A LONG-TIME WATER-TABLE STUDY OF AN IRRIGATION PROJECT IN SOUTHERN ALBERTA

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INTRODUCTION

Adequate crop production in irrigated areas generally requires water-table depths of at least 152 cm (2). Although crop production in arid and semiarid areas is possible with water tables at shallower depths, the danger of waterlogging and salinizing of the surface soil can be reduced by proper irrigation management, or by installing adequate subsurface drainage. In many irrigation districts observation wells are used by project personnel to detect areas where sustained crop production is endangered by water tables rising too close to the surface.

Rapp and van Schaik (4) studied short-time records of some observation wells on the Bow River irrigation project to determine cyclic trends of water tables in glacial till soils during several growing seasons. However, short-time records do not permit estimation of long-time trends as affected by hydrologic cycles and changes in irrigation practices. Rapp *et al* (3) studied the relationships between irrigation water use and various hydrologic budget items from 1958 to 1968, inclusive, for the Vauxhall District of the Bow River Project.

The objective of this study was to determine long-time trends of water-table depths in the Vauxhall District of the Bow River Project in Alberta, Canada.

SITE DESCRIPTION

The Vauxhall District, containing about 26,700 ha (66,000 acres) of irrigable land, has been continously in operation since 1920 (1). In 1950 the Government of Canada acquired the Bow River Project, and since that time improvements, renovations, and extensions have been undertaken.

The Bow River Project is covered with ground moraine. The soil profiles, which are formed over glacial till, are of varying depths. The till is less than 100 cm from the surface over most of the area.

The Vauxhall District is bounded on the northeast by the Bow River and on the east and southeast by Expanse Coulee (Figure 1). A height of land lying between Lateral C and the Main Canal, which is nonirrigable, has a gentle slope to the valleys. There is a general west-to-east elevation difference of about 30 m through the area. The northeast slope to the Bow River is gradual and uniform. The southeast slope to Expanse Coulee is somewhat broken by shallow drainage ways and is therefore more irregular than the northeast slope. The west half of the District has considerable roughness and is composed mainly of long ridges, the slopes of some having a humpy irregularity.

The Vauxhall area receives about 22 cm of precipitation, or 65% of the annual total, during the season May to October, inclusive (3). During the growing season the evaporation from a free water surface at Vauxhall exceeds 75 cm. Data accumulated at the Canada Department of Agriculture Irrigation Research Substation at Vauxhall (5) show that, for maximum growth, alfalfa required about 66 cm of water, pasture grasses about 61 cm, and grains and potatoes about 48 cm. Thus, the average precipitation falls far short of meeting maximum growth requirements.

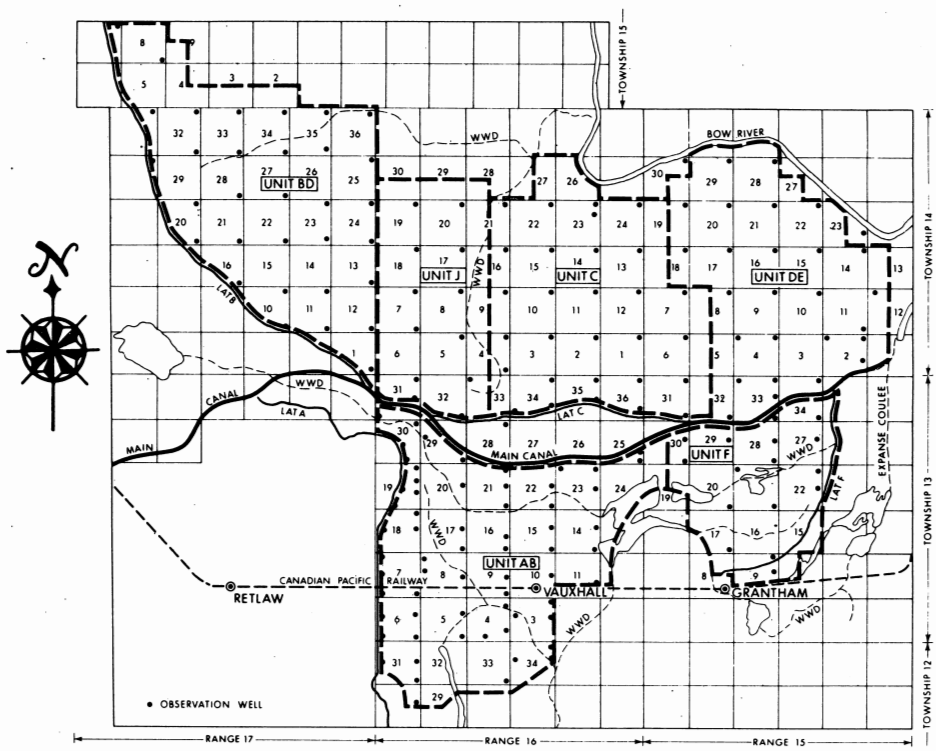

Figure 1. Observation-well location map. Vauxhall District, Bow River Project.

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INVESTIGATION AND ANALYSIS

Groundwater studies were initiated in the Vauxhall District in 1951. A network of 175 permanent observation wells was installed to measure the position of the shallow water tables throughout the area (Figure 1). The network density was about 1 per 2.6 sq km (1 per sq mile) north of the Main Canal and about 1 per 1.3 sq km south of the Main Canal. The usual depth of installation was 3 m, except at a few sites where deeper wells were needed to reach the water table. Water levels in the wells were measured about seven or eight times a year, five to seven measurements being made during the irrigation season from May to October. Readings were taken each year from 1952 to 1968, inclusive, except during 1958 and 1959.

For the purpose of analyzing the water-table data, the District was divided into Units as defined by lateral or branch canal systems (Figure 1). Thiessen polygons, similar in form to those used in hydrology for calculating mean precipitation over an area, were used to obtain a weighting value for each well location. This enabled the computation of an average May-to-October or seasonal water-table depth for each Unit. As this weighting method was laborious, a computer program (LRS 74) was used to process the annual data.

For each season of record, a "depth-to-water-table" map was drawn to delineate areas with different water-table levels. Also, an annual distribution summary was compiled to compare the areal extent of various water-table-depth increments.

The amount of irrigation water delivered during the season to each farm, as well as the area irrigated on each farm, was obtained from project records. The amount or total depth, i.e., cm per hectare, of water delivered for irrigation in each Unit was computed. The percentage of the Unit area irrigated in any year was determined on the basis of the total irrigable and nonirrigable area in the Unit.

RESULTS

Water-table Depths

The mean seasonal (May-to-October) water-table depth for the District during the 15-year period was 169 ± 10 cm. Unit DE had the shallowest mean water table (154 ±18 cm) during this period. The mean water table in Unit F (194 ± 11 cm) was considerably deeper than the District mean. In Units AB, C, J, and BD the long-time mean depths were near the District mean.

The lowest water tables generally occurred at the beginning of the study and in 1961 (Figure 2). Differences between the maximum and minimum seasonal water-table depths for the period ranged from as little as 40 cm for Unit F to as much as 78 cm for Unit J.

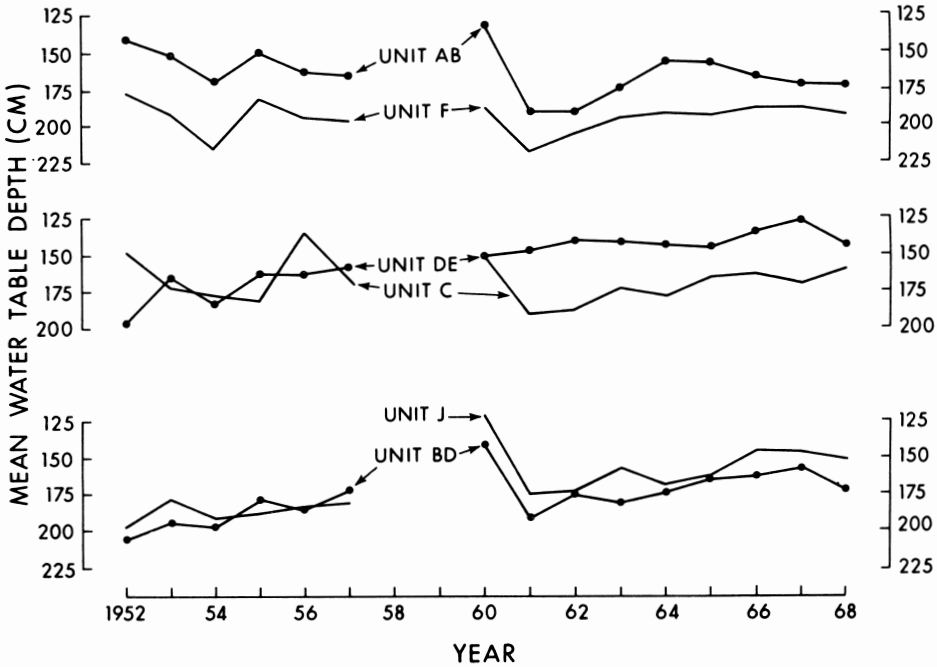

Figure 2. Unit mean water-table depth. Vauxhall District.

Areal Extent of Water Tables Less Than 183 cm

For each season of record the percentage of each Unit area having a seasonal water-table depth less than 183 cm (6 ft) was tabulated (Table I). With some exceptions the extreme values (i.e., maximums and minimums) of water-table depth were recorded in the years in which the extreme values of areal percentage occurred. For instance, the highest percentage of a Unit area with a mean seasonal water-table depth less than 183 cm was in Unit C (93.5% in 1956). This percentage coincides with the highest seasonal water table recorded in the Unit. For the period of record the highest Unit mean percentage occurred in Unit DE (76.5%), which also had the highest mean seasonal water-table. For the District the lowest water table (187 cm) occurred in the same year as the lowest percentage area with a water-table depth less than 183 cm (50.5% in 1954). Also, the highest District water table (145 cm) was recorded in 1960, the same year of occurrence of the highest percentage area with a water-table depth less than 183 cm (77.7%).

For the period from 1963 to 1968 the District averages were higher than the 15-year average of 64.4%. These averages coincided with the above-normal season rainfall in four of the six years (Figure 3).

Irrigation

The average depth of water delivered to each Unit during the 15-year period of record was 36 cm. Thus, with an average of 42.5% of the Unit irrigated, the amount delivered to the irrigated area was 84.7 cm (Table II). The greatest amount of irrigation water was delivered in 1961 to all Units without exception (not shown). The seasonal rainfall from 1957 to 1961, inclusive, was below the normal of 25.6 cm for the period of record. In most Units the percentage area with a water-table depth less than 183 cm in 1961 was considerably less than the 15-year means (Table I). Units AB and F, both south of the Main Canal, received the largest amount of water throughout the period of record.

The percentage of Unit irrigated yearly for the period of record showed that the lowest percentage occurred in the first year and the highest near the end of the study. The high percentage in Unit DE and the lesser amount of irrigation water delivered reflected the efficient use of water on land with topography ideal for irrigation. The water table in Unit DE was

TABLE I PERCENTAGE OF UNIT AREA* WITH WATER-TABLE DEPTH LESS THAN 183 CM, VAUXHALL DISTRICT

Year	Unit AB	F	DE	C	J	BD	Weighted average
1952	68.2	45.1	74.0	72.5	46.4	29.7	58.8
1953	85.4	54.3	55.5	58.5	59.1	37.5	58.5
1954	61.9	44.7	51.1	56.9	46.5	38.8	50.5
1955	72.9	52.9	66.1	61.9	46.3	56.6	60.9
1956	62.4	47.0	60.2	93.5	50.0	51.5	62.0
1957	61.3	36.7	70.8	64.2	53.3	56.7	59.1
1960	80.5	50.1	83.6	83.8	88.7	72.4	77.7
1961	47.3	27.1	84.0	46.2	61.1	44.8	52.5
1962	46.8	38.8	81.0	51.5	60.4	60.6	59.5
1963	51.2	43.8	86.0	63.8	79.3	55.4	64.6
1964	63.3	45.3	86.9	62.3	65.7	57.3	74.5
1965	71.4	50.0	88.7	70.0	69.5	71.2	71.9
1966	54.3	56.3	88.1	71.4	74.2	81.4	71.8
1967	63.4	53.7	92.2	67.6	90.8	82.7	75.4
1968	65.8	42.3	79.2	70.4	77.5	68.2	68.4
Mean	63.7	45.9	76.5	66.3	64.6	57.7	64.4
SD	±21.5	±7.1	±12.6	±11.4	±14.5	±15.2	±8.2
$\frac{SD}{Mean}$ (%)	33.8	15.5	16.5	17.2	22.5	26.4	12.7

*Unit AB, 6315 ha; Unit F, 3090 ha; Unit DE, 5545 ha; Unit C, 5625 ha; Unit J, 3545 ha; Unit BD, 6690 ha; District, 30,810 ha.

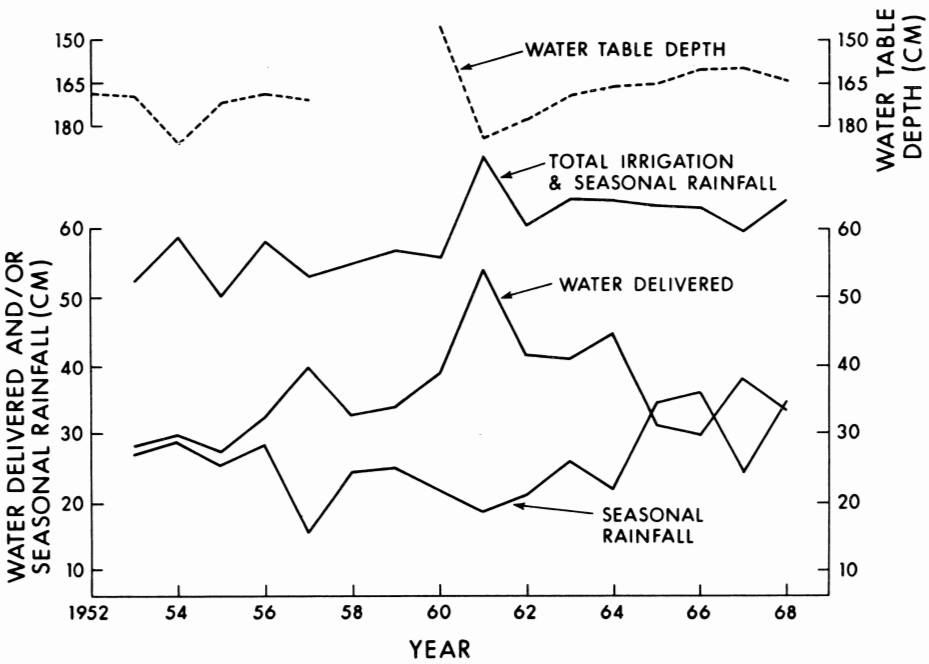

Figure 3. Vauxhall District water-table study, 1952-1968.

not materially different from that in the other Units.

DISCUSSION

During the period of record there was no consistent relationship between seasonal water-table depth and total water available (Figure 3). In some years a relationship between the amount of irrigation water delivered and the seasonal rainfall seemed to exist, the demand for water being high when the rainfall was low, and vice versa. There seems to be no logical explanation for the high water table recorded in 1960 since a normal amount of water was available in the two previous years, during which no readings were taken. Conversely, the water table was lowest in 1961 when the total available water, mainly from irrigation deliveries, was highest. From 1963 to 1968 the seasonal rainfall was generally higher than, and the irrigation water delivered to the District was less than normal whereas the District mean water table was rising. This indicates that seasonal rainfall has a greater influence on the water-table depth than the amount of irrigation water delivered because rainfall covers the entire area whereas irrigation is applied to only a part of the area, generally less than half.

The factors mentioned previously influence water-table fluctuations but they cannot be considered separately. For instance, throughout the period, project management had constructed open drains to prevent ponding of waste waters in the lower portions of farm fields. This may have prevented possible water-table build-up within the District. Therefore, it is difficult to assess the various factors individually since the differences in values recorded between years and between Units probably were too small to affect the mean water tables significantly (Figure 3). Although Rapp and van Schaik (4) found that an irrigation in one field raised the water table for a short period in that field, the overall effect throughout the summer and taken over a larger area seems negligible when mean seasonal water tables over a long period are compared.

SUMMARY AND CONCLUSIONS

Water-table levels were measured for a period of 15 years in the Vauxhall District. The seasonal mean water-table depth was 169 cm with a standard deviation of ± 10 cm. On the average, 64% of

TABLE II SUMMARY OF WATER DELIVERED TO EACH UNIT AND PERCENTAGE OF UNIT IRRIGATED (1952–1968)

Unit	Delivered* (cm)	SD**	Irrigated Area (%)	SD**
AB	44	9	32.9	7.2
F	40	7	38.9	11.2
DE	33	7	58.3	12.6
C	35	7	53.7	14.5
J	38	9	35.9	14.0
BD	33	6	34.1	12.0
Weighted Average	36	7	42.5	11.1

* Values indicate cm of irrigation as calculated for the total Unit.
** Standard Deviation

the area had a water table higher than the accepted standard of 183 cm. Although variability in some Units was high, mean seasonal water-table data indicate that no serious drainage problem exists in the Vauxhall District.

There was no consistent relationship between irrigation water used or the total hydrologic input and the concurrent water-table depth. This indicates that the water table in the Vauxhall District is not a direct function of either irrigation or seasonal rainfall on a long-time basis.

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