UNITED STATES

DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

A STUDY OF THE HYDRAULIC CHARACTERISTICS OF AN UNREINFORCED CONCRETE PROTECTIVE HOOD FOR CANAL LINING UNDERDRAIN FLAP VALVES OF THE WELLTON-MOHAWK CANAL--GILA PROJECT, ARIZONA

Hydraulic Laboratory Report No. Hyd.-270

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION

DENVER, COLORADO

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Branch of Design and Construction
Research and Geology Division
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Laboratory Report No. 270
Hydraulic Laboratory
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Subject: A study of the hydraulic characteristics of an unreinforced concrete protective hood for canal lining underdrain flap valves of the Wellton-Mohawk Canal--Gila Project, Arizona

PURPOSE OF STUDY

To develop a concrete protective hood for flap valves of canal underdrain systems that will provide impact protection, will prevent sediment deposition against the valve flap, and will prevent malfunctioning of the valve flap due to biological growth.

CONCLUSIONS

1. The two-piece hood developed by the laboratory study (Figure 2) will fulfill the requirements listed above. It will keep the flap valve operable at water velocities as low as 1 foot per second, which is about one-third of the average velocity expected in the Wellton-Mohawk Canal.

a. The flap valve will remain operable with continuously moving sand loads on the canal bottom equal to a settled sand depth of at least one-third the height of the protective hood.

b. Moving biological growth in the canal bottom will not entangle the valve flap. However, the ends of some streamers will entangle around the bronze rods connecting the two hood pieces and will cling with the greatest portion streaming downstream and outside of the hood.

c. Only small pieces of biological growth will enter at the top of the opening between the hood pieces, and they will be ejected almost immediately by the outflow of water from the water roller caused by the downstream hood piece (deflector).

2. Biological growth carried by the canal water will tend to cling to rough concrete hood surfaces when contact is made with such surfaces.

RECOMMENDATIONS

1. Use the two-piece hood (Figure 2) for the protection of the flap valves in the Wellton-Mohawk Canal.

2. Finish the concrete hood surfaces as smoothly as possible to aid in the passing of biological growth which is carried by the canal water.

3. Smoothly blend the two bronze rods, which bridge the two pieces of the divided hood, into the concrete surfaces to aid in the passing of biological growth.

4. Mark the location of the protective hoods on the canal bank to guard against hood and valve damage by canal cleaning equipment.

ACKNOWLEDGMENT

Engineers from the Canals Division and Hydraulic Laboratory collaborated in the flap valve protective hood studies discussed in this report.

INTRODUCTION

The Wellton-Mohawk Canal, Gila Project, Arizona, (Figure 1) is only one of several Bureau canals designed with 3-1/2-inch reinforced concrete lining. This lining can withstand a maximum differential water pressure of 0.67 of a foot of water without buckling. To protect the lining against buckling due to differential water pressures resulting from a high water table or rainstorm, 6-inch open-jointed sewer pipe drains have been provided beneath the floor of the canals (Figure 2). At intervals along the course of the canals, the drain pipes pass upward through the bottom lining and are vented by flap valves. It was reported in Hydraulic Laboratory Report No. Hyd. 257, "A Study of the Hydraulic Characteristics of Control Devices for the Underdrain System of the Friant-Kern Canal, Central Valley Project, California," that the head for producing flow was critical, being 0.21 of a foot of water above the invert of the exit of the unsubmerged valve. Therefore, it became evident that any debris collecting against the valve flap could increase the opening head and thus impair the safety of the lining. Since little was known of the ability of protective hoods for preventing the collection of sediment and biological growth in the area of the flap valve opening, a hydraulic study was made of these characteristics, and the study extended to improve designs.

TEST FACILITIES AND PROCEDURE

Full size and 1:4 scale model hoods were used in this study to obtain a qualitative comparison of the sand scour patterns caused by water flow around their surfaces. The hoods were constructed of metal screeds and covered with a cement-plaster mixture. Two flumes were used in the testing. One had a bottom width of 3 feet 8 inches, a depth of 14 inches, and 1-1/2:1 sloping sides where both model and full size hoods were studied. The second one where only the models were studied, had a bottom width of 2 feet, a depth of 2 feet, and vertical sides. The first flume was supplied with river sand that was moved by the water in the immediate vicinity of the hoods but had no general movement at low water velocities. A smaller sand (average size 0.2 of a millimeter) was used in the 2-foot-wide flume to represent the continuous movement of sand in the canal. Biological growth was simulated by cotton fibers soaked in water containing aerosol, and by using natural weeds and algae. Water for both test flumes was supplied by an 8-inch propeller pump and measured by an orifice-venturi meter.

The important consideration of this study was whether the hood would scavenge sand and biological growth from the region adjacent to the valve flap. To find the sand scouring effect of a particular hood or its model, a uniform depth of sand was placed on the bottom of the test flume and around the hood and water was pumped through the flume at a given velocity. Observations of the sand movement were made for a period of 1 hour and the scour at the end of this time recorded by photography. Where there was a continuous movement of sand through the test section, the model was allowed to operate until there was no apparent change in the scour pattern. The test flume was then drained and the scour pattern photographed. Cotton fibers, waterweeds, and algae were dropped into the flowing water upstream of the hood to represent conditions with biological growth.

INVESTIGATION OF THE PROTECTIVE HOODS

At the start of this study it was realized that very few quantitative results could be obtained. The quantity and distribution of silt and biological growth to occur in the canal were unknown. The particle size of wind-blown sand in the canal could be assumed small and easily moved by the water which at maximum canal discharge would have an average velocity of approximately 3 feet per second. The size of the earth material moved into the canal from an inlet by a rainstorm could include small rocks. The smaller particles would probably be moved by the canal water while the larger rocks would remain where deposited. These rocks would cause no trouble to the underdrains unless they were in contact with the valve flap.

An indication of the hood's ability to pass growth was obtained by the use of the cotton fibers, weeds, and algae. The waterweed used had a specific gravity less than that of water, and therefore floated near the surface without contacting the protective hoods. The algae, with a specific gravity nearly equal to that of water, were carried at various depths depending upon the turbulence of the water. The mass of these algae placed in the test flumes broke down very rapidly into streamers composed of a few filaments. The following described tests on the different protective hood designs were made to evaluate the ability of each design to scavenge sand, silt, and biological growth.

Original Hood Design

The original hood design (Figure 3A) was constructed full size because it was not known whether the scavenging ability and scour pattern would be the same for both full size and model. To obtain comparable results in the preliminary tests, a uniform 3/4-inch depth of sand (1/8-inch maximum size) was placed on the floor of the test flume and around the protective hood. It was expected that the canal would be operated for long periods at water velocities as low as 1 foot per second, thereby making it necessary for the hood to scavenge satisfactorily at this velocity. Tests were conducted on this basis. Little or no increase in scour in the area surrounding the hood was noted in the initial tests after 1 hour of operation at 1-foot-per-second water velocity; hence this time period was selected for comparison of the scour patterns for subsequent designs.

The submergence of the original hood design, was limited to 1-1/4 inches by the test facilities. The effect of this slight submergence as compared to the depth in the prototype canal was not known, but was evaluated later by comparing the resulting scour to that for the model which was submerged to a greater depth. The patterns were the same for all practical purposes. The scour pattern for the original full-size hood is shown in Figure 4A. A redistribution of the sand from a uniform depth of 3/4 of an inch, deposited amount of sediment sand of 1-7/8-inch maximum height, 2-1/8 inches downstream of the flap opening. Contour lines at 1/2-inch intervals were placed on the deposited sand and photographs taken to aid in a comparison with subsequent tests. The sand was completely removed along the side of the hood, but it was not cleared in the region adjacent to the flap where it would increase the opening head. No information concerning the correlation between a model and a canal flap valve protective hood was available, so it became important to determine if a model and a full-size hood would give comparable scavenging characteristics.

<u>1:4 scale model.</u> From the test results on the full-size hood, it was concluded that the design was unsatisfactory for keeping the flap valve operable if there was an appreciable amount of sand in the canal. As a further check of these results, a 1:4 scale model was constructed and tested in the same flume as the full-size hood. Normally in model prototype similitude based on the Froude number, the velocity ratio equals the square root of the product of the length ratio and gravity ratio. The gravity ratio for all practical purposes equals 1, leaving $V_r = \sqrt{L_r}$. When this law was applied in testing the 1:4 model, it was found that the velocity was insufficient to move the sand. Therefore, it was necessary to increase the velocity to cause a definite movement of the sand adjacent to the model hood. The scour pattern, resulting from 1 hour's operation at a velocity of 0.77 foot per second and with a uniform sand depth of 3/16 inch (Figure 4B), was similar to that for the full-size hood shown in Figure 4A. The velocity of 0.77 foot per second reproduced quite well the scour pattern of the full-size hood. The maximum height of the sand deposited downstream of the hood was now approximately 1/2 inch, 1 inch downstream of the hood. Sand had been cleared along the hood sides but deposited at the point of flap opening. Even the meager qualitative data of these two tests indicated that this hood in this position on the canal floor was not acceptable.

<u>Original hood with deflectors.</u> Attention was brought to the work performed at Colorado A and M College by Mr. R. L. Parshall concerning the use of riffle-deflector sand traps. The deflectors,

consisting of curved vanes on a canal floor, produce a rolling of the water just downstream from, or immediately behind the line of deflectors, causing a movement of entrapped sand or gravel in a lateral direction. The principle of these sand traps was used in attempting to move the sand deposit away from the downstream face of the original hood design. Various heights and shapes of deflectors were tried on the canal floor near the hood for positions of the hood varying from 0° to 45° right of the direction of water flow. When the deflectors were allowed to project beyond the side of the hood to divert water, very good scouring action was produced across approximately one-half of the hood width. At this point the water velocity was reduced, and the sand movement stopped, thus permitting a sufficient accumulation of sand to hinder flap valve operation. There was also the problem of biological growth accumulating on the deflectors, thus reducing their ability to divert a sufficient amount of water for clearing the sand away from the flap valve. At this time, the deflectors did not seem applicable since all the sediment moving on the canal bottom directly in line with the deflectors moved through the area to be kept clear. A design in which the moving sediment would not enter the critical region and which would have satisfactory scavenging properties was considered most satisfactory.

Rotation of original hood. With the failure of the original hood design to operate satisfactorily, it became necessary to obtain indications of what type of hood might work without the construction of numerous shapes. This was accomplished by studying the original hood rotated to various positions with respect to the canal water flow. A scour test was made with the valve opening 45° right of the direction of flow (Figure 5A). There was no improvement over that of the 0° position; in fact, the sand deposition was worse for the same period of time and velocity. A peak of sand 2-5/8 inches high was deposited 2 inches downstream of the hood. The remainder of the hood boundary was cleared of sand except at the extreme upstream end. This hood position was not acceptable and gave little indication of what shape should be used.

Positions of 80°, 90°, and 100° right of the direction of water flow were used in continuing these tests. The only one of these showing any merit was the 90° position (Figure 5B). Generally the sand was scoured completely from regions where the water passed along the boundary of the hood or was accelerated along a curve. This condition is shown in Figure 5B except for the region at the downstream corner of the hood. Unexpected scour occurred immediately downstream of the hood, apparently caused by the turbulent water passing over the curved portion. From observing the flow of water around the hood in this position and its action upon the sand, it was concluded that a hood mounting the flap valve opening at 90° with respect to the flow direction might keep the valve operable.

Original hood alterations. While the use of a design with the flap mounted at 90° with the direction of flow was being considered by designers in the Canals Division, two alterations were made to the original hood. To allow a flow of water to pass into the area of sand concentration, slots 2 inches high by 4 inches wide at the slot exit were cut through the base of the hood (Figure 6A). The canal floor area covered by sand downstream of the hood was reduced by the flow of water from the slots but the deposited height of 2-3/8 inches of sand was considered objectionable, as well as the possibility of the slots being closed by accumulating sand or aquatic growth.

The second alteration truncated the hood to a downstream height of 6 inches (Figure 6B). This was done to allow water flowing over the hood to be directed into the region immediately downstream to prevent a deposition of sand. Flow of this nature did not occur because sand still accumulated to a depth of 1-3/8 inches, 1-1/2 inches downstream of the hood and over a larger area than before (Figure 6B). Apparently when the projected area of the hood was reduced by truncating the top, the velocity through the test section was decreased causing less scour. This was not considered important for there was no indication that the truncated hood would remove sand from the face of the flap valve.

Elliptical Hood

When the original hood had been positioned with the flap valve opening at 90° with respect to the direction of canal flow, the sand had been moved by the water to clear the area immediately in front and towards the upstream side of the opening as shown on Figure 5B. Where the water had passed over and around the curved portion of the hood, the sand had been moved downstream away from the hood boundary. Observation of this action led to the conclusion that a hood incorporating these two features might clear itself to the extent of having the valve free at all times.

A hood believed to have these two characteristics was made, (Figure 3B). An ellipse was used to define the longitudinal centerline section of the hood while a constant radius of 5-1/2 inches was maintained on the hood ends in the plan section. The flap valve was positioned to open at 90° with respect to the flow. A full-size hood was operated for 1 hour at a water velocity of 1 foot per second with a resulting scour pattern shown in Figure 7A. The hood caused a scouring of the sand in the regions expected but not to the desired degree. The downstream corner of the valve flap remained covered with an appreciable amount of sand. At a 1 foot per second water velocity, the sand could not be moved from the face containing the valve. Velocities in the stagnation area on the downstream end of the hood were too low to support a continuous movement of the sand. The deposit was 1-7/8 inches high at a point 8 inches downstream of the valve centerline, which was considered to be too large for dependable operation. Other objections raised were the valve might be damaged by impact of submerged debris, and weeds might entangle the hood and hold the valve flap closed.

Elliptical hood alterations. A suggestion of altering the hood by recessing the flap valve into the side (valve in the 90° position) also failed because the sand was carried directly into the downstream end of the opening and piled against the flap.

The second alteration made to the elliptical hood placed the flap valve to open into the scoured area at the downstream end. This was done by removing 2-3/4 inches from the end of the hood corresponding to the intersection of the valve casting and the ellipse (Figure 7B). After operating for 1 hour with 1-foot-per-second water velocity, it was found that the flat vertical downstream surface, representing the valve flap, had not changed the scour pattern but that sand was carried back into the region formerly occupied by the downstream portion of the hood and piled against the face of the flap.

The use of deflectors was again tried for moving sand from the valve face in both the 0° and 90° positions, but water velocities were not high enough to impart a continuous movement to the sand from the proper areas. It was concluded that the elliptical hood would not provide a satisfactory solution to the problem.

Circular Hood with Deflector

Observations during the preceding tests indicated that an unsymmetrical hood, with respect to the direction of water flow, possessed better scouring ability than a symmetrical hood. The original hood with the valve opening at 90° with respect to the flow direction

Circular hood with deflector

Observations during the preceding tests indicated that an unsymmetrical hood, with respect to the direction of water flow, possessed better scouring ability than a symmetrical hood. The original hood with the valve opening at 90° with respect to the flow direction produced a scour pattern that would be acceptable if the sand was removed completely across the valve face. A hood similar to the original in the 90° position was constructed in the form of a quarter of a sphere of radius 9-1/8 inches (Figure 3D). The exposed flat face parallel to the flow allowed water to pass directly across the face of the flap valve. A deflector with an open slot at the bottom was added to the face containing the valve to protect the valve from moving debris. The slot at the bottom of deflector provided a water jet into the area where the greatest sand deposit was expected.

As in previous tests, this hood was operated for 1 hour at a water velocity of 1.0 foot per second with a resulting scour shown in Figure 8A. The sand was completely removed from around the base of the hood with the exception of the right downstream corner. In trying to remove the sand from this corner, a slot 2 inches high with a 5-1/8-inch entrance and 6-inch exit was cut through the corner. The corner of the hood was reinforced by the addition of a 7/8-inch-diameter rod to prevent the canal cleaning chain from damaging the hood. At the same time, a 3-inch fillet was added to the base of the hood to aid the passing of biological growth.

After a test like that on the unslotted hood, it was found that the scour along the face containing the valve had moved downstream approximately 6 inches beyond the previous scour (Figure 8B). The sand moved through the slot and was deposited along the entire length of the 6-inch exit, but without completely filling the 2-inch height. It had been thought that the sand moving through the slot might be removed by the water causing the main scour downstream of the hood. In place of this action, the sand moved downstream and to the left, being deposited in a ridge approximately 2 inches high, as shown in Figure 8B. The general appearance of the scour pattern for this hood was good, but two objections to the hood were apparent: (1) the slot beneath the deflector may become plugged, which would reduce the extent of the scour across the valve face; and (2) its shape (with the deflector) would be conducive to the accumulation of biological growth.

Further tests were made on a 1:4 model at a water velocity of 0.97 foot per second instead of the 0.77 foot per second used in the 1:4 model test of the original hood in order to obtain better similarity of scour patterns of the full scale and model hoods. Again a uniform sand depth of 3/16 inch was used. As shown in Figure 9A, the model scour across the face containing the valve was not as complete as that in Figure 8B, but in general the similarity was good. With good similarity established, the slot beneath the deflector of the 1:4 model was closed (objection 1 above) and the scour pattern obtained (Figure 9B). There was a small deposit of sand directly in front of the valve. With the exception of this deposit, the scour pattern was practically the same as in Figure 9A.

When biological growth (objection 2 above) was simulated by water-soaked cotton fibers, they tended to pass under the open slot beneath the deflector and to remain there with the end directly across the valve position. Without knowledge of the amount of sand and growth to be expected in the Wellton-Mohawk Canal, it was desirable to extend these studies to find a hood producing a more dependable action.

Enclosing Hood

A two-section protective hood was proposed. The upstream section was formed around the flap valve and the downstream section butted against the other to provide water passage from the valve (Figure 3C). The profile section of this hood was made in the form of an ogee curve in the belief that a scour of the region immediately downstream might be obtained.

A scour test for 1 hour at 1.0-foot per second water velocity, Figure 10A, proved this hood design to be wrong. Sand had been placed in the water passage from the valve to a depth of 3/4 of an inch before the test was started. The sand depth had increased to 7/8 of an inch at the completion of the test. This not being conclusive a second test was made where no sand was placed in the passage, and an area the width of the hood, extending downstream 1-1/2 inches, was left free of sand. After a scour test, a deposit of sand 1/2 inch in depth was found in the water passage, and the previously free area was completely covered.

This hood design was not considered further in view of the possibility of sand being deposited in the water passage from the valve, thus hindering the flap valve operation.

Exposed Flap Valve

It was proposed that the valve be protected by reinforcing bars placed in the concrete canal lining instead of protecting the flap valve with unreinforced concrete. A full-sized valve was placed in the test flume, and a 1-hour scour test was made. The resulting scour is shown in Figure 10B. The results of this test indicated the proposal to be unsatisfactory. With the added possibility of the reinforcing bars becoming entangled by canal growth, this proposal was abandoned.

Two-piece Hood

Previously mentioned under the section, Original Design, was a series of tests concerning the use of deflectors or vanes to direct the flow of water across the downstream face of the hood. None of the deflectors projected above the top of the hood, the thought being that biological growth flowing with the water could easily become entangled upon the deflector. With the failure of finding a hood design that would be self scavenging with respect to both sand and growth, additional tests were made using deflectors projecting above the original hood. A change in the method of testing the hoods was made to better represent the prototype movement of sand in the canal. This was accomplished by using a sand (average size 0.2 of a millimeter) in the 2-foot-wide test flume whereby continuous movement of the sand was obtained. This movement was prevalent throughout the test flume as well as adjacent to the hood boundary. In this way, it was determined whether the hood could maintain a continuous scouring action.

In the use of a downstream deflector which projected above the hood, a compromise between a complete sand scour and the entanglement of some growth on the deflector was accepted. A drawing of the two-piece hood is shown in Figure 3E. This design was obtained by trial in that metal plates were used in forming the deflector, or downstream piece of the two-piece hood. The height of the projection of the deflector above the original hood was based upon the completeness and rapidity with which the area between the deflector and hood was scoured. Trial tests on 1:4 model hoods were made with deflectors projecting from 0 to 4 inches prototype above the original hood, and having both curved and straight profiles. A 12-inch-wide deflector, straight in profile, projecting 3 inches above the original hood, and with its upstream surface at angle of 69° with respect to the canal floor produced the best scouring action. The distance between the intersection of the base of the hood and the intersection of the deflector with the canal floor was 10 inches. It was necessary to add a concrete backing to the deflector for structural reasons and to aid the passing of the canal cleaning chain. This concrete in itself, eliminates the metal plate used in the initial tests on this design. To prevent the chain from dropping into the space between the two hood pieces, three 3/4-inch bronze rods were bridged between them.

Based on the 1:4 scale model test results, the addition of the concrete to the downstream deflector plate (Figure 3E) reduced the scouring rate in the area between the hood pieces. This was corrected by reducing the distance between bases from 10 to 8 inches prototype which still permitted the flap to swing out to a horizontal position without coming in contact with the face of the deflector. A scour test of 1 hour on this model showed continuous scouring after the short time (3 to 5 minutes) required to remove sand purposely placed between the hood pieces. The scouring starts at the apex of the angle made by the canal floor and the face of the downstream deflector. A roller of water resulting from the deflected portion of the flow had sufficient velocity to keep the sand in suspension between the hood pieces. This sand was gradually ejected from this area by the efflux of water from both sides; thence it was moved downstream by the water passing the side of the hood. The scouring action proceeded rapidly over approximately 7 inches of the distance between bases and was retarded slightly over the remaining inch, presumably due to the influence of the flap valve. All of the flume floor surface between the hood pieces in the 1:4 model was completely scoured in 3 to 5 minutes with an average water velocity of 0.9 foot per second and none of the moving sediment re-entered the space between the hood and deflector. These results indicated a solution to the problem.

A sketch of the two-piece hood was given to the Canals Division for their consideration in planning the final design (Figure 2).

Two-piece hood--Final design. The final design, prepared by the Canals Division to include structural features, included a chamfer to the upstream deflector face, two 3/4-inch bronze rods in place of three, and a 30° slope to the downstream face of the deflector to facilitate passing of a drag chain. A 1:4 scale model of the final design was constructed (Figures 11A and B).

In testing the 1:4 model, a uniform depth of 1 inch of sand (average size 0.2 of a millimeter) was placed in the 2-foot test flume. The model maintained continuous scour at a minimum water velocity of approximately 0.6 foot per second. The time required to move the sand out from between the hood pieces was dependent upon the depth of the sand, and determining this time-sand depth relationship did not appear warranted. The model was operated for 1 hour at a velocity of approximately 0.9 foot per second, which was higher than that required to cause sand movement, but was used to accelerate the scour test. In contrast to previous tests, sand waves were formed throughout the test flume (Figure 11), denoting a continuous sand movement to and from the hood. The scour pattern for the final hood design is shown in Figures 11A and B. The 1 inch depth of sand, which had been placed between the hood pieces before the test, was completely removed within 5 minutes after the start of the test and no sand was carried back into this space during testing. The chamfer that had been added to the deflector upstream face did not noticeably change the scouring pattern. To further check the scouring action, larger size sand (maximum size approximately 1/8 inch) was placed between the hood pieces, and this sand was also rapidly forced out and downstream.

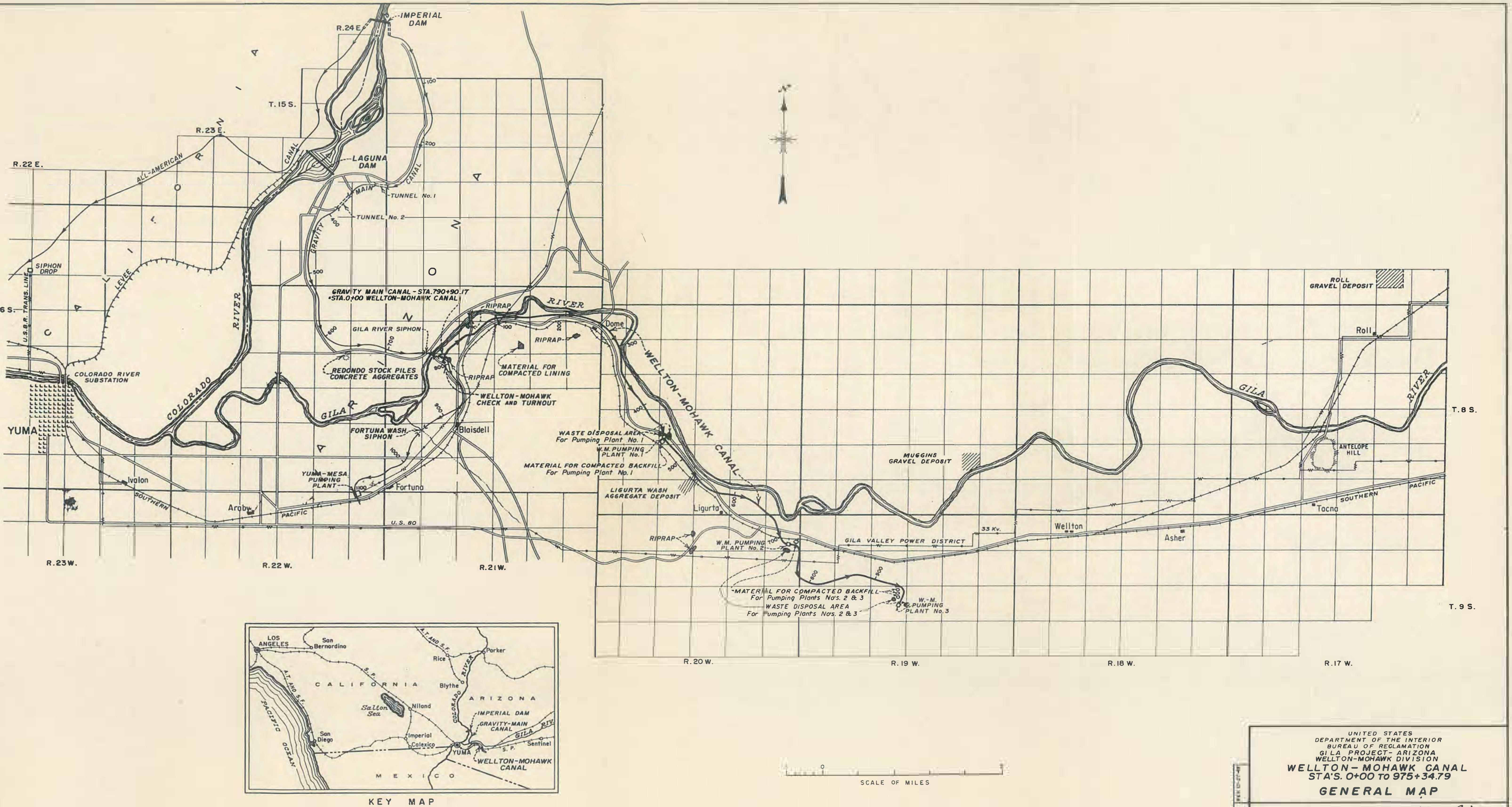
This design was also studied for its ability to pass biological growth by using cotton streamers, natural waterweeds, and algae. This material was dropped onto the water surface 8 to 10 feet upstream of the hood. The weed, having a specific gravity less than that of the water, did not sink sufficiently to entangle the hood at the water submergence used; however, entanglement should occur at water surfaces near the hood top. The majority of the cotton streamers were deflected by turbulence surrounding the hood, but a few became caught under the bronze rods near the deflector (Figure 13A). A short length of the streamer (approximately 1/8 or less of the total length) entered the space between the hood pieces and was forced out and around the bronze rods where the streamer remained caught. The longer section of the streamer was carried downstream in a position where it can be engaged and removed by a chain drag. Algae were caught on the hood in exactly the same manner as the streamers, but the algae did not support a length as long as the cotton streamers. The filaments of the algae had a tendency to slip one upon the other until only very short lengths were retained around the bronze rods. None were caught by the top of the deflector between the rods. When cotton streamers were deliberately placed in the space between the hood pieces, they were rolled about until finally ejected out the sides, thus showing no tendency to become entangled on the valve.

<u>Comparison of original hood, circular hood, and two-piece hood.</u> Models of the original hood, circular hood, and two-piece hood of a 1 to 4 scale were placed in the flume. All three were operated under the

same conditions of time (1 hour) water velocity (0.9 foot per second), and sand depth (approximately 1 inch). The test results are shown on Figures 11 and 12. The deposit against the flap of the original hood was higher than in previous tests. Note that the scour pattern retains a similarity to previous tests with the hood in this position. During the operation of the circular hood, the sand waves moved under the deflector, along the face containing the valve, and the area in front of the valve never completely cleared as in previous tests, although the pattern of scour was essentially the same. The sand in the area between the two pieces of the final hood design was completely removed.

With this final comparison of the scouring ability of the three hoods, it was concluded that the two-piece hood (Figures 2 and 13B) is the most satisfactory.

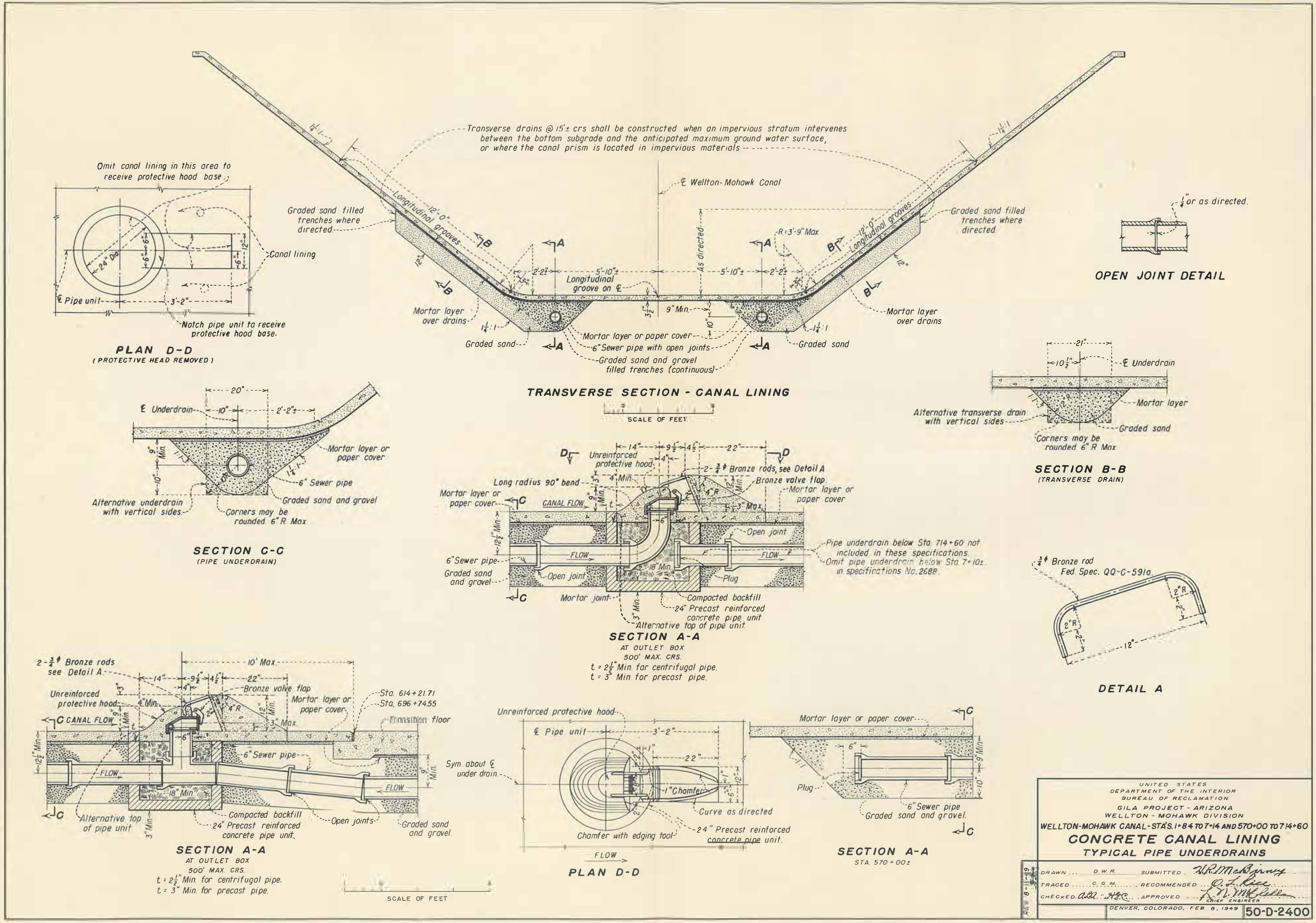
FIGURE 1



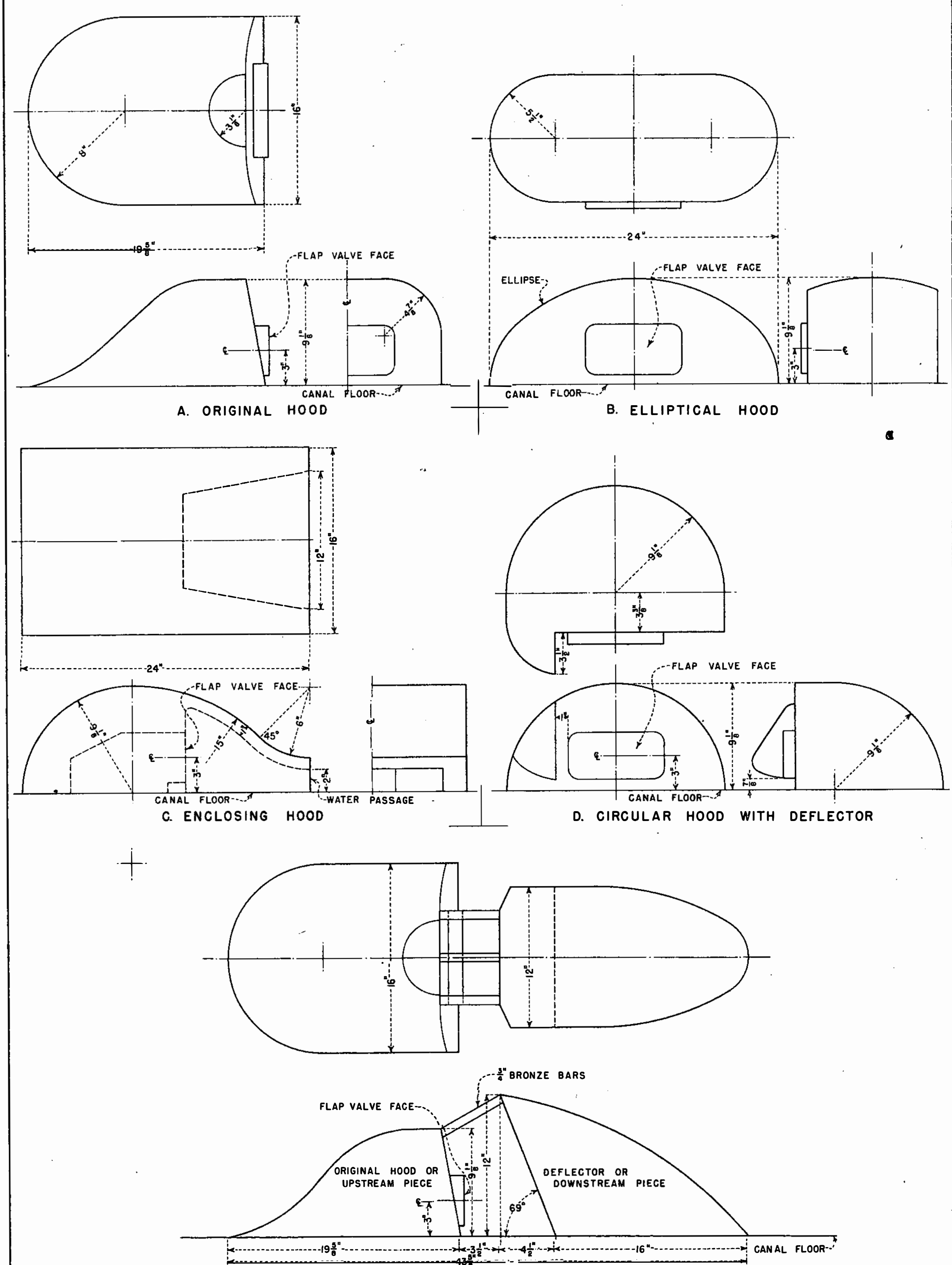
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
GILA PROJECT- ARIZONA
WELLTON-MOHAWK DIVISION
WELLTON-MOHAWK CANAL
STA'S. 0+00 TO 975+34.79
GENERAL MAP

DRAWN: M.A.H. SUBMITTED: H.R. McBirney
TRACED: B.F.W. RECOMMENDED: O.L. Rice
CHECKED: Q.W.R.-H.C. APPROVED: L.N. McClellan CHIEF ENGINEER
DENVER, COLORADO - JUNE 29, '48
50-D-2394

FIGURE 2



Transverse drains @ 15'± crs shall be constructed when an impervious stratum intervenes between the bottom subgrade and the anticipated maximum ground water surface, or where the canal prism is located in impervious materials
℄ Wellton-Mohawk Canal
Graded sand filled trenches where directed
Longitudinal grooves
12'-0"
1¼:1
Longitudinal groove on ℄
As directed
R=3'-9" Max
5'-10"±
2'-2"±
9" Min.
Mortar layer over drains
Graded sand
Mortar layer or paper cover
6" Sewer pipe with open joints
Graded sand and gravel filled trenches (continuous)
TRANSVERSE SECTION - CANAL LINING
SCALE OF FEET
Omit canal lining in this area to receive protective hood base
Canal lining
24" Dia.
℄ Pipe unit
3'-2"
Notch pipe unit to receive protective hood base.
PLAN D-D
(PROTECTIVE HEAD REMOVED)
¼" or as directed.
OPEN JOINT DETAIL
℄ Underdrain
20"
10"
2'-2"±
Mortar layer or paper cover
6" Sewer pipe
Graded sand and gravel
Alternative underdrain with vertical sides.
Corners may be rounded 6" R Max
SECTION C-C
(PIPE UNDERDRAIN)
21"
10½"
Mortar layer
Graded sand
Alternative transverse drain with vertical sides
Corners may be rounded 6" R Max
SECTION B-B
(TRANSVERSE DRAIN)
Unreinforced protective hood
Long radius 90° bend
2-¾" ϕ Bronze rods, see Detail A
Bronze valve flap
Mortar layer or paper cover
CANAL FLOW
Open joint
FLOW
6" Sewer pipe
Graded sand and gravel
18" Min.
Plug
Mortar joint
Compacted backfill
24" Precast reinforced concrete pipe unit
Alternative top of pipe unit.
Pipe underdrain below Sta. 714+60 not included in these specifications. Omit pipe underdrain below Sta. 7+10± in specifications No. 2688.
SECTION A-A
AT OUTLET BOX
500' MAX. CRS.
t = 2½" Min for centrifugal pipe.
t = 3" Min. for precast pipe.
¾" ϕ Bronze rod
Fed. Spec. QQ-C-591a.
2" R
12"
DETAIL A
2-¾" ϕ Bronze rods see Detail A
10' Max.
Sta. 614+21.71
Sta. 696+74.55
Transition floor
Open joints
Graded sand and gravel.
SECTION A-A
AT OUTLET BOX
500' MAX. CRS.
t = 2½" Min. for centrifugal pipe.
t = 3" Min. for precast pipe.
SCALE OF FEET
Unreinforced protective hood
℄ Pipe unit
3'-2"
22"
Sym. about ℄ under drain.
1" Chamfer
Curve as directed
24" Precast reinforced concrete pipe unit.
Chamfer with edging tool
FLOW
PLAN D-D
Mortar layer or paper cover
6" Sewer pipe
Graded sand and gravel.
SECTION A-A
STA. 570+00±
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
GILA PROJECT - ARIZONA
WELLTON - MOHAWK DIVISION
WELLTON-MOHAWK CANAL - STA'S. 1+84 TO 7+14 AND 570+00 TO 714+60
CONCRETE CANAL LINING
TYPICAL PIPE UNDERDRAINS
DRAWN D.W.R. SUBMITTED
TRACED C.G.M. RECOMMENDED
CHECKED APPROVED CHIEF ENGINEER
DENVER, COLORADO, FEB. 8, 1949
50-D-2400



A. ORIGINAL HOOD

B. ELLIPTICAL HOOD

C. ENCLOSING HOOD

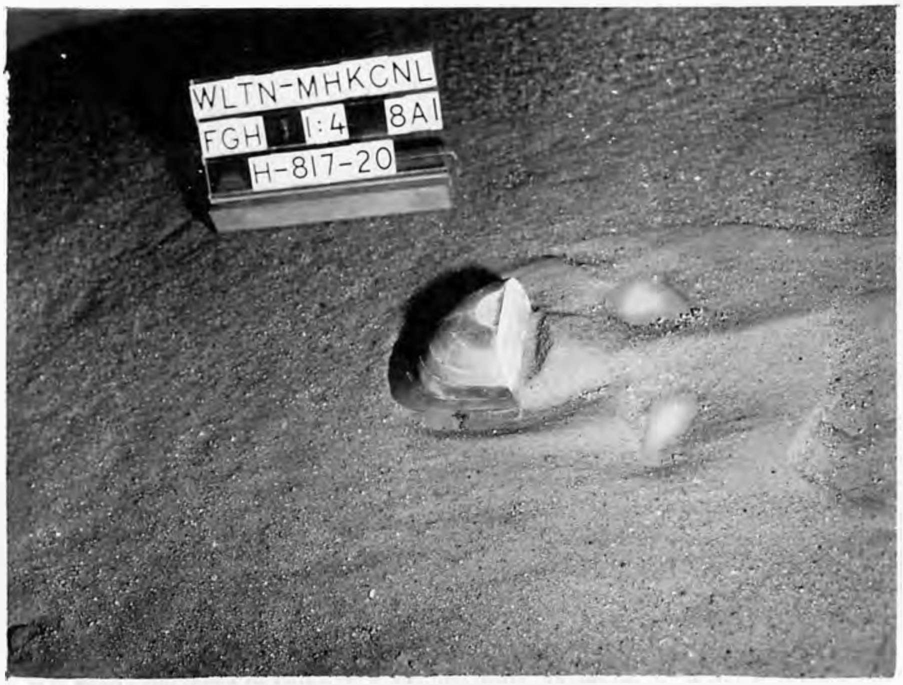
D. CIRCULAR HOOD WITH DEFLECTOR

E. TWO-PIECE HOOD

CANAL UNDERDRAIN PROTECTIVE HOODS

FLAP VALVE PROTECTIVE HOOD STUDY

A. Scour pattern of original protective hood operated 1-hour at 1.0 foot per second water velocity.



B. Scour pattern of 1:4 scale original protective hood operated 1-hour at 0.77 foot per second water velocity.

ORIGINAL HOOD AND 1:4 SCALE MODEL

A. Scour pattern of original protective hood operated 1-hour at 1.0 foot per second water velocity with flap opening 45 degrees right of the water flow direction.

B. Scour pattern of original protective hood operated 1-hour at 1.0 foot per second water velocity with flap opening 90 degrees right of the water flow direction.

ORIGINAL HOOD AT 45 AND 90 DEGREES

A. Scour pattern of altered protective hood operated 1-hour at 1.0 foot per second water velocity in design position. Slots in base 2-inches high by 4-inches wide at exit.

B. Scour pattern of altered protective hood operated 1-hour at 1.0 foot per second water velocity. Slots open and the top truncated to a downstream height of 6 inches.

ALTERATIONS TO ORIGINAL HOOD

A. Scour pattern of elliptical hood operated 1-hour at 1.0 foot per second water velocity with valve opening at side.

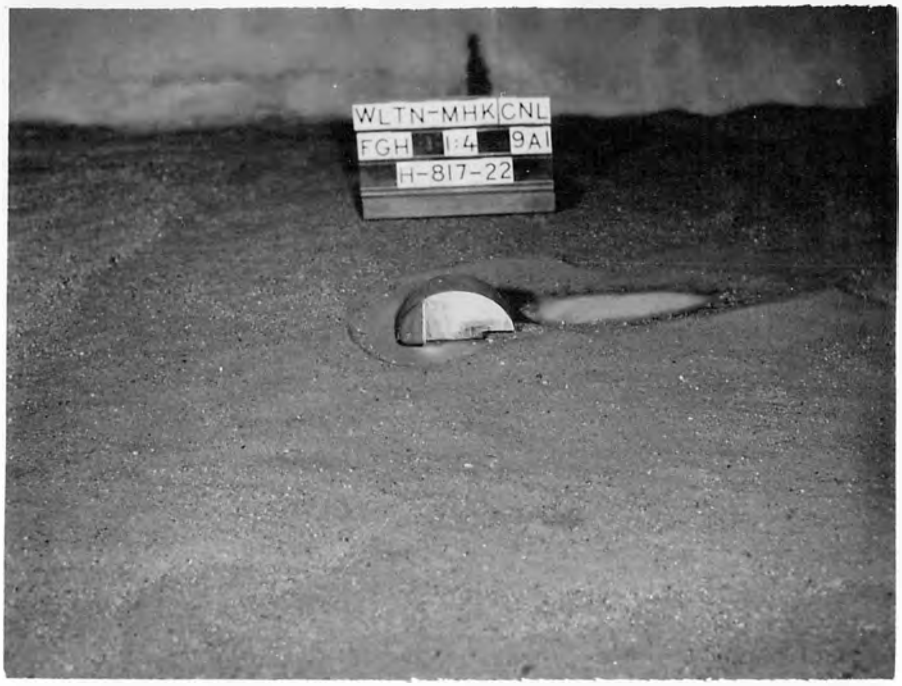
B. Scour pattern of elliptical hood operated 1-hour at 1.0 foot per second water velocity with valve opening downstream.

ELLIPTICAL HOOD

A. Scour pattern of circular hood with deflector operated 1-hour at 1.0 foot per second water velocity.

B. Scour pattern of circular hood with deflector operated 1-hour at 1.0 foot per second water velocity. Slot 2 inches high, 5-1/8-inch entrance (7/8-inch reinforcing bar), and 6-inch exit.

CIRCULAR HOOD



A. **Scour pattern of 1:4 scale circular hood with deflector operated 1-hour at 0.97 foot per second water velocity.**

B. Scour pattern of 1:4 scale circular hood with deflector operated 1-hour at 0.97 foot per second water velocity. Slot closed beneath deflector.

1:4 MODEL OF CIRCULAR HOOD

A. Scour pattern of enclosing hood operated 1-hour at 1.0 foot per second water velocity.

B. Scour pattern of exposed full size flap valve operated 1-hour at 1.0 foot per second water velocity.

ENCLOSING HOOD AND UNPROTECTED FLAP VALVE

A. Scour pattern of 1:4 scale two-piece hood operated with continuous sand movement for 1-hour at 0.97 foot per second water velocity--looking upstream.

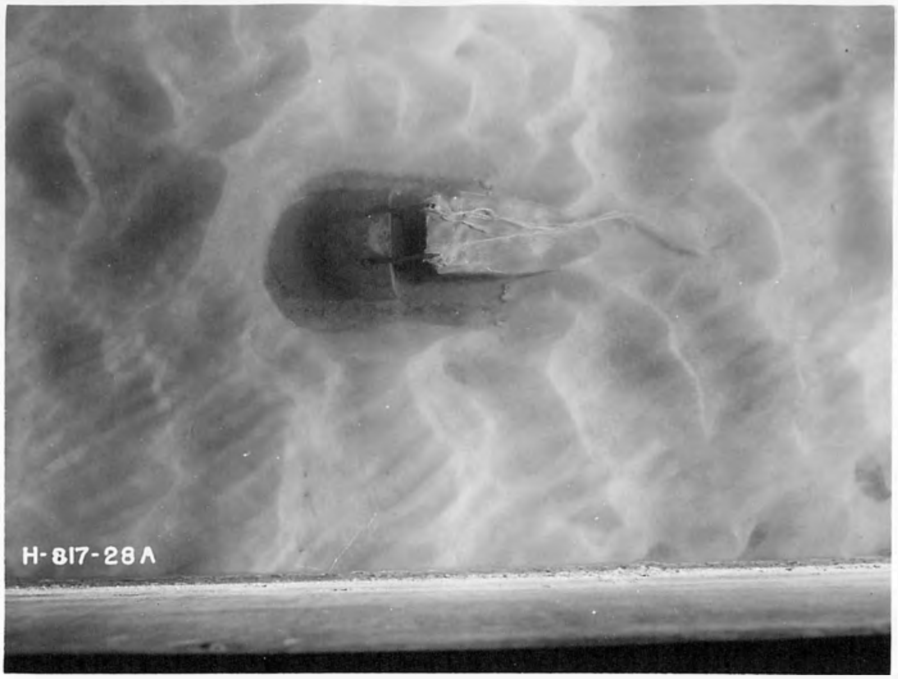
B. Scour pattern of 1:4 scale two-piece hood operated with continuous sand movement for 1-hour at 0.97 foot per second water velocity--looking downstream.

1:4 MODEL OF TWO-PIECE HOOD

A. Scour pattern of 1:4 scale original hood operated with continuous sand movement for 1-hour at 0.97 foot per second water velocity.

B. Scour pattern of 1:4 scale circular hood operated with continuous sand movement for 1-hour at 0.97 foot per second water velocity.

ORIGINAL AND CIRCULAR HOOD--1:4 MODEL



A. Two-piece hood in operation with cotton streamers on downstream section.

B. Profile photograph of two-piece hood--1:4 scale model.

OPERATION AND PROFILE PHOTOGRAPH OF 1:4 MODEL OF TWO-PIECE HOOD