Province of British Columbia
Ministry of Environment
ASSESSMENT AND PLANNING DIVISION

PRELIMINARY REPORT ON THE USE OF ELK LAKE AS A BALANCING RESERVOIR FOR IRRIGATION: POSSIBLE EFFECTS ON LIMNOLOGY, WATER QUALITY AND FISHERIES

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WORKING REPORT

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SUMMARY

Aspects of limnology, water quality and fisheries with regard to the proposed use of Elk Lake as a balancing reservoir for Sooke Lake water from the Greater Victoria Water District were examined. The extra water would be used for irrigation on the Saanich Peninsula.

It would appear that no adverse effects on limnological structure (stratification, temperature) or water quality would occur. An improvement in lake water quality is likely as a consequence of the influx of low nutrient water from Sooke Lake.

The major concerns are those associated with the possibility of fish disease or parasite transfer. A lake water level management plan to take into account the conflicting requirements of fisheries, recreation and storage should be established.

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1. BACKGROUND

The Water Supply Subsection, Inventory and Engineering Branch, is presently carrying out a feasibility study of irrigation alternatives for the Saanich Peninsula. One proposal is to divert Sooke Lake water to Elk Lake through the Greater Victoria Water Board's main trunk system at offpeak periods. Water would then be pumped to agricultural lands on the Peninsula from Elk Lake which would serve as a balancing reservoir.

A request for an assessment of the water quality effects of the above proposal in view of the importance of Elk Lake was made to Aquatic Studies Branch by Inventory and Engineering Branch.

At present Elk Lake is not used as a water supply source. However between 1873 and 1920 the City of Victoria used Beaver Lake as a source of domestic water. In 1942 a pumping and filtering station was established to supply water to the Patricia Bay Air Force Base. The system was turned over to the Municipality of Central Saanich in the late 1950's with the proviso that water be supplied to North Saanich, Sidney and Swartz Bay Ferry Terminal (Oliver, 1972). The water pumped from Elk Lake rose from 340 dam^3 per year to 900 dam^3 per year between 1962 and 1975 (Comeau, 1976). The supply was augmented over this period by wells and by 1976 Elk Lake supplied only 30-50% of the supply to the north part of the Saanich Peninsula (Brown, McDougall and Dakin, 1976). In 1977 the Greater Victoria Water District extended its pipeline to the north part of the peninsula and Elk Lake ceased to be used as a supply for water.

The present proposal was made in 1980 to carry out a feasibility study of storing GVWD water (from Sooke Lake) at off-peak periods in Elk Lake. Elk Lake would then be used as a source of irrigation water for agricultural land on the peninsula. The maximum inflow of Sooke Lake water would be 3 000 dam^3 in a "dry" year. More typically the inflow volume would be less than 3 000 dam^3.

Inflow would be chlorinated, neccessitating dechlorination to protect fish species in the lake.

Elk Lake has been examined from a number of perspectives over the past 30 years. The possibility of using Elk Lake water for irrigation was considered by Johnson (1952). Recreation was considered by Stroyan (1968). Descriptions regarding water quality have been made by Comeau (1976) as well as by other students at the University of Victoria (Crane and Salmond, 1971; Vuori, 1971; Oliver, 1972). Several publications with information on Elk Lake have been completed (Brown and Austin, 1971; Brown, 1969; Brown, 1971). Several surveys of the lake have been made by the Lake Surveys Section of Fish and Wildlife Branch (1954, 1969, 1971, 1973, 1974). These surveys described the bathymetry and fish samples, and recorded some temperature and dissolved oxygen profiles. Most of the existing water quality data have been gathered in the past two years by Aquatic Studies Branch of the Ministry of Environment.

The largest problem with the data is the distinct lack of data in the June through September period. Very little information exists for the summer, warm water period.

2. MORPHOMETRY OF ELK LAKE

Estimates of the morphological parameters of Elk Lake (Figure 1) vary considerably with different reports (Table 1). The data included combine Elk and Beaver Lakes. Beaver Lake should be considered an arm of Elk Lake as it possesses no distinctive characteristics which set it apart from Elk Lake. The volume of "Beaver Lake" is about 5-10% of Elk Lake (Comeau, 1976 cites volumes of Beaver and Elk as 1 500 dam^3 and 15 816 dam^3 respectively). Fish and Wildlife lake survey file site data of 800 dam^3 and 16 474 dam^3 respectively.

3. PRESENT LIMNOLOGICAL CONDITIONS

The following description has been assembled from the scattered sampling done over the previous 10 years.

The water residence time, based on preliminary information (Obedkoff, pers. comm.) varies between 4.3 and 11.9 years for the years 1977 to 1980. The mean water residence time is 7.5 years.

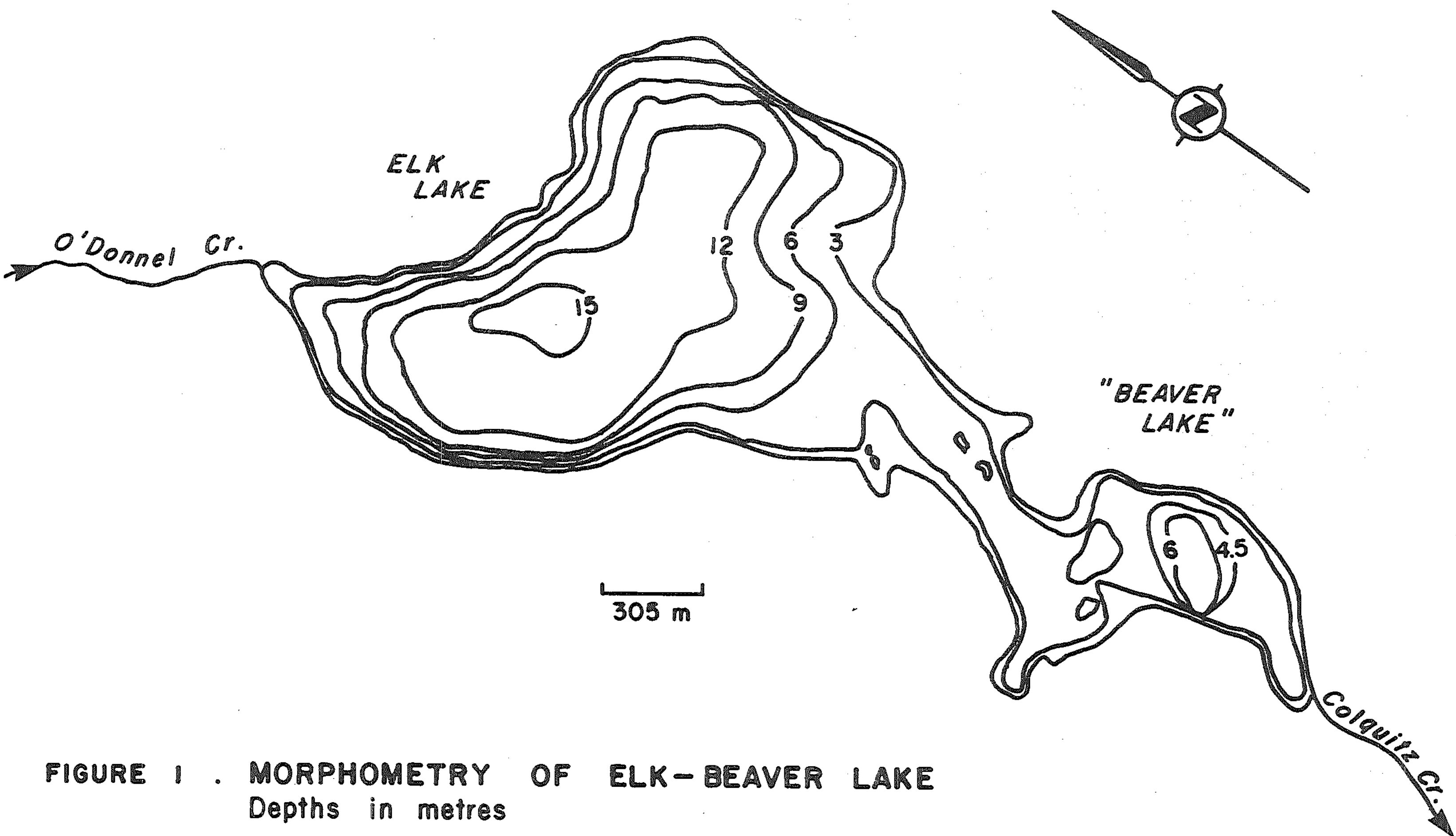


FIGURE 1 . MORPHOMETRY OF ELK-BEAVER LAKE
Depths in metres

TABLE 1: Elk Lake Morphometry (includes Beaver Lake)

drainage area	995 HA (Comeau, 1976) 621 HA or 825 HA (Crane and Salmond, 1971) 1058 HA (Johnson, 1952)
lake surface area	263.4 HA (Comeau, 1976) 189 HA (Crane and Salmond, 1971) 226 HA (Johnson, 1952) 186 HA (Fish and Wildlife Branch Survey, 1971)
mean depth	7.63 m (Comeau, 1976) 9.15 m (Crane and Salmond, 1971) 8.8 m (Fish and Wildlife Branch, 1971)
maximum depth	18.3 m (Comeau, 1976) 16.7 m (Crane and Salmond, 1971) 15.3 m (Fish and Wildlife Branch, 1971)
% littoral	58% (Comeau, 1976)
lake volume	16 423.774 m^3 (16 423.8 dam^3) (Crane and Salmond, 1971) 15 815.5 dam^3 (Comeau, 1976) 16 474 dam^3 (Fish and Wildlife Branch, 1971)

The lake is generally regarded as eutrophic based on productivity criteria. The lake has extensive growths of aquatic macrophytes (Ceratophyllum and Elodea) and conspicuous growth of algae. Harvesting of these macrophytes takes place annually between June and September over the entire lake. In 1980 approximately 358 tonnes (wet weight) were cut and removed from the lake (Kanhoffen, pers. comm.).

The high level of lake productivity appears to result in low summer water clarity, although the paucity of data during the summer fails to confirm this (Figure 2). Hypolimnetic oxygen depletion occurs during summer stratification (Figure 3). This oxygen depletion is relevant to the consideration of the current proposal.

4. PHYSICAL LIMNOLOGY CONSIDERATIONS

The most important consideration appears to be lake stratification. Depending on the level of withdrawal of water from the lake, a number of effects might occur. The present normal stratification pattern, arbitrarily beginning in early spring (February, March), indicates that the lake is isothermal at 5-6° and water likely circulates through its entire depth by wind mixing. As the input of heat into the lake increases, the surface layer becomes warmed and stratification begins to appear (Figure 4). The stratification is well established by May and maximum heat content of the lake appears to occur in August. During this period the epilimnion occupies a depth of 3-7 metres and a well defined thermocline is centred 6-9 metres below the surface. The remainder of the lake volume is hypolimnetic water, largely anaerobic because of oxygen demand and a lack of exchange with surface waters.

Beginning in September a net loss of heat from the lake occurs and the stratification becomes less well established as the temperature gradient between the surface and bottom becomes lessened. When the surface cools to 8-10°C, the same temperature as the hypolimnion, the lake becomes very susceptible to mixing. The mixing is caused by wind induced water movement. During November through February, Elk Lake does not normally strat-

FIGURE 2. RECORDS OF WATER TRANSPARENCY (Secchi depth) FOR ELK LAKE.

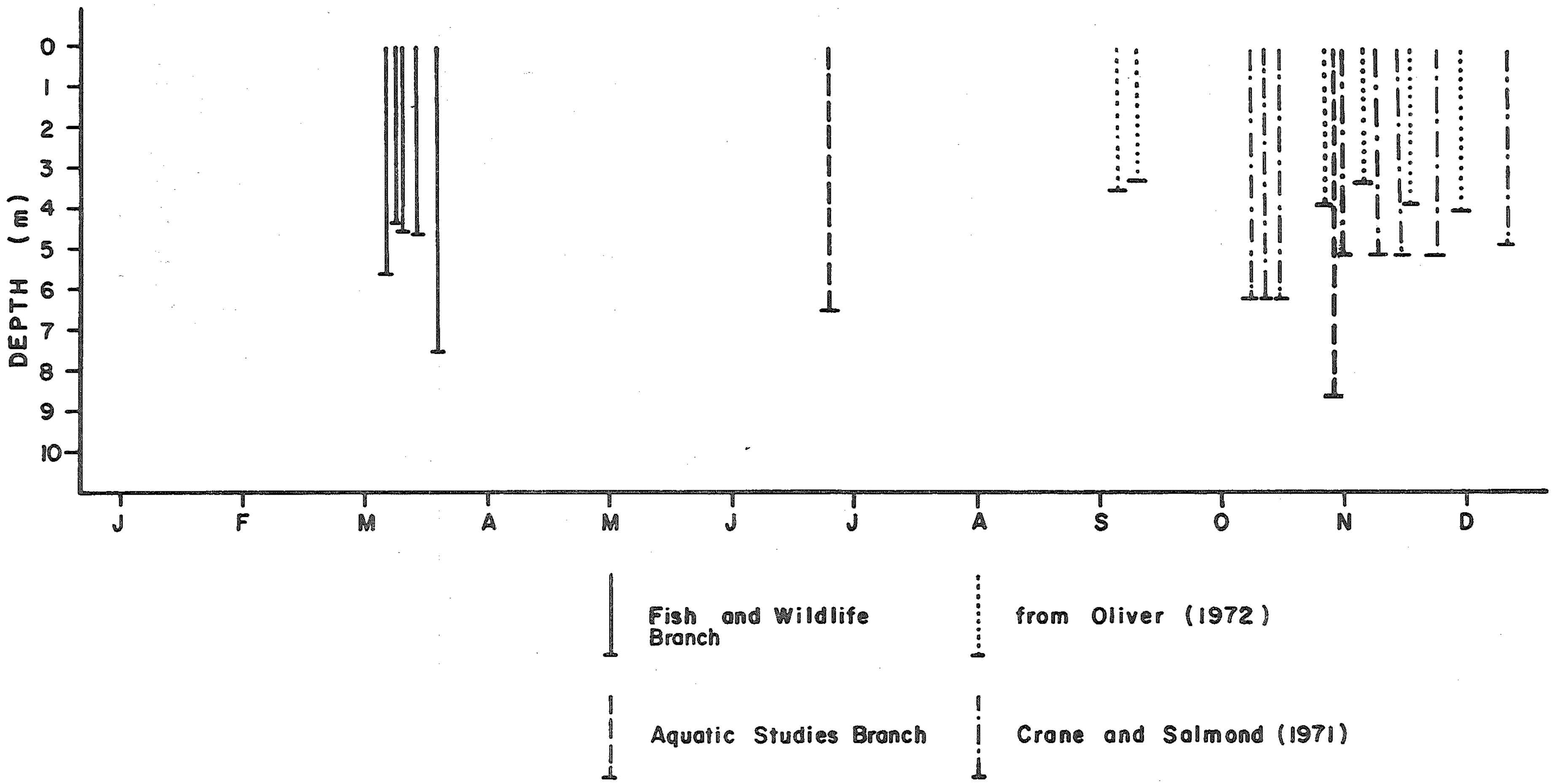


FIGURE 3. TIME-DEPTH DIAGRAM FOR DISSOLVED OXYGEN (% saturation) IN ELK LAKE. Based on a number of data sources.

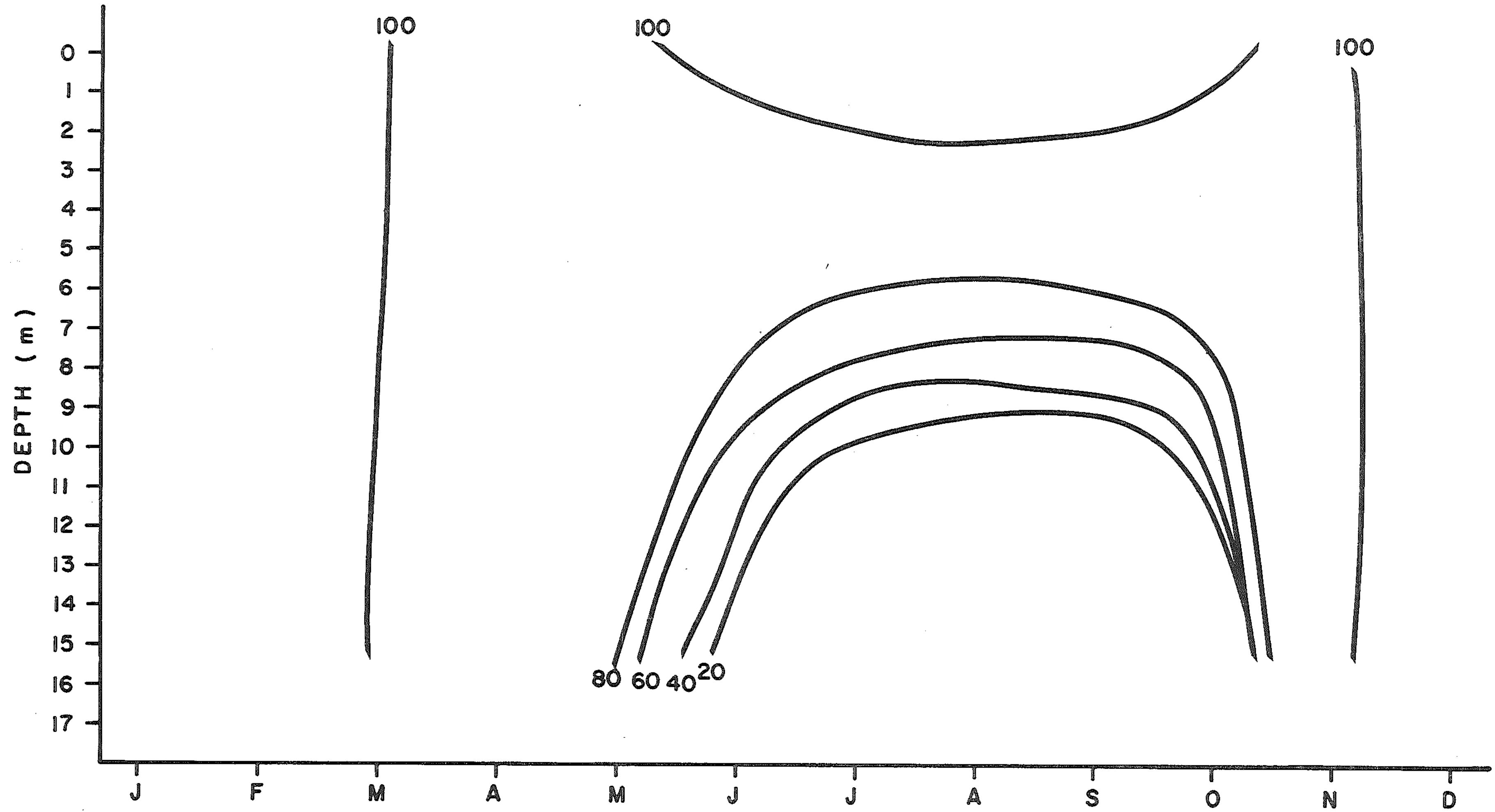
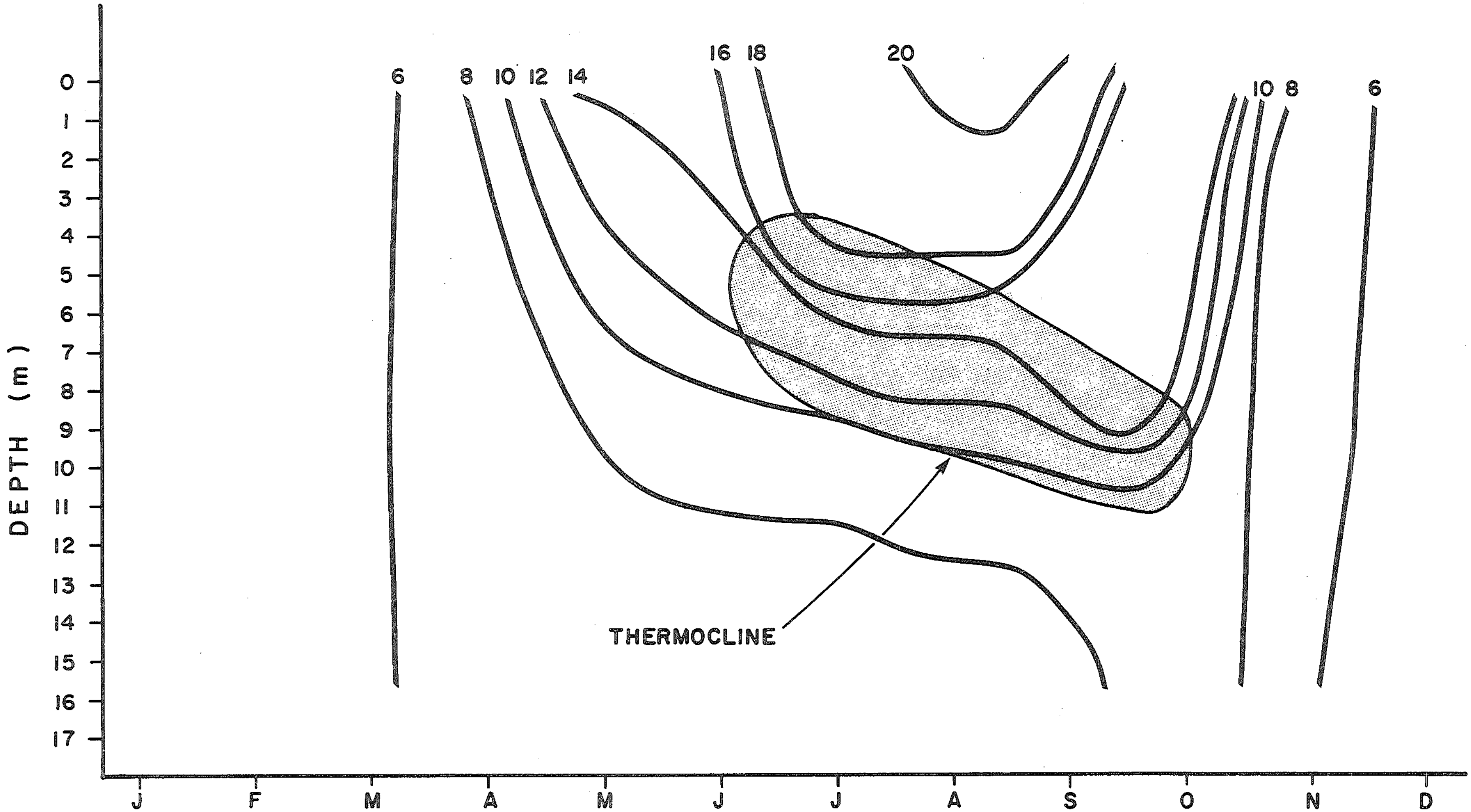


FIGURE 4 . TIME—DEPTH DIAGRAM FOR TEMPERATURE IN ELK LAKE .



ify, except in rare circumstances when ice forms. Through the winter the entire water column is normally at 5-8° depending largely on the air temperature.

The important period for the purpose of examining the storage proposal is the May through September period when water would be put into Elk Lake and withdrawn from it. The inflow water quality into the lake is substantially different from the lake itself. The major factor is temperature. There are also differences in nutrient content (these are discussed later) and in salinity.

Salinity can be a determining factor in density of water (and hence the level at which the water flows through the lake) but in this case, the salinity of Sooke Lake water (specific conductance about 50 umhos/cm or 40 mg/L total dissolved solids) is not sufficiently different from Elk Lake water (160 umhos/cm or 100 mg/L) to be a factor at the given temperatures (i.e., above 8°C).

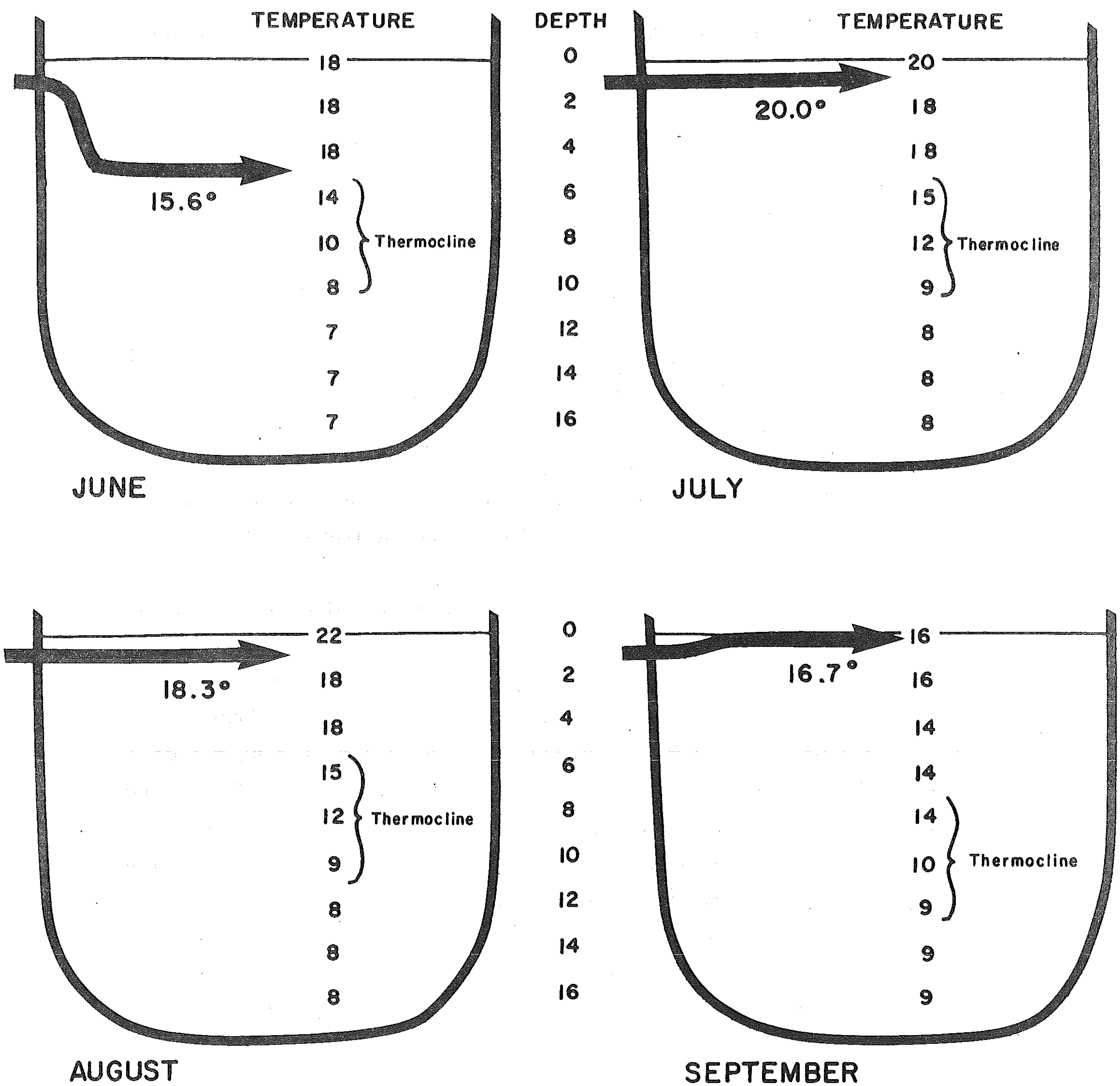
Using temperatures of the incoming Sooke Lake water (Table 2), a number of different effects on the thermal structure of Elk Lake can be visualized (Figure 5). In June, the incoming temperature is about 15°C, the water would flow into the lake at or near the depth of the 15° isotherm in the lake. For most of the month this level is 4-6 metres deep. During the later parts of the summer, the inflow water temperature increases but so does the temperature of the lake surface waters. In each case the incoming water would still flow along the isotherm of the same temperature. In July and August the inflow would be much closer to the surface (1 to 2 metres) and by September the inflow water would be generally warmer than the lake surface waters and tend to flow across the surface of the lake. It should be emphasized that these are idealized conditions. Results may vary depending on the heating of Elk Lake, changes in the inflow temperature and the degree of wind mixing at any time during the summer. However the above description should suffice to describe the general effect of the inflow, which would be a thickening of the water layer at the incoming water temperature.

TABLE 2: Mean Summer Water Temperatures in the Greater Victoria Water District* System

	at Humpback Reservoir	Victoria tap temperature
May	13.3	20.0
June	15.6	20.6
July	20.0	21.1
August	18.3	21.1
September	16.7	18.3

* Information from GVWD Oct. 1980.

FIGURE 5. EXPECTED INFLOW TEMPERATURE PATTERNS FOR ELK LAKE.



More important is the depth of withdrawal. In this case, the general water quality of the lake and fisheries habitat could be improved by using a deep withdrawal depth. By using a deep depth (say 12-14 metres) the deoxygenated hypolimnetic water could be drawn out of the lake. This withdrawal would not only allow fish to utilize a greater depth of water but would likely increase benthic productivity. It would reduce nutrient content of the lake by removing the most nutrient rich water and minimize any regeneration of nutrients from the sediments. Such nutrient regeneration occurs much more rapidly at low oxygen concentrations. The deepest layer of water, after being taken out would be replaced by the layer of water directly above, which in turn would be displaced by the warmer, fully oxygenated incoming Sooke Lake water.

5. NUTRIENT CONSIDERATIONS

Another factor to consider is the effect on the productivity of Elk Lake of the influx of a large volume of water (3 000 dam^3) of low nutrient content. Certainly the increased water exchange rate of the lake would be expected to lower the plankton productivity of the lake. However a nutrient input also accompanies the influx of water. The nutrient concentrations of Elk Lake and Sooke Lake water are given in Table 3.

The ratio of nitrogen to phosphorus, indicates that the limiting (critical) nutrient is phosphorus. The amount of phosphorus in the lake at overturn appears to be about 3.8 tonnes (22 ug/L, 17 300 dam^3). The input of phosphorus into the lake would be 0.36 tonnes, (12 ug/L, 3000 dam^3). Thus the additional Sooke Lake water would increase the loading of phosphorus by 9.4%. However, 3 000 dam^3 of water must also be removed from the lake and if the <u>same</u> water were removed (theoretically) there would be no net effect on the lake. However the possibility exists that water with a much higher nutrient content (hypolimnetic water) could be removed to cause a net loss of phosphorus from the lake. The bottom waters in June 1980 (at the beginning of stratification) were about 20 ug/L but at the end of the summer (October) approached 50 ug/L (10 October 1979)*. If the concentra-

* Concentration on 3 Nov. 1980 was an extraordinary 393 ug/L total phosphorus (78 ug/L ortho phosphorus) at 12 metres depth.

TABLE 3: Comparative Nutrient Concentrations of Sooke and Elk Lakes

Parameter	Sooke Lake*	Elk Lake**
nitrogen-ammonia	9	31
nitrogen-nitrate	120	240
nitrogen-organic	590	470
phosphorus-ortho	13	13
phosphorus-total dissolved	5	7
phosphorus-total	12	22

all values in ug/L

* from analysis of tap water
** site 1100844 (Elk Lake at Centre) 3 March, 1980
1, 5 and 10 metres.

tion over the summer is 35 ug/L, then removal of 3 000 dam^3 of water with this concentration of phosphorus would mean the removal of 1.05 tonnes of phosphorus and thus a net loss from the lake of 0.69 tonnes or 13% of the content of phosphorus of the lake. The open water productivity of the lake would be expected to respond directly to the phosphorus concentration and result in an equal reduction in algal growth.

It should be noted however that any reduction of phosphorus may or may not have an effect on the growth of vascular aquatic plants. The two major species in the lake may derive some of their nutrient supply from the water itself and some from the lake sediments. In any case, a reduction in nutrients would present the opportunity for a reduction in growth of algae and some vascular aquatic plants.

6. FISHERIES AND BIOLOGICAL TRANSFER

One concern from the standpoint of fisheries is that either fish disease or fish parasites might be transferred from Sooke Lake to Elk Lake. Very little is known with regard to these factors and some investigations should be carried out on the possibility of such a transfer.

For the planktonic communities, some information on the composition and numbers of phytoplankton and zooplankton exists (Austin, pers. comm.), but is in the form of uncompiled data and an unfinished M. Sc. thesis (Sylvia Lang). The assessment of any impact from the transfer of zooplankton or phytoplankton would require that the existing data be assessed or that additional data be gathered. However, it would seem unlikely that any harmful consequence would result from the transfer of phytoplankton or zooplankton species.

Management of lake water levels requires consideration of three separate aspects. It is advantageous for fisheries (outlet flow) and recreation that water levels fluctuations be within defined limits. For fisheries, extreme fluctuations would cause difficulties with maintaining flows in Colquitz Creek. For water-based recreation, any water level drawdown greater than one metre would likely require extension of beaches. However, for water storage capability, some flexibility of water levels would be advantageous to take advantage of natural inflows to the lake and a drawdown of 1.5 metres could be required under some conditions. It would appear that a water level operation scheme should be drawn up to take into consideration the requirements of fisheries, recreation and storage.

7. CONCLUSIONS

1. At present, Elk Lake is a very productive lake, exhibiting a number of undesirable characteristics from recreation and fisheries habitat perspectives. The lake has luxuriant algal and vascular plant growth, poor water clarity in summer and hypolimnetic oxygen depletion.

2. The additional input of 3700 dam^3 of low nutrient water from the Greater Victoria Water District could be beneficial to the water quality of Elk Lake and improve fisheries habitat if deep water withdrawals are made from the lake. This would produce increased water exchange in the lake* and a net reduction of phosphorus in the lake.

3. Inflows of water would generally be subsurface during the summer, but could be across the surface of the lake in September. These inflows, if they occurred across the surface, would be warmer than normal lake surface temperatures.

4. To avoid impairment of recreation or downstream fisheries, water level fluctuations should be within an acceptable range of natural lake levels.

* Hydrologic water balance is presently under consideration by Hydrology Section Inventory and Engineering Branch.

5. Chlorine residuals from the inflow water should be maintained below a concentration necessary to protect fisheries. Dechlorination facilities should be included in the cost and planning of the project.

6. Fish parasite and fish disease profiles should be prepared for both Elk and Sooke Lake to examine the possibility of transfer of parasites or disease.

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