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ORIGINAL

# SUMAS RIVER DYKING PROPOSAL

# BENEFIT STUDY

REPORT TO THE

FRASER RIVER JOINT PROGRAM COMMITTEE

R. Princic

Planning Division

Water Planning and Management Branch

June, 1972

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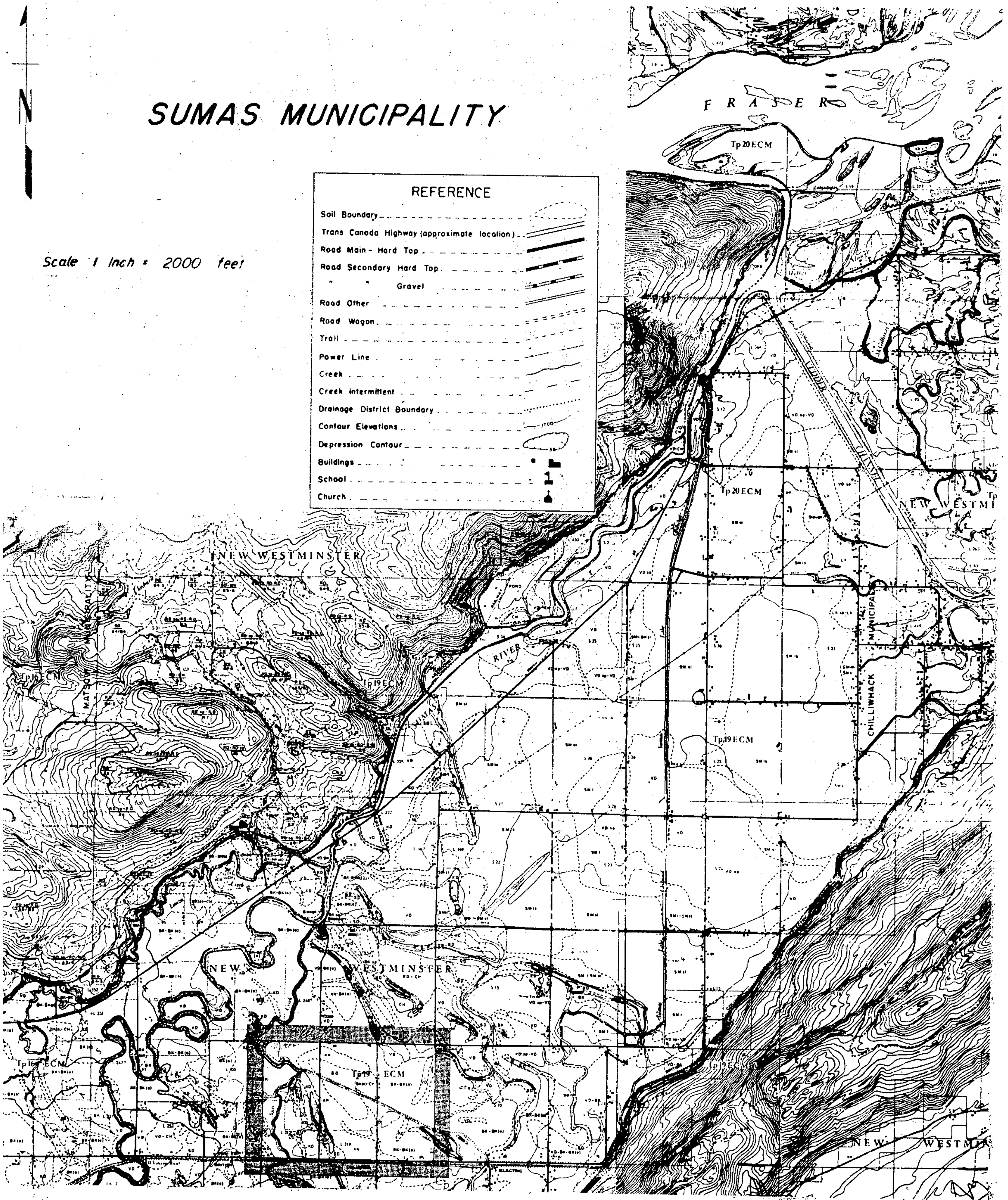
# SUMAS MUNICIPALITY

*Scale 1 inch = 2000 feet*



## SUMMARY

## FEASIBILITY STUDY
## FLOOD PROTECTION BENEFITS SUMAS RIVER AREA

### A) OBJECTIVE

To evaluate the Sumas River dyke rehabilitation costs and the associated benefitting area to determine the benefit-cost ratio.

### B) SCOPE

The benefit study is limited to the sector bounded by the Sumas River, the Vedder Canal and the Vedder Mountain.

### C) DYKING PROPOSAL

The existing dyke alignment is to be retained, however, two alternative levels of protection are to be examined.

Alternative (i) Protection to the 1935 flood level-existing outlet conditions
(ii) Protection to the 1951 " " -existing outlet conditions
or Protection " 1935 " " -Improved outlet conditions
(iii) Protection to the 1951 " " -Improved outlet conditions

### D) ASSUMPTIONS

(1) The economic life of the dyke is 35 years.

(2) The discount rate is 7%.

(3) Sumas is primarily agricultural; no change in landuse is anticipated.

### E) RESULTS OF STUDY

Table (1) shows the benefits, costs and B/C ratio for the Sumas flood protection scheme.

TABLE (1)

BENEFIT-COST RELATIONSHIP FOR SUMAS DYKING PROPOSAL

| Level of Protection | Benefits * | Costs ** | B/C Ratio *** |
|---|---|---|---|
| a) Protection to 1935 Flood<br>Existing outlet conditions | | | |
| Alternative (1) | $2,284,000 | $2,166,000 | 1.1 |
| (2) | 2,284,000 | 2,068,000 | 1.1 |
| (3) | 2,284,000 | 1,819,000 | 1.3 |
| b) Protection to 1951 Flood<br>with Existing outlet conditions<br>or Protection to 1935 Flood<br>with Improved outlet conditions | | | |
| Alternative (1) | $2,223,000 | $1,658,000 | 1.3 |
| (2) | 2,223,000 | 1,572,000 | 1.4 |
| (3) | 2,223,000 | 1,484,000 | 1.5 |
| c) Protection to 1951 Flood<br>Improved outlet conditions | | | |
| Alternative (3) | $1,481,000 | $1,150,000 | 1.3 |

* Rate of discount 7% - Economic life of dyke 35 years.

** Includes annual maintenance and bank protection.

*** For B/C ratios using other discount rates (6% and 8%) see Appendix (2).

## Feasibility Study

## Flood Protection Benefits Sumas River Area

### A) OBJECTIVE

To evaluate the Sumas River dyke rehabilitation costs and the associated benefitting area and determine the benefit-cost ratio.

### B) SCOPE

The benefit study is limited to the sector bounded by the Sumas River, the Vedder Canal and the Vedder mountain.

The benefits and engineering costs are to be based on protection against flooding of the Sumas River and not by flooding from the Vedder and Fraser Rivers.

### C) DYKING PROPOSAL

The existing dyke alignment is to be retained. The alternative levels of protection to be examined are as follows:

| Level of Protection | Outlet Condition | Design Section |
|---|---|---|
| (1) Protection to 1935 flood | Existing | Alternative (1) |
| " " " | " | Alternative (2) |
| " " " | " | Alternative (3) |
| (11) Protection to 1951 flood or " 1935 " | Existing<br>Improved | Alternative (1) |
| Protection to 1951 flood or " 1935 " | Existing<br>Improved | Alternative (2) |
| Protection to 1951 flood or " 1935 " | Existing<br>Improved | Alternative (3) |
| (111) Protection to 1951 flood | Improved | Alternative (3) |

D) ASSUMPTIONS

(1) The economic life of the proposed dyking scheme is assumed to be 35 years.

(2) The discount rate selected for use in the body of the report is 7%. Appendix (2) is provided to show the effects of other discount rates (6% and 8%) on benefits and the B/C ratios.

(3) The entire area of Sumas is zoned agricultural. Industrial development within the basin area is not anticipated.

E) DEPTH AND EXTENT OF FLOOD

Data on flood frequency, elevations, and duration of flooding has been provided by the Engineering Division. (See Appendix 6).

F) ANALYSIS OF FLOOD DAMAGE POTENTIAL-DAMAGE CRITERIA

(1) Agricultural Damage and Income Loss

(a) Crop Damage

Flooding of the Sumas Basin can be expected to occur at any time between October and February. Agricultural activity at this time of year is at the lowest possible level.

Since annual crops are planted long after flood waters have receded and are normally harvested before flooding occurs, no direct damage is expected to these crops. The only crop damage likely to occur is to perennial plants as a result of standing water. Pasture, hay and legume fodder species, raspberries and one large nursery are the only crops of any significance which would suffer damage from winter flooding in Sumas.

Any extended period of soil saturation would require the pasture, hay and legume crops to be plowed under and reseeded. Other perennial crops, small fruit and nurseries, destroyed by high water would have to be re-established. Appendix (4) provides an estimate of the weighted per acre damage (not including the nursery) for the agricultural land in Sumas.

Perennial species are able to tolerate some degree of flooding without suffering severe damage. Beyond some maximum tolerable period, however, measurable damage is likely to occur. The amount of damage is expected to increase with the duration of flooding until at some point there is complete loss. Damage to perennial crops as a result of surface flooding is estimated as follows (B.C. Department of Agriculture, Cloverdale):

| Duration of Flooding | % of Crop Damage |
|---|---|
| 0-5 days | 0 |
| 6-10 days | 20% |
| 11-18 days | 50% |
| 19 days and over | 100% |

The nursery at Sumas could be flooded by water of the 1935 and 1951 flood levels. Surface water lasting 29 days (1935 flood) and 11 days (1951 flood) is expected to cause 100% and 50% damage for each of the respective flood levels. The estimate damage for the 80 acre nursery is $275,000 if flooded by a 1935 level flood and $137,000 if flooded by a 1951 flood level (B.C. Department of Agriculture, Cloverdale).

An estimate of agricultural crop damage including the acreage flooded for each flood level is shown in Appendix 5 (a).

(b) Milk Losses

It is assumed that sufficient warning would be given to evacuate all milk cows from the flooded area.

The disruption caused by the evacuation along with the associated crowding and lack of facilities is likely to cause considerable loss in production. It is assumed that milk cows would not produce during the period of evacuation. In addition it is felt that one full month of production would be lost because of the disruption (B.C. Department of Agriculture, Dairy Division).

Average daily production per milk cow in the Fraser Valley is now estimated to be 33 pounds per day (annual production per milk cow in the Fraser Valley in 1971 was 1200 pounds).

The duration of flooding is based on the hydrographs provided by the Engineering Division. (Appendix 6). The weighted average duration of flooding and the length of evacuation of the various floods is estimated to be:

| | Existing Conditions | | Improved Conditions | |
|---|---|---|---|---|
| Flood Level | Duration | Evacuation | Duration | Evacuation |
| 1935 | 38 | 68 | 8 | 38 |
| 1951 | 19 | 49 | 5 | 35 |
| 1954 | 9 | 39 | | |
| 1955 | 4 | 34 | | |

The weighted average price of bulk milk in the Fraser Valley in 1971 was reported to be $6.10 per hundredweight (B.C. Milk Board).

The total number of dairy cows forced to evacuate because of flooding and the expected loss in milk production is estimated for each flood level in Appendix 5 (b).

(c) Extra Feed Cost

Flooding in Sumas would result in losses of stored feed and would cause delays in the production of feed and forage crops in spring. It is estimated that perhaps 2 tons of hay equivalents would be required to provide cows with sufficient nourishment to see them through until the first hay production.

Because of feed scarcity during the winter period it is estimated that extra cost for feed could be up about $15 per ton.

For an estimate of extra cost for feed see Appendix 5 (c).

(d) Hog Production

B.C. Department of Agriculture officials felt that hogs would be off their feed during and after each move, but would not lose continuously during the entire evacuation. It was estimated that hogs would lose 17 lbs. during the evacuation and return journey (1963 Benefit Study).

Meat from top grade hogs was worth about 30 cents per pound in 1971 (Canada, Department of Agriculture, Livestock Division). Total number of hogs forced to evacuate and the expected monetary loss at each flood level is estimated in Appendix 5 (d).

(e) Poultry - Egg Production

Egg producers in Sumas are located near the fringe of the maximum floodable area. Only floods of the 1935 and 1951 levels are expected to cause serious damage.

It is estimated that about 6 months of production would be lost by a 1935 level flood and 4 months of production by a flood of the 1951 level.

The 1971 average price of eggs in the Lower Mainland area was $9.50 per case (B.C. Egg Marketing Board).

Total egg production and expected income loss for each flood is estimated in Appendix 5 (e).

(f) Poultry - Broiler and Fryer Production

Broiler producers in Sumas are located near the fringe of the area floodable by a maximum expected flood. Only floods of the 1935 and 1951 levels are expected to cause serious damage.

Between 2 and 3 weeks of production is expected to be lost in addition to the flood duration. It is estimated that about 7 and 5 weeks of production would be lost by each of the 1935 and 1951 flood levels respectively.

Officials with the B.C. Department of Agriculture felt that 2/3 of the production of broilers and fryers would be lost as a result of a flood (1963 Benefit Study). The other 1/3 represents a partial recovery (birds over 5 weeks old were considered salvable). Average price of live broilers and fryers is 22.5 cents per pound or about 85 cents per bird (B.C. Broilers and Fryers Marketing Board).

Loss of production and income loss expected at each flood is estimated in Appendix 5 (f).

(2) Damage to Milking Equipment

Damage to milking equipment is estimated to be $20 per milk cow. This figure represents an updating of the $15 used in the 1963 report.

An estimate of damages to milking equipment, for each flood is provided in Appendix 5 (g).

(3) Damage to Barns and Outbuildings

Damage to barns and outbuildings was estimated to be $100 and $25 respectively (1963 Benefit Study).

Since 1961 costs of construction and materials have increased by some 5% annually (Central Mortgage and Housing Corporation, "Canadian Housing Statistics", Composite Index of Construction Costs). On this basis it is estimated that costs of repairs to barns and outbuildings have increased by 50%. The updated damage (cost of repairs) to barns and outbuildings in 1971 is estimated to be $150 and $40 respectively.

An indication of the number of barns and outbuildings inundated at each flood level and the subsequent monetary damage is provided in Appendix 1 (a).

(4) Damage to Houses

Damage to houses is estimated from field survey carried out during the summer of 1971. Houses in the Sumas area are considered to suffer the following structural and content damage.

| Level of Flooding Above Ground Level | Damage per House (Structure and Content) |
|---|---|
| 1' | $1,700. |
| 2' | 3,900. |
| 3' | 5,000. |
| 4' | 6,700. |
| 5' | 7,600. |
| 6' | 8,100. |
| 7' | 8,900. |
| 8' | 9,100. |
| 9' | 9,500. |
| 10' | 9,500. |
| + 10' | 14,800. |

The number of houses flooded in Sumas ranges from 13 at the lowest flood to 214 at the highest. Appendices 1 (b) - 1 (g) indicate the number of houses flooded at each flood level and provides an estimate of damages.

(5) <u>Loss of Use of Dwelling</u>

Flooding which results in forced evacuation of housing represents a direct cost to the owner. The estimated cost is equal to the number of houses flooded at each flood stage, times the number of days during which they cannot be occupied, times the daily rented value of the house.

The length of evacuation depends on the depth and duration of flooding. Because of the nature of flooding in the area and the availability of data it is possible to estimate the duration of inundation for each foot of flooding (using hydrographs fig. 1 and 2, Appendix 6). In order to allow some time for restoration of services (water, hydro etc.), clean-up and repairs to houses,the following additional time is added to the duration of floods.

Additional Evacuation Time at
<u>Different Levels of Flooding in Sumas</u>

| Water Level Above Ground | Additional Evacuation (Days) |
|---|---|
| 0 ft. | 7 |
| 0-2 ft. | 45 |
| 2 ft. or more | 60 |

The rental value of houses in any area is estimated to be 1% of their market value. The value of homes (less property) in Sumas is estimated to average $15,000 (survey conducted during summer of 1971). The monthly rental value for houses in Sumas is $150. An estimate of the loss of use of dwellings for each flood level is provided in Appendices 1 (a) - 1 (g).

(6) Extra Food Costs

Extra food cost is the additional daily expense incurred as a result of not eating in ones home. This cost is considered to be 1/3 more than what an average person would normally spend.

It is estimated that the extra cost of food is equal to 36 cents per person per day. Since each household in Sumas has an average of 4 persons (D.B.S. Census 1966), extra food cost is estimated to be $1.45 per household per day.

For an estimate of extra food costs at each flood level see Appendices 1 (a) - 1 (g).

(7) Damage to Roads

Two values are used to calculate road damages at Sumas. A figure of $2,000 per mile of road is used to calculate damages for floods of short duration, less than 7 day flooding, (estimate used in the Squamish report) and $9,000 per mile is used to calculate damages to roads flooded for periods longer than one week (estimate based on Report of Damages from 1948 Fraser River Flooding and Royal Commission Report on the Winnipeg Flood).

For an estimate of the total miles of road flooded and the resulting damages for each flood see Appendix 1 (a).

G) BENEFIT - COST

(1) Protection to 1935 Flood Level - Existing Outlet Conditions

An estimate of the potential damages prevented by improving the Sumas dykes (with the condition of the outlet remaining as it is), to a level which would protect against a 1935 level flood is provided in Appendices 1 (a) - (g), 3 and 5 and is summarized below:

| Flood | Interval of Recurrence | Existing Conditions Total Benefits | Existing Conditions Annual Benefits | Improved Conditions Total Benefits | Improved Conditions Annual Benefits | Total Annual Benefits |
|---|---|---|---|---|---|---|
| 1935 | 50 yrs. | $3,417,400 | $ 68,348 | $552,100 | $11,040 | $57,308 |
| 1951 | 20 yrs. | 2,220,900 | 111,045 | 252,300 | 12,610 | 98,435 |
| 1954 | 20 yrs. | 319,400 | 15,970 | | | 15,970 |
| 1955 | 20 yrs. | 94,300 | 4,710 | | | 4,710 |
| | | | | TOTAL....... | | $176,423 |

Capitalized at 7% over 35 years the annual benefits, $176,423, have a present value of $2,284,000. (For the present value using discount rates of 6% and 8% see Appendix 2 ).

Alternative (1)

(i) Benefits

$2,284,000

(ii) Costs

Dyking costs for Alternative (1) (for description of Alternative (1) dyke design, see 3a in Appendix 7) were estimated by the Engineering Division, Water Planning & Management Branch to be $1,697,000. Additionally the Engineering Division indicated that annual maintenance costs would equal about 2% of the estimated capital costs or $439,000 over the expected life of the dyke.

The report "Preliminary Cost Estimates for the District of Sumas, Bank Protection" indicates that bank protection would cost $30,000.

(iii) Benefit - Cost Ratio

$$\frac{\$2,284,000}{\$2,166,000} = 1.1$$

Alternative (2)

(i) Benefits

$2,284,000

(ii) Costs

Dyking costs for Alternative (2) (for description of Alternative (2) dyke design, see 3b in Appendix 7) were estimated by the Engineering Division, Water Planning & Management Branch to be $1,540,000. In addition the Engineering Division indicated that annual maintenance costs would equal about 2 1/2% of the estimated capital costs or a total of $498,000 over the expected life of the dyke.

Bank protection costs have been estimated to be $30,000.

(iii) Benefit - Cost Ratio

$$\frac{\$2,284,000}{\$2,068,000} = 1.1$$

Alternative (3)

(i) Benefits

$2,284,000

(ii) Costs

Dyking costs for Alternative (3) (for description of Alternative (3) dyke design, see 3c in Appendix 7) were estimated by the Engineering Division, Water Planning & Management Branch to be $1,289,000. Additionally the Engineering Division indicated that annual maintenance costs would equal about 3% of the estimated capital costs or a total of $500,000 over the expected life of the dyke.

Bank protection costs have been estimated to be $30,000.

(iii) Benefit - Cost Ratio

$$\frac{\$2,284,000}{\$1,819,000} = 1.3$$

(2) Protection to 1951 Flood with Existing Outlet Conditions or 1935 Flood with Improved Outlet Conditions

The benefits of improving the Sumas dykes to withstand a 1951 level flood with the present outlet or a 1935 level flood given an improved outlet is provided in Appendices 1 (a) - (g), 3 and 5 and is summarized below:

| Flood | Interval of Recurrence | Existing Conditions Total Benefits | Existing Conditions Annual Benefits | Improved Conditions Total Benefits | Improved Conditions Annual Benefits | Total Annual Benefits |
|---|---|---|---|---|---|---|
| 1935 | 50 yrs. | $3,417,400 | $ 68,348 | $552,100 | $11,040 | $57,308 |
| 1951 | 20 yrs. | 2,220,900 | 111,045 | 252,300 | 12,610 | 98,435 |
| 1954 | 20 yrs. | 319,400 | 15,970 | | | 15,970 |
| | | | | | | $171,713 |

Capitalized at 7% over 35 years the annual benefits, $171,713 have a present value of $2,223,000. (For the present value using discount rates of 6% and 8% see Appendix 2).

Alternative (1)

(i) Benefits

$2,223,000

(ii) Costs

Dyking costs for Alternative (1) (for description see 3a in Appendix 7) were estimated by the Engineering Division, Water Planning & Management Branch to be $1,293,000. In addition the Engineering Division indicated that annual maintenance costs would equal about 2% of the established capital costs, or $335,000 over the expected life of the dyke.

Bank protection costs have been estimated to be $30,000.

(iii) Benefit - Cost Ratio

$$\frac{\$2,223,000}{\$1,658,000} = 1.3$$

Alternative (2)

(i) Benefits

$2,223,000

(ii) Costs

Dyking costs for Alternative (2) (for description see 3 b in Appendix 7) were estimated by the Engineering Division, Water Planning & Management Branch to be $1,165,000. In addition the Engineering Division indicated that annual maintenance costs would equal about 2 1/2% of the estimated capital costs $377,000, over the expected life of the dyke.

Bank protection costs have been estimated to be $30,000.

(iii) Benefit - Cost Ratio

$$\frac{\$2,223,000}{\$1,572,000} = 1.4$$

Alternative (3)

(i) Benefits

$2,223,000

(ii) Costs

Dyking costs for Alternative (3) (for description see 3c in Appendix 7) were estimated by the Engineering Division, Water Planning & Management Branch to be $1,047,000. In addition the Engineering Division indicated that annual maintenance costs would equal about 3% of the capital costs, or $407,000 over the expected life of the dyke.

The cost of bank protection has been estimated to be $30,000.

(iii) Benefit - Cost Ratio

$$\frac{\$2,223,000}{\$1,484,000} = 1.5$$

(3) Protection to 1951 Flood - Improved Outlet Conditions

The benefits of upgrading the Sumas dykes to withstand a flood of the 1951 level given improved outlet conditions is provided in Appendices 1 (a) - (g), 3 and 5 and is summarized below:

| Flood | Interval of Recurrence | Existing Conditions Total Benefits | Existing Conditions Annual Benefits | Improved Conditions Total Benefits | Improved Conditions Annual Benefits | Total Annual Benefits |
|---|---|---|---|---|---|---|
| 1951 | 20 yrs | $2,220,900 | $111,045 | $252,300 | $12,610 | $98,435 |
| 1954 | 20 yrs | 319,400 | 15,970 | | | 15,970 |
| | | | | | | $114,405 |

Capitalized at 7% over 35 years the annual benefits, $114,405 have a present value of $1,481,000. (For the present value using discount rates of 6% and 8% see Appendix 2)

Alternative (3)

(i) Benefits

$1,481,000

(ii) Costs

Dyking costs for Alternative (3) (for description see 3c in Appendix 7) were estimated by the Engineering Division, Water Planning & Management Branch to be $807,000. In addition the Engineering Division indicated that annual maintenance costs would equal about 3% of the established capital costs, $313,000 over the expected life of the dyke.

The cost of bank protection has been estimated to be $30,000.

(iii) Benefit - Cost Ratio

$$\frac{\$1,481,000}{\$1,150,000} = 1.3$$

REFERENCES


1. British Columbia, Department of Lands, Forests and Water Resources, Water Resources Services, "Report on Fraser River Flood Control Benefit Study", Robertson, A.R.D. Senior Hydraulic Engineer, Feb. 1963.
2. Royal Commission on Flood Cost-Benefit 1958, Winnipeg, Manitoba, Dec. 1958.
3. Squamish Benefit-Cost Study, Engineering Division, Inland Waters, Dept. of Energy, Mines and Resources, unpublished report, 1967.
4. B.C. Department of Agriculture regional offices at Cloverdale and Abbotsford.
5. B.C. Egg Marketing Board, Abbotsford.
6. B.C. Broiler Marketing Board, Cloverdale

# APPENDICES

POSSIBLE FLOOD DAMAGES IN 1971 - 1935, 1951, 1954, 1955 FLOOD IN SUMAS

| LEVEL OF FLOOD | FARMLAND ACRES | FARMLAND LOSS | HOUSES NUMBER / TOTAL LOSS OF USE | HOUSES NUMBER / TOTAL DAMAGE | EXTRA FOOD COSTS | BARNS NUMBER DAMAGED | OUTBUILDINGS NUMBER DAMAGE | LOSS OF MILK | DAMAGE TO MILKING EQUIPMENT | EXTRA FEED COST | LOSS PRODUCTION EGGS POULTRY AND HOGS | ROADS MILES / DAMAGE | TOTAL DAMAGES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Existing Conditions<br>1955<br>72 Ft. | 0 | 0 | 13<br>$3,100 | 13<br>$30,900 | $900 | 25<br>$3700 | 23<br>$900 | $24,600 | $7,200 | $10,800 | $200 | 6<br>$12,000 | $94,300 |
| 1954<br>72.7 Ft | 435 | $28,700 | 32<br>$8,700 | 32<br>$87,400 | $2,400 | 49<br>$7300 | 52<br>$2100 | $56,500 | $14,400 | $21,600 | $300 | 10<br>$90,000 | $319,400 |
| 1951<br>77.6 Ft | 7,174 | $608,300 | 147<br>$52,000 | 147<br>$888,500 | $15,100 | 216<br>$32,400 | 280<br>$11,200 | $216,000 | $43,800 | $64,200 | $10,400 | 31<br>$279,000 | $2,220,900 |
| 1935<br>80.7 Ft | 8,800 | $849,200 | 214<br>$90,500 | 214<br>$1,556,800 | $26,200 | 287<br>$43,000 | 374<br>$15,000 | $353,200 | $51,600 | $77,400 | $19,700 | 35<br>$315,000 | $3,417,400 |
| Improved Conditions<br>1951<br>73.1 Ft | 0 | 0 | 40<br>$9,600 | 40<br>$101,000 | $2,900 | 60<br>$9,000 | 65<br>$2,600 | $60,200 | $17,100 | $25,600 | $300 | 12<br>$24,000 | $252,300 |
| 1935<br>74 ft | 730 | $48,200 | 49<br>$13,700 | 49<br>$190,200 | $4,000 | 77<br>$11,600 | 79<br>$3,200 | $77,300 | $20,200 | $30,300 | $400 | 18<br>$153,000 | $552,100 |

| LOSS OF USE - DAMAGE - EXTRA FOOD COSTS- SUMAS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Flood Freq-uency | Level of Flood-ing above Ground Level | Length of Evac-uation period (DAYS) | Damage per House | No. of Houses | Loss of use per House * | Total Loss of Use | Damage to Houses | Extra food Costs |
| present conditions | 1 ft. | 47 | $1,700 | 9 | 235 | 2115 | $15,300 | $613.35 |
| | 2 ft. | 49 | 3,900 | 4 | 245 | 980 | $15,600 | $284.20 |
| | TOTAL | | | 13 | | 3095 | $30,900 | $897.55 |
| 1955 Flood 72 ft | | | | | | | | |

* Rental Rate per month $150

| LOSS OF USE - DAMAGE - EXTRA FOOD COSTS- SUMAS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Flood Freq-uency** | **Level of Flood-ing above** Ground Level | **Length of Evac-uation period** (DAYS) | Damage per House | No. of Houses | Loss of use per House * | Total Loss of Use | Damage to Houses | Extra food Costs |
| present condi-tions | 1 ft | 48 | $ 1,700 | 19 | 240 | $ 4,560 | $ 32,300 | $ 1,322 |
| | 2 ft | 53 | 3,900 | 9 | 265 | 2,385 | 35,100 | 692 |
| | 3 ft | 70 | 5,000 | 4 | 350 | 1,800 | 20,000 | 406 |
| 1954 Flood 72.7 ft | TOTAL | | | 32 | | $ 8,745 | $ 87,400 | $ 2,420 |

* **Rental Rate per month** $150

LOSS OF USE - DAMAGE - EXTRA FOOD COSTS- SUMAS

| Flood Freq-uency | Level of Flood-ing above Ground Level | Length of Evac-uation period (DAYS) | Damage per House | No. of Houses | Loss of use per House * | Total Loss of Use | Damage to Houses | Extra food Costs |
|---|---|---|---|---|---|---|---|---|
| present condi-tions | 1 ft | 47 | $ 1,700 | 10 | 235 | $ 2,350 | $ 17,000 | $ 681 |
| | 2 ft | 53 | 3,900 | 36 | 265 | 9,540 | 140,400 | 2,767 |
| | 3 ft | 73 | 5,000 | 12 | 365 | 4,380 | 60,000 | 1,270 |
| | 4 ft | 77 | 6,700 | 40 | 385 | 15,400 | 268,000 | 4,466 |
| | 5 ft | 80 | 7,600 | 10 | 400 | 4,000 | 76,000 | 1,160 |
| 1951 Flood 77.6 ft | 6 ft | 83 | 8,100 | 26 | 415 | 10,790 | 210,600 | 3,129 |
| | 7 ft | 85 | 8,900 | 9 | 425 | 3,825 | 80,100 | 1,109 |
| | 8 ft | 87 | 9,100 | 4 | 435 | 1,740 | 36,400 | 505 |
| | TOTAL | | | 147 | | 52,025 | 888,500 | 15,087 |

* Rental Rate per month $150

LOSS OF USE - DAMAGE - EXTRA FOOD COSTS-

| Flood Frequency | Level of Flooding above Ground Level | Length of Evacuation period (DAYS) | Damage per House | No. of Houses | Loss of use per House * | Total Loss of Use | Damage to Houses | Extra food Costs |
|---|---|---|---|---|---|---|---|---|
| present conditions | 1 ft | 48 | $ 1,700 | 10 | 240 | 2,400 | $ 17,000 | $ 696 |
| | 2 ft | 55 | 3,900 | 29 | 275 | 7,975 | 113,100 | 2,313 |
| 1935 | 3 ft | 75 | 5,000 | 22 | 375 | 8,250 | 110,000 | 2,392 |
| Flood | 4 ft | 81 | 6,700 | 16 | 405 | 6,480 | 107,200 | 1,879 |
| 80.7 | 5 ft | 86 | 7,600 | 36 | 430 | 15,480 | 273,600 | 4,489 |
| ft | 6 ft | 91 | 8,100 | 12 | 455 | 5,460 | 97,200 | 1,583 |
| | 7 ft | 96 | 8,900 | 40 | 480 | 19,200 | 356,000 | 5,568 |
| | 8 ft | 100 | 9,100 | 10 | 500 | 5,000 | 91,000 | 1,450 |
| | 9 ft | 103 | 9,500 | 26 | 515 | 13,390 | 247,000 | 3,883 |
| | 10 ft | 105 | 9,500 | 9 | 525 | 4,725 | 85,500 | 1,370 |
| | 11 ft | 106 | 14,800 | 4 | 530 | 2,120 | 59,200 | 615 |
| | TOTAL | | | 214 | | 90,480 | 1,556,800 | 26,238 |

* Rental Rate per month $150

LOSS OF USE - DAMAGE - EXTRA FOOD COSTS-

| Flood Freq-uency | Level of Flood-ing above Ground Level | Length of Evac-uation period (DAYS) | Damage per House | No. of Houses | Loss of use per House * | Total Loss of Use | Damage to Houses | Extra food Costs |
|---|---|---|---|---|---|---|---|---|
| improv-ed condi-tions | 1 ft | 47 | $ 1,700 | 27 | 235 | $ 6,110 | $ 45,900 | $ 1,840 |
| | 2 ft | 49 | 3,900 | 9 | 245 | 2,205 | 35,100 | 639 |
| | 3 ft | 66 | 5,000 | 4 | 330 | 1,320 | 20,000 | 383 |
| 1951 Flood 73.1 ft. | TOTAL | | | 40 | | 9,635 | 101,000 | 2,862 |

* Rental Rate per month $150

| LOSS OF USE - DAMAGE - EXTRA FOOD COSTS- SUMAS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Flood Frequency | Level of Flooding above Ground Level | Length of Evacuation period (DAYS) | Damage per House | No. of Houses | Loss of use per House * | Total Loss of Use | Damage to Houses | Extra food Costs |
| improved conditions 1935 74 ft | 1 ft | 49 | $ 1,700 | 10 | 245 | $ 2,450 | $ 17,000 | $ 710 |
| | 2 ft | 52 | 3,900 | 26 | 260 | 6,760 | 101,400 | 1,960 |
| | 3 ft | 68 | 5,000 | 9 | 340 | 3,060 | 45,000 | 887 |
| | 4 ft | 70 | 6,700 | 4 | 350 | 1,400 | 26,800 | 406 |
| | TOTAL | | | 49 | | 13,670 | 190,200 | 3,963 |

* **Rental Rate per month** $150

FLOOD BENEFITS AND BENEFIT-COST RATIOS FOR DISCOUNT RATES OF 6%, 7% & 8% AND A 35 YEAR TIME PERIOD FOR THE VARIOUS DYKING PROPOSALS

| Level of Protection | Costs | Annual Benefits | Benefits Discount Rate 6% | B/C Ratio | Benefits Discount Rate 7% | B/C Ratio | Benefits Discount Rate 8% | B/C Ratio |
|---|---|---|---|---|---|---|---|---|
| (a) 1935 Flood Existing Outlet | | | | | | | | |
| Alternative (1) | $2,166,000 | $176,423 | $2,558,000 | 1.2 | $2,284,000 | 1.1 | $2,056,000 | .9 |
| (2) | 2,068,000 | 176,423 | 2,558,000 | 1.2 | 2,284,000 | 1.1 | 2,056,000 | 1.0 |
| (3) | 1,819,000 | 176,423 | 2,558,000 | 1.4 | 2,284,000 | 1.3 | 2,056,000 | 1.1 |
| (b) 1951 Flood-Existing outlet 1935 Flood-Improved outlet | | | | | | | | |
| Alternative (1) | $1,658,000 | $171,713 | $2,490,000 | 1.5 | $2,223,000 | 1.3 | $2,001,000 | 1.2 |
| (2) | 1,572,000 | 171,713 | 2,490,000 | 1.6 | 2,223,000 | 1.4 | 2,001,000 | 1.3 |
| (3) | 1,484,000 | 171,713 | 2,490,000 | 1.7 | 2,223,000 | | 2,001,000 | 1.3 |
| (c) 1951 Flood Improved Outlet | | | | | | | | |
| Alternative (3) | $1,150,000 | $114,405 | $1,659,000 | 1.4 | $1,481,000 | 1.3 | $1,333,000 | 1.2 |

OTHER AGRICULTURAL LOSS - EGGS - POULTRY - HOGS

| FLOOD FREQUENCY | HOGS | POULTRY EGGS | POULTRY BROILERS | | | TOTAL DAMAGES |
|---|---|---|---|---|---|---|
| EXISTING CONDITIONS 1955 | $ 184 | - | - | | | $ 200 |
| 1954 | $ 255 | - | - | | | 300 |
| 1951 | $ 826 | $ 4,845 | $ 4,698 | | | $10,400 |
| 1935 | $1,020 | $23,465 | $15,029 | | | $39,500 |
| IMPROVED CONDITIONS 1951 | $ 306 | - | - | | | 300 |
| 1935 | $ 428 | - | - | | | 400 |

AVERAGE PER ACRE CROP DAMAGE

DYKING DISTRICT - SUMAS WINTER FLOODING

| (1) Type of Crop or Crop-Group | (2) Average Per Acre Damage | (3) Total Acreage in Crop | (4) % Each Crop of Total Acreage | (5) Weighted Value of Each Crop |
|---|---|---|---|---|
| (1) Tame Hay + Legume Crops + Other Fodder Crops | $ 75 | 6,600 | 39.42 | $ 29.56 |
| (2) Pasture | $ 75 | 3,342 | 19.96 | $ 14.97 |
| (3) Tree Fruits | $ 2,000 | 64 | .38 | $ 7.60 |
| (4) Strawberries | $ 500 | 8 | .05 | $ .25 |
| (5) Raspberries | $ 900 | 241 | 1.44 | $ 12.96 |
| (6) Other Small Fruit | $ 400 | 22 | .13 | $ .52 |
| (7) Other Crops | Not Damaged | 6,466 | 38.6 | - |
| | | 16,743 | 100.00 | $ 65.86 |

APPENDIX 5 (a)

AGRICULTURAL DAMAGE

| | | Present Dyke Conditions | | | Improved Conditions | |
|---|---|---|---|---|---|---|
| (a) | Crop Damage | | | | | |
| (1) | Total acres flooded | 1935 flood = 10,000 | | | 4,200 | |
| | | 1951 flood = 8,200 | | | 3,000 | |
| | | 1954 flood = 2,500 | | | | |
| | | 1955 flood = 1,800 | | | | |
| (2) | Total acreage cultivated | 1935 flood = 8,700 | | | 3,654 | |
| | (87% of total acreage flooded) | 1951 " = 7,134 | | | 2,610 | |
| | | 1954 " = 2,175 | | | | |
| | | 1955 " = 1,556 | | | | |
| (3) | Average duration of flooding | 1935 = 38 days | 100% | | 8 days | 20% |
| | | 1951 = 19 " | 100% | | 5 days | 0 |
| | | 1954 = 9 " | 20% | | | |
| | | 1955 = 4 " | 0 | | | |
| (4) | Average Suffering damage | 1935 flood = 8,700 | | | 730 | |
| | | 1951 " = 7,134 | | | 0 | |
| | | 1954 " = 435 | | | | |
| | | 1955 " = 0 | | | | |
| (5) | Acres of Nursery crops flooded | 1935 = 80 | 100% | | 0 | |
| | | 1951 = 80 | 50% | | 0 | |
| (6) | Damage to Nursery | 1935 = $275,000 | | | | |
| | | 1951 = $137,500 | | | | |

(7) Per acre damage in Sumas = $66 per acre

(see Appendix (4) )

(8) Total Agricultural Damage

| | | | | Improved Conditions |
|---|---|---|---|---|
| 1935 | = | 574,200 + 275,000 | = $849,200 | $48,180 |
| 1951 | = | 470,844 + 137,500 | = $608,344 | 0 |
| 1954 | = | | $ 28,710 | |
| 1955 | = | | 0 | |

(b) Milk Losses

(1) No. of Dairy Cows Flooded - Sumas

| Floods | (i) Existing Conditions | | | (ii) Improved Conditions | | |
|---|---|---|---|---|---|---|
| | Yarrow | Sumas | Total | Yarrow | Sumas | Total |
| 1935 | 1680 | 900 | 2580 | 560 | 450 | 1010 |
| 1951 | 1540 | 650 | 2190 | 455 | 400 | 855 |
| 1954 | 420 | 300 | 720 | | | |
| 1955 | 210 | 150 | 360 | | | |

(2) Length of Evacuation

| | Existing | Improved |
|---|---|---|
| 1935 flood | 68 | 38 |
| 1951 " | 49 | 35 |
| 1954 " | 39 | |
| 1955 " | 34 | |

(3) Milk loss per cow per day 33 pounds

(4) Cost of milk per pound = $.061

(5) Total loss of milk

| | (i) Existing Conditions | (ii) Improved Conditions |
|---|---|---|
| 1935 flood | $353,160 | $77,259 |
| 1951 flood | $216,015 | $60,239 |
| 1954 flood | $ 56,525 | |
| 1955 flood | $ 24,639 | |

(c) <u>Extra Feed Cost</u>

(1) <u>No. of Dairy Cows Flooded</u>

| | (i) Existing Conditions | (ii) Improved Conditions |
|---|---|---|
| 1935 | 2,580 | 1,010 |
| 1951 | 2,190 | 855 |
| 1954 | 720 | |
| 1955 | 360 | |

(2) Extra feed required T. of hay equivalents and <u>extra cost</u>

| | | | | |
|---|---|---|---|---|
| 1935 | 5,160 | $77,400 | 2,020 | $30,300 |
| 1951 | 4,280 | $64,200 | 1,710 | $25,650 |
| 1954 | 1,440 | $21,600 | | |
| 1955 | 720 | $10,800 | | |

(3) Extra cost of feed $15. per ton.

(d) Loss of Hog Production

(1) Total number of hogs in Sumas = 483 (1966 DBS)

(2) Number of hogs per acre = .02

(3) Area flooded

| | (i) Existing Conditions | (ii) Improved Conditions |
|---|---|---|
| 1935 flood | 10,000 | 4,200 |
| 1951 flood | 8,200 | 3,000 |
| 1954 flood | 2,500 | |
| 1955 flood | 1,800 | |

(4) Number of hogs in flooded area

| | (i) Existing Conditions | (ii) Improved Conditions |
|---|---|---|
| 1935 flood | 200 | 84 |
| 1951 flood | 164 | 60 |
| 1954 flood | 50 | |
| 1955 flood | 36 | |

(5) Loss during evacuation period = 17 lbs per hog

(6) Price of pork per pound = 30 cents

(7) Total loss from evacuation

| | | (i) Existing Conditions | (ii) Improved Conditions |
|---|---|---|---|
| 1935 flood | = | $1,020 | $428 |
| 1951 flood | = | $ 836 | $306 |
| 1954 flood | = | $ 255 | |
| 1955 flood | = | $ 184 | |

(e) Poultry - Egg Production

(1) Total production of eggs in floodable area of Sumas

| | | (i) Present Conditions | (ii) Improved Conditions |
|---|---|---|---|
| 1935 flood | = | 95 cases per week | 0 |
| 1951 flood | = | 30 cases per week | 0 |
| 1954 flood | = | 0 | |
| 1955 flood | = | 0 | |

(2) Loss of production = 1935 flood = 6 months

1951 flood = 4 months

(3) Total egg production 1935 flood = 2470 cases

1951 flood = 510 cases

(4) Loss of production 1935 flood = 1067 cases

1951 flood = 533 cases

(5) Value per case - $9.50

(6) Total loss of production 1935 flood level = $23,465

1951 " " = $ 4,845

(f) Poultry - Broilers and Fryers

(1) Total annual production in floodable area of Sumas

| | (i) Present Conditions | (ii) Improved Conditions |
|---|---|---|
| 1935 flood | 196,000 | 0 |
| 1951 flood | 86,000 | 0 |
| 1954 flood | 0 | |
| 1955 flood | 0 | |

(2) Weekly production 1951 - 1,650 broilers 1935 - 3,770 broilers

(3) Loss of production 1935 = 7 weeks

1951 = 5 weeks

(4) Price per bird = 85 cents

(5) Number of birds lost 1935 level = 17,681

(2/3 x 7 x 1,650) 1951 level = 5,527

(6) Loss of poultry 1935 flood = $15,029

1951 flood = $ 4,698

(g) Damage to Milking Equipment

(1) Number of milk cows in the floodable area of Sumas

| | (i) Present Conditions | (ii) Improved Conditions |
|---|---|---|
| 1935 flood = | 2,580 | 1,010 |
| 1951 flood = | 2,190 | 855 |
| 1954 flood = | 720 | |
| 1955 flood = | 360 | |

(2) Damage per milk cow = $20

(3) Damage to milking equipment:

| | (i) Present Conditions | (ii) Improved Conditions |
|---|---|---|
| 1935 flood = | $51,600 | $20,200 |
| 1951 flood = | $43,800 | $17,100 |
| 1954 flood = | $14,400 | |
| 1955 flood = | $ 7,200 | |

# REPORT ON FLOOD FREQUENCIES, ELEVATIONS, AND DURATIONS IN THE SUMAS LAKE AREA

## OBJECTIVES

To provide data on the frequencies, elevations, and durations of floods to allow evaluation of the benefits of improving the dykes protecting the Sumas Lake area from flooding by the Sumas River.

This report does not cover flooding caused by high water in the Fraser River, the Vedder Canal, or the Vedder River.

## AVAILABLE DATA

The peak stage caused by flooding in the lake area was recorded for the 1935 flood (1). Daily stages of the floodwater in the lake area during the 1951 flood period were available along with estimates of the daily inflow into the lake area (1). Data on pre-1957 pumping capacity and present capacity were also available (1) and (2). Streamflow data for the Sumas River at Huntingdon were available covering the period 1951 to 1970, not including the 1951 flood, except that the peak stage reached by the flood was recorded. Elevations of the Sumas River and Sumas Canal at the pump station were available from 1948 to 1970.

An earlier report prepared for the Committee (3) summarized the flood problem in general and outlined the particular difficulties of this area.

## INTRODUCTION

Figure 1 shows the general layout of the area.

Flooding of the Sumas Lake area is caused by a combination of two factors. One factor is the elevation of the Sumas River at the dam, the other is the combined flow of the Sumas River and the Sumas Canal at the dam. The two factors are not directly related and, for damaging flooding to occur, it is necessary for both factors to be high at the same time. The elevation of the river determines whether the dykes will fail whilst the flow in the river, together with the flow in the Sumas

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(1) Report on "Sumas River Floods" by V. Raudsepp, B.C. Water Rights Branch, 1951-52.

(2) Report "Sumas River Pump Station" by Associated Engineering Services Limited, 1970.

(3) Report "The Problem of Flooding of Sumas Lake Area from the Sumas River", Engineering Division, January 1971.

Lake Canal, determines if the dykes do fail, whether there would be sufficient flow of water to overload the pumps and cause flooding.

The elevation of the Sumas River at the dam is governed by the elevation of the Fraser River at the mouth of the Sumas River. Only during the extremely widespread storms does the Fraser River reach high stage at the same time as the Sumas River reaches high flows. Such conditions occurred in 1935 and 1951 when the dykes did fail and serious flooding did occur.

## METHOD

As the flooding problem is caused by the coincidence of high values of two different parameters, Sumas River flow and Fraser River elevation, and the historic record of the combined data was short, a conventional frequency analysis of the occurrence of flooding events was not feasible. Even a frequency analysis of a single parameter to obtain values in the 50-year recurrence interval range could be very inaccurate if based only on a 20-year record. An analysis of the frequency of the combination of two events on a 20-year record would be extremely unreliable.

It was therefore considered that the only meaningful method of estimating annual damages under present conditions was to assume that flood events over the period of record constituted a representative sample of the long term population of events and that, in any future period of the same duration, similar damages would occur. Since the dyking system was built in 1922, extremely severe floods were recorded in January 1935 and February 1951. Over the past 20 years since 1951, the only period for which flow records were available, conditions severe enough to cause flooding, had the dykes failed, occurred only on two occasions; in November 1954 and November 1955. Conditions necessary to cause flooding were considered to be that the Sumas River elevation above the dam must have exceeded the confidence level of the existing dykes, estimated at 85.0' Sumas Datum (4), and also that the combined flow of the Sumas River and Sumas Canal must have exceeded the present pumping capacity, approximately 1,150 cfs. The selection of the confidence limit was based on a comparison of existing dyke grades and design water levels.

A routing computation was carried out for these four events to estimate what flooding might occur under present conditions. The following assumptions were made:

1. that, once the river level exceeded 85.0' Sumas Datum, the dykes no longer afforded any protection and the total river flow would enter the lake area. Although this latter assumption might be conservative for the case of a minor breach, it is quite possible in the case of a major breach. In fact, a major breach might cause drawdown of the Upper Sumas River sufficient to cause inflow from the Fraser River. In such a case, the gates in the dam would be closed and there would be no doubt that all the river flow would have to enter the lake.

---

(4) Sumas Datum = Geodetic Survey of Canada Datum + 69.7 ft.

2. that the pumping capacity was that existing today.

Flows for the Sumas River and Sumas Canal were estimated by the unit hydrograph method except that, where recorded flows at Huntingdon were available, these were used. Estimated inflows into the Sumas River Basin resulting from overflow from the Nooksack River were included in the flow estimates and thus the effect of the Nooksack River need not be considered separately.

In order to be able to estimate the damages which would be prevented if the dykes were rehabilitated, routing computations were carried out for the four events to estimate what flooding might occur under improved conditions. The following assumptions were made:

1. that the dykes were improved to safely withstand elevations equivalent to those of the 1935 flood,

2. that the pumping capacity would not be increased beyond that existing today.

## RESULTS

Results of the routing computations are shown as hydrographs of water elevations in the lake area in Figures 2-5 and are summarized in Table 1.

TABLE 1

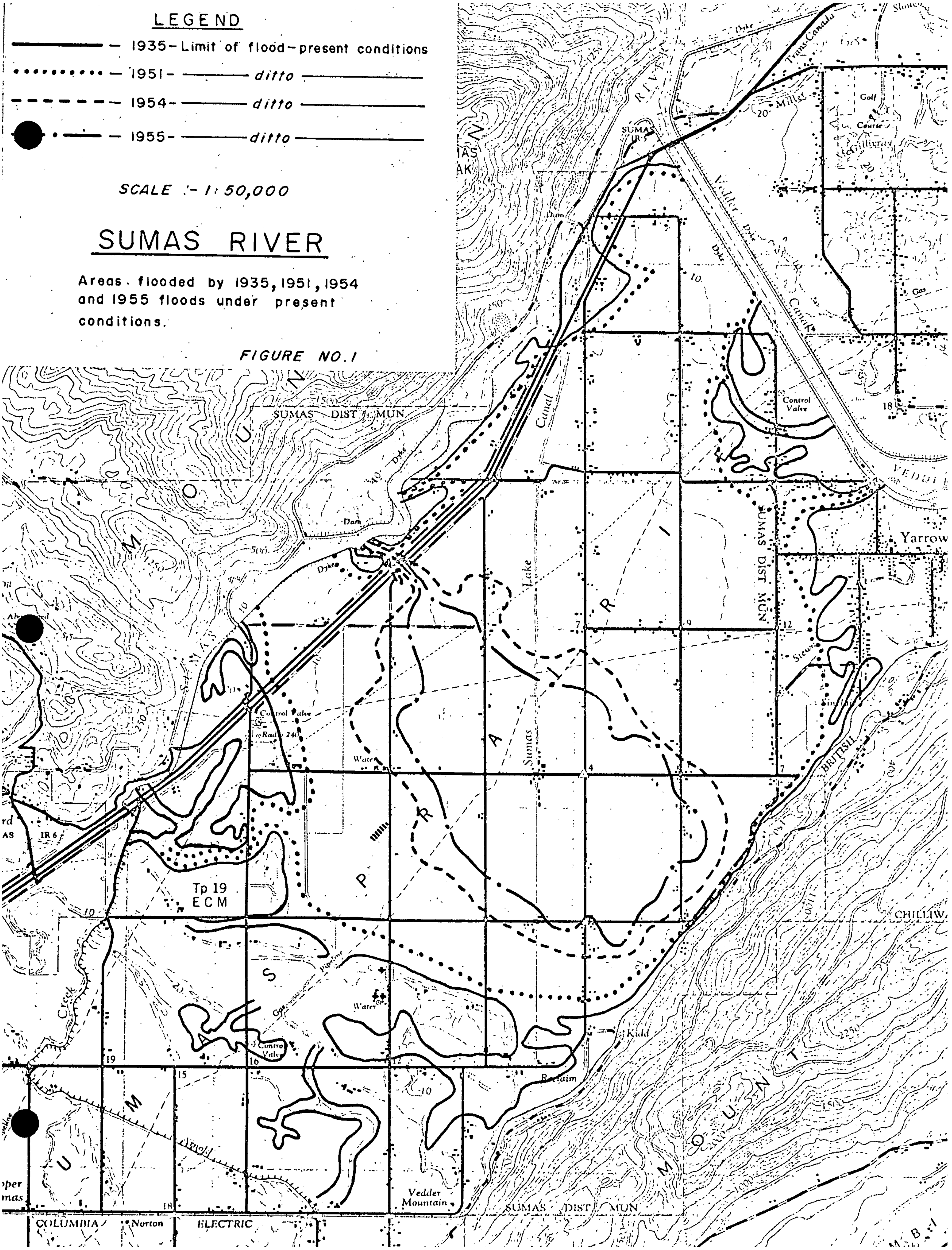
Flood Elevations, Areas and Durations

| Flood | Existing Conditions | | | Improved Conditions | | |
|---|---|---|---|---|---|---|
| | Peak Elevation | Area Flooded | Duration of Flooding Above 70.0' | Peak Elevation | Area Flooded | Duration of Flooding Above 70.0' |
| | Sumas Datum | Acres | Days | Sumas Datum | Acres | Days |
| 1935 | 80.7 | 10,000 | 47 | 74.0 | 4,200 | 11 |
| 1951 | 77.6 | 8,200 | 28 | 73.1 | 3,000 | 7 |
| 1954 | 72.7 | 2,500 | 11 | No Flooding | | |
| 1955 | 72.0 | 1,800 | 5 | No Flooding | | |

Flooding under improved conditions would be a result of runoff from the area draining directly into the lake and not as a result of any dyke failure. This flooding could only be reduced by means of increased pumping capacity.

The benefits of dyke improvement could be considered to be equivalent to the difference between damages under existing conditions and those under improved conditions, assuming that any future 20-year period would include floods equivalent to those of 1951, 1954 and 1955, and that any 50-year period would also include one flood equivalent to that of 1935.

Engineering Division, Pacific Region
Water Planning and Operations Branch
24 January 1972




# SUMAS RIVER

Areas flooded by 1935, 1951, 1954 and 1955 floods under present conditions.

*FIGURE NO. 1*

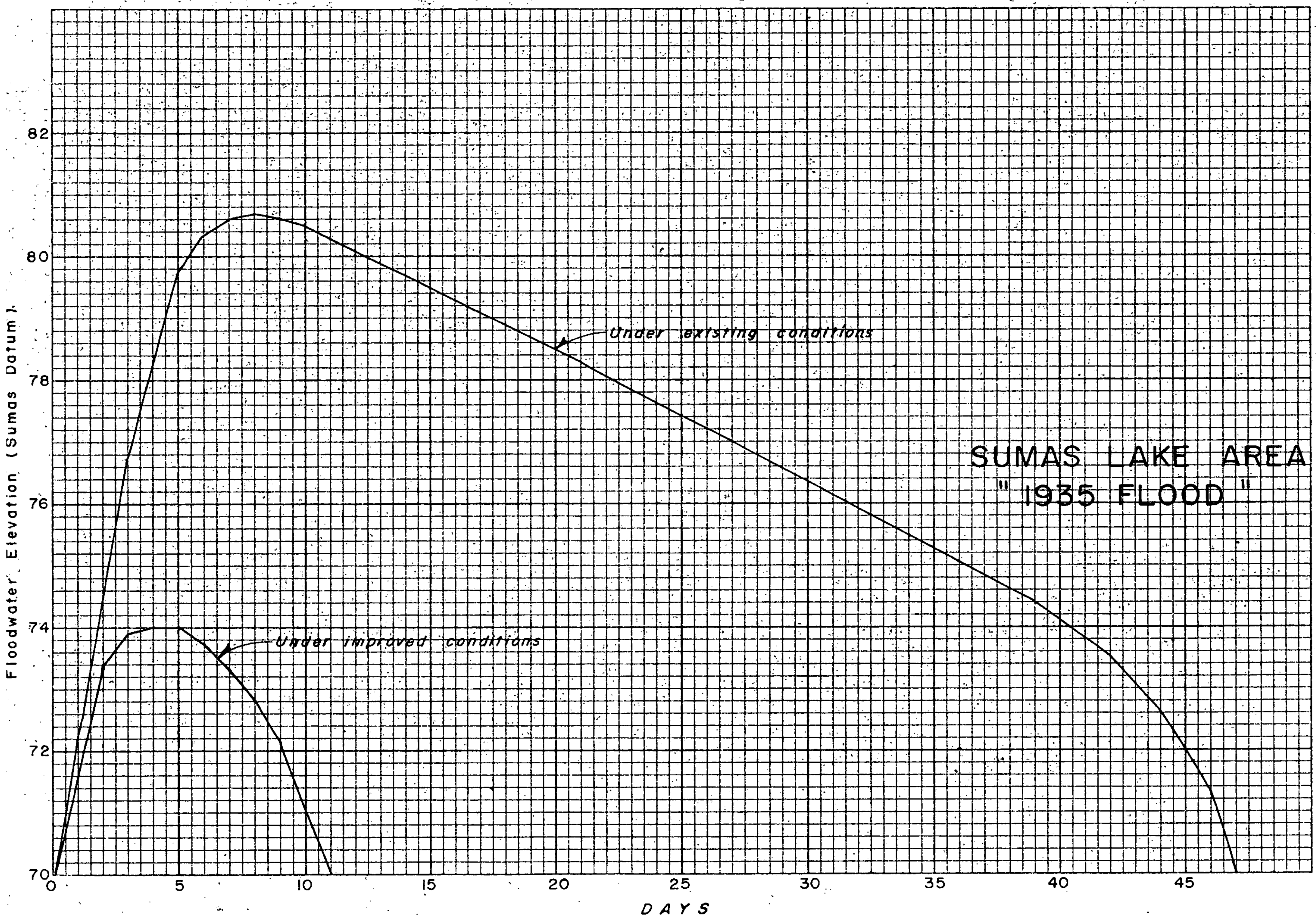

SUMAS LAKE AREA
"1935 FLOOD"
Under existing conditions
Under improved conditions
Floodwater Elevation (Sumas Datum)
DAYS
0
5
10
15
20
25
30
35
40
45
70
72
74
76
78
80
82

FIG. 2

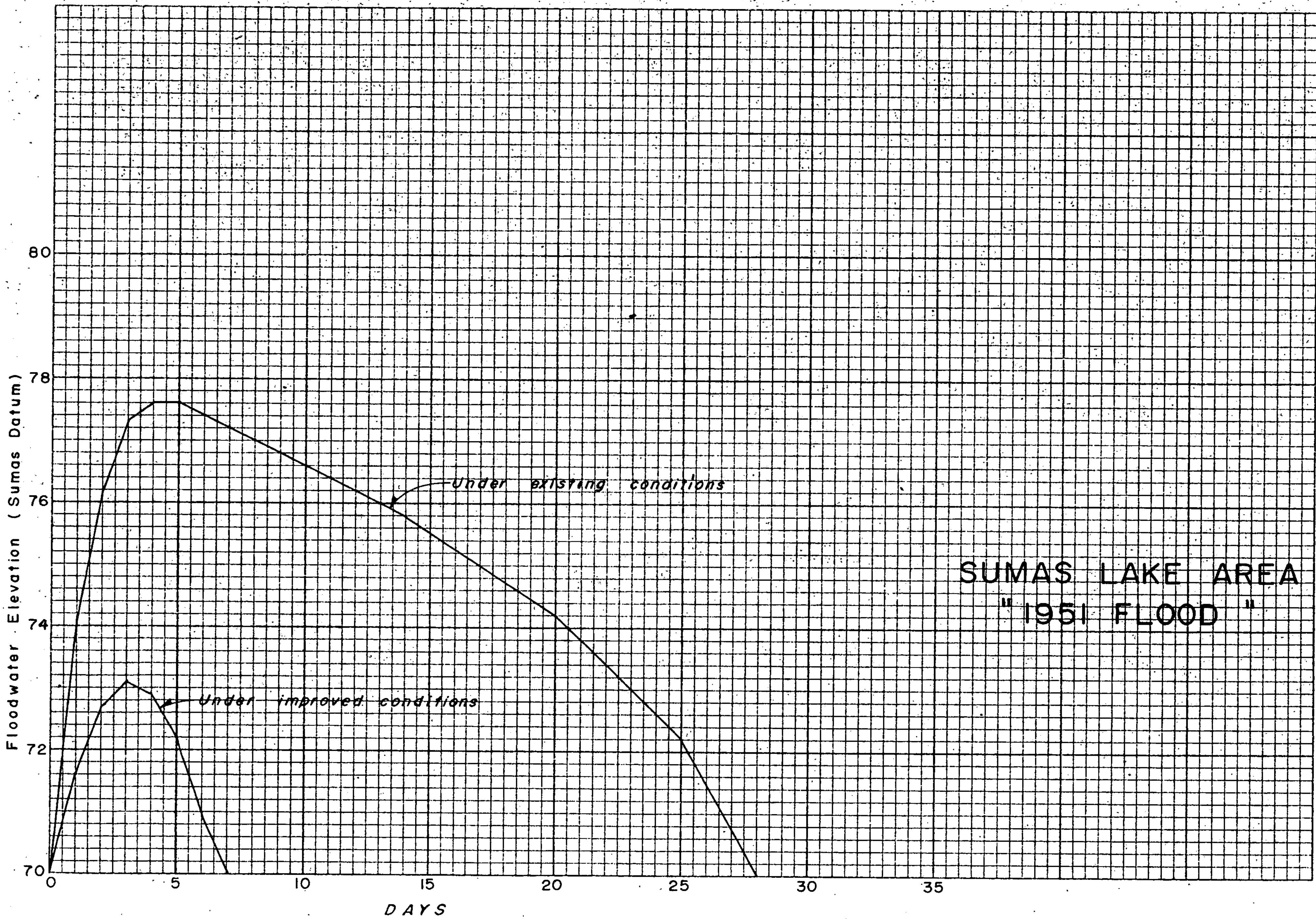
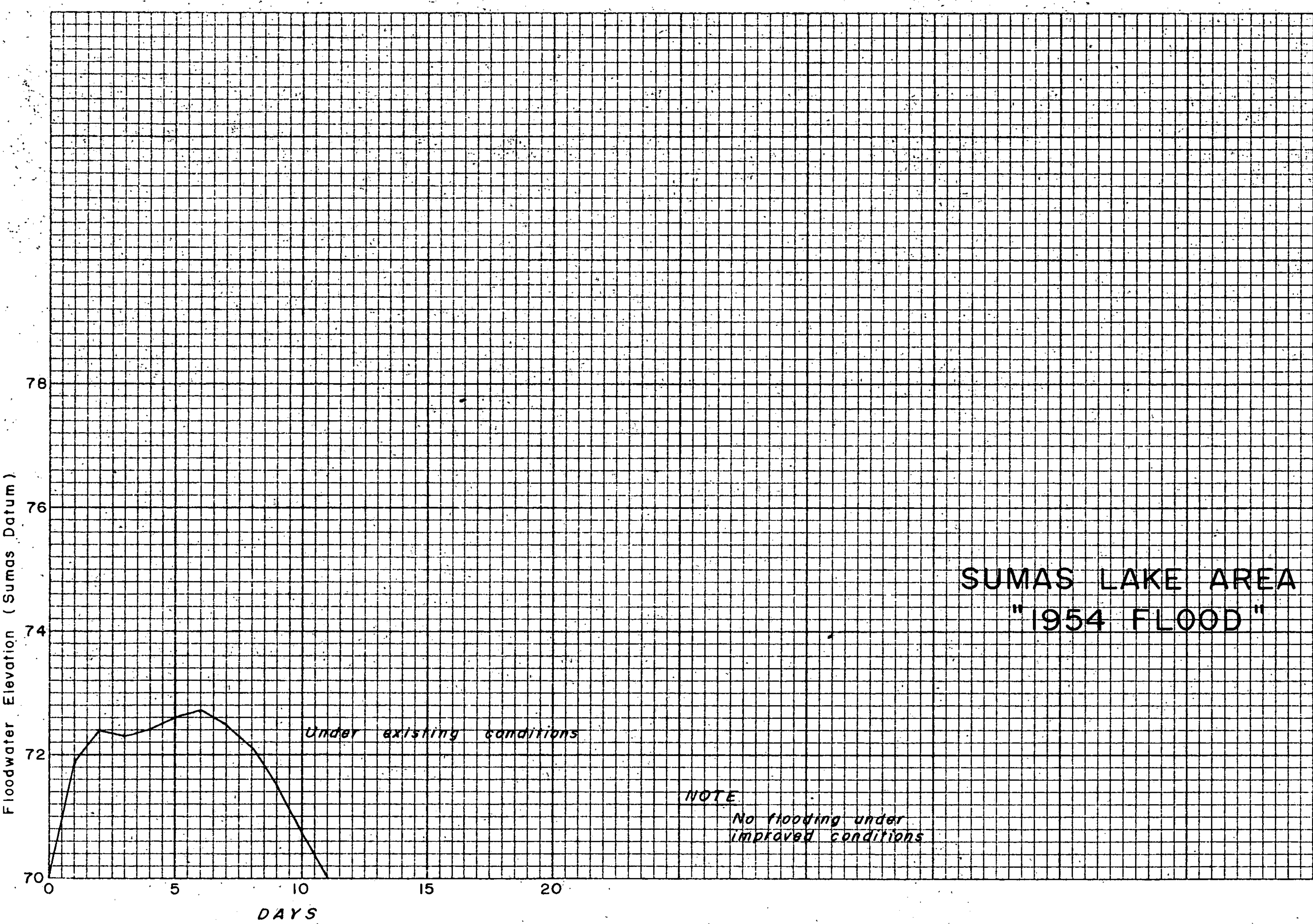

SUMAS LAKE AREA
"1951 FLOOD"
Under existing conditions
Under improved conditions
Floodwater Elevation (Sumas Datum)
80
78
76
74
72
70
0
5
10
15
20
25
30
35
DAYS

FIG. 3

FIG. 4


SUMAS LAKE AREA
"1954 FLOOD"
Floodwater Elevation (Sumas Datum)
78
76
74
72
70
0
5
10
15
20
DAYS
Under existing conditions
NOTE
No flooding under improved conditions

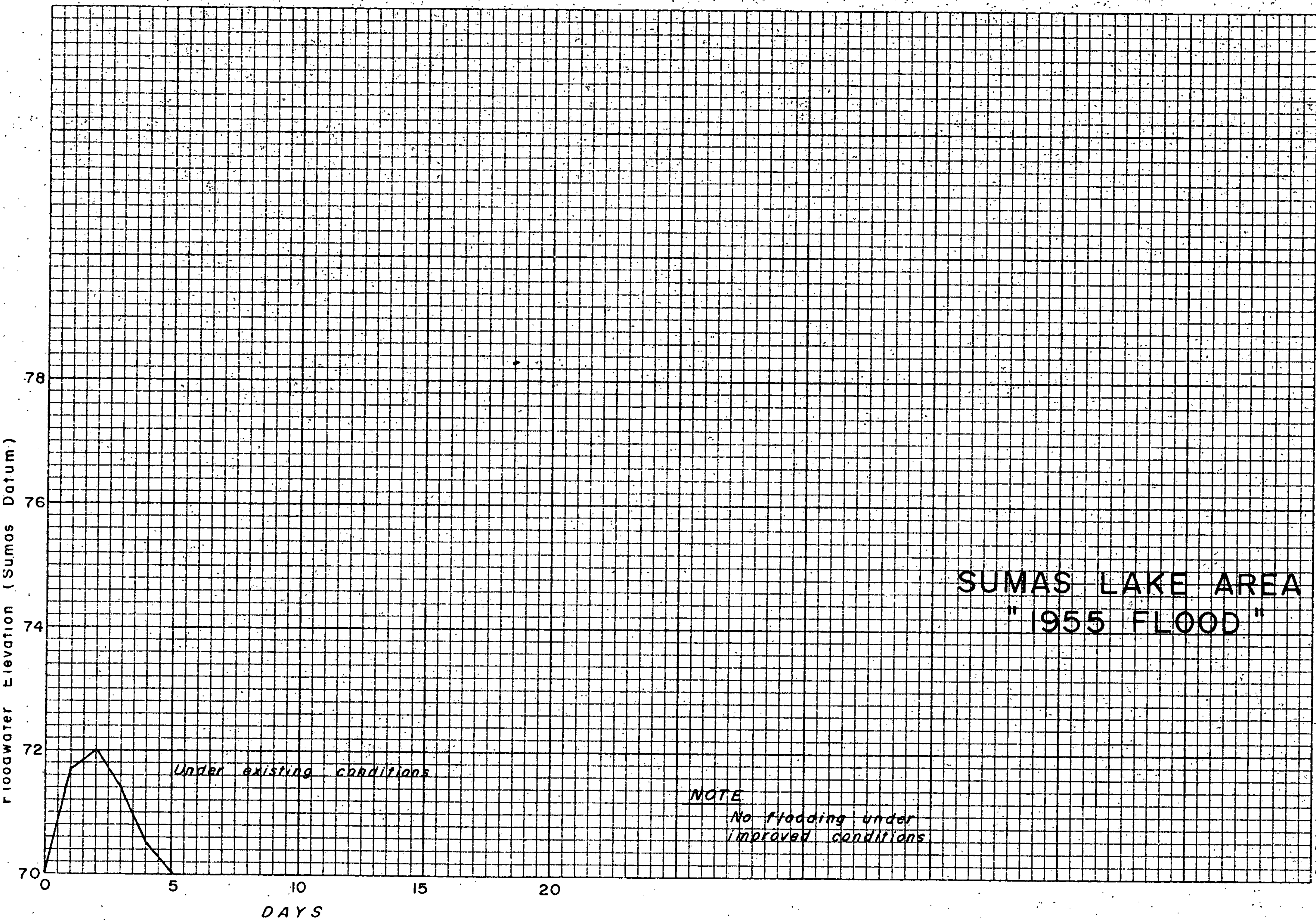

SUMAS LAKE AREA
"1955 FLOOD"
Floodwater Elevation (Sumas Datum)
70
72
74
76
78
0
5
10
15
20
DAYS
Under existing conditions
NOTE
No flooding under improved conditions

FIG. 5

# PRELIMINARY ESTIMATE OF DYKE IMPROVEMENT COSTS

## UPPER SUMAS RIVER DYKES

## DISTRICT OF SUMAS

Engineering Division, Pacific Region
Water Planning and Operations Branch
23 May 1972

# Preliminary Estimate of Dyke Improvement Costs

## Upper Sumas River Dykes

## District of Sumas

## 1. Introduction

A preliminary estimate of the dyke improvement costs for providing flood protection from the Sumas River in the District of Sumas has been prepared for the Fraser River Joint Program Committee by the Pacific Region, Engineering Division, Water Planning and Operations Branch. The work was authorized by the Committee's Program Director and results are to be used in preparation of a benefit-cost study for the area.

As shown on Plan #1, the dykes included in this estimate are the Sumas River dyke west of the Sumas River dam, the Saar Creek dyke and the Intercepting Canal dyke. In addition, short sections of dykes would be constructed to close the gaps along the B.C. Hydro Railroad embankment which will be utilized as part of the flood protection work. These dykes will provide flood protection for 28,000 acres in the Sumas Prairie area.

Costs were estimated for providing protection against winter floods equal to the magnitudes of the two major floods which occurred in 1935 and 1951. A total of seven estimates were made for the design combination of three dyke grades and three alternative dyke cross-sections. Major construction works required include rehabilitation of 9.6 miles of dykes, the construction of 1,300' of new dykes and raising bridges on seven road crossings.

## 2. Design Grades

Design grades for the 1935 and 1951 floods were developed for the existing outlet condition and for the possible future condition that the outlet capacity would be improved through a new dam at the mouth of the Sumas River.

a. Design Grades under Existing Outlet Condition

The 1951 design grade was plotted on the basis of a report [1/] on Sumas River floods which recommended raising the existing dyke

1/ B.C. Water Resources Report, dated 1951-1952, on:
Part I Sumas River Floods
Part II Supplementary Report on Possibilities of Winter Flood Protection in Sumas Dyking District.

... 2.

grades by from one to two feet. The 1935 grade, designed for protection against a larger flood combined with a higher Fraser River level, was estimated to be one foot higher than the 1951 design grade.

b. Design Grade under Improved Outlet Condition

The design grades under this condition were selected on the assumption that a new dam with greater outlet capacity would be constructed to replace the existing dam at the mouth of Sumas River as part of the Fraser River flood control work. A report 2/ on the dam has indicated that the existing outlet capacity would require 1.7' head to pass a flood of the 1935 or 1951 magnitude. It has been assumed that, by increasing the outlet capacity, the design profiles under existing conditions could be lowered by one foot. The design grade profile on the upstream side of Highway #401 bridges would be kept at a minimum elevation of 22.3' in order that water backing-up during a flood by a possible log jam at the bridge would spill over the highway on the west side, which is 1.3' below the design grade.

Profiles of the design grades are shown on Plan #1.

3. Design Sections

The three alternative design sections used in the estimate are described below.

a. Alternative Design Section #1

Dyke design sections used in this alternative are based on the general criteria set by the Fraser River Joint Program Committee and designs recommended by the soil consultants. 3/ Treatment for possible liquefaction due to earthquake is not considered in the estimate. The design standards are as follows:

(1) General side slopes for dykes to be:

| | | |
|---|---|---|
| Landside | 2.5:1.0 | |
| Riverside | 3.0:1.0 for silt | |
| | 2.5:1.0 for sand and gravel. | |

(2) Crest widths to be 12' minimum for dykes with a trafficable road surface.

2/ "Report on Sumas River Pump Station" by Associated Engineering Service Ltd., 1970.

3/ Report on "Sumas Dykes-Investigations and Remedial Treatment" by Ripley, Klohn & Leonoff International Ltd., March 12, 1970.

Report on "Sumas Dykes-Underseepage" by Ripley, Klohn & Leonoff International Ltd., August 14, 1970.

(3) Gravel surfacing to be provided for dykes with crest width of 12' or wider.

(4) Stripping to be required on the crest and landside slope of dykes where new materials are to be placed.

(5) Gravel drains to be provided on the landside dyke toe to control seepage through the dykes.

(6) A continuous seepage relief trench to be constructed near the landside toe of dykes where underseepage control would be required.

(7) Allowances to be made for seeding grass on dyke slopes and replacing old fences and gates.

b. Alternative Design Section #2

This design section has a 5' wide crest with a 12' wide gravel road on the landside toe to replace the 12' wide crest required for Alternative Design Section #1. It has a cost advantage for dykes requiring a substantial quantity of fill and is considered to be adequate for flood protection by soil consultants in other areas of the Lower Fraser Valley. However, dyke maintenance in this case would not be so convenient as in the case with a road on the dyke crest.

c. Alternative Design Section #3

This is the most economical design section. It is essentially the same as Alternative Design Section #2 except that the riverside slope would be 2.5:1.0 instead of 3.0:1.0 for silt dykes. The steeper riverside slope would reduce the safety factor against slope failure due to drawdown of the river and would require more dyke maintenance work if it is adopted.

Typical sections for the three alternative designs are shown on Plan #2.

4. <u>Other Design Considerations</u>

Bridges at Highway #401 crossings would not need to be raised. Water backing-up during flood by possible log jam at the bridge would spill over the 4,000' section of highway on the west side. The highway grade of this section, as shown on the Department of Highways' 1964 profile, is at an elevation of 21.0' or 1.3' below the 1951 dyke design grade. The spilled water would return to the Sumas River via Lonzo Creek. No allowance was made for scour protection under the bridges.

Quantities of dyke fill were taken from the dyke cross-sections surveyed in 1962 by the B.C. Water Resources Service at 1,000' intervals and some scattered sections which were surveyed in 1969 by the Engineering Division. Unit prices for earthwork were based on the current bid unit prices adjusted by local factors.

... 4.

## 5. Estimated Costs

A summary of estimated project costs including dyke construction, engineering design, additional dyke right-of-way and legal survey for various design grades and sections in 1972 costs are as follows:

| Design Grade & Outlet Condition | Design Section | Project Cost $ |
|---|---|---|
| 1. 1935 flood, existing | Alternative #1 | 1,697,000 |
| 2. " " " | Alternative #2 | 1,540,000 |
| 3. " " " | Alternative #3 | 1,289,000 |
| 4. 1951 flood, existing or 1935 " improved | Alternative #1 | 1,293,000 |
| 5. 1951 " existing or 1935 " improved | Alternative #2 | 1,165,000 |
| 6. 1951 " existing or 1935 " improved | Alternative #3 | 1,047,000 |
| 7. 1951 " improved | Alternative #3 | 807,000 |

The relationship of costs versus design grades for various design sections are shown in Figures 1 and 2.

The schedule of quantities, unit prices and estimated costs are given in Table 1 to Table 7.

Engineering Division, Pacific Region
Water Planning and Operations Branch
23 May 1972

TABLE 1

Design Grade for 1935 Flood and Existing Outlet Condition

Alternative Design Section #1

Schedule of Quantities, Unit Prices and Costs

| Item | Unit | Quantity | Rate | Amount |
|---|---|---|---|---|
| | | | $ | $ |
| Clearing and grubbing | LS | | | 21,600 |
| Stripping | SY | 364,810 | .30 | 109,300 |
| Slope trimming | CY | 73,600 | 1.10 | 81,000 |
| Toe drain excavation | CY | 3,552 | 1.10 | 3,900 |
| Toe drain fill | CY | 36,060 | 2.50 | 90,200 |
| Embankment fill | CY | 253,400 | 2.25 | 570,000 |
| 6" depth gravel surfacing | CY | 11,419 | 3.60 | 41,100 |
| Bituminous surfacing | ton | 755 | 15.00 | 11,300 |
| Underseepage control | LS | | | 66,000 |
| Seeding grass | acre | 60 | 300.00 | 18,000 |
| Floodboxes | LS | | | 3,500 |
| Fences | LF | 51,900 | .85 | 44,100 |
| Gates | each | 24 | 100.00 | 2,400 |
| Raising roads at dyke crossings | LS | | | 21,900 |
| Raising bridge at: | | | | |
| McDermott Road North | LS | | | 27,500 |
| Atkinson Road | LS | | | 24,600 |
| Wells Line Road | LS | | | 12,600 |
| Lamson Road | LS | | | 12,600 |
| Cole Road | LS | | | 16,300 |
| Bowman Road | LS | | | 16,300 |
| McDermott Road South | LS | | | 11,500 |
| Sub-total - Direct Cost | | | | 1,205,700 |
| Total dyke construction cost including 10% contingencies and 15% engineering supervision | | | | 1,525,000 |
| Engineering design 8% of direct cost | | | | 96,000 |
| Additional dyke right-of-way | | | | 49,000 |
| Legal survey | | | | 27,000 |
| Total Project Cost | | | | $1,697,000 |

TABLE 2

Design Grade for 1935 Flood and Existing Outlet Condition

Alternative Design Section #2

Schedule of Quantities, Unit Prices and Costs

| Item | Unit | Quantity | Rate | Amount |
|---|---|---|---|---|
| | | | $ | $ |
| Clearing and grubbing | LS | | | 25,200 |
| Stripping | SY | 364,810 | .30 | 109,300 |
| Slope trimming | CY | 73,600 | 1.10 | 81,000 |
| Toe drain excavation | CY | 5,492 | 1.10 | 6,000 |
| Toe drain fill | CY | 38,000 | 2.50 | 95,000 |
| Embankment fill | CY | 193,774 | 2.25 | 436,000 |
| 6" depth gravel surfacing | CY | 11,419 | 3.60 | 41,100 |
| Bituminous surfacing | ton | 755 | 15.00 | 11,300 |
| Underseepage control | LS | | | 66,000 |
| Seeding grass | acre | 60 | 300.00 | 18,000 |
| Floodboxes | LS | | | 3,500 |
| Fences | LF | 51,900 | .85 | 44,100 |
| Gates | each | 24 | 100.00 | 2,400 |
| Raising roads at dyke crossings | LS | | | 21,900 |
| Raising bridge at: | | | | |
| McDermott Road North | LS | | | 27,500 |
| Atkinson Road | LS | | | 24,600 |
| Wells Line Road | LS | | | 12,600 |
| Lamson Road | LS | | | 12,600 |
| Cole Road | LS | | | 16,300 |
| Bowman Road | LS | | | 16,300 |
| McDermott Road South | LS | | | 11,500 |
| Sub-total - Direct Cost | | | | 1,082,200 |
| Total dyke construction cost including 10% contingencies and 15% engineering supervision | | | | 1,369,000 |
| Engineering design 8% of direct cost | | | | 87,000 |
| Additional dyke right-of-way | | | | 57,000 |
| Legal survey | | | | 27,000 |
| Total Project Cost | | | | $1,540,000 |

TABLE 3

Design Grade for 1935 Flood and Existing Outlet Condition

Alternative Design Section #3

Schedule of Quantities, Unit Prices and Costs

| Item | Unit | Quantity | Rate | Amount |
|---|---|---|---|---|
| | | | $ | $ |
| Clearing and grubbing | LS | | | 18,900 |
| Stripping | SY | 241,037 | .30 | 72,300 |
| Slope trimming | CY | 41,384 | 1.10 | 45,500 |
| Toe drain excavation | CY | 8,280 | 1.10 | 9,100 |
| Toe drain fill | CY | 30,240 | 2.50 | 75,600 |
| Embankment fill | CY | 162,730 | 2.25 | 366,100 |
| 6" depth gravel surfacing | CY | 11,260 | 3.60 | 40,500 |
| Bituminous surfacing | ton | 755 | 15.00 | 11,300 |
| Underseepage control | LS | | | 66,000 |
| Seeding grass | acre | 40 | 300.00 | 12,000 |
| Floodboxes | LS | | | 3,500 |
| Fences | LF | 51,920 | .85 | 44,100 |
| Gates | each | 24 | 100.00 | 2,400 |
| Raising roads at dyke crossings | LS | | | 21,900 |
| Raising bridge at: | | | | |
| McDermott Road North | LS | | | 24,600 |
| Atkinson Road | LS | | | 22,400 |
| Wells Line Road | LS | | | 12,600 |
| Lamson Road | LS | | | 12,600 |
| Cole Road | LS | | | 16,300 |
| Bowman Road | LS | | | 16,300 |
| McDermott Road South | LS | | | 11,500 |
| Sub-total - Direct Cost | | | | 905,500 |
| Total dyke construction cost including 10% contingencies and 15% engineering supervision | | | | 1,146,000 |
| Engineering design 8% of direct cost | | | | 73,000 |
| Additional dyke right-of-way | | | | 43,000 |
| Legal survey | | | | 27,000 |
| Total Project Cost | | | | $1,289,000 |

TABLE 4

Design Grade for 1935 Flood and Improved Outlet Condition
or
Design Grade for 1951 Flood and Existing Outlet Condition

Alternative Design Section #1

Schedule of Quantities, Unit Prices and Costs

| Item | Unit | Quantity | Rate $ | Amount $ |
|---|---|---|---|---|
| Clearing and grubbing | LS | | | 18,000 |
| Stripping | SY | 315,606 | .30 | 94,700 |
| Slope trimming | CY | 72,894 | 1.10 | 80,200 |
| Toe drain excavation | CY | 3,552 | 1.10 | 3,900 |
| Toe drain fill | CY | 36,060 | 2.50 | 90,200 |
| Embankment fill | CY | 153,288 | 2.25 | 345,000 |
| 6" depth gravel surfacing | CY | 11,374 | 3.60 | 40,900 |
| Underseepage control | LS | | | 60,000 |
| Seeding grass | acre | 51 | 300.00 | 15,300 |
| Floodboxes | LS | | | 3,500 |
| Fences | LF | 51,900 | .85 | 44,100 |
| Gates | each | 24 | 100.00 | 2,400 |
| Raising roads at dyke crossings | LS | | | 11,100 |
| Raising bridge at: | | | | |
| McDermott Road North | LS | | | 24,600 |
| Atkinson Road | LS | | | 22,400 |
| Wells Line Road | LS | | | 10,400 |
| Lamson Road | LS | | | 10,400 |
| Cole Road | LS | | | 13,600 |
| Bowman Road | LS | | | 13,600 |
| McDermott Road South | LS | | | 8,600 |
| Sub-total - Direct Cost | | | | 912,900 |
| Total dyke construction cost including 10% contingencies and 15% engineering supervision | | | | 1,155,000 |
| Engineering design 8% of direct cost | | | | 73,000 |
| Additional dyke right-of-way | | | | 38,000 |
| Legal survey | | | | 27,000 |
| Total Project Cost | | | | $1,293,000 |

TABLE 5

Design Grade for 1935 Flood and Improved Outlet Condition
or
Design Grade for 1951 Flood and Existing Outlet Condition

Alternative Design Section #2

Schedule of Quantities, Unit Prices and Costs

| Item | Unit | Quantity | Rate $ | Amount $ |
|---|---|---|---|---|
| Clearing and grubbing | LS | | | 21,600 |
| Stripping | SY | 315,606 | .30 | 94,700 |
| Slope trimming | CY | 72,894 | 1.10 | 80,200 |
| Toe drain excavation | CY | 5,492 | 1.10 | 6,000 |
| Toe drain fill | CY | 36,060 | 2.50 | 90,000 |
| Embankment fill | CY | 105,361 | 2.25 | 237,000 |
| 6" depth gravel surfacing | CY | 11,241 | 3.60 | 40,500 |
| Underseepage control | LS | | | 60,000 |
| Seeding grass | acre | 51 | 300.00 | 15,300 |
| Floodboxes | LS | | | 3,500 |
| Fences | LF | 51,900 | .85 | 44,100 |
| Gates | each | 24 | 100.00 | 2,400 |
| Raising roads at dyke crossings | LS | | | 11,100 |
| Raising bridge at: | | | | |
| McDermott Road North | LS | | | 24,600 |
| Atkinson Road | LS | | | 22,400 |
| Wells Line Road | LS | | | 10,400 |
| Lamson Road | LS | | | 10,400 |
| Cole Road | LS | | | 13,600 |
| Bowman Road | LS | | | 13,600 |
| McDermott Road South | LS | | | 8,600 |
| Sub-total - Direct Cost | | | | 810,000 |
| Total dyke construction cost including 10% contingencies and 15% engineering supervision | | | | 1,025,000 |
| Engineering design 8% of direct cost | | | | 65,000 |
| Additional dyke right-of-way | | | | 48,000 |
| Legal survey | | | | 27,000 |
| Total Project Cost | | | | $1,165,000 |

TABLE 6

Design Grade for 1935 Flood and Improved Outlet Condition
or
Design Grade for 1951 Flood and Existing Outlet Condition

Alternative Design Section #3

Schedule of Quantities, Unit Prices and Costs

| Item | Unit | Quantity | Rate | Amount |
|---|---|---|---|---|
| | | | $ | $ |
| Clearing and grubbing | LS | | | 15,300 |
| Stripping | SY | 211,707 | .30 | 63,500 |
| Slope trimming | CY | 41,384 | 1.10 | 45,500 |
| Toe drain excavation | CY | 8,280 | 1.10 | 9,100 |
| Toe drain fill | CY | 30,240 | 2.50 | 75,600 |
| Embankment fill | CY | 109,655 | 2.25 | 246,700 |
| 6" depth gravel surfacing | CY | 11,260 | 3.60 | 40,500 |
| Underseepage control | LS | | | 60,000 |
| Seeding grass | acre | 33 | 300.00 | 9,900 |
| Floodboxes | LS | | | 3,500 |
| Fences | LF | 51,920 | .85 | 44,100 |
| Gates | each | 24 | 100.00 | 2,400 |
| Raising roads at dyke crossings | LS | | | 11,100 |
| Raising bridge at: | | | | |
| McDermott Road North | LS | | | 24,600 |
| Atkinson Road | LS | | | 22,400 |
| Wells Line Road | LS | | | 10,400 |
| Lamson Road | LS | | | 10,400 |
| Cole Road | LS | | | 13,600 |
| Bowman Road | LS | | | 13,600 |
| McDermott Road South | LS | | | 8,600 |
| Sub-total - Direct Cost | | | | 730,800 |
| Total dyke construction cost including 10% contingencies and 15% engineering supervision | | | | 924,000 |
| Engineering design 8% of direct cost | | | | 58,000 |
| Additional dyke right-of-way | | | | 38,000 |
| Legal survey | | | | 27,000 |
| Total Project Cost | | | | $1,047,000 |

TABLE 7

Design Grade for 1951 Flood and Improved Outlet Condition

Alternative Design Section #3

Schedule of Quantities, Unit Prices and Costs

| Item | Unit | Quantity | Rate | Amount |
|---|---|---|---|---|
| | | | $ | $ |
| Clearing and grubbing | LS | | | 12,100 |
| Stripping | SY | 193,290 | .30 | 58,000 |
| Slope trimming | CY | 41,384 | 1.10 | 45,500 |
| Toe drain fill | CY | 21,320 | 2.50 | 53,300 |
| Embankment fill | CY | 64,225 | 2.25 | 144,500 |
| 6" depth gravel surfacing | CY | 10,723 | 3.60 | 38,600 |
| Underseepage control | LS | | | 48,000 |
| Seeding grass | acre | 37 | 300.00 | 11,100 |
| Floodboxes | LS | | | 3,500 |
| Fences | LF | 51,920 | .85 | 44,100 |
| Gates | each | 24 | 100.00 | 2,400 |
| Raising roads at dyke crossings | LS | | | 7,000 |
| Raising bridge at: | | | | |
| McDermott Road North | LS | | | 22,400 |
| Atkinson Road | LS | | | 20,900 |
| Wells Line Road | LS | | | 8,900 |
| Lamson Road | LS | | | 8,900 |
| Cole Road | LS | | | 8,400 |
| Bowman Road | LS | | | 8,400 |
| McDermott Road South | LS | | | 6,400 |
| Sub-total - Direct Cost | | | | 552,400 |

| | |
|---|---|
| Total dyke construction cost including 10% contingencies and 15% engineering supervision | 699,000 |
| Engineering design 8% of direct cost | 44,000 |
| Additional dyke right-of-way | 37,000 |
| Legal survey | 27,000 |
| Total Project Cost | $807,000 |

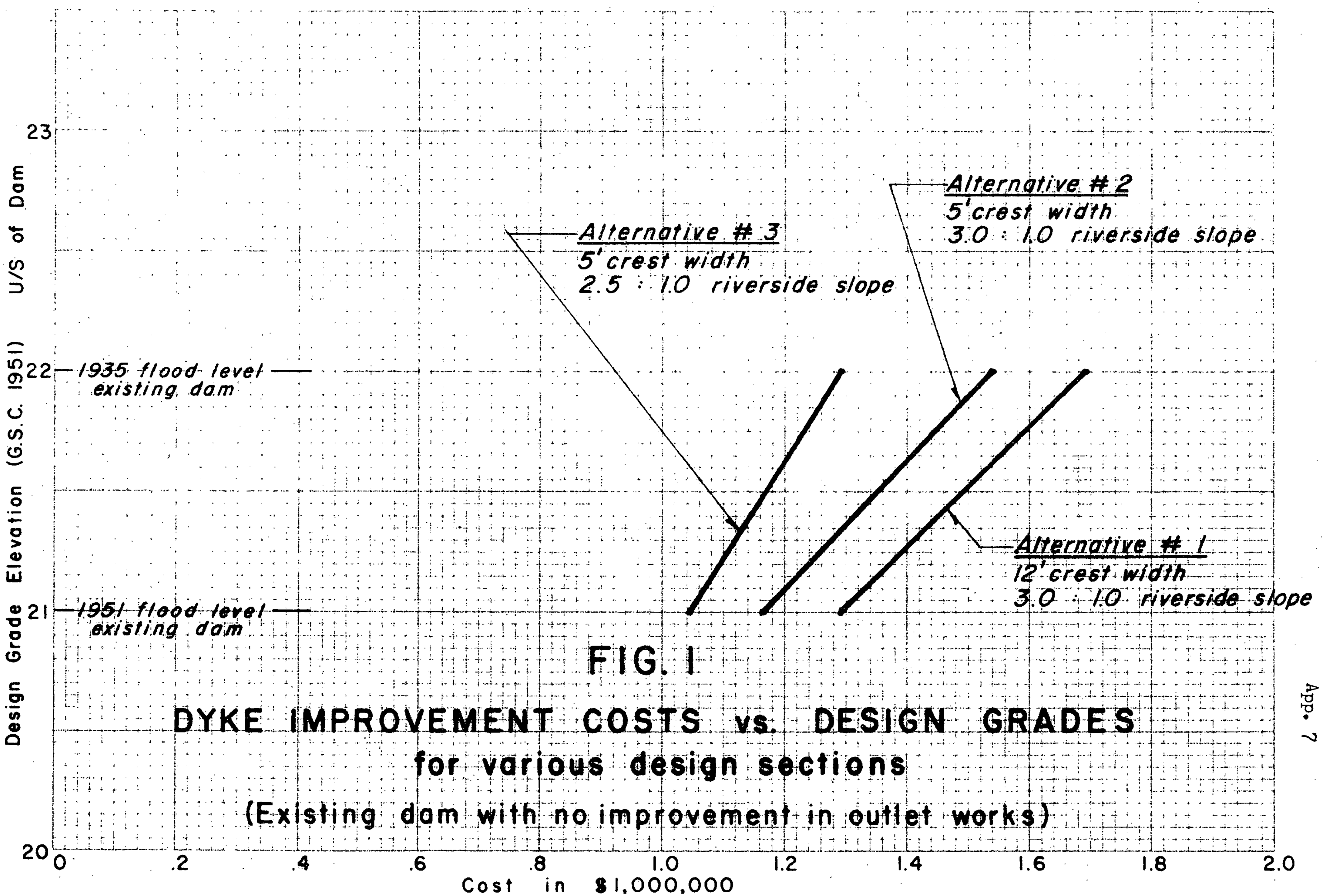



FIG. I

DYKE IMPROVEMENT COSTS vs. DESIGN GRADES

for various design sections

(Existing dam with no improvement in outlet works)

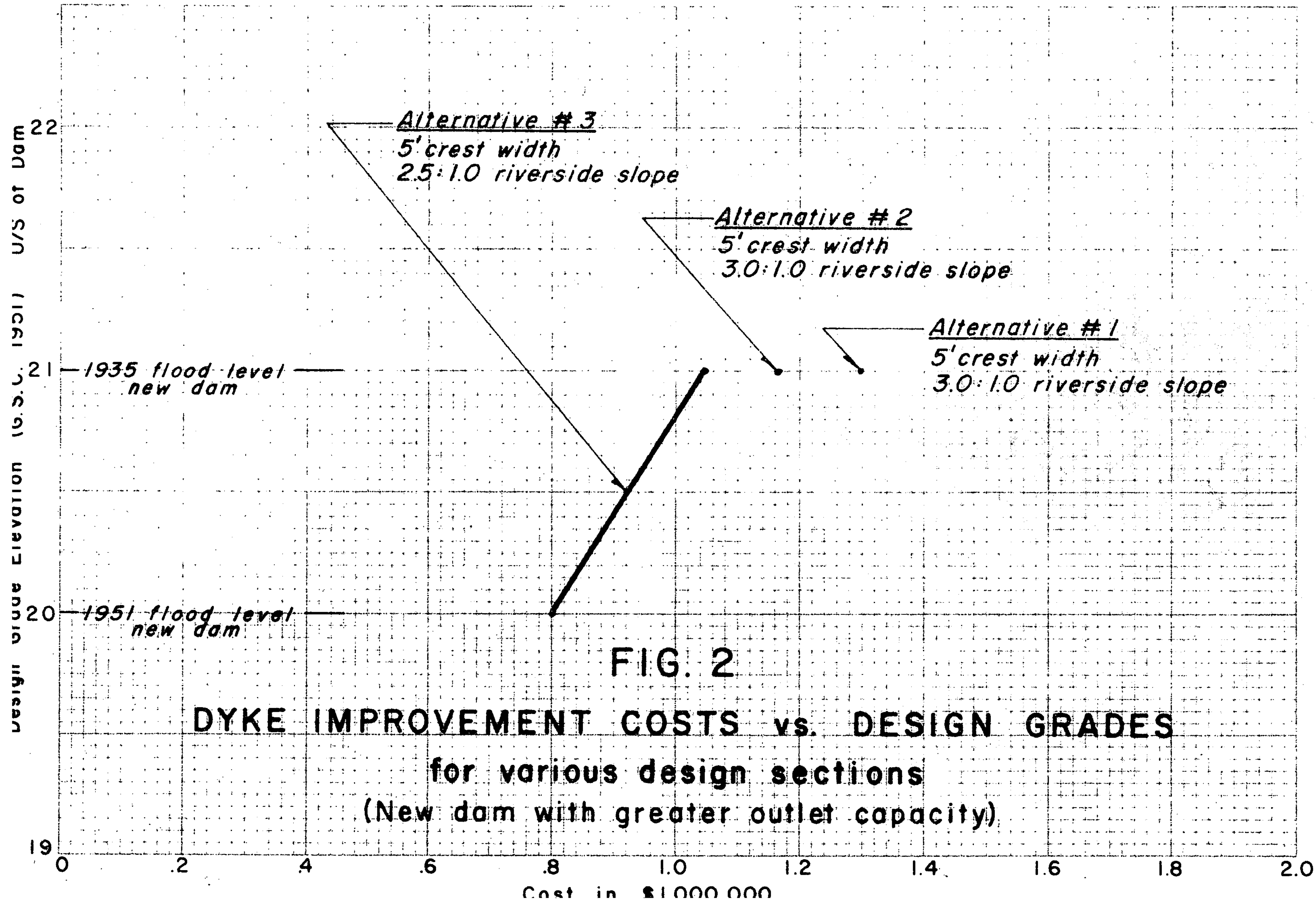
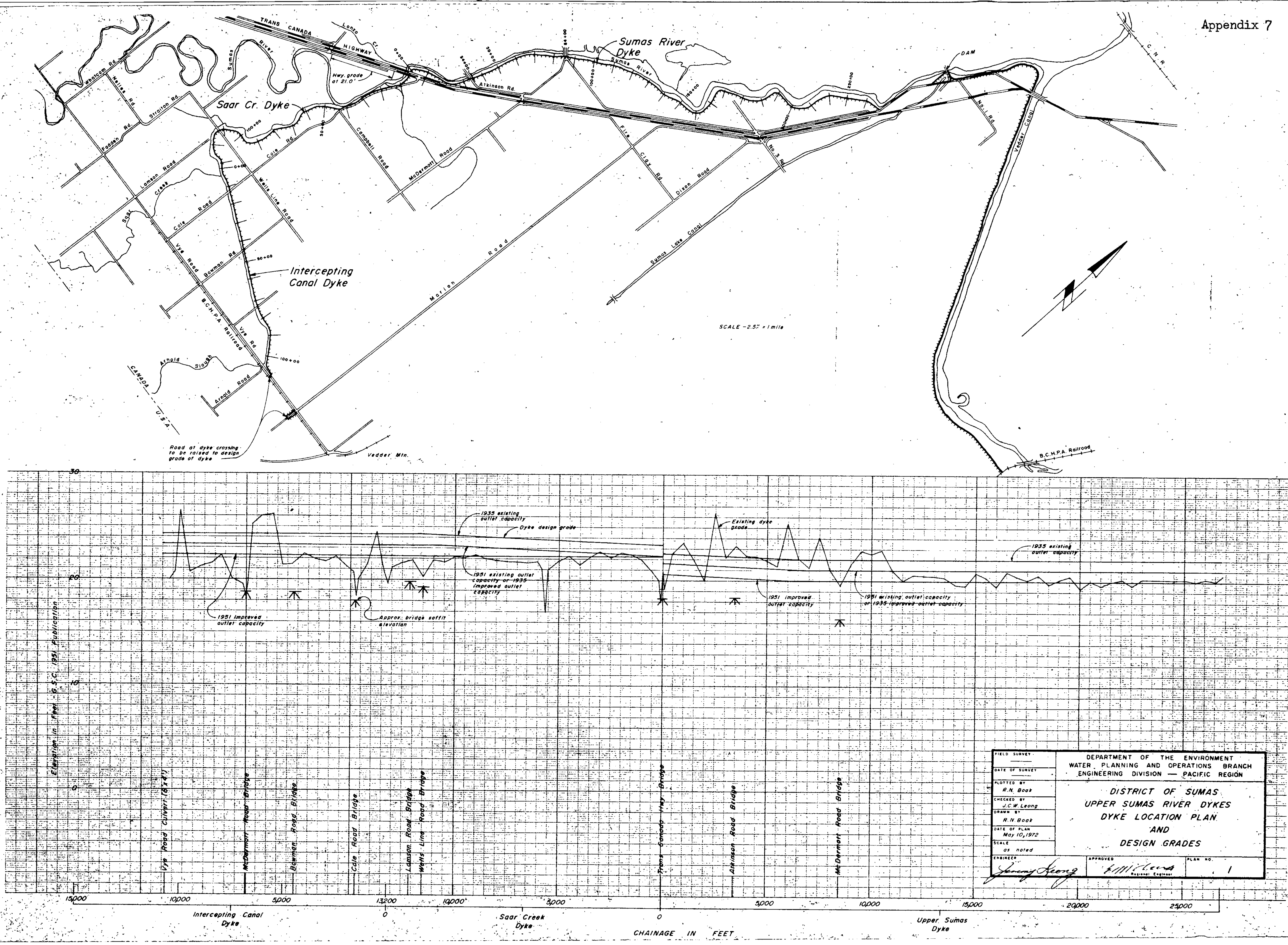


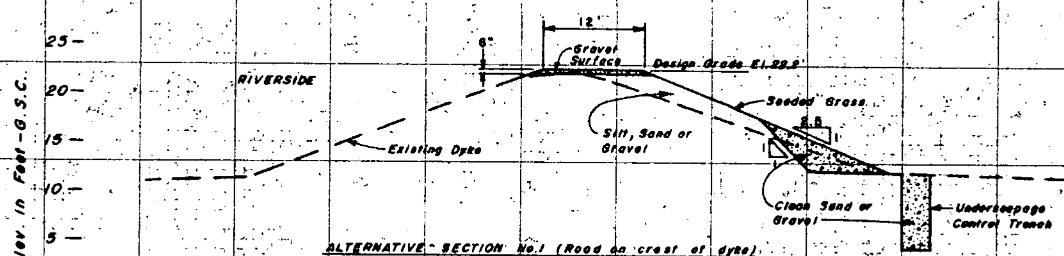

FIG. 2

DYKE IMPROVEMENT COSTS vs. DESIGN GRADES

for various design sections

(New dam with greater outlet capacity)

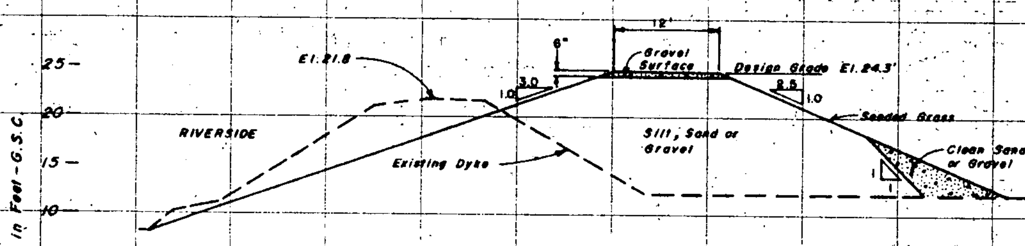

DEPARTMENT OF THE ENVIRONMENT
WATER PLANNING AND OPERATIONS BRANCH
ENGINEERING DIVISION — PACIFIC REGION
DISTRICT OF SUMAS
UPPER SUMAS RIVER DYKES
DYKE LOCATION PLAN
AND
DESIGN GRADES
PLOTTED BY R.N. Book
CHECKED BY J.C.W. Leong
DRAWN BY R.N. Book
DATE OF PLAN May 10, 1972
SCALE as noted
PLAN NO. 1
Sumas River Dyke
Saar Cr. Dyke
Intercepting Canal Dyke
TRANS CANADA HIGHWAY
Hwy. grade at 21.0'
Vedder Canal
B.C.H.P.A. Railroad
C.N.R.
DAM
CANADA
U.S.A.
SCALE - 2.5" = 1 mile
Road at dyke crossing to be raised to design grade of dyke
Vedder Mtn.
1935 existing outlet capacity
Dyke design grade
Existing dyke grade
1951 existing outlet capacity or 1935 improved outlet capacity
1951 improved outlet capacity
Approx. bridge soffit elevation
Elevation in Feet - G.S.C. 1951 Publication
Vye Road Culvert (6'x4')
McDermott Road Bridge
Bowman Road Bridge
Cole Road Bridge
Lamson Road Bridge
Wells Line Road Bridge
Trans Canada Hwy. Bridge
Atkinson Road Bridge
Intercepting Canal Dyke
Saar Creek Dyke
Upper Sumas Dyke
CHAINAGE IN FEET




ALTERNATIVE SECTION No.1 (Road on crest of dyke)

SECTION AT STA.49+00 SUMAS RIVER DYKE

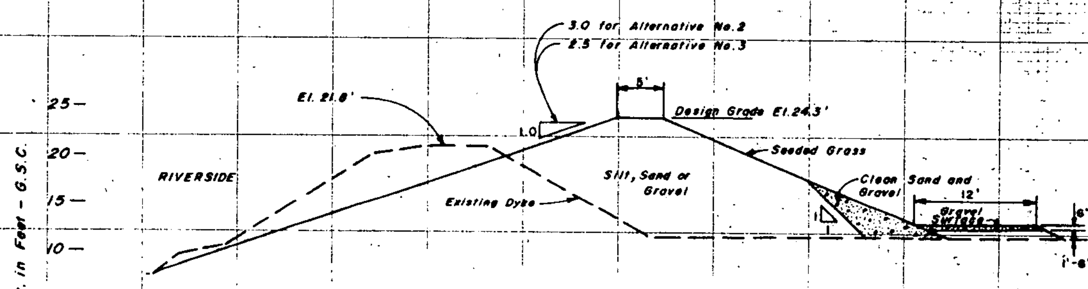
(TYPICAL FROM STA.25+00 TO 145+00)




ALTERNATIVE SECTION No. 1 (Road on crest of dyke)

STATION AT 30+00 INTERCEPTING CANAL DYKE

TYPICAL




ALTERNATIVE SECTIONS No. 2 and 3 (Road on landside of dyke)

~~SECTION AT 30+00 INTERCEPTING CANAL DYKE~~

TYPICAL

| | |
|---|---|
| FIELD SURVEY | DEPARTMENT OF THE ENVIRONMENT<br>WATER PLANNING AND OPERATIONS BRANCH<br>ENGINEERING DIVISION — PACIFIC REGION |
| DATE OF SURVEY | |
| PLOTTED BY R.N. Book | DISTRICT OF SUMAS<br>UPPER SUMAS RIVER DYKES<br>TYPICAL CROSS SECTIONS |
| CHECKED BY J.C.W. Leong | |
| DRAWN BY R.N. Book | |
| DATE OF PLAN May 11, 1972 | |
| SCALE 1" = 10' | |
| ENGINEER Jimmy Leong | APPROVED [signature] Regional Engineer — PLAN NO. 2 |