

NWRI CONTRIBUTION 85-20

Krishnappan (50)

**APPLICATION OF MOBED TO QU'APPELLE RIVER
BETWEEN CRAVEN AND PASQUA LAKE**

by

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L7R 4A6

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ABSTRACT

To improve conveyance in the reach of Qu'Appelle River between Craven and Pasqua Lake, the Saskatchewan Water Corporation has proposed a channel improvement scheme to be implemented under the "Agreement on Qu'Appelle River Channel Conveyance" signed by Canada and Saskatchewan. In this report, the scheme is tested for its effectiveness using MOBED. The model predictions indicate that the proposed scheme will not be effective and would cause additional problems. It is recommended that alternative schemes be explored with the help of models such as MOBED.

RÉSUMÉ

Pour améliorer l'adduction dans le bief de la rivière Qu'Appelle entre les lacs Craven et Pasqua, la Saskatchewan Water Corporation a proposé un plan d'amélioration du chenal devant être mis en oeuvre en vertu de l'Accord Canada-Saskatchewan portant sur l'adduction du chenal de la rivière Qu'Appelle. Dans le présent rapport, on vérifie l'efficacité du plan au moyen du modèle MOBED. Les prévisions du modèle indiquent que le plan proposé ne sera pas efficace et causerait d'autres problèmes. On recommande de chercher à élaborer d'autres plans à l'aide de modèles comme le MOBED.

MANAGEMENT PERSPECTIVE

At the initiative of the IWD staff in Regina, the river improvement works for the Qu'Appelle downstream from Craven to Pasqua Lake has been analyzed in this report.

The analysis takes into account that the river bed is mobile and that over the year the river conveys sediment as well as water. MOBED, a verified model designed for such analysis, shows that the straightening of the river to improve conveyance will lose effect in seven years and flooding will re-occur. There will also be problems with upstream features affected by erosion such as the W.S.C. gauge. A useful life of seven years for the project may not be economic and further expenditures will be necessary to avoid or reduce future floods in the main channel or in the tributaries.

T. Milne Dick
Chief
Hydraulics Division

PERSPECTIVE-GESTION

Le rapport présente l'analyse des travaux d'amélioration de la rivière Qu'Appelle en aval, du lac Craven au lac Pasqua, qu'a entreprise le personnel de la DGEI de Regina.

L'analyse tient compte du fait que le lit de la rivière est mobile et qu'au cours de l'année, le cours d'eau transporte des sédiments aussi bien que de l'eau. Le MOBED, modèle éprouvé conçu pour ce genre d'analyse, indique que le redressement de la rivière effectué pour améliorer l'adduction ne produira plus l'effet voulu au bout de sept ans et que les inondations se reproduiront. Certaines caractéristiques en amont touchées par l'érosion poseront également des problèmes, par exemple les données de l'indicateur de niveau d'eau de la DRHC seront faussées. Il se peut que le projet, n'ayant une vie utile que de sept ans, ne soit pas rentable et qu'il faille engager d'autres dépenses pour éviter ou réduire les futures inondations dans le chenal principal ou dans les émissaires.

Le chef,
T. Milne Dick
Division de l'hydraulique

1.0 INTRODUCTION

In the whole of the Qu'Appelle River system the reach between Craven and Pasqua Lake has been identified as a "bottleneck" for conveyance (Ref. 1). During the years of high spring runoff it backs the water upstream in the Last Mountain Lake causing the water level in the lake to rise which in turn causes extensive shoreline erosion. During dry years, it causes the water levels in lower lakes to drop well below optimum levels required for adequately sustaining water uses for domestic, livestock, irrigation and recreation.

To overcome this problem, the Saskatchewan Water Corporation is proposing a conveyance improvement scheme for the reach between Craven and Pasqua Lake to be implemented under the Agreement on Qu'Appelle River Channel Conveyance signed by Canada and Saskatchewan in 1984. The proposed scheme involves several meander cutoffs and dredging of the existing channel at several reaches. A total of 1.35 million cubic metres of excavation is required with an estimated cost of 4.535 million dollars. The details of the scheme are summarized in a design team report published by Saskatchewan Water Corporation (1).

It is estimated in the design team report (Ref. 1) that the new channel will have a capacity of $14.16 \text{ m}^3/\text{s}$ with a minimum freeboard of 0.3 metres. But these estimations were made on the basis of Manning's equation with a fixed Manning's coefficient of 0.03. No consideration was given to the movement of sediment and the associated bed level changes. Therefore, it was decided to verify the design by applying the mobile boundary flow model, MOBED, to the reach with and without the proposed channel modifications. The details of the model application and the model results are presented in this report.

2.0 SALIENT FEATURES OF MODEL MOBED

MOBED is a computer model capable of calculating water and bed levels in a natural stream when flow and sediment inputs are time

dependent. It takes into account the bedform roughness characteristics and the sediment transporting capacities of the mobile boundary flows. Hence, the model is ideally suited for predicting long term response of a river for modifications imposed on it. Complete details of the model can be found in a users manual (2) and its update (3).

3.0 APPLICATION OF MOBED TO EXISTING RIVER

The existing river reach between Craven and Pasqua Lake is shown in Fig. 1. The reach is 117.5 km long with an average bedslope of 0.00008. The reach contains a large number of meander bends that are remarkably regular in a number of locations suggesting that the river is mature and stable. To define the flow cross-sectional shapes fully, surveys were conducted at about 560 sections within the reach. For the purpose of model application, 14 typical cross-sectional shapes were selected. The locations of the selected sections are shown in Fig. 2 where the profile of the river is illustrated. Three out of these fourteen cross-sections are depicted in Fig. 3 as examples to show the size of the stream under investigation.

To determine the size distribution of the bed sediment in the reach, grab samples were collected at three different sections along the reach. The upstream section is near Craven while the downstream section is near the Pasqua Lake. The middle section is near Highway Number 6, (see Fig. 2). At each section four samples were taken: one at each bank and two samples in the middle of the stream. The bank samples were taken at a location where the water depth is about 0.3 metres. Size distributions of the bed samples collected at upstream and downstream sections are shown in Fig. 4. It can be seen from this figure that the size distribution shows a decreasing trend in the downstream direction. A representative median grain size of .064 mm was selected for the model.

In applying MOBED to the existing river reach, the Craven control is selected as the upstream boundary and the inlet of the Pasqua

Lake as the downstream boundary. Flowrate entering the Craven Control forms the upstream boundary condition for the model while the water level at the Pasqua Lake forms the downstream boundary condition. A total of 48 grid stations were selected to represent the 117.5 km length of the river. The distance between the consecutive grid stations is held constant at 2.5 km. Using bed elevations as shown in Fig. 2, the model was run for a constant flowrate at Craven Control of $14.16 \text{ m}^3/\text{s}$ (500 cfs) and a constant lake water level at Pasqua Lake of 479.00 m (1571.5 ft). The resulting water surface elevations from the model are plotted in Fig. 2. Two sets of water surface profiles were predicted: one using a grain size for sediment of 0.100 mm and the other using a grain size value of .064 mm. Note that the effect of particle size is not significant in this range. In addition to the predicted water surface elevations, the bank elevations for selected sections are also shown in Fig. 2. From this it can be seen that for all the sections downstream of Highway Number 6, at least one bank is below the predicted water level implying that flooding is inevitable for this section of the river reach for a flowrate of $14.16 \text{ m}^3/\text{s}$. Flowrate was gradually reduced in the model until the predicted water surface levels were below the existing bank levels for all sections. This flowrate was found to be $8.50 \text{ m}^3/\text{s}$ (300 cfs). Therefore, one can conclude from the model prediction that the existing river can safely convey a flowrate of only $8.50 \text{ m}^3/\text{s}$.

4.0 APPLICATION OF MOBED TO MODIFIED RIVER

The planview of the modified stream is shown in Fig. 1. As a result of the meander loop cutoffs and channel realignment the length of the modified stream between Craven control and Pasqua Lake has been reduced to 77.5 km. The reduction in length amounts to 40 km which brings the slope of the modified river up to .00013. Fig. 5 shows the initial bed profile of the modified stream and the location of sections for which the flow cross-sectional shapes are selected. There are

altogether seventeen such sections. Fig. 5 also shows the water surface elevation as determined by the design team of Saskatchewan Water Corporation (dashed line). This water surface elevation was computed using Manning's equation with a fixed Manning's coefficient of 0.03.

MOBED was applied to this modified river. Again, Craven Control was chosen as upstream boundary and the inlet of Pasqua Lake as downstream boundary. A total of 32 grid stations were chosen to represent the length of 77.5 km. Therefore, the distance between consecutive grid stations remained the same at 2.5 km. Assuming equilibrium conditions, i.e., the sediment entering the upstream boundary section is in balance with the transporting capacity of the flow at that section, the model was run for a steady flow of $14.16 \text{ m}^3/\text{s}$ at the upstream boundary and a constant water level elevation of 479.00 m at the downstream boundary. The results are shown in Fig. 5. It can be seen from Fig. 5 that the water surface elevations computed by the model agrees reasonably well with the levels predicted by the design team. It should be pointed out here that for MOBED, there is no need to specify the roughness coefficient such as Manning's 'n'. The model predicts the roughness characteristics of the flow by considering both the skin friction loss and the form loss which are expressed in terms of sediment and flow characteristics. The water level predicted by the model, therefore, depends on the size of the sediment. Two different sediment size values of 0.100 mm and .064 mm were used in the model to test the effect of sediment size on predicted water levels. It can be seen from Fig. 5 that the difference in the predicted water levels is not significant.

The water levels predicted by assuming equilibrium conditions represent the flow condition that would exist just after modification of the channel. As time progresses, the flow would erode sediment from upstream reaches because of the increased slope and the absence of corresponding increase in sediment supply from upstream. The model MOBED was again applied to predict the evolution of the bed profile.

The water level elevations predicted for equilibrium conditions were used as initial conditions and the sediment inflow at the upstream boundary (Craven Control) was assumed to be the same as that which existed prior to channel modifications. The bed levels as a function of time predicted by the model are shown in Fig. 6 together with the initial bed and water levels. It can be seen from Fig. 6 that the stream bed degrades at the upper reaches and aggrades in the lower reaches because of the increase in slope. The degradation moves downstream and the aggradation moves upstream as time progresses. At the end of a 3-year period the degradation has moved down to steel bridge from Craven Control, while the aggradation has moved up to Loon Creek confluence from the lake. A maximum degradation of 4.30 m of the Craven Control and a maximum aggradation of 2.70 m at a distance of 10 km upstream of Pasqua Lake have been predicted. The water levels predicted at the end of a 3-year period are also shown in Fig. 6. These water levels indicate that flooding is likely in the downstream reaches near the lake and at some upstream locations near steel bridge. It should be noted here that the predictions were carried out by running the model with a constant flow rate equal to the design flowrate for the whole of the simulation period. Therefore, the predicted time scale of three years is only a conservative estimate. To predict the true time scale, the model was run using a flow hydrograph derived from synthesized flow data that approximate the flow regime after the modifications are implemented. The details are given below.

4.1 Derivation of a Representative Flow Hydrograph

The synthesized flow data supplied by the Saskatchewan Water Corporation were used to derive a representative hydrograph for the study reach. The data set covers a period of sixty-seven years starting in 1911 and ending in 1977. The raw data of monthly average discharge expressed in cfs are shown in Table 1.

To derive a representative hydrograph from the data given in Table 1, the following procedure was used. The discharge was considered in a number of intervals as shown in the first column of Table 2. For each interval, the number of occurrences of monthly discharge were counted (column 3) and a frequency or a probability of occurrence of flow in a particular interval was computed (column 4) by dividing the number of occurrences by the total number of months in the period of record. The duration of flow in days for each discharge interval in one calendar year (column 5) was then computed by simply multiplying the values in column 4 by 365. Using the duration values in column 5, a flow hydrograph consisting of daily flows for a calendar year was constructed by distributing the high flows during the months of April and May and the low flows during the summer months. The shape of the hydrograph thus constructed is shown in Fig. 7.

4.2 MOBED's Prediction Using the Derived Hydrograph

Using the derived hydrograph shown in Fig. 7 as the upstream boundary condition, MOBED was rerun to predict the bed level changes. Sediment inflow at the upstream boundary was assumed to be the same as that existed in the original channel as before. The downstream boundary condition of lake level as a function of time was obtained from a stage discharge curve published in the Handbook of Hydraulics for the Qu'Appelle River System (Ref. 4).

The bed level variations predicted by MOBED are shown in Fig. 8. Bed levels corresponding to three different time periods are plotted in Fig. 8. From this figure, it can be seen that the degradation and the aggradation pattern of the channel is similar to that predicted for the constant flow rate. However, the magnitudes of degradation and aggradation and the time scale are different. With the variable flow, time scale has been stretched. Now, it takes seven years for the average bed slope to approach to the original channel slope. The degradation upstream is two times the value predicted for the

constant flow. The maximum aggradation is also higher and is equal to 3.50 m.

The predicted water levels at the end of seven year period are shown in Fig. 8. These water levels correspond to a flow rate of 15.70 m³/s which is very close to the design flow rate of 14.16 m³/s. From these water levels, one can see that the flooding is likely to occur at a number of locations. Reaches near Steel Bridge and Loon Creek confluence are particularly vulnerable.

4.3 Discussion of MOBED's Predictions

The model predictions indicate a significant channel degradation immediately downstream of the Craven Control structure. The magnitude of degradation as predicted by the model represents the amount that the flow would want to scour. However, if the local geology is such that the flow encounters non-erodible layers before reaching the maximum predicted degradation, then the flow would move the degradation further downstream and the process may continue. The same thing will happen when the degradation is limited by the process of armouring of the stream bed as well. It is possible to include factors such as thickness of erodible bed layers and natural armouring of stream bed when simulating flows with MOBED. But, this would require more information on geology and sediment size distribution of stream bed. The predicted aggradation downstream near the lake is going to be a problem because it will raise the water levels and cause flooding. It may be very tempting to resort to maintenance dredging to remove the aggraded sediment. But, it is not a wise solution because it will aggravate the degradation problem upstream. Both the magnitude and extent of the degradation will increase. Moreover, the aggradation problem is likely to persist for a considerable time into the future and the maintenance dredging may have to become a regular ongoing maintenance activity. The average amount of dredging that may be required will be in the order of 70,000 metric tons per year.

The detrimental effects of river channelization involving meander cutoffs have been discussed by Parker and Andres (5) who examined the effects of river channelization of the East and West Prairie Rivers in Alberta. The effects of channelization of East Prairie River are monitored by the Alberta Department of Environment and the data clearly show the detrimental effects of degradation and the aggradation that have resulted from channelization. The degradation and aggradation patterns observed in the East Prairie River and those predicted by MOBED for the Qu'Appelle River show signs of similarity even though the stream and the channelization characteristics are different.

5.0 CONCLUSIONS AND RECOMMENDATIONS

From the model predictions shown in Fig. 8, one can conclude that the proposed conveyance improvement scheme in Qu'Appelle river is not going to be effective in the long run. The problem of flooding will resurface within seven years of channel modifications. The aggradation downstream near the lake will negate all the dredging that has been planned for this reach. It will also have an impact on Loon Creek. Water levels in the creek will rise and might cause flooding. The degradation in the upstream reaches could be detrimental to the existing gauging station of the Water Survey of Canada located near Craven Control. Any other structures in this reach susceptible to lowering of bed level would also be affected.

Alternate schemes that would have minimum impact on river regime should be explored. One possibility would be to leave out the meander loop cut offs of the present proposal and simply widen the channel. The other possibility would be to build dikes at selected reaches. All these options could be evaluated for their impacts using models such as MOBED.

ACKNOWLEDGEMENTS

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2. Krishnappan, B.G. "Users Manual: Unsteady, Non-uniform, Mobile Boundary Flow Model - MOBED". Hydraulics Division, National Water Research Institute, Burlington, Ont., February 1981.
3. Krishnappan, B.G. "MOBED - Users Manual Update". Hydraulics Division, National Water Research Institute, Burlington, Ontario, August 1983.
4. Saskatchewan Department of the Environment. "Qu'Appelle River Conveyance Study: Appendix I - Handbook of Hydraulics for the Qu'Appelle River System". Report No. HYD-5-4-, 1975.
5. Parker, G. and D. Andres. "Detrimental Effects of River Channelization". RIVERS '76, Proc. 3rd Annual Symposium of the Waterways Harbors and Coastal Engineering, Division of ASCE, Colorado State University For Collins, Colorado, U.S.A., Aug. 10-12, 1976.

TABLE 1

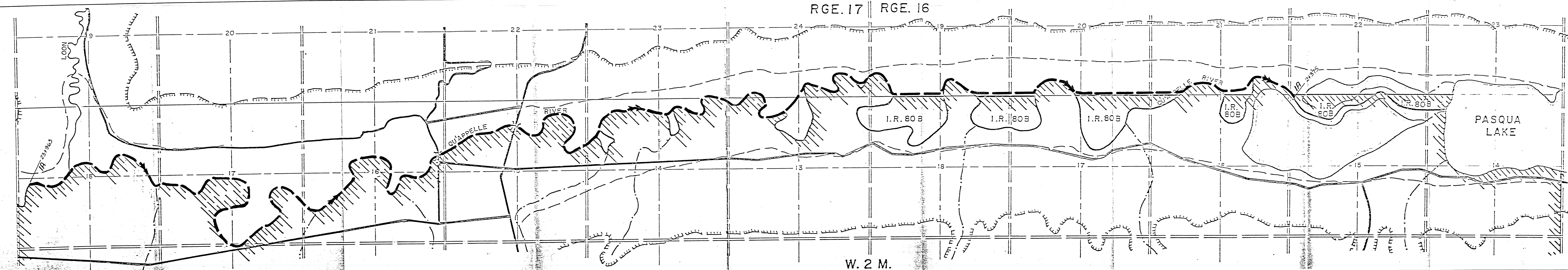
Monthly Average Discharges in cfs (Data Provided by Saskatchewan Water Corporation)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1911	9	7	8	192	5	12	10	9	8	7	159	213
1912	194	68	8	509	436	92	36	432	103	99	21	232
1913	211	117	15	89	78	153	7	459	36	123	230	182
1914	229	70	8	50	11	14	11	9	8	7	46	202
1915	197	126	0	9	10	9	9	9	8	7	8	8
1916	8	7	197	878	557	508	502	599	439	320	224	215
1917	243	101	9	512	252	145	2	142	30	91	209	202
1918	218	78	2	243	3	10	9	9	8	7	8	8
1919	8	11	6	251	5	11	10	9	8	7	8	8
1920	8	7	9	440	13	33	11	55	13	128	228	185
1921	189	89	13	76	71	152	42	249	331	111	267	199
1922	212	115	185	719	666	512	479	376	41	35	268	206
1923	220	88	12	612	399	499	252	315	1	9	226	177
1924	209	74	4	290	6	12	10	9	8	7	8	8
1925	86	106	10	625	404	221	2	58	74	9	224	185
1926	206	106	3	19	7	11	10	9	8	7	8	8
1927	8	62	127	915	635	512	504	500	451	243	291	192
1928	184	67	7	357	10	50	11	299	33	117	216	193
1929	221	84	1	11	9	10	9	91	0	9	7	8
1930	8	7	7	193	4	11	9	9	8	7	8	8
1931	8	7	8	7	10	99	84	75	69	0	9	7
1932	8	7	7	7	9	89	83	78	69	45	0	9
1933	7	8	7	150	9	14	85	87	61	0	9	7
1934	8	7	7	8	9	80	60	41	67	37	42	0
1935	9	47	2	94	75	1	9	90	65	0	9	7
1936	8	7	7	402	264	4	1	33	2	8	7	8
1937	8	7	8	7	9	59	39	11	36	6	33	42
1938	31	47	53	101	70	92	87	72	69	46	0	9
1939	7	8	7	166	112	5	89	66	80	45	44	0
1940	9	7	8	63	1	59	63	42	66	44	0	9
1941	7	8	70	184	131	3	85	87	68	0	9	7
1942	8	7	76	276	170	4	17	11	7	7	7	84
1943	242	169	191	791	619	506	426	369	0	9	39	176
1944	200	118	2	30	5	12	9	9	9	7	8	8
1945	8	7	7	7	9	60	80	150	0	9	7	8
1946	8	7	178	240	3	10	10	9	9	7	7	8
1947	88	154	5	845	590	501	88	456	99	0	242	225
1948	250	148	0	1063	765	499	499	499	82	0	183	310
1949	215	96	1	8	9	10	9	68	0	9	7	8
1950	8	7	7	423	310	4	9	9	8	7	119	268
1951	235	170	9	637	586	506	397	459	302	61	268	233
1952	257	82	8	624	318	99	2	183	101	0	215	185
1953	248	134	32	69	3	775	650	499	499	418	220	225
1954	236	61	0	44	4	17	16	351	370	129	204	172
1955	241	104	104	1057	1397	924	876	772	499	499	399	349
1956	349	349	222	1374	746	757	503	499	470	118	233	222
1957	202	72	299	401	6	10	9	9	8	7	8	8
1958	162	163	12	267	0	9	25	96	0	9	7	8
1959	8	7	81	2	10	110	90	60	80	63	0	9
1960	7	8	145	659	197	408	5	9	8	7	8	119
1961	227	124	161	1	10	27	90	53	68	46	46	0
1962	9	7	63	115	1	10	83	85	70	45	44	0
1963	9	7	64	2	10	87	112	85	63	0	9	7
1964	8	7	8	79	0	71	64	50	70	35	42	0
1965	9	54	4	199	166	226	2	9	8	7	8	8
1966	8	7	181	3098	7	13	10	10	8	7	8	8
1967	8	7	7	538	318	5	10	82	0	9	7	8
1968	8	7	192	3	9	9	9	12	8	7	8	8
1969	8	7	8	1545	750	738	500	499	342	250	216	228
1970	234	153	2	637	784	568	499	99	169	92	264	217
1971	215	165	0	1275	599	443	0	9	9	7	23	206
1972	215	88	226	247	2	9	9	25	5	8	7	8
1973	8	7	7	7	9	91	27	93	65	0	9	7
1974	8	7	8	2300	1440	1001	951	802	499	499	399	349
1975	349	349	315	744	906	887	676	499	499	440	399	283
1976	193	102	315	1897	758	799	673	499	499	263	209	223
1977	194	74	0	9	10	115	114	105	11	6	8	8
MEAN	114	68	57	402	236	206	152	176	108	70	103	104

TABLE 2

Flow Duration Data for Qu'Appelle River Near Craven

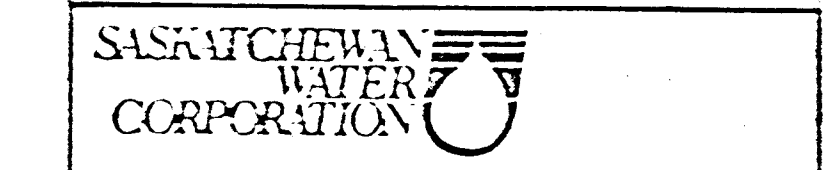
Internal Discharge in cfs	Mean Discharge in cfs	Number of Months in Which Discharge was in the Interval	Duration as a Fraction of Total Period of Record	Duration in Days in One Calendar Year
0-10	5	3 ⁰⁶	.38060	139
10-12	11	41	.05100	19
12-14	13	5	.00622	2
14-17	165	5	.00622	2
17-20	185	1	.00124	1
20-25	225	3	.00373	1
25-30	275	4	.00498	2
30-35	325	8	.00995	4
35-40	375	6	.00746	3
40-45	425	14	.01741	6
45-50	475	9	.01119	4
50-60	55	10	.01244	4
70-70	65	30	.03731	13
70-80	75	20	.02488	9
80-100	90	44	.05473	20
100-120	110	24	.02985	11
120-140	130	8	.00995	4
140-170	155	21	.02612	9
170-200	185	30	.03731	14
200-250	275	18	.02239	8
300-350	325	20	.02488	9
350-400	375	10	.01244	4
400-450	425	15	.01866	7
450-500	475	23	.02861	10
500-600	550	24	.02985	11
600-700	650	12	.01493	6
700-800	750	13	.01617	6
800-1000	900	9	.01119	4
1000-1200	1100	3	.00373	1
1200-1400	1300	3	.00373	1
1400-1700	1550	2	.00249	1
1700-2000	1850	1	.00124	1
2000-2500	2250	1	.00124	1
	TOTAL	804	.00001	365



W. 2 M.

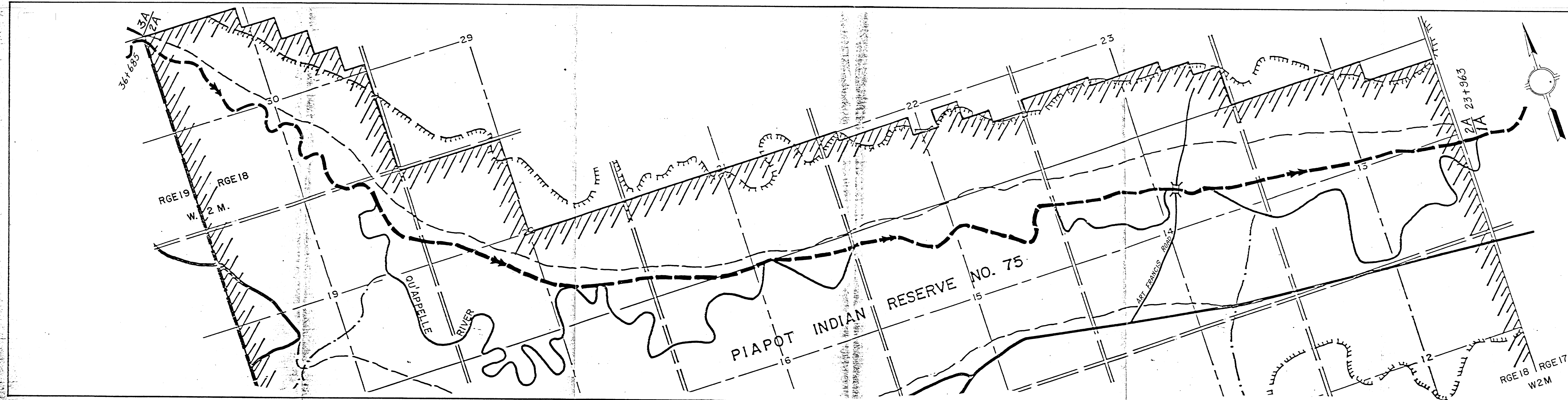
- LEGEND
- ROAD
 - INTERMITTENT STREAM
 - HIGHWAY
 - VALLEY EDGE
 - TOE OF SLOPE
 - INDIAN RESERVE BDRY.
 - RIVER
 - PROPOSED CHANNEL IMPROVEMENT

REFER TO PLAN NO. 801-P3-1093 SHEETS 1 to 8



KEY PLAN
QU'APPELLE RIVER DEVELOPMENT
E. BDRY PIAPOT I.R. TO PASQUA LAKE
SHOWING
PROPOSED CONSTRUCTION-DITCH 1A
TWP 21 RGE 16, 17 W2M

Submitted by:	DATE:	Designed by:	DATE:
J. F. MACIAG	FEB 85	J. F. MACIAG	FEB 85
Drawn by:	DATE:	Checked by:	DATE:
J. TAM	MARCH 85		
Recommended by:	DATE:	Approved by:	DATE:
Plan No. 801-P3-80		Sheet 2 of 5	



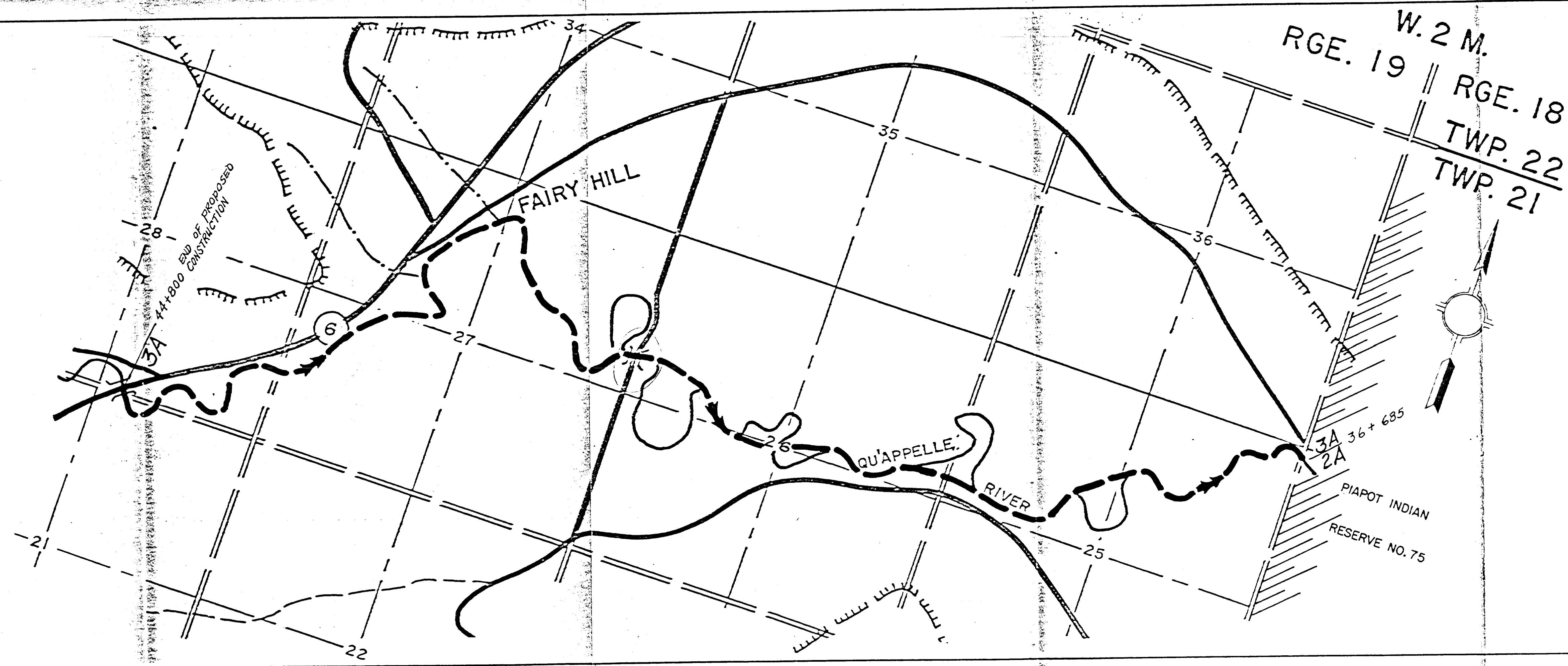
- LEGEND**
- ROAD ———
 - INTERMITTENT STREAM ———
 - HIGHWAY ———
 - VALLEY EDGE ———
 - TOE OF SLOPE ———
 - INDIAN RESERVE BDRY. ———
 - RIVER ———
 - PROPOSED CHANNEL IMPROVEMENT ———

REFER TO PLAN NO. 801-P3-1098 SHEETS 1 to 5



KEY PLAN
 QU'APPELLE RIVER DEVELOPMENT
 PIAPOT INDIAN RESERVE
 SHOWING
 PROPOSED CONSTRUCTION-DITCH 2A
 TWP 21 RGE 18 W2M

Submitted by:	DATE:	Designed by:	DATE:
J. F. MACIAG	FEB '85	J. F. MACIAG	FEB '85
Drawn by:	DATE:	Checked by:	DATE:
J. TAM	MARCH '85		
Recommended by:	DATE:	Approved by:	DATE:
Plan No. 801-P3-80			Sheet 3 of 5



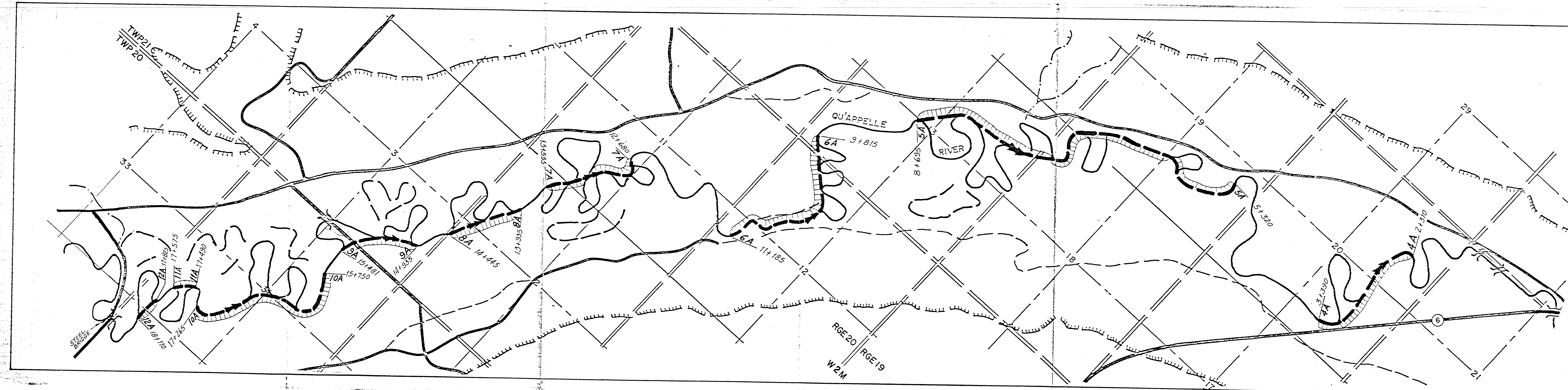
- LEGEND
- ROAD -----
 - INTERMITTENT STREAM -----
 - HIGHWAY -----
 - VALLEY EDGE -----
 - TOE OF SLOPE -----
 - INDIAN RESERVE BCRY. -----
 - RIVER -----
 - PROPOSED CHANNEL IMPROVEMENT -----

REFER TO PLAN NO. 801-P3-1099 SHEETS 1 of 3

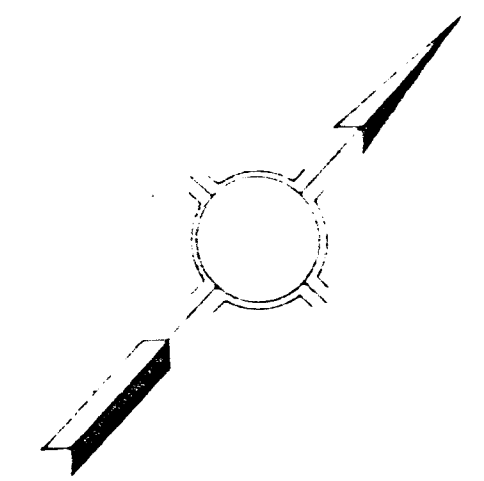


KEY PLAN
 QU'APPELLE RIVER DEVELOPMENT
 No 6 HWY TO WEST BORY. PIAPOT I.R.
 SHOWING
 PROPOSED CONSTRUCTION-DITCH 3A
 TWP 21 RGE 19 W2M

Submitted by:	Date:	Designed by:	Date:
J. F. MACIAG	FEB '85	J. F. MACIAG	FEB '85
Drewn by:	Date:	Checked by:	Date:
J. TAM	MARCH '85		
Recommended by:	Date:	Approved by:	Date:



- LEGEND
- ROAD -----
 - INTERMITTENT STREAM -----
 - HIGHWAY -----
 - VALLEY EDGE -----
 - TOE OF SLOPE -----
 - INDIAN RESERVE BDR. -----
 - RIVER -----
 - PROPOSED CHANNEL IMPROVEMENT -----
 - SPOIL PILES -----

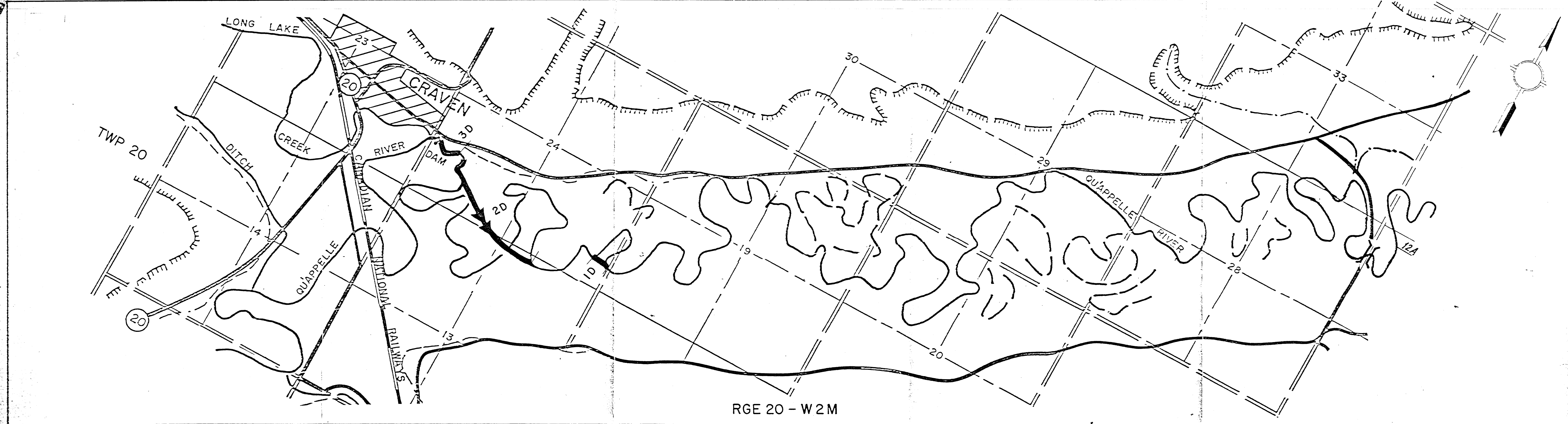


REFER TO PLAN NO. 801-P3-1100 SHEETS 1 OF 6



KEY PLAN
 QU'APPELLE RIVER DEVELOPMENT
 STEEL BRIDGE TO No. 6 HWY
 SHOWING
 PROPOSED CONSTRUCTION-DITCHES 4A-12A
 TWP 20,21 RGE19,20 W2M

Submitted by:	Date:	Designed by:	Date:
J. F. MACIAG	FEB 85	J. F. MACIAG	JAN 85
Drewn by:	Date:	Checked by:	Date:
TAM	MARCH 85		
Recommended by:	Date:	Approved by:	Date:



- LEGEND
- ROAD ————
 - INTERMITTENT STREAM ————
 - HIGHWAY ————
 - VALLEY EDGE ————
 - TOE OF SLOPE ————
 - INDIAN RESERVE BORY. ————
 - RIVER ————
 - PROPOSED CHANNEL IMPROVEMENT ————
 - AS CONSTRUCTED DITCH ————



KEY PLAN
 QU'APPELLE RIVER DEVELOPMENT
 CRAVEN TO STEEL BRIDGE
 SHOWING
 AS CONSTRUCTED DITCHES 1D TO 3D
 TWP 20 RGE 20, 21 W2M

Submitted by:	Date:	Designed by:	Date:
J. F. MACIAG	FEB '85	J. F. MACIAG	FEB '85
Drewn by:	Date:	Checked by:	Date:
J. TAM	MARCH '85		
Recommended by:	Date:	Approved by:	Date:

Plan No. 801-P3-80
 Sheet 1 of 5

FIGURE 1 (in 5 sections)

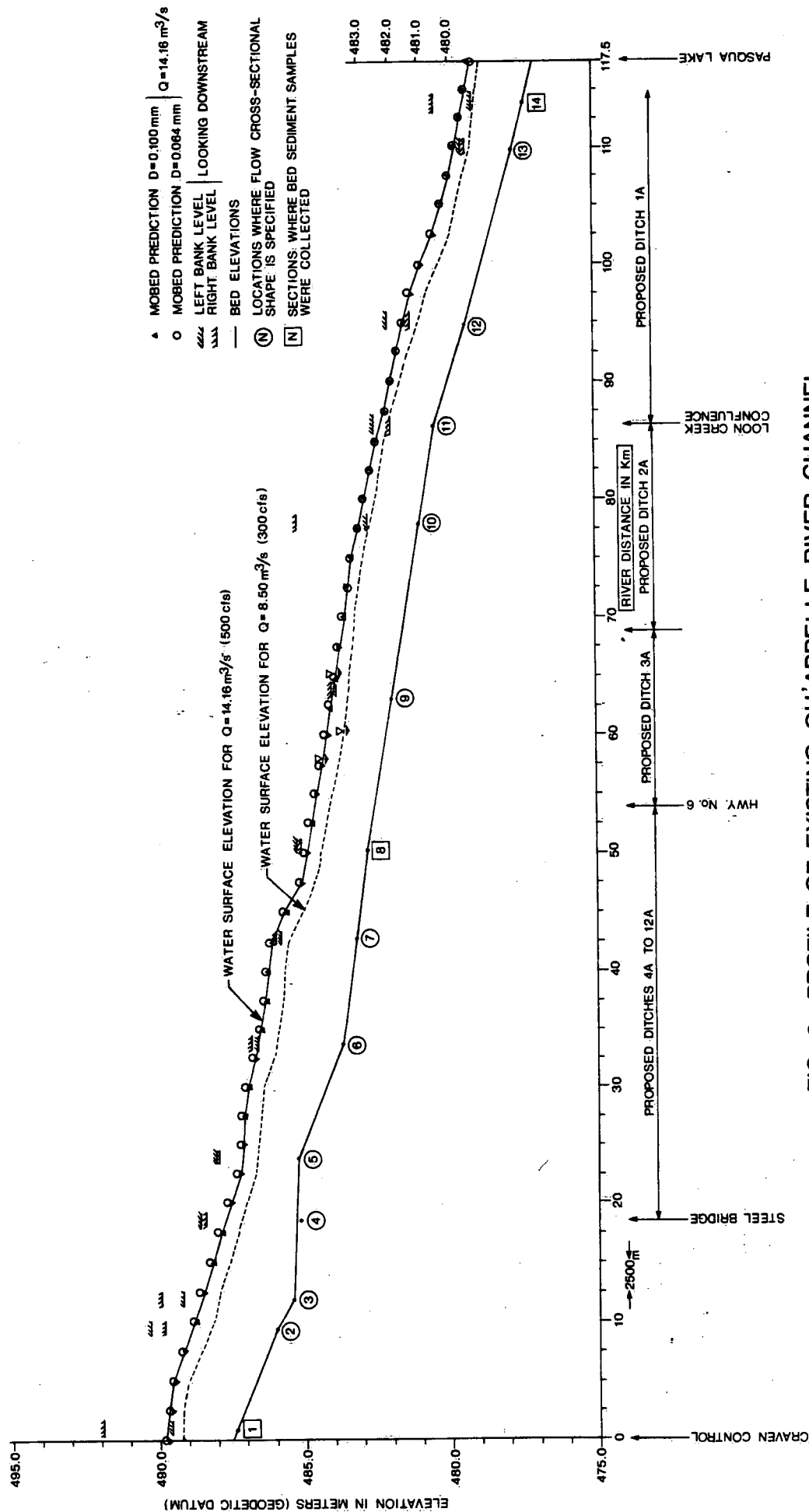


FIG. 2 PROFILE OF EXISTING QU'APPELLE RIVER CHANNEL
BETWEEN CRAVEN AND PASQUA LAKE

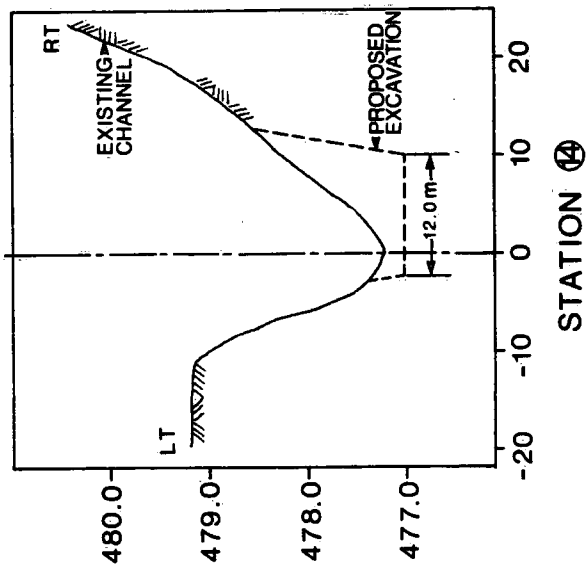
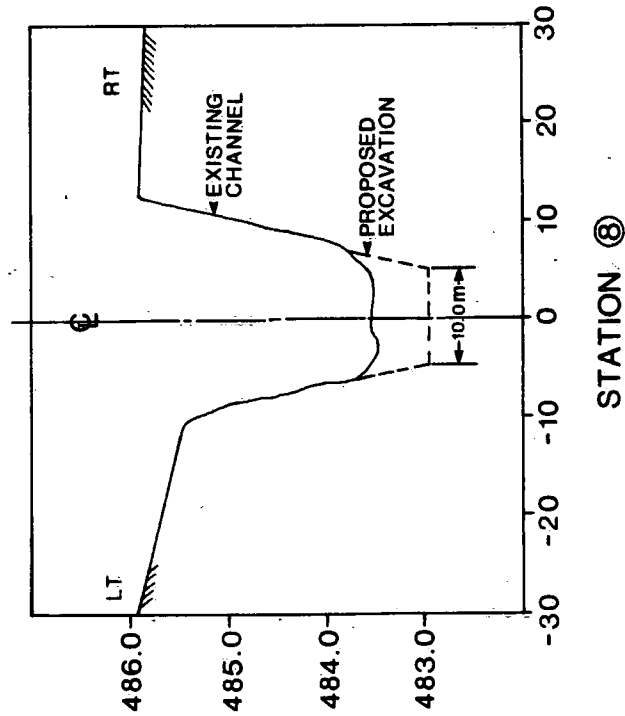
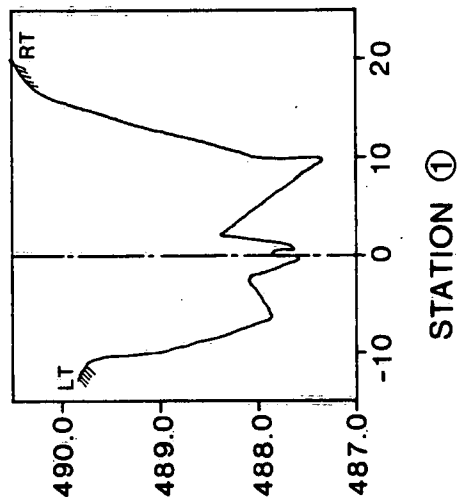


FIG. 3 TYPICAL CROSS-SECTIONAL SHAPES OF QU'APPELLE RIVER
BETWEEN CRAVEN AND PASQUA LAKE

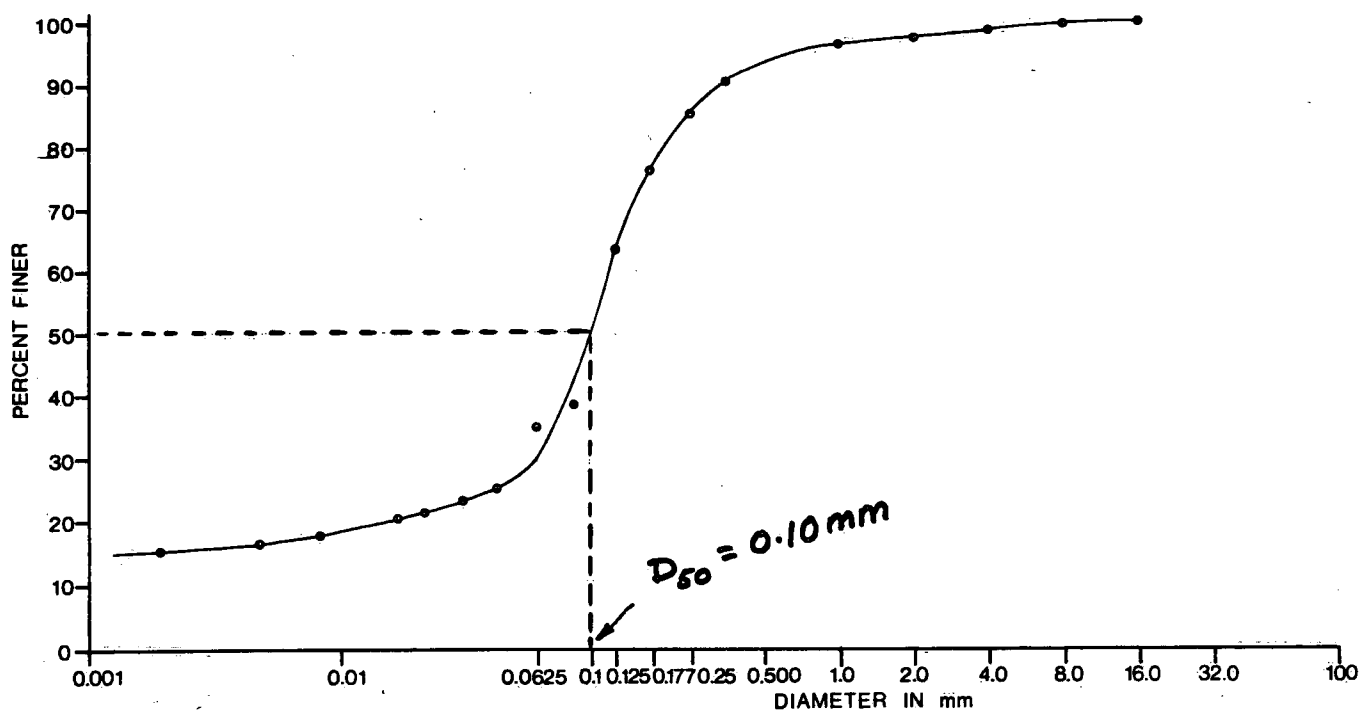


FIG. 4a BED SEDIMENT SIZE DISTRIBUTION AT CRAVEN (STATION 1)

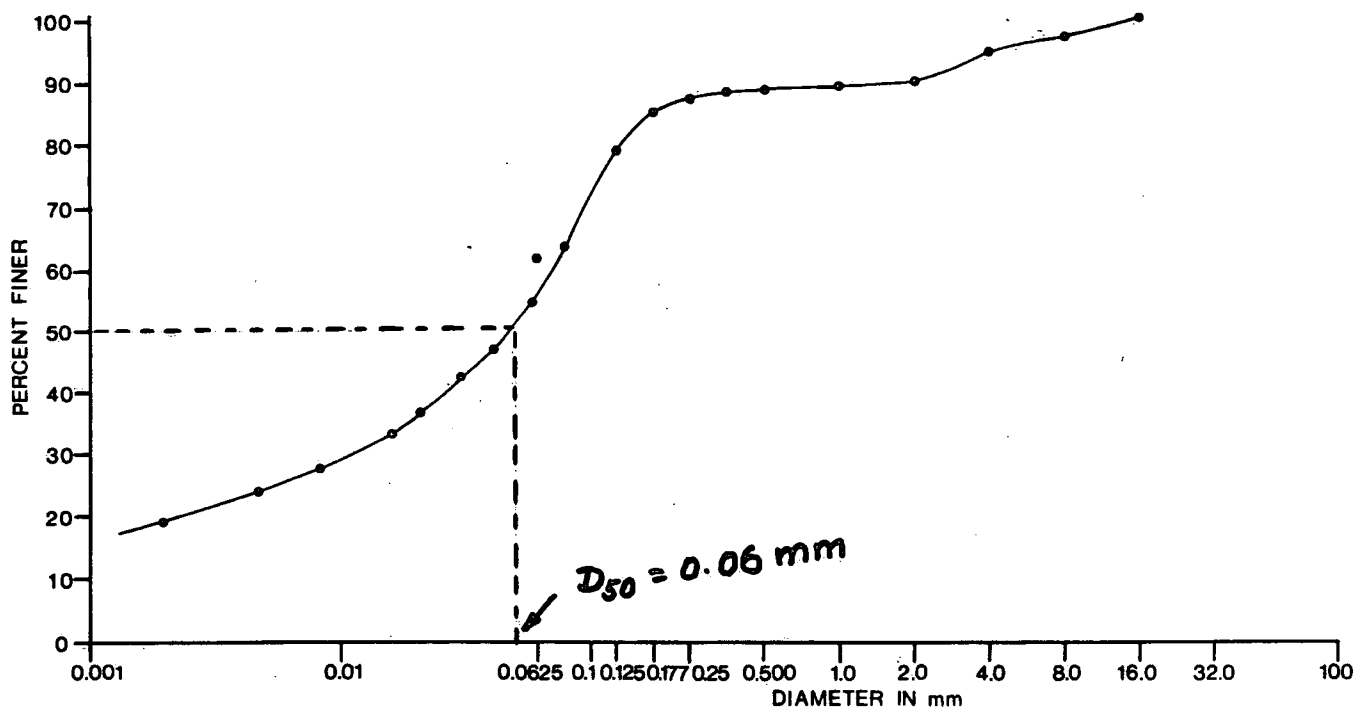


FIG. 4b BED SEDIMENT SIZE DISTRIBUTION NEAR PASQUA LAKE (STATION 14)

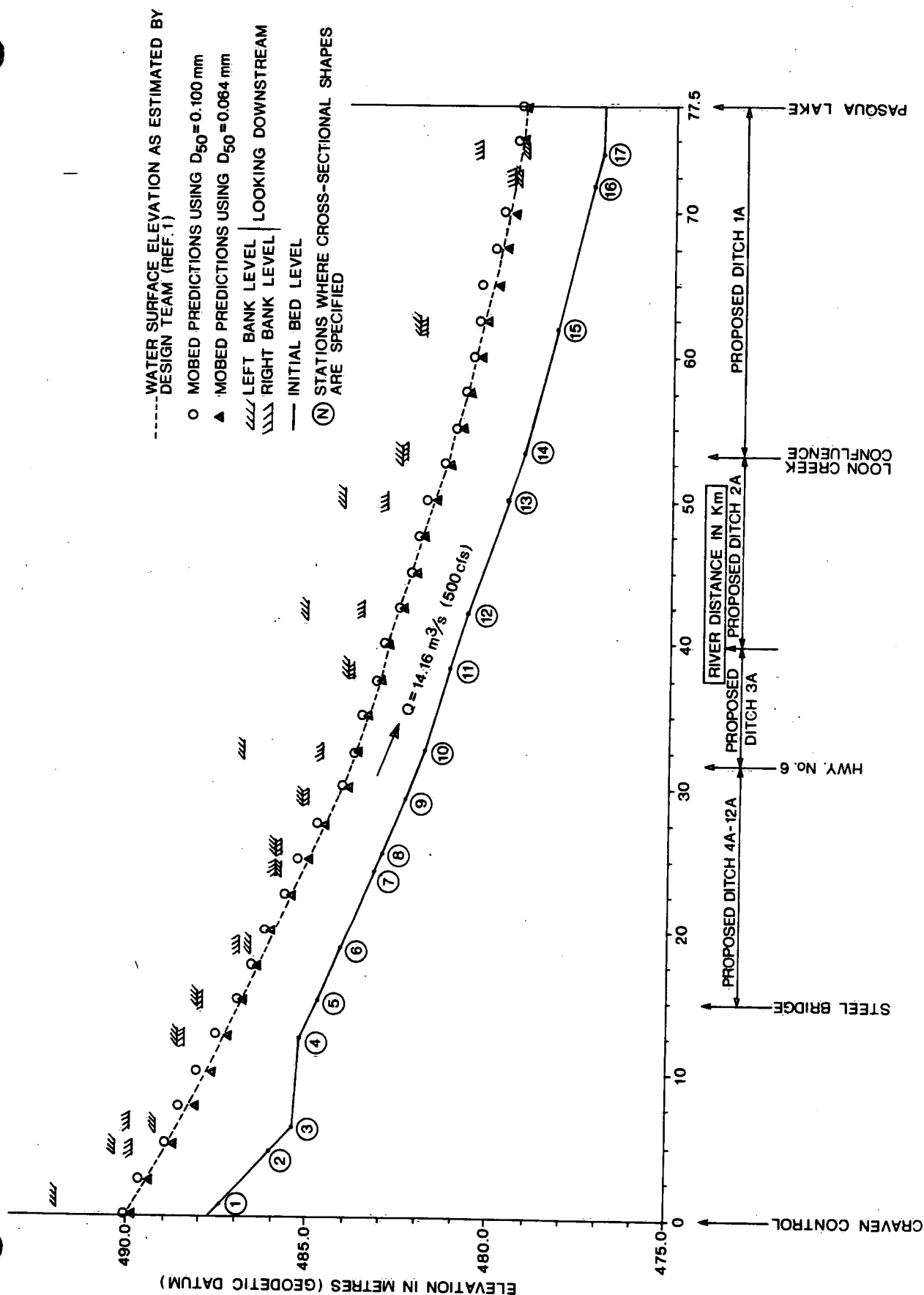


FIG. 5 PROFILE OF THE MODIFIED RIVER CHANNEL BETWEEN CRAVEN AND PASQUA LAKE

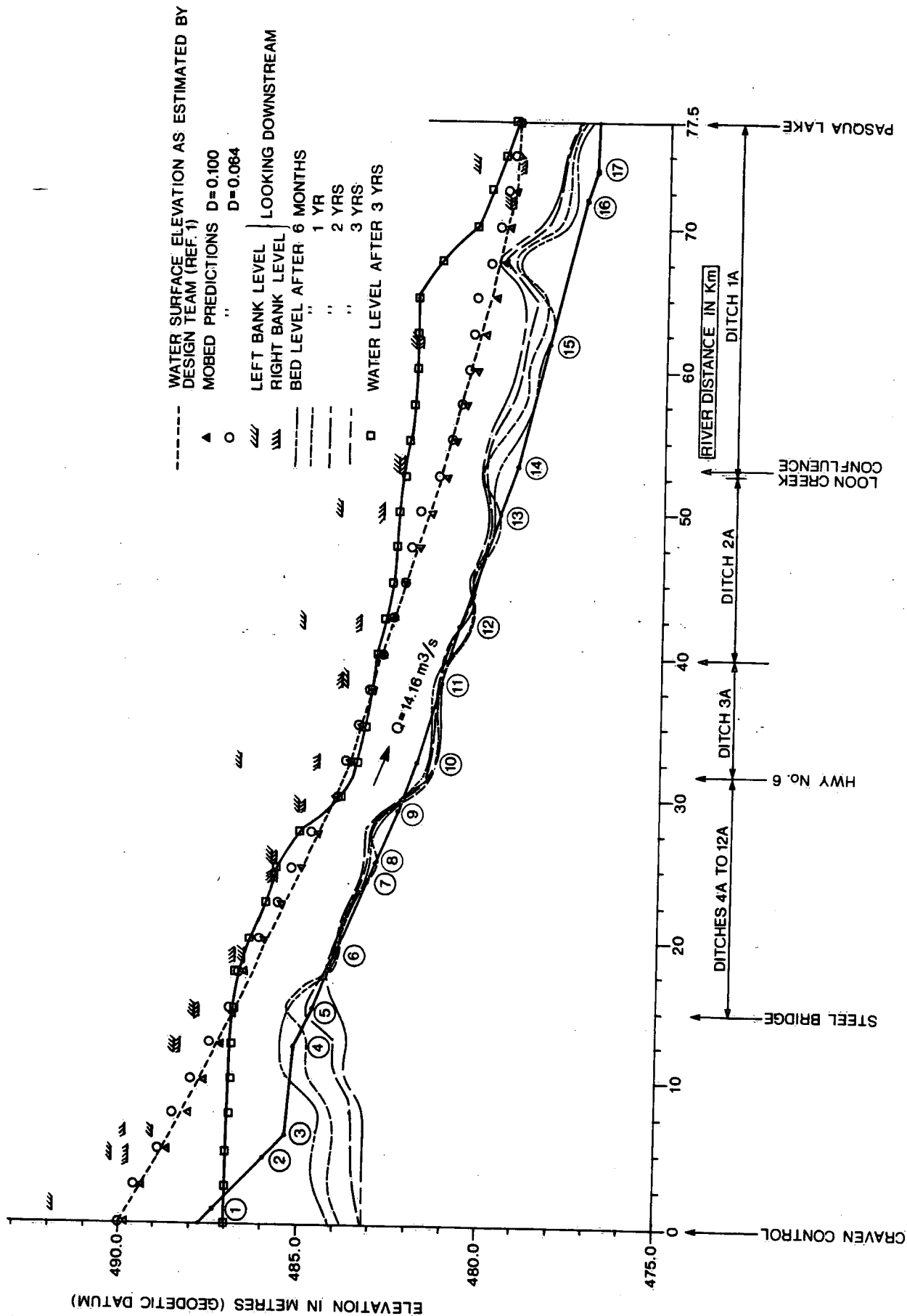


FIG. 6 VARIATION OF BED LEVELS AS PREDICTED BY MOBED FOR THE QU'APPELLE RIVER REACH BETWEEN CRAVEN AND PASQUA LAKE

QUAPPELLE RIVER NEAR CRAVEN

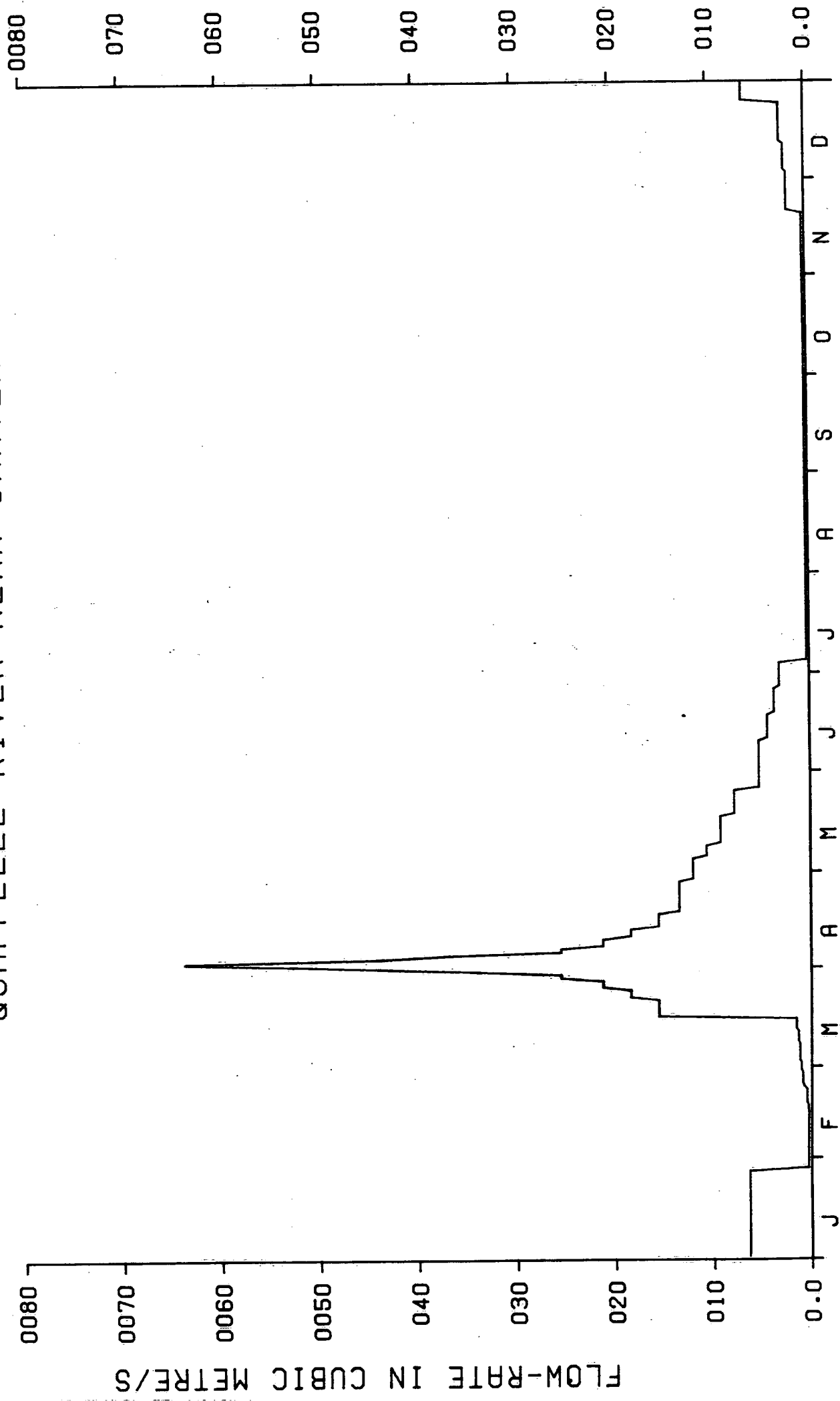


Fig. 7 Derived Hydrograph

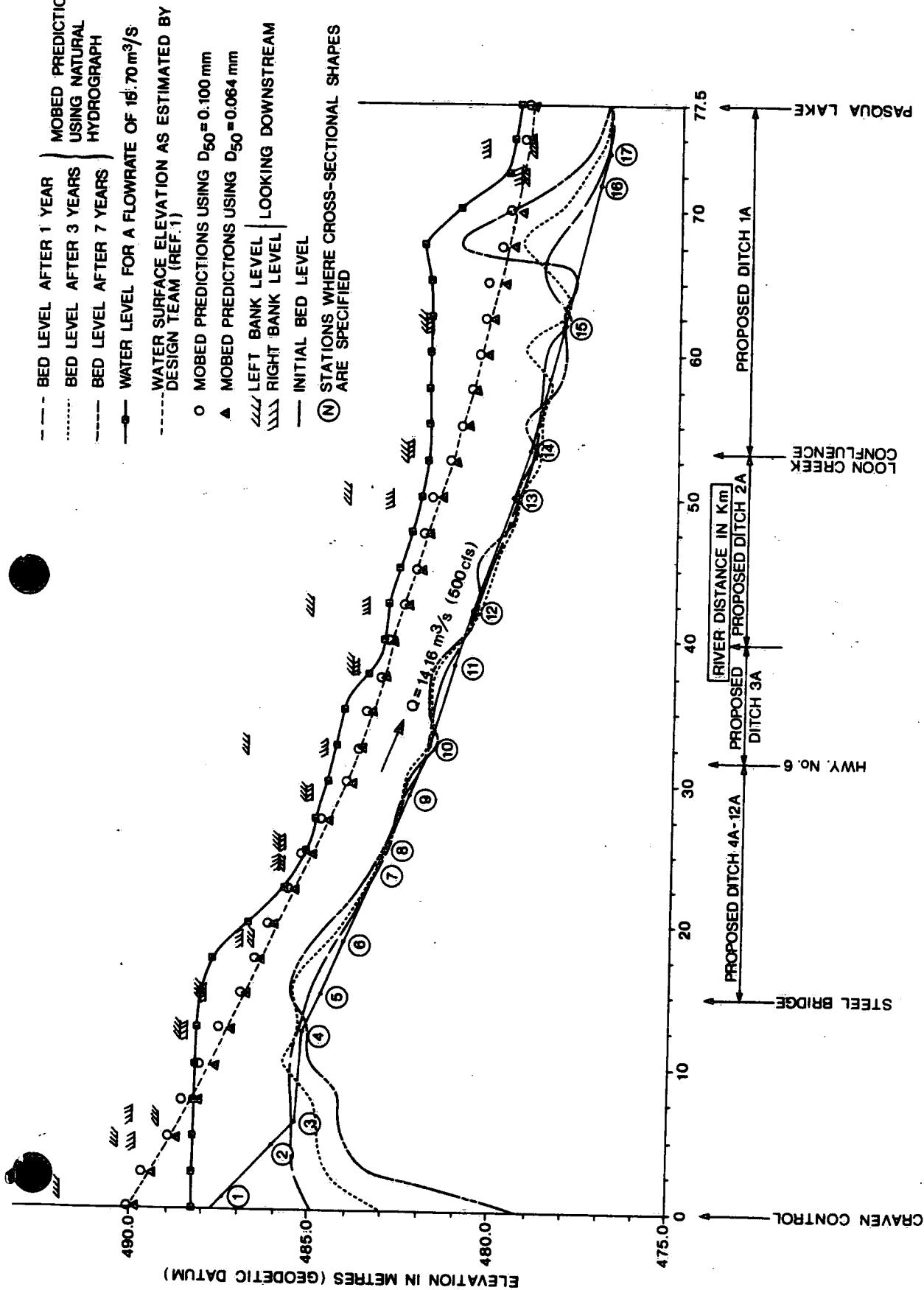


Fig. 8 Variation of bed levels as predicted by MOBED for the Qu'Appelle River between Craven and Pasqua Lake using natural hydrograph.