Bechtel Corporation

HEBGEN DAM, MONTANA POWER COMPANY

Effects of August 1959 Earthquake

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On September 11 and 12, 1959, J. G. Patrick and M. L. Dickinson of Bechtel inspected the damage to Hebgen Dam and visited the large landslide several miles downstream in the Madison River canyon caused by the earthquake of August 17, 1959. The Montana Power Company, owner of the dam, furnished plane transportation between Butte and West Yellowstone, Montana, and ground transportation at the site. Ray Ball, Chief Engineer, provided drawings and photos showing damage to the structures. Glen Jones, Construction Engineer, accompanied us on the inspection of both the dam and the landslide and furnished additional pertinent information concerning effects of the quake.

HEBGEN DAM

Hebgen Dam, which was constructed by the Montana Reservoir and Irrigation Company in 1914, is an earthfill about 90 feet high located on the Madison River approximately 20 miles northwest of West Yellowstone, Montana.

Fig. 1
LOCATION MAP
(AAA - N. W. States)

Details of the dam and its appurtenant structures as originally constructed are shown on Plate 1 (Drawing 31001-D). Geological sections developed from the core wall excavation, two exploratory shafts interconnected by an exploratory drift, and five core drill holes are shown on Plate 2 (Drawing 11403-E).

Bedrock, as indicated by the logs of the core drill holes, is predominantly limestone, somewhat weathered, with some intrusive veins of hard quartzite. No ! It is exposed in the precipitous left (south) abutment and is overlain by about 25 feet of streambed sands and gravels in the river section. The right (north) abutment is slide and slope wash material consisting of rock fragments in a sandy matrix with occasional lenses of water sorted material.

The dam is 20 feet wide and 720 feet long at the crest. The upstream shell has a slope of 3:1, and is constructed of relatively impervious materials presumably excavated from borrow pits in the reservoir. The downstream slope is 2-1/2:1, originally with two narrow berms which have since been eradicated by maintenance operations. The downstream shell is constructed of semi-pervious to pervious materials consisting of streambed sands and gravels and terrace talus material placed on top of an indefinite amount of rockfill from necessary structure excavation. It is probable that the fill was placed by mule-drawn scrapers without benefit of roller compaction.

The dam has a central vertical concrete core wall, 3-foot thick at the top throughout its length. The wall is battered and varies in section from 16-foot bottom thickness from the left abutment extending across the streambed to a 6-foot thick base beyond. It is founded on rock for a distance of about 570 feet north of the left abutment into the deep right bank terrace, at which point the base is stepped upward almost vertically for about 80 feet and continues into the right abutment on a talus foundation under the spillway. Vertical exploratory shafts were sunk to bedrock where the core wall leaves bedrock and in the abutment at the north side of the spillway. The two shafts were connected by an exploratory drift just above the rock surface.

The spillway control structure, located on the right abutment, consists of eight 7-foot wide by 13-foot high flashboard bays separated by 3-foot thick piers, and has an 18-inch thick flat floor slab and a 14-inch thick deck 16 feet wide. The spillway channel downstream from the control structure is a lined trapezoidal section with 4-inch thick plain concrete paving, having a bottom width of 56 feet and 1-1/2:1 side slopes on a 0.3 percent grade. The lower end tapers to a 40-foot bottom width on a steep grade to the river.

The low-level outlet structure, located on a rock bench cut into the base of the steep left abutment, consists of a low intake tower with a stoplog control and a 12-foot I. D. wood-stave lined, cast-in-place concrete culvert with an uncontrolled free discharge outlet.

The reservoir has a maximum water surface at elevation 6544.6, with an area of 13,500 acres and a capacity of 346,000 acre-feet. It was essentially full at the time of the quake.

EARTHQUAKE

The earthquake, which occurred at 11:38 p.m. on August 17, 1959, was estimated by Dr. J. Stewart Williams, seismologist, U. S. Coast and Geodetic Survey, to have had an intensity of approximately IX at West Yellowstone and probably about X at the epicenter, as measured by the Modified Mercalli Scale of XII.[1] The maximum intensity of the shock as reported by the University of

(1) Deseret News & Telegram, Salt Lake City, September 12, 1959

California was 7.8 on the Richter scale (10 maximum), as compared with 7.5 - 7.75 for the 1952 Bakersfield quake and 8.25 for the 1906 San Francisco earthquake.[1] The motion is reported by residents in the area to have been essentially vertical, with little or no sensation of horizontal movement.

Displacement occurred on two faults, tentatively designated the Hebgen and the Red Canyon faults, which run in a northwesterly-southeasterly direction north of Hebgen Lake.

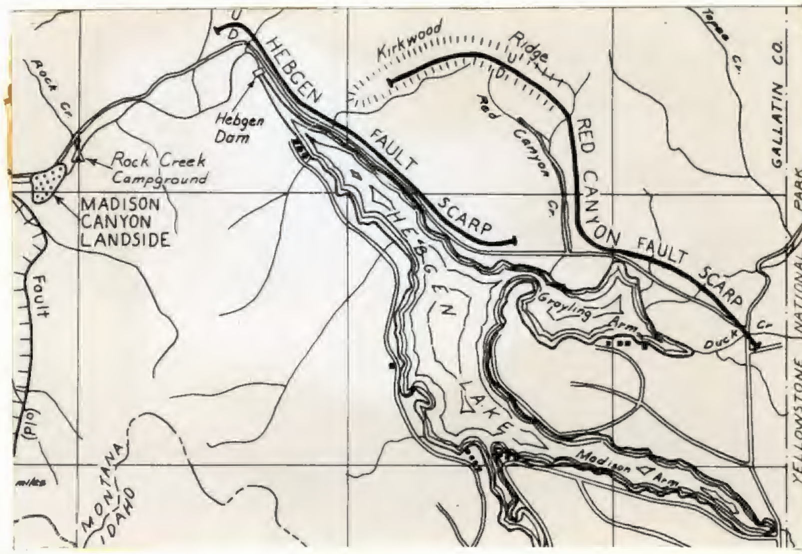

Fig. 2
MAP OF FAULTS
(GeoTimes, Oct. 1959)

The Hebgen fault is close to the north shoreline for several miles and is on the side hill of the north abutment only about 700 feet from the end of the dam.

Fig. 3
AIR VIEW OF HEBGEN DAM

Fig. 4
FAULT IN NORTH ABUTMENT

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(1) Engineering News-Record, August 27, 1959

Vertical displacement along the faults is clearly visible from the air throughout much of their length. A short distance downstream from the dam where they pass through a public campground, the vertical displacement is 12 to 15 feet, with an apparent down-thrust on the river side.

Fig. 5 Fig. 6

HEBGEN FAULT AT CAMPGROUND DOWNSTREAM FROM DAM

There is evidence of downward movement along a considerable length of the north shore line of the lake, as vegetation formerly at the high water line is now partially submerged. There also seems to have been some tilting of the reservoir area since some portions of the south shore are now several feet above water level. Apparently, however, the downward movement exceeded the uplift in the reservoir area, since the lake level lowered about 0.8 foot during the night. This represents about 10,000 acre-feet, which is far more than could be accounted for in discharge through the spillway and sloshing over the dam.

EFFECT ON DAM

Judging from the reported intensity of the earthquake, the observed length of the fault and the amount of its displacement, and the close proximity of the fault to the north abutment, the dam must have been subjected to tremendous disruptive forces. Subsequent to the earthquake, a careful survey was made to measure the deflections and settlements, which are shown in plan on Plate 3 (Drawing 140-59) and on three sheets of cross sections, Plates 4 - 6. Various elevations and distances in the vicinity of the left abutment, as measured in the recent survey, check relatively with previous measurements and, therefore, this abutment was assumed to have remained stable in measuring the movements. These quantitative data were supplemented by verbal information obtained in discussions with Ray Ball, Glen Jones, and the resident operator at the dam.

Embankment. Considerable settlement and cracking occurred in the earth embankment, generally small near the left abutment and a maximum from about the center of the dam northward to the right abutment. The crest settled approximately one foot for the first 300 feet from the left abutment, 1 to 2 feet in the next 300 feet, with a maximum of about 4 feet adjacent to the spillway.

Fig. 7
HEBGEN DAM - AIR VIEW
FROM RIGHT ABUTMENT
(Montana Power Co. Photo)

Fig. 8
CREST SETTLEMENT
ADJACENT TO SPILLWAY

The top of the upstream slope adjacent to the core wall also settled about one foot near the left abutment, increasing to a maximum of 5 to 6 feet about 350 feet from the left abutment, and then decreasing to approximately 3 feet adjacent to the spillway. Soundings taken on the submerged portion of the upstream face indicate some upward bulging of the lower portion, as might be expected. The amount of the bulge, however, could not be ascertained accurately since the only data for comparison are the theoretical original dimensions which are not believed to be accurate.

A number of intermittent longitudinal cracks, up to about 6 or 8 inches wide and several feet long, appeared in the crest in the northerly portion of the embankment near the spillway and in the upper portion of the upstream slope across its entire length. Those downstream from the core wall appeared to be due to settlement rather than to a major shear plane, while those on the upstream slope resembled the top cracking of a general slippage. Sudden drawdown in the wake of waves (see later) may have contributed to the upstream slope damage. There were no transverse cracks.

Core Wall. Assuming that the core wall remained stable at the left abutment, horizontal deflections and vertical settlements increase from this point northward across the dam. The top has a maximum downstream deflection of 0.8 foot about 200 feet north of the left abutment, which then decreases to zero deflection at a point about 415 feet from the left abutment, with an increasing upstream deflection north of this point reaching a maximum of 2.8 feet at the north end of the dam adjacent to the spillway. The 600± feet of core wall from the left abutment northward shows little or no settlement. Beyond this point, the settlement increases, reaching a maximum of 0.6 foot adjacent to the spillway.

Spillway. The spillway was discharging approximately 1,000 cfs over the flashboards at the time of the quake. The severe shock and the downward and outward movement of the right abutment terrace pushed the entire spillway about 1.8 feet into the dam, severely cracking the left headwall. The entire control structure settled about one foot, but remained substantially intact with the piers still vertical so that it was operable. The spill was shut off several hours later by installing additional flashboards. The lining of the trapezoidal spillway channel was severely disrupted just below the control structure and at several downstream locations. The flow through the control structure abetted this deterioration and the lower end of the spillway washed out, with a continuing progressive failure upstream until further damage was stopped by installing flashboards. Although the control structure is still operable, complete reconstruction will be necessary. Reservoir control is now being accomplished by the intake and the low level outlet conduit, which suffered only slight damage. By September 11, the reservoir had been drawn down about 50,000 acre-feet to elevation 6539, or 5 feet below the maximum.

Fig. 10
SPILLWAY CONTROL STRUCTURE
(M. P. Co. Photo)

Fig. 11
SPILLWAY CHUTE
(M. P. Co. Photo)

There is a 3-inch wide vertical crack in the core wall about 470 feet north of the left abutment, and three additional small cracks between this point and the spillway. While the core wall might be expected to crack at the point where the base was stepped vertically upward from rock to a foundation on deep overburden, the top of this crack is nearly 100 feet south of this point.

Fig. 9
CRACK IN CORE WALL

At the time of our inspection, an exploratory shaft was being excavated adjacent to the crack on the downstream side of the core wall. Although this had reached a depth of only about 10 feet at the time, the gravelly material was becoming increasingly dry, indicating that the upper portion had been saturated by surface water rather than by seepage through the crack.

Apparently there is but little leakage through the core wall as a result of the cracking. Originally there was some concern in this respect since a considerable seepage flow issued from the river bank of the terrace near the downstream toe of the dam. As soon as flow through the spillway was shut off, however, this seepage stopped and it became apparent that the flow entered the terrace material from the broken spillway channel lining rather than by seepage through the dam.

Waves. The resident operator of the dam lives in a cottage along the main road approximately 1500 feet downstream from the dam. At the first shock of the earthquake, which occurred during the night, he rushed out to the road, which is adjacent to the river. It was bright moonlight, and visibility was good. He first noted a greatly increased flow in the river and, thinking that the dam might have failed, ran up the road to higher ground where it crosses the right abutment. He then saw that the badly disrupted spillway was probably the cause of the increased flow. He noted, however, that water had apparently flowed over the top of the dam. According to his report, within the next few minutes a large wave or swell travelled down the reservoir, rode up the upstream face and poured over the core wall to a depth of about 3 feet. As the wave receded, a deep trough developed and, judged from the height of the intake structure, exposed a vertical depth of approximately 30 feet of the upstream face below the water surface. Subsequently, two similar waves of long duration flowed over the core wall at intervals of several minutes, likewise causing deep troughs in their wake. It thus seems apparent that at least four waves (one before the operator arrived) overtopped the dam.

Fig. 12
HEIGHT OF WAVE
(M. P. Co. Photo)

It seems somewhat doubtful, however, that the waves actually flowed in a 3-foot depth of solid water over the top of the core wall. The erosion of the downstream slope was less severe than might be expected if that much water had overpoured the core wall on four successive occasions. Numerous small gulleys, generally about 12 to 18 inches deep with maximum spot depths of as much as 3 feet, were created but there was no general washout of a substantial amount of material. Furthermore, and probably more significant, there is a small wood frame valve house approximately one-third the distance down the downstream slope and about 100 feet north of the left abutment. The foundation timbers of this structure are partially rotted and it would not have been difficult to overturn the house. The structure, however, although slightly canted and somewhat eroded around the base, was still essentially in place. It is doubtful that it could have withstood flows of water such as the operator described as overtopping the dam. It seems more reasonable that the waves riding down the reservoir and up the upstream slope created a large splash as they hit the 3 to 5 feet of exposed vertical face of core wall, thus creating an impression of considerably greater height.

One further observation, however, seems pertinent. The concrete core wall which remained essentially intact with but minor settlement, may have been a substantial factor in preventing more serious damage and possible failure of the dam by the wave overtopping. If there had been no core wall, the substantial settlement of the dam would have permitted the waves to overtop the crest to a considerably greater depth. The much greater flow might have been sufficient to have cut flow channels through the crest, with the possibility that continuing progressive failure might have destroyed the dam. Thus, the outdated use of a vertical concrete core wall may have been a significant factor in preventing a much greater catastrophe.

Roads. The main access road, State Highway 287 from West Yellowstone down the Madison River canyon, was severely disrupted at several locations, especially where the road was on fill, such as adjacent to small bridges. At these locations, the fill flattened out, causing deep cracks in the road surface with abrupt vertical offsets where the fill settled adjacent to bridge abutments. This type of damage, although rather extensive, was relatively easy to repair. Little damage occurred to the concrete bridges, perhaps because they are founded on firm material.

Fig. 13
TYPICAL DAMAGE TO STATE
HIGHWAY 287 AT SMALL BRIDGE
(M. P. Co. Photo)

Two major slides occurred on the north rim of the reservoir, each destroying several hundred feet of the road. These slipouts were the major damage and required construction of bypass sections uphill from the slides.

MADISON CANYON SLIDE

The Madison River canyon downstream from Hebgen Dam is relatively narrow and deep. About seven miles downstream from the dam and approximately one mile before the river emerges into a wide, flat valley, a major landslide occurred in the left (south) canyon wall. At this point, the steep slope of schist and gneiss, supported near the base by a buttress of stronger dolomite, rose approximately 1300 feet above streambed level. The shock of the earthquake triggered a slide along planes of weakness in the weathered schist on a face oriented a little upstream of parallel to the river with its top extending slightly back of the crest of the ridge. The volume of rock involved was about 43,000,000 cubic yards.[1] The slide must have moved at an extremely fast rate, since there is considerable evidence that its descent was so sudden that it entrapped large volumes of air and, in effect, rode on compressed air. It is also reported by survivors and substantiated by some physical evidence that a violent wind was induced in the canyon. Nine bodies were recovered from campgrounds near the fringe of the slide and nineteen missing persons are believed to be buried beneath the slide.

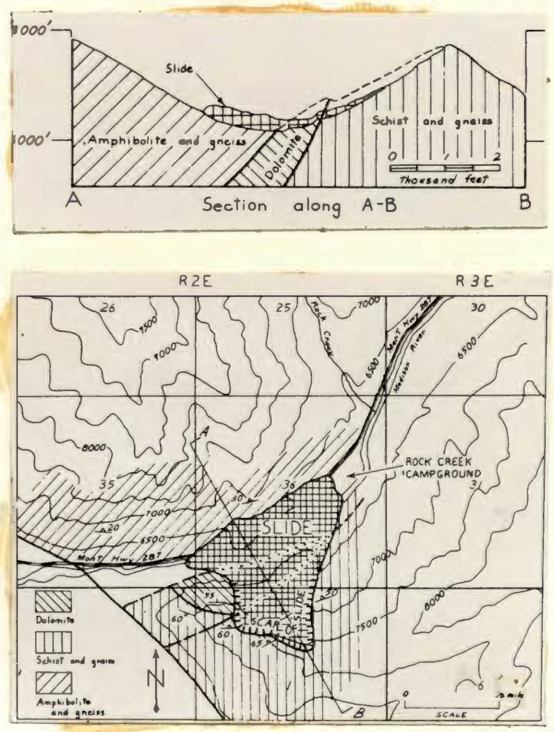


Fig. 14
DIAGRAM OF LANDSLIDE
(GeoTimes, Oct. 1959)

(1) Civil Engineering, October 1959

The slide filled the canyon to a depth of 220 feet above streambed at its low point and rode up the far side against the right canyon wall to a height of 400 feet above streambed, the furthest travel being nearly 5000 feet from the face. It filled the canyon for a length of approximately 4500 feet along the river,

Fig. 15
AIR VIEW
LOOKING DOWNSTREAM
(M. P. Co. Photo)

with an upstream slope of approximately 7:1, a rather flat and gently rounded crest, and a downstream slope of about 12:1. In general, larger and tougher quartzite and dolomite rocks formed the downstream portion and rode up the far side of the canyon to the greatest height.

Fig. 16
TOP OF LANDSLIDE
LOOKING UPSTREAM

Fig. 17

PANORAMA OF LANDSLIDE FROM UPSTREAM HIGH POINT SHOWN IN FIGURE 16

The weaker schist materials were more finely ground and fanned out over the upstream slope, this phenomena possibly being abetted by a secondary slip. It should be noted that this resulted in a roughly zoned embankment, generally graded from fairly fine materials upstream to larger and more open rock in the body of the slide and the downstream slope.

Flow through the disrupted spillway of Hebgen Dam, augmented by some 200 to 300 cfs inflow downstream, quickly began to form a lake (later named Slide Memorial Lake) behind the slide embankment.

Fig. 18
FILLING OF SLIDE MEMORIAL LAKE
(M. P. Co. Photo)

Fig. 19
AIR VIEW OF LANDSLIDE, LAKE, AND EXCAVATED SPILLWAY

As the lake filled, leakage of approximately 200 cfs developed, principally through the north side, which was not blanketed as thoroughly by the fine material. It is reported that this seepage flow quickly cleared up, indicating that no major piping was occurring. If the lake had filled to the full depth of the slide, it would have had a volume of nearly 100,000 acre-feet with a surface partially submerging the toe of Hebgen Dam. The possibility of failure of the slide embankment, especially by overtopping, would have created a tremendous hazard in the downstream valley.

Acting under emergency orders, the Corps of Engineers, with the advice of several consultants, mobolized a large amount of equipment and began excavating a spillway over the top of the slide to safely conduct the flow. This was cut into the low part of the slide to a depth of 30 feet, reducing the maximum water depth to 190 feet and the volume of the lake to approximately 70,000 acre-feet. The spillway channel has a 250-foot bottom width and extends on a flat gradient for approximately 1000 feet through the crest into a long vertical curve ending in a 10 percent grade down the back slope. The channel has a total length of about 3500 feet.

Fig. 20
INTAKE SECTION OF SPILLWAY

Fig. 21
TRANSITION SECTION OF SPILLWAY

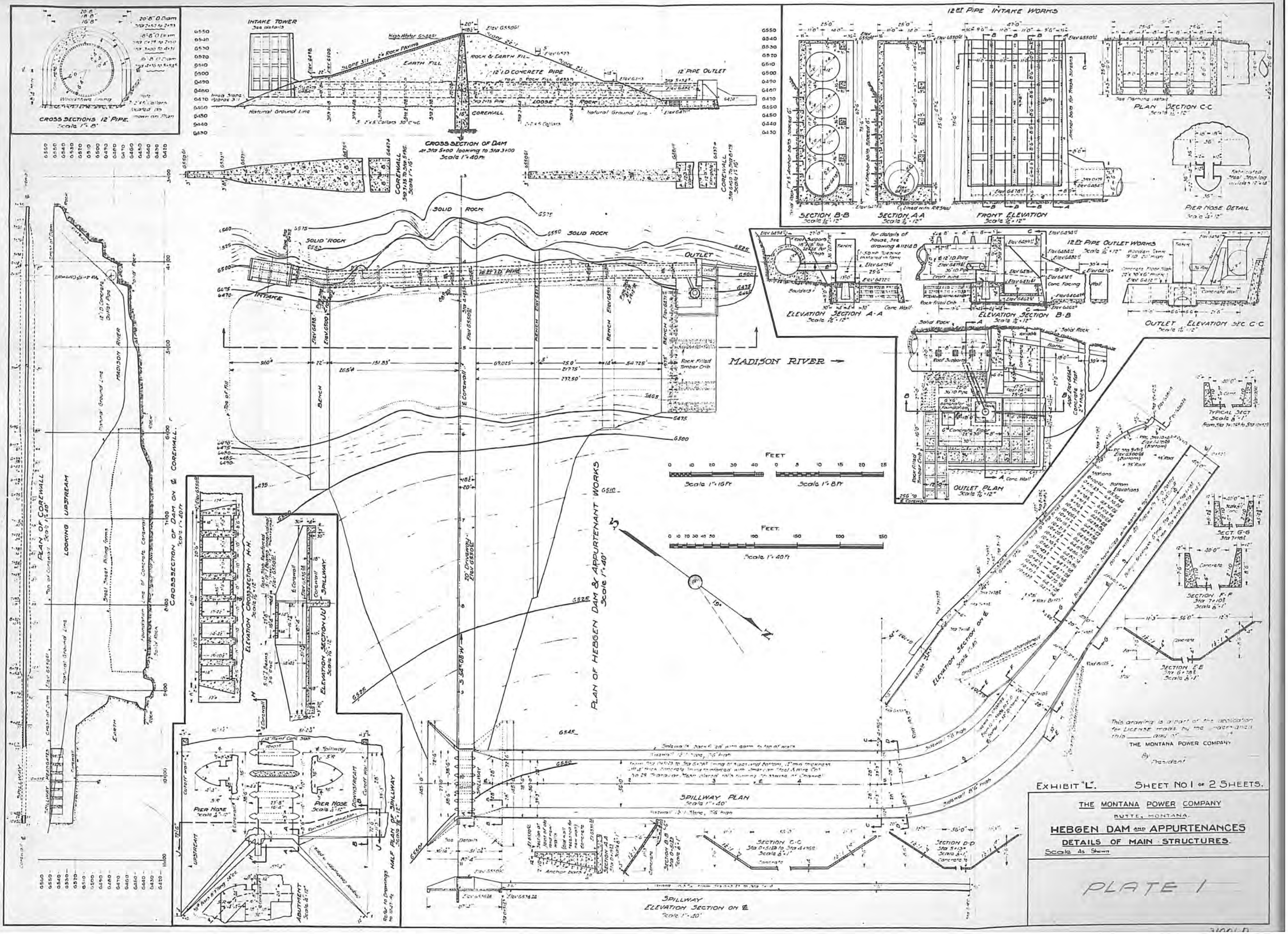
On September 12, a controlled flow of approximately 700 cfs was flowing through the spillway. This was regulated at Hebgen Dam, releases from which were being controlled by the Corps of Engineers. Velocity in the flat gradient crest section was low, the water flowing without riffles. As the velocity increased down the back slope, considerable erosion was taking place, developing a series of small cascades.

Fig. 22
CHUTE SECTION OF SPILLWAY

Although the channel appeared to be stabilizing itself to a considerable extent, it meandered to the weak spots and tended to concentrate in a narrow, deeper channel. This was being remedied by dumping large rock at the points of weakness and by dozers working in the stream pushing material into the low spots to keep the flow spread over a considerable width.

The spillway channel is planned for a capacity of 10,000 cfs, which is somewhat greater than the flood of record at this location where all major floods occur from snowmelt. Recent reports in engineering literature indicate that the stabilization efforts are believed to have been successful so that all expected flows can be carried safely over the slide.[1]

(1) Civil Engineering, October 1959

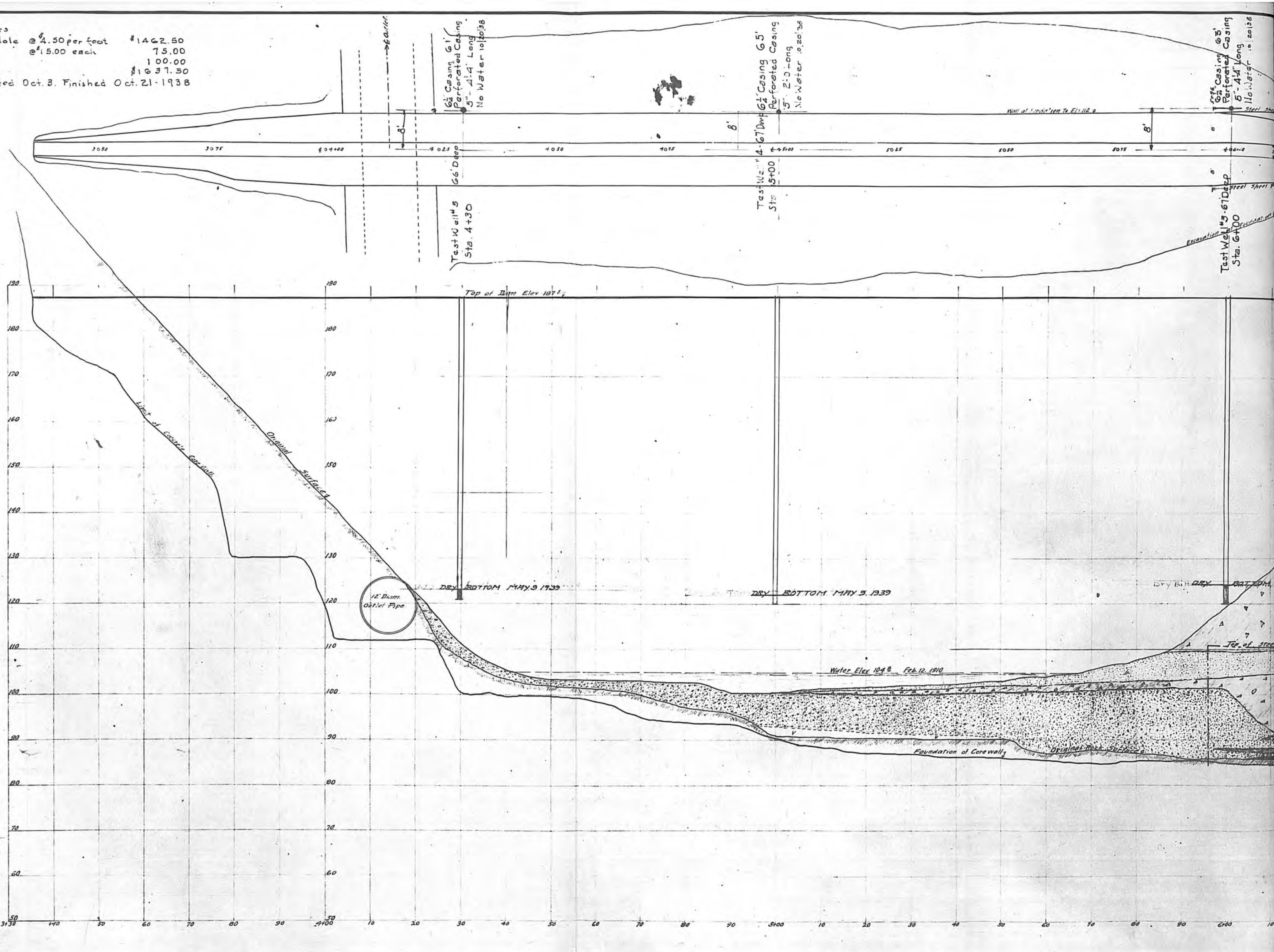


CROSS SECTIONS 12' PIPE. Scale 1"=8'
INTAKE TOWER
CROSS SECTION OF DAM At Sta 5+00 looking to Sta 3+00 Scale 1"=40 Ft.
12' I.D CONCRETE PIPE
12' PIPE OUTLET
EARTH FILL
COREWALL
12 Ft PIPE INTAKE WORKS
SECTION B-B
SECTION A-A
FRONT ELEVATION
PLAN SECTION C-C
PIER NOSE DETAIL
12 Ft PIPE OUTLET WORKS
ELEVATION SECTION A-A
ELEVATION SECTION B-B
OUTLET ELEVATION SEC C-C
OUTLET PLAN
SOLID ROCK
INTAKE
OUTLET
MADISON RIVER
PLAN OF COREWALL
LOOKING UPSTREAM
CROSSSECTION OF DAM ON ℄ COREWALL
PLAN OF HEBGEN DAM & APPURTENANT WORKS Scale 1"=40'
ELEVATION CROSSSECTION H-H
ELEVATION SECTION J-J SPILLWAY
HALF PLAN OF SPILLWAY
PIER NOSE
ABUTMENT
SPILLWAY PLAN Scale 1"=40'
SPILLWAY ELEVATION SECTION ON ℄ Scale 1"=40'
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SECT G-G
TYPICAL SECT
ELEVATION SECTION ON ℄
FEET
Scale 1"=16 Ft
Scale 1"=8 Ft
Scale 1"=40 Ft
This drawing is a part of the application for LICENSE made by the undersigned this ___ day of ___
THE MONTANA POWER COMPANY
By ___ President
EXHIBIT "L". SHEET No 1 of 2 SHEETS.
THE MONTANA POWER COMPANY
BUTTE, MONTANA.
HEBGEN DAM AND APPURTENANCES
DETAILS OF MAIN STRUCTURES.
Scale As Shown
PLATE I

Test Well Drilling Costs

325 feet of Casad Hole	@ $4.50 per foot	$1462.50
5 - 5" Drive shoes	@ $15.00 each	75.00
Moving fee.		100.00
TOTAL		$1637.50

Drilling Started Oct. 3. Finished Oct. 21 - 1938



Montana Reservoir and Irrigation Co.

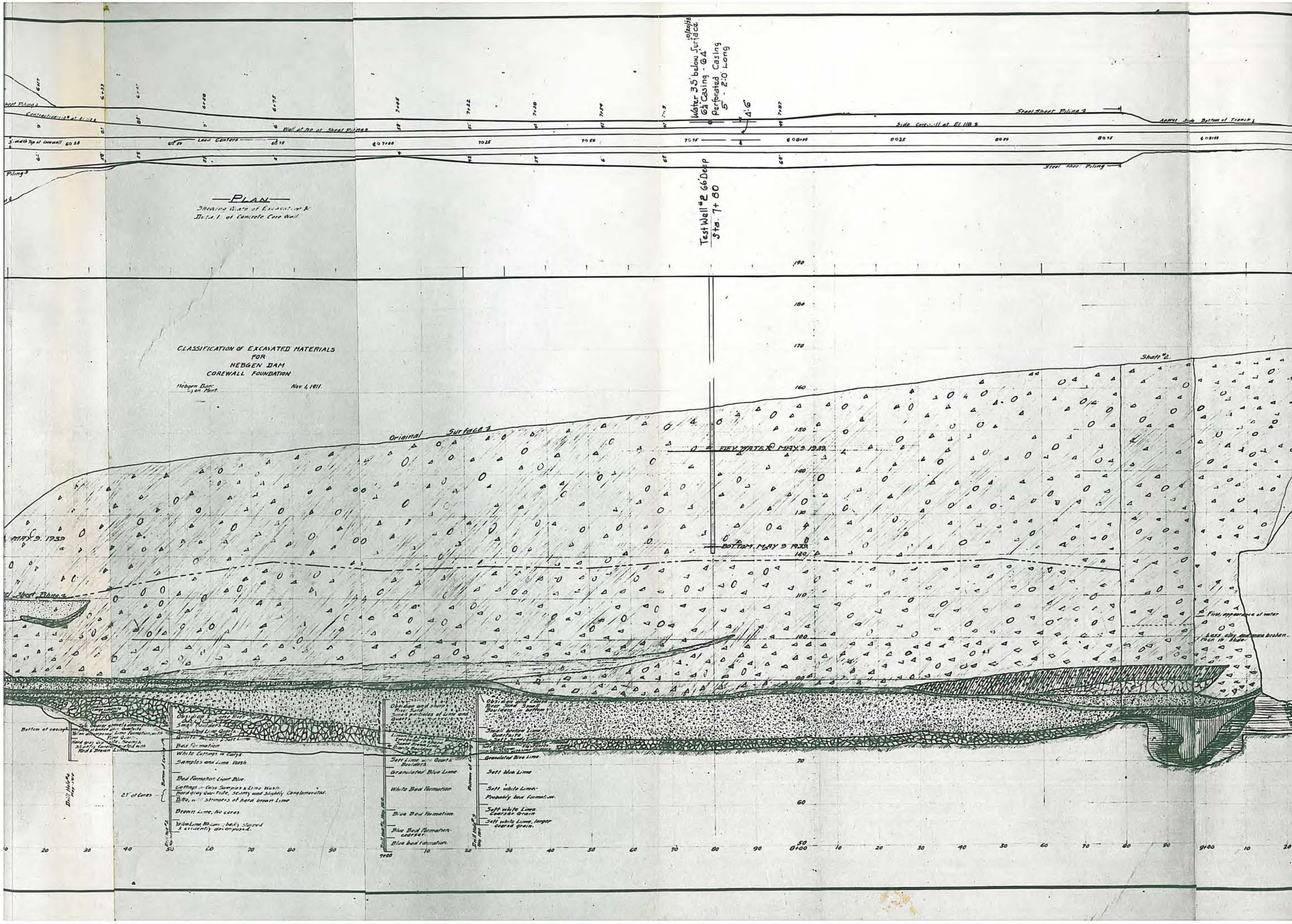
HEBGEN DAM.

Section on Center Line. Plan & Sections of Core Wall.

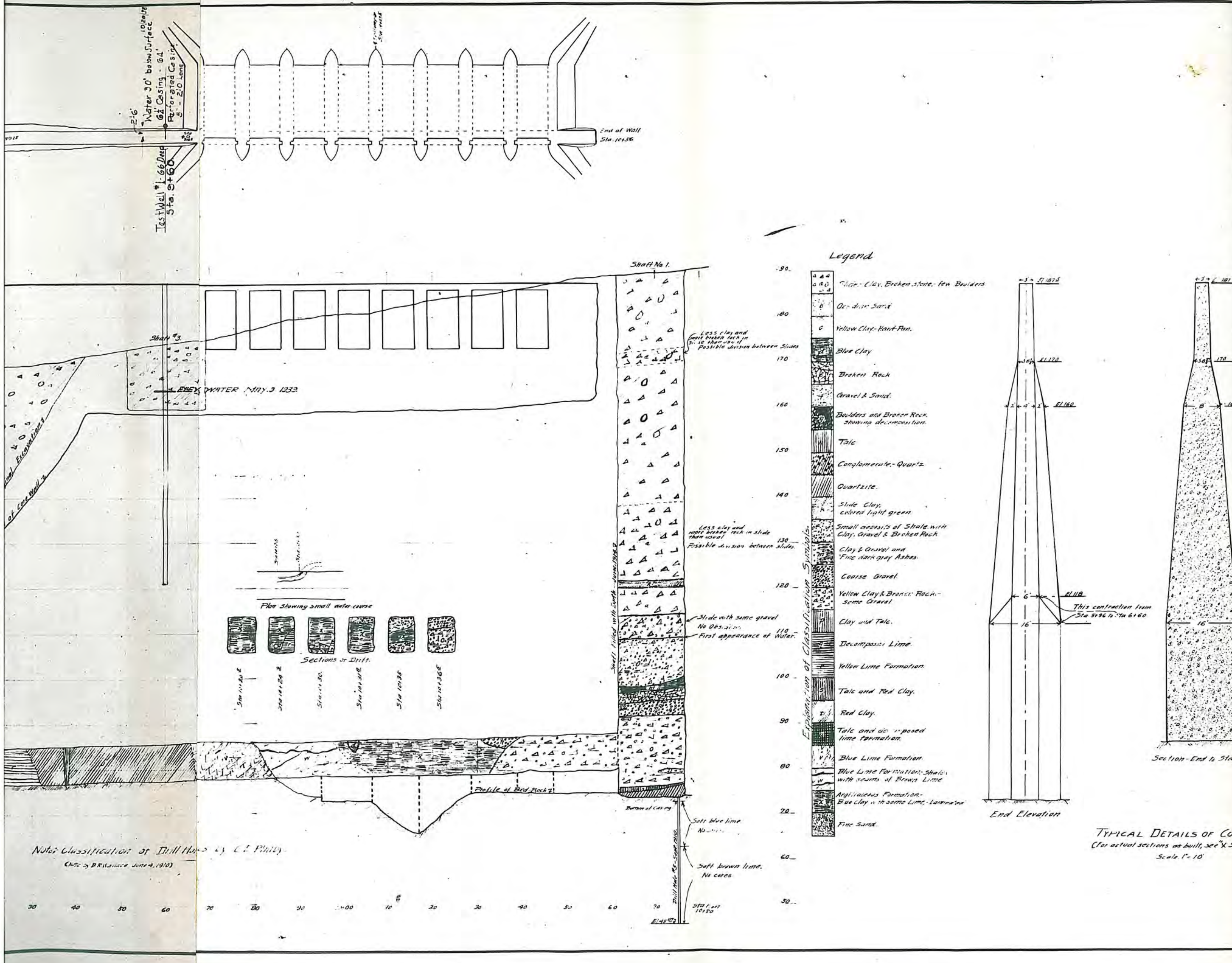
Showing Classification of Materials in Core Wall Excavation. Showing Details of Concrete Core Wall.

Scale, - 1" = 10'

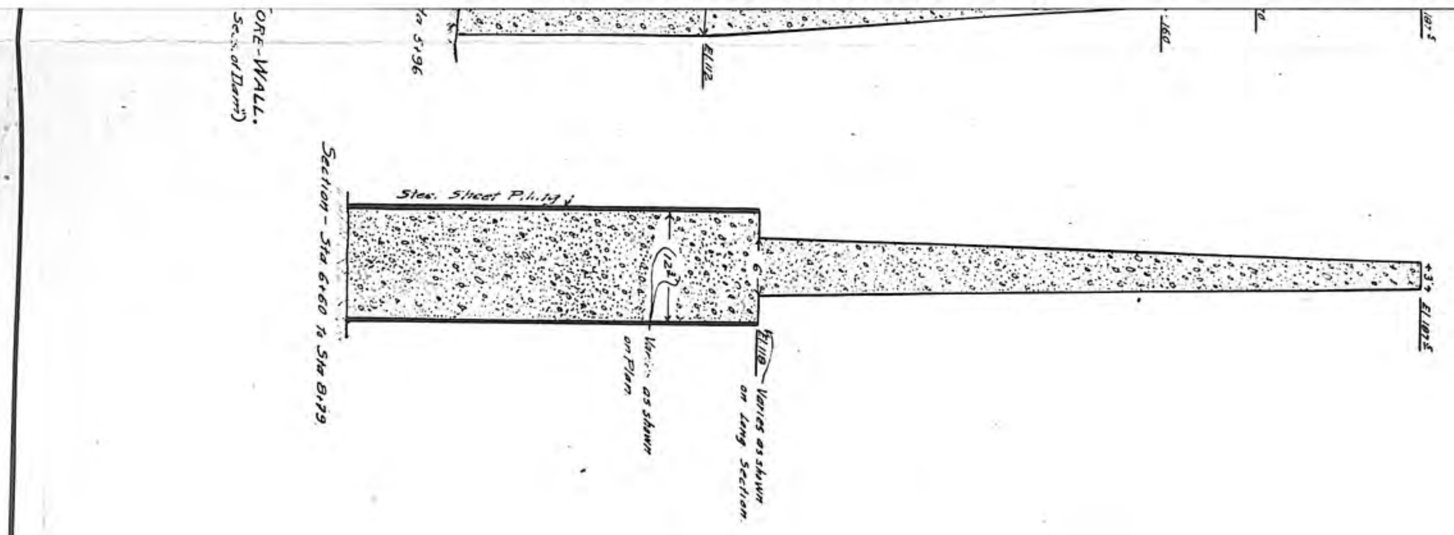
Original Drawing by B. R. Wallace, Nov. 1, 1911. - Details Filled in and Traced, Oct. 6, 1914



PLAN
Showing Waste of Excavation & Detail of Concrete Core Wall
Steel Sheet Piling
Side Corewall at El 118
Steel Sheet Piling
Test Well #2 66' Deep
Sta. 7+80
Water 35' below Surface 10/20/38
6¼" Casing - 6Δ'
Perforated Casing
5' - 2'0 Long
4'6"
CLASSIFICATION OF EXCAVATED MATERIALS
FOR
HEBGEN DAM
COREWALL FOUNDATION
Nov 1, 1911.
Original Surface
ELEV. WATER MAY 9 1939
BOTTOM MAY 9 1939
MAY 9 1939
Shaft #2
First appearance of water
Bottom of casing
Bed Formation
White Cuttings in Calyx
Samples and Lime Wash
Bed Formation Light Blue
Brown Lime, No cores
27' of Cores
Soft Lime with Quartz Boulders
Granulated Blue Lime
White Bed Formation
Blue Bed Formation
Blue Bed Formation coarser
Blue bed formation
Granulated Blue Lime
Soft blue Lime
Soft white Lime
Probably bed formation
Soft white Lime Coarser Grain
Soft white Lime, larger coarse grain



Water 30' below Surface 10/20/13
64' Casing - 64'
Perforated Casing 5' - 20 long
Test Well #L 66 Deep
Sta. 9+60
End of Wall
Sta. 10+56
Shaft No. 1.
Shaft #3.
ELEV. WATER MAY 3 1933
of Core Wall
Less clay and more broken rock in slide than usual
Possible division between Slides
Possible division between slides.
Slide with some gravel
No Obstacles
First appearance of Water.
Shaft Filled with Earth
Plan Showing small water-course
Sections of Drift.
Profile of Bed Rock
Bottom of Casing
Soft blue lime
Soft brown lime.
No cores
Sta. 10+80
Note: Classification of Drill Holes by C.E. Platt.
Legend
Slide - Clay, Broken stone, few Boulders
Yellow Clay - Hard-Pan.
Blue Clay
Broken Rock
Gravel & Sand.
Boulders and Broken Rock, showing decomposition.
Talc
Conglomerate - Quartz
Quartzite.
Slide Clay, colored light green.
Small deposits of Shale with Clay, Gravel & Broken Rock
Clay & Gravel and Fine dark gray Ashes.
Coarse Gravel.
Yellow Clay & Broken Rock - some Gravel
Clay and Talc.
Decomposed Lime.
Yellow Lime Formation.
Talc and Red Clay.
Red Clay.
Blue Lime Formation.
Blue Lime Formation - Shale with seams of Brown Lime
Argillaceous Formation - Blue clay with some Lime - Laminated
Fine Sand.
Explanation of Classification Symbols.
This contraction from Sta. 5+96 to Sta. 6+60
End Elevation
Typical Details of Co
(For actual sections as built, see
Scale 1" = 10'



—Montana Reservoir and Irrigation Co.—

—HEBGEN DAM.—

Section on Center Line.

Showing Classification of Materials excavated for Core Wall Foundation.

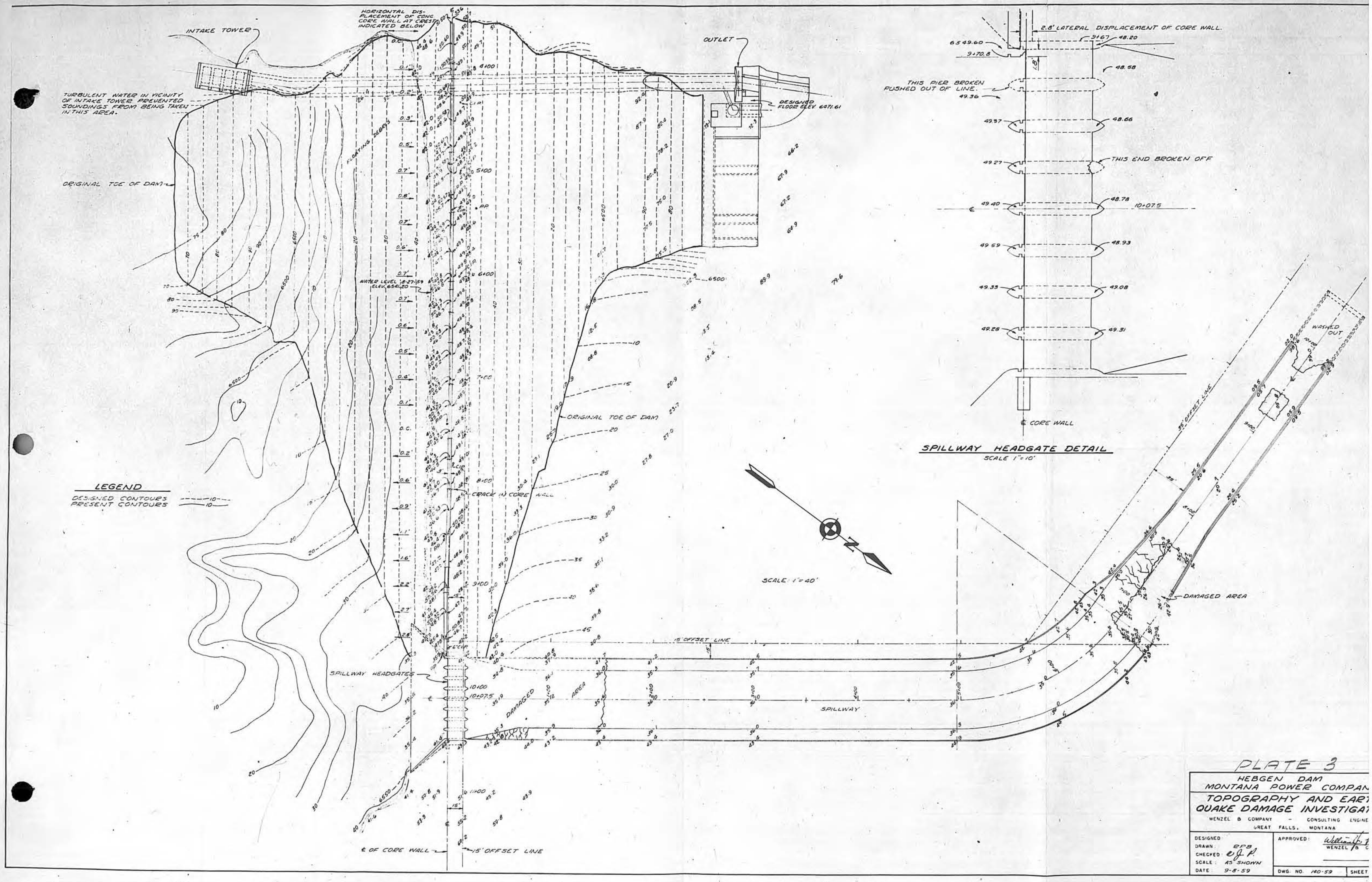
Plan & Sections of Core Wall.

Showing Details of Concrete Core Wall.

Original drawing by B.R.Wallace, Nov. 1, 1911 Details filled in and traced Oct. 1 1914

Scale, 1" = 10'

PLATE 2


INTAKE TOWER
HORIZONTAL DISPLACEMENT OF CONC. CORE WALL AT CREST INDICATED BELOW
OUTLET
DESIGNED FLOOR ELEV. 6471.61
TURBULENT WATER IN VICINITY OF INTAKE TOWER PREVENTED SOUNDINGS FROM BEING TAKEN IN THIS AREA.
ORIGINAL TOE OF DAM
FLOATING DEBRIS
WATER LEVEL 8-27-59 ELEV. 6541.20
CRACK IN CORE WALL
LEGEND
DESIGNED CONTOURS
PRESENT CONTOURS
SPILLWAY HEADGATES
DAMAGED AREA
SPILLWAY
15' OFFSET LINE
35' OFFSET LINE
℄ OF CORE WALL
SCALE: 1" = 40'
WASHED OUT
2.8' LATERAL DISPLACEMENT OF CORE WALL.
THIS PIER BROKEN PUSHED OUT OF LINE.
THIS END BROKEN OFF
℄ CORE WALL
SPILLWAY HEADGATE DETAIL
SCALE 1" = 10'
PLATE 3
HEBGEN DAM
MONTANA POWER COMPANY
TOPOGRAPHY AND EARTHQUAKE DAMAGE INVESTIGATION
WENZEL & COMPANY - CONSULTING ENGINEERS
GREAT FALLS, MONTANA
DESIGNED:
DRAWN: EPB
CHECKED:
SCALE: AS SHOWN
DATE: 9-8-59
APPROVED:
DWG. NO. 140-59
SHEET

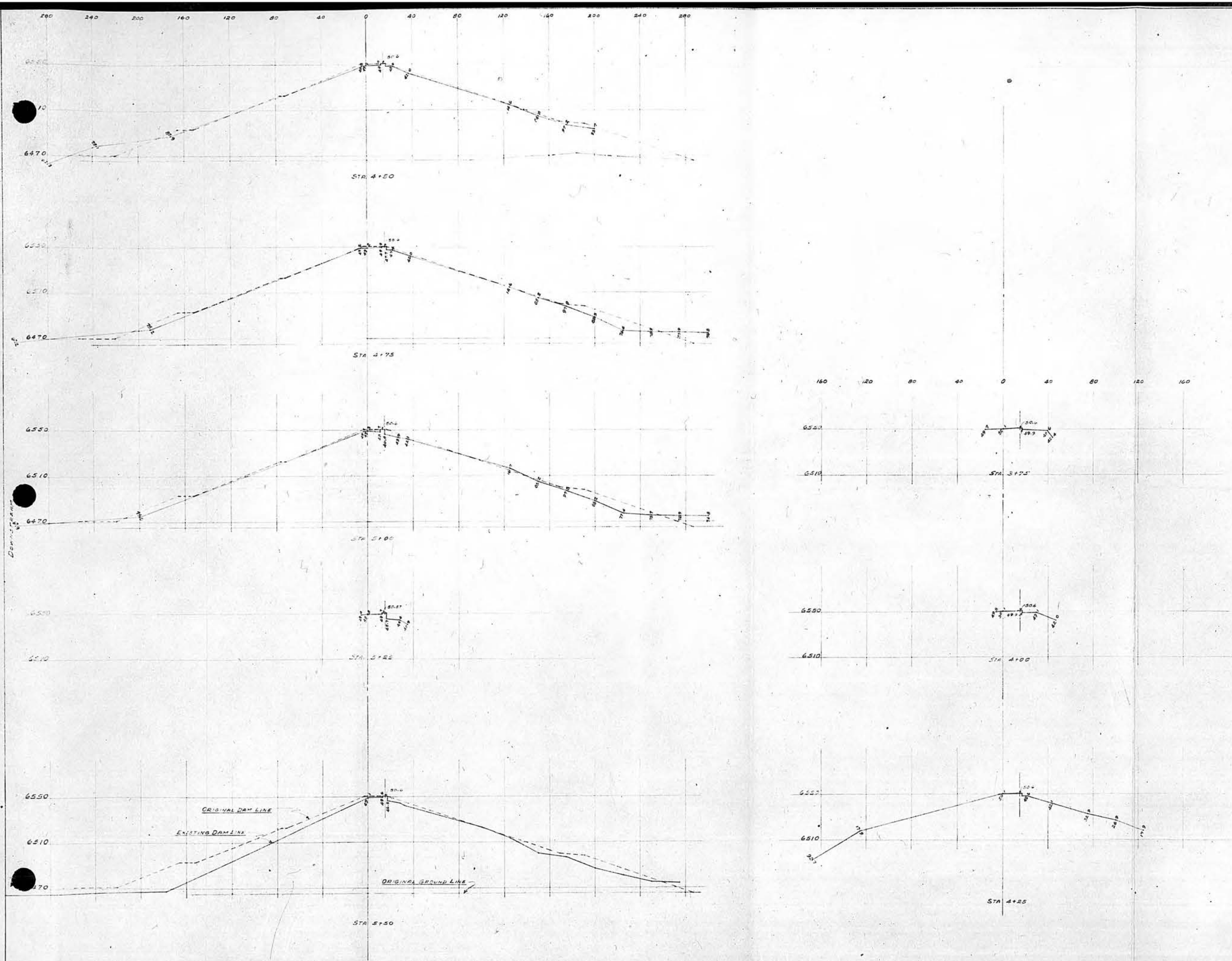


PLATE 4

HEBGEN DAM

CROSS SECTIONS

AFTER AUG 17, 1959 EARTHQUAKE

SHEET #1

THE MONTANA POWER CO.
BUTTE, MONTANA

DRAWN R. POOLE	SCALE 1" = 40'
TRACED	DATE SEPT 1959
CHECKED	DRAWING
APPROVED	NUMBER

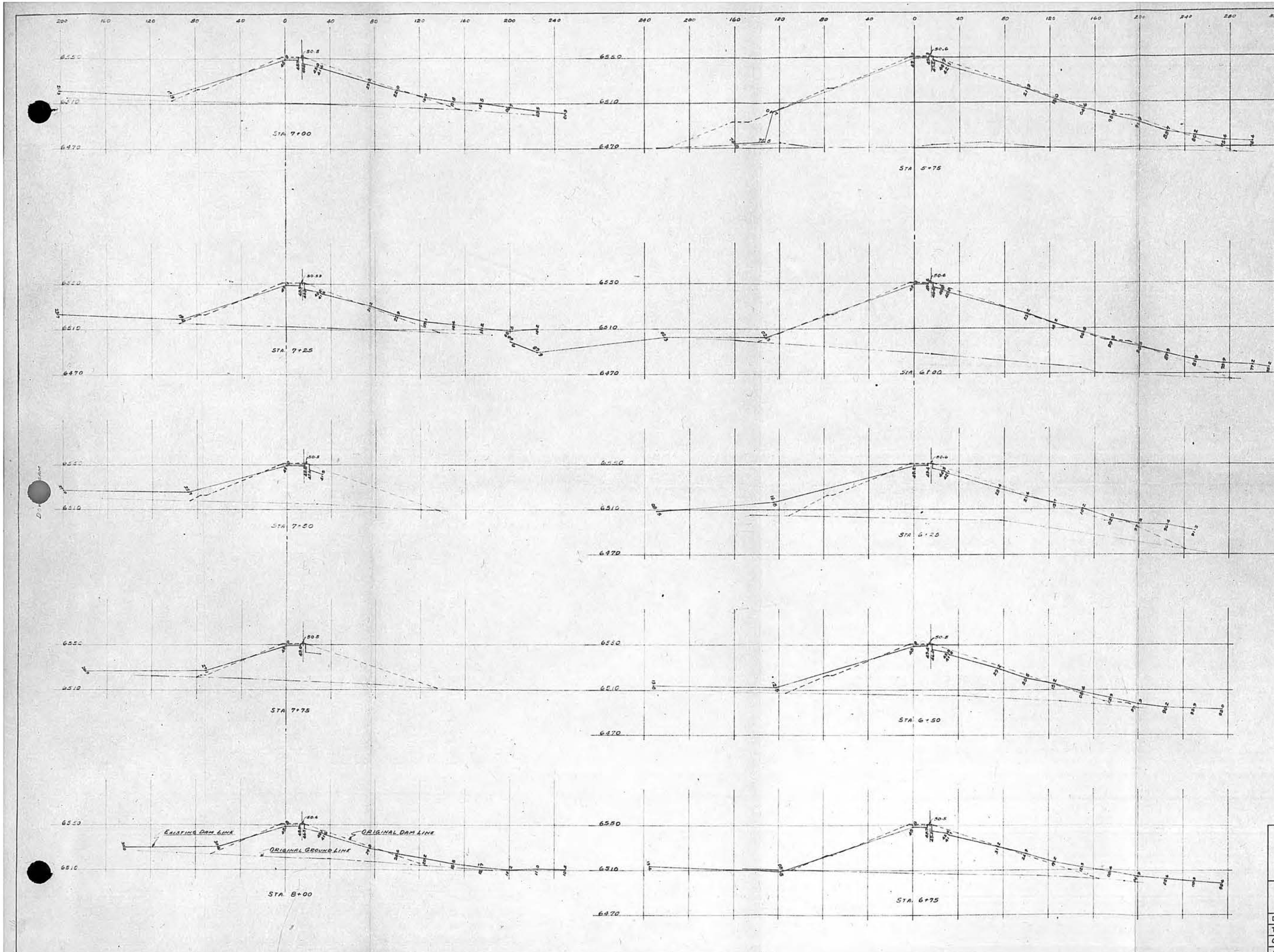


PLATE 5

HEBGEN DAM **CROSS SECTIONS** **AFTER AUG 17, 1959 EARTHQUAKE** SHEET #2	
THE MONTANA POWER CO. BUTTE, MONTANA	
DRAWN E. POOLE	SCALE 1" = 40
TRACED	DATE SEPT. 1959
CHECKED	DRAWING
APPROVED	NUMBER

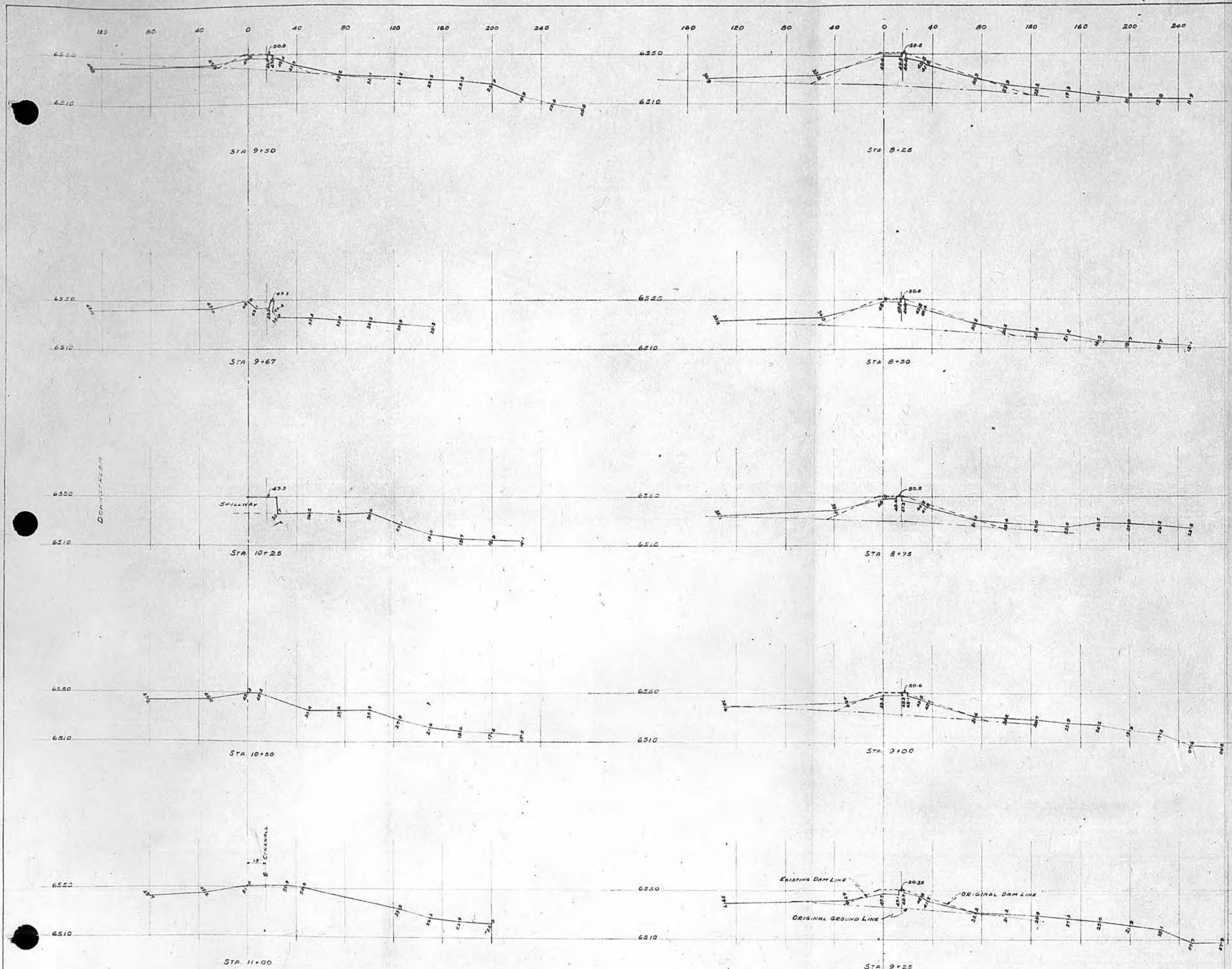


PLATE 6

HEBGEN DAM

CROSS SECTIONS

AFTER AUG. 17, 1959 EARTHQUAKE

SHEET #3

THE MONTANA POWER CO.
BUTTE, MONTANA

DRAWN R. POOLE	SCALE 1" = 40'
TRACED	DATE SEPT. 1959
CHECKED	DRAWING
APPROVED	NUMBER