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HYDRAULIC MODEL STUDIES OF A TURNOUT FROM LATERAL WB38 CHUTE - WAHLUKE BRANCH CANAL - WASHINGTON

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Bureau of Reclamation

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16. ABSTRACT

A 1:6 scale model of a turnout from a Wahluke Branch Canal lateral chute was used to develop the hydraulic design of the entrance into the turnout. An efficient design consisting of a grill over an entrance in the chute floor was developed; a discharge coefficient was determined from the results for application to the design of similar turnouts. Baffle bars consisting of vertical strips of corrugated metal were developed to distribute the flow from the compartment beneath the floor of the chute into the constant-head orifice compartment. General guidelines were developed for using the baffle bars at other turnouts.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. *DESCRIPTORS*--/ laterals/ orifices/ *turnouts/ *grills/ *baffles/ canals/ *chutes/ Washington/ discharges/ hydraulic models/ hydraulics/ culverts/ Vee-notched weirs/ hydraulic jump/ discharge coefficients/ hydraulic design

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by

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August 1970

Hydraulics Branch
Division of Research
Office of Chief Engineer
Denver, Colorado

UNITED STATES DEPARTMENT OF THE INTERIOR * BUREAU OF RECLAMATION
Walter J. Hickel, Secretary
Ellis L. Armstrong, Commissioner

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CONTENTS

PURPOSE

The purpose of the study was to develop the hydraulic design of turnouts from a lateral chute in Block 25 of the Wahluke Branch Canal.

CONCLUSIONS

1. The length of the intake in the floor of the chute was shortened 50 percent; this intake was long enough to divert the design flow of 75 cubic feet per second (2.12 cubic meters per second) from the chute.

2. T-bars in the grill (grizzly) of the floor intake were replaced with 3- by 3-inch (76.2- by 76.2-millimeter) angles placed with the apex pointing up. The spacing between centers of the angles is 6-7/16 inches (163.26 mm).

3. Vertical baffles spaced across the opening between the compartment under the floor of the chute and the constant-head orifice turnout compartment improved the flow distribution into the constant-head orifice.

4. A coefficient of discharge was determined for the grizzly for use in the design of other grizzlies at other turnouts.

5. General guidelines were determined for use in the design of baffle arrangements at other turnouts.

GENERAL APPLICATION

The results of this study can be applied to the design of similar turnouts from canal chutes and of drop-type energy dissipators as illustrated in Engineering Monograph No. 25.[1]

INTRODUCTION

Wahluke Branch Canal, a part of the Columbia Basin Project, is located in East Central Washington about 20 miles (32 kilometers) southeast of Ephrata, Figure 1. Lateral WB38, is a chute from the canal to the Wahatis Wasteway, Figure 1. From the chute there are several turnouts to other laterals, Figure 2, the largest is the turnout at WB38C, Figures 3 and 4, which was model tested in this study. The capacity of this turnout is 75 cfs (2.12 cms) diverted from a flow of 75 cfs (2.12 cms) to 192 cfs (5.44 cms) in Lateral WB38.

THE MODEL

The model, Figure 5, built to a geometrical scale of 1:6, included a 3.5- by 4.0-foot (1.07- by 1.22-m) head box; a 105-foot (32-m) prototype length of the chute; the turnout grill to WB38C lateral; the constant-head orifice structure in the turnout; the culverts from the constant-head orifice structure to the trapezoidal canal lateral; the exit transition from the culverts; a 30-foot (9.14-m) prototype length of the rock-lined trapezoidal canal. A slide gate at the outlet from the head box was used to regulate the flow depth and velocity in the chute. A portable orifice venturi meter measured the total flow to the head box; the Vee-notch weir box measured the flow remaining in the chute downstream from the turnout. A fixed weir at the downstream end of the rock-lined canal section maintained the proper water surface elevation in the canal.

THE INVESTIGATIONS

The primary purpose of the investigation was to insure that the grill (grizzly) over the entrance to the turnout to WB38C lateral from Lateral WB38 chute discharge the proper quantity of flow from the chute in a hydraulically satisfactory manner. In developing the design, it was necessary to investigate a range of flows from 75 cfs (2.12 cms) to 192 cfs (5.44 cms) in the chute; in all cases the flow to be diverted was 75 cfs (2.12 cms). The results of the study were to be applied to the design of the other turnouts from the chute.

The Preliminary Design

The preliminary design of the turnout to WB38C, Figures 6 and 7, utilized a grizzly 20 feet (6.10 m) long in the concrete floor of the chute through which the flow to the turnout entered.

With only 75 cfs (2.12 cms) in the chute, the grizzly discharged about 73 cfs (2.07 cms) into the turnout, Figure 8. The other 2 cfs (0.06 cms) continued along the top flat surfaces of the T-bars to the far end of the grill. It appeared that this quantity of flow would continue along the top flat surfaces of the T-bars for a great distance. Since 73 cfs (2.07 cms) entered the

[1] "Hydraulic Design of Stilling Basins and Energy Dissipators," U.S. Department of the Interior, Bureau of Reclamation Engineering Monograph No. 25 by A. J. Peterka.

turnout in about the first third of the grizzly's length, the grizzly appeared to be longer than necessary, Figure 8.

Operation of the structure with 75 cfs (2.12 cms) being diverted from 192 cfs (5.44 cms) in the chute was completely satisfactory at the grizzly, Figures 5 and 8. However, it was noted that the downstream half of the grizzly could be covered and the performance was just as satisfactory.

With 192 cfs (5.44 cms) in the chute, the flow that entered the turnout was concentrated on the left side of the constant-head orifice structure. Actually some reverse flow occurred on the right side. With 75 cfs (2.12 cms) in the chute, the flow into the constant-head orifice structure was more evenly distributed with slightly more flow on the right side.

Modifications

The grizzly was shortened to half its original length by eliminating the downstream portion. The 4-inch (101.6-mm) wide T-bars were replaced with 1-1/4-inch (31-3/4-mm) by 1-1/4-inch (31-3/4-mm) angles with 1-1/16-inch (27-mm) open spaces between the 1-1/4-inch (31-3/4-mm) surfaces. The flat surfaces of the angles still carried a small portion of the flow across the entrance at the chute discharge of 75 cfs (2.12 cms).

The 1-1/4-inch (31-3/4-mm) angles were then replaced with 3-inch (76.20-mm) by 3-inch (76.20-mm) angles placed with the apex up at 6-7/16 inches (163-1/4 mm) on centers, Figure 4. The clearance between the floor of the chute and the sloping floor beneath the grizzly was reduced at the downstream end when the grizzly and entrance was shortened. To provide additional room, the slope of the floor beneath the grizzly was steepened.

The concept of placing the angles with the apex up appeared to be an excellent one since the required amount of flow entered the openings between angles for all lateral flows. However, finding a method of anchoring the ends of the angles to the floor of the chute to prevent them from becoming a debris trap presented some problems.

The steeper slope on the floor beneath the grizzly was unsatisfactory since the hydraulic jump in the compartment below the floor of the chute was much more turbulent and the turbulence carried into the constant-head orifice structure. It was believed that the flatter slope in the previous design provided a more streamlined entrance into the jump and better energy dissipation in the form of fine-grained turbulence.

The flatter slope was reinstalled and a test was made to evaluate the need for the grizzly. At 192 cfs (5.44 cms) in the chute with the grizzly removed, the water level in the downstream compartment of the constant-head orifice fluctuated tremendously, often overtopping the walls. With the grizzly in place, the fluctuations were reduced to about 6 inches (152.40 mm) and the flow in both compartments of the constant-head orifice structure was much more stable. The grizzly also reduced the wave heights and smoothed the flow in the chute downstream from the entrance to the turnout.

To provide better flow distribution into the constant-head orifice structure, vertical baffle bars 5-1/3 inches (135.47 mm) wide were placed at various spacings across the opening from the compartment below the floor of the chute. This bar width was used because it was anticipated that strips of corrugated metal (two corrugations wide) would be used to provide strength and rigidity to the long, slender baffles.

Recommended Design

The recommended design, Figures 3, 4, and 9, utilizes the 10-foot-long turnout grill made from the 3- by 3-inch (76.2- by 76.2-mm) angles on 6-7/16-inch (163.26-mm) centers with the apex of the angles up.

A scheme for supporting the grill at the downstream end was developed and tested that provided maximum clearance between the floor of the chute and the sloping floor of the turnout entrance and would catch a minimum amount of debris at low flows. Leaves and small twigs from dried Russian thistles added to the flow in the chute were not detained on the grill. It was noted that rocks in bedload sediment could become wedged between the angles; however, this type of debris was not expected.

No hydraulic problems were encountered when 75 cfs (2.12 cms) was diverted from chute flows ranging between 75 cfs (2.12 cms) and 192 cfs (5.44 cms), Figures 10 and 11. Nor were any adverse conditions noted when none of the flow in the chute was diverted.

At 75 cfs (2.12 cms) in the chute, some foam from the hydraulic jump in the compartment below the lateral floor appeared on the downstream end of the grizzly, Figure 10. However, less than 1 cfs (0.03 cms) was carried across the grizzly. At discharges of 76 cfs (2.15 cms) or more in the chute, 75 cfs (2.12 cms) was diverted into the turnout and the hydraulic performance in the chute was excellent, Figures 11 and 12.

The arrangement of the baffles between the compartment beneath the floor of the chute and the constant-head orifice turnout structure was developed in the model using wood slats, Figure 9, to represent the 5-1/3-inch (135.47-mm) wide corrugated metal baffles in the prototype, Figure 3. Corrugated metal strips (two corrugations wide), were used to provide strength and rigidity to the long, slender baffles. Closer spacing of the strips at the downstream end of the compartment improved the distribution of flow into the constant-head turnout when the chute was discharging 192 cfs (5.43 cms). Placing two strips together at the upstream end of the compartment improved the flow around the upstream corner into the constant-head orifice structure when the chute flow was 75 cfs (2.12 cms). Further, it was determined that the total flow area of the openings between the strips could be reduced to approximately, but not less than, the flow area of the two orifices between the two compartments of the constant-head orifice turnout structures. Therefore, the total number of 5-1/3-inch (135.47-mm) wide strips was limited to 16.

APPLICATION OF THE RESULTS TO OTHER TURNOUTS

To apply the results of this study to the design of the grizzlies at other turnouts from the chute, the discharge coefficient was determined for the grizzly discharge expression referred to in Engineering Monograph No. 25[1]

$$L = \frac{Q}{CSN\sqrt{2gy}}$$

where L is the length of grizzly, Q is the total discharge, C is an experimental coefficient, S is the average space width between angles including the end spaces to canal walls, N is the number of spaces, g is the acceleration of gravity, and y is the flow depth in the canal. The value of C for the 10-foot (3.05-cm) long grill discharging 75 cfs (2.12 cms) was 0.47. Since the same size angles and spacing was to be used at other turnouts, the required grizzly lengths could be determined for the given flow depths and discharges through the grizzly.

In applying the results of this study to the design and arrangement of the vertical baffle strips at the flow entrances to the other constant-head orifice turnouts, two general requirements were met. First, the total number of strips that was used was limited to the number that would not reduce the area between baffles to less than the flow area of the orifices between compartments in the constant-head orifice. Second, the open area was proportioned between baffles across the width of the opening as closely as possible to the spacing developed for the turnout in this investigation.

[1] Op. cit. p. 1

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Figure 1. Location Map.

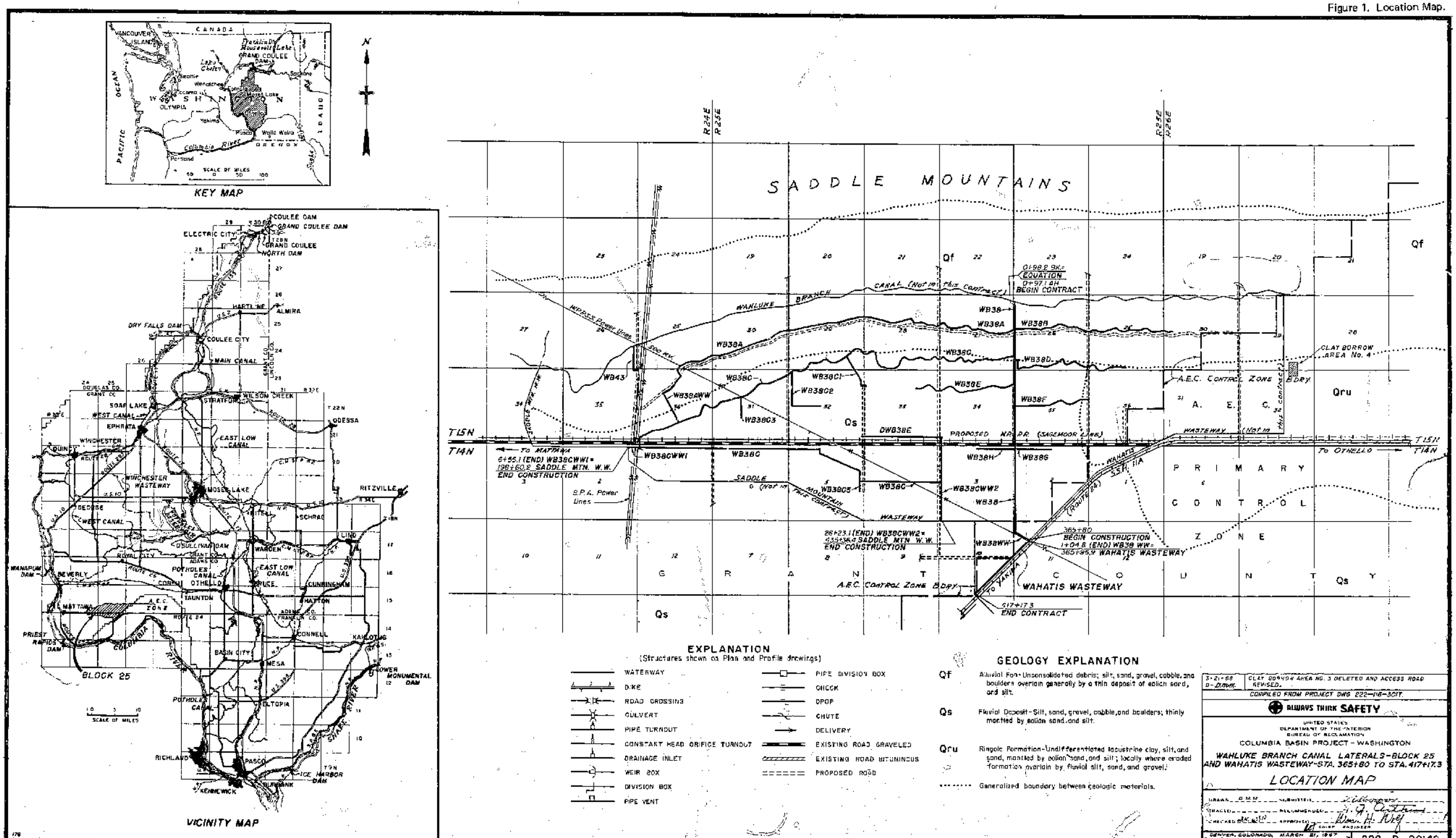


Figure 2. Chute Plan, Profile, and Sections.

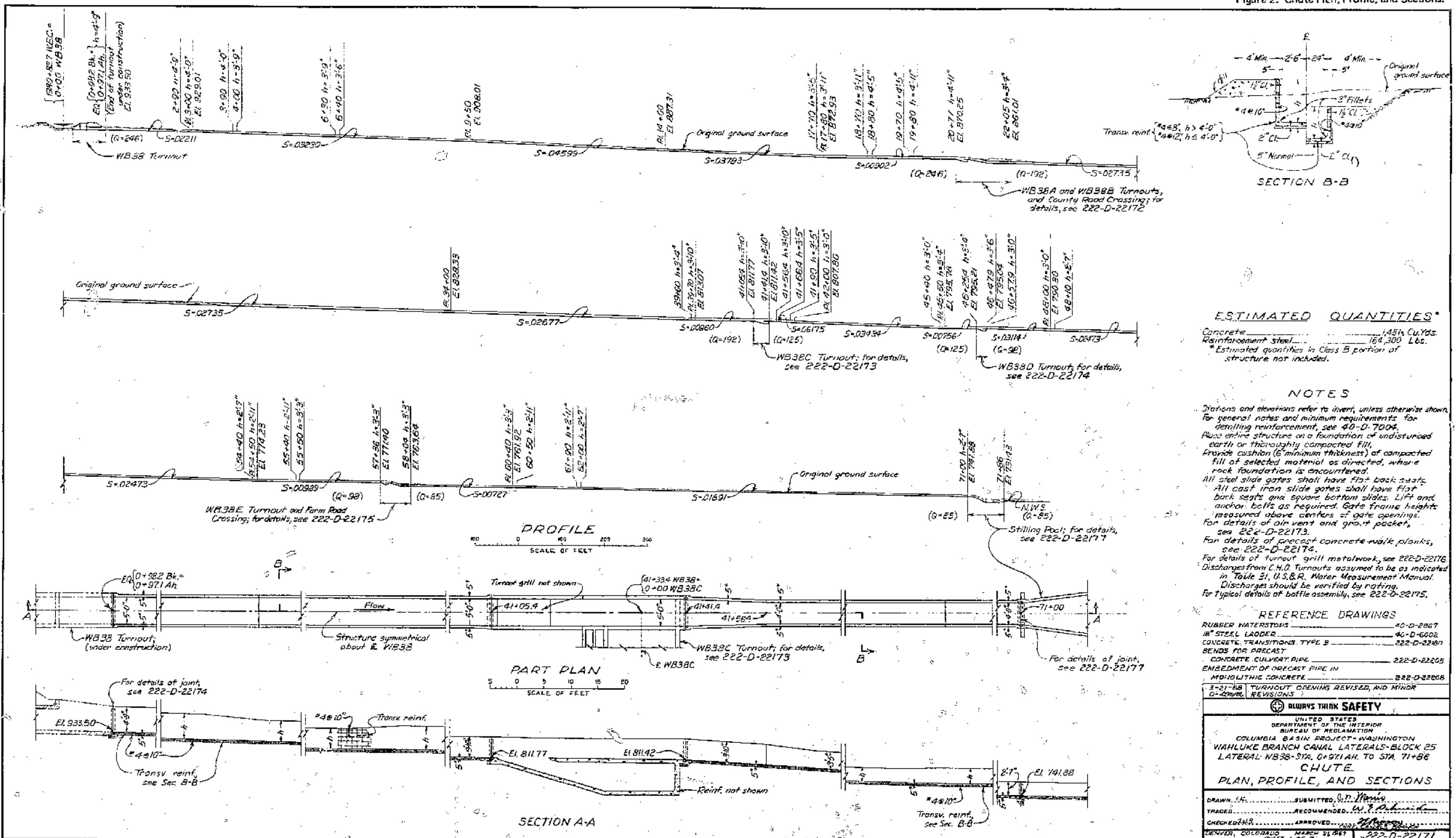
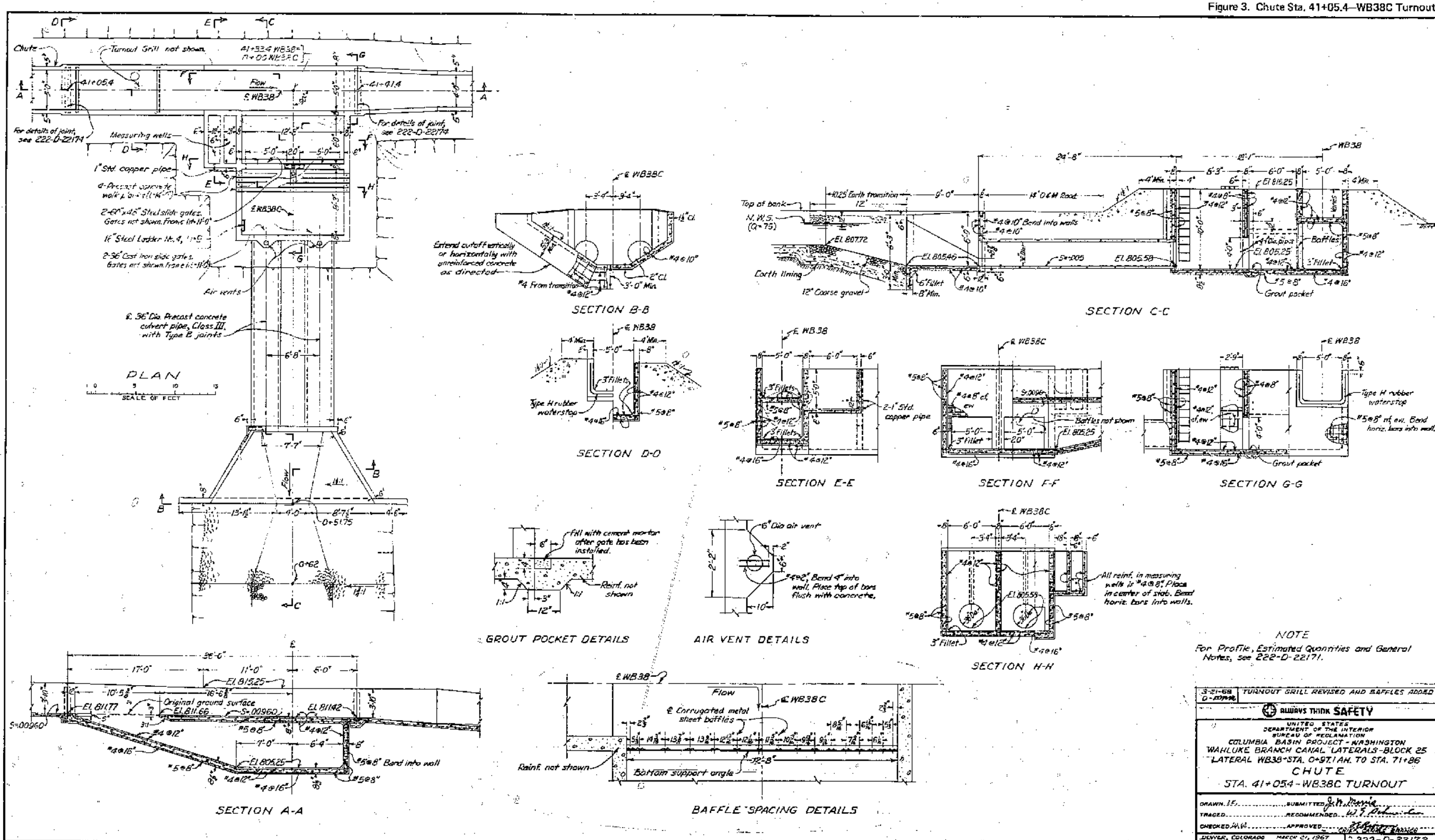


Figure 3. Chute Sta. 41+05.4–WB38C Turnout.



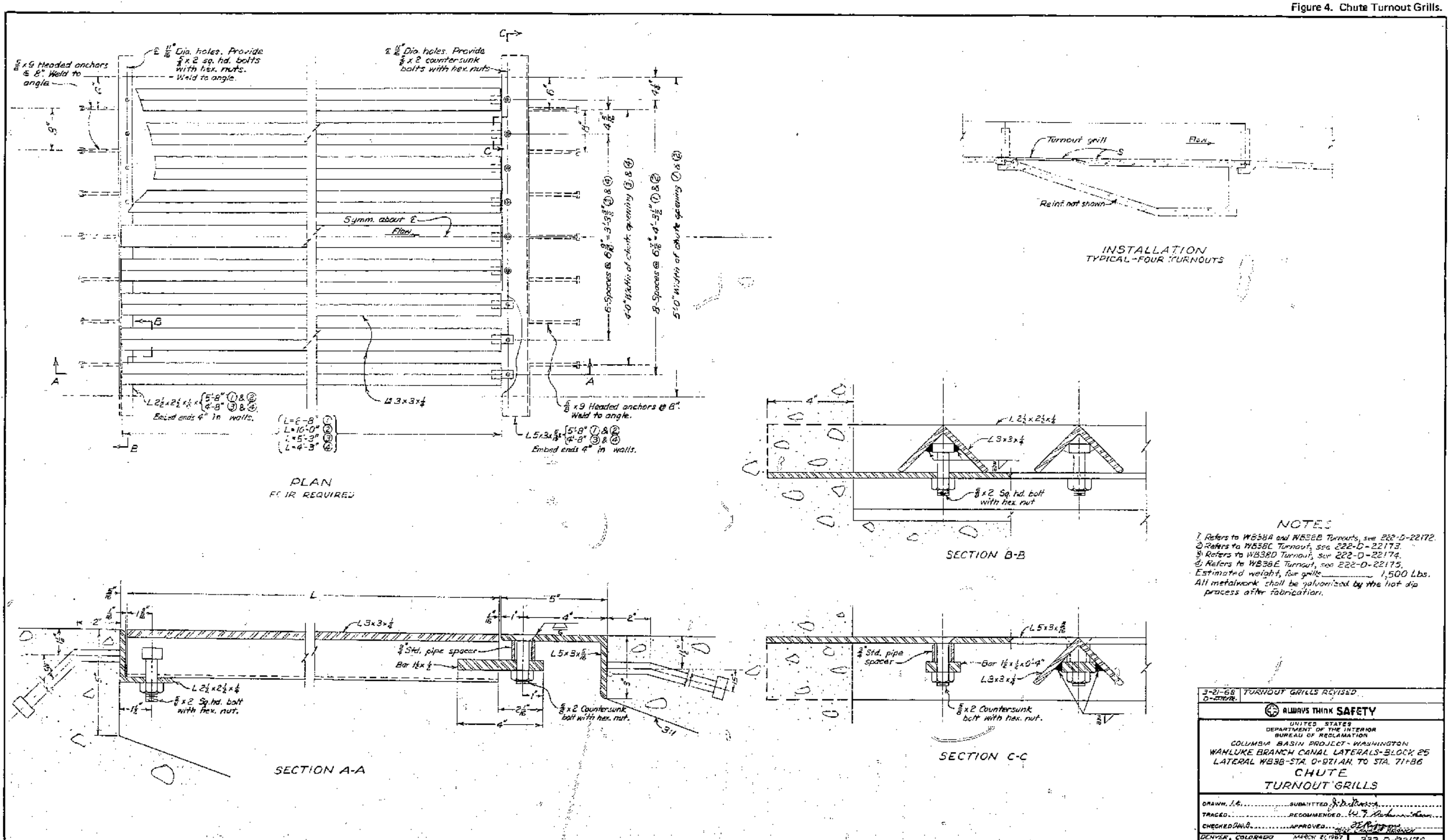
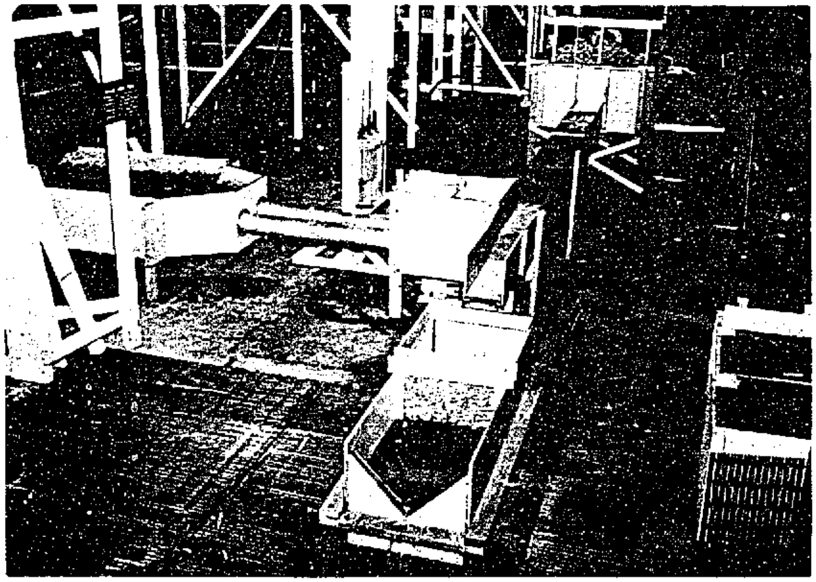
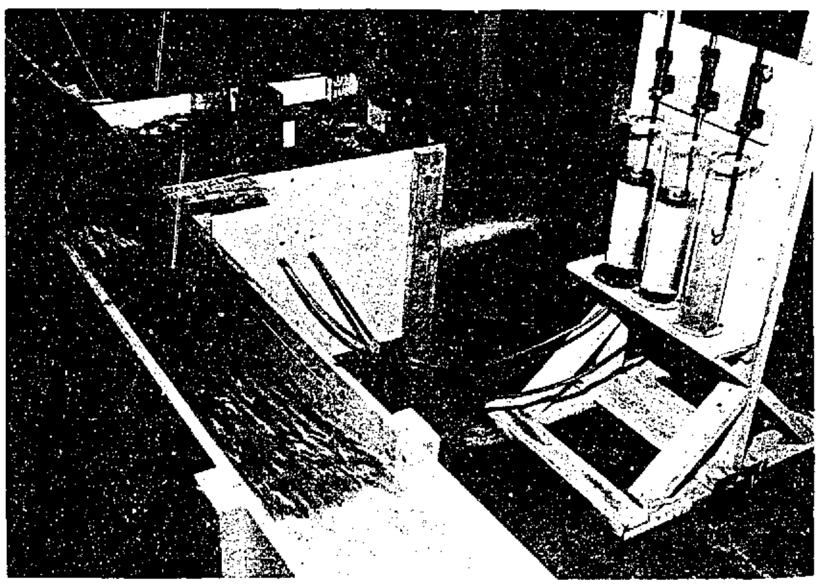


Figure 4. Chute Turnout Grills.

Figure 5



General view looking upstream along chute showing the head box and vee-notched wier box with the constant-head orifice turnout, pipe culverts, and canal lateral extending to the left. Photo P222-D-67488



Looking downstream showing the turnout grill and the constant-head orifice structure with the two head gages to regulate the flow diverted from the chute. Photo P222-D-67490

WAHLUKE BRANCH CANAL
1:6 SCALE MODEL PRELIMINARY DESIGN

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Figure 6. Preliminary Chute Sta. 41+05.4—WB 38C Turnout.

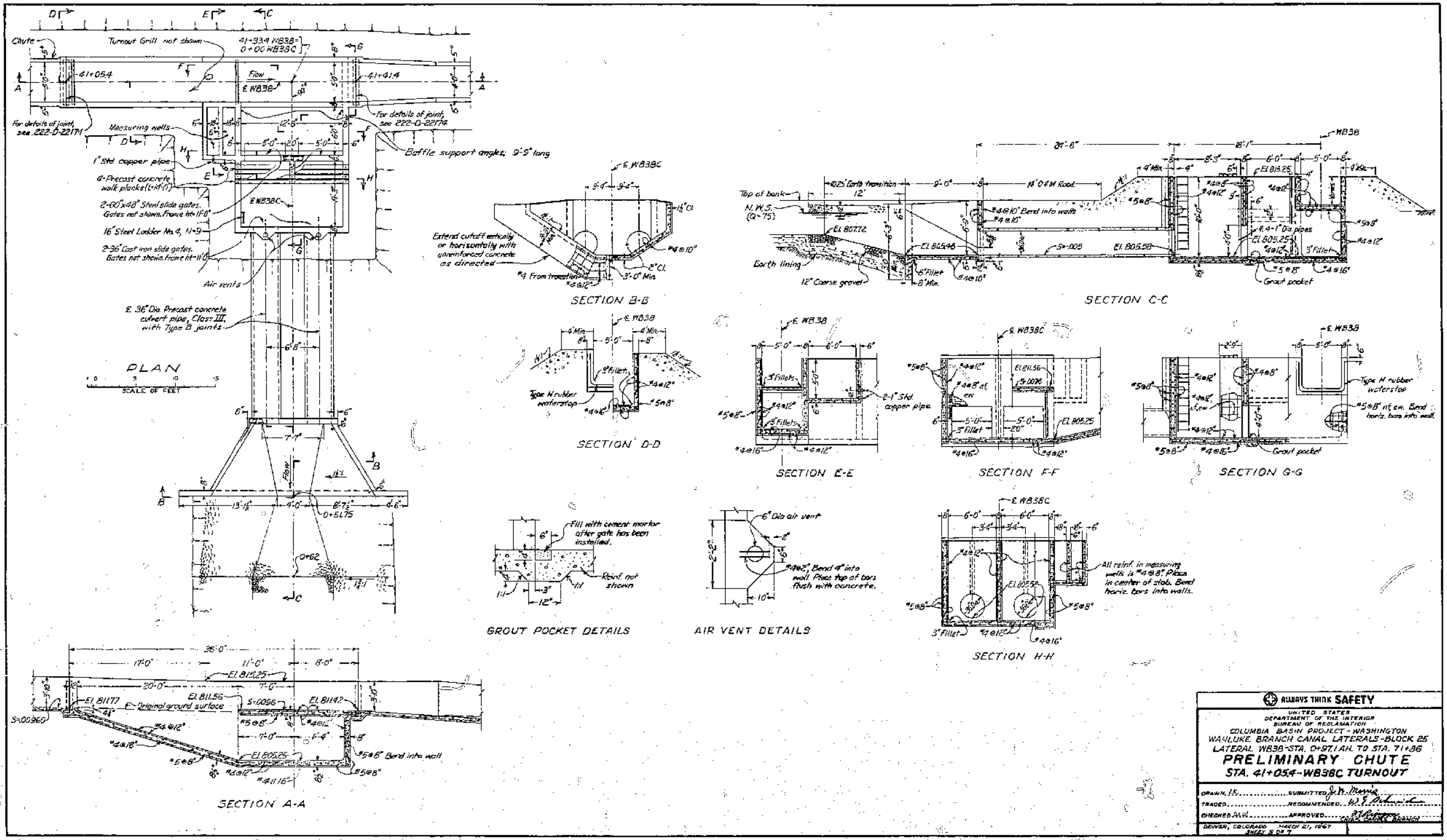
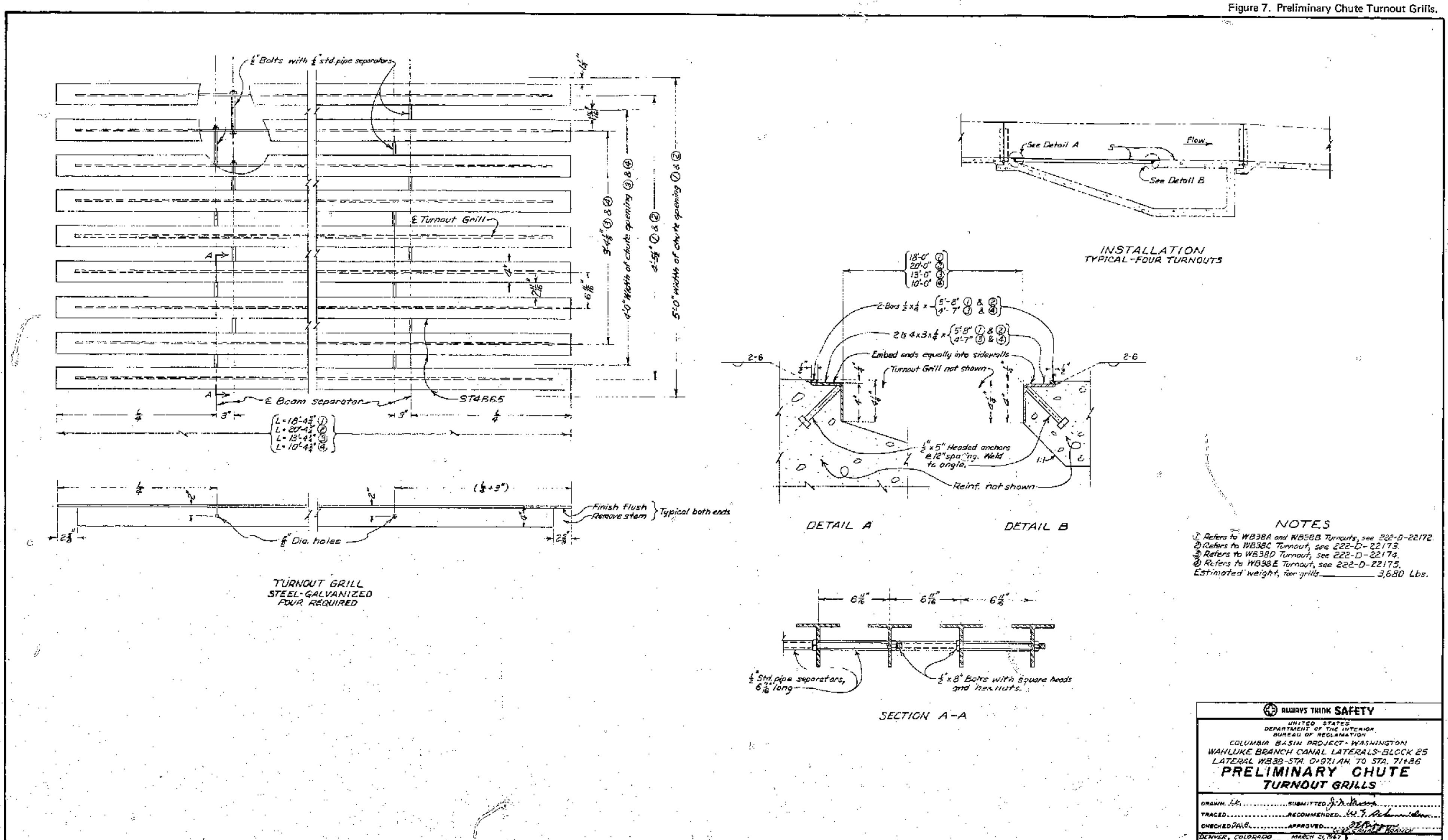
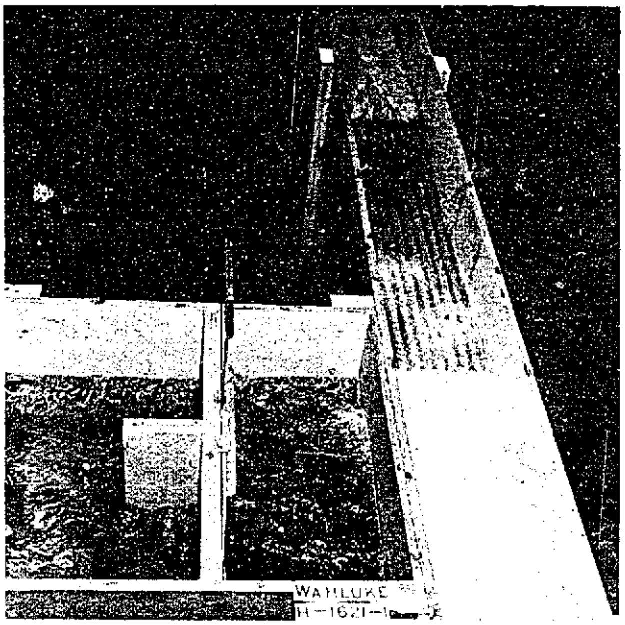
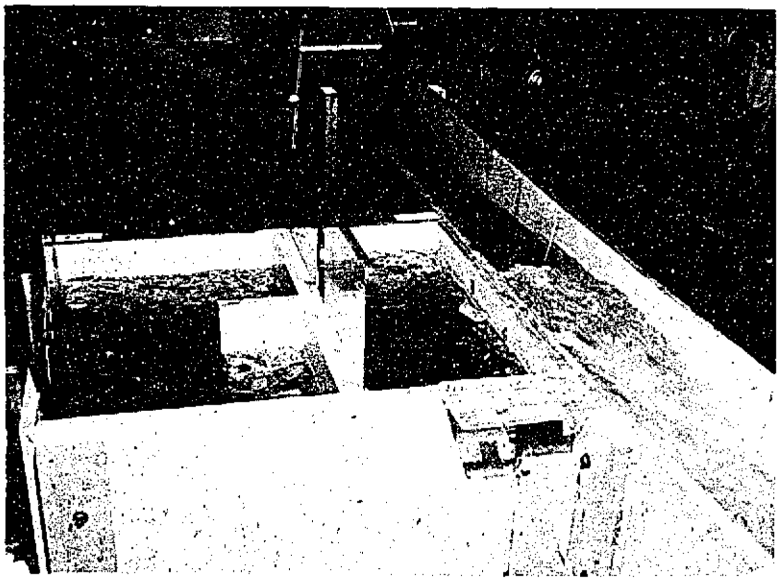


Figure 7. Preliminary Chute Turnout Grills.





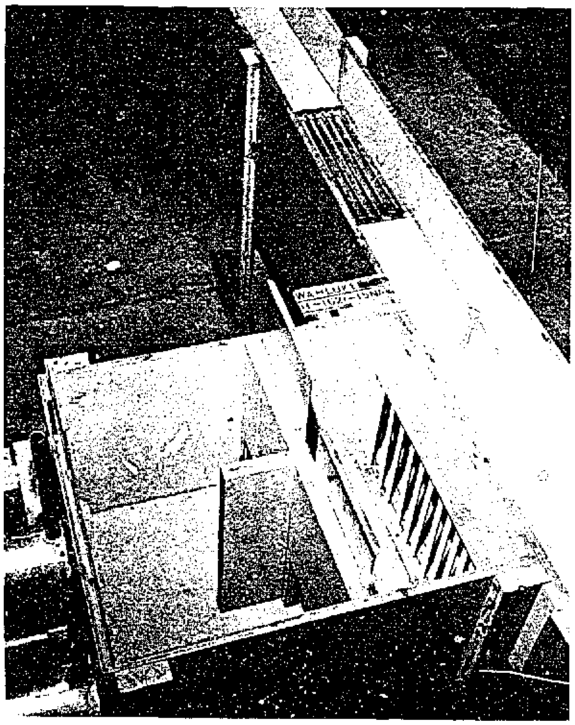
Chute flow is 75 cfs (2.12 cms) with 73 cfs (2.07 cms) diverted. Photo P222-D-67487



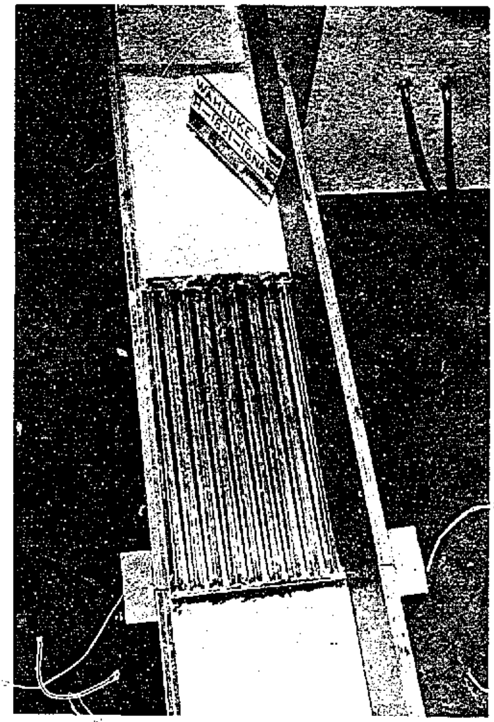
Chute flow is 192cfs (5.43 cms) 75 cfs (2.12 cms) in turnout. Photo P222-D-67489

WAHLUKE BRANCH CANAL
PRELIMINARY DESIGN OPERATION
1:6 SCALE MODEL

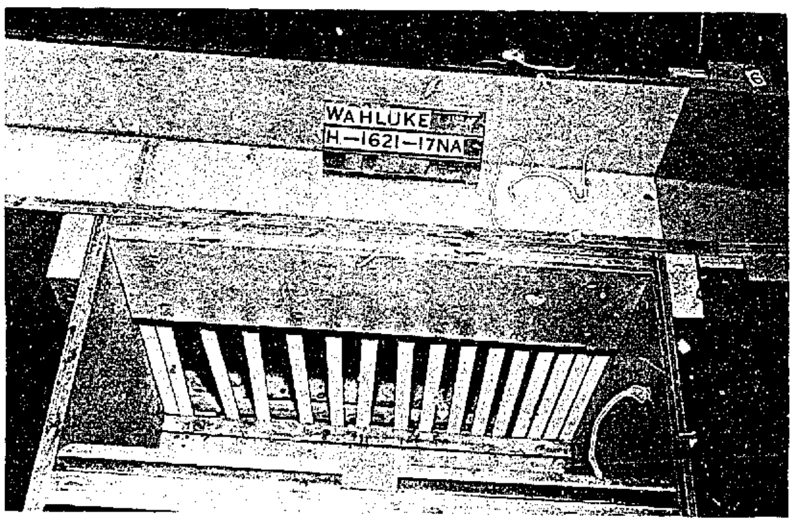
Figure 9



General view looking upstream. Photo P222-D-67491

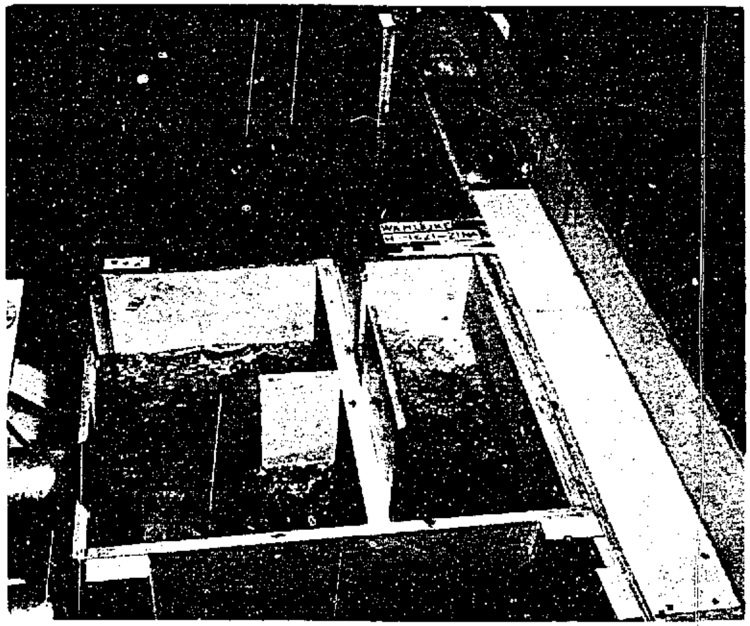


Grizzly looking downstream. Photo P222-D-67492

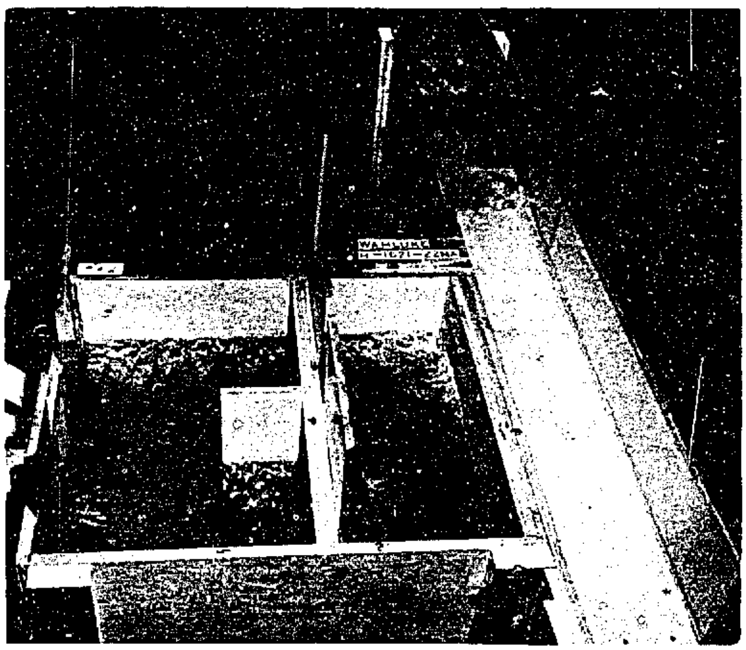


Baffled turnout looking upstream. Photo P222-D-67493

WAHLUKE BRANCH CANAL
MODEL VIEWS OF RECOMMENDED DESIGN
1:6 SCALE MODEL



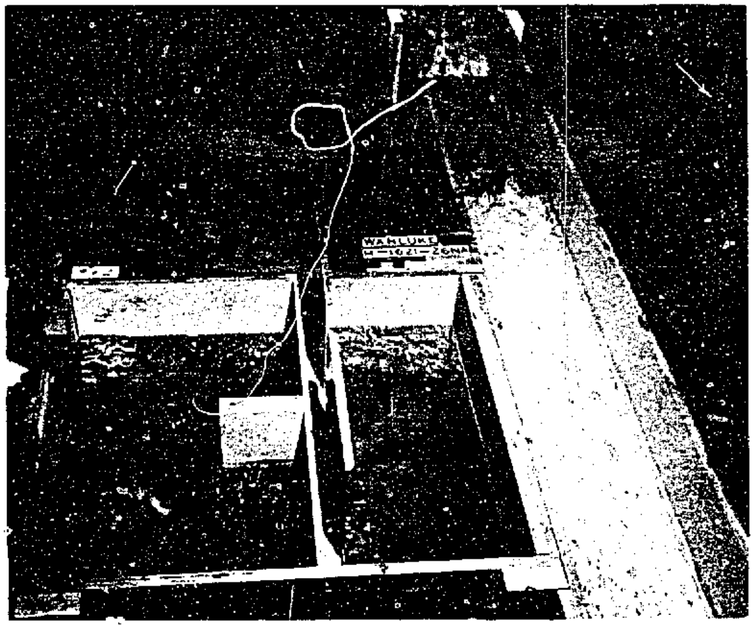
Chute flow is 75 cfs (2.12 cms). Photo P222-D-67494



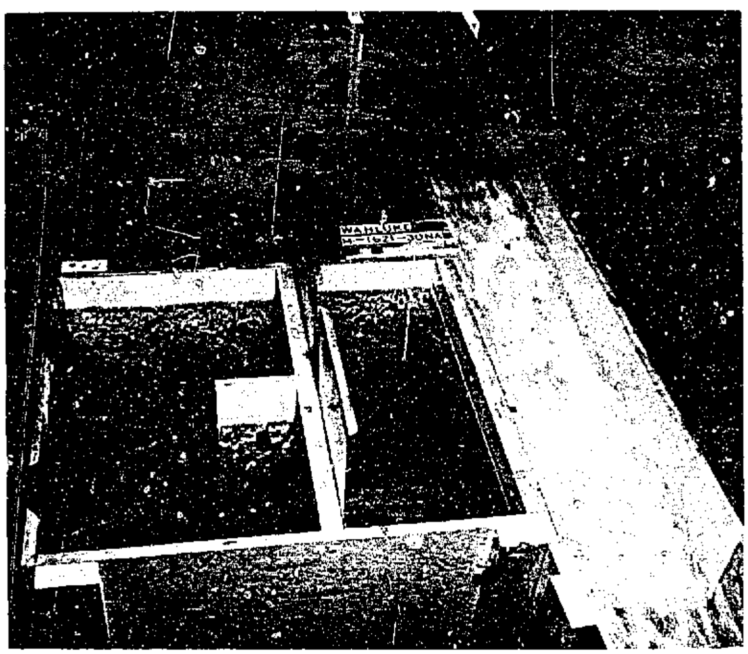
Chute flow is 80 cfs (2.26 cms). Note: 75 cfs (2.12 cms) in turnout. Photo P222-D-67495

WAHLUKE BRANCH CANAL
RECOMMENDED DESIGN OPERATION
1:6 SCALE MODEL

Figure 11



Chute flow is 95 cfs (2.69 cms). Photo P222-D-67496



Chute flow is 192 cfs (5.43 cms). Note: 75 cfs (2.12 cms) in turnout. Photo P222-D-67497

WAHLUKE BRANCH CANAL
RECOMMENDED DESIGN OPERATION
1:6 SCALE MODEL

CONVERSION FACTORS--BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, E 380-68) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given in the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg; that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Where approximate or nominal English units are used to express a value or range of values, the converted metric units in parentheses are also approximate or nominal. Where precise English units are used, the converted metric units are expressed as equally significant values.

Table I

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
LENGTH		
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
	0.3048 (exactly)*	Meters
	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
	1.609344 (exactly)	Kilometers
AREA		
Square inches	6.4516 (exactly)	Square centimeters
Square feet	929.03*	Square centimeters
	0.092903	Square meters
Square yards	0.836127	Square meters
Acres	0.40469*	Hectares
	4,046.9*	Square meters
	0.0040469*	Square kilometers
Square miles	2.58999	Square kilometers
VOLUME		
Cubic inches	16.3871	Cubic centimeters
Cubic feet	0.0283168	Cubic meters
Cubic yards	0.764555	Cubic meters
CAPACITY		
Fluid ounces (U.S.)	29.5737	Cubic centimeters
	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
	0.473166	Liters
Quarts (U.S.)	946.358*	Cubic centimeters
	0.946331*	Liters
Gallons (U.S.)	3,785.43*	Cubic centimeters
	3.78543	Cubic decimeters
	3.78533	Liters
	0.00378543*	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	764.55*	Liters
Acre-feet	1,233.5*	Cubic meters
	1,233,500*	Liters

Table II

QUANTITIES AND UNITS OF MECHANICS

Multiply	By	To obtain
	MASS	
Grains (1/7,000 lb)	64.79891 (exactly)	Milligrams
Troy ounces (480 grains)	31.1035	Grams
Ounces (avdp)	28.3495	Grams
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Short tons (2,000 lb)	907.185	Kilograms
	0.907185	Metric tons
Long tons (2,240 lb)	1,016.05	Kilograms
	FORCE/AREA	
Pounds per square inch	0.070307	Kilograms per square centimeter
	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
	47.8803	Newtons per square meter
	MASS/VOLUME (DENSITY)	
Ounces per cubic inch	1.72999	Grams per cubic centimeter
Pounds per cubic foot	16.0185	Kilograms per cubic meter
	0.0160185	Grams per cubic centimeter
Tons (long) per cubic yard	1.32894	Grams per cubic centimeter
	MASS/CAPACITY	
Ounces per gallon (U.S.)	7.4893	Grams per liter
Ounces per gallon (U.K.)	6.2362	Grams per liter
Pounds per gallon (U.S.)	119.829	Grams per liter
Pounds per gallon (U.K.)	99.779	Grams per liter
	BENDING MOMENT OR TORQUE	
Inch-pounds	0.011521	Meter-kilograms
	1.12985×10^{6}	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
	1.35582×10^{7}	Centimeter-dynes
Foot-pounds per inch	5.4431	Centimeter-kilograms per centimeter
Ounce-inches	72.008	Gram-centimeters
	VELOCITY	
Feet per second	30.48 (exactly)	Centimeters per second
	0.3048 (exactly)*	Meters per second
Feet per year	0.965873×10^{-6}*	Centimeters per second
Miles per hour	1.609344 (exactly)	Kilometers per hour
	0.44704 (exactly)	Meters per second
	ACCELERATION*	
Feet per second^2	0.3048*	Meters per second^2
	FLOW	
Cubic feet per second (second-feet)	0.028317*	Cubic meters per second
Cubic feet per minute	0.4719	Liters per second
Gallons (U.S.) per minute	0.06309	Liters per second
	FORCE*	
Pounds	0.453592*	Kilograms
	4.4482*	Newtons
	4.4482×10^{-5}*	Dynes
	WORK AND ENERGY*	
British thermal units (Btu)	0.252*	Kilogram calories
	1,055.06	Joules
Btu per pound	2.326 (exactly)	Joules per gram
Foot-pounds	1.35582*	Joules
	POWER	
Horsepower	745.700	Watts
Btu per hour	0.293071	Watts
Foot-pounds per second	1.35582	Watts
	HEAT TRANSFER	
Btu in./hr ft^2 deg F (k, thermal conductivity)	1.442	Milliwatts/cm deg C
	0.1240	Kg cal/hr m deg C
Btu ft/hr ft^2 deg F	1.4880*	Kg cal m/hr m^2 deg C
Btu/hr ft^2 deg F (C, thermal conductance)	0.568	Milliwatts/cm^2 deg C
	4.882	Kg cal/hr m^2 deg C
Deg F hr ft^2/Btu (R, thermal resistance)	1.761	Deg C cm^2/milliwatt
Btu/lb deg F (c, heat capacity)	4.1868	J/g deg C
Btu/lb deg F	1.000*	Cal/gram deg C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
	0.09290*	M^2/hr
	WATER VAPOR TRANSMISSION	
Grains/hr ft^2 (water vapor transmission)	16.7	Grams/24 hr m^2
Perms (permeance)	0.659	Metric perms
Perm-inches (permeability)	1.67	Metric perm-centimeters

Table III

OTHER QUANTITIES AND UNITS

Multiply	By	To obtain
Cubic feet per square foot per day (seepage)	304.8*	Liters per square meter per day
Pound-seconds per square foot (viscosity)	4.8824*	Kilogram second per square meter
Square feet per second (viscosity)	0.092903*	Square meters per second
Fahrenheit degrees (change)*	5/9 exactly	Celsius or Kelvin degrees (change)*
Volts per mil	0.03937	Kilovolts per millimeter
Lumens per square foot (foot-candles)	10.764	Lumens per square meter
Ohm-circular mils per foot	0.001662	Ohm-square millimeters per meter
Millicuries per cubic foot	35.3147*	Millicuries per cubic meter
Milliamps per square foot	10.7639*	Milliamps per square meter
Gallons per square yard	4.527219*	Liters per square meter
Pounds per inch	0.17858*	Kilograms per centimeter

GPO 830-619

ABSTRACT

A 1:6 scale model of a turnout from a Wahluke Branch Canal lateral chute was used to develop the hydraulic design of the entrance into the turnout. An efficient design consisting of a grill over an entrance in the chute floor was developed; a discharge coefficient was determined from the results for application to the design of similar turnouts. Baffle bars consisting of vertical strips of corrugated metal were developed to distribute the flow from the compartment beneath the floor of the chute into the constant-head orifice compartment. General guidelines were developed for using the baffle bars at other turnouts.

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DESCRIPTORS–/ laterals/ orifices/ *turnouts/ *grills/ *baffles/ canals/ *chutes/ Washington/ discharges/ hydraulic models/ hydraulics/ culverts/ Vee-notched weirs/ hydraulic jump/ discharge coefficients/ hydraulic design
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