

D-8560
RES-3.50

JUN 23 1999

MEMORANDUM

To: Charles Liston, D-8290

From: Leslie Hanna
Hydraulic Engineer

Brent Mefford
Technical Specialist

Subject: Results from the Model Study of the Tracy Facility Crab Screen

Background

In the fall of 1998 the Tracy Fish Collection Facility (TFCF) (figures 1 and 2) experienced an invasion of Mitten crabs. The crabs are an exotic species that first showed up in the Sacramento River Delta about 8 years ago. The crab population has exploded in a relatively short period. The crabs have a 3-year life span. Crabs are born in the ocean, the young migrate upstream into fresh water where they live, then, when ready to spawn, they migrate downstream to the ocean to lay their eggs and die. It is during this downstream migration that the TFCF becomes inundated with crabs. The TFCF is responsible for collecting fish drawn into the Delta Mendota canal and returning the fish to the delta. Reclamation installed a traveling screen built by Farm Pump and Irrigation (FPI) Company as a temporary measure at Tracy in 1998 to determine if the screen could be effective at passing fish into the facility while removing crabs. Further testing of the screen was performed at Reclamation's Water Resource Research Laboratory (WRRL) in Denver, Colorado.

Results

1. Two different belt configurations were tested on the screen; the conventional wire belt typically used by FPI (figure 3a), and a custom belt developed by Reclamation (figure 3b). Laboratory testing showed that screen performance was very effective for removing crabs for both belts tested; however, the custom belt design with the plastic coated cable provides a larger area and smoother surface for passing fish than the standard wire belt typically used for collecting debris. The designs developed by Reclamation for the screen guide system and modified crab screen are shown in the Appendix A (drawings 214-D-24051 and WRRL 1).

2. The crab screen will be set on a guide system that will allow the screen to be retracted periodically (appendix A; drawing CBFAME) to flush fish and predators (that may hold up upstream from the screen). Guide ramps are located on both the upstream and downstream sides of the screen to minimize the formation of back eddies that might provide a haven for predators (drawing 214-D-24051).

3. Operation of the crab screen at slow speeds (≤ 2.5 ft/min) contributes to the effectiveness of fish passage through the screen and also works well for removing crabs. However, further tests will be needed in the field to determine the most effective screen speed if large numbers of crabs are present.

5. Four-inch-long brushes will be attached to each of the screen angle stiffeners (at approximately 4-ft intervals) to assist in removing crabs and debris. The brush stiffness should be comparable to that designated as MSG 0.06 WSN (American Brush Company) (figure 4).

6. A 4-inch brush will also be used to seal the space between the upstream ramp and the screen to prevent crabs from being pulled beneath the screen.

7. A guide plate positioned parallel to the screen at a distance of 4 inches will be added next to the upstream face of the screen to capture the crabs after they are removed from the flow (figure 5). This will prevent their escape as they are moved up and over the upstream face of the screen and deposited into a hopper (figures 6 and 7).

8. As a result of observations in crab behavior, it was determined that the best way to remove and dispose of the crabs, after they have been removed from the flow, is to deposit the crabs into a hopper located on the back side of the traveling screen. An auger will lift the crabs from the hopper into a dumpster or truck. The hopper will be fabricated by the water district.

9. A spray wash system and rotary brush were very effective in removing crabs and debris from the screen and depositing them into a hopper located on the back side of the screen (figure 7).

10. Additional tests conducted with physical barriers look promising as a means for diverting and removing crabs (while still allowing fish passage) from the Tracy primary channel before they reach any of the louver structures.

Test Set-up

The traveling screen was tested in the Denver WRRL Laboratory in a 4-ft-wide by 8-ft-deep flume. The screen tested was 4-ft wide by 12-ft high and was installed in the flume at an angle of 80° in order to provide adequate fish passage through the screen belt openings (figure 8). Four-inch-long brushes were attached to angle iron stiffeners (positioned about every 4 ft) across the width of the screen to assist in carrying crabs and debris up and over the screen. A floor ramp was installed upstream from the screen at a 5:1 slope to the height of the top of the bottom roller on the screen. This

was installed to provide a smooth flow transition from the flume area to the open area of the traveling screen and to help maintain strong flow velocities along the channel invert. Initial tests showed that a rubber seal located at the end of the floor ramp to seal the space between the ramp and the screen was not adequate. High velocities in the flume pulled the rubber seal down beneath the screen. As a result, the rubber seal was replaced with a flat brush which performed well and will be included in the final design. The speed of the screen was controlled by a variable speed controller yielding a maximum speed of 5 ft/min. Testing was conducted with flow velocities ranging from about 1 ft/s to 3.5 ft/s measured in the center of the flume about 8 ft upstream from the screen with a Sontek acoustic Doppler velocimeter (ADV) probe.

Screen Cleaning system

Both a high pressure spray wash and rotary brush were used. Water was supplied to the spray bars at a pressure of 60 psi and effectively removed debris from the screen. However, the field tests conducted in 1998 found that some crabs which held tightly to the screen were not removed by spray alone. A rotary brush was mounted on the back side of the screen about 1.5 inches from the screen face and about 12 inches below the top of the screen (figure 7). The rotary brush rotated in the same direction and turned at the same speed as the screen and was found to be very effective when used with the spray wash system. The spray wash system final design will consist of three spray wash bars, two directed at the top and one at the bottom of the rotary brush (WRRL 1).

Screen belts

Two different belt configurations were tested on the screen. The belt that was initially installed and tested on the screen was FPI's conventional wire belt weave similar in geometry to that of a chain link fence with 2-in-wide by 4-in-high openings (figure 3a). The second configuration used on the screen was a custom belt design developed by Reclamation using plastic coated cable laced through a series of eyelets welded to stainless steel support rods. The resulting screen mesh is a rectangular shape with an opening of 1.5 inches horizontal and 4.5 inches vertical (figure 3b). The final mesh opening size for this custom belt was determined by tests conducted in the flume with a stationary wire grid used to determine the maximum size opening that would prevent movement of crabs to the downstream side (figure 9).

Although both belts performed adequately in allowing small fish to pass through, the rectangular shape provided a larger area for the fish to negotiate and easier access through the screen. In addition, the vertical plastic-coated cables on the custom belt are softer and more flexible than the wire belt and are therefore more forgiving should any fish be swept into it at the higher velocities. Methods for clamping the cables together on the custom belt will be investigated, including methods that will allow easy adjustment of the cables should they stretch.

Debris pick-up bars and 4-inch brushes extending the width of the screen were installed on both belts at approximate intervals of 4 ft. The purpose of these brushes is to assist in the collection of debris and crabs and to carry them up and over the steep face of the screen (figure 4).

Investigations

Crab Observations

When the flow velocity in the flume was less than or equal to about 1.8 ft/s the crabs were able to maneuver on the bottom of the flume fairly well. At these velocities the crabs were able to grab onto even small appurtenances in the flume to prevent movement if desired. However, most of the crabs did eventually make their way to the screen and grab onto the mesh until they were carried above the water surface (figure 11). When the crabs reached a height of 3 to 6 inches above the water surface they had a tendency to crawl or fall repeatedly back into the water. In general, the crabs that hung on for a longer period of time (including those that approached the top of the screen), eventually loosened their grip to crawl down the screen, and as a result, fell from the screen back into the flow where the process began over again. When the screen speed was increased, the crabs simply crawled back down the screen more quickly.

For velocities greater than 1.8 ft/s the crabs were readily swept onto the screen and were unable to back away from it. Their behavior was similar to that at the lower velocities except the crabs were less able to maneuver themselves into different positions and were sometimes pinned against the screen backwards or upside down (this was especially true for velocities greater than 2.5 ft/s). However, at these higher velocities, the crabs became worn out quickly through their repeated efforts to stay within the flow. After a few minutes the crabs stayed on the brushes and were carried up and over the screen.

Crabs were also tested at night since past observations demonstrated that they may be more active at that time. Although the crabs appeared to be more lively when tested at night their behavior in response to the traveling screen was similar to the behavior they exhibited during daylight. Therefore all subsequent testing was conducted during the daytime.

Guide Plate

As a result of the crab behavior exhibited in response to the screen, the screen was modified to include a solid steel plate (10-ft long by 4-ft wide by 1/4-in thick) installed parallel to the screen at a distance of 4 inches to allow passage of the brushes (figure 5). The purpose of the plate was to trap the crabs within compartments created by the plate and the brushes as they rose up the face of the screen (figure 11). The bottom edge of the plate was located 2 to 3 inches above the water surface so that the crabs would become trapped before they started their climb back to the water surface. This configuration proved to be extremely effective in removing the crabs from the flow. Most of the crabs were removed from the upstream face of the screen within a very short time. However, some of the crabs were able to escape over the edge or through bent bristles of the brushes to drop down to the next brush. The brushes used in this case were designated as MGS 0.036 (American Brush Company). A set of stiffer brushes (American Brush Company MGS 0.06) were tested and proved effective for the final design. The guide plate installed at TFCF will be controlled to maintain a 2 to 3-in clearance above the water surface. Plate movement will be activated by a water surface sensor which will feed into a controller and computer which will set the position of the plate with a drum hoist (figure 10). This type of arrangement was tested in the

laboratory and worked well. In addition, the plate was modified using spring loaded rollers to allow lateral movement of the plate to provide expansion of the area between the plate and screen for passage of large amounts of sticks and debris (figure 12). The final design for the guide plate is shown in appendix A (drawing CPLATE).

Although tests with this arrangement showed that a slow screen travel speed (≤ 2.5 ft/min) worked well in removing the crabs from the flow, further experiments will be needed after the screen is installed at the site to determine the most effective speed for removing crabs since behavior may be slightly different for healthier crabs and large numbers of crabs. Keeping the speed slow is also more conducive to fish passage since it allows the fish more time to negotiate their way through the openings.

Fish Observations

Limited fish experiments were conducted using trout, splittail, striped bass, and blue gill. All tests conducted thus far with fish were conducted with the screen speed set at 2.5 ft/min. An extensive study with fish was not conducted in the laboratory tests because prototype water quality and light conditions could not be simulated. Further fish passage tests will be conducted in the prototype.

The following are general observations from the limited tests conducted:

Trout - The trout ranged in size from about 3 inches to 10 inches in length. Two test trials were conducted with the conventional wire belt with six fish in each trial. Two trials were also conducted with the custom cable belt with six and eight fish per trial. In general these strong swimmers remained upstream from the screen throughout the experiments. The trout that went through the screen generally did so facing upstream into the flow. Occasionally a fish would swim back and forth through the screen when flume velocities were very low (less than 1 ft/s). However, as soon as the flow velocity was increased above 1 ft/s most of the trout swam upstream well away from the screen. One experiment was conducted for a 27-hour period with 7 small trout and 2 large trout left in the flume overnight at a flume flow velocity of 2.0 ft/s. All fish remained upstream from the screen during the entire test. However, many of the trout had found refuge from the high velocity flow by sticking close to the side walls where velocities were lower.

Splittail - The splittail ranged in length from about 3 to 4 in. Only one test trial was conducted with the custom belt and eight fish. At velocities greater than 2 ft/s about half of the splittail went through the screen easily and under control. They had a tendency to either swim forward well away from the screen or go through it after touching their tails to the screen. In general the splittail that went through the screen did so under control and remained in a position with their heads pointed upstream as they went through. The other half remained upstream from the screen, seeking shelter from the high velocity flow next to the wall where velocities were lower.

Striped Bass - The size of the striped bass ranged in length from 3 in to 5 in. Two test trials were conducted with the conventional wire belt with five fish in each trial. Two test trials were also conducted with the custom cable belt with six and eight fish. Most of these species went through the screen at velocities greater than 2 ft/s, although some

would contact the mesh before going through. In these cases, the plastic coating and flexibility of the custom belt appeared to be more fish-friendly for passage than the standard wire belt. Like the other species some remained upstream from the screen.

Blue Gill - The size of the blue gill ranged in length from 3 in to 5 in. Two test trials were conducted with the conventional wire belt with five fish in each trial. Two trials were also conducted with the custom cable belt with six and eight fish. These species are weaker swimmers than the other species tested and went through the screen fairly quickly at velocities greater than 1.5 ft/s. Often times they were swept sideways into the mesh. Some remained pinned against the screen for a short period of time before passing through the screen. One blue gill was caught between the weave of the standard wire belt and could not escape. Again, the custom belt with the coated cable appeared to have less impact than the standard wire mesh on fish passage, and also eliminated the potential for fish to be caught between the mesh weave.

Additional testing with fish may be desired to determine if various species pass through the screen without sustaining injury.

Debris

Tests were conducted with aquatic vegetation (*Egeria*) and woody material to determine the effectiveness of the two screen configurations for removing large debris. Tests conducted with the standard wire belt showed good performance in removing debris, although some small sticks were occasionally caught between the mesh weave. The *Egeria* accumulated next to the screen and was carried out by the debris brushes.

The custom belt also performed very well in removing large debris. Debris clung easily to the cable belt. As a result, this allowed more of the debris to be carried by the belt itself and reduced the amount of debris accumulating in front of the screen prior to being picked up by a brush (figures 12 and 13).

Physical Barrier Tests

With the exploding Mitten crab population, the numbers of crabs expected to arrive at the TFCF could be in the hundreds of thousands in the coming years. Therefore, a means for removing crabs from the primary channel may be necessary to keep the primary louvers from being plugged by crabs. The Tracy primary channel is nearly 100-ft wide. Several alternatives were investigated to determine the feasibility for diverting crabs across to one side of the channel for removal. Physical barriers tall enough to block crab migration yet short enough to allow the downstream migration of fish were tested.

Initial tests were conducted with a 6-in PVC pipe cut in half lengthwise to act as a crab barrier and to direct the migration of crabs into a trap (figure 14). The half-pipe was installed at a 45° angle to the side wall in an 8-ft-wide test flume with the open side of the pipe facing upstream. The tests were conducted with velocities ranging from 0.5 ft/s to 3 ft/s. This arrangement was effective in directing crabs downstream into a trap. Fish introduced into the flow consisted of trout, splittail, blue gill, and striped bass. At velocities greater than or equal to 2 ft/s, about a quarter of the fish immediately went

over the pipe. However, many fish found refuge from the high velocity flow close to the flume invert in front of the pipe. Many of these fish were also directed along the pipe into the crab trap.

As a result of these investigations a new barrier system was developed consisting of a series of 6-in-high walls staggered at a distance and overlap of about 14 inches, and installed at a 45° angle (figure 15). The gap between the barriers was designed to allow bottom swimming fish an escape path between the structures while still directing crabs with a strong downstream flow current into a trap at the downstream end of the barriers. With this configuration, crabs introduced into the flume at a high flow velocity (> 2 ft/s) were flipped over upside down as they approached the gap between barriers and were sometimes carried right over the barriers. This occurred as a result of a wake which formed due to the angle and proximity of the barriers. Fish introduced into the flow were sometimes caught in the wake and instead of continuing downstream between the barriers, became disoriented and swam in circles before finally being carried downstream.

A third configuration was developed using dye to position alternating 4 ft and 2 ft barriers to eliminate the wake and produce a continuous downstream flow on both sides and between the barriers. The final configuration resulted in the 2-ft sections positioned parallel to the side walls and the 4-ft sections positioned at a 30° angle off the side wall (figure 16). This time several fish holding close to the bottom of the flume went through the gap between the barriers to continue their journey downstream. Crabs introduced into the flow sometimes stopped momentarily in front of the openings between barriers, but would then continue downstream into the trap at the downstream end. None of the crabs ventured through the openings.

Although only a limited number of test cases were conducted with physical barriers, the investigations show good results. A continuous barrier may be successful at the TFCF since the depth of flow and turbidity is greater than that tested in the laboratory. This may result in more fish staying higher in the water column and going over the barriers. This arrangement may also be more successful with the barriers oriented at an angle of 30° instead of 45° to produce a stronger downstream flow and minimize eddy formation. The second configuration of alternating barriers allowed fish an escape route through the barriers while still successfully moving crabs downstream into a trap. Although the barriers may still direct some fish into the trap, the trap can be designed with openings to allow fish passage; and may incorporate a traveling screen similar to the one installed in the secondary channel to remove the crabs and pass fish.

bc: D-8560 (Hanna, Mefford)

WBR:LHanna:rlc:6/23/99:303/445-2146
(j:\wpfiles\crabrpt.wpd)

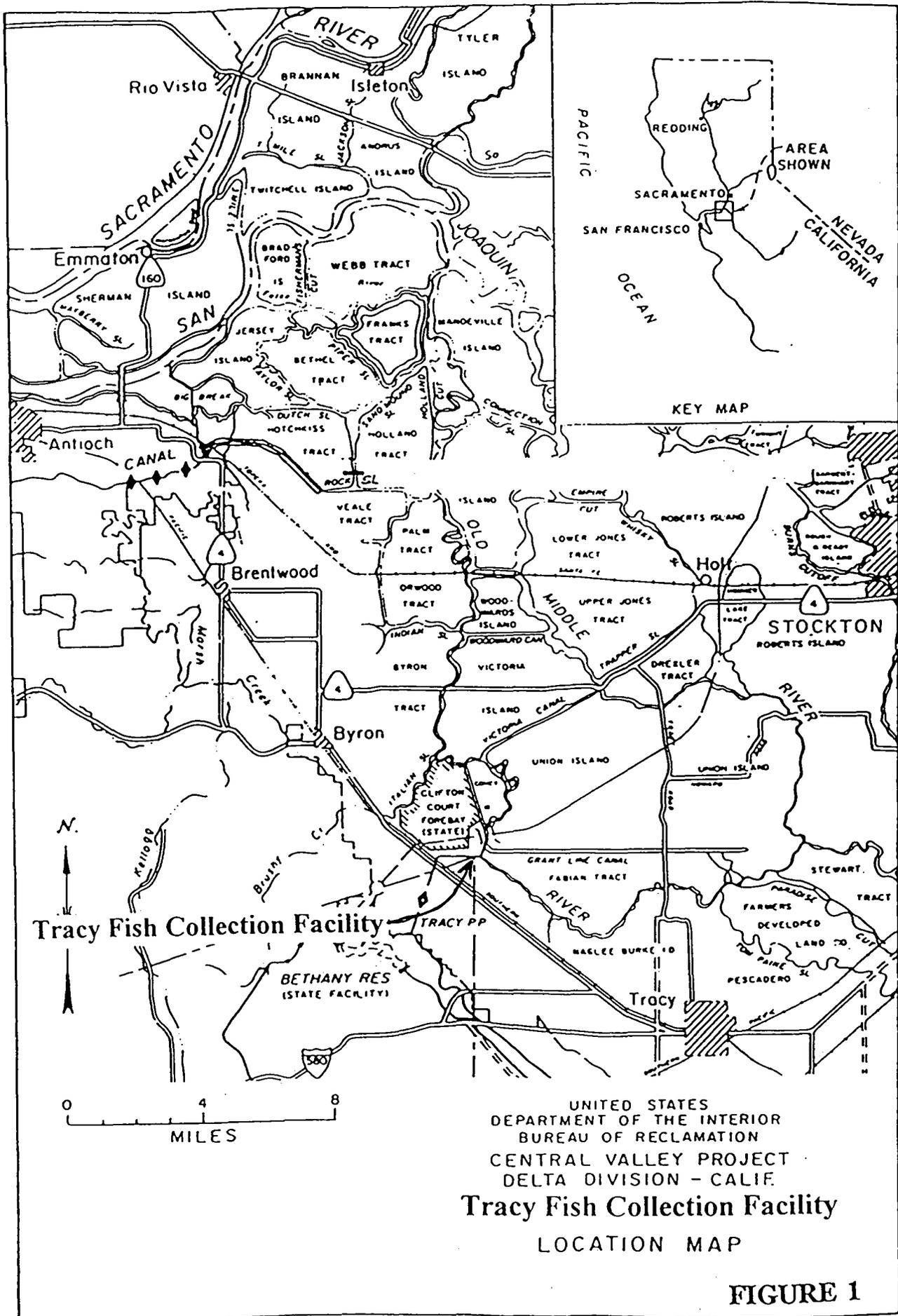


FIGURE 1

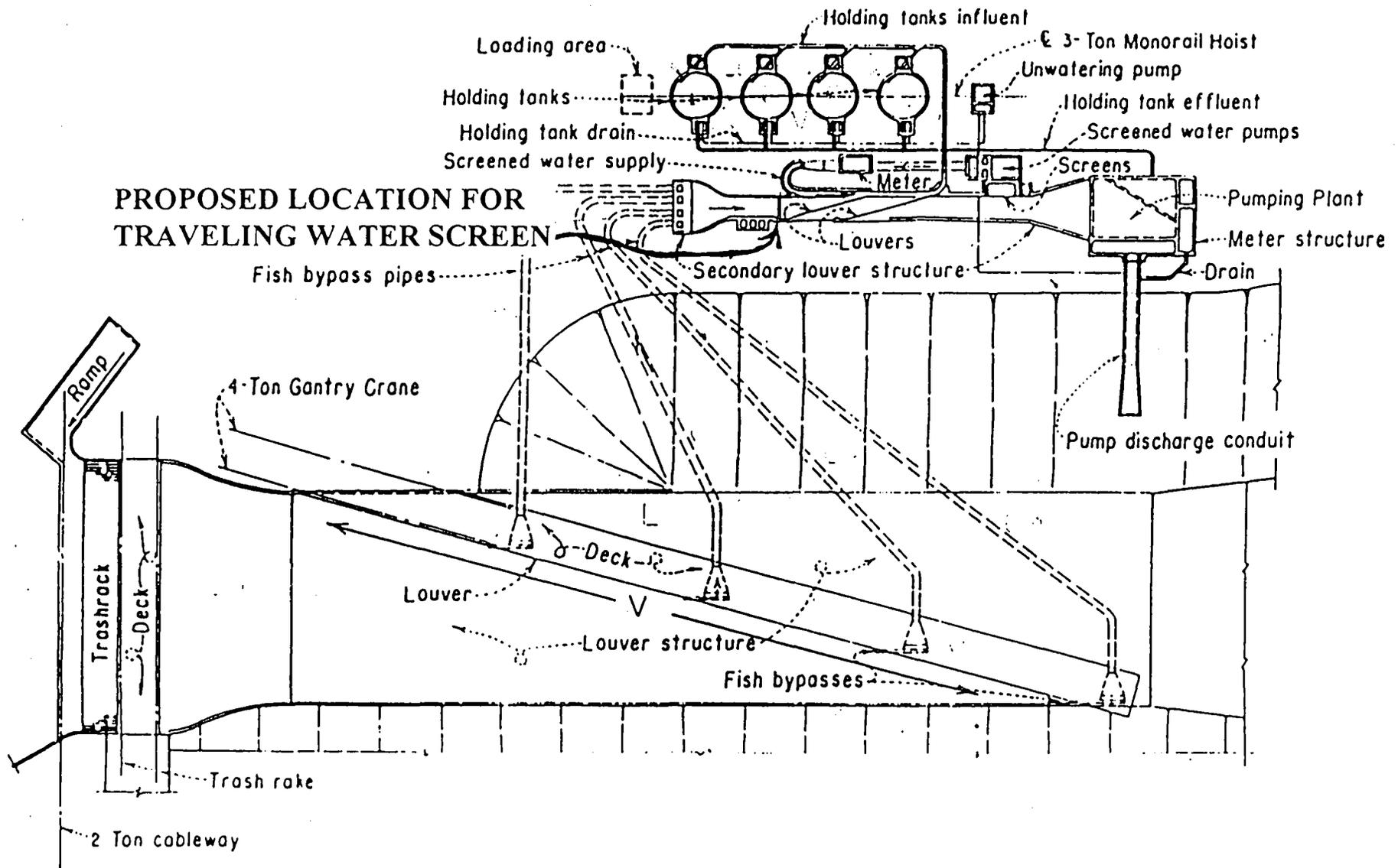


Figure 2. Plan view of the layout of Tracy Fish Collection Facility (TFCF).



a) FPI's conventional wire belt.



b) Custom belt developed by Reclamation.

Figure 3. FPI's traveling water screen installed in Denver Laboratory's 4-ft flume (view from top).

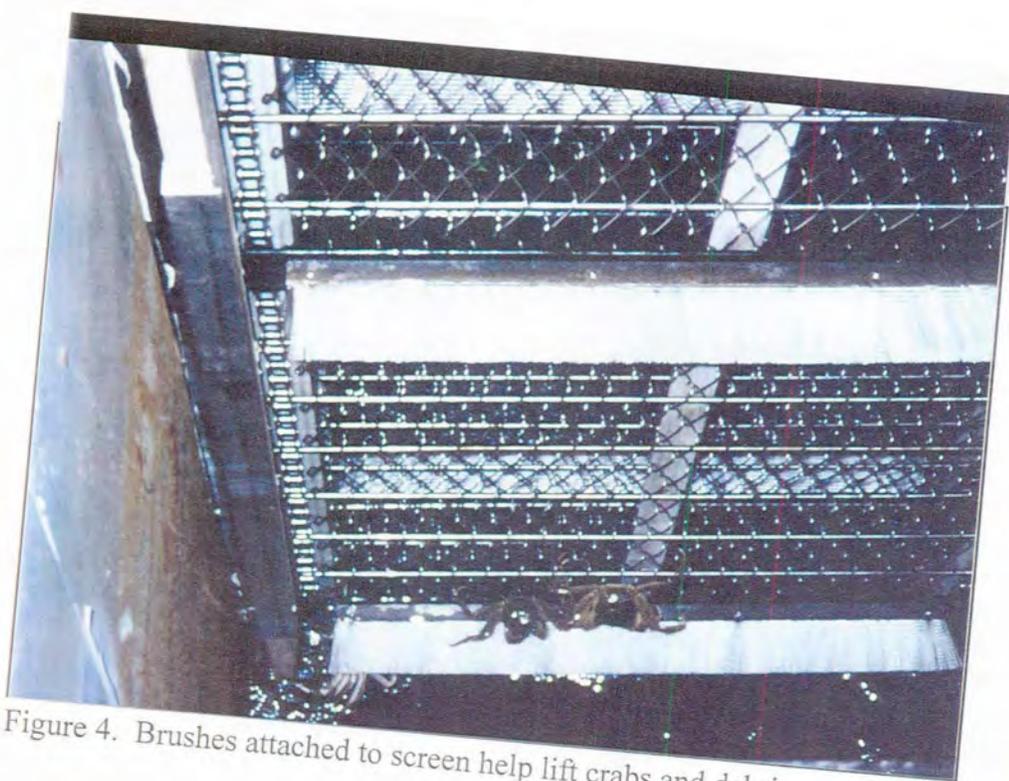


Figure 4. Brushes attached to screen help lift crabs and debris.



Figure 5. Guide plate installed parallel to screen traps crabs to prevent escape.

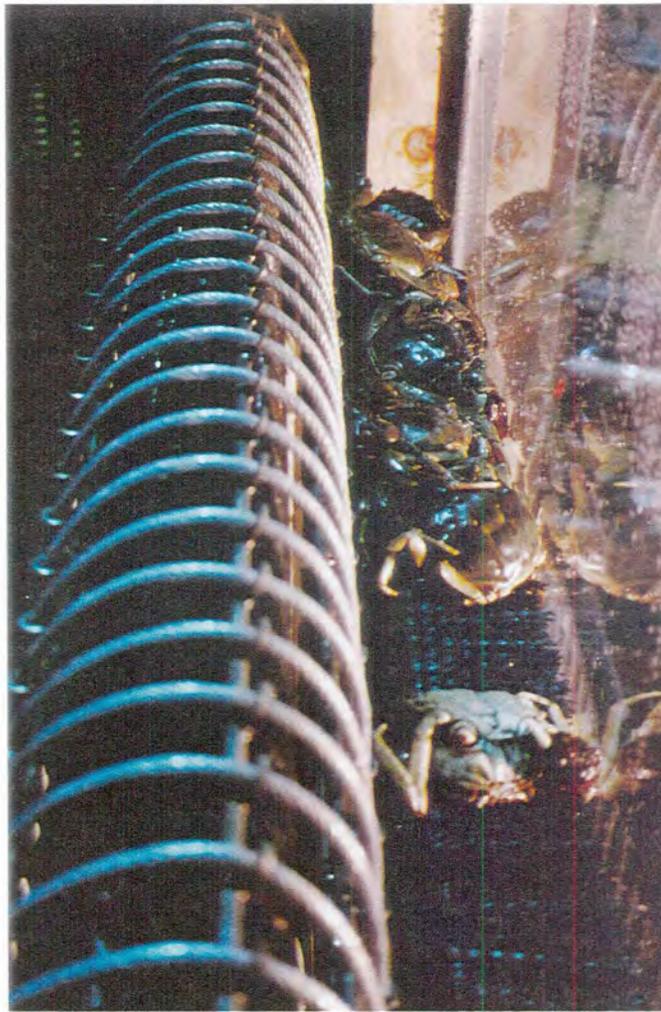


Figure 6. Crabs lifted to top of screen are confined by brushes and guide plate.

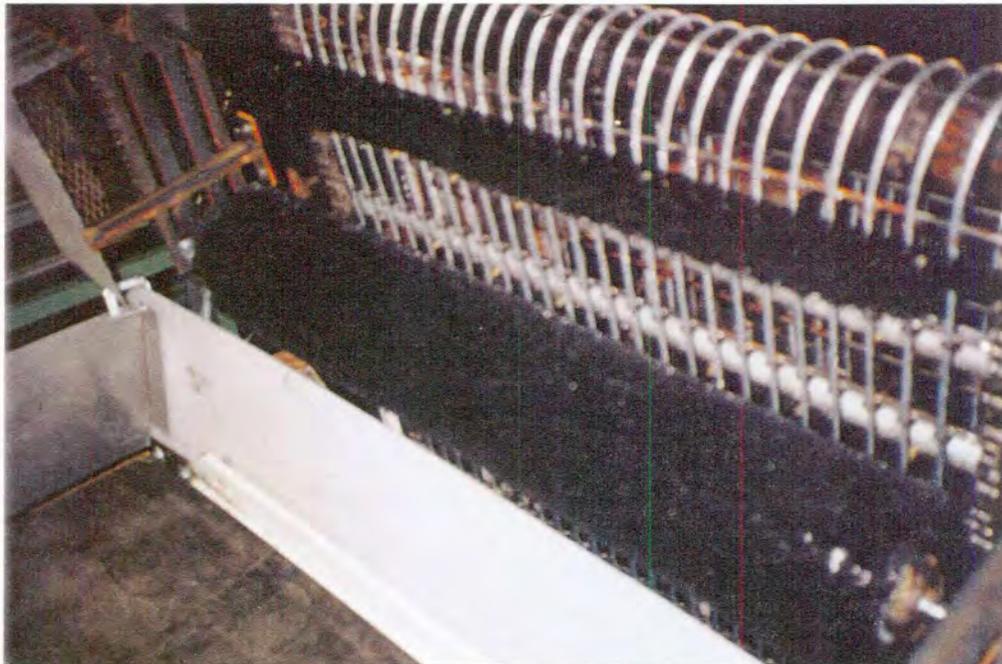


Figure 7. Rotary brush installed on back side of screen to assist in disposing crabs and debris into a hopper.



a) View looking downstream at screen.



b) Side view through plexiglass wall.

Figure 8. Traveling screen installed at 80° in the Denver Laboratory 4-ft-wide by 8-ft-deep flume.

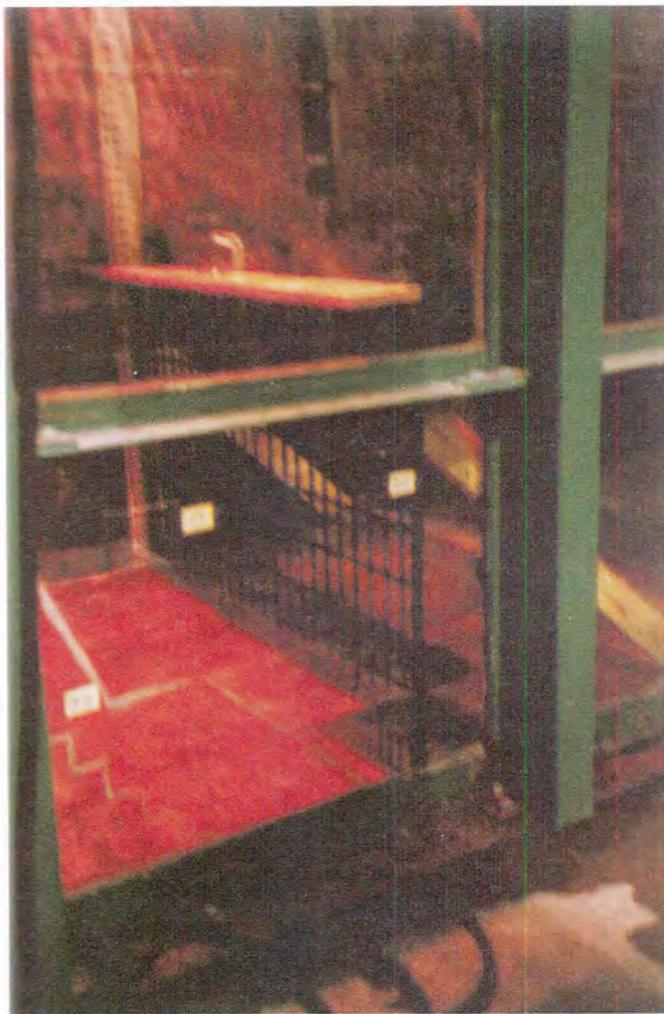


Figure 9. Wire grid tested to determine optimum size for removing crabs and passing fish.

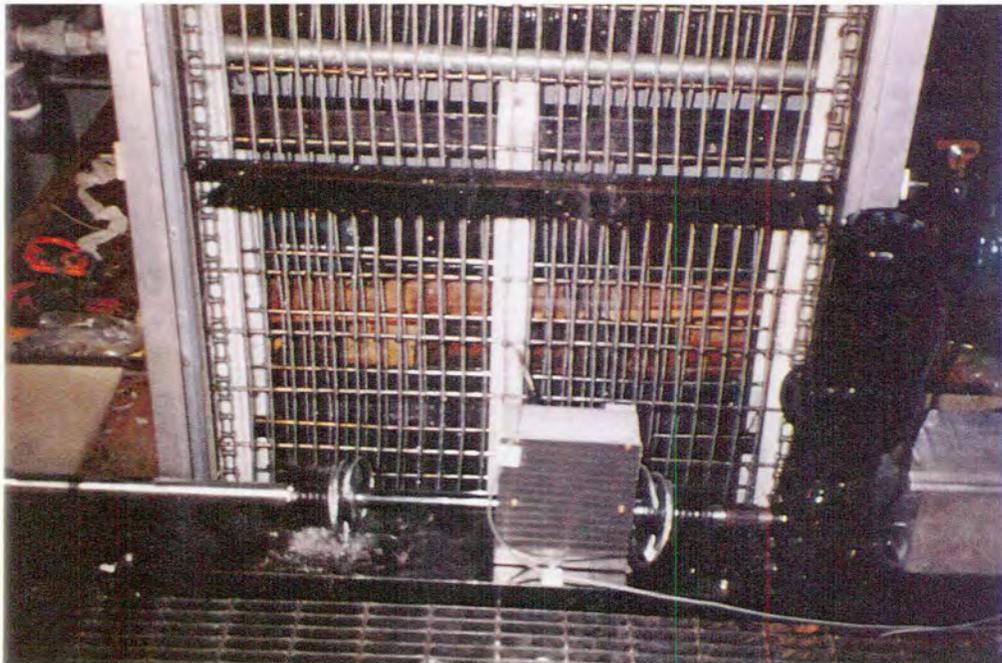


Figure 10. Drum hoist used to lift clear plexiglass guide plate.



Figure 11. Crabs trapped by rising brushes and clear plexiglass guide plate.

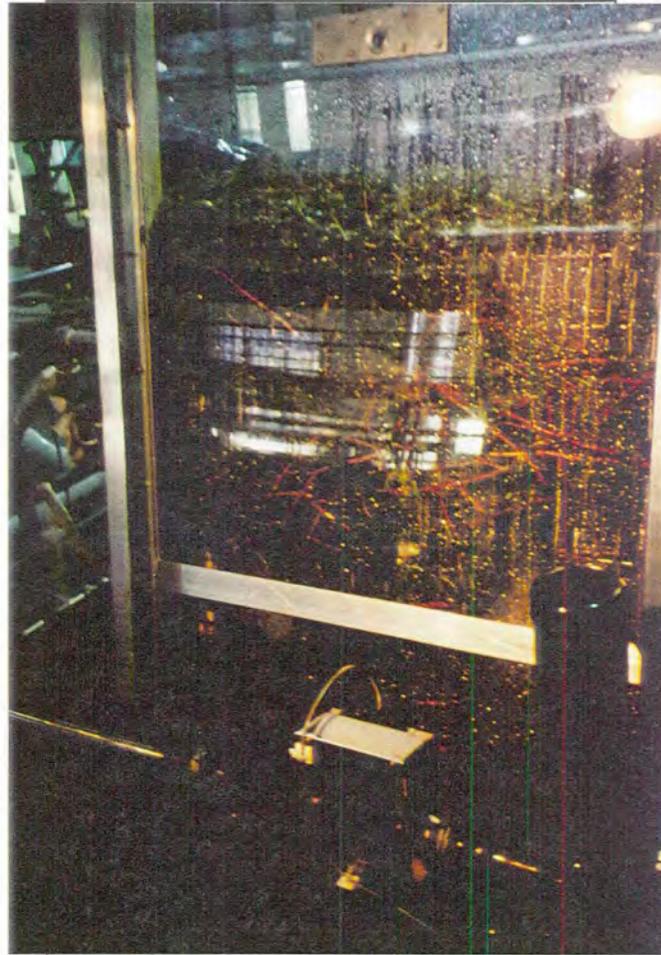


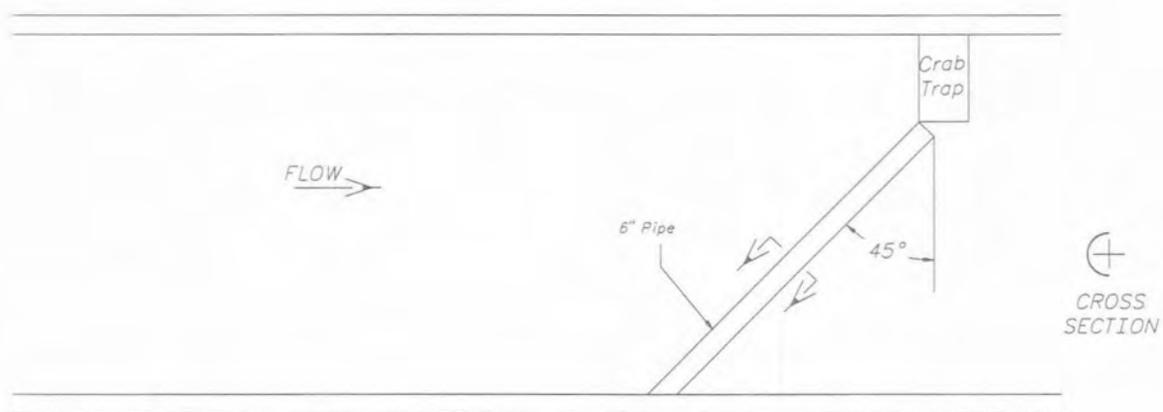
Figure 12. Debris trapped behind clear plexiglass guide plate.



Figure 13. Guide plate spring loaded rollers compress to allow passage of large amounts of debris.



a) Half-pipe barrier used for model tests.



b) Plan outline of half-pipe physical barrier.

Figure 14. Physical barrier tested for diverting crabs into a trap.

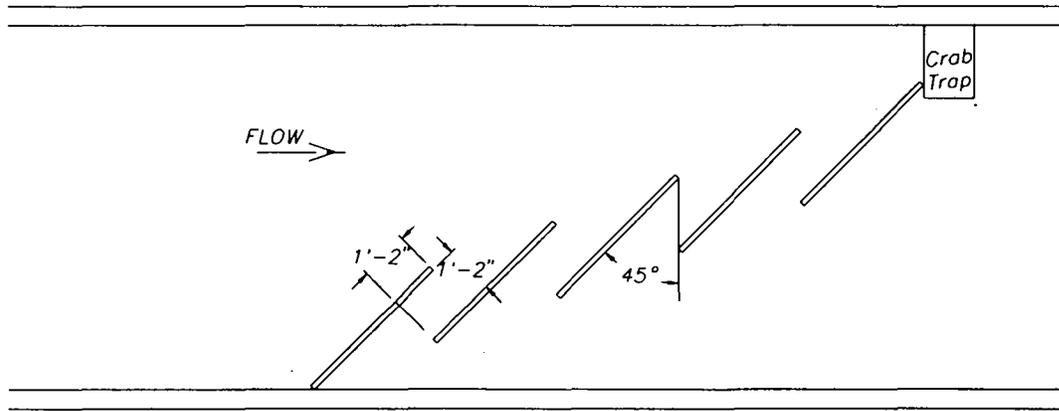


Figure 15. Alternating barriers at 45 degrees; configuration 1.

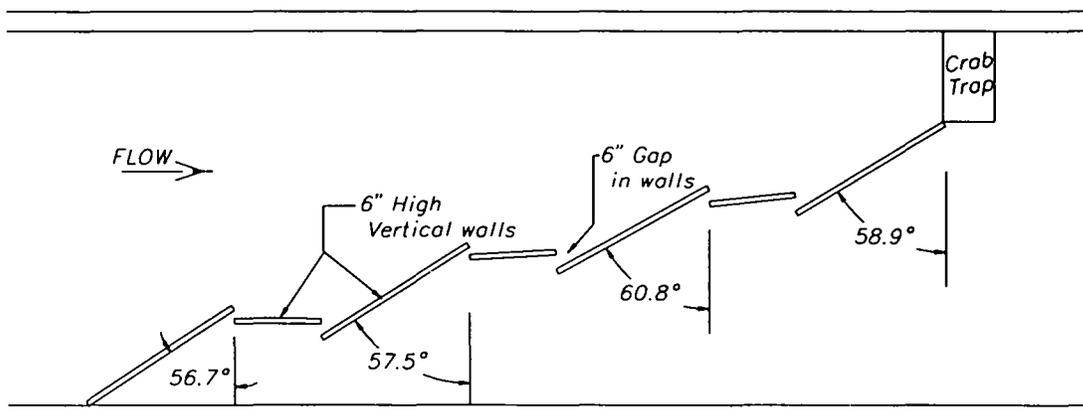
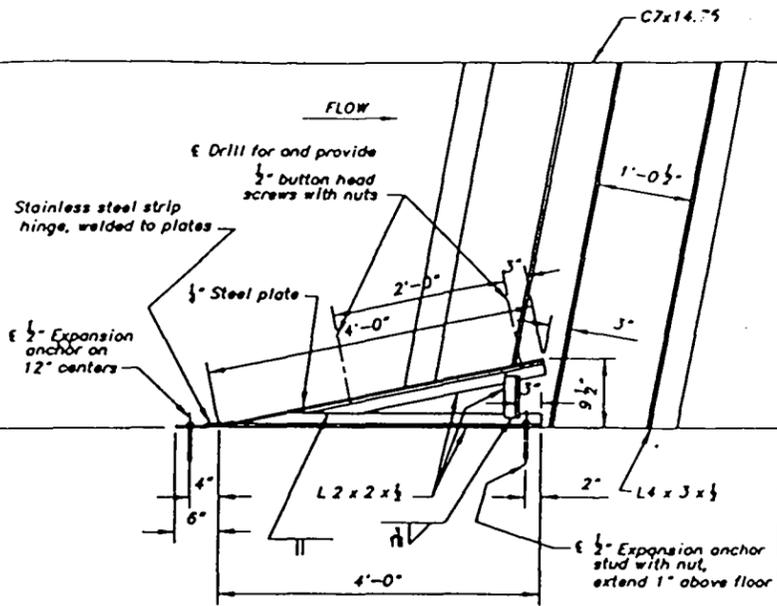
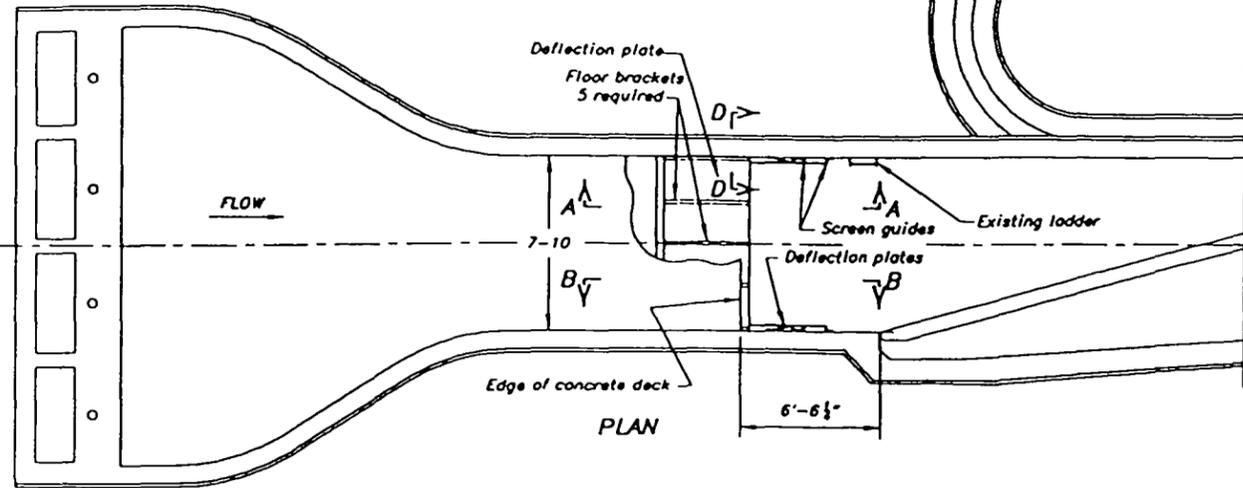


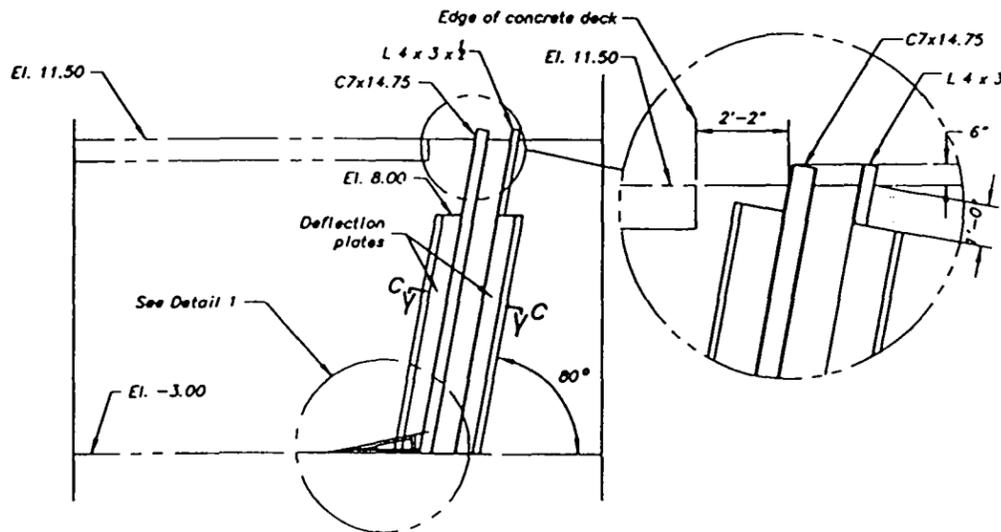
Figure 16. Alternating barriers; configuration 2.

APPENDIX A

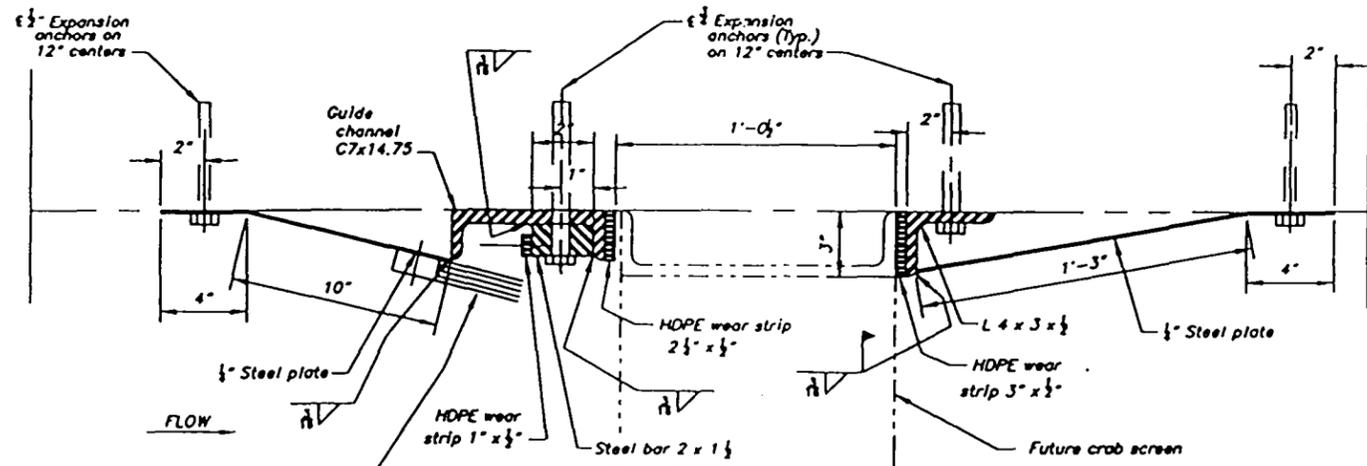


DETAIL 1

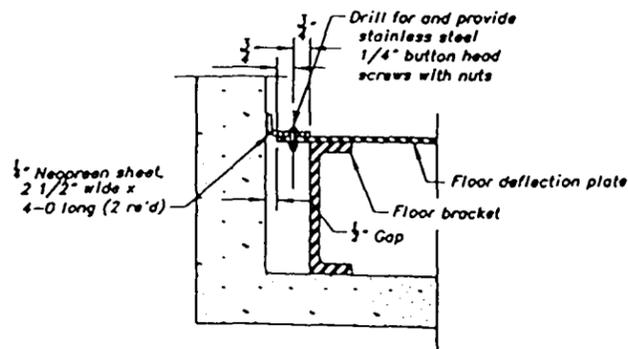
NOTE: Drill, tap and countersink for and provide 3/8\"/>



SECTION A-A
SECTION B-B (OPPOSITE HAND)



SECTION C-C



SECTION D-D

NOTES

Coat all mild steel with potable epoxy paint.
Move existing ladder as necessary for guide installation.

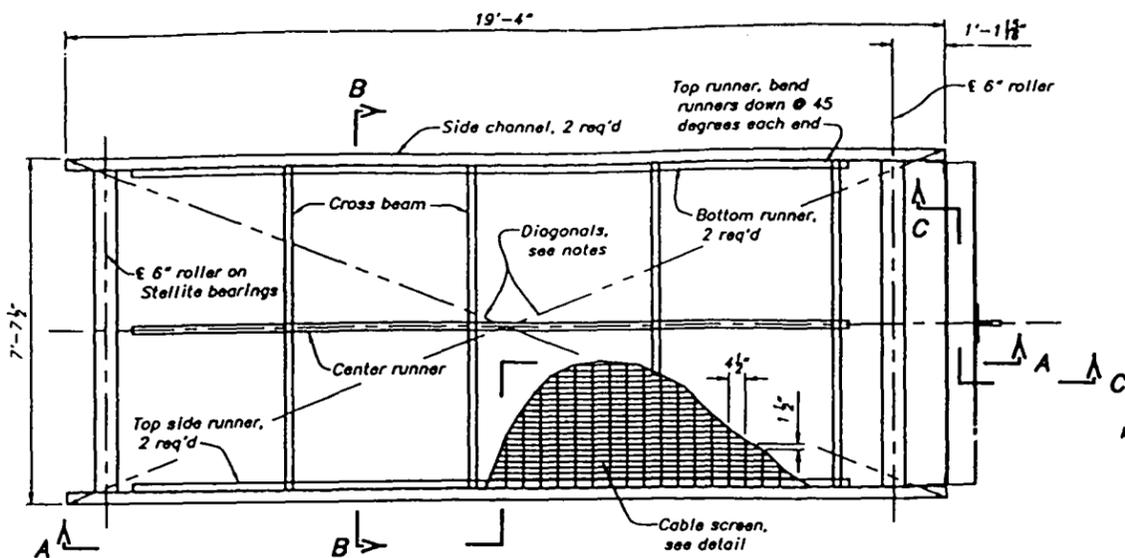
REFERENCE DRAWINGS

FISH COLLECTING FACILITIES	
GENERAL PLAN	214-0-19556
GENERAL SECTIONS	214-0-19557
GENERAL ARRANGEMENT	214-0-19568

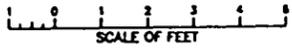
⊕ ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT - CALIFORNIA
DELTA DIVISION - DELTA - MENDOTA INTAKE CANAL
TRACY FISH COLLECTING FACILITIES
SECONDARY LOUVER STRUCTURE
CRAB SCREEN GUIDES
PLAN - SECTIONS - DETAILS

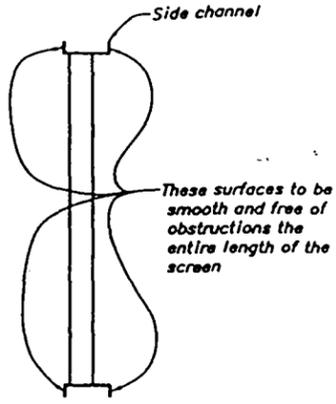
DESIGNED BY	CHIEF
DRAWN BY	REK APPR
APPROVED	
DATE	NOV 21 1964
PROJECT NO.	214-D-24051
SHEET NO.	1 OF 1



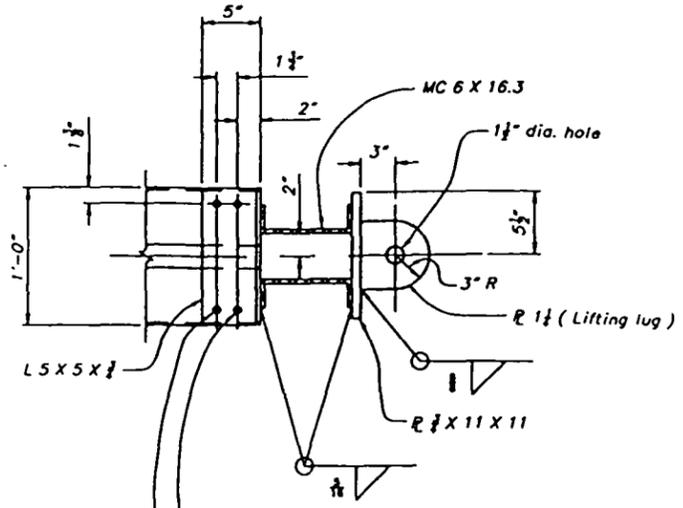
PLAN - LOOKING UPSTREAM



Mount motor and gear box on top and left side of screen (looking upstream). Motor and gear box assemblies shall not project upstream of the plane of the upstream screen face or downstream of the plane of the downstream screen face.

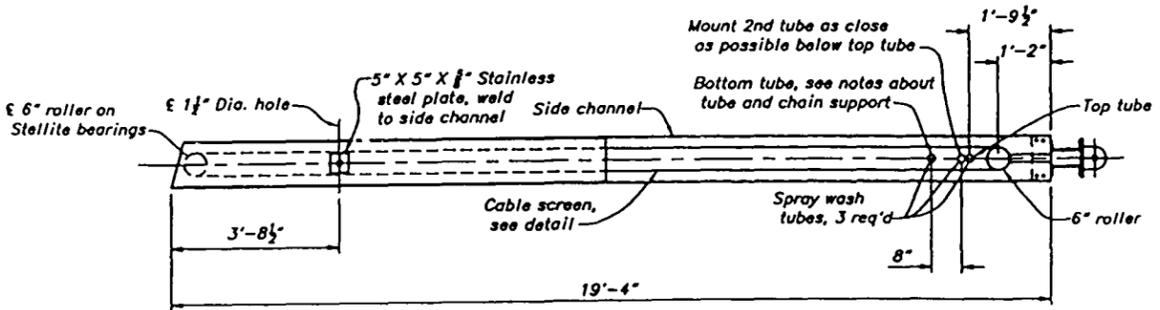


SECTION B-B

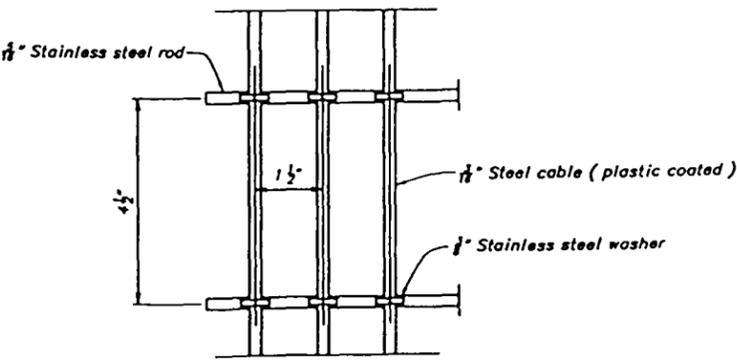


Drill 1/2" dia. holes and provide 1/2" dia. ASTM A325 high strength steel hex bolts with hex nuts and hardened washers (all galvanized). Bolt length to suit.

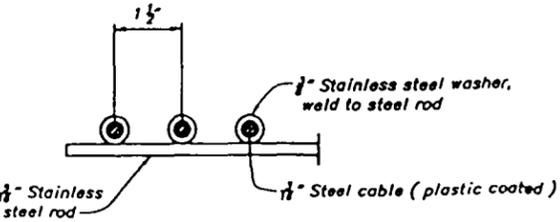
SECTION C-C



SECTION A-A



CABLE SCREEN DETAIL



NOTES

Length of diagonals shall be no more than 1/4" difference. Chain supports on downstream side of screen shall not extend above lowest edge of bottom spray wash tube.

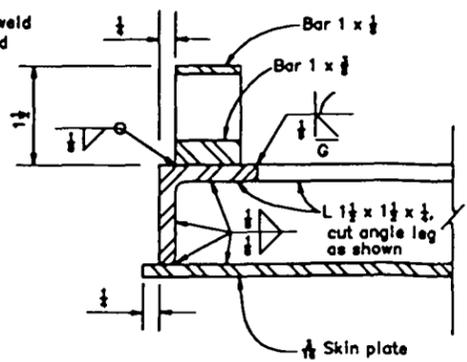
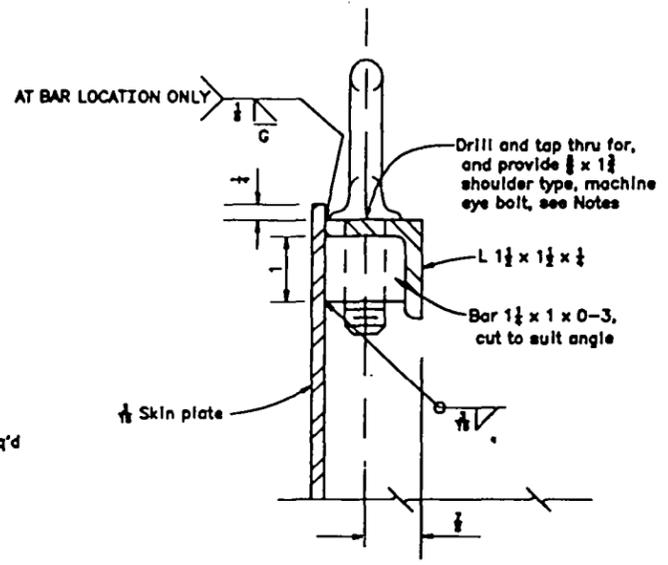
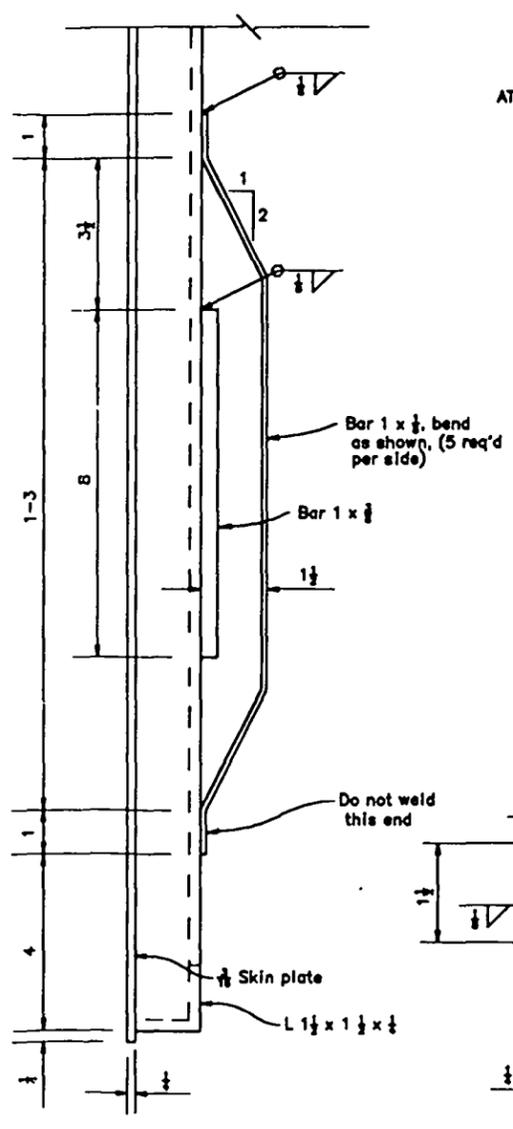
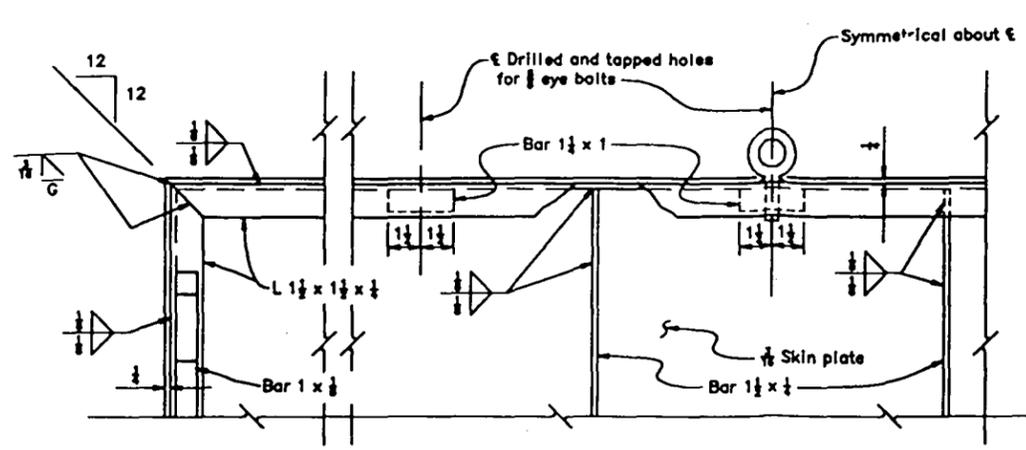
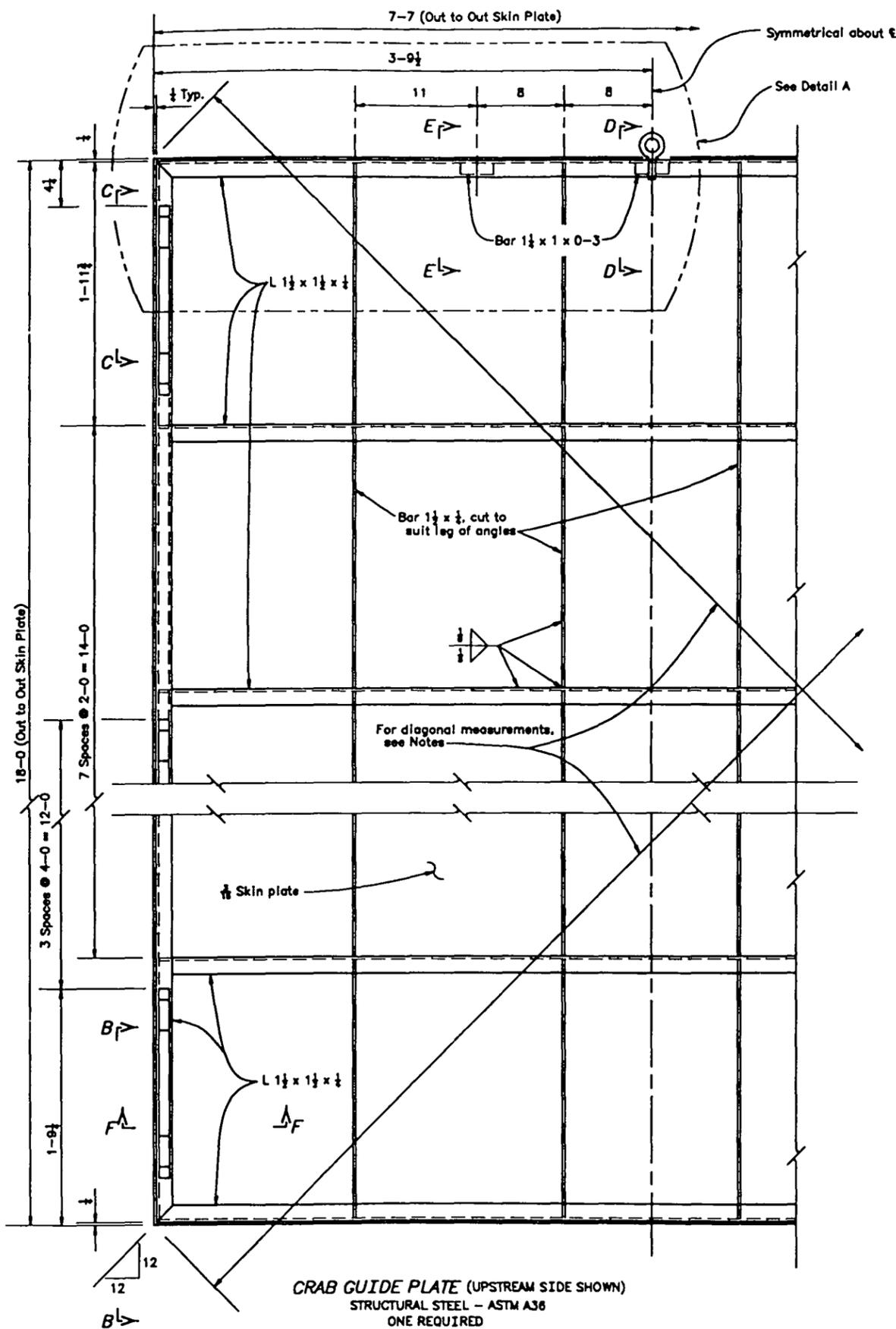
⊕ ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

TRACY CRAB SCREEN

DESIGNED _____ TECH. APPR. _____
DRAWN _____
CHECKED _____ APPROVED _____

DATE SYSTEM _____ DATE PLOTTED _____
DRAWN BY: [Name] CHECKED BY: [Name]
DATE: [Date] SHEET 1 OF 1



NOTES

Welding symbols apply to the joints of all members of similar identification. All fillet welds shall be returned. The crab guide plate shall be square with an allowable variation of not more than 0.25-inch between overall diagonal measurements. Special precaution and measures shall be taken to minimize and control warpage while welding the members. The shoulder type, machine eye bolt shall have a working load limit of at least 5200 pounds. Drill drain holes in skin plate and/or angles as required. Coat all steel with potable epoxy paint.

Estimated weight ----- 1420 pounds.

ALWAYS THINK SAFETY

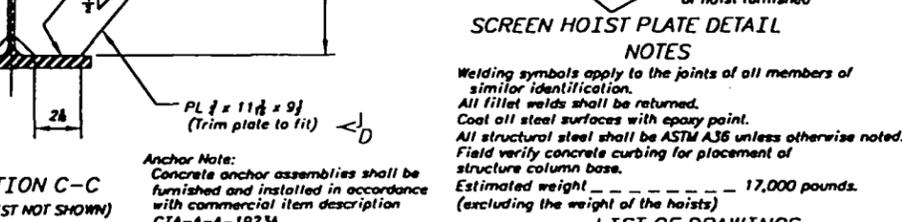
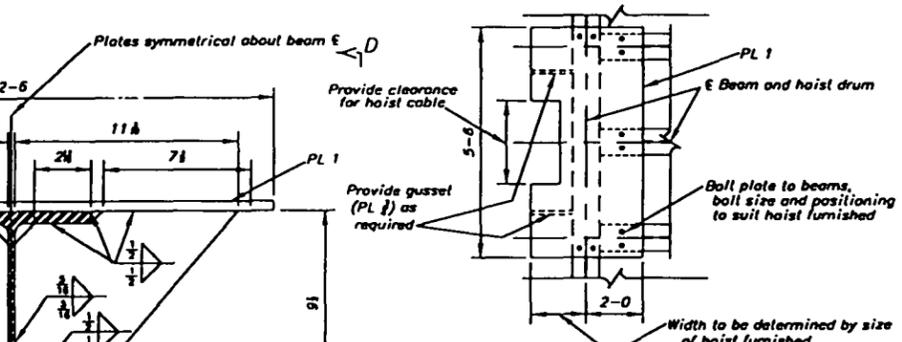
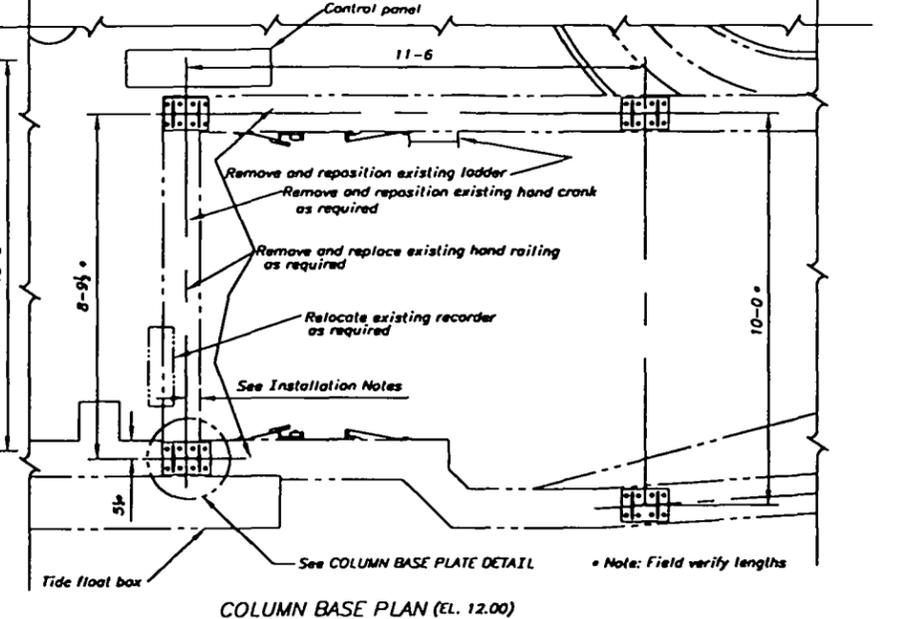
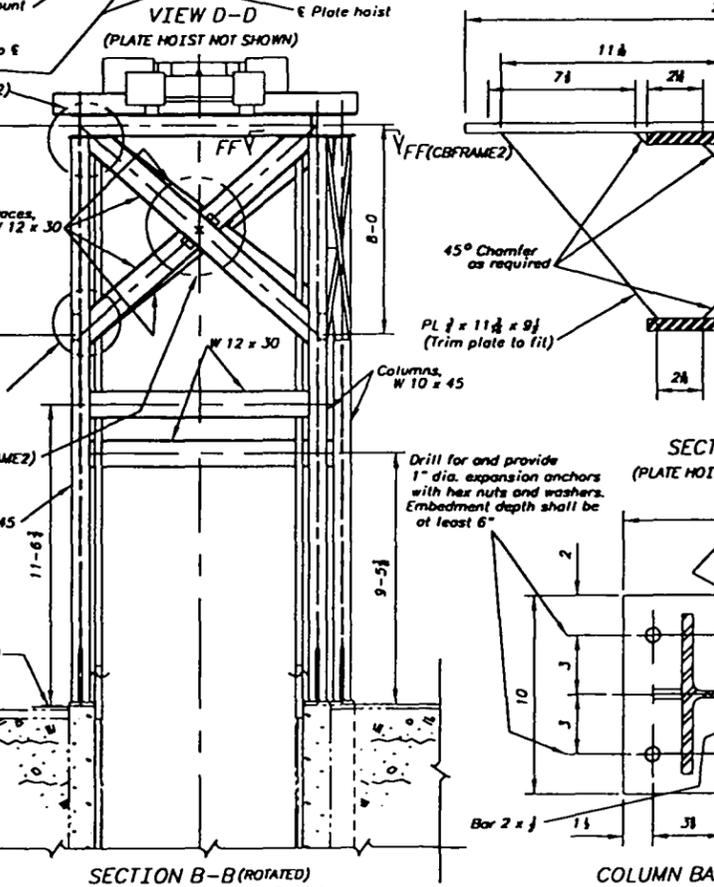
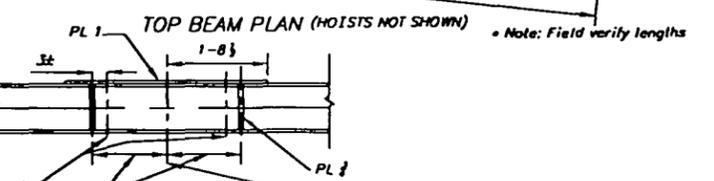
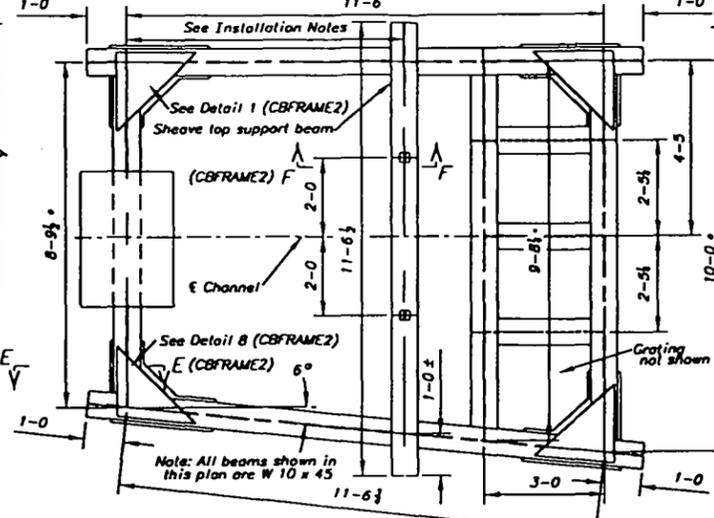
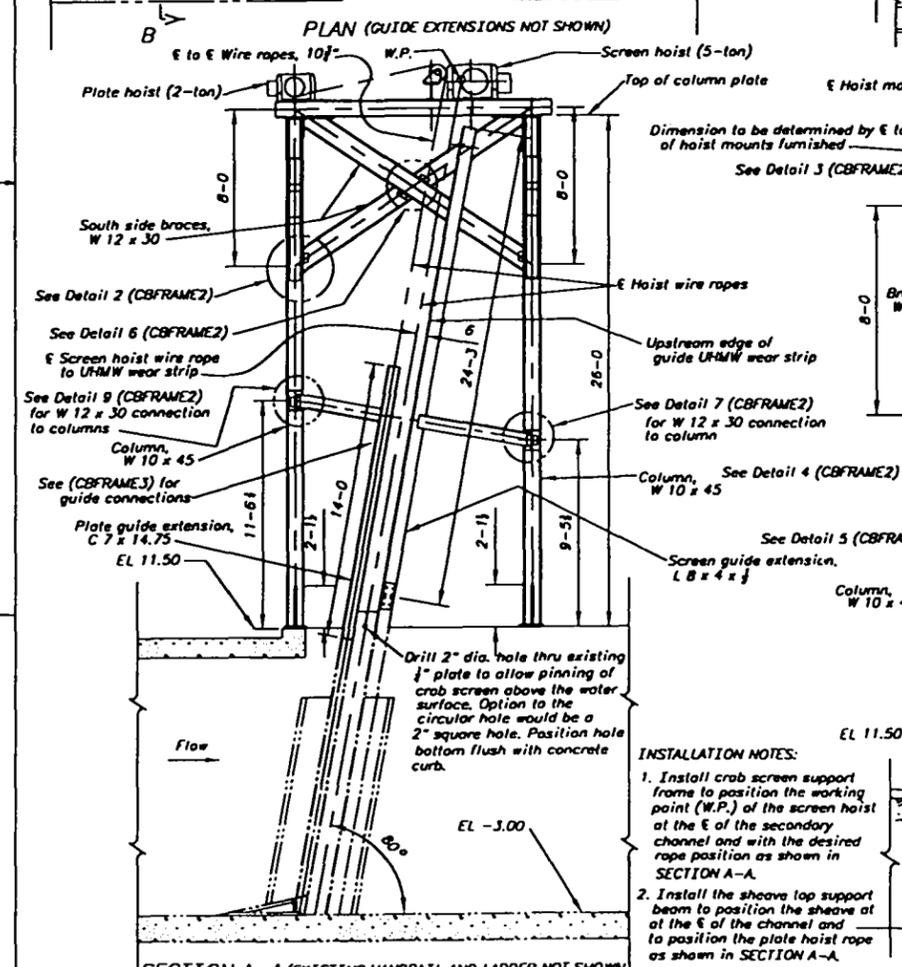
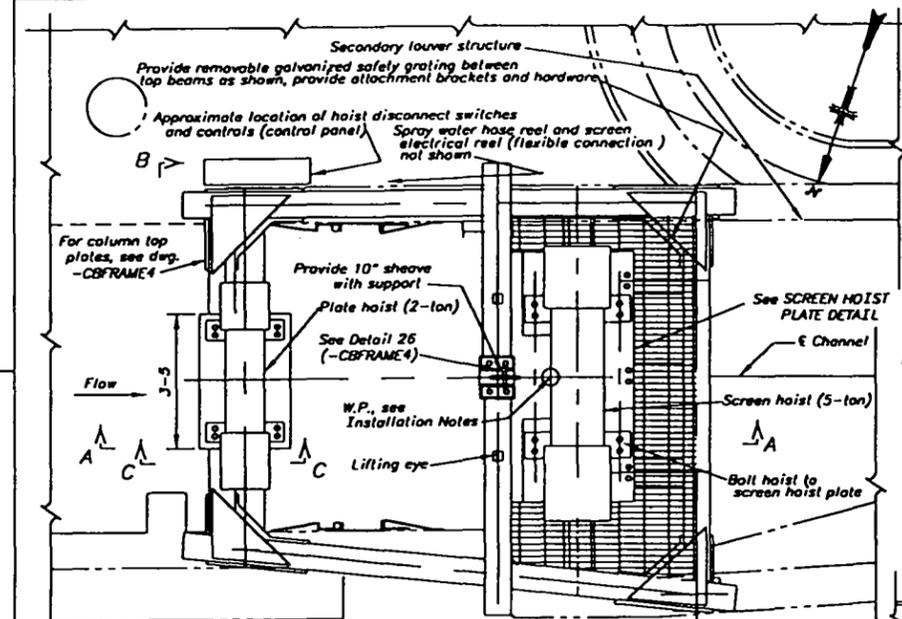
DESIGNED BY R. Christensen
 DRAWN BY R. Christensen
 CHECKED BY []
 DATE AND TIME PLATED []

**CENTRAL VALLEY PROJECT - CALIFORNIA
 DELTA DIVISION - DELTA-MENDOTA INTAKE CANAL
 TRACY FISH COLLECTING FACILITIES
 SECONDARY LOUVER STRUCTURE
 CRAB GUIDE PLATE
 SECTIONS AND DETAILS**

DESIGNED BY R. Christensen
 DRAWN BY R. Christensen
 CHECKED BY []
 DATE AND TIME PLATED []

DESIGNED BY R. Christensen
 DRAWN BY R. Christensen
 CHECKED BY []
 DATE AND TIME PLATED []

CBFRAME



- NOTES**
- Welding symbols apply to the joints of all members of similar identification.
All fillet welds shall be returned.
Cool all steel surfaces with epoxy paint.
All structural steel shall be ASTM A36 unless otherwise noted.
Field verify concrete curbing for placement of structure column base.
Estimated weight ----- 17,000 pounds.
(excluding the weight of the hoists)
- LIST OF DRAWINGS**
- CRAB SCREEN SUPPORT FRAME
INSTALLATION - PLANS - SECTIONS - DETAILS - CBFRAME
BEAMS - ASSEMBLY - DETAILS - CBFRAME2
GUIDES - ASSEMBLY - DETAILS - CBFRAME3
BEAMS - COLUMNS - DETAILS - CBFRAME4

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT - CALIFORNIA
DELTA DIVISION - DELTA - MENDOTA TWIN CANAL
TRACY FISH COLLECTING FACILITIES
SECONDARY LOUVER STRUCTURE
CRAB SCREEN SUPPORT FRAME
INSTALLATION - PLANS - SECTIONS - DETAILS

DESIGNED: [Signature] CHECKED: [Signature]
DRAWN: [Signature] REVISION: [Signature]

APPROVED: [Signature]

DATE PLOTTED: [Signature] DATE IN HAND: [Signature]
APPROVED FOR: [Signature] CHECKED FOR: [Signature]
DRAWN: [Signature] SHEET 1 OF 4

- INSTALLATION NOTES:**
1. Install crab screen support frame to position the working point (W.P.) of the screen hoist at the E of the secondary channel and with the desired rope position as shown in SECTION A-A.
 2. Install the sheave top support beam to position the sheave at the E of the channel and to position the plate hoist rope as shown in SECTION A-A.

