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MANITOBA DEPARTMENT OF AGRICULTURE AND CONSERVATION

Water Control and Conservation Branch

RED RIVER FLOODWAY

Outlet Control Works

MEMORANDUM ON PRELIMINARY DESIGN

H.G. ACRES & COMPANY LIMITED
Consulting Engineers
Niagara Falls, Canada

June 25, 1962

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MEMORANDUM ON PRELIMINARY DESIGN

1 - Introduction:

The Red River Floodway is designed to have a flatter gradient than the corresponding reach of the Red River. In consequence, a control structure is required at its lower end to maintain water levels in the channel, to dissipate the destructive kinetic energy of the falling water, and to achieve a smooth confluence of the channel and the river.

The control structure will consist of a low concrete rollway and a stilling basin contained between parallel, vertical training walls. A short transition channel upstream from the rollway and an exit channel connecting the stilling basin to the Red River complete the outlet control works.

The control works occupies a reach of about 1,800 feet between station -14+00 on the floodway centreline and the Red River. The confluence of the exit channel with the river will lie approximately one-half mile north of St. Andrews Dam.

2 - Hydraulic Conditions:

(a) - Design Requirements - The following are the basic requirements of the outlet control works design as defined by the Floodway Division:

(i) - The dissipation of destructive kinetic energy up to the design flood discharge of 60,000 cfs in the floodway channel is to be ensured.

(ii) - The control structure is to withstand a discharge of 100,000 cfs which may result either with the occurrence of 1,000-year flood or under other conditions of emergency operation of the floodway at lower flood frequencies.

(iii) - The flow conditions are to be those which may occur with all flood control works in operation. These include the Shellmouth Reservoir and Portage Diversion, in addition to the Red River Floodway. The range of flow conditions to be considered has been defined as those combinations of flows in the Red River and the Assiniboine River which will occur 90 per cent of the time.

(iv) - Provision has been made for conveyance of up to 100 cfs in a low flow pilot channel in the centre of the floodway, and conduits are to be provided through the outlet structure to pass this flow with a maximum headwater elevation of 726.2 at the beginning of the upstream transition channel. If the crest of the outlet structure is more than four feet above the channel grade, additional outlets are to be provided to prevent silt deposition against the structure.

The location of the structure is dictated by considerations of bank stability between the structure and the east bank of the Red River, and requires an exit channel about 1,100 feet in length connecting the structure with the river downstream from the stilling basin. It is considered that effective dissipation of the destructive kinetic energy created in dropping the water surface through the control structure will have been achieved if the flow immediately below the confluence with the Red River can be shown to be substantially unaltered from that which would occur under natural conditions.

(b) - Data - The Floodway Division has supplied a general arrangement and cross section of the proposed channel at its lower end. It has also provided correlation and rating curves to enable calculation of water levels and discharges under all possible conditions within the specified range, and has defined the downstream flow conditions in the Assiniboine River as influenced by operation of the Shellmouth Reservoir and Portage Diversion. Typical flow conditions and water surface elevations for selected floodway flows are given in Table 1.

TABLE 1

WATER LEVELS AND FLOWS FOR SELECTED FLOODWAY FLOWS

	Floodway Flows						
	10,000	30,000	50,000	60,000	80,000	80,000	100,000
Corresponding elevation at inlet	753.85	762.00	767.85	770.25	774.50	774.50	778.30
Elevation at inlet - natural conditions .	753.85	762.00	767.85	770.25	774.50	771.68	772.30
Increase above natural water level ...	0.0	0.0	0.0	0.0	0.0	2.82	6.00
Flow at Redwood - natural conditions							
Minimum Assiniboine contribution ..	50,000	81,500	123,400	165,000	267,000	198,000	212,000
Maximum Assiniboine contribution ..	60,500	90,300	130,600	172,500	273,000	206,600	221,000
Average Assiniboine contribution ...	55,500	86,700	127,400	169,000	270,000	202,000	217,000
Total flow at outlet - with all flood control works in operation							
Minimum Assiniboine contribution ..	44,000	69,200	102,800	137,000	239,300	167,200	179,600
Maximum Assiniboine contribution ..	37,900	61,400	98,800	145,200	250,300	182,200	197,300
Average Assiniboine contribution ...	41,000	65,700	98,000	137,000	246,200	173,800	190,000
Water level at floodway outlet - with all flood control works in operation							
Minimum Assiniboine contribution ..	724.18	728.72	733.48	737.92	751.80	742.28	744.02
Maximum Assiniboine contribution ..	722.72	727.43	732.96	739.10	753.16	744.41	746.48
Average Assiniboine contribution ...	723.50	728.17	732.84	737.96	752.63	743.20	745.45
Flow at Redwood Bridge - with all flood control works in operation							
Minimum Assiniboine contribution ..	34,000	39,200	52,800	77,000	159,300	87,200	79,600
Maximum Assiniboine contribution ..	27,900	31,400	48,800	85,200	170,300	102,200	97,300
Average Assiniboine contribution....	31,000	35,700	48,000	77,000	166,200	93,800	90,000
Elevation at Redwood Bridge - with all flood control works in operation							
Minimum Assiniboine contribution ..	-	-	745.82	751.60	-	754.21	753.36
Maximum Assiniboine contribution ..	-	-	744.90	753.33	-	756.91	756.80
Average Assiniboine contribution....	-	-	744.70	751.60	-	755.50*	755.50*

*Fixed safe elevation at Redwood Bridge with emergency dyking effective

3 - Preliminary Design:

(a) - Hydraulic Design - Before the details of the floodway channel were known, an interim design of the outlet structure was prepared so that hydraulic model testing could be started. A rollway 162-foot wide was selected, and a 135-foot long stilling basin lying between vertical and parallel training walls was proposed.

An approach channel 500-foot long was also provided to effect a smooth transition from the trapezoidal section of the floodway to the rectangular section at the entrance to the structure.

Preliminary model tests have been performed on the basis of this interim design and the following observations made:

(i) - The length of the stilling basin can be reduced from the theoretical 136 feet to about 120 feet.

(ii) - The stilling basin apron at elevation 707.5 feet is satisfactory.

(iii) - Wing walls upstream from the rollway, returned at 90 degrees to the centreline of the structure, provide satisfactory approach conditions. The upstream transition channel should be riprapped for about 400 feet upstream from the structure.

(iv) - Wing walls at the lower end of the stilling basin will not be required to prevent erosion adjacent to the training walls.

(v) - The downstream exit channel was tested for a number of different configurations.

> In no case was any scour evident on the west bank of the Red River; however, moderate to heavy scour would occur in the exit channel itself for most configurations at design flood discharge. A satisfactory configuration appears to be the continuation of the channel with bed width equal to the stilling basin width and side slopes of 6:1. Preliminary tests indicate that riprap slope protection would be required throughout the length of the channel up to about design flow tailwater elevation for the foregoing configuration.

More recent flow criteria and channel configuration received from the Floodway Division have been evaluated, and it has been determined that no substantial change in the interim hydraulic design of the structure would be required because of the minor variations introduced. Therefore, the results of the interim model test program are considered directly applicable to the preliminary design presented herein.

(b) - Foundations and Excavations - Foundation explorations have indicated that there are from 14 to 21 feet of silty clay overlying some 22 to 33 feet of till and gravels which are in contact with the limestone bedrock. The bedrock surface varies between elevation 707 and 712 in the immediate vicinity of the control structure and, in one hole near the riverbank along the channel centreline, the bedrock was encountered at elevation 705.

Samples recovered from the clay stratum consist of a heterogeneous mixture of light to dark brown dessicated silty clay with random silt pockets. Sands and gravels are also present in various proportions.

The till samples consist mainly of light brown silt with gravel up to 1-inch diameter. It should be noted, however, that the coarser gravel and boulders present were not recoverable in the sampling process. The clay content of the material is low as confirmed by tests.

Although average slopes of 6:1 were arbitrarily selected for the interim design to agree with the proposal for the floodway channel, it is believed that steeper slopes would be acceptable from the point of view of long-term stability. Therefore, in carrying out the detail design of the outlet works, attention will be given to the possible economies which might be realized by introducing steeper slopes. Average values of 2.5:1 have been assumed for temporary slopes during construction, but these will also receive further consideration before final designs are prepared.

Bedrock core recovered indicates that the rock is a massive limestone which, partly because of its nodular structure and partly through its differential hardness and texture, has been leached in its upper layers. The top 6 to 15 feet of core recovered from the exploratory holes exhibited varying degrees of leaching.

The design is such that a bedrock foundation for the entire concrete structure is assured. As is quite often the case, weathered materials occur at the bedrock surface and therefore it will be desirable to excavate to sound rock a few feet below. Consolidation of rock foundations beneath some parts of the structure may also be required.

Although clay layers and solution cavities are commonly encountered in limestone foundations, no evidence of these can be inferred from the exploratory drilling. The explorations performed were not extensive however, and it appears prudent to consider that such conditions may exist. As a part of the general construction contract, it is proposed to have shallow check holes put down when the foundation has been exposed, to confirm that clay seams and solution cavities do not exist in the upper rock strata. Should clay layers be encountered, a moderate increase in size of shear check would be required. Solution cavities would be excavated and filled with concrete.

(c) - Description of Structure - The hydraulic forces imposed by the maximum probable flow of 100,000 cfs are such that a mass concrete rollway with a key into bedrock is required to ensure stability. In the interim design for preliminary model tests, chute blocks were provided on the downstream face of the rollway to assist in forming and stabilizing the jump. Further model tests will be undertaken to determine whether the chute blocks may be omitted. Consideration must also be given to the problem of damage to chute blocks by ice floes.

Two conduits, 42 inches in diameter, are provided through the rollway to pass low flow discharges of up to 100 cfs with the pilot channel flowing full.

The floor of the stilling basin has been established from hydraulic considerations at elevation 707.5 and is thus at or just below the bedrock surface. A sectional reinforced concrete slab averaging five feet thick has been considered as a lining for the floor. Partial relief of uplift pressures is provided through the open joints of this slab.

To assist in stabilizing the location of the hydraulic jump, a sill is proposed at the downstream end of the stilling basin. This end sill also serves to deflect upward and assist in the dissipation of any high velocity jet travelling along the floor of the stilling basin.

Parallel training walls are proposed from upstream of the rollway to the lower end of the stilling basin. Opposite the rollway, these walls are raised to contain the abutting earthfill dykes which are of sufficient height to prevent overtopping under conditions of maximum probable discharge. Downstream from the rollway the walls are continued at a uniform height of 45.5 feet above the stilling basin floor, thus coinciding with the maximum tailwater level anticipated. This provides about 14 feet of freeboard over design flood tailwater elevation, but no freeboard during the maximum probable flood. As the downstream slopes of the dykes and exit channel sides will be riprapped, some reduction in freeboard might be considered under design flood conditions with consequent overtopping under more severe flows. Further model testing may demonstrate that savings may be realized in this manner.

For economy of section, the water faces of the training walls would be battered. However, hydraulic design considerations preclude adoption of this shape, and the training walls have therefore been designed with vertical water faces. Walls of the cantilever type have been introduced in the preliminary design, but further analyses of alternatives will be performed.

Excessive pressures on the walls may be avoided by placing free-draining backfill against the structure and, therefore, those portions of the connecting dykes near the structure may require the importation of granular borrow material. Elsewhere, all possible use will be made of the excavated clays and till for backfill and dyke construction

Upstream wing walls are proposed at 90 degrees to the centreline of the structure to contain the upstream slope of the dykes. They are maintained above the design flow headwater level to minimize contraction losses at the entrance to the structure.

Downstream wing walls are not required from hydraulic considerations. However, short wing walls returned at 90 degrees have been introduced to contain a rockfill section at the toe of the dykes.

(d) - Summary - The following is a summary of the more important features of the outlet control works as proposed in the preliminary design:

Rollway width	162 feet
Rollway crest level	Elevation 730.0
Stilling basin width	162 feet
Stilling basin length	120 feet
Stilling basin floor level	Elevation 707.5
End sill crest level	Elevation 716.5
Upstream transition channel length	513 feet
Downstream exit channel length ..	1,100 feet
Overall length of control structure	195 feet
Design flow	60,000 cfs
Maximum probable flow (1,000-year flood or emergency operation)	100,000 cfs
Headwater level	
At 60,000 cfs	Elevation 752.2
At 100,000 cfs	Elevation 762.0

Tailwater level

At 60,000 cfs	Elevation 737.92 to 739.10
At 100,000 cfs	Elevation 744.02 to 753.16

4 - Estimate of Cost:

A brief schedule of quantities and costs is presented in Appendix A. The preliminary estimate of cost for the outlet control works is approximately $2,775,000. This amount covers construction costs plus 10 per cent contingencies, but does not include indirect items such as interest during construction, administration and insurance, engineering, and property acquisition.

It should be noted that the estimate includes the cost of nearly 1,800 feet of channel as well as that of the control structure.

5 - Proposed Construction Schedule:

With construction of the outlet control works commencing in April of 1963, it is anticipated that the work can be completed by the end of that year. A preliminary proposal as to the scheduling of construction is shown in Appendix B.

6 - Requirements for Final Design:

Before proceeding with final design of the outlet control works, it will be necessary to obtain confirmation from the Floodway Division of the design criteria and data with respect to:

(a) - The floodway channel design upstream from the control works.

(b) - The low flow discharge requirement for the outlet structure.

(c) - The effect of the Shellmouth Reservoir and Portage Diversion flood control operation on downstream flow conditions.

(d) - Rating and correlation curves required to develop water levels at the inlet and outlet sites.

(e) - Operating rules for the inlet as they may affect downstream flow conditions including emergency operation for flows in excess of the design flood.

APPENDIX A

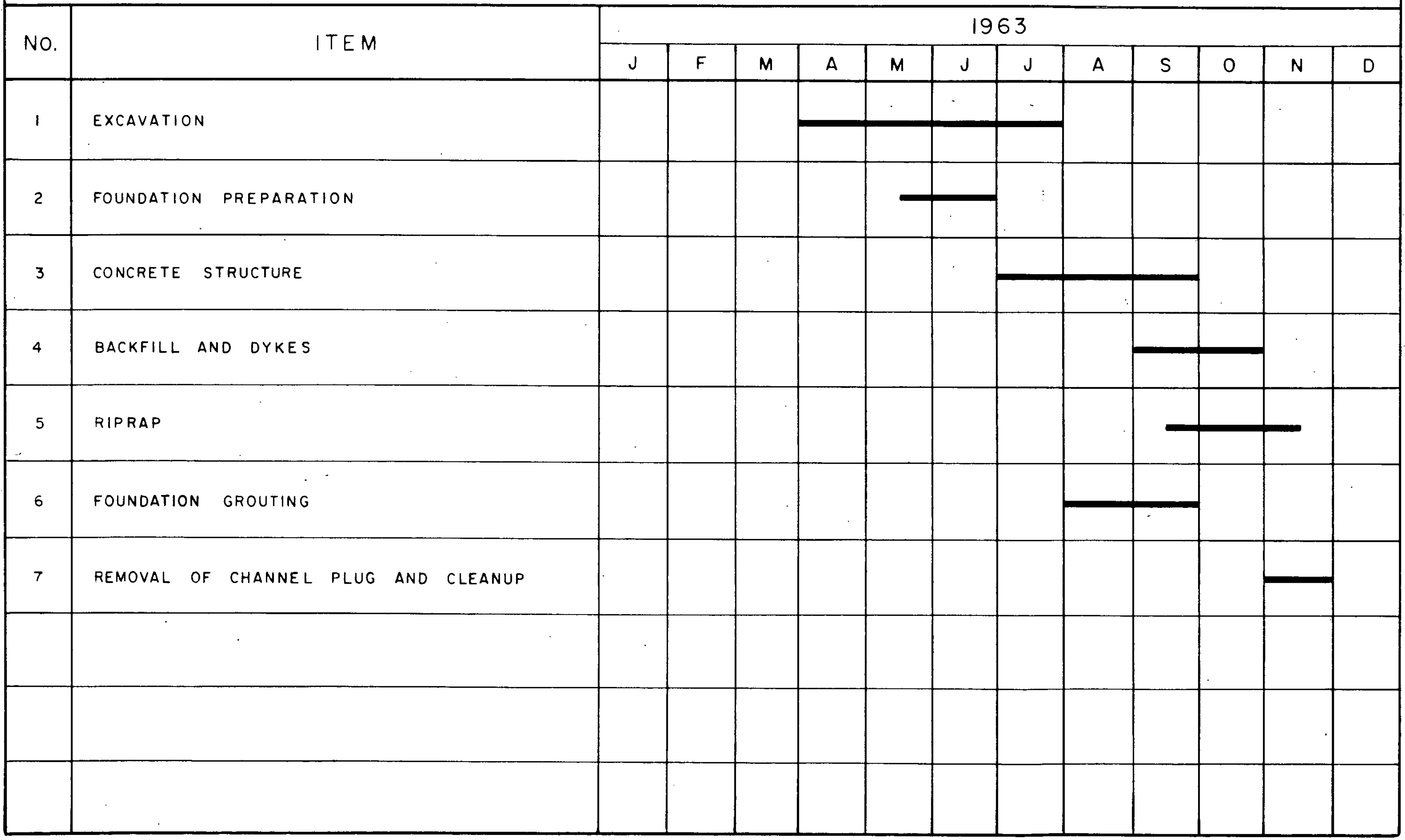
RED RIVER FLOODWAY

Outlet Control Works

PRELIMINARY ESTIMATE OF COST

Item	Quantity	Unit	Unit Cost	Amount
1 - Excavation				
Rock	10,000	C.y.	$ 3.00	$ 30,000
Clay	650,000	C.y.	.30	195,000
Till	530,000	C.y.	1.25	662,500
Subaqueous	11,000	C.y.	5.00	55,000
2 - Dewatering	-	-	Sum	30,000
3 - Foundation Preparation, including grouting	-	-	Sum	100,000
4 - Concrete, including cement				
Mass	13,000	C.y.	25.00	325,000
Reinforced	8,000	C.y.	29.00	232,000
5 - Formwork				
Straight	70,000	S.f.	2.00	140,000
Curved	12,000	S.f.	4.00	48,000
6 - Steel Reinforcement	1,100,000	Lb	.15	165,000
7 - Dykes and Backfill				
Till	40,000	C.y.	.75	30,000
Gravel	70,000	C.y.	2.25	157,500
Rock	6,000	C.y.	1.00	6,000
8 - Transition and Filters	40,000	C.y.	2.25	90,000
9 - Riprap	51,000	C.y.	5.00	255,000
Subtotal SPOIL - 1,151,000 cy				$2,521,000
Contingencies				252,000
TOTAL				$2,773,000

RED RIVER FLOODWAY
OUTLET CONTROL WORKS
PROPOSED CONSTRUCTION SCHEDULE




RED RIVER
EXISTING PROPERTY LINE
PI 'A'
STA. 0 + STA. 95 + 06.2
PI 'B'
STA. 6 + 13.6
PI 'C'
STA. 17 + 92.2
PI 'D'
STA. 26 + 54.8
PI 'J'
STA. 78 + 58.4
BOTTOM OF DOWNSTREAM CHANNEL EXCAVATED TO ROCK
RIPRAP ON ALL DOWNSTREAM CHANNEL SURFACES (EXCEPT BOTTOM) UP TO ELEVATION 740'
ASSUMED ROCK CONTOURS
STILLING BASIN EL. 707.5'
CREST EL. 730'
SLOPE TRANSITION
RIPRAP ON ALL CHANNEL SURFACES UP TO ELEVATION 765'
START OF TRANSITION
DYKE EL. 765'
SPOIL DISPOSAL AREA
EL. 775'
EL. 765'
EL. 753'
EL. 755'
EL. 756'
EL. 757'
EL. 758'
EL. 754'
EL. 727.2'
EL. 722.6'
EL. 729.5'
SECTION A-A
SCALE : 1" = 50'
195'
EL. 766'0'
TOP OF TRAINING WALL EL. 753'
CREST OF ROLLWAY EL. 730'
TOP OF END RETAINING WALL EL. 723'
PILOT CHANNEL
FILL
TOP OF STILLING BASIN SLAB, EL. 707.5'
TOP OF END SILL EL. 716.5'
EL. 708'
SECTION B-B
SCALE : 1" = 50'
162'
TOP OF DYKE EL. 765'
TOP OF RETAINING WALL EL. 766'
TOP OF TRAINING WALL EL. 753'
CREST OF ROLLWAY EL. 730'
RIPRAP
CHUTE BLOCKS
CLAY
TILL
FILL
2 LOW FLOW CONDUITS 3.5' DIAMETER
TOP OF STILLING BASIN SLAB EL. 707.5'
DATE
No.
REVISIONS
APP.
CH.
DRAWN
CHECKED
APPROVALS
ARCHITECTURAL
CIVIL
CONSTRUCTION
ELECTRICAL
GEOLOGY
HYDRAULIC
MECHANICAL
APPLIED MECHANICS
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PROVINCE OF MANITOBA
DEPARTMENT OF AGRICULTURE AND CONSERVATION
WATER CONTROL AND CONSERVATION BRANCH
RED RIVER FLOODWAY
OUTLET CONTROL WORKS
GENERAL ARRANGEMENT
MATERIAL LIST No.
INDEX No.
DATE JUNE 22, 1962
SCALE 1 INCH = 100 FEET (EXCEPT AS NOTED)
DRAWING No. SK-940-C-82
SHEET OF
REV.

January 19, 1962

Wolcock

RED RIVER FLOODWAY

Outlet Control Works

PRELIMINARY QUANTITY AND COST CALCULATIONS

Item	Quantity	Unit	Unit Cost	Amount
1 - Excavation				
A - Structure				
(a) - Rock	29,700	C.y.	$ 3.00	$ 89,100
(b) - Till	114,600	C.y.	1.25	143,250
(c) - Clay	178,000	C.y.	0.30	53,400
B - Transitions				
(a) - Rock	600	C.y.	3.00	1,800
(b) - Till	87,400	C.y.	1.25	109,250
(c) - Clay	127,000	C.y.	0.30	38,100
C - Downstream Channel				
(a) - Rock	3,000	C.y.	3.00	9,000
(b) - Till in the dry	296,600	C.y.	1.25	370,750
(c) - Till in the wet	7,000	C.y.	5.00	35,000
(d) - Clay in the dry	354,300	C.y.	0.30	106,290
2 - Rock Anchors				
(a) - Drilling	11,500	L.f.	1.00	11,500
(b) - Supply, grouting, etc. ...	46,200	Lb	0.50	23,100
3 - Concrete (Cement Included)				
(a) - Mass	27,000	C.y.	25.00	675,000
(b) - Reinforced	3,100	C.y.	25.00	77,500
4 - Reinforcing Steel				
(a) - Supply	200,000	Lb	0.10	20,000
(b) - Handling and placing	200,000	Lb	0.05	10,000

Preliminary Quantity
and Cost Calculations - 2

Item	Quantity	Unit	Unit Cost	Amount
5 - Formwork				
(a) - Curved	8,000	S.f.	$ 4.00	$ 32,000
(b) - Flat	110,000	S.f.	2.00	220,000
6 - Backfill				
Sand and gravel (imported	157,800	C.y.	2.20	347,160
7 - Riprap				
Placed	56,000	C.y.	6.00	336,000
8 - Dewatering	-	-	Sum	30,000
Total				$2,738,200
Estimate				$3,000,000