WATER RESOURCES OF THE VERNON IRRIGATION DISTRICT

by

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ABSTRACT

The Okanagan Valley is an important agricultural area in south-central British Columbia. Due to the low annual precipitation and a high rate of evapotranspiration, irrigation is necessary for the production of most crops.

Since water shortage problems in the valley are likely to arise in the future, since irrigation accounts for over 90% of the consumptive use of water in the valley, and since data on the actual irrigation operation is sparse, a detailed study was made of one district.

Vernon Irrigation District, the largest district in the Okanagan Basin, was selected for detailed study. Its distribution system has recently been modernized. The history of the development of the district is outlined and the old system and the way in which it operated are described. The reasons for selection of the new system, the criteria used in its design, and the way in which the new system now operates are described. Particular attention is paid to scheduling--the timing of the application of water to the crops--since this offers one of the best opportunities for the conservation of water in the future. Minor conflicts with other users of the water resource are identified and suggestions given for minimizing such conflicts.

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CHAPTER I

INTRODUCTION

The Okanagan Valley is a broad, irregular rift-valley in the interior of British Columbia extending approximately 120 miles north from the Canada-United States border. The average annual precipitation varies from about 15 inches in the northern part of the valley near Vernon, which is barely sufficient for the production of some forage and pasture crops, to about 8 inches at Osoyoos in the south. Many crops flourish if provided with additional moisture through irrigation.

Since before 1900, agriculture has been the most important economic activity in the valley although tourism has expanded greatly in the last decade. The irrigation systems which supply water for the farms were mostly begun early in the century and consequently by the 1950's, had not only become rather obsolete in terms of todays irrigation technology but also most of the systems needed rehabilitation to conserve water and increase their reliability. In the last decade many of the distribution systems of the irrigation districts in the Okanagan have been rehabilitated under the A.R.D.A. agreement which allows for federal and provincial assistance. With growing problems of water shortage and water pollution as the valley population and industrialization increases, the federal and provincial governments have undertaken a joint study of water quantity and quality management in the Okanagan basin.

Since irrigation accounts for more than 90% of the consumptive use of water, familiarity with irrigation is necessary in order to carry out studies of water resources in the Okanagan Valley. Unfortunately, discharge and consumptive use data are at best scattered and incomplete and, in any case, records of the amount of irrigation water used, say, twenty years ago are of limited use today when irrigation practices, efficiency of application, and crops are substantially different from what they were.

To obtain an understanding of irrigation practice in the Okanagan, it was decided to study a particular irrigation district in detail to find out how it actually operated and to try to identify problems and conflicts with other resource users and opportunities for better management. Vernon Irrigation District, the largest district in the Okanagan Valley was selected for the study. Although it has a lower water consumption per acre than other districts in the Okanagan, Vernon Irrigation District is typical in that it has several reservoirs with a relatively complex operating pattern, and records of water availability and consumptive use are not available. Also replacement of the old distribution system by a new one has just been completed, thus offering an opportunity to study a modern installation.

In this thesis, the history of the development of the district is first outlined to give some background perspective, and the old system and its operation is described. The reasons for selecting the new system are outlined and the criteria used in its design are given. Operation of the pipeline and reservoir systems, and scheduling, the procedure for deciding when to apply water to a crop are described. Some minor conflicts for water use were evident and these are described together with suggestions for managing the water supply to minimize such conflicts in the future.

CHAPTER II

VERNON IRRIGATION DISTRICT

GENERAL DESCRIPTION

The Okanagan Valley is a dry valley in the south-central interior of British Columbia (Figure 1). Summers are warm and dry and winters are cool and moderately dry. Historically, the main industry has been agriculture although in recent years tourism has become increasingly important. Since the climate is so dry, irrigation is required for almost any form of agriculture in the valley.

The Vernon Irrigation District (referred to as V.I.D. in this thesis) lies at the north end of the Okanagan Valley. It encompasses a total of 27,400 acres of which approximately 9200 acres were registered for tax purposes as being irrigated in 1971. The irrigated lands lie generally along the east-west Coldstream Valley and the north-south valley which leads from the Columbia-Fraser watershed boundary in the north to Okanagan and Kalamalka Lakes in the south. The altitude of irrigated lands varies from 1200 to 2100 feet. High, tree covered terrain extends beyond the steep-sided valleys both north and south of the District to an elevation of about 6000 feet. Since precipitation increases with elevation while evaporation decreases with elevation, most of the run-off originates from the higher levels. Most of the run-off comes from snowmelt and as a result peak flows occur in May and early June. Excess water is stored in Haddo, Aberdeen and King Edward

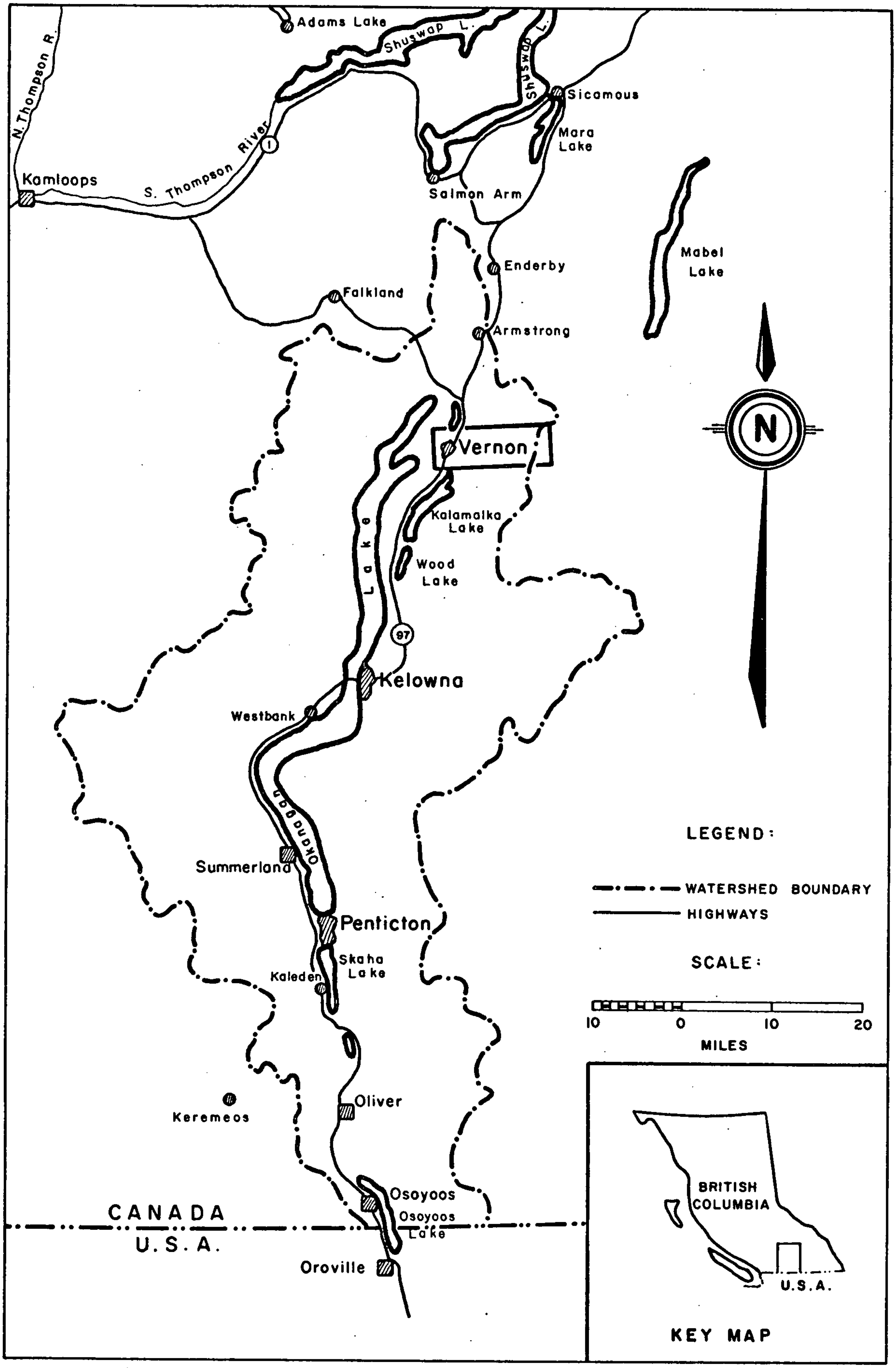

Fig. 1 OKANAGAN BASIN IN BRITISH COLUMBIA.

Lakes which lie to the south of the District at an elevation of 4000 to 4500 feet. The stored water is released to meet irrigation needs later in the irrigation season when the demand exceeds the unregulated flow from the remainder of the watershed. Although irrigation is required for most crops, precipitation (which is higher in the District than elsewhere in the Okanagan Valley and much higher than in the southern portion of the valley) is sufficient to permit some crops such as hay, to grow without irrigation.

CLIMATE

With an average of 150 frost free days a year, Vernon at lattitude 50° 15' north, lies at the approximate northern limit for the commercial growing of tree fruits in the interior of British Columbia. The climate is mild continental with warm summers, cool winters, and low annual precipitation. Cold spells of below zero temperatures may be expected every winter with below freezing temperatures occurring between mid-September and mid-May, though prolonged periods of extreme cold are rare. The following table gives an indication of the climatic conditions of the area.

TABLE I

CLIMATIC DATA

	Vernon	Vernon (Coldstream)
Elevation in feet	1383	1582
Average January Temperature	23°F	21°F
Average July Temperature	68°F	66°F
Average January Precipitation	1.7"	1.5"
Average July Precipitation	1.0"	1.2"
Average Annual Precipitation	15.5"	15.1"
Average Frost Free Days	151	147

The proportion of the land devoted to various agricultural activities varies from year to year but the following table taken from "Farming in the Vernon Irrigation District" (14), gives an indication of the relative importance of the various crops.

TABLE II

LAND USE

		UNDER IRRIGATION		
CROP	TOTAL ACRES	ACRES	PERCENT OF CROP	PERCENT OF TOTAL IRRIGATED AREA
Fruit	2553	2519	99	37
Vegetables	709	707	100	10
Grain	1165	312	27	5
Hay	3265	1887	58	27
Pasture	3337	1097	33	16
Other	6551	366	6	5
Total	17,580	6888		

Of a total of 6888 acres irrigated, 3268 acres comprised grain, hay or pasture with a low irrigation water requirement compared to tree fruits. This, along with higher precipitation and lower evaporation, accounts for the fact that Vernon Irrigation District has a lower total annual water demand than districts in the south Okanagan Valley where tree fruits form a higher proportion of the total crop.

HISTORY

In 1892, the Earl of Aberdeen purchased the Coldstream Ranch from the Honorable Forbes George Vernon. His intention was to develop the land by bringing irrigation water to it and then sell the improved land to settlers. It can be said that this was the beginning of commercial fruit growing in the Okanagan. Irrigation was actually instituted by the Honorable Couttes-Marjorie Banks, manager of the Coldstream Ranch, who employed Mr. F. B. Kirby, B.C. Land Surveyor to survey a ditch for irrigation of part of the Ranch. This ditch was constructed and expanded in later years to serve lands further down the valley. It became known as the North Ditch and was still in use in 1965. The Coldstream Estate Company was formed to develop and to sell the irrigated land. Another Ranch manager, Mr. Ricardo, developed the Orchard Ditch, King Edward, Abbotsford and Walker systems from local sources of water--mostly diversions of Coldstream Creek (Figure 2). In 1905, Mr. Ashcroft was engaged to survey the Duteau Creek watershed to determine the feasibility of using it for irrigation supply purposes. On his recommendation, the canals now known as the Grey and South Canals were subsequently constructed along the north and south sides of the Coldstream Valley.

For the control and ownership of this new system, which was to serve the lands east of the B.X. Creek, The White Valley Power and Irrigation C[illegible]ny was formed, the shares in this company being [illegible]ginall[illegible] the Coldstream Estate Company. By an arrangement with the Land and Agriculture Company, the Grey Canal was extended west and north, and finally across the Swan Lake Valley to Goose Lake in 1910, and north and south from there to eventually spill excess water into Okanagan Lake in 1914.

By 1915, approximately $423,000 had been spent on the system,

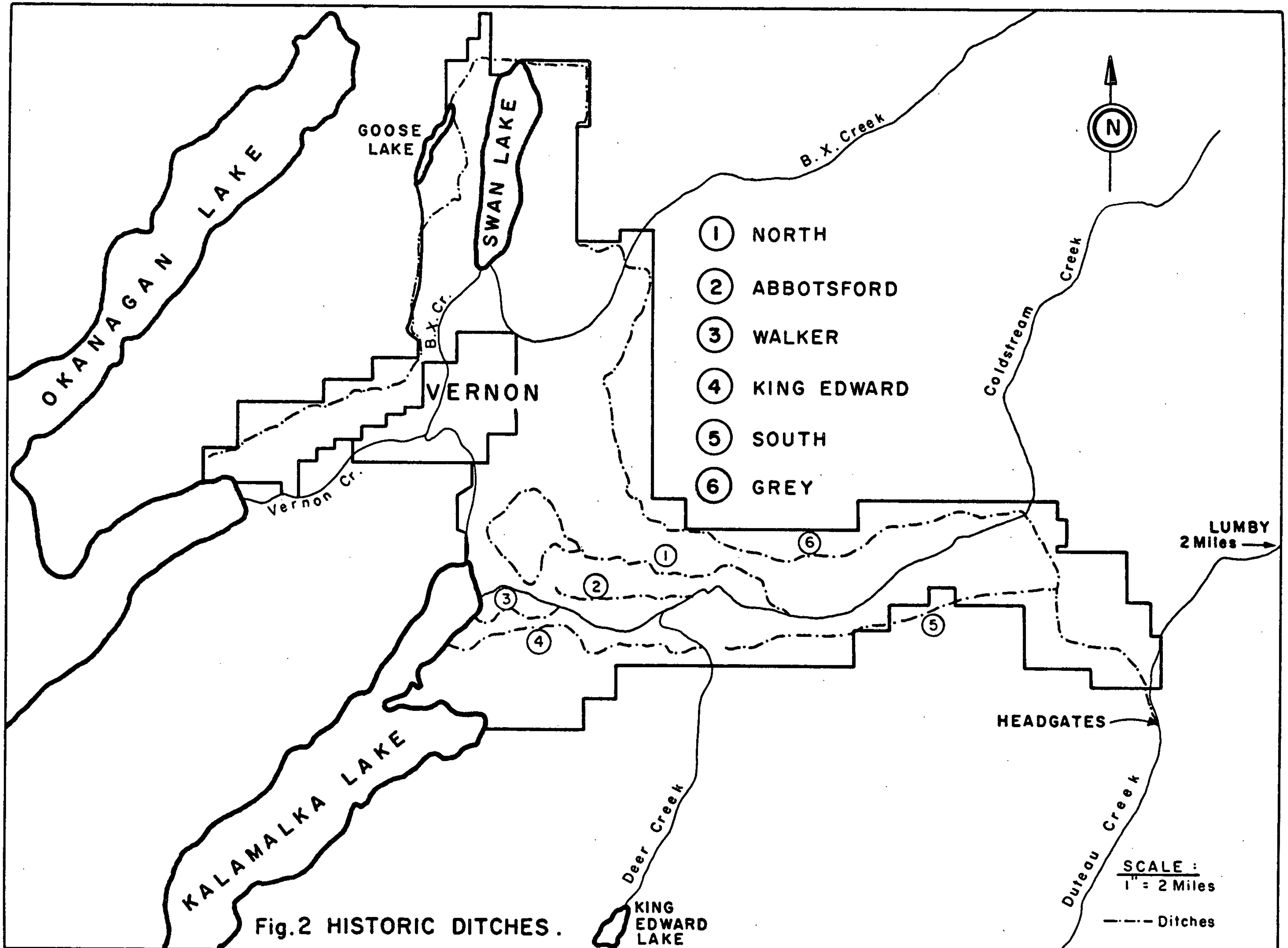

Fig.2 HISTORIC DITCHES.

the operating loss that year was $12,000, and the system was badly in need of repair. On the advice of Mr. E. A. Cleaveland, Comptroller of Water Rights, the land owners petitioned the provincial government to form an improvement district under the Water Act. As an improvement district, the area would be eligible for provincial assistance for improving the water distribution system. The petition was granted and in 1920 the area was formed into a district and named the Vernon Irrigation District.

Under the Water Act, the Lieutenant Governor in Council has the power to incorporate an area into an improvement district by Letters Patent. An improvement district is a public corporate body and may have all the powers necessary to carry out its objectives. Among its powers are the power to sue and be sued, to borrow money, to issue bonds, to levy and collect taxes and tolls, and to construct and maintain works for the distribution of water. The powers of the district are exercised by Trustees who are elected by the landowners in the district.

Since incorporation in 1920, the Vernon Irrigation District has passed through several periods of hard times. Mr. G. C. Tassie was engaged as General Manager in 1937, and under his guidance a program of more permanent works was instituted. However, lack of funds prevented any major program of rehabilitation, and only the more critical parts of the system received attention. Between 1945 and 1963, repairs included lining of parts of the canal system with concrete slabs to prevent seepage, replacement of steel flumes, and laying of some asbestos-cement pipe.

In general, up until construction of the new system commenced in 1965, lack of money prevented any but the most urgent repairs and replacements from being made. In 1961, the federal government passed the Agricultural and Rural Development Act (A.R.D.A.). This act states that the minister may, with the approval of the Governor in Council, enter into an agreement with any province providing for the joint undertaking of projects for the development of income and employment opportunities in rural areas. Included are projects for the development of water supplies for agricultural or other rural purposes and projects for the more efficient use and economic development of rural lands. Under this agreement, project costs are divided equally among the provincial and federal governments and the landowners in the benefiting area.

When, in 1962, the Vernon Irrigation District manager resigned, the district trustees decided to try to operate the district without an irrigation manager. An engineering consultant who was called in to assist in the operation of the system, suggested that a renewal program be instituted. The trustees went to the Department of Lands, Forests, and Water Resources to obtain assistance in planning. The Water Investigations Branch carried out a study of the V.I.D. in 1964 and 1965, under the A.R.D.A. agreement with the assumption of A.R.D.A. financing. In 1965 a report was prepared which compared the feasibility of rehabilitating the old system with the construction of a completely new pipeline system. The study considered only the water distribution system although the application method was a consideration in design. The study was quite comprehensive since, to quote the report, "any decision to adopt an alternative which involves abandoning works that have successfully provided irrigation water to the District for over fifty years, should not be made before an alternative of improving the existing system is carefully scrutinized" (5). Although the study dealt mainly with the rehabilitation of the ditch system and the construction of a pipeline system, other alternatives considered in the study were:

1. pressurization of the existing system
2. canalization of Coldsteam Creek
3. pumping from Okanagan, Kalamalka, and Swan Lakes
4. pumping from Okanagan Lake to supply the Belle Vista area

These alternatives posed problems of screening, blockage of sprinklers, high cost of pumping schemes compared to gravity, and generally higher costs than rehabilitating the ditch system or construction of a buried pipeline system. Therefore, no extensive consideration was given to the alternatives listed above, and instead, the study concentrated on the alternatives of rehabilitating the ditch system and providing a new pipline system. The main points considered in the study are outlined in Chapter III. The pipeline system was chosen and between 1965 and 1970, the Vernon Irrigation District gradually changed to the pipeline system. In 1971 the District operated entirely without delivery ditches.

OPERATION OF THE OLD IRRIGATION SYSTEM

The old distribution system of the Vernon Irrigation District, parts of which were in use until 1970, consisted of some 57 miles of open canals and about 37 miles of distribution pipeline. Most of it was constructed between 1900 and 1920 or before the District was incorporated.

Water was regulated by storage and release from Aberdeen and Haddo Lakes. After release from Haddo Lake, the water flowed down Duteau Creek to the Vernon Irrigation District diversion at which point the water entered the Grey Canal at the approximate elevation of 2150 feet. From the canal, the water was conveyed by syphon and flume to the irrigators land.

The farmers had to order water for irrigation at least twenty-four hours in advance of the desired delivery time. The water was ordered from the Water Bailiff who in turn ordered the water from the Chief Water Bailiff. The Chief Water Bailiff added up all the water required for all the areas, added an amount for seepage losses, and ordered the dam operator at Haddo Lake to open or close the control as required to supply the estimated amount. The amount of excess water ordered to satisfy seepage losses was in the order of 30 per cent.

Regulation of water was generally by means of gates and valves located along the canal. The morning that the irrigator was to receive water, the Water Bailiff arrived to open the control at the farmer's outlet. This control was the property of the District and only employees of the District were permitted to adjust it. Irrigators paid only for water actually used by them, and it was measured by means of weirs or gates or by calculation from sprinkler nozzle sizes and supply pressure.

There were problems with this type of measurement as sometimes the measuring flumes were tilted by frost action or blocked by debris from the canal. When the frost action occurred, it was necessary to recalibrate the flume, whereas in the case of debris blockage, the District was usually obliged to extend the period of flow to make up for the reduced discharge rate. Twenty-four hours before the farmer finished irrigating, he would again call on the Water Bailiff to shut off the water.

The farm irrigation systems in the Vernon Irrigation District consisted mainly of furrow irrigation in which the field had furrows constructed with gentle slopes to prevent erosion. The irrigator allowed water to flow down a furrow until the ground had enough moisture, then sealed off that furrow and transferred the flow to the next furrow. This operation was repeated until the field or farm was irrigated. The farmer had no scientific method of knowing when the land was sufficiently moist, but relied on his experience and knowledge of the physical characteristics of his own soil -- the feel, look and smell of it. If insufficient water were applied to the crop, consequences ranged from sub-optimal growth to permanent wilting and loss of the crop. Therefore, it was natural that the irrigator would try to apply more water than necessary in order to have a safety margin. This safety margin was also good from the point of view of salt build-up as salt concentrations may build up to levels toxic to the crop, if insufficient drainage water passes through the root zone. Therefore, some application of irrigation water over and above that required for consumptive use is desirable to leach soluble salts from the root zone. For the Okanagan, leaching requirements are fairly modest and it is generally considered that over winter precipitation is almost sufficient to leach undesirable salts from the root zone.

CHAPTER III

NEW IRRIGATION SYSTEM

DESIGN

In order to take advantage of the opportunities offered under the Agricultural and Rural Development Act, the trustees of the Vernon Irrigation District requested the Department of Lands, Forests, and Water Resources to carry out a study to determine the best method of rehabilitating the irrigation system. This was done and in the report, which was published in 1965, two main alternatives were examined. The first involved replacement of all components in the existing system with a remaining life of less than twenty-five years and lining the canals. The second scheme involved a new system consisting entirely of pipeline buried below the frost line. The supply pressure would be supplied generally by gravity, but some pumping would also be involved.

Comparison of Alternatives

The estimated annual cost per acre over twenty-five years was twenty-three dollars for reconstructing the ditch system and twenty-eight dollars for the new pipeline system. Despite the cost difference, the pipeline system was chosen. The main reasons for the choice of the pipeline are outlined in the following paragraphs.

1. Rebuilding the old system would mean that the area was still served by a fifty year old system.

2. The ditch system was designed for furrow irrigation which depended on a plentiful supply of cheap labour. Many farmers had changed to sprinkler irrigation and the trend appeared to be toward an increase in sprinkler irrigation and a decrease in furrow irrigation. With the ditch system, many small pumps would be required for sprinkling and if the cost of pumping were added to that of rebuilding the ditches, the total would be much more than the cost of supplying the water under pressure in the pipeline. In other words, the total cost of supplying water to the sprinklers would be less with the pipeline conveyance system than with the ditch system.

3. A ditch system is subject to the ingress of debris and weeds which tend to clog sprinkler heads unless screening is undertaken at the intake. With the pipeline system, debris could be removed by one set of screens at each intake, whereas, with the ditch system, each irrigator would require a set of screens.

4. The new system would be constructed of long lasting components not exposed to frost or other mechanical damage and hence should have low maintenance costs.

5. The water losses of about 30 per cent, due mainly to seepage from canals, would be reduced to almost nil with the construction of the pipeline system. The water saved in this way was estimated to be enough to irrigate 1500 to 2000 additional acres.

6. During the rehabilitation of the old system, all components

with a useful life of twenty-five years of less would be replaced. After that time, further expenditures would be required. The pipeline system should not require significant capital expenditures for fifty years.

In summary, it was felt that, from a long term point of view, the pipeline system offered the cheapest and best irrigation service. With the pipeline system, the area could also be served with chlorinated water at little additional cost. This was an important consideration as many areas were serviced with shallow wells which probably derived a large amount of recharge from the seepage losses from the canals. The rehabilitation of the system would have tended to reduce seepage which could have perhaps resulted in dry wells.

Design Criteria for the Pipeline System

Duty. The water sales records of the Vernon Irrigation District were studied by the Water Investigations Branch to determine the so-called 'duty' of water for the District (i.e. the total depth of water application in a season). It was found that there had been a slight decline in total water demand over the years between 1950 and 1963 and this was attributed to the increase in sprinkler irrigation and the associated increase in application efficiency. The maximum duty of water between 1953 and 1963 was calculated to be an average of 15.0 inches over the irrigated area.

In 1959, a soil survey of the North Okanagan Valley was undertaken by the Soil Survey Branch, British Columbia Department of Agriculture. The Vernon Irrigation District was divided into soils areas to compare the water requirements. Tree fruit irrigation demands are higher than those for other types of crops. Therefore, to obtain a maximum figure for water requirements of the area, tree fruit demands were used in the calculations. An average duty of 18.3 inches was calculated. The large difference with the 15.0 inch figure calculated from records was accounted for by the fact that large areas such as those growing grain and hay crops were lightly irrigated, thus bringing down the overall average. For design purposes, the duty assumed by the Water Investigations Branch was an average of 16 inches.

Maximum demand rate. From the District records it was calculated that the average maximum demand rate for the hottest sixteen day period (July 16 to 31) was 4.2 U.S. gallons per minute per acre. The actual design rate would have to exceed the average maximum demand rate to meet requirements of areas with above average maximum demand rates and to meet instantaneous peaks. However, a continued decrease in furrow irrigation would tend to reduce the maximum demand rate.

Based on soil and consumptive use requirements, the maximum demand rate was calculated to 5.6 U.S. gallons per minute per acre.

Using these figures as a guide, the Water Investigations Branch decided to use 6.0 U.S. gallons per minute per acre for the rehabilitation of the ditch system and 5.0 U.S. gallons per minute per acre for the pipeline system for purposes of comparing the two systems.

The pipeline scheme would supply water under pressure and it was assumed that with it, sprinkler irrigation would be adopted throughout the District with a resultant lowering of the maximum demand rate. As described in the previous section, the pipeline system was chosen. The figure of 5 U.S. gallons per minute per acre was retained as a design criterian.

Pressure. The pipeline system was designed to provide 100 feet of head of water at the old canal level. This pressure would be sufficient to irrigate by sprinklers all land formerly served by gravity from the old system.

OPERATION OF NEW IRRIGATION SYSTEM

Distribution System

The Vernon Irrigation District system is now a newly renovated system consisting of approximately nineteen miles of 50 inch to 24 inch concrete and steel pipe in the main line (Figure 3). Branch lines service each area with laterals and outlets deliver water to each farmer. The water is released from the dam at Haddo Lake and flows approximately fifteen miles down Duteau Creek. At this point a small diversion dam has been constructed which impounds about thirty acre-feet when full. This reservoir is sufficient to supply the district for four hours and twenty minutes at maximum demand rate of 38,000 U.S. gallons per minute. Water is screened before it enters the main intake pipe. The irrigation water from this point is

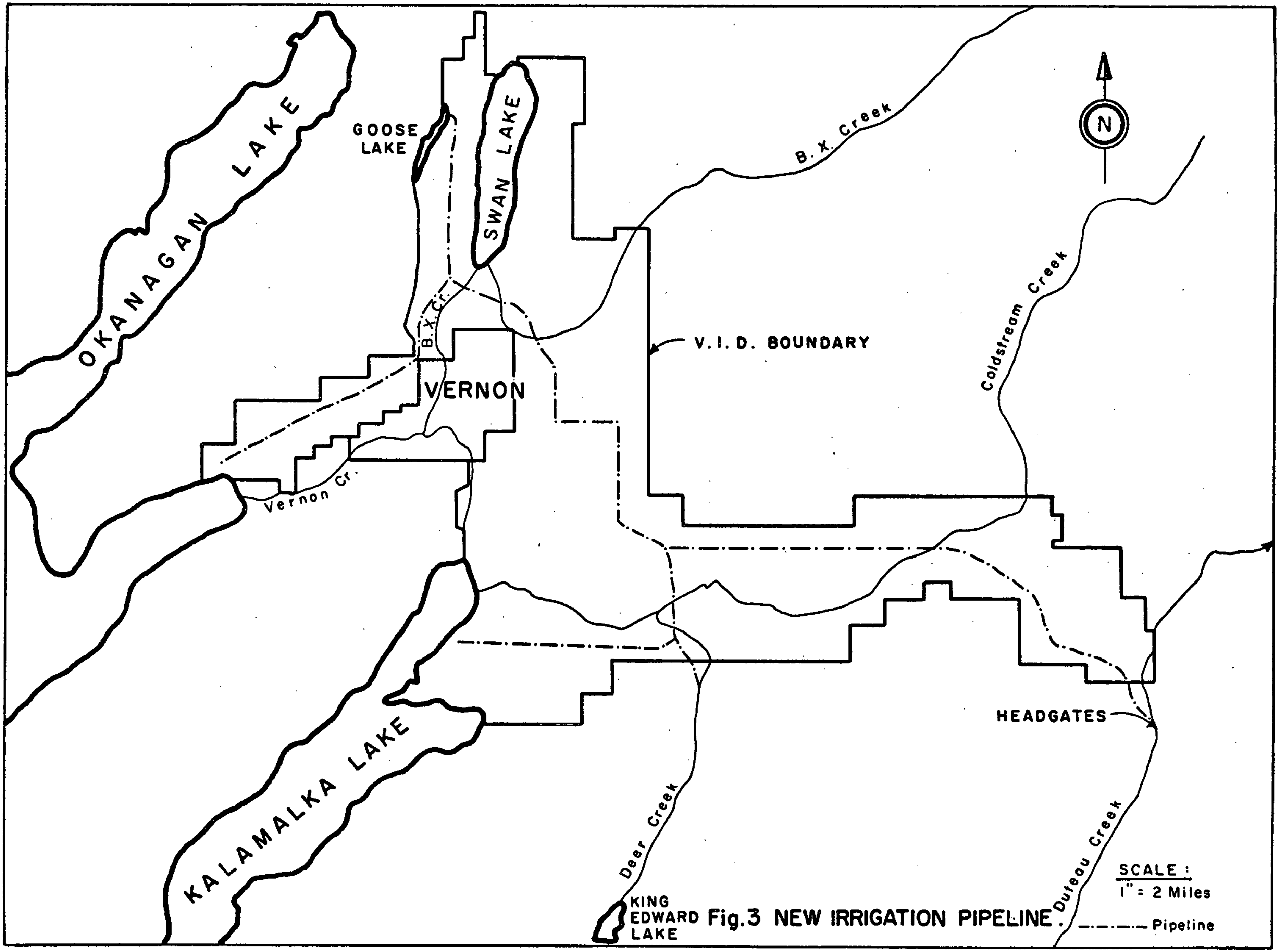

Fig.3 NEW IRRIGATION PIPELINE

delivered through a completely closed system.

Similarly, water released from King Edward Lake flows down Deer Creek and passes into the system at a small diversion. There is very little storage at this diversion, so releases from King Edward Lake are controlled very carefully to avoid wastage.

At the irrigators' delivery point, the District maintains two valves; both are below frost line. One opens the line into the stand-pipe and the other drains the stand-pipe. At the upper end of the stand-pipe is the farm valve owned and maintained by the irrigator.

In the spring when the farmer is ready to start irrigation, he calls the District and requests that his water be turned on. An employee of the District then proceeds to close the drain valve and open the main valve. From this time to the end of the irrigation season, the farmer has water "on tap". He may use the water for the length of time he wishes--only the maximum rate is fixed.

The maximum rate of application for the district as a whole of 5 U.S. gallons per minute per acre was determined as described in the previous section. This rate also applies to the farmer's individual irrigation system. Each system is thus designed to use water at a rate calculated on the basis of 5 gallons per minute per acre over the whole acreage. In practice the water is applied at a much greater rate at any one time, the area which must be irrigated at any one time depending on the safe irrigation interval which in turn, depends on the water holding capacity of the soil and the consumptive use. For example, if a farmer had a twenty acre plot with a safe interval of ten days, his system would be designed to deliver (20 x 5) 100 gallons per minute , and this would be applied to two acres at a time if he operated on a one day cycle or one acre at a time if he operated on a twelve hour cycle. Thus, the farmer requires sufficient equipment to enable him to irrigate at least one acre at a time. The larger the spread of the equipment, the less frequently it has to be moved.

In order to control the application rate under varying pressure conditions, the District requires that a flow control valve be placed under each sprinkler head. The flow control valves used in the Vernon Irrigation District (Dole type) consist of a metal cylinder with a rubber diaphragm inside it. In the rubber diaphragm is a hole arranged such that, as the pressure increases, the size of the hole decreases and the flow decreases. If the pressure decreases, the size of the hole increases, thereby allowing the flow to increase. In order to encourage its policy concerning flow control valves, the District supplies them to the irrigators free of charge. The District polices the system and the Water Bailiffs have the power to shut off the water if flow control valves have been altered or removed.

Operation of the system requires that the pipeline be kept full at the headgates diversion at all times by regulation of water releases from Haddo Lake. This system requires a new skill on the part of the Chief Water Bailiff in that, since irrigators no longer are required to order water in advance, he must now be able to accurately predict the water use over the next twelve hour period. If too much water is ordered from the reservoir, it will spill over the diversion at the headgates and be wasted. If too little water is ordered, the pipe will empty and pressure loss at the lower end of the system will prohibit irrigation. When determining the amount of water to order from Haddo Lake, the Chief Water Bailiff considers the weather, the time of year and the time of week. A change in weather from cool to warm or wet to dry would dictate an increase in flow. The time of year indicates what the irrigators are doing with their crops. If they are starting harvest, they will be stopping irrigation. Variation in demand with the time of week is a phenomenon which has developed with the new system. For example, at the Coldstream Ranch, with over 1200 acres under irrigation, the manager has determined that by shutting down irrigation during the weekend, the ranch can save money which otherwise would have to be paid in overtime to workers moving irrigation pipes, without risk to their crops.

After balancing all the above factors the Chief Water Bailiff makes an educated guess as to the water demand and orders the water from Haddo Lake. The water takes approximately eight hours to travel from the dam at Haddo Lake to the headgates and the pond at the headgates holds enough water for about four and one-third hours at maximum demand. A delicate balance must be maintained if water wastage is to be kept to a minimum. For the first year of operation, the demand at the headgates was observed to change relatively slowly and almost linearly during both the increasing and decreasing demand cycle. This is probably due to the fact that the District is so large that the variations caused by individuals are insignificant. No problems are anticipated with prediction of water demands on a daily basis.

Plans have been made to install an automatic gate system at the lake outlet when finances permit. The water level in the headgates pond will be monitored continuously and the gate operation at the lakes will be radio controlled. As the level in the headgates pond goes down, the control at the dam can be opened to release more water. This procedure will ensure an adequate supply of water at the headgates while keeping spill to a minimum. Also, natural flow from the uncontrolled portion of the watershed can be utilized more readily. However, in view of the limited storage at the diversion of only about four hours supply and the time of travel of eight hours from the reservoir, very careful design will be necessary.

Reservoir System

The Vernon Irrigation District has four storage reservoirs as shown in Figure 4. Aberdeen, the largest, drains directly into Haddo Lake which is much smaller in storage volume (Table III). From Haddo Lake water is released into Duteau Creek and after travelling about fifteen miles, can be diverted into the Vernon Irrigation District irrigation scheme at the diversion dam at Headgates. If the water is not diverted, it continues down Duteau Creek and eventually into the Fraser Watershed. About seven and one half miles to the west

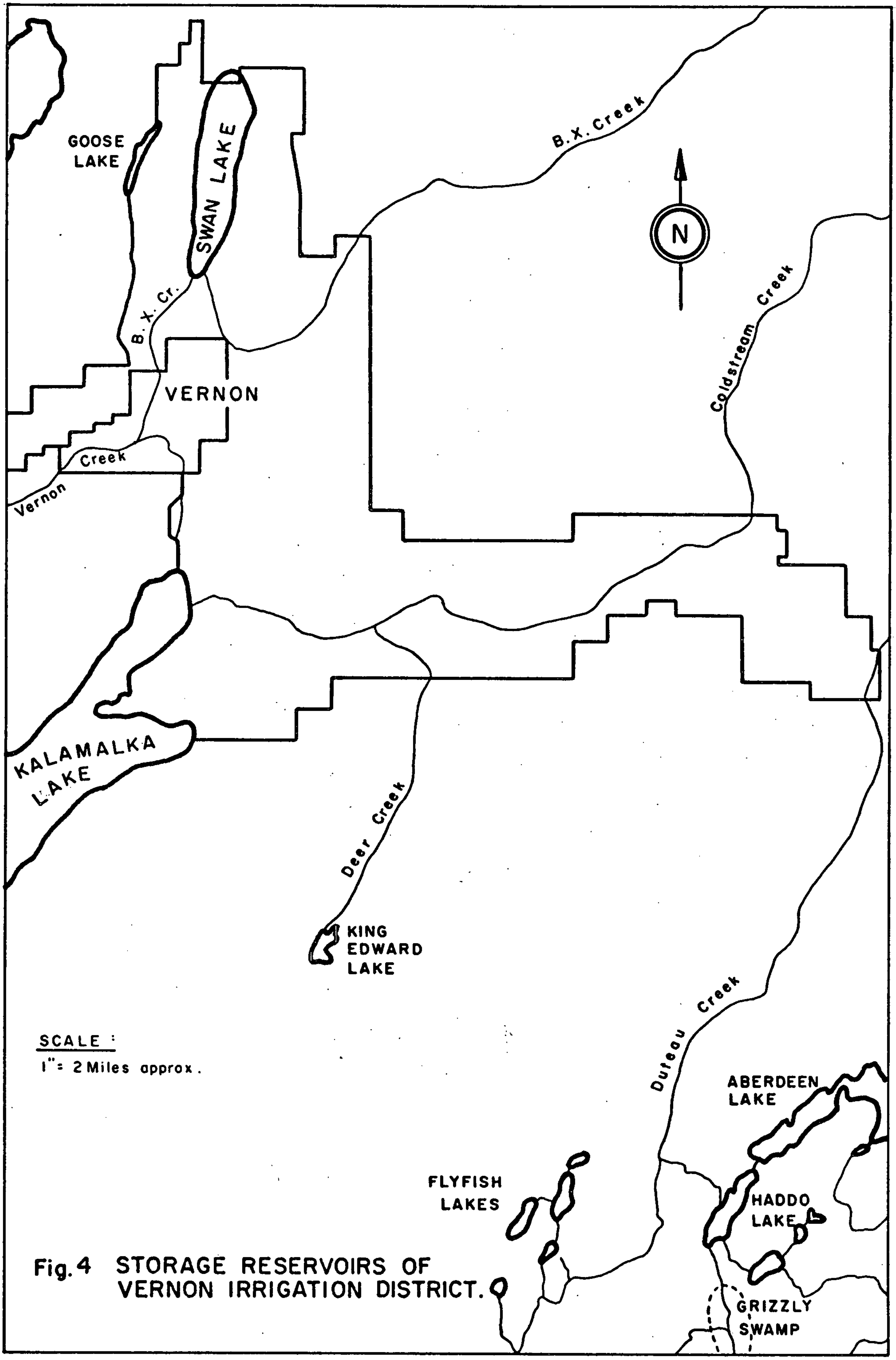

Fig. 4 STORAGE RESERVOIRS OF VERNON IRRIGATION DISTRICT.

lies King Edward Lake. The water from this lake flows down Deer Creek to a diversion dam and then, if it is not diverted into the irrigation scheme, this water flows into Kalamalka Lake. The last storage lake is Goose Lake, a balancing reservoir on the north-west side of the District. Goose Lake has little natural inflow but has a live storage of 1275 acre-feet.

TABLE III

CATCHMENT AREA, STORAGE, AND GOVERNING WATER LEVELS OF VERNON IRRIGATION DISTRICT RESERVOIRS (5)

RESERVOIR	CATCHMENT AREA SQ. MI.	LIVE STORAGE AC. FT.	WATER ELEVATIONS FEET (GEODETIC)		SURFACE AREAS ACRES	
			MAX.	MIN.	MAX.	MIN.
Aberdeen Lake	20.7	8,693.6	4,196.0	4,172.0	576.2	112.0
Haddo Lake	19.2	2,498.3	4,167.1	4,146.6	176.3	30.0
King Edward Lake	4.6	1,253.5	4,485.0	4,465.0	82.3	47.0
Goose Lake	Negligible	1,275.0	1,637.0	1,617.0	89.0	47.0

The District Irrigation Manager-Engineer has the responsibility for operation of the reservoirs and the main criteria used to operate the dams is that there is maximum carry over, for insurance against drought next season.

At the end of the irrigation season, the lake outlets are closed and remain closed until the beginning of the next irrigation season (except for domestic water releases from Haddo Lake). During the spring freshet, there is seldom sufficient run-off to completely fill Aberdeen Lake since it has a large storage volume in comparison to its watershed area. King Edward Lake sometimes fills and spills but not as often as Haddo Lake which almost always spills large amounts of water. In order to use some of the spilled water, it is channelled to Goose Lake through the irrigation system and may fill Goose Lake before the irrigation demand has become substantial. The pattern of reservoir releases is as follows: during the first part of the irrigation season while the demand is relatively low, water is drawn from Haddo Lake which is refilled from Aberdeen Lake as necessary. As the demand increases King Edward Lake is tapped. At the peak demand of the season Goose Lake is also opened and all inputs into the system are used.

The ideal situation at the end of the irrigation season is to have Goose and Haddo Lakes empty, some carry over in King Edward Lake and as much carry over as possible in Aberdeen Lake. The above procedure is illustrated in Figures 5 and 6. The hydrographs shown have been derived from recorded discharges in B.X. Creek in 1967 since detailed records of inflow into the lakes are not available. B.X. Creek, has the same general watershed characteristics as the lakes in the Vernon Irrigation District and the hydrograph shown is believed to be reasonably representative. The vertical lines show that the reservoir is full and the inflow is transmitted directly to outflow. For example, on May 18, (Figure 5) Haddo Lake was full and the water was diverted to Goose Lake. On June 21, the outflow from the watersheds became less than the irrigation demand. Therefore, storage water had to be released to satisfy the demand. On July 15, all the reservoirs

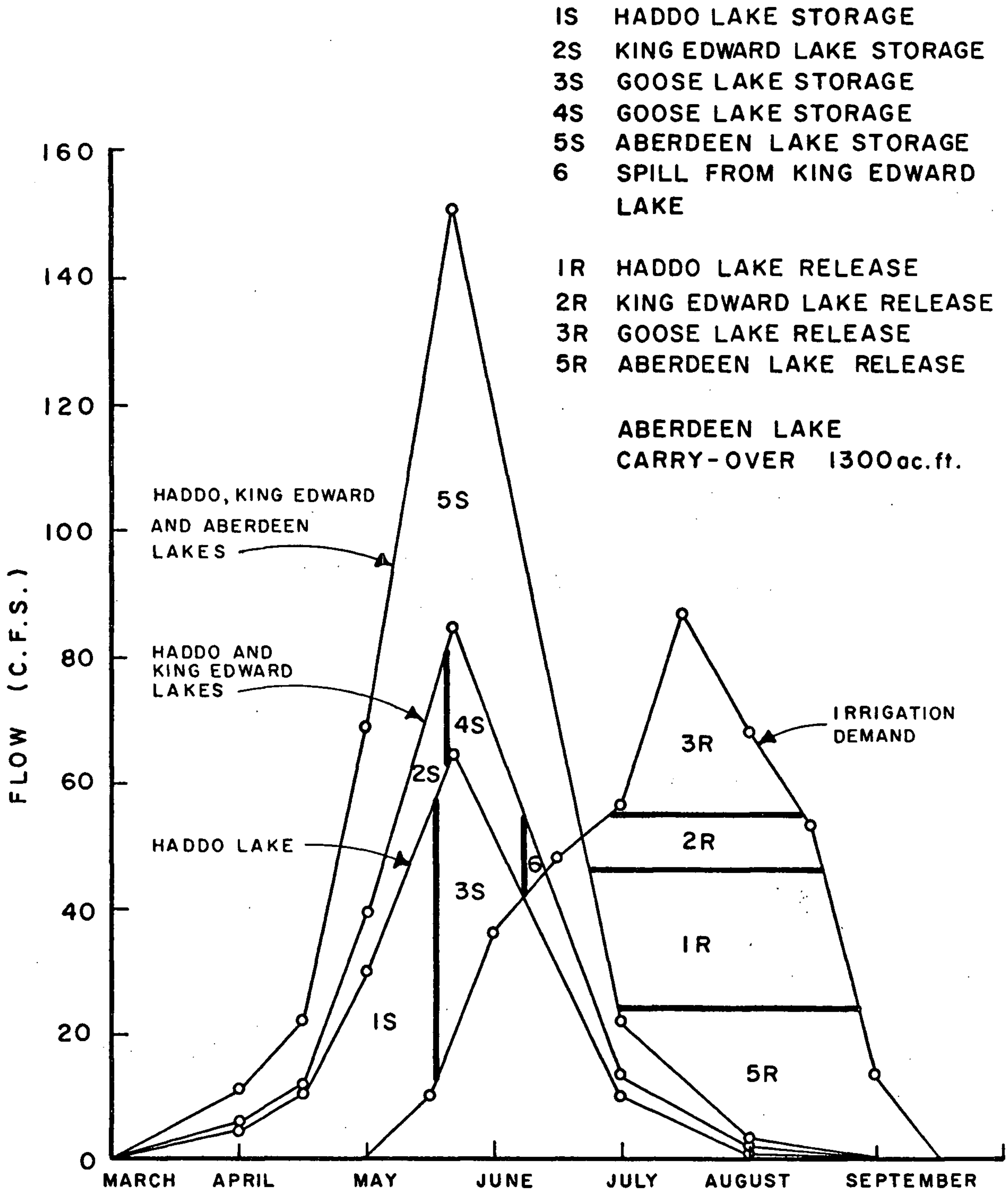

Fig.5 HYDROGRAPHS OF LAKE INFLOW AND RELEASE IN HIGH FLOW YEAR.

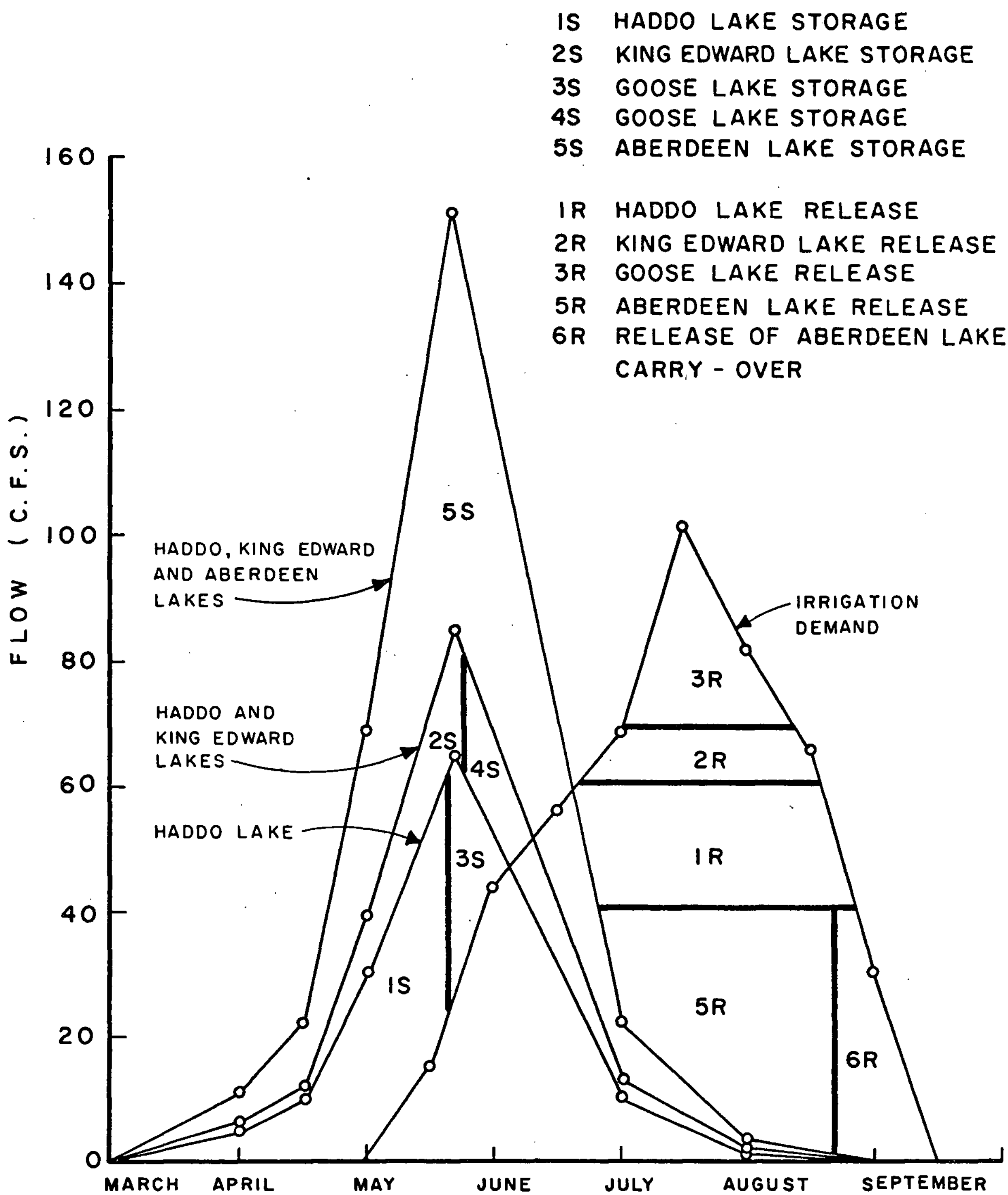

Fig.6 HYDROGRAPHS OF LAKE INFLOW AND RELEASE IN LOW FLOW YEAR.

were contributing to the peak irrigation demand.

During any one year, the total demand might be larger than the total inflow to the lakes. The carry over from the previous year would then be used to satisfy the demand (Figure 6). In the year illustrated in Figure 5 the total demand was less than the total inflow so there was carry over for the next year.

CHAPTER IV

SCHEDULING THE APPLICATION OF WATER

Scheduling of irrigation means the application of the correct amount of water at the time when it is needed by the soil (17). The objective of scheduling is to maintain the soil moisture content within an optimal range, while applying as little water as possible. Since scheduling offers one of the main opportunities for economising on the use of water, it is considered in some detail in the following sections.

EQUIPMENT USED IN SCHEDULING

The most common method of scheduling used in the Okanagan Valley was evolved by Dr. Wilcox, of the Summerland Research Station, who named it the "Balance Sheet" method. The equipment for this method consists of a balance sheet (Figure 7), a rain gauge and an evaporimeter. The Black Belanni Plate evaporimeter, (Figure 8) was introduced to Canada in 1957 and met all but one of the requirements for use in the Okanagan; it uses water as an evaporating medium and the water froze in the spring and fall as the temperature dipped at higher sites along the valley wall. The evaporimeter was sometimes damaged, and the records were lost for the period while the evaporimeter was frozen. Dr. Wilcox developed an evaporimeter especially for use in the Okanagan Basin and termed it the "Ogopogo" evaporimeter

Figure 7. BALANCE SHEET

Grower: John Doe Month: May, 1964

Safe Irrigation Interval: 6 days Credit Depth: 1.68 inches

Date	Water Use	Rain	Credit Depth	Balance	
1	.20		1.68	1.48	Started irrigating 7 a.m.
2	.24			1.24	
3	.25			.99	
4	.19			.80	
5	.19			.61	
6	.25			.36	Finished irrigating 7 a.m.
7	.18	.16		.34	
8	.23			.11	
9	.26		1.68	1.42	Started irrigating 7 a.m.
10	.16	.20		1.42	Raining
11	.08	.23		1.42	Raining
12	.10	.15		1.42	Raining
13	.18	.06		1.30	
14	.28			1.02	Finished irrigating 7 a.m.
15	.23			.79	
16	.10	.50		1.02	(Rainfall credited to balance on May
17	.22			.80	14)
18	.30			.50	
19	.30			.20	
20	.30			-.10	Stopped for mowing
21	.25		1.68	1.33	Started irrigating 7 a.m.
22	.30			1.03	
23	.28			.75	
24	.25			.50	
25	.26			.24	
26	.27			-.03	Finished irrigating 7 a.m.
27	.20		1.68	1.45	Started irrigating 7 a.m.
28	.15			1.30	
29	.20			1.10	
30	.20			.90	
31	.25			.65	Balance of .65 carried over to June

(Figure 9) (16). The evaporating surface is the end of a cylindrical carborundum block approximately 5 cm. in diameter and 6.6 cm. long which has been placed in a bottomless polyethylene bottle. A tube leads from the bottle to the reservoir which has a capacity sufficient to supply the evaporimeter with liquid for the period between readings. A glass shield ten to twelve inches in diameter is placed three inches above the evaporating surface to protect it from rain. The evaporating liquid used is a mixture of methanol and distilled water which does not freeze until the temperature reaches about 10°F. The rain gauge may be of any type, but the commercially made wedge-shaped plastic model is the most popular.

GENERAL PROCEDURE

When the irrigation is started, the appropriate credit depth is added to the balance on the sheet. Each day thereafter, the balance sheet is debited with the amount of water used by the crop which is estimated from the evaporation measured by the evaporimeter. If the irrigation cycle is completed before the balance on the sheet reaches zero, the sprinkler lines are shut down and left idle until the balance reaches zero. At this point, the next irrigation is started and the balance sheet credited with the amount of water applied.

The balance sheet shown (Figure 7) is for a plot of land with an irrigation interval of six days and a credit depth of 1.68 inches. The depth of application would be determined by multiplying the credit depth by a factor which accounts for the application efficiency. In

Figure 8. Bellani Plate Evaporimeter

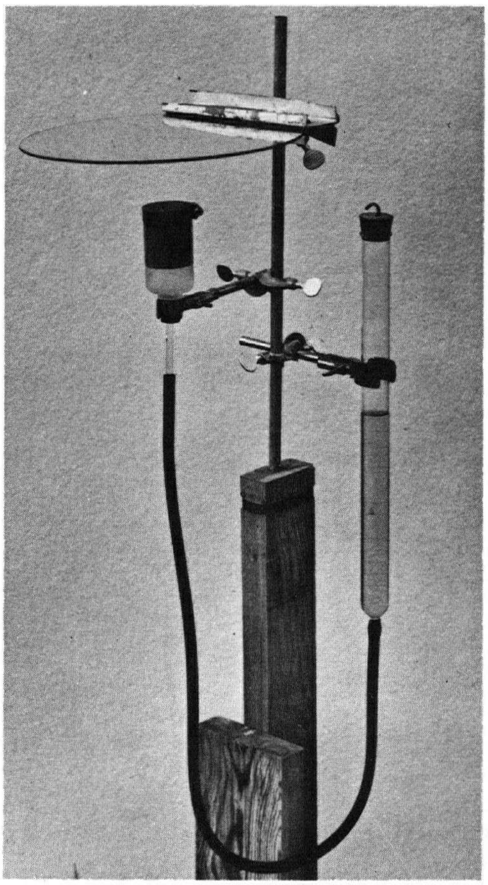

Figure 9. Ogopogo Evaporimeter

the illustration, irrigation was begun on panel one on the first of May. This is the panel for which the soil moisture balance was kept. The farmer then added the 1.68 inches to the previous balance, subtracted the water use or evapotranspiration for that day, and entered the balance (1.48). Irrigation continued with the lines being changed every twelve hours and, each day, the water use was subtracted from the previous balance to show how much water was left in the soil in panel one. At the end of the sixth day, one irrigation cycle was completed and the balance sheet showed that there was still moisture (0.36") in the soil. The system was shut down and the irrigator waited until the balance sheet reached an amount approximately equal to the daily water use, whereupon he started irrigating again.

CREDIT FOR RAIN

When rain occurs, any unsaturated panel benefits, but can only hold additional water up to field capacity. When a panel is irrigated, its moisture content is raised to field capacity, and therefore, rain occurring on that same day can be counted only up to the amount of evapotranspiration occurring while the panel is being irrigated. In order to take full advantage of rain, a budget would be needed for each panel in the field.

In practice, however, a budget is kept for only one panel of the field rather than each individual panel. Therefore, an elaborate set of rules has evolved to ensure that the field does not dry to the point where crops are damaged. With this system, if irrigation is in progress, credit is only given for rain up to the evapotranspiration for the day; any more credit could cause an unwarrented delay in starting the next irrigation which could result in excessive drying of the soil at some point in the field during the next irrigation.

When no irrigation is in progress, credit for rain can be given only up to the balance on the sheet at the time when the last irrigation cycle was completed. Between irrigation cycles the whole field receives benefit from the rain. The wettest part of the field receives the least benefit; in fact, only up to field capacity at that point. The wettest part is, of course, the soil at the last point irrigated, and field capacity there is represented by the balance at the first setting, as shown on the balance sheet at cessation of irrigation. Giving more credit than this for rain could cause an unwarrented delay in the start of the next irrigation (19).

These rules are illustrated on the balance sheet (Figure 7). On the tenth, rain amounted to 0.20 inches, 0.04 inches more than the evapotranspiration. Even so credit for that rain could be given only to the balance on the previous day, (1.42") as irrigation was is progress. The same applies to the rain which occurred on the eleventh and twelfth. On the sixteenth, irrigation was not in progress and rain occurred. Credit for this rain was given up to the level or balance on the day that irrigation ceased (1.02).

CHOOSING A SITE FOR THE EVAPORIMETER

Evapotranspiration from a small irrigated plot is greater when the plot is surrounded by dry unirrigated land than when it is in the middle of a large irrigated area. This is due to the advection of heat from the surrounding dry land and is sometimes referred to as the "oasis effect". In the Okanagan, a high proportion of the irrigated land abuts or lies close to dry land and in these circumstances placing the evaporimeters in the centre of the irrigated land would give readings too low to represent the very long marginal areas. Evaporimeters placed on dry land often show much higher rates of evaporation than those placed within an irrigated area and hence cannot represent conditions over the irrigated land satisfactorily. A reasonable compromise is a site chosen near the edge of the irrigated land where it adjoins dry land or in a small non-irrigated plot within the irrigated area. In any case, the evaporimeters must be placed where they do not receive water from the sprinklers.

SCHEDULING FOR IRRIGATION DISTRICTS

Some Irrigation Districts operate evaporation stations for the use of irrigators throughout the district. In this case the evaporimeters must be located so that the readings will represent the driest irrigated area within the district. This means that some orchards will receive excess water, but at least all orchards should receive enough. The problem of orchards receiving too much water can only be solved by installing more evaporimeters.

The District evaporimeters are read by an employee and the water use figures are posted on a bulletin board on the side of a road travelled frequently by the irrigators. Irrigators copy the figures and keep the balance sheet for their own orchards. One improvement which might be applied to the system is the installation of an automatic telephone answering service. The evaporation readings could be read into a tape recorder and irrigators would only need to dial the appropriate telephone number to obtain the evapotranspiration figures, which they need to keep their own water balance.

ADVANTAGES OF SCHEDULING

The main advantage of scheduling is that it permits maximum use of the available water resources. Other benefits include:

1. Water wastage is reduced to a minimum which results in lower pumping costs, reduced seepage and less leaching of nutrients from the soil.

2. Less time is spent irrigating; this saving in time may amount to as much as 30% in the Vernon area.

3. In cool or rainy weather, irrigation can be discontinued without fear of damage to crops due to lack of water.

4. As the same amount of water is applied at each irrigation, the design features of the system may be standardized (nozzle size, pressure, length of set).

5. The irrigator can have greater confidence and peace of mind knowing his crop will not suffer because of lack of water. Before the advent of scheduling, some irrigators shut down during wet or cool

weather but they worried about the damage that could occur if they did not start irrigating soon enough. With scheduling, they can be confident that no damage will result to their crops.

PROBLEMS WITH SCHEDULING

Scheduling as it is practised, using a simple budget for a farm rather than a budget for each panel involves the assumption that the weather remains constant or changes only gradually. Weather however, is not always so co-operative and some wilting of the crop can occur if precautions are not taken (Figure 10). As an example, assume that an orchard requires two inches of water every ten days in the heat of summer. This means that the average peak evapotranspiration is 0.20 inches per day. If during cool weather in June, the average evapotranspiration happens to be only 0.10 inches per day the grower who is using the balance sheet procedure finishes his irrigation and waits for ten days before starting to irrigate again. If the weather then turns hot and the average evapotranspiration becomes 0.20 inches per day, by the time the last part of the orchard is irrigated, the soil there contains 1.00 inch less water than it had the last time when it was irrigated and the soil water deficit now is 3.00 inches. If the soil is now given the standard application of two inches, a deficit of one inch will remain. The deficit can be cumulative over the irrigation season and could build up to the point where the crops could be permanently damaged. In order to avoid this difficulty the rule was developed that irrigation must be started when the available water content at the starting point falls to 60%. In the example cited this

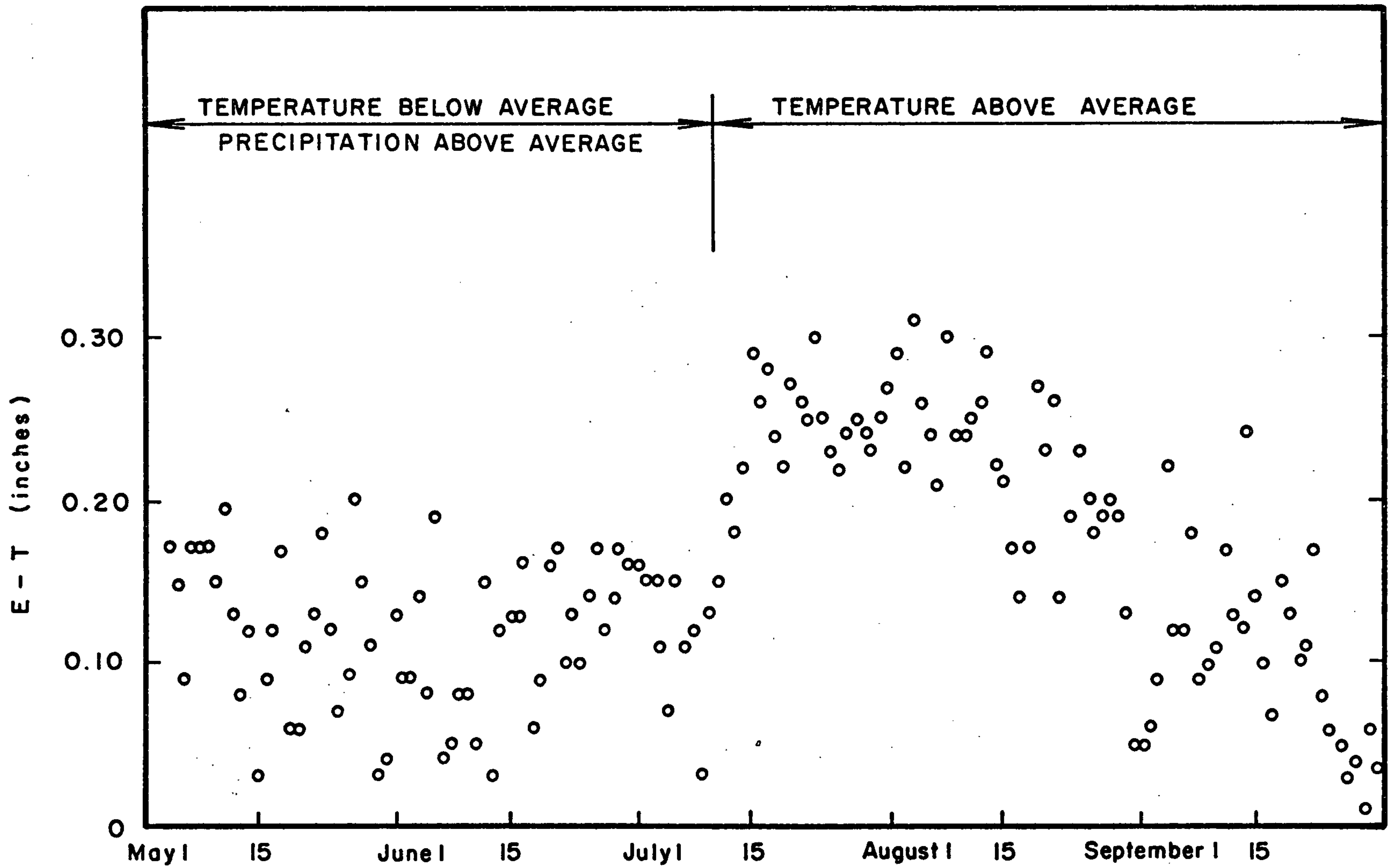

Fig. 10 DAILY EVAPOTRANSPIRATION AT SUMMERLAND RESEARCH STATION, 1971.

would allow the water content just before irrigation to fall to as low as 36% of the soil moisture storage, a value which does not seem to damage fruit trees, although shallow rooted cover crops may wilt occassionally.

USE OF SCHEDULING

Although the "Balance Sheet" method of scheduling has been developed to a very sophisticated state, relatively few of the growers in the Okanagen Valley are using it. Some growers have their own set procedure which they feel is satisfactory, and they see no need for change. Some are not suited by temperament or education to the keeping of balance sheets and regulating their irrigation accordingly. Perhaps some irrigators feel that a plentiful supply of water is a natural right inherited from their forefathers and see no need for conservation. Some, certainly, are not aware of the need for conservation nor of the availability of scheduling procedures. Also, the present "tax" method of payment for irrigation service does not encourage farmers to save water since under this system farms for which water service is maintained, must pay a flat rate whether of not the maximum allowable water is used. The minimum requirement of an irrigation system is that it is designed to cover the field with sufficient irrigation water during the one or two weeks of hottest weather in summer. Some growers turn on the water in the spring and run their system all season at the maximum rate. Therefore, for most of the year, water is being applied at a rate in excess of the evapotranspiration rate. This water as well as being wasted, leaches nutrients such as nitrogen and boron from the soil, nutrients which not only are expensive to replace but also can cause water quality problems in the water down stream from the irrigator's field.

The cost of setting up an individual evaporimeter station in 1971 is less than $50.00 and Department of Agriculture and Summerland Research Station personnel are always available and willing to assist with the installation. At the time of writing evaporimeters were supplied from the Research Station and rain gauges were obtained locally from a commercial source.

CHAPTER V

ADDITIONAL USES OF DUTEAU CREEK

FISHERIES

Part of Duteau Creek, below the Vernon Irrigation District diversion, provides a spawning and rearing area for Pacific Salmon (Figure 11). As many as two thousand Chinook have been known to spawn in Duteau Creek (23). A constant supply of clean water is critical in the life cycle of the salmon. The adults lay their eggs in gravel on the creek bed in the fall of the year. It is necessary to have an adequate flow of water over the gravel so that the eggs will be provided with enough oxygen through the winter. In the spring, the eggs hatch and the young fish remain in the fresh water system for one year and then they migrate to the ocean. When they are three to seven years old, the salmon return to the stream from which they originated, to spawn and die. During the spawning season, enough water must be provided to allow the fish to swim and spawn.

If the fish population is to be maintained there must be a year round supply of water below the Vernon Irrigation District diversion (Figures 12 and 13). The old V.I.D. diversion dam is reported to have leaked badly enough so that sufficient water escaped down stream to maintain the fish population. With the erection of the new watertight diversion dam, the water will have to be released if the fish population is to be maintained. The Canada Department of Fisheries

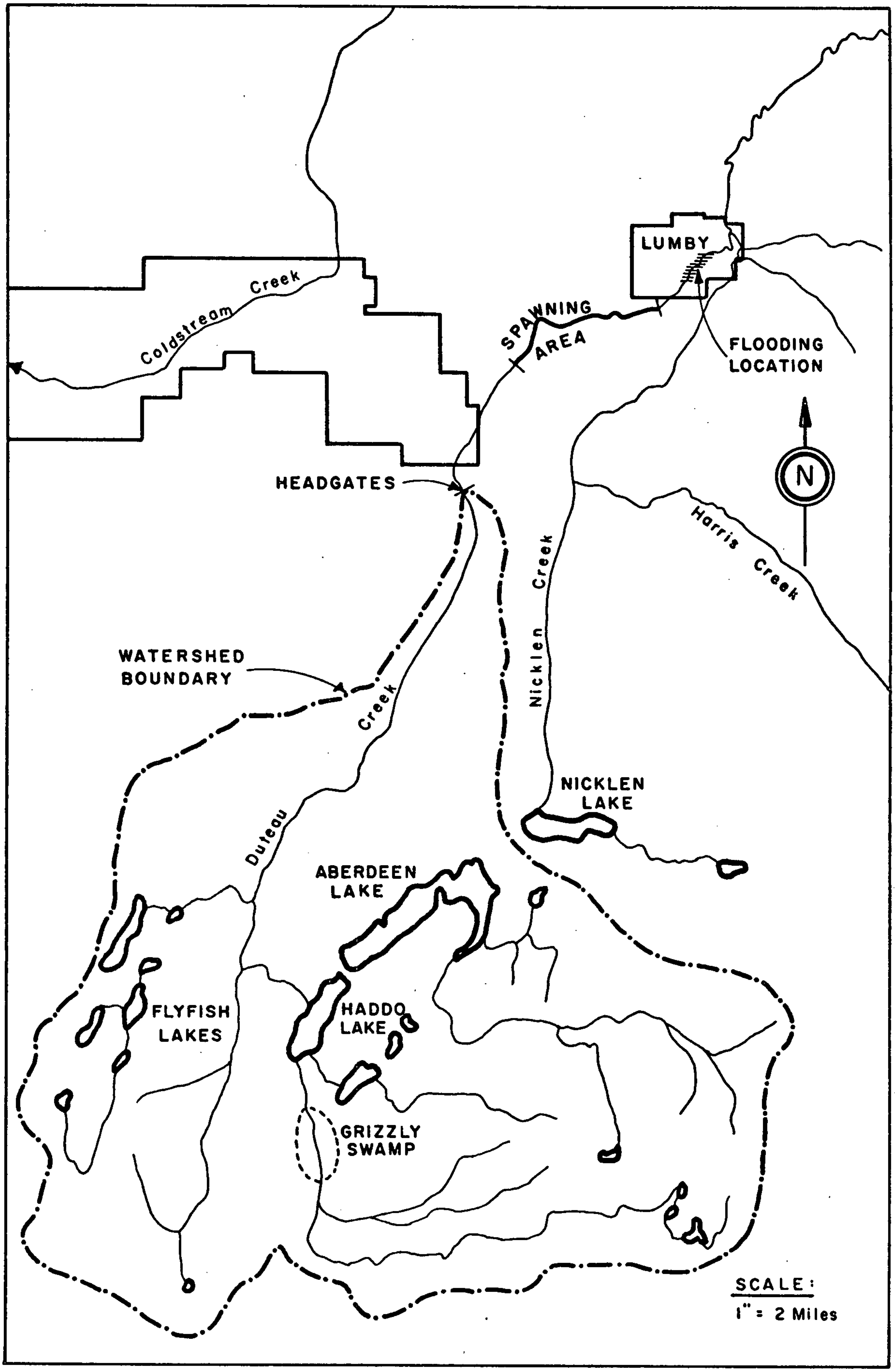

Fig. 11 FLOODING AND SPAWNING LOCATION IN DUTEAU CREEK WATERSHED.

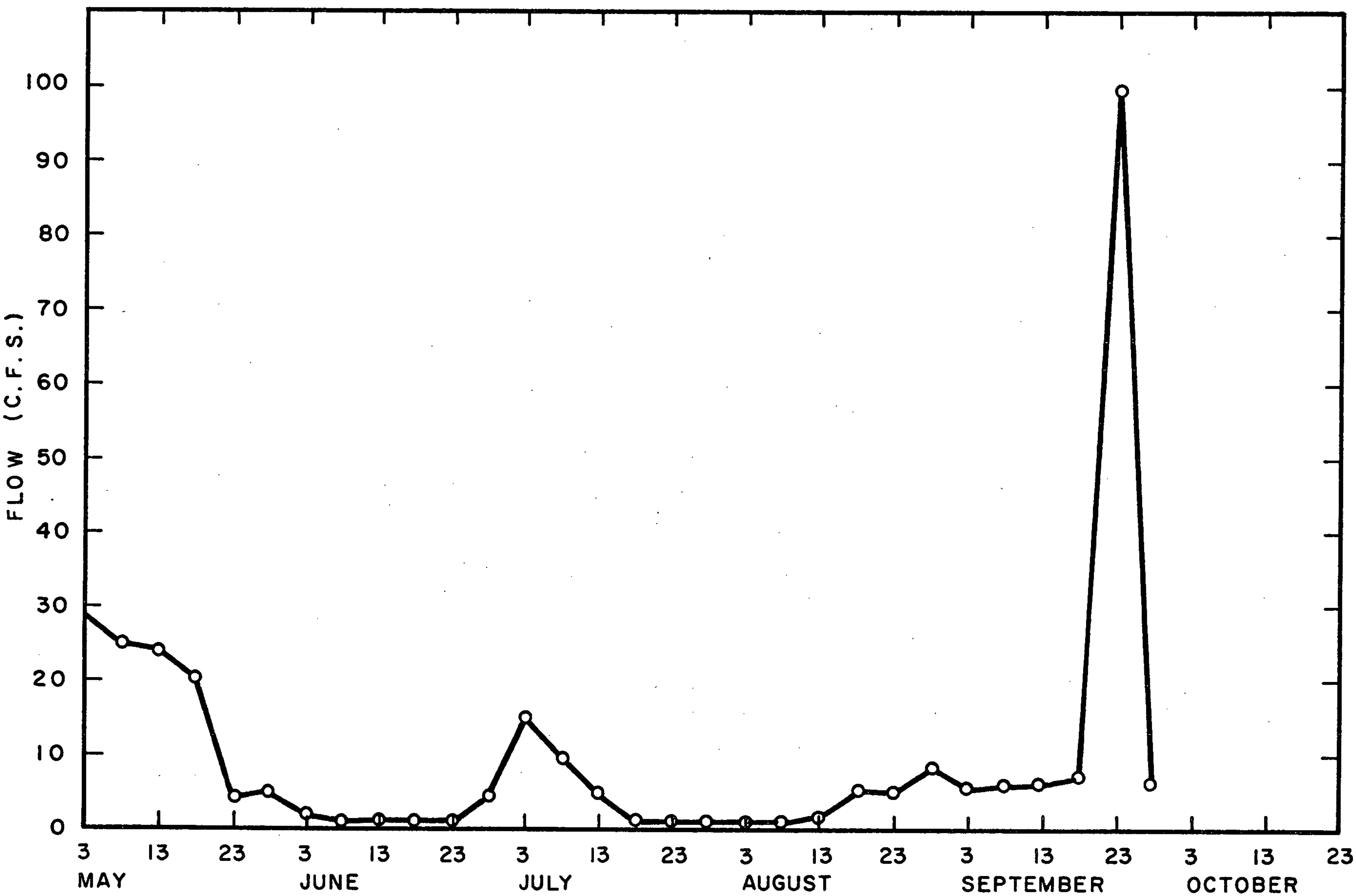

Fig. 12 DISCHARGE IN DUTEAU CREEK BELOW THE VERNON IRRIGATION DISTRICT DIVERSION, LOW FLOW YEAR, 1963.

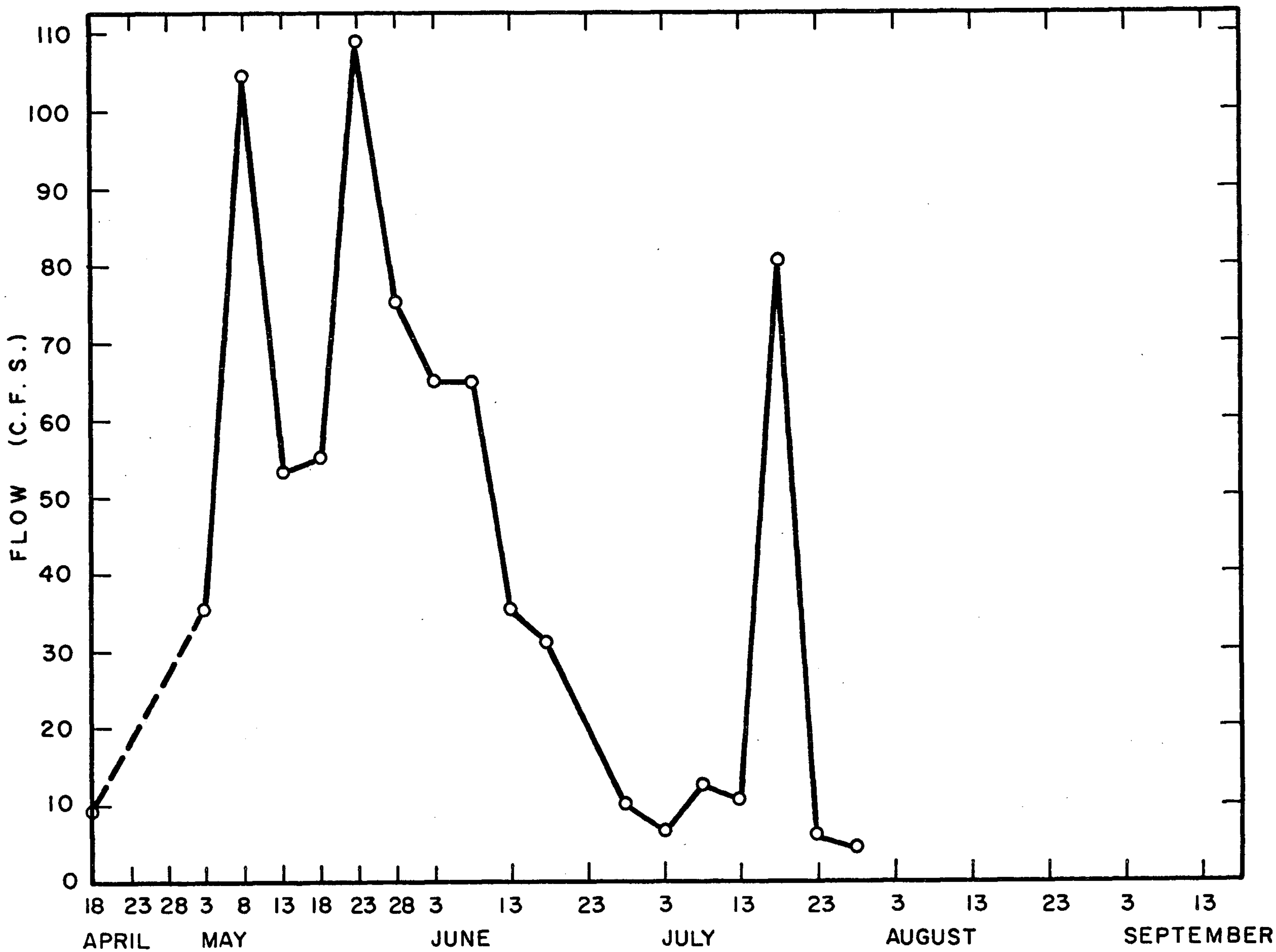

Fig.13 DISCHARGE IN DUTEAU CREEK BELOW THE VERNON IRRIGATION DISTRICT DIVERSION, HIGH FLOW YEAR .

in Vancouver estimated flow requirements at 4.0 cfs. during non-spawning periods while 7.0 cfs. are required for four months (September through December) during spawning (23). This amounts to 3600 acre feet per year which represents 26% of the total storage capacity of Vernon Irrigation District.

FLOOD PROTECTION AT LUMBY

Approximately seventeen miles east of Vernon is the small town of Lumby, where the main economic activities are cattle ranching and wood processing. The town has suffered in the past from flood damage from the combined effect of high flows in Bassette and Duteau Creeks. The main concern has been the loss of employment for approximately twenty-five men for two weeks per year while a sawmill is rendered inoperable by high water. The Water Investigations Branch of the British Columbia Department of Lands, Forests and Water Resources has studied the problem, recommended channel improvements and proceeded with the necessary construction. The estimated cost of the project was $46,000.00 and the design peak daily discharge was 650 cfs. corresponding to a flood with a return period of 50 years (2). For the present, it appears that Lumby is out of danger from floods from the two creeks. However, in the face of increasing population and lack of zoning, there is little doubt that problems will arise in the future. Therefore, the problem of flooding in Lumby should be included in any comprehensive plan for increased control of water from Duteau Watershed.

CHAPTER VI

PLANS FOR THE FUTURE

At the present time, there is some minor conflict over the use of water from Duteau Creek and it is probable that this conflict will increase in the coming years unless remedial measures are undertaken. Two obvious types of solution to this water resource problem are construction of additional storage and better management of the existing system.

CONSTRUCTION OF ADDITIONAL STORAGE

This has been the traditional solution to water shortage problems, perhaps because the engineering profession has historically been commissioned to solve problems by construction of new facilities. Studies have already been made of constructional measures to increase water availability in Vernon Irrigation District. Present dams could be enlarged and new dams could be built to hold more of the spring freshet waters from snowmelt. The Haddo Lake watershed also has a unique feature which could be utilized to produce another water saving project. Haddo Lake watershed is divided into two distinct parts; that which drains first into Aberdeen Lake, and that part of the watershed which drains directly into Haddo Lake without first passing through Aberdeen Lake (Figure 11). These two areas are each approximately twenty square miles and would be expected to produce approximately the same amount of run-off. Aberdeen is usually capable of containing all the run-off from its watershed and in fact rarely fills. Haddo Lake however, has only about one quarter the storage volume and as a result the lake fills and then much of the freshet water is spilled and, from the point of view of irrigation, is wasted. The topography of the watershed lends itself to the construction of a canal which would take water from the Grizzly Swamp area, which would ordinarily drain directly into Haddo Lake, and convey this water to Aberdeen Lake thus utilizing more of the storage volume available at Aberdeen Lake. Increasing the height of the Haddo Lake dam is less feasible as this would involve a number of saddle dams around the perimeter of the storage area.

MANAGEMENT

The second method of solving the water conservation problem involves better management. Many suggestions have been made but all involve some special problems and before these suggestions can be implemented, the problems must be resolved. These problems are examined in the following section.

Economic Incentive

Economists show that the consumption of a commodity decreases as its cost increases. This could be applied to irrigation water in the Vernon Irrigation District by the implimentation of a unit cost for water. In 1971, the tax for irrigation water service in V.I.D. was $27.00 per acre. This is rather insignificant when compared to the annual prunning, spraying, picking and other costs which are estimated at $300.00 per acre. However, $27.00 is significantly greater than the $2.00 to $5.00 per acre per year charged to irrigators in other parts of Canada and an increase in the cost of water might raise the farmers' annual costs above annual revenue thereby squeezing out those presently operating on a small profit margin. Unemployment is already a problem and the cost of supporting unemployed farmers could be much greater than possible gains from higher charges. Also, it was estimated in the 1965 report that the cost of water-meters for all users would be $150,000.00. Changing to a different form of charging for water use could create severe social problems and would require a major change in government policy. It seems that such a change could not be quickly brought about.

Extra Equipment

Under some circumstances, if an irrigator purchases extra equipment he can conserve water. Extra equipment allows the irrigator to cover his field in a shorter time interval and this means he can shut down his lines while the weather is cool or wet, but, if there is a sudden change to hot dry weather, he can still irrigate the whole farm before the soil drys out too much. In Vernon Irrigation District, however, the maximum delivery rate to a farm is set at 5 U.S. gallons per minute per acre. Extra equipment would be of little advantage since lower application rates would have to be used in conjunction with extra equipment thus lengthening the time for each application.

Better Operation of Reservoirs

At present the Vernon Irrigation District operates two snow courses in the Haddo Lake watershed. These yield results which tell whether this run-off will be greater or less than usual but do not give precise estimates of the expected run-off. Therefore, the reservoirs are operated with little knowledge of the inflow which will occur. If better hydrologic data were available to the manager of the district, the lakes could be operated to obtain maximum use of available water for all resource users. However, techniques will have to be perfected and hydrologic stations installed in the area before this type of management can become a reality.

Scheduling

This method of determining the precise time irrigation is required, holds promise of water conservation in the Okanagan Valley. The biggest problem is to get the irrigators to use it. Teaching programs so far have proved unsuccessful in inducing large numbers of irrigators to switch to scheduling. Perhaps few people see the need for water conservation. However, it is not hard to visualise the valley divided into zones by evapotranspiration rates, and daily water use figures for farmers use published in newspapers, included with farm news and available by telephone. At present, no commercial production of the Ogopogo evaporimeter is underway and the only models available have been those produced by Summerland Research Station. Also, extension personnel in the valley are probably already too overworked to introduce and back up a significant scheduling education program.

Drip Irrigation

Research is currently underway at the Summerland Station on a new type of irrigation system. The system utilizes small diameter (1/16" to 1/32") tubes called "drippers", as a method of delivering the water to the trees. The irrigation water is delivered to the field in the conventional manner but perhaps at a lower pressure. Plastic tubing of two to three inch diameter is then used to deliver the water near the trees--probably between every second row of trees. The water then enters a dripper which takes it to a header. From the header, drippers lead to between five and ten points around the tree to deliver the water to the soil where it will be quickly picked up by the roots. With drip irrigation, the whole field is irrigated at the same time.

SUMMARY

The problems and conflicts of the water resource users of Duteau Creek watershed seem likely to increase in the future. Alternative solutions of these problems at the system level include construction of more reservoirs, construction of a diversion canal, and improved management of the existing system in a number of ways. There may be room for better reservoir operation but the need for better hydrologic data will have to be satisfied first, and the implementation will involve learning more about the hydrology of the area and about the system as a whole. There is also some oportunity for conserving water through scheduling which involves learning at the farmer level. It seems that management of the system should be looked on partly as a learning process which will allow both the system managers and the farmers to anticipate their problems, understand the opportunities and alternatives, and deal with problems in good time.

CHAPTER VII

CONCLUSIONS

This study has examined the Vernon Irrigation District, the largest irrigation district in the Okanagan Valley, and one which has recently been modernized. The old system has served the residents well and it is to be hoped that the new one will serve equally well. Reasons for the selection of the new system, design criteria, and details of the operation of the system have been given in the hope that they may prove valuable to designers of future systems, farmers and irrigation managers.

As water demands continue to grow, management problems will become more complex and will require more accurate information about the availability and use of water for their solution. New multi-use management policies will have to be formulated to include non-irrigation demands. Eventually, it may be necessary to construct additional storage facilities and also perhaps to induce the farmers to conserve water. Water can be conserved by scheduling, and the problems and potential of this process have been examined in some detail. Before it can be widely adopted, however, there will have to be an extensive learning program, not only on the part of the irrigators, but also on the part of the planners and system managers. Also new techniques such as drip irrigation which will make water conservation easier may be developed, provided there is continued research in irrigation.

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GLOSSARY

Application Efficiency - The ratio of net volume of desired application to the gross volume of water delivered by the sprinklers to effect the desired application.

Application Rate - The rate at which irrigation water is applied to the soil. Units: inches per hour.

Effective Rooting Depth - That depth in the soil above which the roots obtain 90% or more of their water between irrigations.

Evapotranspiration - Water transpired by plants, built into plant tissue, and evaporated from the soil surface. Also called "Consumptive Use".

Evapotranspiration Rate - Rate of evapotranspiration expressed in inches per day, per irrigation interval, per month or per growing season.

Field Capacity - Soil water content retained by the soil following an irrigation or heavy rain, after downward movement of water has materially decreased. It is the upper limit of soil water available for plant use. Units: percentage of dry weight of soil, inches of water per foot of soil or per profile.

Infiltration - The downward movement of free water into the soil through the soil surface.

Infiltration Rate - The rate of downward movement of free water into the soil through the soil surface. Units: inches per hour.

Irrigation Cycle - The number of days to irrigate a given area not counting the time lost during or between irrigations.

Irrigation Interval - The number of days between the start of an irrigation at any one spot and the start of the next irrigation at the same spot.

Leaching - The process of removing soluble material from the soil by passage of water through the soil.

Maximum Allowable Soil Water Deficit - The range of water content between field capacity and that water content below which growth and yield are affected adversely.

Peak Evapotranspiration - The average daily evapotranspiration during the period of maximum evapotranspiration, for a period of any stated length. Units: inches per day.

Permanent Wilting Point - The water content of the soil when plants growing in it are wilted to the point where they will not recover when placed in the dark for 12 hours in an atmosphere of 100% relative humidity. It occurs at about 15 atmospheres or 15 bars of soil moisture tension. Units: percentage of dry weight of soil. Also called "Permanent Wilting Percentage".

Safe Interval - The maximum interval in days that can be allowed between irrigations in the heat of the summer without danger of impairing plant growth or yield.

Scheduling of Irrigation - A procedure whereby water is applied in such a manner that the soil water content is maintained within the optimum range, without unnecessary wastage of water.

Seasonal Evapotranspiration - The total evapotranspiration during the growing season of the crop. Units: inches of water .

Soil Water Deficit - Field capacity minus actual soil water content. Units; inches per foot of soil or per profile.

Transpiration - Evaporation of water from the surface of the plant, and in particular from the leaves. It does not include evaporation of water adhering to the outside of leaves because of rainfall, irrigation or dew.