and Oxygen Profiles in Woahink Lake. (Data from McGie and Breuser, 1962; W. Saltzman, personal communication, 1964; and McGie personal communication, 1966)

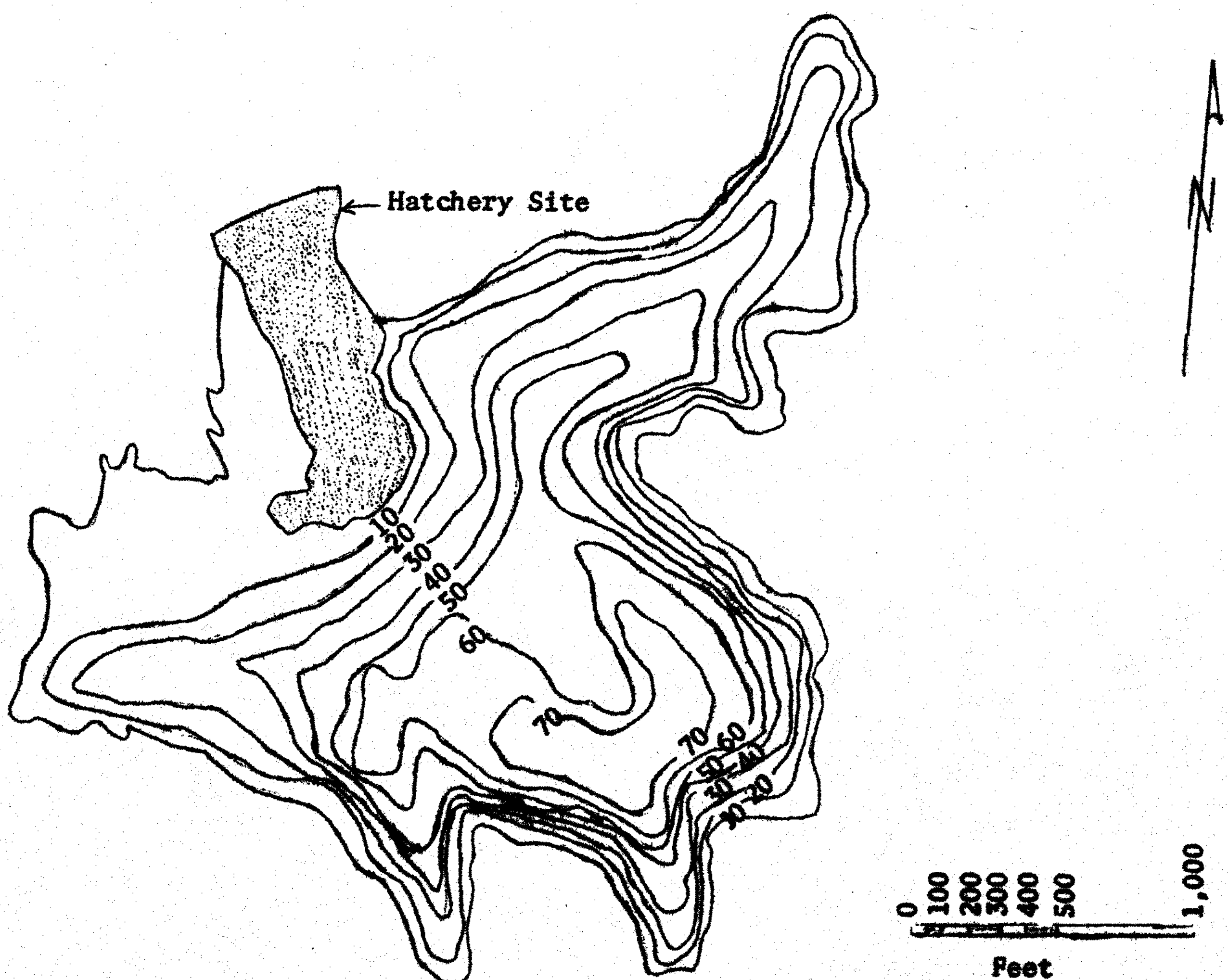

Figure 3. Contour Map of Munsel Lake Showing Potential Hatchery Site

lily cover the shoal area along the west shore. The shoreline of the other three sides is littered with fallen conifers. The total drainage basin is 3.3 square miles.

Munsel Lake has one major, one minor, and three intermittent tributaries. The annual discharge from the lake into Munsel Creek is about 3,000 acre feet. The creek leaves the northwest corner of the lake and flows in a southerly direction, discharging into Siuslaw Bay at Florence. The estimated maximum flow was 40 cfs at the mouth on January 31, 1964. Minimum flows of about 0.75 cfs occur in September and October each year.

Munsel Creek has a unique flow pattern because of its watershed. Fall precipitation is held back by the extensive sand areas and the ponding in the lakes so it does not attain high flows until about late November. During the winter and spring the flow is higher and more stable than in other comparable sized streams.

Part of the flow in Munsel Creek is direct seepage from the sand formation below Munsel Lake. This water is high in ferrous iron, low in dissolved oxygen, and low pH as it enters the creek. As a result, it is fairly corrosive.

Limnology--Munsel Lake is homothermous from December to March each year at 46-47 F (Skeesick, 1966). In March the lake begins to stratify with the epilimnion approximately 20-feet thick containing about 50% of the volume of the lake (Figures 4 and 5). The epilimnion gradually warms to a maximum of 72 F in July and August (Figure 6), while the temperature in the deepest part of the lake remains constant. As the epilimnion begins to cool in late summer and autumn, it gradually increases in depth at the rate of about 10 feet per month.

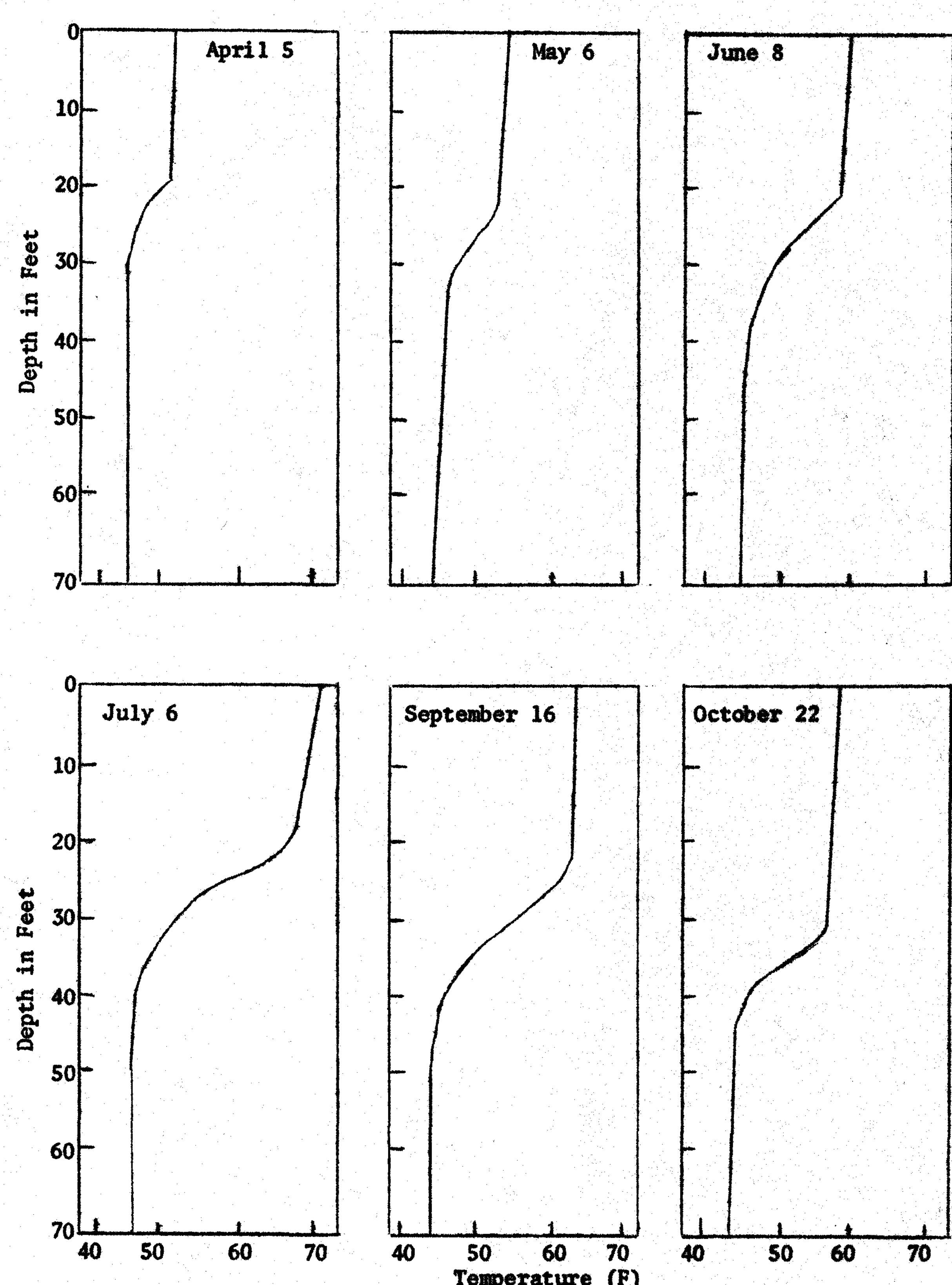

Figure 4. Temperature Profiles in Munsel Lake, 1964 (From Skeesick, 1966)

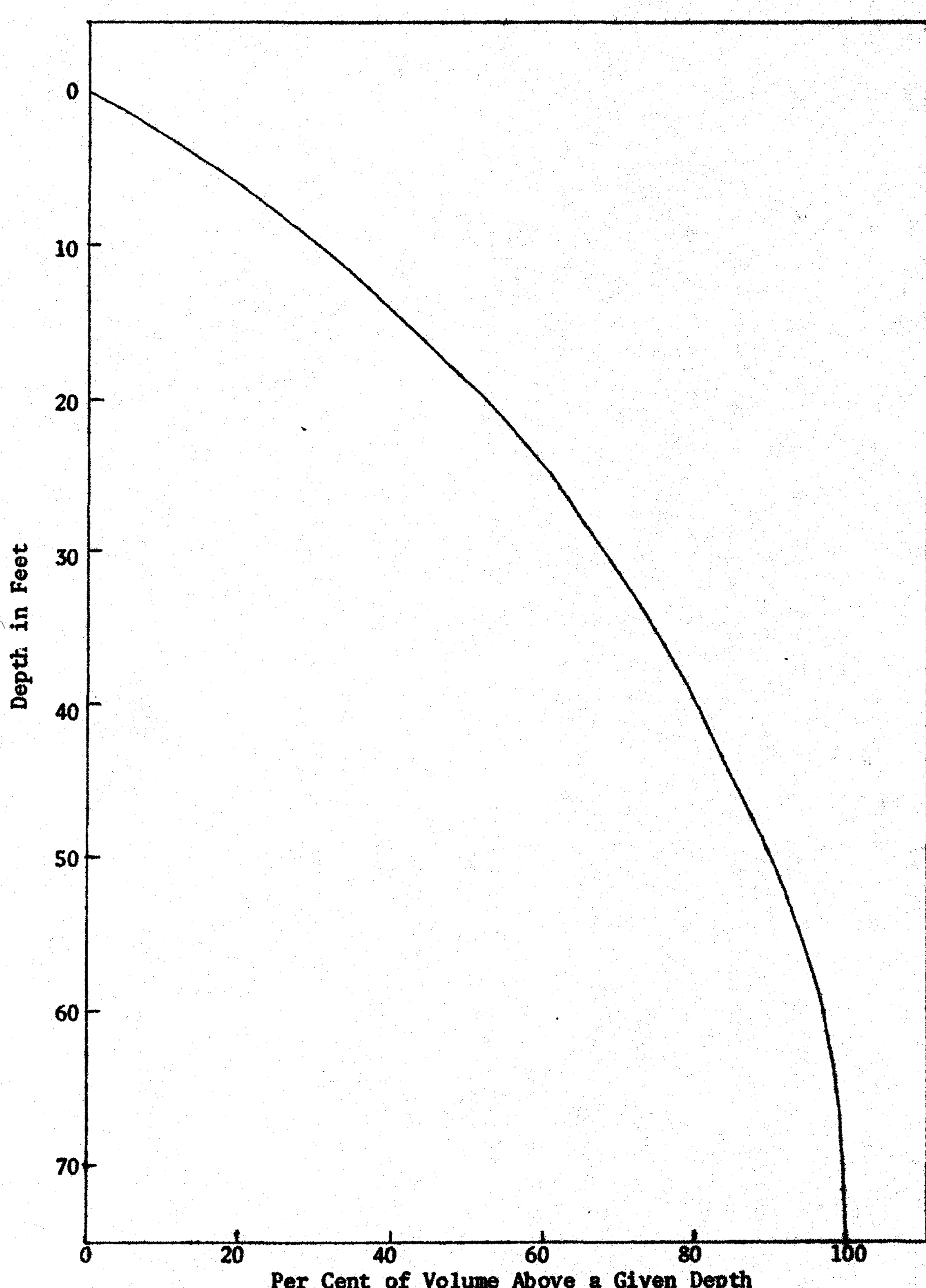

Figure 5. Relationship Between Depth and Volume in Munsel Lake

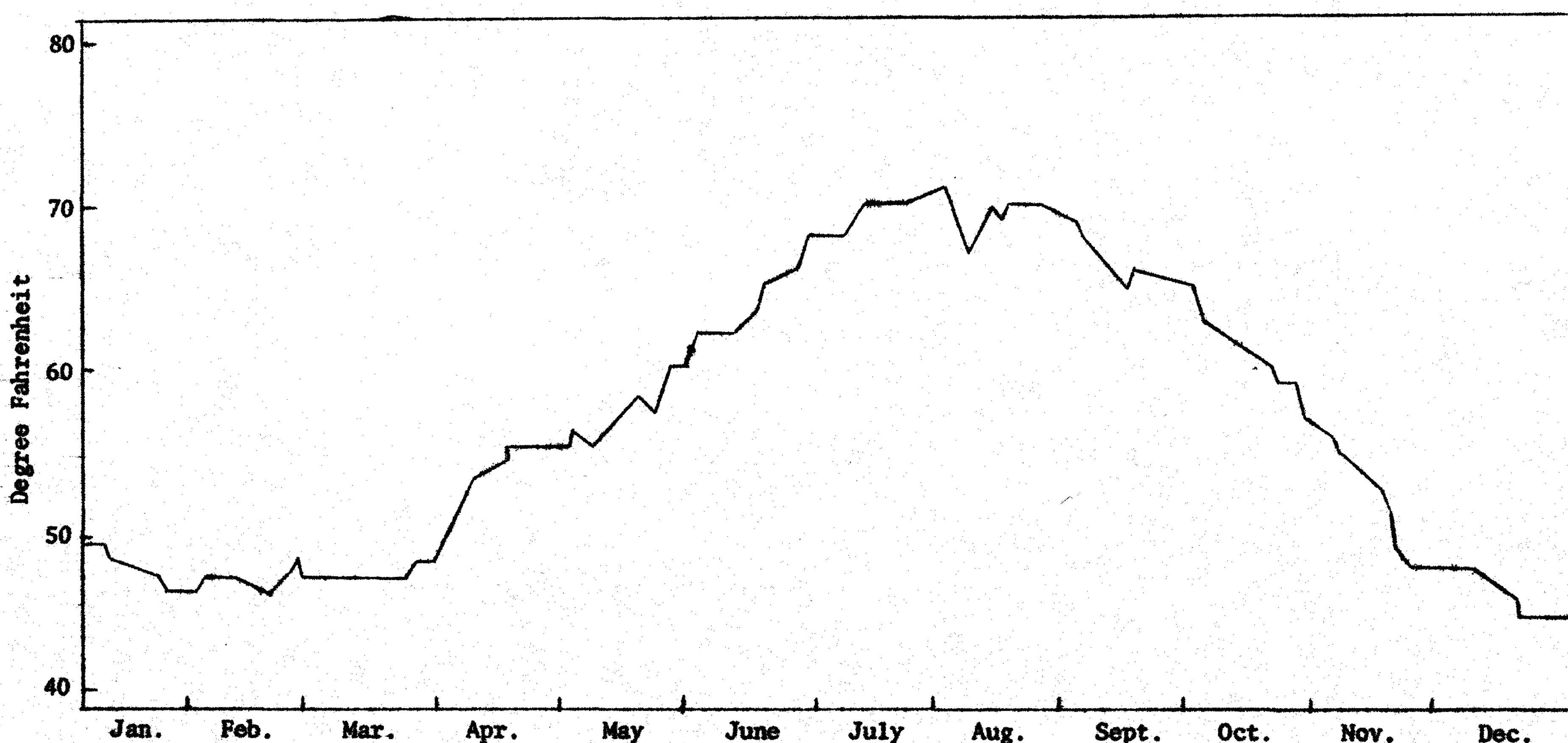

Figure 6. Surface Temperature of Munsel Lake, 1964 (From Skeesick, 1966)

The variations in the dissolved oxygen concentrations are the result of stratification. Starting from a saturated condition in the spring, the epilimnion remains at about 9 ppm (100% saturated), the thermocline increases to about 12 ppm (120% saturated), and the lower hypolimnion declines to less than 1 ppm (<8% saturated) during the period of stratification (Figure 7).

Chemical analysis of Munsel Lake water indicated a methyl orange alkalinity range from 2.4 ppm at the surface to 13.0 ppm at 60 feet. The pH ranged from 7.4 at the surface to 6.2 at 60 feet concurrent with carbon dioxide (CO_2) values of 2.5 ppm and 15 ppm. Total hardness was 36 ppm while total dissolved solids was 48.4 ppm (Oakley, 1962).

The depth of visibility of an 8-inch Secchi disc has always been greater than 10 feet and occasionally as high as 16 feet. The lower visibilities were always associated with plankton blooms.

Present use--Munsel Lake is moderately important as a recreational area and water supply. There are 11 summer cabins and three permanent dwellings on the lake. A public boat ramp is on the southwest corner of the lake.

Early season trout anglers are the primary users of the lake although some effort is expended on warm-water fish. The calculated effort has ranged between 3,000 and 4,500 angler-hours per season (Skeesick, op cit) with an estimated catch of 2,000 to 4,600 planted trout in recent years. The incidental catch includes coho, kokanee, black bass, perch, bluegill, brown bullhead, and warmouth. Sculpin are abundant but do not contribute to the catch. Coho fry have been planted each year since 1967. Some of these fish are known to remain in the lake for over 2 years and contribute to the catch as 10.5-inch to 12-inch "kokanee."

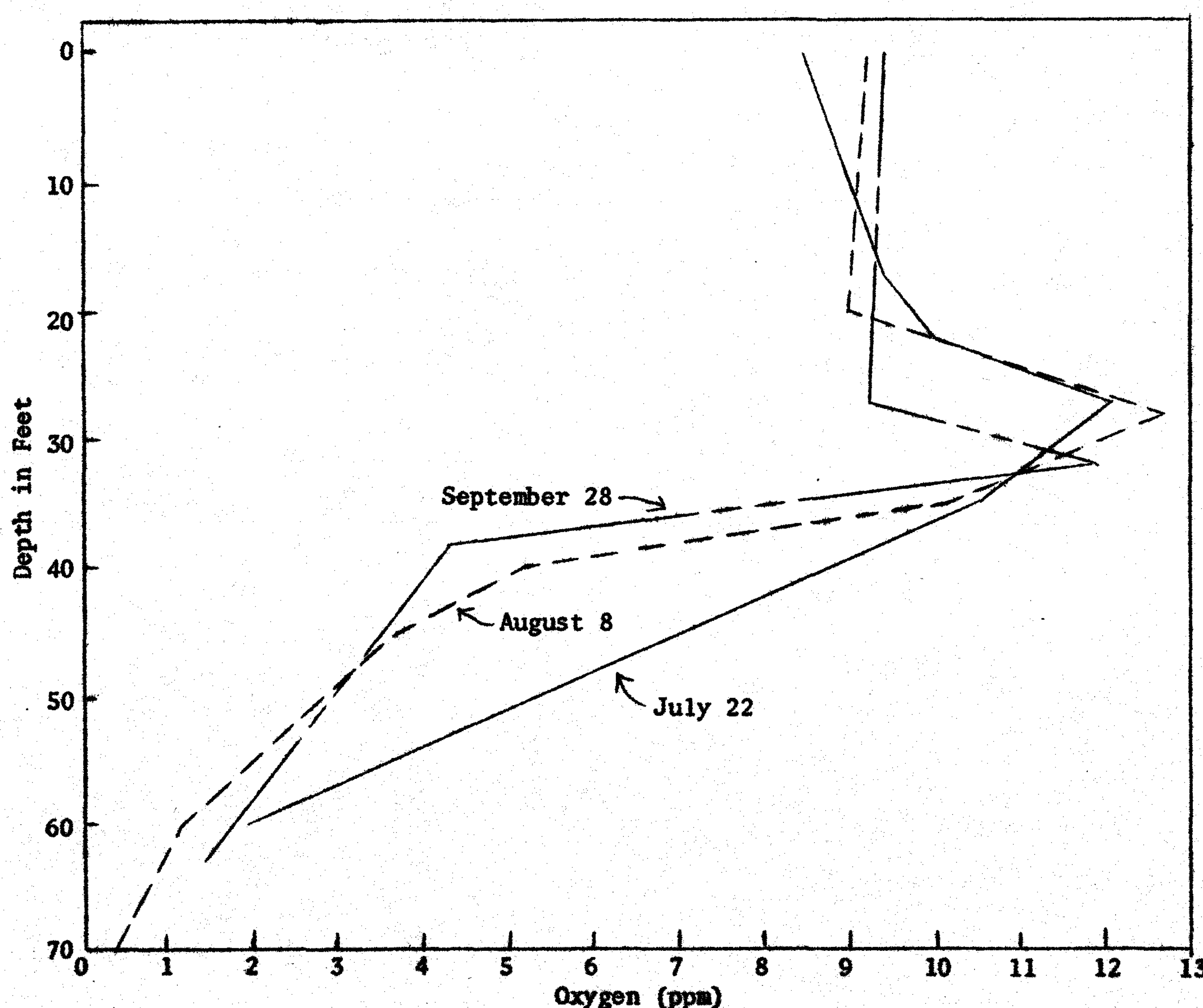

Figure 7. Summer Oxygen Concentration Profiles in Munsel Lake, 1964 (From Skeesick, 1966)

The city of Florence maintains a small diversion dam and water right for 1 cfs from Munsel Creek. At one time, Munsel Creek was their water supply but now is only for emergency use.

The Oregon Game Commission has an inactive weir located 30 feet below the city water intake. It consists of two electrically driven screen drums that are 10 feet long and 4 feet in diameter. At one side is a trap that may be operated to catch either downstream migrants or adults.

Hatchery potential--Munsel Lake could provide sufficient water for a hatchery provided subsurface water is used for cooling in the summer. Water from a lake bottom intake would have to be mixed with surface water in varying proportions depending upon the temperatures of the two water masses. A hypothetical pumping and mixing schedule based upon characteristics in 1964 indicates that deep water pumping would be necessary from June 10 through September 30 with a maximum volume of 7.3 cfs needed (Table 2).

Since the hypolimnetic water is deficient in dissolved oxygen, some means of aeration would have to be developed.

The most suitable location for a hatchery is a flat peninsula on the northwest side (refer to Figure 3). The point is about 10 acres and has a maximum elevation of about 8 feet above lake level. The area is currently unimproved and has a dense stand of pine, huckleberry, and rhododendron. An access road crosses the property and a power line is immediately adjacent to it.

Flanking the hatchery site is a shallow bay of 3.7 acres which may be incorporated into a hatchery development. Possibilities include using it as a settling basin to trap food particles and excreta, as an auxiliary

Table 2. Proposed pumping schedule for Munsel Lake based upon a volume of 17 cfs and maximum temperature at the hatchery of 63 F (calculated on the basis of water conditions in 1964) 1/

Time period	Cfs from deep intake	Temperature of deep intake water(F)	Cfs from surface intake	Temperature of surface water (F)
Jan. 1-June 10	0	--	17.0	65
June 10-20	1.9	47	15.1	66
June 20-30	4.0	47	13.0	68
July 1-10	5.2	47	11.8	69
July 10-20	5.7	47	11.3	71
July 20-31	6.7	49	10.3	72
Aug. 1-10	6.7	49	10.3	72
Aug. 10-20	6.2	49	10.8	71
Aug. 20-31	6.3	51	10.7	70
Sept. 1-10	7.3	55	9.7	69
Sept. 10-20	6.8	57	10.2	68
Sept. 20-30	7.3	59	9.7	66
Oct. 1-Dec. 31	0	--	17.0	65

1/ *Data from Skeesick (op. cit).*

rearing pond, or as a pilot project to determine the feasibility of using lake water for a hatchery.

Smolts could be released directly into the lake or into Munsel Creek, 200 yards west of the hatchery site. They would be subjected to only 3 miles of stream environment before entering the Siuslaw River estuary. The stream is inhabited by very few predators and is well protected from avian predation by a dense brush cover.

Returning adults could be accommodated at the abandoned Game Commission weir. A city street ends 100 feet from the present weir but could easily be extended to the trapping area.

If higher flows for adult trapping are needed earlier in the fall, check dams could be built at the outlets of each of the four lakes in the chain. About 500 acre-feet of additional water could be stored in the spring for release in the fall.

Potential problems--Pumping hypolimnetic water from and discharging used water into the lake may cause a disruption of stratification, nitrogen supersaturation, disease problems, or eutrophication.

Destruction of stratification might occur but it seems unlikely that it would, since initial stratification occurs during a windy period and resists mixing when there is a 6 F temperature differential (refer to Figure 4). At the time pumping is initiated, surface temperatures are higher so the energy necessary to cause mixing would be even greater. During the period of stratification, used water from the hatchery would be returned to the lake at temperatures between 60 F and 65 F. This water would be intermediate in density so it would be expected to sink into the thermocline and form a lens which would help protect the colder water from mixing.

At the time stratification begins, the lake would be saturated with dissolved nitrogen. As the isolated water of the thermocline and upper hypolimnion heat, they become supersaturated with nitrogen. In Cultus Lake, which has a shorter stratified period than Munsel, nitrogen concentrations of 116% saturation were observed in the summer at the 30-foot level (Harvey, 1967). Since some of the water to be pumped from Munsel Lake in late summer would have undergone in situ heating, some supersaturation can be expected. Mixing with epilimnetic water may, however, reduce the supersaturation to an innocuous level. If not, some means of dispersing the dissolved nitrogen would be necessary.

No fish diseases are known to exist in Munsel Lake at the present but may be introduced through hatchery operation. Drawing water from the surface and bottom and discharging it into the thermocline should prevent recirculating contaminated water through the hatchery during the period of stratification. Locating the intake and discharge on opposite sides of the peninsula should prevent recirculation during the unstratified periods.

The effect of hatchery discharge on the lake ecosystem is open to conjecture. Munsel Lake is fairly oligotrophic at present. Zooplankton feeders such as kokanee appear to do well but aquatic insect predators such as trout undergo a reduction in condition factor after planting. Other indications of poor quantities of larger food items is the general paucity of warm-water fish. Addition of uneaten food, excreta, and metabolic wastes would probably increase the production of phytoplankton, zooplankton, and aquatic insects, and ultimately fish to some extent. Zooplankters would also be circulated through the hatchery adding some live organisms to the diet of the fish.

The annual increment of nutrient would be offset to some extent by the flushing rate of Munsel Lake. In an average year, the discharge from the lake approximately equals the volume of the lake, and the great majority occurs during the period the lake is well mixed. If it became necessary, the discharge from the hatchery could be piped or channelled to the outlet for about half the year.

Clear Lake

Physiography--Clear Lake is the second lake in the Munsel Lake chain. It is 149 acres, 80 feet deep, and has a volume of 5,982 acre-feet (Figure 8). The lake has a north-south aspect with a high timbered ridge along the east shore and lower timbered ridges along the north and south shores. The entire west shore is an exposed sand dune that is encroaching on the lake.

Both ends of the lake are gently sloping and have emergent aquatic vegetation while the sides are steep and lack aquatic plants. Some cover for fish exists along the east shore from trees that have fallen into the lake. The total drainage basin of Clear Lake is 1.1 square miles.

The only tributaries of consequence are the inlet from Collard Lake and the outlet into Aikerly Lake. Midsummer flows in each stream are virtually nil.

Limnology--The stratification pattern is more variable in Clear Lake than in Munsel Lake. The minimum temperature of the hypolimnion has varied from 47 F in 1964 to 56 F in 1960 (Figure 9) indicating that for the latter year, stratification did not occur until late April. The long axis of the lake parallel to the prevailing wind direction and the long wind create the potential for greater mixing that delays stratification in some years.

The oxygen concentrations in Clear Lake vary from nearly saturated (8-9 ppm) in the epilimnion to supersaturated (>10 ppm) in the thermocline and to near anoxia (<1 ppm) at the bottom (Figure 10). When Clear Lake stratifies, the epilimnion extends down to about 30 feet and includes about 60% of the volume (Figure 11).

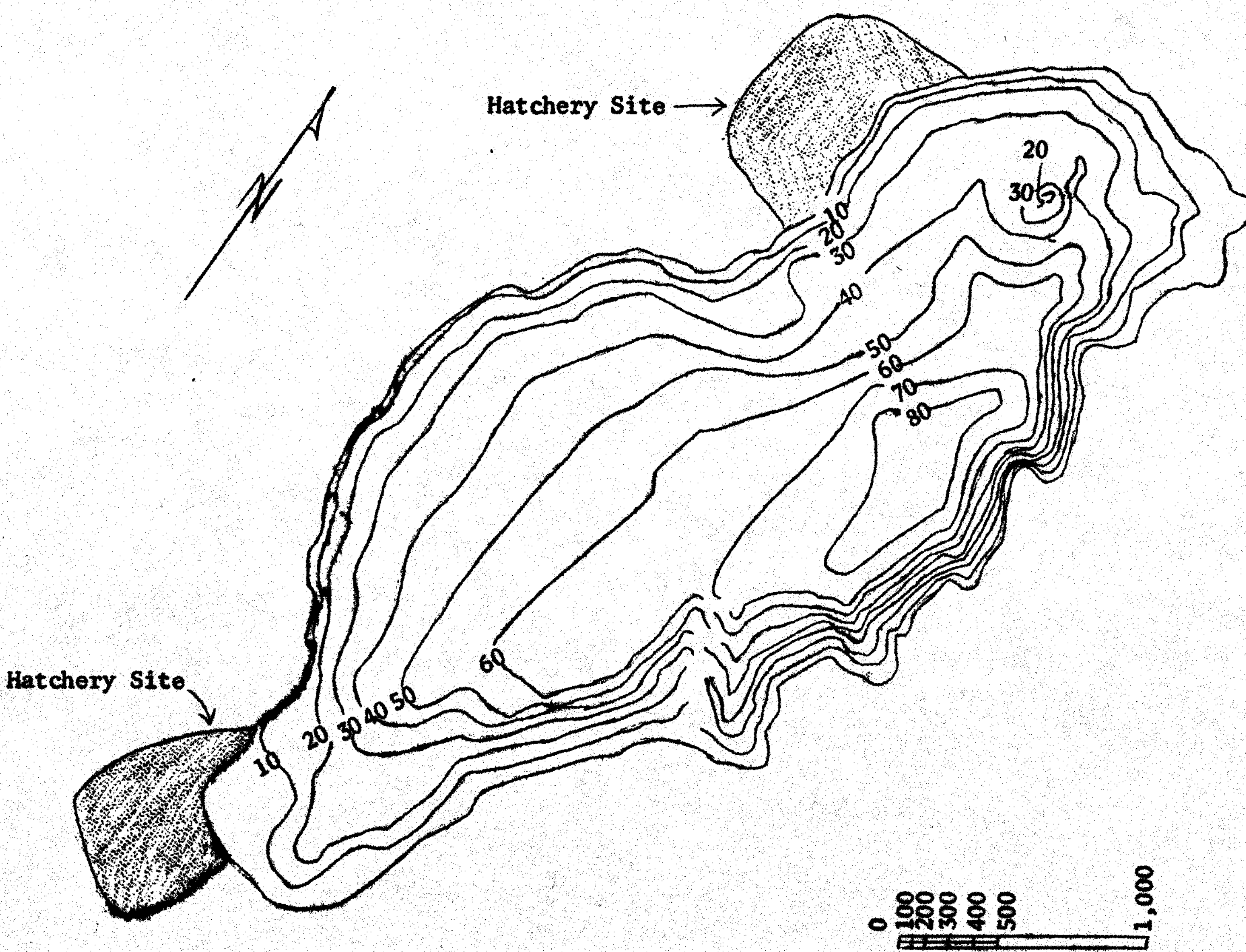

Figure 8. Contour Map of Clear Lake Showing Possible Hatchery Sites

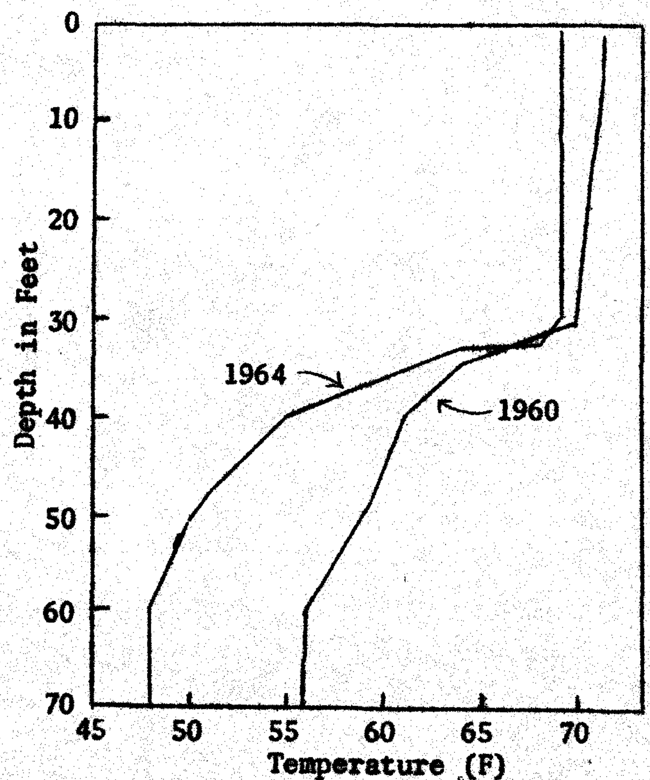

Figure 9. Temperature Profiles in Clear Lake. (Data from Kruse and Oakley, 1962, and author's personal records, 1964)

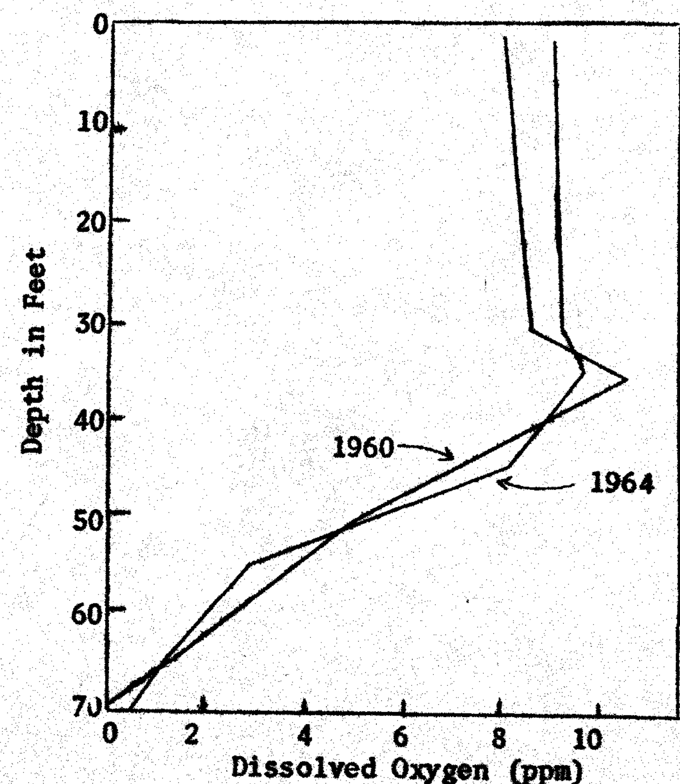

Figure 10. Summer Oxygen Concentration Profiles in Clear Lake. (Data from Kruse and Oakley, 1962, and author's personal records)

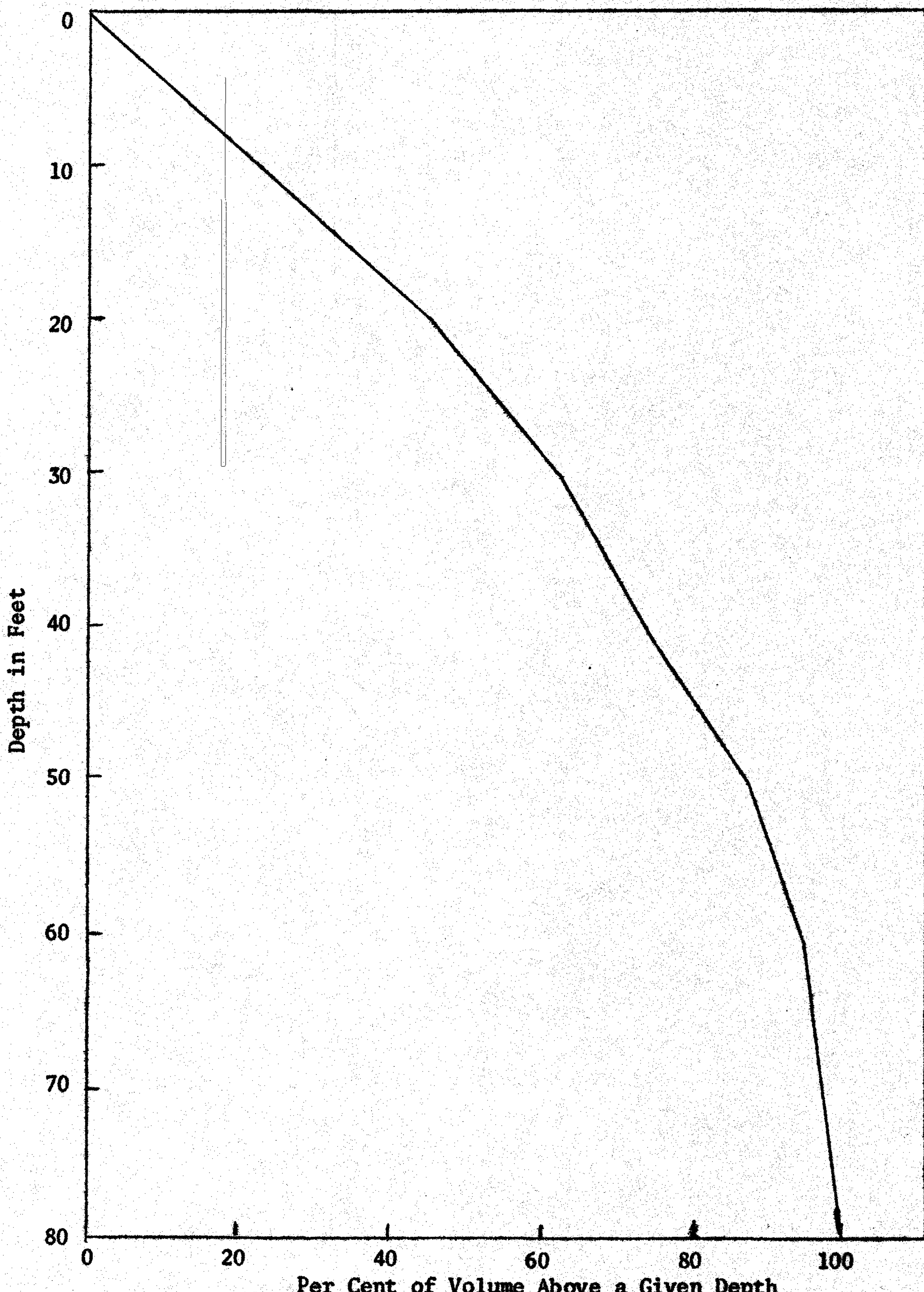

Figure 11. Relationship Between Depth and Volume in Clear Lake

Chemical analysis of Clear Lake water indicated a methyl orange alkalinity range from 12 ppm on the surface to 21 ppm at 65 feet. The pH ranged from 7.6 at the surface to 6.1 at 65 feet while the CO_2 concentration varied from 2 to 14 ppm over the same depths. The total hardness and total dissolved solids of a composite sample were 14 and 45 ppm, respectively (Kruse and Oakley, 1962).

Secchi disc visibilities ranged from 12 to 29 feet indicating the clarity of the water.

Present use--The only significant use of Clear Lake is as the water supply for Heceta Water District.

There is one summer residence at the south end of the lake. The only vehicle access is via a private road or across the sand dunes in a "beach buggy."

Very little angling effort occurs because of lack of boats, public access, or trout planting. A few trout stocked in Munsel and Aikerly lakes immigrate to Clear Lake.

Since 1967 coho salmon fry have been released into Clear Lake to utilize the lake environment. Some of these fish are known to stay in the lake and contribute to the meager salmonid fishery in their second and third summers of life.

The warm-water fish species present include squawfish in addition to those listed for Munsel Lake.

Hatchery potential--Clear Lake could provide sufficient water of regulated temperature in some years but not in others. Pumping schedules, assuming that Clear Lake heats and cools at the same rate that Munsel Lake does, indicate that sufficient cool hypolimnetic water existed in 1964 but not in 1960.

Hatchery sites exist at each end of the lake (refer to Figure 8). Both sites are privately owned land covered with pines, rhododendron, and salal. There are no access roads and power is only available at the site on the south end of the lake.

Smolts should probably be transported the 1/2 mile to Munsel Creek for release. This would prevent predation and prohibit smolts from taking up residence in Clear, Aikerly, or Munsel lakes.

Adults could be trapped at the Munsel Creek weir.

Potential problems--The problems of stratification disruption, nitrogen supersaturation, disease, and eutrophication described for Munsel Lake would also apply at Clear Lake and may be more severe. Since Clear Lake has a more irregular stratification pattern than Munsel Lake, it would be expected that the stratification could be disrupted more easily.

The flushing rate of Clear Lake is lower than Munsel Lake because the watershed area is reduced and the volume of the lake is greater. Consequently, a greater proportion of the hatchery effluent would remain in the basin to be recycled through the hatchery in succeeding years, increasing the potential for a chronic disease problem. The longer retention time would also increase the nutrient concentration, leading to greater eutrophication of the lake.

Use of Clear Lake water in a hatchery may not be compatible with its present use as a water supply for Heceta Water District. Any increase in plankton or suspended sediment concentration would intensify water treatment problems, and use of certain chemicals in the hatchery may be prohibited.

Floras Lake

Physiography--Floras Lake is an embayment which has been cut off from the ocean by a narrow sand spit. The lake is 223 acres, has a maximum depth of 37 feet, and a volume of 4,170 acre-feet (Figure 12).

The lake has a north-south aspect with a timbered plateau to the east and south, a low sand dike to the west and a marshy flood plain to the north. The total drainage area of the lake is 9.9 square miles.

Floras Lake has three unnamed tributaries that support small coho runs. The discharge from the lake flows northward, joining Floras Creek and New River. The water level in Floras Lake fluctuates 5 to 6 feet annually because it is at sea level and has a constricted outlet.

Limnology--Floras Lake is not known to stratify. The lake was homothermous at 62 F on August 17, 1960, 64 F on August 1, 1966, and 65 F on September 9, 1966. Oxygen concentrations at a variety of depths ranged between 8.5 and 9.2 ppm on the same sampling dates. Methyl orange alkalinities varied between 10 and 16 ppm, pH ranged from 7.2 to 7.6 and CO_2 was 2-3 ppm with a total hardness of 24 ppm and total dissolved solids of 89 ppm on August 17, 1960 (McGie and Breuser, 1962).

The well mixed character of Floras Lake is the result of wind exposure. The Cape Blanco area is subjected to severe southerly gales in winter and a strong northwest diurnal sea breeze in the summer. Wind stress in the summer is particularly severe because of virtually unimpeded air flow from the ocean travelling some 6,000 feet along the axis of the lake.

Turbidity in Floras Lake is always high, although no objective data documents it. Presumably rapid cycling of nutrients and heavy wind mixing are the primary causes.

Present use--Floras Lake is moderately exploited by sport fishermen and summer recreationists. A campground and boat launch provide public access at the north end of the lake and numerous summer homes have private access along the east side of the lake.

Primary angling effort is directed toward hatchery trout with some effort for black bass. Coarse-scaled suckers, coho salmon, sculpins, and sticklebacks are also known to inhabit the lake.

Hatchery potential--Floras Lake could provide sufficient water of acceptable temperature to fulfill the needs of a hatchery.

The best hatchery site appears to be on the northeast shore adjacent to the Coos County Boi Cope Park (refer to Figure 12). The land is flat,

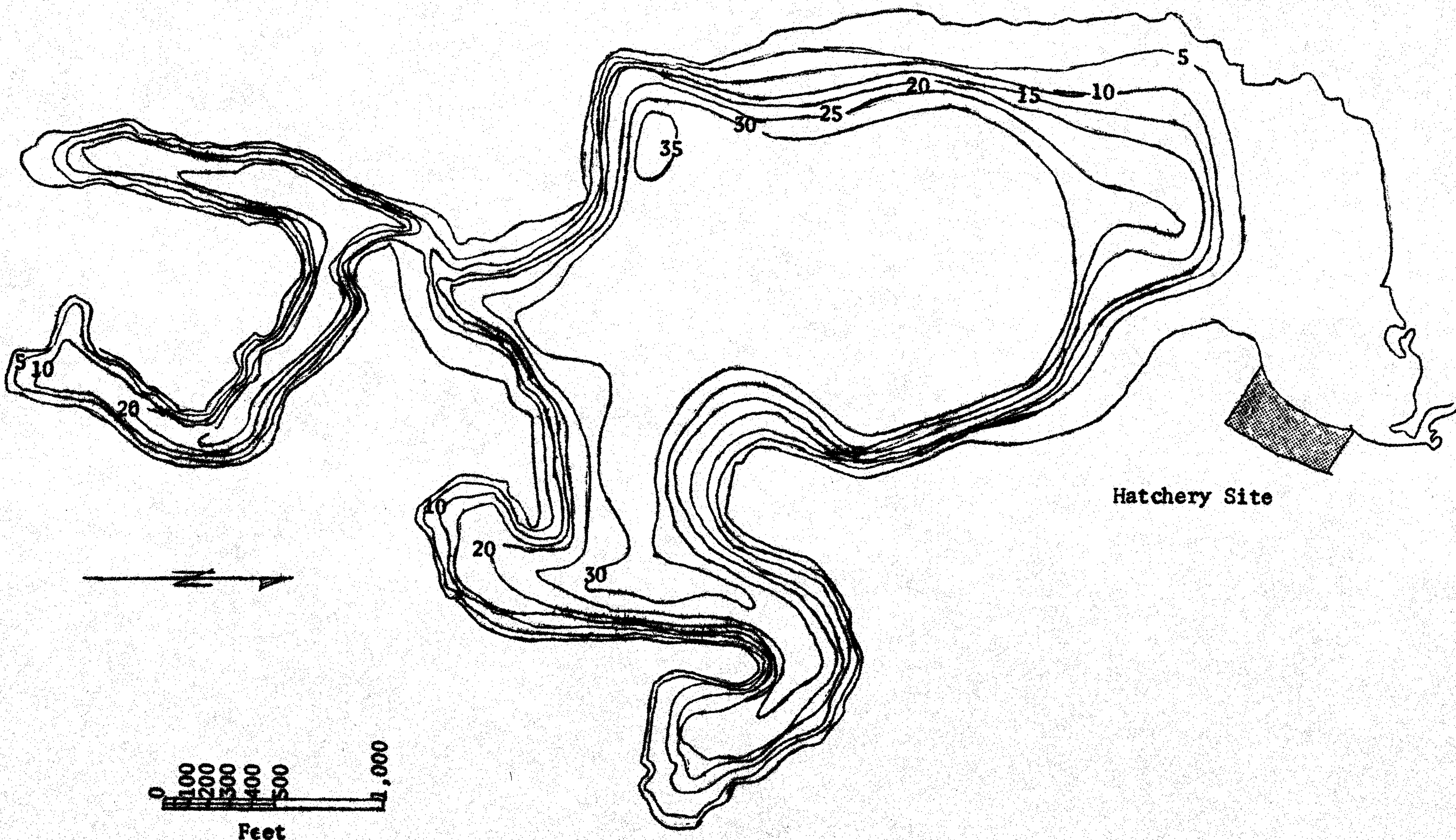

Figure 12. Contour Map of Floras Lake Showing Potential Hatchery Site

but covered with coastal pine and brush. It is approximately 15 feet above the lake level.

Coho smolts could be released directly into the adjacent outlet and adults could be trapped in the outlet or at the hatchery outfall.

Potential problems--Disease, eutrophication, turbidity, fluctuating water level, and winds are the main problems anticipated.

Lack of stratification prevents any segregation of the water mass which has passed through the hatchery so some recycling may occur throughout the year. The strong mixing which occurs will cause dilution of disease organisms but consequently will not give the hatchery any relief from exposure.

The accretion of nutrients from the hatchery should occur at a slower rate than in Munsel or Clear lakes because Floras Lake has about three times the watershed area but only approximately equal volume so the flushing rate is greater.

To what degree the turbidity of Floras Lake would affect hatchery operation is not known. Visibilities of 2 feet or less could be expected at certain times.

The main effect of fluctuating water levels would be in the adult trapping program. Any trap placed in the outlet would have to function over a several foot range of water levels and would require considerable diking to restrict flow to a regular channel. A trap at the hatchery would need to be placed above high water with ingress provided so fish could move in at various water levels.

The Cape Blanco area around Floras Lake is known for frequency and severity of its winds. Southerly gales would halt outdoor work several days each winter. Cold foggy days and the prevailing strong northwest sea breeze would hinder hatchery operations many days each summer.

Loon Lake

Physiography--Loon Lake is a flooded canyon created by a massive landslide. The sides and outlet end are steep timber-covered slopes. The inlet end is flat pastureland of lakebed origin that became exposed as erosion reduced the height of the barrier at the outlet. The lake is 269 acres, has a maximum depth of 107 feet, and has a volume of 15,550 acre-feet (Figure 13).

The total drainage basin of Loon Lake is approximately 80 square miles. Lake Creek is the major tributary although three intermittent streams flow directly into the lake.

Mill Creek, the outlet of the lake, flows through a narrow, steep-walled canyon for several miles below the lake. Stream flows were estimated to range between 5 cfs and 9,000 cfs by comparison to measured flows in a nearby stream.

Limnology--Loon Lake stratifies very strongly with a midsummer epilimnion approximately 15 feet thick, corresponding to about 25% of the volume (Figures 14 and 15). The midsummer surface temperature was 74 F while the bottom temperature was 46 F in July 1966, reflecting the cooler winter climate and warmer summer climate found in the intermountain area. The relatively shallow epilimnion indicates less wind induced mixing than occurs among coastal plain lakes.

The dissolved oxygen concentrations in Loon Lake are unique among the lakes being considered (refer to Figure 14). The epilimnion is nearly saturated (8 ppm) but the concentration in the thermocline is depressed to about 65% saturation (6 ppm). The upper hypolimnion increases to 72% saturation (8.5 ppm) while the lower hypolimnion declines to less than 30% saturation (3 ppm). The depressed dissolved

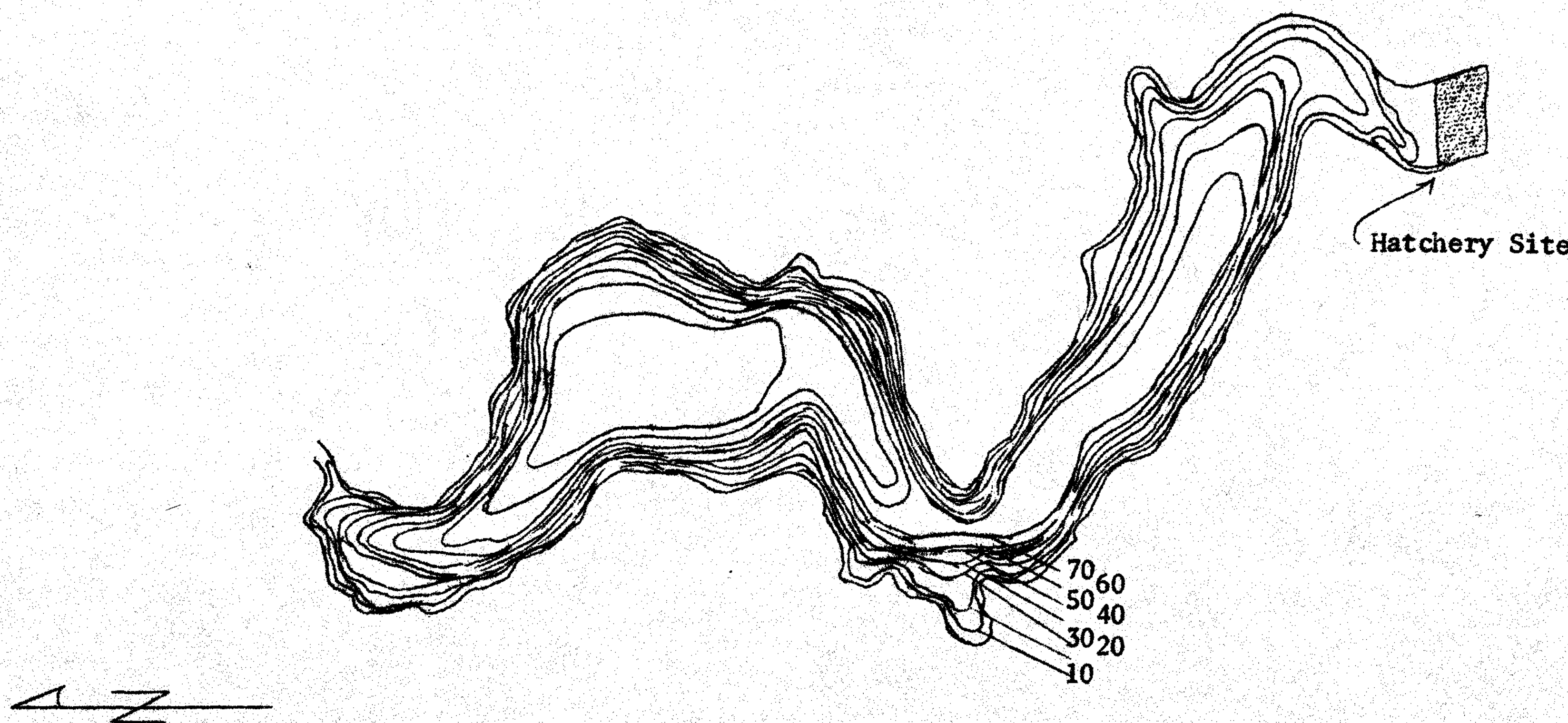

Figure 13. Contour Map of Loon Lake Showing Potential Hatchery Site

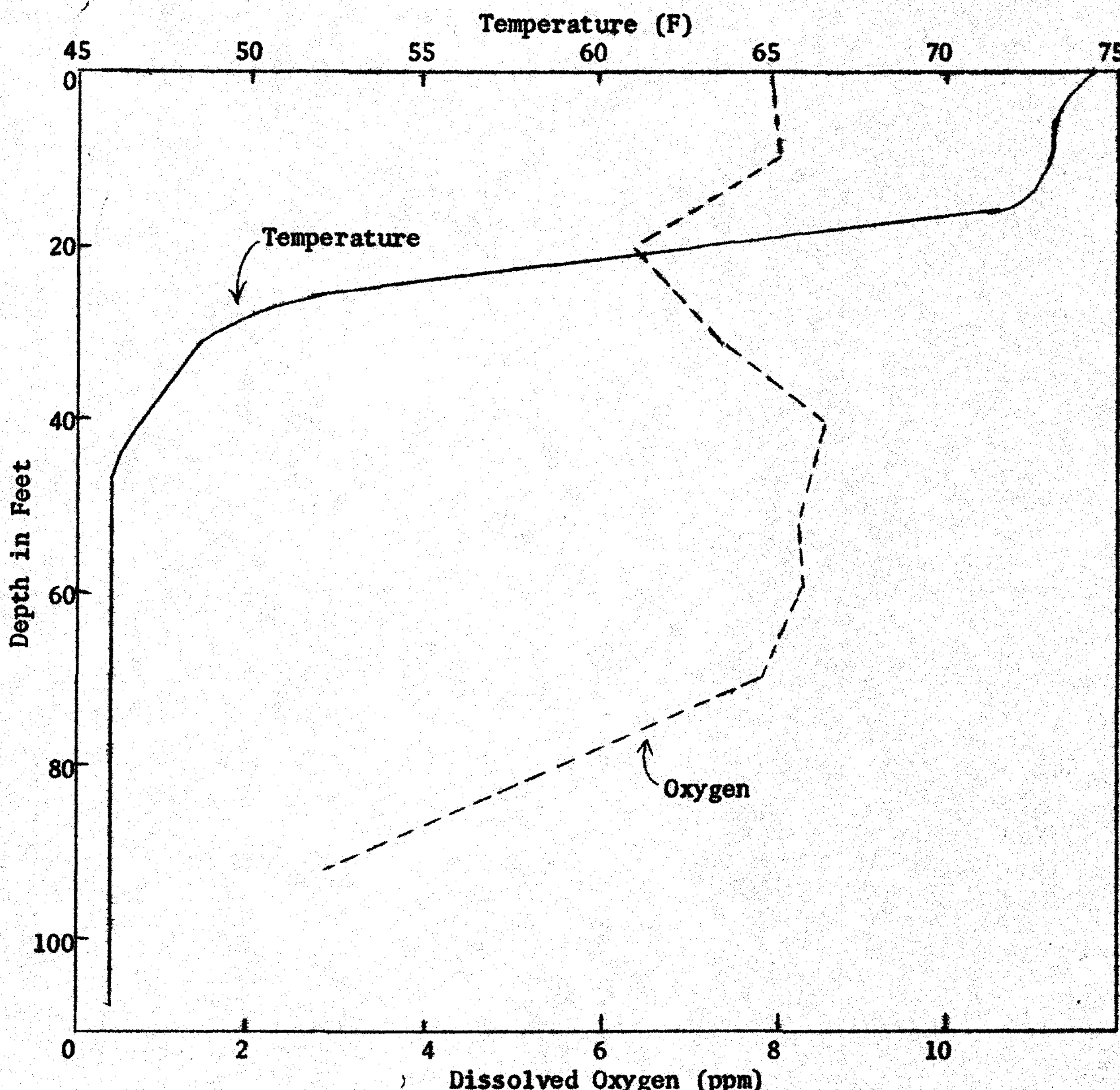

Figure 14. Temperature and Oxygen Concentration Profiles in Loon Lake July 1966 (A. M. McGie, Oregon Fish Commission, Personal Communication)

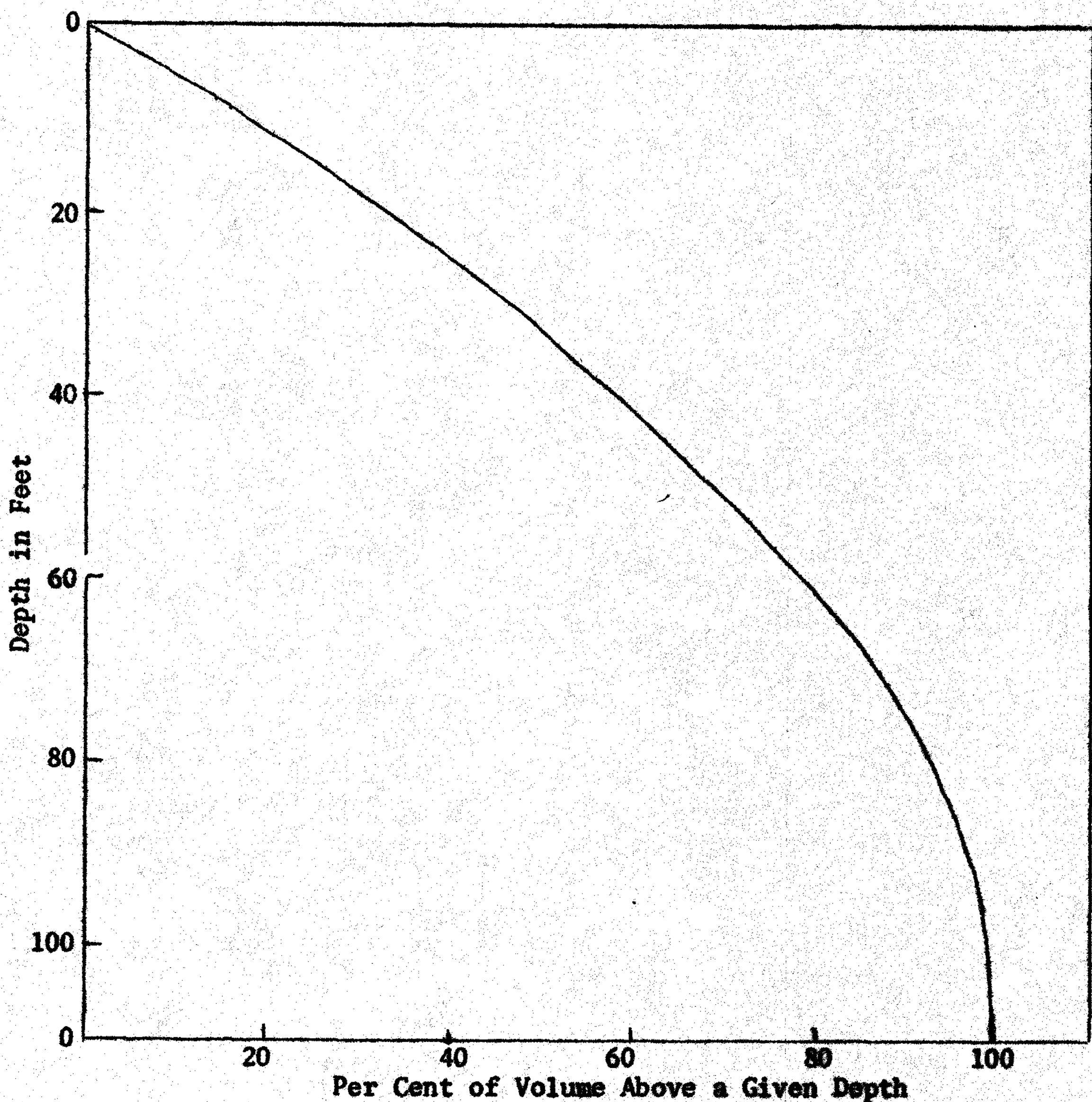

Figure 15. Relationship Between Depth and Volume in Loon Lake

oxygen concentration in the thermocline was not evident in samples taken June 19, 1958 (Saltzman, 1959). The thermocline and hypolimnion were noticeably turbid, indicating that part of the winter silt load was still trapped in the basin.

No chemical analyses other than dissolved oxygen have been recorded and no visibilities have been measured. However, the lake is known to become turbid in the winter and remain so for considerable periods.

Present use--Loon Lake is quite popular with fishermen, campers, and water skiers.

The trout fishery is open all year and is based primarily on hatchery fish. A diverse group of warm-water fish inhabit the lake but the species composition is not known.

A Bureau of Land Management campground, beach, and boat launch are located near the outlet while a resort and private summer cabins flank the upper portion of the lake.

Hatchery potential--The volume of the hypolimnion is greater than what is needed to operate the hatchery through the entire warm-water period. Water temperatures could be fluctuated over a broad range to suit the needs of a hatchery.

A high flushing rate would minimize any problems of eutrophy or disease.

The only suitable hatchery site is the land adjacent to the inlet (refer to Figure 13). A paved road and power lines extend past the hatchery site.

Smolts should be hauled to a release site below the lake to prevent injuries in the cascades below the lake, migrational delays, and predation in the lake.

Returning adults could best be handled at a trap constructed some distance below the outlet of the lake.

Potential problems--Turbidity, nitrogen saturation, an adult trapping facility, remoteness, and length of intake pipe are the main problems foreseen. Turbid water during the winter and spring would be a chronic problem. The large watershed of the lake is predominantly timberland that is being actively logged. Severe erosion is common because the terrain is steep and the soils are unstable.

Potential nitrogen supersaturation problems at Loon Lake would closely parallel those already described for Munsel Lake. An adult trapping facility would be hard to operate and maintain because it would be some distance from the hatchery and have to withstand floods of about 10,000 cfs.

To make full use of the hypolimnetic water, a pipe would have to extend about 2,000 feet down the lake. About 80% of the volume of the lake would be available from a pipe about 600 feet long.

The remoteness of the area would present certain problems. It is 25 miles to Reedsport and 10 miles are crooked and narrow. Because this area is mountainous, power, telephone, mail, and schoolbus service would be uncertain.

Triangle Lake

Physiography--Triangle Lake is a flooded canyon resulting from earth movement. It is a remnant of what was once a much larger lake. Extensive flatland to the northeast of the lake is sedimentary material deposited in the original lake and subsequently exposed as erosion of the outlet reduced the water level. The upper watershed and the rest of the surrounding terrain are moderately steep, timbered slopes. The lake is 293 acres, has a maximum depth of 90 feet and volume of 15,390 acre-feet (Figure 16).

The total drainage basin of Triangle Lake is approximately 60 square miles. Lake Creek which flows through Triangle Lake is the major tributary. Little Lake Creek and two intermittent streams flow directly into the lake. Flows range from 10.6 cfs to over 4,000 cfs at the outlet of the lake (Saltzman, 1965).

Limnology--Triangle Lake stratifies very strongly with a midsummer epilimnion occupying the upper 12 feet corresponding to about 25% of the volume (Figures 17 and 18). In midsummer of 1961, the surface was 78 F and the bottom was 45 F (Saltzman, op. cit.) which was the widest range of temperatures encountered for the lakes being investigated. Little wind mixing occurs as is obvious from the shallow epilimnion.

The dissolved oxygen concentration in the surface waters approached saturation but was only about 50% of saturation at 70 feet.

No chemical analyses or visibilities have been measured. In some recent years, landslides in the watershed have caused the lake to remain turbid most of the winter.

Present use--Triangle Lake is a popular recreational area. The west and north shores are lined by permanent and summer homes, resorts, and businesses.

The primary use of the lake is for swimming and water skiing. There are several developed beaches at the resorts and many boats moored at private docks. A public dock and boat launch is located on the west side of the lake.

Angling is diverse with effort directed toward native cutthroat, black bass, bluegill, and brown bullheads.

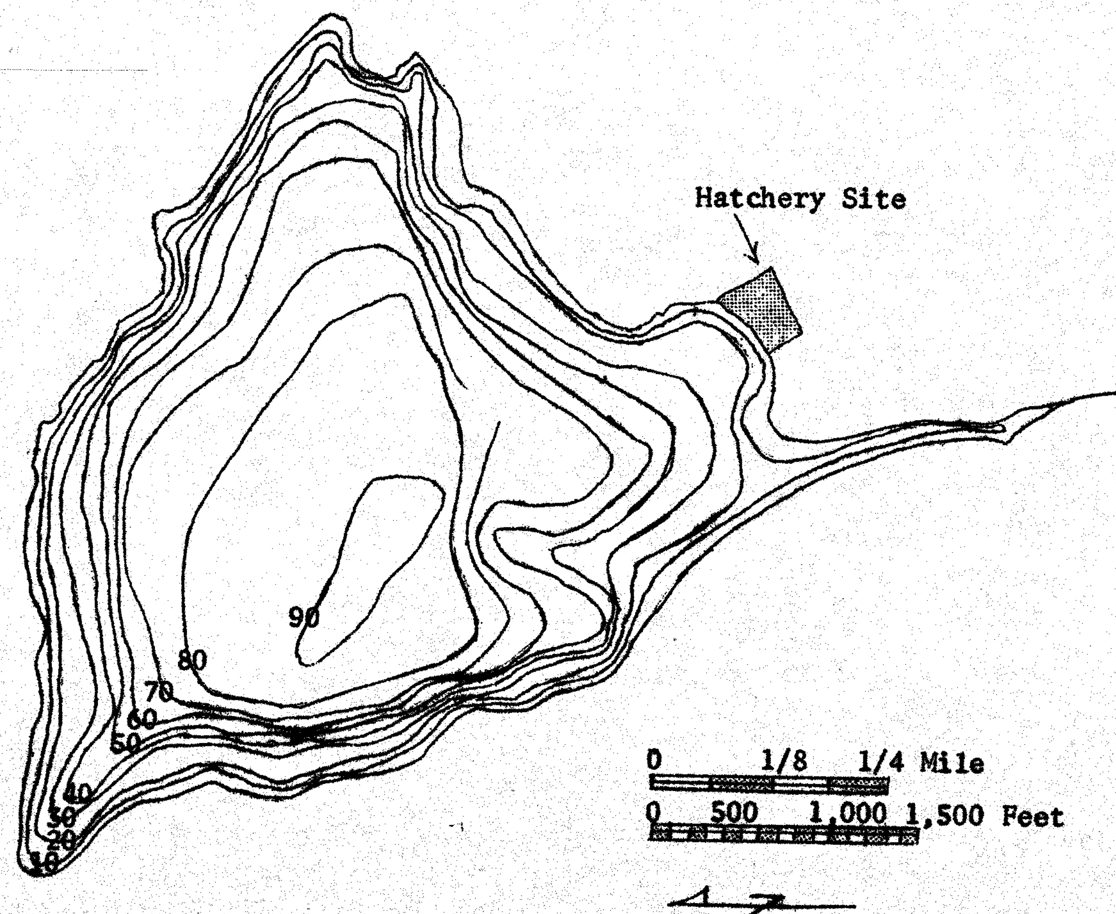

Figure 16. Contour Map of Triangle Lake Showing Potential Hatchery Site

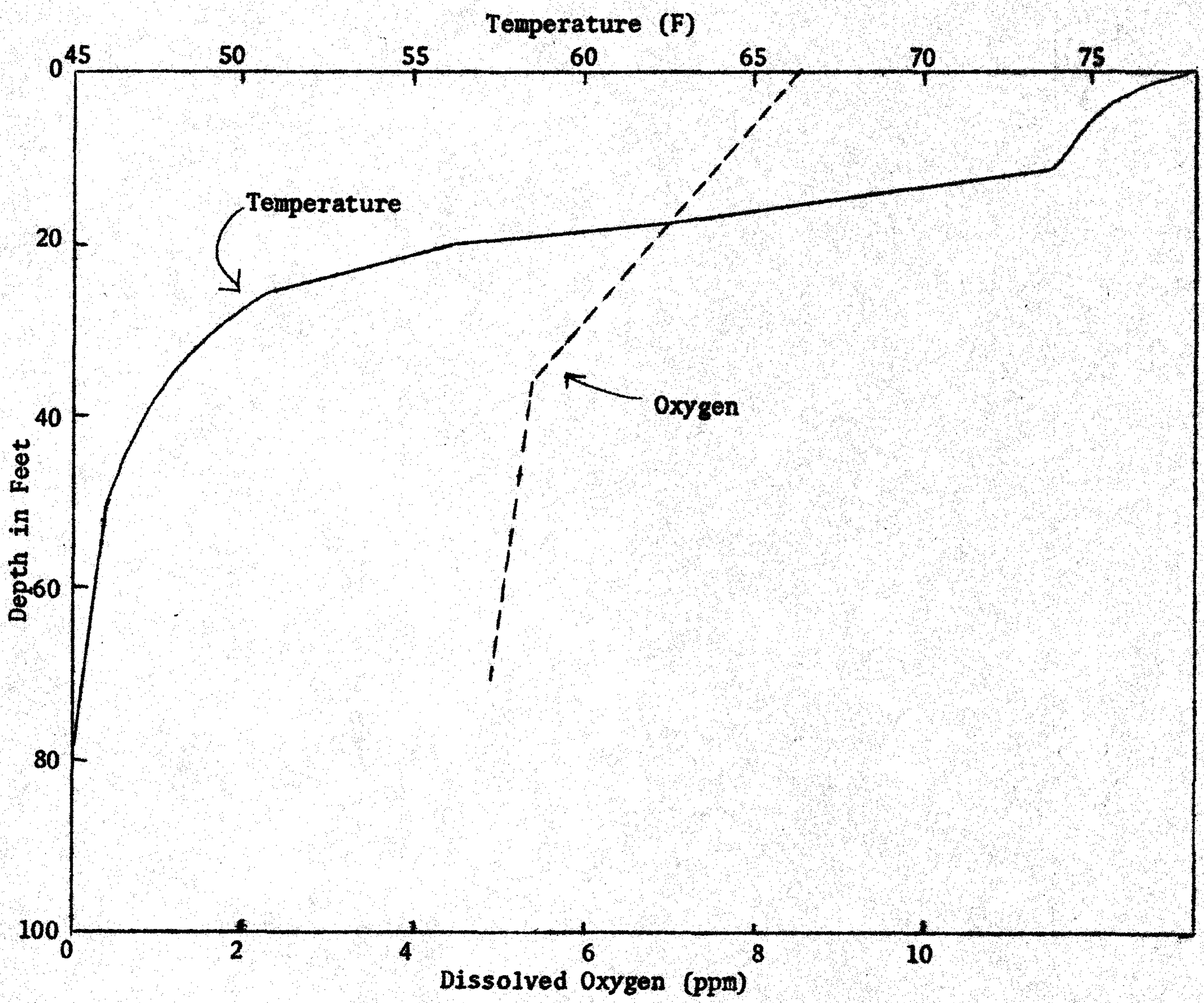

Figure 17. Temperature and Oxygen Concentration Profiles in Triangle Lake (Data from W. Saltzman, August 1966)

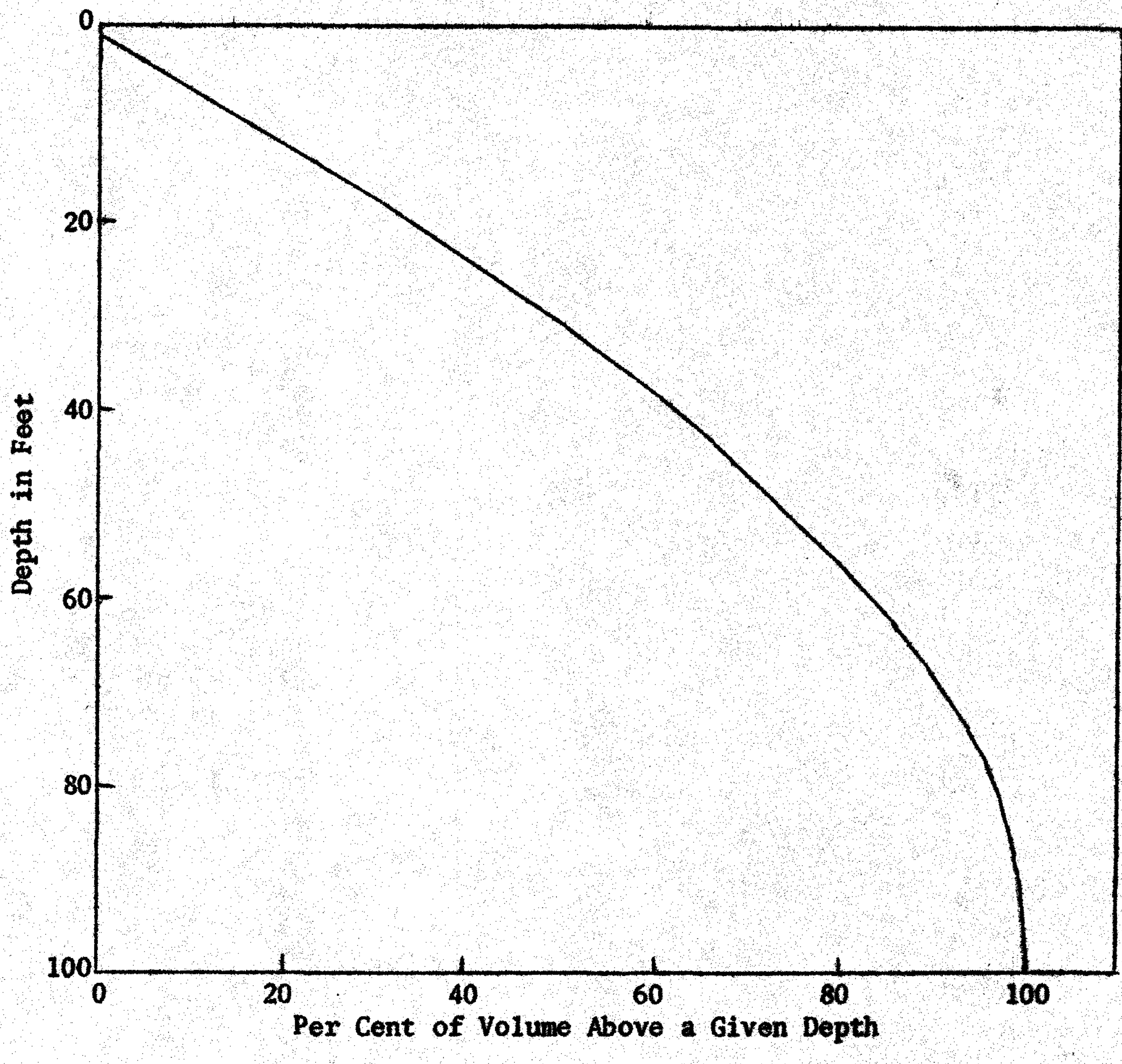

Figure 18. Relationship Between Depth and Volume in Triangle Lake

Disease and parasites have created some fish management problems. Stocked rainbow trout have undergone marked decline in condition and developed lesions indicating myxosporidia infections (Saltzman, op. cit.) to the extent that the planting program was discontinued. Between 66 and 75% of the native cutthroat have circular scars about 0.25-inch in diameter that have tentatively been identified as lamprey wounds.

Hatchery potential--The volume of the hypolimnion is far in excess of the quantity of water needed to operate a hatchery during the warm-water period. A wide range of water temperatures would be available to suit the needs of the hatchery.

The high flushing rate of the lake will minimize any problems of eutrophication.

The only suitable hatchery site is gently sloping land on the south side of the lake near the Triangle Lake Rod and Gun Club (refer to Figure 16). A gravel road and power lines extend to the site.

Smolts could be hauled about 1/4 mile and released in the outlet to minimize predation and migration delays.

Returning adults could best be handled at a trap below the barrier at the outlet of the lake.

Potential problems--Turbidity, nitrogen supersaturation, adult trapping facilities and disease are the major problems to be expected.

Extended periods of turbidity are expected to be a sporadic problem. Federal agencies own extensive land in the watershed so it may be possible to minimize this problem by working closely with them.

Potential nitrogen supersaturation problems in Triangle Lake would closely parallel those already described for Munsel Lake.

Adult trapping facilities would necessarily be some distance from the hatchery. A substantial structure would be necessary to withstand flows of several thousand cfs. Maintaining and protecting a structure away from the main installation would create extra work.

The disease indigenous to the lake would need to be controlled to make the hatchery a success.

DISCUSSION

The concept of using naturally impounded water would cause changes in current hatchery design and add complexity to hatchery operations.

Design

The biggest change in facilities will be the piping for drawing subsurface water to the hatchery site, the devices for aerating and mixing the hypolimnetic and epilimnetic waters, and the mechanisms for dispersing excess dissolved nitrogen. Other piping will probably be necessary to insure that discharge water does not recycle.

Designing an adult trapping facility some distance from the hatchery will also offer challenges. The problem common to each of the potential sites will be to design a trap that operates with a minimum of care and is poacher-proof. Different problems at each site include minimizing corrosion in Munsel Creek, adjusting for various water levels at Floras Lake and handling the high volumes in Lake Creek (Triangle Lake) and Mill Creek (Loon Lake).

Operation

The type of water supply offered by the coastal lakes would add new dimensions to hatchery operations.

On the positive side, having water of controlled temperature would allow regulation of growth rates, diseases, and species to be reared.

Water temperatures in the winter would be higher and more constant than what would be experienced in a stream so more rapid development of eggs and early growth of fry would be expected. As soon as the lake stratified the hatchery manager would have a choice of temperatures from which to draw. There would be no diel fluctuation in water temperature as the season progressed. Warmer or colder water could be drawn to either increase or reduce growth rates. After stratification breaks up in the fall, the hatchery would operate on ambient temperature water that would be in the range of 45-47 F. Greater winter growth would be expected from fingerlings held in a lake hatchery rather than in a stream hatchery.

The ability to fluctuate temperatures during the summer could also aid in disease control and treatment. Since some diseases are only virulent within certain temperature ranges, it may be possible to use temperature regimes that would minimize their effects.

The warmer temperatures in the winter and early spring may allow a variety of uses of the hatchery. It may prove advantageous to incubate and rear fall chinook at a "lake" hatchery for transfer to a "stream" hatchery where additional rearing and release could occur. This would accelerate growth so fish could be liberated at a larger size or earlier.

On the negative side, precautions must be taken against introducing diseases to the system and methods of minimizing pollution must be developed.

Comparisons

The several factors considered in locating a hatchery on a lake (Table 3) indicate that Munsel Lake would be the best choice for a

Table 3. Summary of factors considered in locating a coho hatchery on five Western Oregon lakes

Lakes	Water of adequate temperature	Hatchery location	Road access to hatchery site	Power available	Turbidity	Release of smolts	Development of adult handling facilities	Disease problems
Clear	Marginal	Good	None	Close	Very low	Some hauling desirable	Easy	Unknown
Munsel	Sufficient	Excellent	Yes	Yes	Very low	Easy	Easy	Unknown
Floras	Excess	Good	Yes	Yes	Moderate (chronic)	Easy	Moderate	Unknown
Triangle	Excess	Good	Yes	Yes	High--some winters	Some hauling desirable	Difficult	Probable
Loon	Excess	Poor	Yes	Yes	High--each winter	Some hauling desirable	Difficult	Unknown

hatchery. Minimum modification of existing hatchery designs would be necessary to make full use of this water supply.

Floras Lake is ranked second because of its lack of stratification, constant turbidity, and windy environment. Easy liberation of smolts and recapture of adults are definite assets.

Loon and Triangle lakes are about equal for third or fourth rank depending on whether diseases or prolonged turbidity would be more difficult to combat. Each has cold water in excess of summer needs but each would present problems due to remoteness and trapping adults in a large stream.

Clear Lake must be ranked last. In some years insufficient cool water is trapped in the hypolimnion so the hatchery would have to operate on a restricted supply or use warmer than desirable water in late summer. Hatchery discharge into the lake may also be incompatible with its use by the Heceta Water District.

SUMMARY

The review of coastal lakes was undertaken to see if a hatchery water supply of 17 cfs and maximum temperature of 65 F could be developed.

Of the 11 major coastal lakes, six were excluded because they were either too warm or had an insufficient quantity of cold water. Five lakes warranted further study.

Existing information indicated that adequate water supplies could be developed from Floras, Loon, Munsel, and Triangle lakes each year and in some years, Clear Lake could also be used. Information on the physiography, limnology, present use, hatchery potential, and potential problems of each hatchery water supply are presented.

Changes in hatchery design to use the lakes studies will necessarily include extensions of pipes to reach the deep portions of the lakes, aeration devices, and adult trapping facilities removed from the hatchery.

Changes in hatchery operation may include deliberate variations of temperature to adjust growth rates, control diseases, and allow production of various species. Precautions against introducing diseases or polluting the lake will be necessary.

Comparing the lakes as potential hatchery sites based on factors other than temperature and volume available leads to the ranking of (1) Munsel, (2) Floras, (3 and 4) Loon and Triangle (interchangeable), and (5) Clear Lake.

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