PRAIRIE PROVINCES WATER BOARD

Apportionment Committee

Progress Report

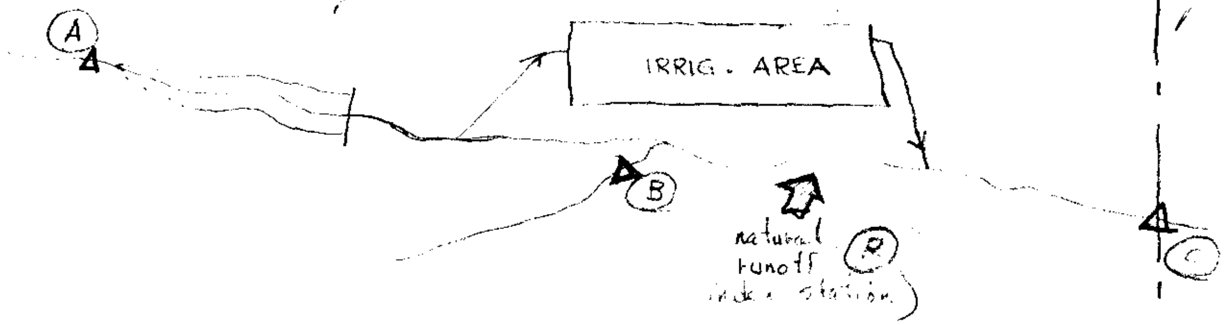
on

Methods of Determining Natural Flow, Depletions and Other Factors Necessary for Apportionment of the Waters of the Saskatchewan-Nelson River System

September 1, 1965

Stream Depletion Method

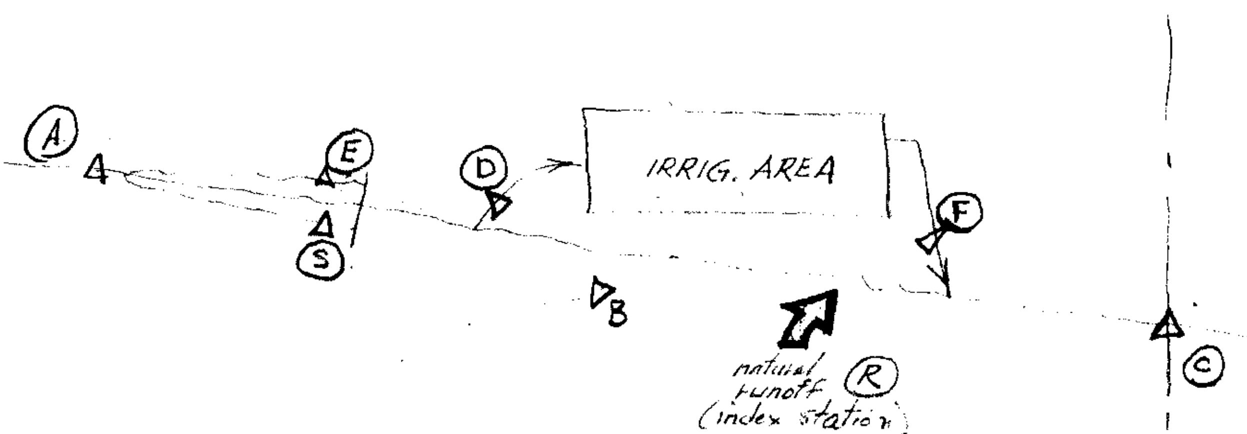
Measure all inflow above diversion, and use index stations to obtain natural increment of inflow between these upstream stations and the main boundary station.



Natural Flow @ C = A + B + R

Project Depletion Method

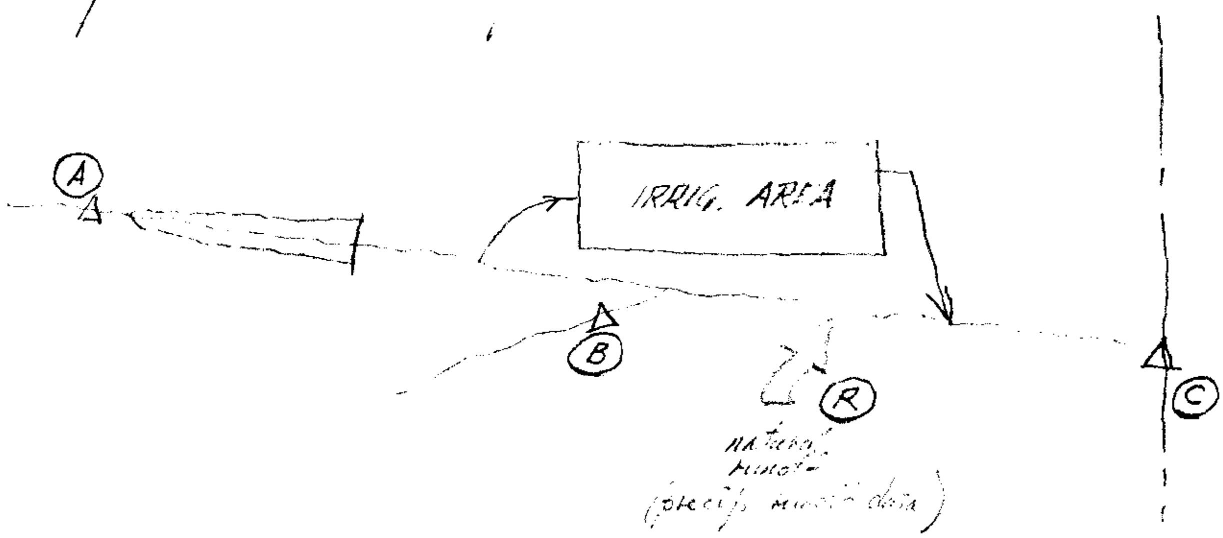
The computation of the natural flow [illegible] consumptive use [illegible] added [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] above that station.



Natural Flow @ C = C (actual) + [(S₁ − S₂) − E + D − F]

Inflow-Outflow Method (Rinflow)

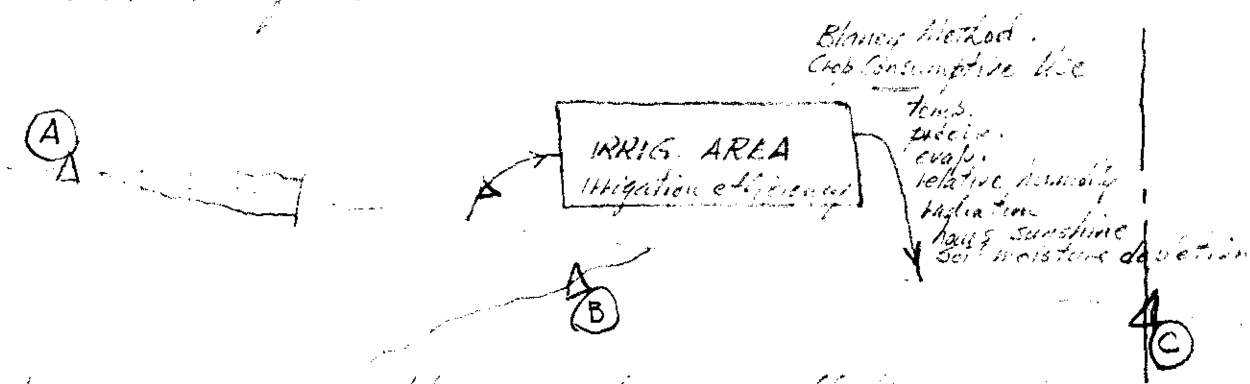
Measured by the change in relationship between the sum of the natural flows of certain key tributaries near the sum of the [illegible] and the natural flow at the boundary station



Natural flow @ C = (A + B + R) K + const.

Consumptive Use Method

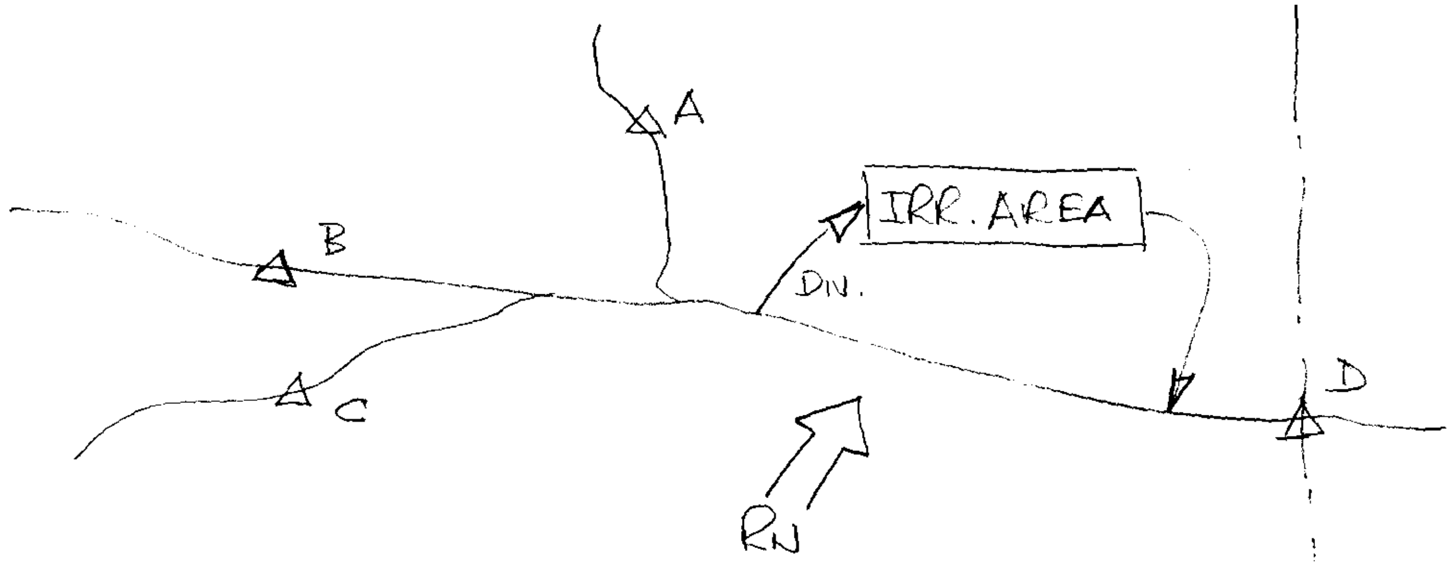
Includes all evapo-transpiration and evaporation from land on which there is plant growth of any kind plus the evaporation from bare land and from the water surface.



Net consumptive use = total consumptive use − effective precip.

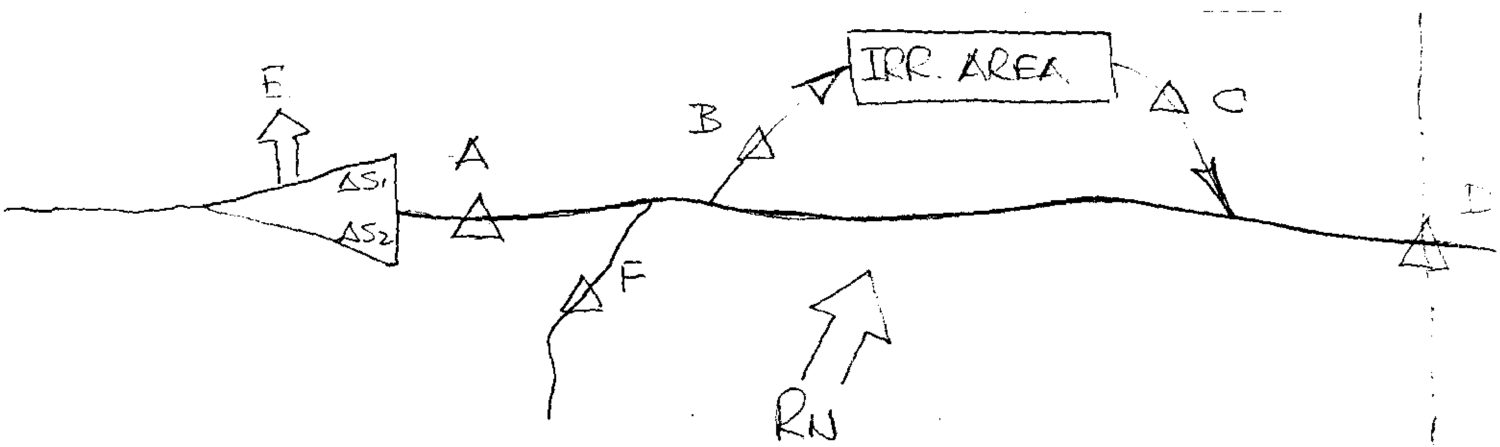
Total irrigation req'mt = net consumptive use ÷ irrigation efficiency + total seepage − total evaporation.

Total diversion = total irrig. req'mt + net return flow



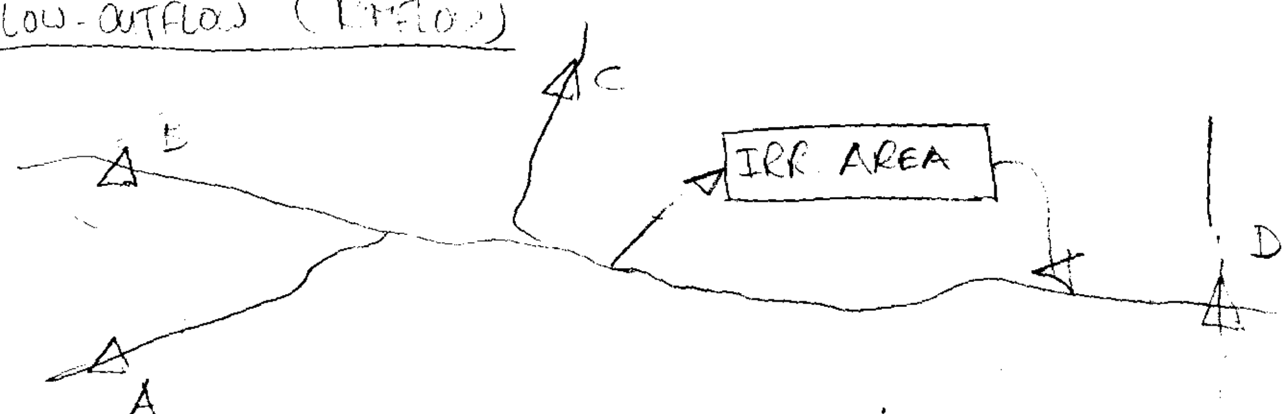
NAT FLOW$_D$ = A + B + C + R_N
NET DEP = NAT FLOW$_D$ − D.

PROJECT DEPLETION



NAT FLOW$_D$ = A + $(S_1 - S_2)$ + E + F + B − C + R_N
NET DEPL RES = $(S_1 - S_2)$ + E
NET DEPL IRR = B − C.

INFLOW - OUTFLOW (RIVFLOW)



NAT FLOW$_D$ = aA + bB + cC + d

204.5-Rpt. (Suppl.)

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I N D E X

Page

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INTRODUCTION

Methods of determining natural flow, depletions and any other factors necessary for apportionment of the waters of the Saskatchewan-Nelson River system.

In connection with the problem of recommending allocations of water between one province and another, which may be made in several ways, it is desired to make an assessment of the various methods of computing the natural flow.

Accepted definition of natural flow - The flow of any stream before diversion for either consumptive or non-consumptive purposes.

If there had been no man-made use of the waters, the river flow as recorded at any location would have been the natural flow. Since the regime of certain portions of the river system have been interfered with, we must find an acceptable method of reconstructing the natural flows.

The following comments on the various tributaries of the system are indicative of the possible discrepancies between annual recorded flows and annual natural flow figures on the basis of our present study status.

North Saskatchewan River at Alberta-Saskatchewan Boundary	- Recorded = Natural Flow.
North Saskatchewan River at the Forks	- Recorded = Natural Flow.
Battle River at Alberta-Saskatchewan Boundary	- Recorded = Natural Flow.
Red Deer River at Alberta-Saskatchewan Boundary	- Recorded approximately 8% greater than the average annual natural flow for the 1960-64 period - addition of Bow River irrigation water returning to the Red Deer River.
South Saskatchewan River at Alberta-Saskatchewan Boundary	- Recorded approximately 18% less than the average annual natural flow for the 1960-64 period - due to the consumptive use in irrigation and water returning to Red Deer River.

South Saskatchewan River below Red Deer Forks	-	Recorded approximately 16% less than the average annual natural flow for the 1960-64 period.
Saskatchewan River at The Pas - Saskatchewan-Manitoba Boundary	-	Recorded approximately 8% less than the average annual natural flow for the 1960-64 period.

Recorded flows for the other small tributaries crossing the Saskatchewan-Manitoba Boundary are assumed to be natural flow or could easily be computed with the exception of the Qu'Appelle River.

The above percentage comparison is based on the average of the last five years of record, which gives a more realistic figure than one for the period of record extending from 1911 to 1964.

In observing the percentage difference between recorded and natural flows it must be remembered that the recorded flows are considered to be within a 5% limit of accuracy. This fact should be kept in mind when assessing the merits of the methods to be described for the computation of the natural flow.

The committee suggests four methods of computing the natural flow of streams crossing interprovincial boundaries.

1. STREAM DEPLETION METHOD.
2. PROJECT DEPLETION METHOD.
3. INFLOW-OUTFLOW METHOD.
4. CONSUMPTIVE USE METHOD.

The application of any method will be to the South Saskatchewan River below Red Deer Forks. If a method will work for this portion of the system it should be an acceptable method for the whole Saskatchewan-Nelson River basin.

STREAM-DEPLETION METHOD

Principle

Measure all inflow above diversions, establish index stations to obtain natural incremental inflow between these upstream stations and the main gauging station at the interprovincial boundary.

Data Required

(a) Gauging stations on each large tributary and on the main stem, just upstream from any diversion.

(b) Gauging station on the main stream at the interprovincial boundary.

(c) A reasonably accurate measurement or estimate of the "natural runoff" from the naturally contributing drainage areas of the various ungauged tributaries and main stem reaches.

In practice, however, the achievement of (c) above is a matter of considerable difficulty, and the accuracy of the results is not likely to be of the same order as that of the stream flow measurements in (a) and (b). It is believed that the establishment of a number of index stations in various areas of the drainage basin unaffected by irrigation operations, to give annual figures for runoff per unit area, would be the best approach to solving this problem.

This item is one of the major factors of concern in all the methods to be described and network requirements would be the same for all methods except some consolidation of the network could be undertaken in the Consumptive Use Method.

Data Available

(a) & (b) Fairly good network available.

(c) Insufficient data. Part of the difficulty is to locate stations within the area that are not affected by irrigation use.

Application of Method

Gauging stations required:

No.	Existing	New	Name of Station
*(1)	x		(Red Deer River at Red Deer)
2	x		Red Deer River at Drumheller
3	x		Rosebud River at Redland
4	x		Bullpound Creek near the Mouth
5	x		Berry Creek near the Mouth
6	x		Red Deer River near Jenner
7	x		Blood Indian Creek near the Mouth
8	x		Alkali Creek near the Mouth
9	x		Red Deer River at Bindloss
10	x		Western Irrigation District Canal at Chestermere
11		x	Bow River below junction with Highwood River
12	x		Bow River above junction with Oldman River
13	x		Little Bow River below Travers Dam
14	x		South Saskatchewan River at Medicine Hat
15		x	South Saskatchewan River at Empress Ferry
16	x		Oldman River above junction with Bow River
17	x		Oldman River near Monarch
** 18	x		Willow Creek near Claresholm
**(19)		(x)	(Oldman River above diversion to L.N.I.D.
*** 20		x	Belly River above junction with Oldman River
21	x		Lethbridge Northern Irrigation District Canal
**** 22	x		St. Mary River near Lethbridge
23	x		Waterton River near Waterton Park
24	x		Belly River at International Boundary
25	x		St. Mary River at International Boundary
26	x		Rolph Creek near Kimball
27	x		Lee Creek at Cardston
28		x	Seven Persons Creek near the Mouth

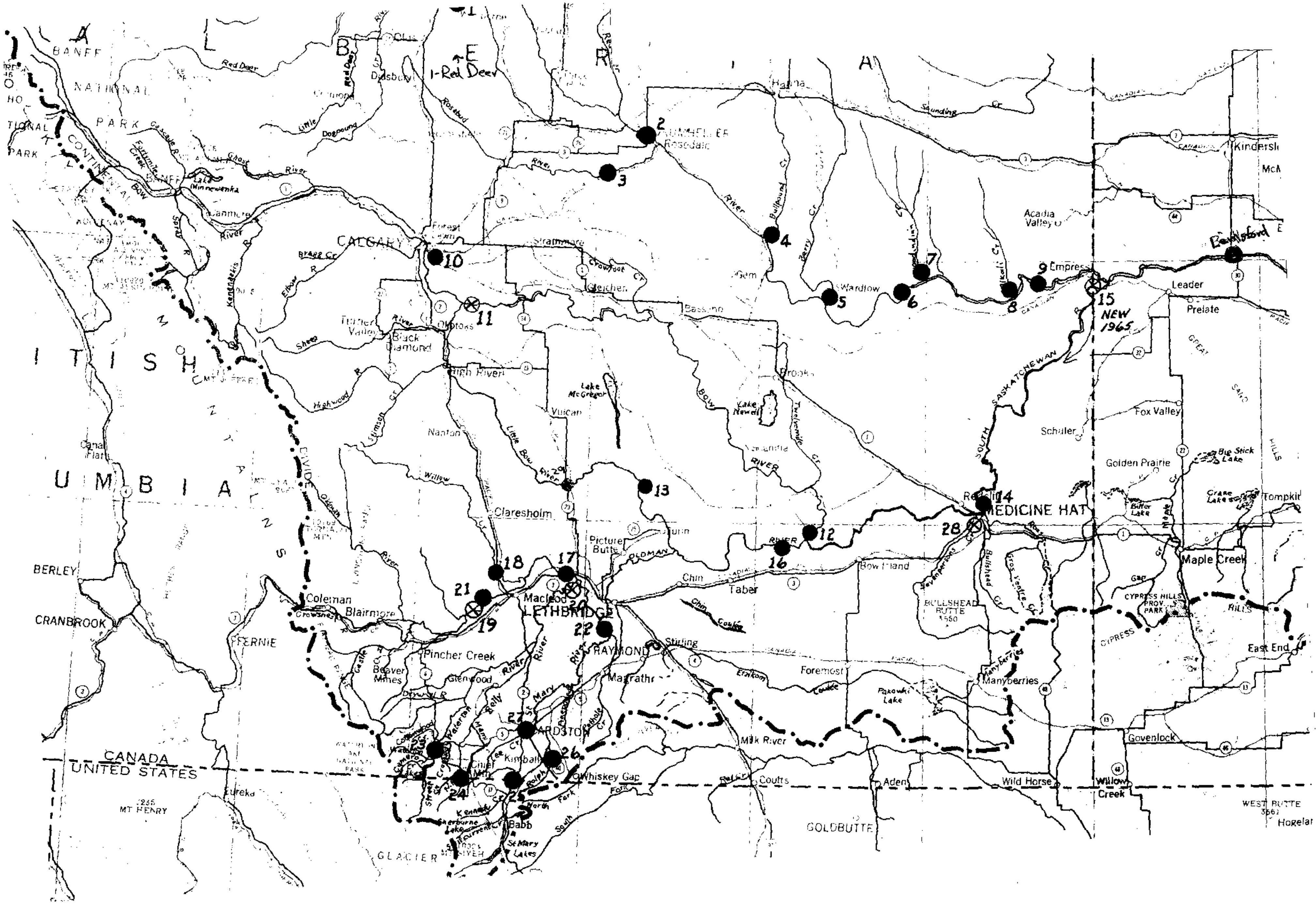
* Not needed at present, but would be in case of a large diversion not far downstream, in the future.

** 18 & 19 could be used as an alternative to 17 and 21.

*** Needed if net depletion of Belly River required separately.

**** Needed if net depletion of St. Mary River required separately.

(See map attached to this section for station locations)



BANFF
NATIONAL
PARK
1-Red Deer
Didsbury
Red Deer
Rosebud
Hanna
DRUMHELLER
Rosedale
2
3
4
5
6
7
8
9
10
11
12
13
14
15
NEW
1965
16
17
18
19
20
21
22
23
24
25
26
27
28
Sounding Cr
Kindersl
Acadia Valley
Eastsford
Empress
Leader
Prelate
Ghost
River
Lake Minnewanka
Canmore
Bow
CALGARY
Forest Lawn
Strathmore
Crowfoot Cr
Gleichen
Bassano
Gem
Wardlow
Bullpound Cr
Berry Cr
Elbow R
Bragg Cr
Sheep
Turner Valley
Black Diamond
Okotoks
High River
Highwood
Lake McGregor
Vulcan
Nanton
Little Bow River
Willow
Claresholm
Lake Newell
Brooks
Twelvemile Cr
RIVER
SOUTH SASKATCHEWAN
MEDICINE HAT
Redcliff
Schuler
Fox Valley
Golden Prairie
Big Stick Lake
Crane Lake
Tompkin
Maple Creek
Picture Butte
OLDMAN
RIVER
Chin
Taber
Bow Island
Chin Coulee
BULLSHEAD BUTTE
Bullshead Cr
CYPRESS HILLS PROV. PARK
CYPRESS
HILLS
East End
Coleman
Blairmore
Crowsnest
Macleod
LETHBRIDGE
RAYMOND
Stirling
Foremost
Etzikom Coulee
Pakowki Lake
Manyberries
Pincher Creek
Beaver Mines
Glenwood
Belly River
St. Mary
Magrath
CARDSTON
Kimball
Whiskey Gap
Milk River
Coutts
Aden
Wild Horse
Willow Creek
Govenlock
Waterton
Chief Mtn
CANADA
UNITED STATES
Eureka
MT HENRY
Babb
St Mary Lakes
North Fork
South
GLACIER
GOLDBUTTE
WEST BUTTE
Hogelar
CRANBROOK
FERNIE
BERLEY
CONTINENTAL
DIVIDE
I T I S H
U M B I A
A L B E R T A

Calculation of Stream Depletion

The South Saskatchewan River just below the Red Deer Forks is made up of flows from:

1. Bow River.
2. Oldman River.
3. Red Deer River.
4. Reach of South Saskatchewan River from Bow Junction to Red Deer Forks.

Taking these basins separately, the natural flows and net depletions are:

Bow River

Natural Flow = 10 + 11 + R_N (Bow)

Net Depletion = 10 + 11 + R_N (Bow) - 12

Where R_N(Bow) is the "natural runoff" from the Bow River basin not accounted for by the gauging stations.

Oldman River

Natural Flow = 25 + 26 + 27 + 23 + 24 + 17 + 21 + 13 + R_N (Oldman)

Net Depletion = 25 + 26 + 27 + 23 + 24 + 17 + 21 + 13 + R_N (Oldman) - 16

Where R_N (Oldman) is the "natural runoff" from the Oldman River basin not accounted for by the gauging stations.

Red Deer River

Natural Flow = 2 + 3 + 4 + 5 + 7 + 8 + R_N (Red Deer)

Net Depletion = 2 + 3 + 4 + 5 + 7 + 8 + R_N (Red Deer) - 9

Where R_N (Red Deer) is the "natural runoff" from the Red Deer River basin not accounted for by the gauging stations.

South Saskatchewan River Reach from Bow Junction to Red Deer Forks

Inflow to Reach = 12 + 16 + 28 + R_N (S.S.R.)

Net Depletion = 12 + 16 + 28 + R_N (S.S.R.) - 15

Where R_N (S.S.R.) is the "natural runoff" of South Saskatchewan River from Bow Junction to Red Deer Forks.

South Saskatchewan River just below Red Deer Forks

Natural Flow = 2 + 3 + 4 + 5 + 7 + 8 + 10 + 11 + 13 + 17 + 21 + 23 + 24 + 25 + 26 + 27 + 28 + R_N (Bow) + R_N (Red Deer) + R_N (Oldman) + R_N (S.S.R.)

Net Depletion = 2 + 3 + 4 + 5 + 7 + 8 + 10 + 11 + 13 + 17 + 21 + 23 + 24 + 25 + 26 + 27 + 28 + R_N (Bow) + R_N (Red Deer) + R_N (Oldman) + R_N (S.S.R.) - 9 - 15

NOTE 1: Little Bow River below Travers Dam (#13)

It is realized that it is an over-simplification to use flow figures for this station, because of diversions from the Highwood River upstream, and diversions into or out of Travers Reservoir. However, the quantities involved are so small that it is felt that this approach is reasonable.

NOTE 2: R_N ("Natural Runoff")

This quantity must include any natural accretions from groundwater, or losses to groundwater and evaporation. No suggestion is made here regarding a method for estimating these quantities.

Accuracy

An attempt has been made to analyze the probable accuracy of results obtained from the preceding formulae by using the principle that the Probable Error of the sum of a number of independent measurements is equal to the square root of the sum of the squares of the individual Probable Errors. It should be noted that Probable Error considers only accidental errors, and that it is defined as a plus or minus quantity within which limits the actual accidental error has a 50% chance of falling. Systematic errors in measurement, therefore, are not considered in this analysis and could, obviously, change the picture somewhat.

The period of analysis chosen was May 1 to September 30 of the year 1961, that is the normal irrigation season in a dry year in which the Natural Runoff would be small. Since we have chosen a year in which we are considering the Natural Runoff to be negligible it is obvious that this analysis also does not consider the effect of error in determination of the Natural Runoff. The percentage error of this estimation, for several index basins, is likely to be considerably larger than that for measured stream flows.

Examples - For Period May 1 - Sept. 30, 1961, Natural Runoff Nil.

Bow River

Natural Flow = 135,220 + 1,772,814 = 1,908,034 Ac.-Ft.

Net Depletion = 1,908,034 - (1,205,092) = 702,942 Ac.-Ft.

$$\text{Probable Error} = \sqrt{(6761)^2 + (88,640)^2 + (60,255)^2}$$
$$= \sqrt{45,711,121 + 7,857,049,600 + 3,630,665,025}$$
$$= \underline{107,394 \text{ Ac.-Ft.}}$$

$$\text{Percentage of Natural Flow} = \frac{107,394}{1,908,034} = \underline{5\tfrac{1}{2}\%}$$

Oldman River

Natural Flow = 324,620 + 1,304 + 16,278 + 371,180 + 129,932 + 687,870 + 131,070 + 5,408 + 0 = 1,667,662 Ac.-Ft.

Net Depletion = 1,667,662 - 1,209,408 = 458,254 Ac.-Ft.

$$\text{Probable Error} = \sqrt{(16231)^2 + (65)^2 + (814)^2 + (18559)^2 + (6496)^2 + (34398)^2 + (6553)^2 + (270)^2 + (60470)^2}$$
$$= \sqrt{5,533,742,288} = \underline{74,389 \text{ Ac.-Ft.}}$$

$$\text{Percentage of Natural Flow} = \frac{74,389}{1,667,662} = \underline{4\tfrac{1}{2}\%}$$

South Saskatchewan River Below Red Deer Forks

Natural Flow = 512,450 + 17,790 + (1000) + (1000) + (1000) + (1000) + 135,220 + 1,772,814 + 5,408 + 687,870 + 131,070 + 371,180 + 129,932 + 324,620 + 1,304 + 16,278 + 1,207 = 4,111,143 Ac.-Ft.

Net Depletion = 4,111,143 - 629,900 - 2,423,700 = 1,057,543 Ac.-Ft.

$$\text{Probable Error} = \sqrt{\begin{gathered}(25622)^2 + (890)^2 + (50)^2 + (50)^2 + (50)^2 + (50)^2 + (6761)^2 + (88640)^2 + (271)^2 + (34391)^2 + (6553)^2 + \\ (18559)^2 + (6496)^2 + (16231)^2 + (65)^2 + (814)^2 + (61)^2 + (31495)^2 + (121185)^2\end{gathered}}$$
$$= \sqrt{18,308,816,382} = \underline{135,310 \text{ Ac.-Ft.}}$$

$$\text{Percentage of Natural Flow} = \frac{135,310}{4,111,143} = \underline{3\ 1/3\%}$$

Since the Probable Error assumed in each of the individual measurements involved in the above calculation was assumed to be $\pm 5\%$, it appears that the Probable Error in the Natural Flow calculations is of approximately the same order. However, consideration of the formula for Probable Error used above would indicate that the more the individual flow measurements on tributaries there are, the less the Probable Error will be (hence the 3 1/3% P.E. when the whole South Saskatchewan basin is considered as a unit). This reasoning seems illogical at first glance, but it must be remembered that this is for accidental errors only.

Comparison of certain years results with that of the Project Depletion Method (P.D.M.) on a water year basis:

South Saskatchewan River below Red Deer Forks - Ac.-Ft.

	Project Depletion Method		Stream Depletion Method	
	Natural Flow	Net Depletion	Natural Flow	Net Depletion
1959	6,963,000	635,000	6,401,630	186,630
1961	5,570,000	1,066,000	5,460,000	1,041,000
1964	7,312,000	919,000	7,193,000	810,100

This is only to point out the importance of establishing index stations to determine runoff per unit area for incremental inflow. The precipitation in 1961 was low, therefore, there is little difference in the two methods. However, the years 1959 and 1964 indicate a need for more data on natural runoff from naturally contributing areas not gauged at present.

Advantages

1. Less gauging stations required than for the Project Depletion Method; more than for the Inflow-Outflow Method.

Disadvantages

1. Would provide net depletion for river reaches but not for individual projects.

PROJECT DEPLETION METHOD

Principle

The computation of the natural flow would comprise the recorded flow at an interprovincial boundary plus any man-made net depletions above that point.

A Project

Any operational unit using or storing water.

Data Required

(a) Gross diversion to irrigation and other consumptive use projects.

(b) Return flow from project areas, surface and subsurface.

(c) Index of natural runoff from precipitation.

(d) Accretions from or losses to groundwater.

(e) Change in reservoir storage.

(f) Evaporation.

Data Available

(a) Gross diversion data are available for all irrigation areas.

(b) Surface return flow - partial data, thee irrigation areas.

(b), (c) & (d) Groundwater geology lacking in most areas. Require additional natural flow index stations within irrigated areas.

(e) & (f) Sufficient data to establish factors for these two items.

Application of Method

1. Compute net depletion or total consumptive use in an irrigation district by the use of gross diversion and return flow figures. Due to insufficient data on return flow quantities we are unable to obtain absolute quantities for the irrigated areas.

2. Compute change in reservoir storage adjusted for evaporation.

To demonstrate the application of this method we have taken the consumptive use percentage figures found on page 32 of Mr. A. G. Underhill's "Report on Irrigation Water Use Study" dated October 1963. The percentages appear to be realistic based on the partial data available for the W.I.D., E. I. D., and B. R. D.

Consumptive Use Percentages (A. G. Underhill)

	Consumptive Use % of Gross Diversion
Western Irrigation District (W.I.D.)	50
Eastern Irrigation District (E.I.D.)	60
Bow River Development (B.R.D.)	65
St. Mary & Milk River Development (S.M.R.D.)	65
Lethbridge Northern Irrigation District (L.N.I.D.)..	65
United Irrigation District (U.I.D.)	60
Aetna Irrigation District (A.I.D.)	60
Leavitt Irrigation District (L.I.D.)	60
Mountain View Irrigation District (M.V.I.D.)	60
MacLeod Irrigation District (M.I.D.)	60

(Map attached shows irrigation districts)

The natural flow figures in the following tabulation are comprised of the Consumptive Use figure plus the recorded flows of the Red Deer River at Empress and South Saskatchewan River at Medicine Hat.

PROJECT DEPLETION METHOD + RESULTS

WATER YEAR BASIS - ALL FIGURES + 10^3

Year	Total Gross Diversion	Consumptive Use	N.F. [illegible]R. Below [illegible] Forks	Consumptive Use % of N.F.	Year	Total Gross Diversion	Consumptive Use	N.F. [illegible]R. Below N.D. Forks	Consumptive Use % of N.F.
1910-11	17[illegible]	102	11,[illegible]7	1	1937-38	1,0[illegible]	64[illegible]	[illegible],830	10
12	163	98	8,779	1	39	1,080	651	[illegible],276	12
13	185	111	8,866	1	40	1,045	632	5,108	12
14	333	198	6,645	3	41	1,059	637	3,960	16
15	247	145	12,823	1	42	916	551	8,858	6
16	245	146	13,334	1	43	1,102	670	7,794	9
17	248	145	11,181	1	44	1,084	656	4,305	15
18	555	325	6,251	5	45	1,074	649	6,206	10
19	577	342	5,268	6	46	1,146	692	6,928	10
20	498	300	8,516	4	47	1,007	608	8,667	7
21	843	503	6,[illegible]53	8	48	743	449	13,250	3
22	809	477	5,700	8	49	1,170	704	4,314	16
23	585	353	9,044	4	50	1,172	712	6,714	11
24	995	603	6,350	9	51	610	373	12,218	3
25	751	455	7,463	6	52	670	405	10,744	4
26	814	490	6,509	8	53	568	346	10,930	3
27	444	271	12,345	2	54	1,050	649	10,643	6
28	581	350	1[illegible],538	3	55	807	492	8,707	6
29	859	509	6,499	8	56	848	517	8,120	6
30	1,211	731	6,[illegible]93	10	57	1,226	754	6,126	12
31	1,131	680	4,143	16	58	1,190	729	7,326	10
32	906	547	6,[illegible]95	8	59	1,034	635	6,963	9
33	1,040	624	6,667	9	60	1,233	759	6,593	12
34	1,088	652	6,606	10	61	1,723	1066	5,570	19
35	1,234	745	6,004	12	62	1,631	1005	5,704	18
36	1,032	615	4,7[illegible]9	13	63	1,521	942	6,317	15
37	1,242	747	4,386	17	64	1,499	919	7,312	13

The preceding tabulated natural flow figures are in very close agreement with the natural flow figures shown in P. P. W. Board Report No. 1 (1911-48) dated November 1950 and the additional figures in Report No. 3 (1949-52).

Accuracy

Assessment of the consumptive use factor as it affects the resultant natural flow total.

Let us look at the figures for 1941 and 1964 which was a low year and an average year. The consumptive use total is approximately 60% of the gross diversion. Let us assume that the consumptive use factor was 75% of the gross diversion, or 15% higher than the correct figure.

	Total Gross Diversion	Consumptive Use 75%	Using 75% Factor Natural Flow	Using 60% Factor Actual Nat. Flow	Difference in Percent
1941	~~916~~ 1059	~~687~~ 794	4,117	3,960	4% –
1964	1,499	1,124	7,517	7,312	3% –

This would indicate that we do not need an absolute figure for the return flow factor to achieve reliable results, within the standard accuracy of hydrometric survey data.

The federal Water Resources Branch has increased its field surveys in two of the irrigation districts (W.I.D. and E.I.D.) to obtain a more accurate picture of the return flows. The increase in gauging stations includes several to serve as index stations of natural runoff, others to record surface runoff which had been formerly estimated. A number of groundwater wells are being observed and several precipitation gauges have been installed to fill in the network operated by the Meteorological Branch and that of the Searle Grain Company, Limited. At the end of the 1965 season we expect to arrive at some conclusion with respect to what portion of gross diversion which might appear as sub-surface flow in the Eastern Irrigation District. If this is achieved we will possibly be in a position to give a fairly accurate figure for the return flow. The development of a gauging station, groundwater well and precipitation network for other areas is being delayed pending the outcome of the E.I.D. study.

Cost of field operations in the W.I.D. and E.I.D. in 1965, with forty-four gauging stations, several groundwater well and precipitation gauges is approximately $25,000 per season. The cost of developing the stations now in operation was approximately $110,000.

Advantages

1. Provides net depletion figures for each project.
2. Data can be used to analyse the efficiency of irrigation areas and, in turn, the extent and trend of beneficial use of the water.
3. Accuracy of factors to produce net depletion would probably allow for index stations rather than a complex network.

Disadvantages

1. Rather dense network of hydrometeorological stations.
2. The necessity of studying difficult portions of the hydrologic cycle.

INFLOW-OUTFLOW METHOD

Principle

The Inflow-Outflow method of measuring depletion by man's activities may be measured by the change in relationship between the sum of the natural flows of certain key tributaries near the rim of the basin and the natural flow at the Alberta-Saskatchewan boundary.

Data Required

(a) Period of recorded natural flows in the upper reaches of the basin to correlate with the recorded natural flows at the lower main stem station.

(b) Index of natural runoff from precipitation.

Data Available

(a) No natural flow data were available at the interprovincial boundary or lower main stem station.

(b) Insufficient data.

Application of Method

Streamflow measurement stations required for the suggested Inflow-Outflow Method for the South Saskatchewan River below Red Deer Forks:

No.	Existing	New	Name of Station
1	x		Red Deer River at Red Deer
* 11		x	Bow River junction with Highwood River (adjusted)
17	x		Oldman River at Monarch (adjusted)
23	x		Waterton River near Waterton Park
24	x		Belly River at Mountain View (adjusted)
25	x		St. Mary River at International Bdry. (adjusted)
27	x		Lee Creek at Cardston
29	x		Little Bow River at Carmangay

* 11 - Would replace Bow River at Calgary, Elbow River at Calgary, Fish Creek, Sheep and Highwood Rivers.

(adjusted)- For storage or diversion above station.

(See map, page 5, for station locations.)

To assess the possibilities of this method, the natural flow figures computed by the Project Depletion Method were accepted as being correct. Using the basic equation $y = ax + b$, a relationship was established between the annual figure and the total annual flow of the "rim" stations. The application of this factor to the "rim" flow stations gave the following comparative results.

SOUTH SASK. RIVER BELOW RED DEER FORKS

FLOW FIGURES IN AC-FEET ÷ 10^3

Year	Project Depletion Method N.F.	Using Rim Stations	% Difference	Year	Project Depletion Method N.F.	Using Rim Stations	% Difference
1911-12	8779	9300	-6	1937-38	6830	7120	-4
13	9266	9070	-2	39	5276	5270	+ -
14	6645	6750	-2	40	5108	4980	+2
15	12823	12830	- -	41	3960	3840	+3
16	13334	14000	-5	42	8858	8950	-1
17	11181	10920	+2	43	7794	7810	- -
18	6251	6520	-4	44	4305	4650	-8
19	5268	5240	+ -	45	6206	6530	-5
20	8516	8060	+5	46	6928	6970	-1
21	6253	6400	-2	47	8667	8320	+4
22	5700	5970	-5	48	13260	10960	+17
23	9044	9710	-7	49	3814	4220	-11
24	6350	7070	-11	50	6714	6470	+4
25	7463	7610	-2	51	12218	10980	+10
26	6509	6490	+ -	52	10744	9620	+10
27	12345	12560	-2	53	10930	10530	+4
28	11538	12040	-4	54	10643	10690	- -
29	6499	6970	-7	55	8707	8560	+2
30	5998	6300	-5	56	8120	7610	+6
31	4143	4240	-2	57	6126	6100	+ -
32	6895	7450	-8	58	7326	7000	+4
33	6667	6940	-4	59	6963	7100	-2
34	6606	6650	-1	60	6593	6560	+1
35	6004	5930	+1	61	5570	6090	-9
36	4789	4480	+6	62	5704	5890	-3

The accuracy of this method is difficult to access because of the original assumption that the natural flow computed by the Project Depletion Method was correct. The agreement is amazing with the years of large percentage discrepancies coinciding with either above or below normal precipitation in the lower reaches. The method is so simple and straightforward that further analysis of its possibilities should be examined. Precipitation - runoff data to be collected for the two previous methods would suffice this requirement.

Advantages

1. Simplicity - use the data from eight gauging stations, with only a few requiring adjustment for upstream storage or diversion.

Disadvantages

1. Would not provide unit area information - only basin depletion.

CONSUMPTIVE USE METHOD

Principle:

This method of estimating the irrigation requirement of an area is based upon the concept of consumptive water use, which includes all evapo-transpiration and evaporation from land on which there is plant growth of any kind plus the evaporation from bare land and from the water surface. This amount of water depends primarily upon the type of crop and the climatic conditions. Various empirical formulae have been suggested for the calculation of this consumptive use. All these formulae take into account one or more of the climatic factors like temperature, precipitation, evaporation, relative humidity, radiation, hours of sunshine, etc. All these formulae also require in addition to the above climatic factors, at least one constant which is purely empirical in nature and the value of which depends upon the nature of the plant, growth pattern, and certain physiological features of the plant. Amongst the various empirical formulae, the one suggested by H. Blaney has been widely recommended for use all over the world because of its requiring as simple data as monthly and annual percentage of daytime hours and the mean monthly temperatures. Again, Blaney's method has the additional advantage that by measuring experimentally the consumptive use by soil-moisture depletion method or other laboratory methods for various crops, the value of the Blaney seasonal coefficient for each plant can be found once and for all, because this coefficient appears to be approximately constant for most areas where irrigation is practiced.

In order to find the net consumptive use of a crop during any period, the effective precipitation and any other available water can be subtracted from the total consumptive use requirement for the period. Next, knowing the irrigation efficiency, which depends upon the irrigation practice, soil characteristics, general slope of land, topography, skill of irrigator (if any) and most of other factors, and which can actually be measured in the field, we can calculate the total irrigation requirement of a crop for a period by dividing the net consumptive use by the irrigation efficiency. To this total water requirement by all the crops, is added the total seepage and evaporation losses from the various conveyance channels and lake bodies, in order to get the gross irrigation requirement or total depletion figure. By adding to this total irrigation requirement, the net return flow figure, we can get an estimate of the total diversion requirement.

Present Status of Information

The Federal Water Resources Branch has not yet made any comprehensive studies in terms of the Consumptive Use Method. However, some interim work has been done in this connection to evaluate consumptive use of various crops in E.I.D. by making use of latest experimentally measured consumptive use figures supplied by the Federal Agricultural Research Station, Lethbridge, instead of using Blaney's formula which is not suitable because of the lack of knowledge of Blaney's seasonal coefficient for the crops in the Prairie Provinces.

There is a need for more precise experimentally measured monthly consumptive use information for each individual crop of the Prairie Provinces and a good estimation of irrigation efficiency and conveyance losses.

Improvements

By some experimental methods an idea could be obtained about the absorption capacity of the soil, so that the water loss due to absorption and deep percolation at farmland could be added to net consumptive use to get the total crop irrigation requirement at the farm itself. This will eliminate the need of using irrigation efficiency, the used values of which are very doubtful.

Extent of Information in Each Major Irrigation District

Data	District					
	W.I.D.	E.I.D.	B.R.D.	L.N.I.D.	S.M.R.D.	U.I.D
Diversion into	Yes	Yes	Yes	Yes	Yes	Yes
Surface Return Flow	Most Major Channels	Total Return Flow 1965	Most Major Channels	No	No	No
Groundwater Levels	Not Known	Yes Some	Yes Some	Not Known	Yes Some A.R.C.	No
Groundwater Geology	---	Very Little	---	---	---	---
Precipitation Observations	Meteorological Branch & Searle Grain Co., Ltd. - Insufficient					
Temperature Observations	Many in Alberta - sufficient to compute evaporation for all districts.					
Evaporation Observations	Calgary, Vauxhall, Whiskey Gap, Manyberries; Medicine Hat, Lethbridge, Brooks - Bellami Cup; Rosemary and Strathmore to be established in 1965.					
Humidity Observations	Calgary, Lethbridge, Medicine Hat, Vauxhall (dewpoint observed at evaporation station)					
Wind Speed	Calgary, Lethbridge & Medicine Hat. Vauxhall at evaporation station.					
Crop Census	No	Yes	No Longer Recorded	Yes 1959-64	Partial Taber to Medicine Hat	No

Advantages

1. The method does not require any elaborate hydrometric network and data other than that for return flows.
2. The method has been widely used all over the world, in the form of Blaney's formula.
3. The value of consumptive use figures measured at one experimental farm can be used reasonably well over the surrounding area.

Disadvantages

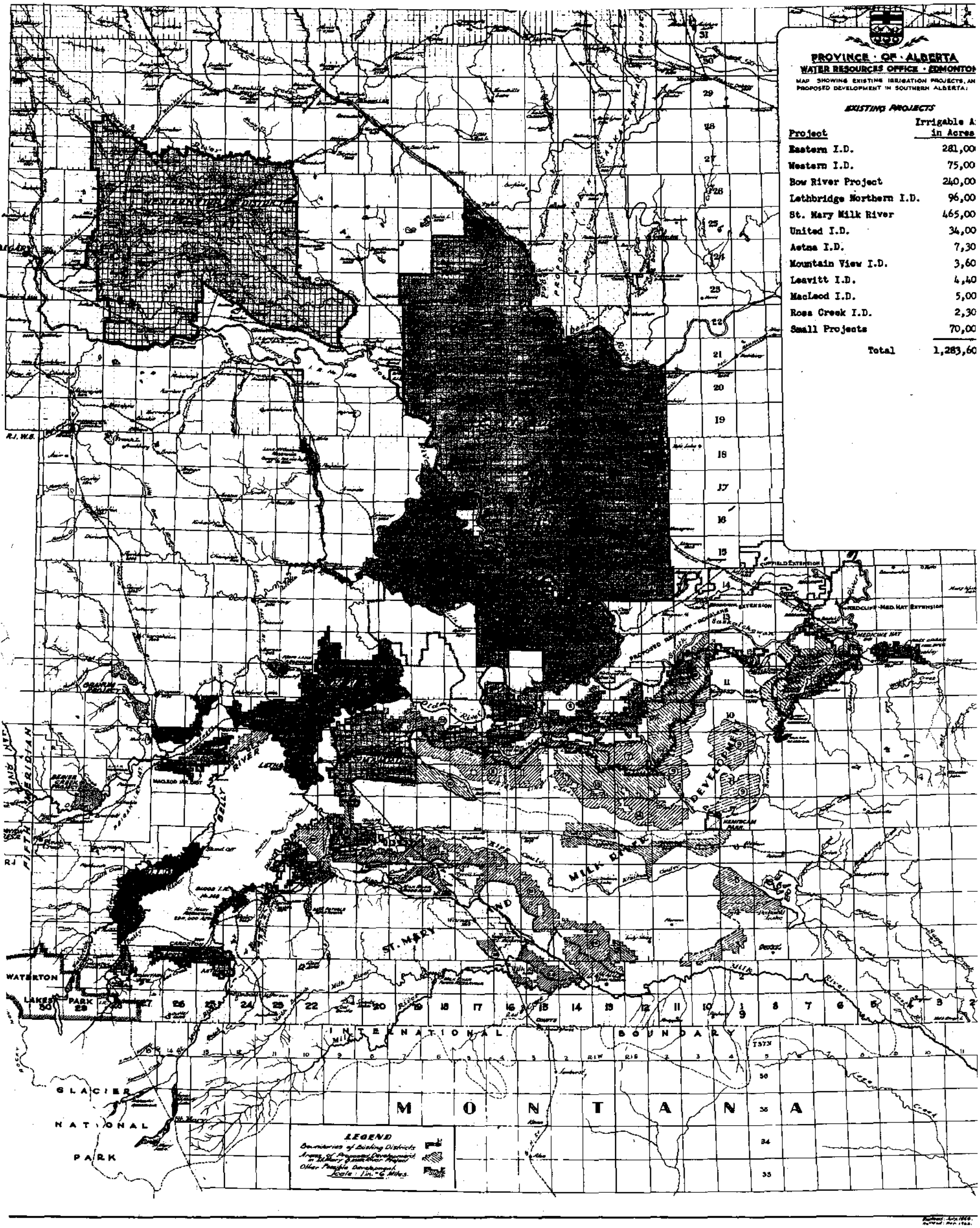
1. Irrigation efficiency is difficult to be estimated accurately and is expensive to be measured.
2. The method has never been tried for the Prairie Provinces before.
3. Consumptive use figures would not be available for use in computing the natural flow until late in the season.

Some idea of the complexity of the computations required can be observed from the two attached sheets showing the cropping pattern, livestock population and average yield of the various crops in the Eastern Irrigation District for the years 1960 to 1964.

EASTERN IRRIGATION DISTRICT
CROP AND LIVESTOCK REPORTS
1960 - 1964

	Acres				
	1960	1961	1962	1963	1964
Wheat	17,761	16,075	18,321	19,144	24,769
Oats	20,513	19,475	23,094	18,305	14,989
Barley	19,067	16,848	14,868	20,346	20,790
Flax	9,788	8,717	7,296	6,611	10,819
Rye	198	408	373	295	309
Mixed Grain	4,617	5,278	6,510	4,862	5,200
Peas	2,530	3,486	1,610	2,136	2,955
Beans	4	3	5		3
Carrots			8	25	41
Corn	82	37	2	35	57
Corn Fodder	595	556	783	1,280	
Turnips	10	15	50		15
Potatoes	1,510	2,005	2,231	2,257	2,564
Alfalfa Hay	39,318	46,165	54,922	54,313	50,680
Alfalfa Seed	738	332	468	1,044	1,530
Sweet Clover Hay	2,310	3,009	2,399	1,833	1,996
Sweet Clover Seed	451	421	94	268	
Green Feed	7,187	9,450	4,928	3,201	3,217
Silage					1,208
Mustard Seed	45		16	110	96
Rape Seed	98				
Sunflower Seed	125	177	167	65	25
Canary Seed					66
Small Seeds	1,715	503	238	819	704
Tame Pasture	32,851	30,887	33,522	32,434	33,217
Summerfallow	27,562	24,185	17,535	22,692	19,664
Garden	686	435	730	817	703
TOTAL:	189,761	188,467	190,170	192,892	195,617

	LIVESTOCK				
Horses	1,872	2,014	2,019	2,035	2,089
Dairy Cows	4,212	4,148	4,413	4,592	4,451
Beef Cattle	64,584	67,699	57,763	69,236	46,509
Calves & Yearlings				65,764	47,829
Bulls	1,486	1,632	1,561	1,509	1,734
Hogs	20,557	22,335	15,110	15,478	21,421
Sheep	36,275	40,429	27,720	25,110	24,044
TOTAL:	128,986	138,257	108,586	183,724	148,077


PROVINCE · OF · ALBERTA
WATER RESOURCES OFFICE · EDMONTON
MAP SHOWING EXISTING IRRIGATION PROJECTS, AN
PROPOSED DEVELOPMENT IN SOUTHERN ALBERTA
EXISTING PROJECTS
Project
Irrigable A in Acres
Eastern I.D. 281,00
Western I.D. 75,00
Bow River Project 240,00
Lethbridge Northern I.D. 96,00
St. Mary Milk River 465,00
United I.D. 34,00
Aetna I.D. 7,30
Mountain View I.D. 3,60
Leavitt I.D. 4,40
MacLeod I.D. 5,00
Rosa Creek I.D. 2,30
Small Projects 70,00
Total 1,283,60
CALGARY
FIFTH MERIDIAN
BELLY RIVER
ST. MARY
MILK RIVER
MEDICINE HAT
WATERTON LAKES PARK
INTERNATIONAL BOUNDARY
GLACIER NATIONAL PARK
M O N T A N A
LEGEND
Boundaries of Existing Districts
Other Possible Development
Scale: 1 in. = 6 Miles.