MISCELLANEOUS PAPER H-68-1

RIPRAP PROTECTION FOR SUBIMPOUNDMENT DAMS, REND LAKE RESERVOIR, ILLINOIS

Hydraulic Model Investigation

by

N. R. Oswalt

June 1968

Sponsored by

U. S. Army Engineer District
St. Louis

Conducted by

U. S. Army Engineer Waterways Experiment Station
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ARMY-MRC VICKSBURG, MISS.

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
VICKSBURG, MISSISSIPPI 39181

REPLY REFER TO: WESHS

13 June 1968

SUBJECT: Model Study of Riprap Protection for Subimpoundment Dams, Rend Lake Reservoir

District Engineer
U. S. Army Engineer District, St. Louis
906 Olive Street
St. Louis, Missouri 63101

1. This letter is the final report of model tests of the "Big Muddy" Subimpoundment Dam, Rend Lake Reservoir, conducted at the Waterways Experiment Station during March and April, 1968. The purpose of these tests was to provide data needed to plan reconstruction of the "Big Muddy" and "Casey Fork" subimpoundment dams. As requested in your letter of authorization (Subject: Rend Lake Reservoir, Illinois - Riprap Protection, Subimpoundment Dam, Model Study) dated 21 February 1968, tests were conducted to determine the size riprap needed to insure stability of the crown and downstream slope of the "Big Muddy" and "Casey Fork" overflow embankments at the most severe flow conditions anticipated.

2. A 25 ft section of the overflow portion of the dam was installed in an existing 2.5-ft-wide flume at a scale of 1:10. The model reproduced a 10-ft-high section of the original dam shape, having upstream and downstream 1:3 slopes, a 13.58-ft-wide crest at elev. 412 with a 3.5 ft deep waterstop at the crest centerline (Incl 1). The thickness of riprap was 1 1/2 times the maximum stone diameter for all tests.

3. A total of six riprap gradations were used during the model test program. Gradations #1, #2 and #3 simulated, within model accuracy, the original design 12, 16 and 20 inch riprap, respectively, whereas, gradations #4, #5 and #6 simulated progressively larger stone (Incl 2 and 3). Riprap gradation #2 was used on the upstream slope and gradation #1 on the upstream side of the crown of the embankment as shown in Incl 1.

With this stone protection the upstream side of the embankment remained stable during all tests. Gradations #1, #4, #5 and #6 were tested on the downstream slope and the downstream side of the crest at unit discharges ranging from 6.2 cfs/ft (15,000 cfs) up to 18.0 cfs/ft (43,800 cfs). During tests with each discharge the tailwater was varied from several feet above to several feet below normal tailwater. With normal tailwater, free flow conditions existed at all discharges. The headpool versus discharge relationship for free flow over the embankment is given on Incl 4.

4. Total failure occurred on the downstream slope with gradation #1 as was experienced in the prototype. While maintaining a constant unit discharge of 12.3 cfs/ft (30,000 cfs) the tailwater was lowered from a submerged condition through the elevation at which initial stone movement occurred (elev. 413.0), then to normal tailwater (elev. 410.8), and finally down to total failure (elev. 410.4), where a mass movement of stone on the downstream slope left the core exposed. Total failure of gradation #1 (max. stone 170#) at other unit discharges also occurred very near the normal tailwater (Incl 5). Initial stone movement for various discharges is indicated on each tailwater versus unit discharge plot. The plots were made using unit discharge so that results could be readily correlated with design conditions at either of the two subimpoundment dams.

5. Gradation #4 (max. stone 400#) under exposure to identical test conditions was more stable than gradation #1 but total failure did occur with tailwater lowered only about 1.5 ft below normal tailwater (Incl 6). Total failure of gradation #5 (max. stone 780#) was not obtained until the tailwater was lowered 4 ft below normal for a 18 cfs/ft unit discharge. For lesser unit discharges considerable stone movement was evident though total failure never occurred (Incl 7). Gradation #6 (max. stone 1400#) remained essentially stable with only a few stones relocating during tests at the full range of discharge-tailwater conditions (Incl 8).

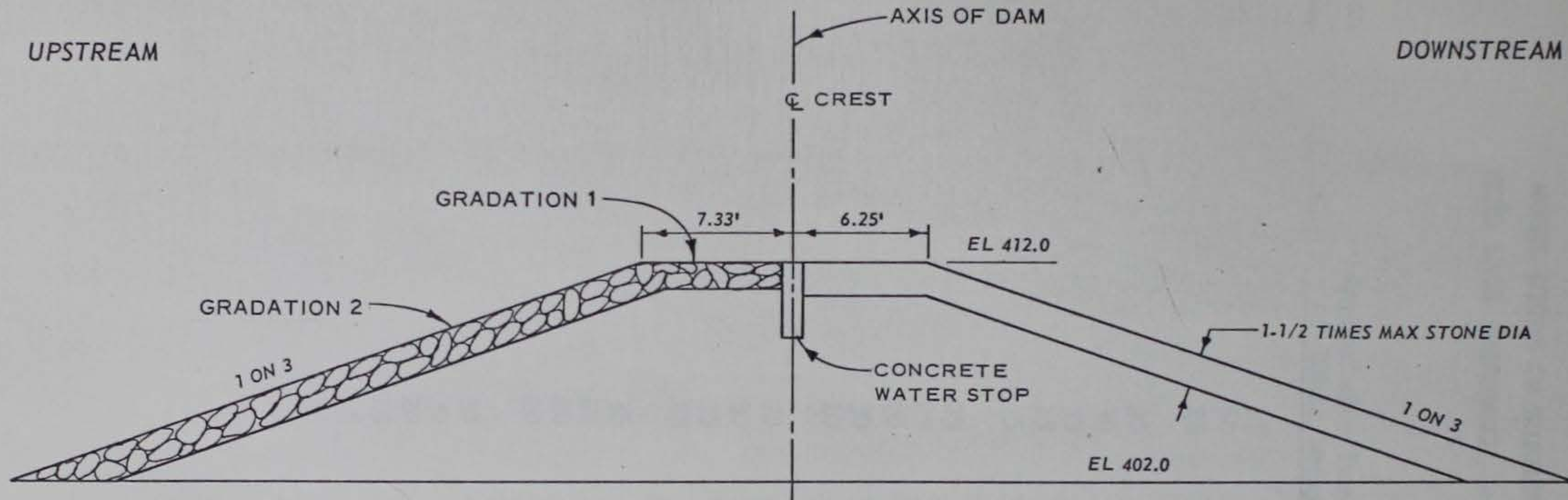
6. During gradation #6 testing, timbers simulating prototype logs and debris were floated over the dam during flows of 30,000 and 43,800 cfs with little effect on the riprap stability. In addition, a 5 ft dia. hole (Incl 9) was formed on the downstream slope before inducing flow to determine if failure would result from a local breach in the riprap. Under flows of 30,000 and 43,800 cfs with the tailwater varied from elev. 413 to 407, no serious stone movement resulted in the model (Incl 10).

7. Observation of flow patterns during various tests showed that when the structure is not submerged the jet flows down the rock slope until it reaches the tailwater where it changes directions quickly without penetrating deeply into the tailwater. The resulting flow pattern is characterized by standing waves on the water surface and a reverse roller underneath (Incl 11 and 12). With the tailwater at or near normal most of the stones displaced appear to come from the area where the jet intersects the tailwater. With the testing procedure, which involved setting a discharge with the structure submerged and then lowering the tailwater in finite steps, the point of most severe attack moved down the slope as the tailwater was lowered. It is speculated that in this region of intersection the interaction of the jet coming down the slope and the upstream undercurrent in the downstream roller result in a combined lift-drag force more conducive to stone movement than the predominately drag force exerted on the stones further up the slope.

8. On 26 April 1968, a conference was held at the Waterways Experiment Station to discuss model test results. At that time representatives of your office and the Lower Mississippi Valley Division were furnished preliminary copies of most of the material contained in this report. Following discussion of the test data and observation of tests of gradations #5 and #6 the conferees agreed that gradation #6 should provide satisfactory protection for the downstream face of the embankments at any anticipated flow condition. This gradation calls for a 50 percent size of about 550# (22-inch diameter sphere) with the maximum size stone weighing about 1400# (30-inch diameter). Provision of the 50 percent size is considered to be more important than holding to the exact gradation.

12 Incl (dupe)
as

Copies w/incl furnished:
LMVD
Mr. Douma, OCE



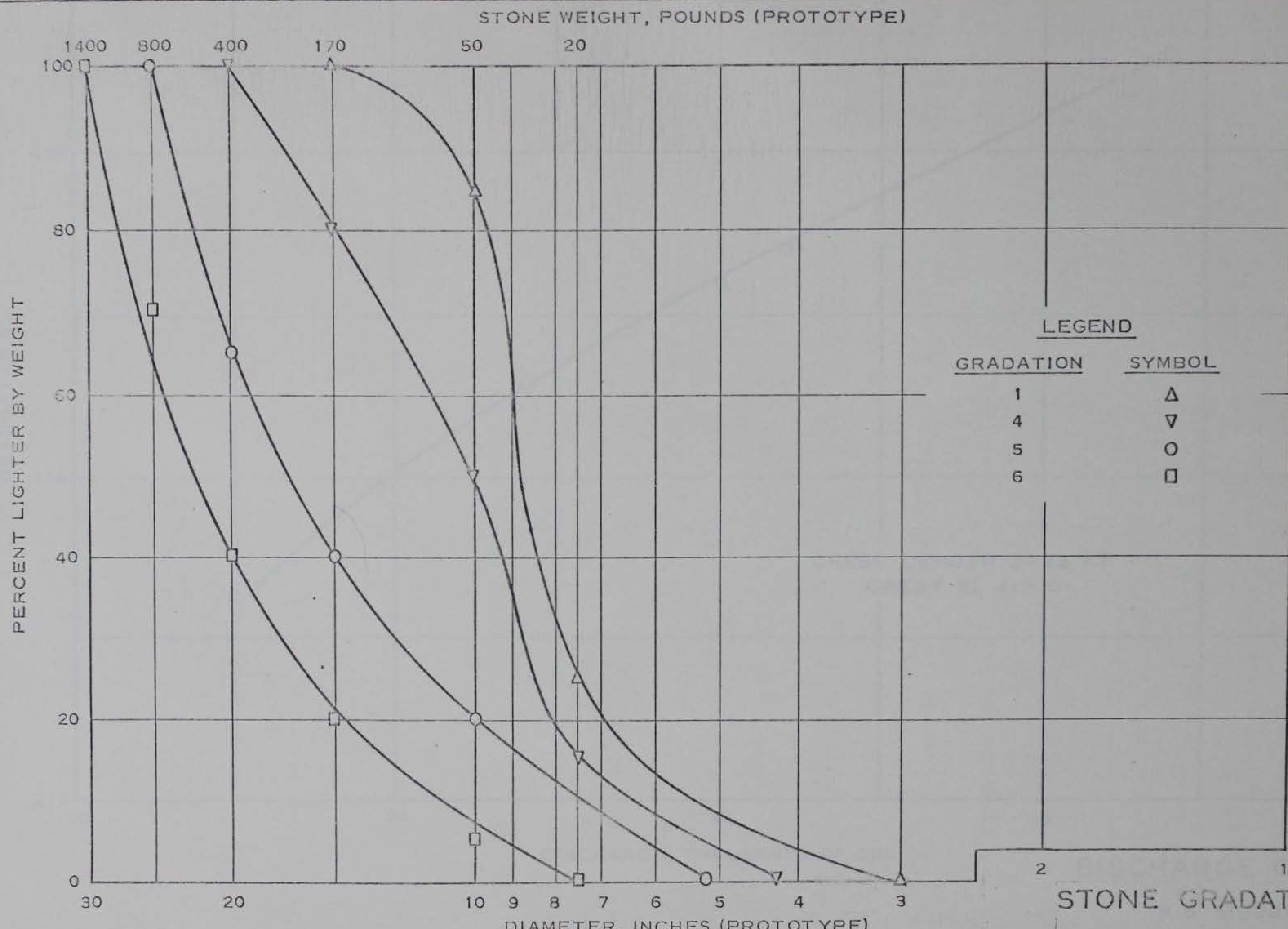
RIPRAP PROTECTION FOR
SUBIMPOUNDMENT DAMS
REND LAKE RESERVOIR

INCL 1

MODEL STUDY OF SUBIMPOUNDMENT DAMS -

REND LAKE RESERVOIR, RIPRAP GRADATIONS

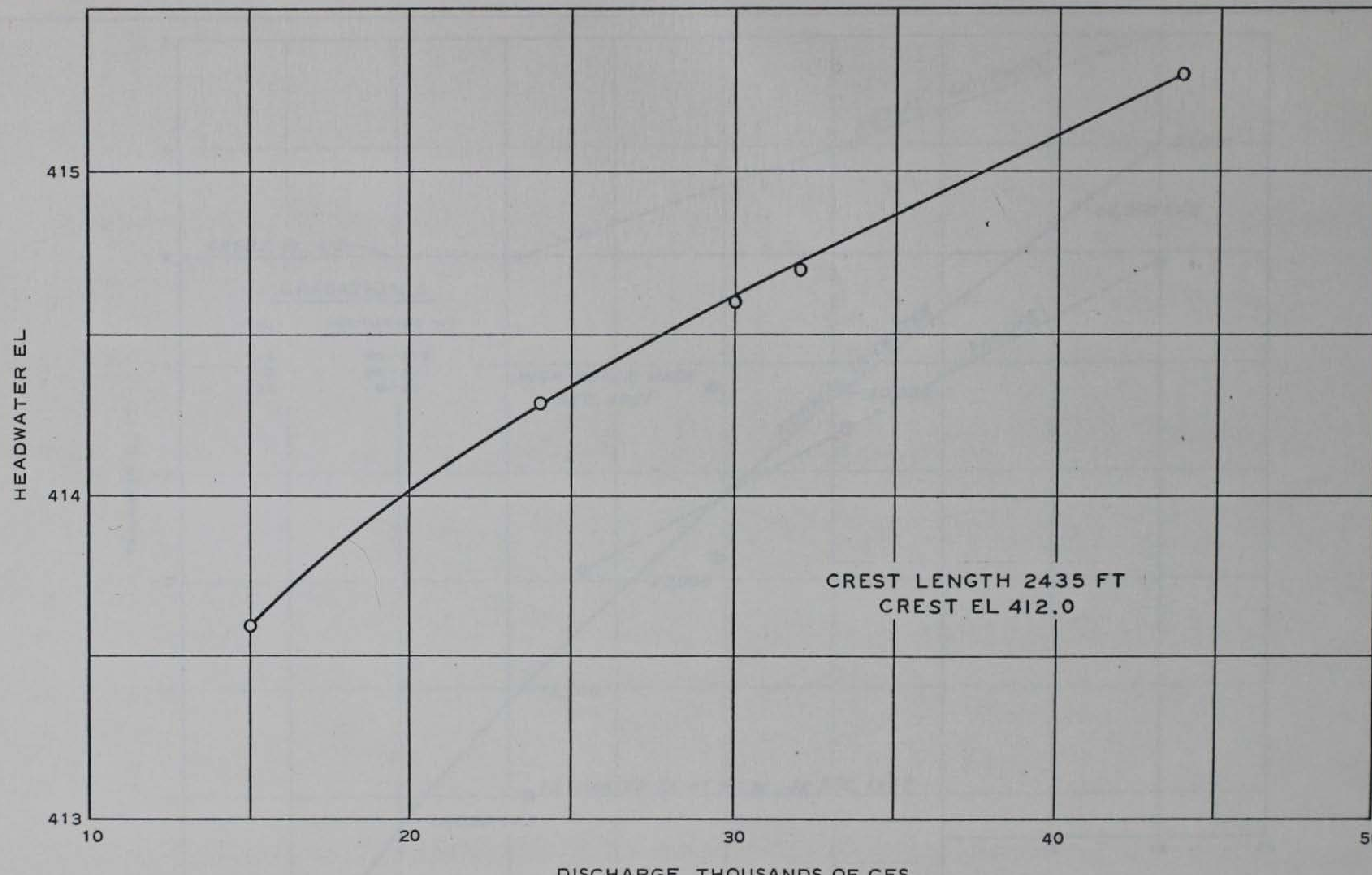
Gradation No.	Approximate Percent of Total Weight	Prototype Weight Pounds
1	15	50 - 170
	60	20 - 50
	25	6 - 20
2	20	200 - 400
	30	100 - 200
	35	20 - 100
	15	Less than 15
	5	Less than 3
3	25	350 - 700
	25	175 - 350
	20	90 - 175
	30	Less than 90
	10	Less than 15
4	20	170 - 400
	30	50 - 170
	35	20 - 50
	15	6 - 20
5	35	400 - 780
	25	170 - 400
	20	50 - 170
	20	20 - 50
6	30	780 - 1400
	30	400 - 780
	20	170 - 400
	15	50 - 170
	5	20 - 50



STONE GRADATION

2 1

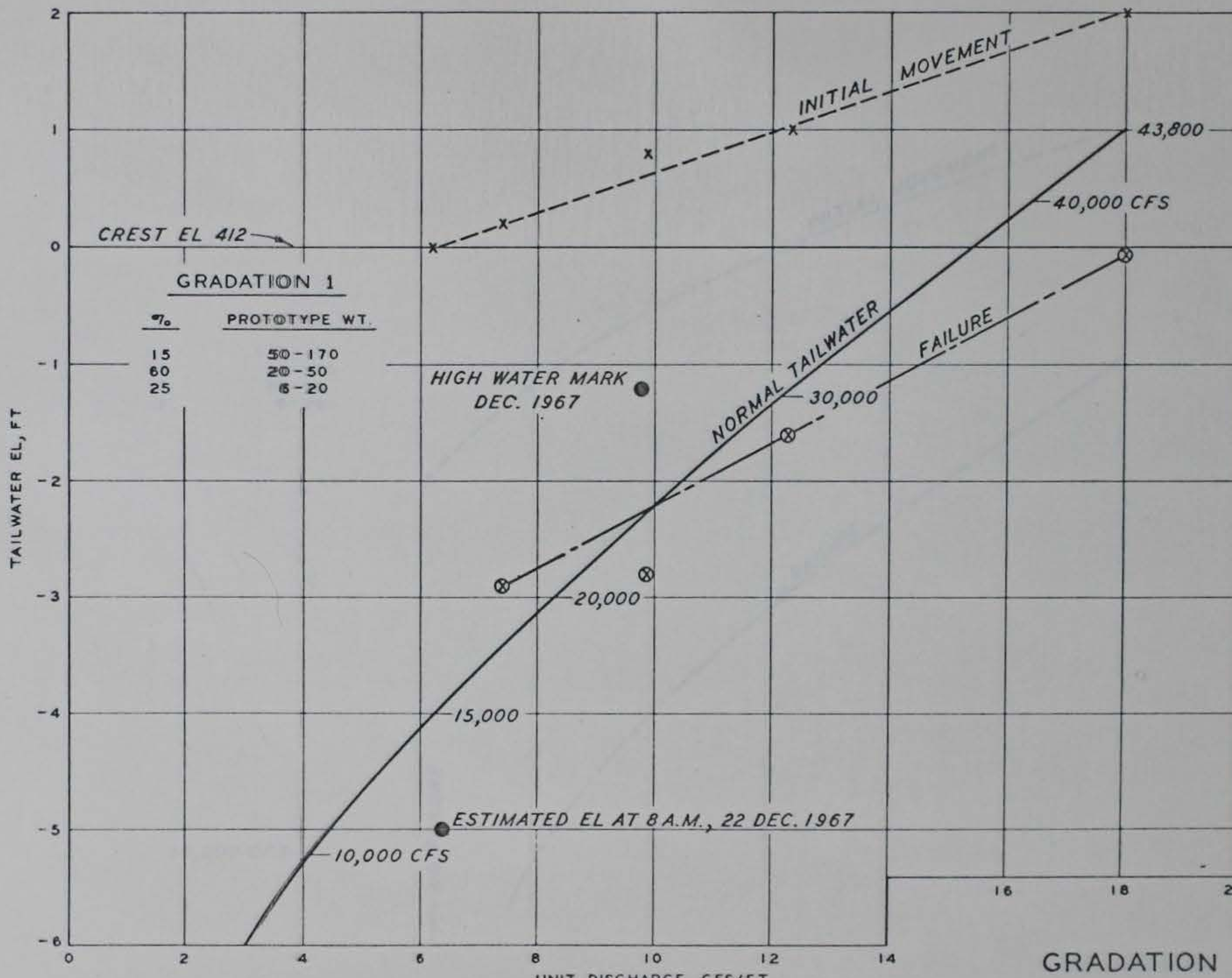
INCL 3



DISCHARGE CURVE

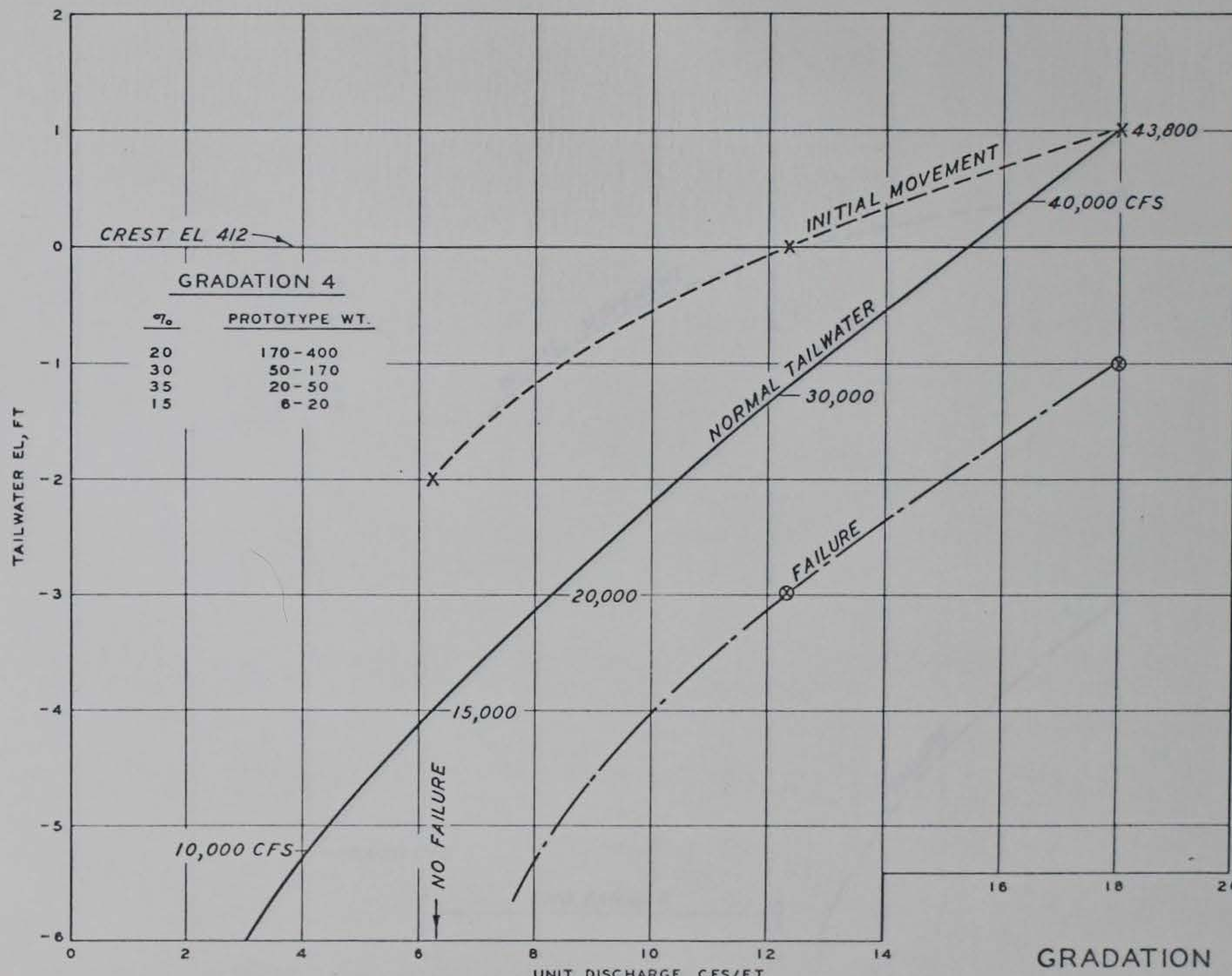
BIG MUDDY

INCL 4



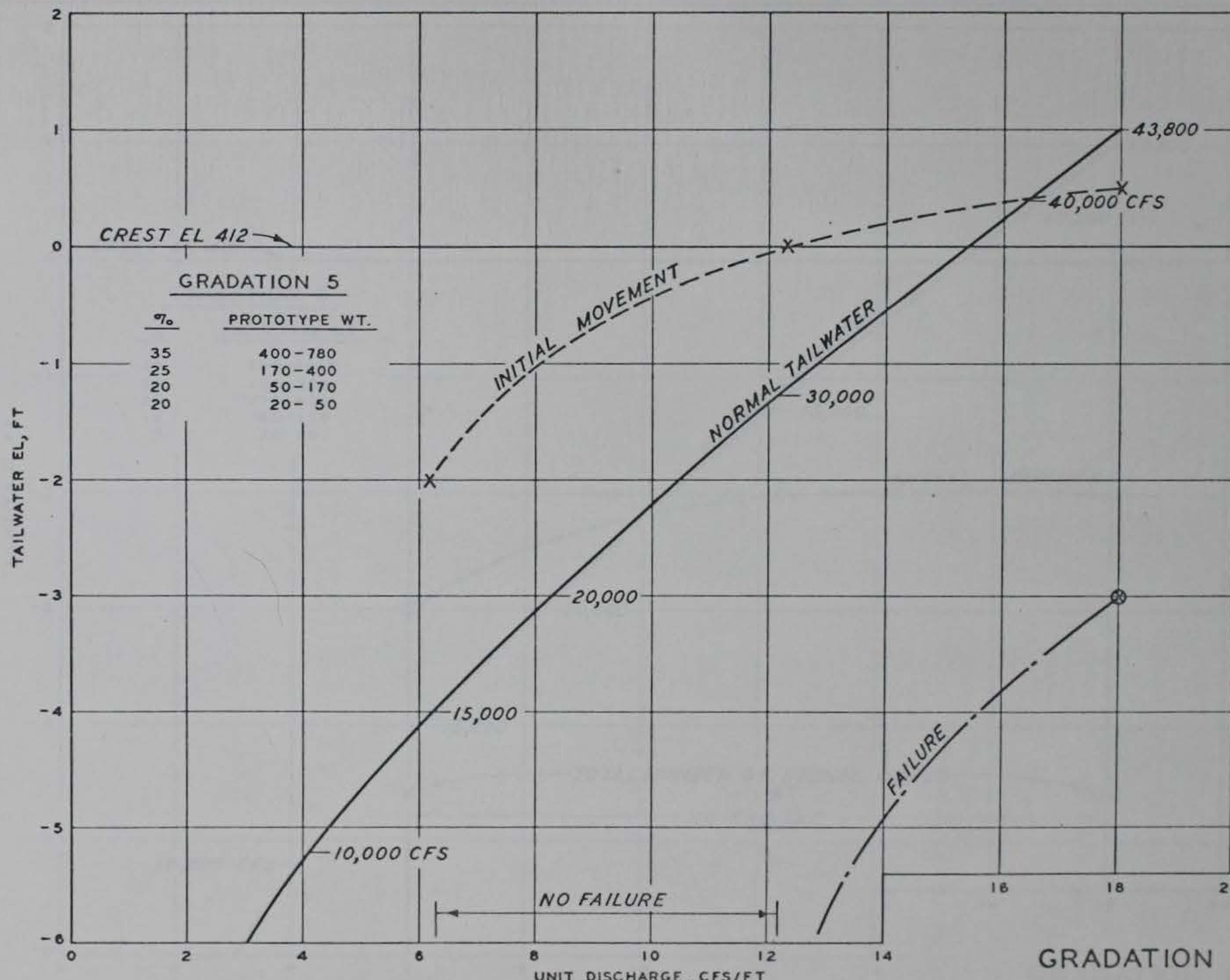
GRADATION 1

BIG MUDDY CREST LENGTH 2435 FT



GRADATION 4

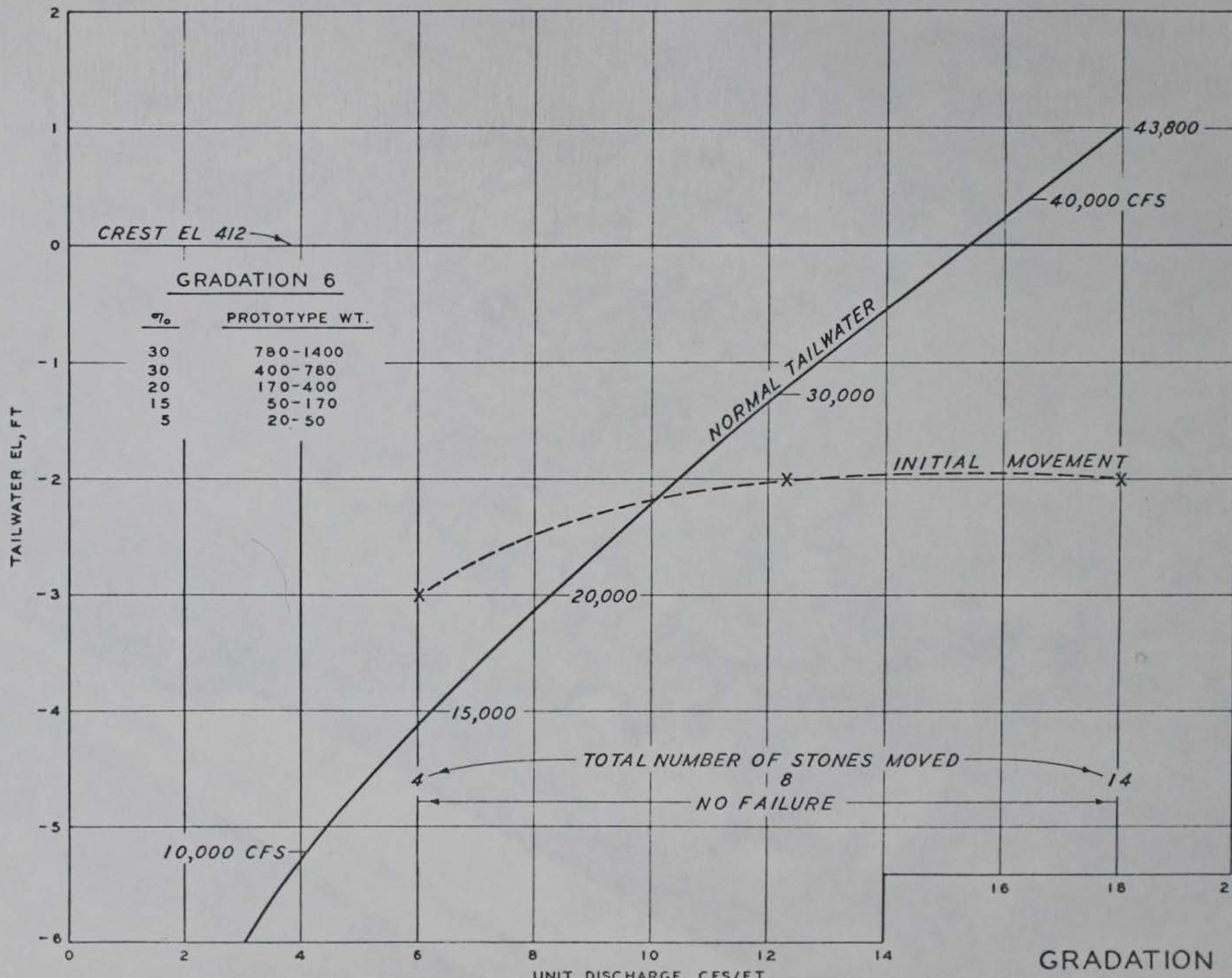
BIG MUDDY CREST LENGTH 2435 FT



GRADATION 5

BIG MUDDY CREST LENGTH 2435 FT

INCL 7



GRADATION 6

BIG MUDDY CREST LENGTH 2435 FT

INCL 9

SECTION MODEL OF RIPRAP PROTECTION FOR SUBIMPOUNDMENT DAM

REND LAKE RESERVOIR

Scale 1:10

Gradation #6 before testing.
Note the 5 ft dia area with stones removed.

INCL 10

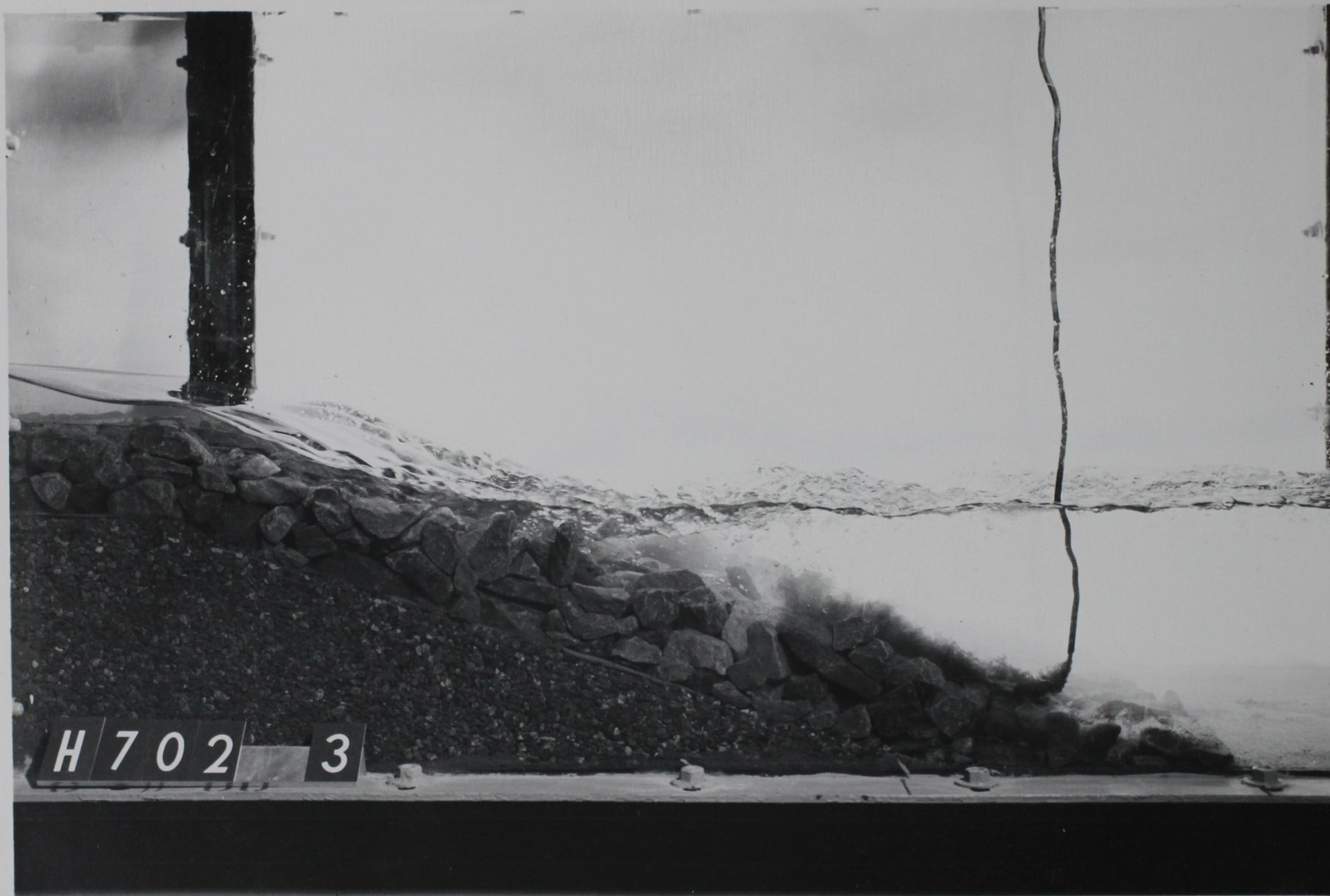
SECTION MODEL OF RIPRAP PROTECTION FOR SUBIMPOUNDMENT DAM

REND LAKE RESERVOIR

Scale 1:10

Gradation #5 after testing.

Q = 30,000 cfs	Q = 43,800 cfs
T. W. varied from (El. 412.0 / El. 407.0)	T. W. varied from (El. 413.0 / El. 407.0)



INCL 11

SECTION MODEL OF RIPRAP PROTECTION FOR SUBIMPOUNDMENT DAM

REND LAKE RESERVOIR

Scale 1:10

Gradation #5 during test
Q = 30,000 cfs
T. W. = 409.8 (1.0 ft below normal)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SECTION MODEL OF RIPRAP PROTECTION FOR SUBIMPOUNDMENT DAM

REND LAKE RESERVOIR

Scale 1:10

Gradation #5 during test
Q = 43,800 cfs
T. W. = 412.0 (1.0 ft below normal)