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HYDRAULIC MODEL STUDY OF CONTRA COSTA CANAL FISH SCREEN STRUCTURE AND TRASH RAKE

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The Bureau of Reclamation and the Contra Costa Water District (CCWD) have initiated planning and pre-design activities which will lead to the installation of fish screens at CCWD's Rock Slough Diversion. Fish screens are required per Section 3406(b) of the Central Valley Project Improvement Act (CVPIA), and the Los Vaqueros Biological Opinion for Delta smelt, issued by the Fish and Wildlife Service in September 1993.
Two separate physical models were used to evaluate designs for the Contra Costa Canal fish screen structure facility. One model was constructed for the purpose of evaluating approach flow conditions and velocity distributions along the length of the structure and to determine required baffling to produce a uniform velocity distribution . A second model was constructed to evaluate the proposed hydrorake system that will be installed at the facility to remove debris from the screens.

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HYDRAULIC MODEL STUDY OF CONTRA COSTA CANAL FISH SCREEN STRUCTURE AND TRASH RAKE

by

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Denver, Colorado

October 1999

UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

U.S. Department of the Interior
Mission Statement

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to tribes.

CONTENTS

CONTENTS - continued

Tables

Figures

PURPOSE

The hydraulic model study was conducted to evaluate screen velocity distributions of the proposed Contra Costa Canal (CCC) site B-West fish screen structure and to determine required baffling to produce a uniform velocity distribution along the length of the structure. In addition, a separate model was constructed to evaluate trash rake performance for removing large and small debris from the fish screen structure.

INTRODUCTION

The CCC facilities and operations serve as Contra Costa Water District's (CCWD) main water supply and delivery system. The CCC intake is located off Rock Slough on the lower San Joaquin River (figure 1), just south of Big Break and Dutch Slough [1]. The CCC has diverted water (unscreened diversions) since 1940 from the San Joaquin/Sacramento River Delta which receives water from various Central Valley Project storage reservoirs (i.e., Shasta, Folsom, and Trinity Reservoirs). Currently, CCC diverts some 120,000-135,000 acre-ft/yr [CCWD, 1993], including minor diversions made from Mallard Slough (located just south of Chipp's Island and connected to the south shore of Session Bay).

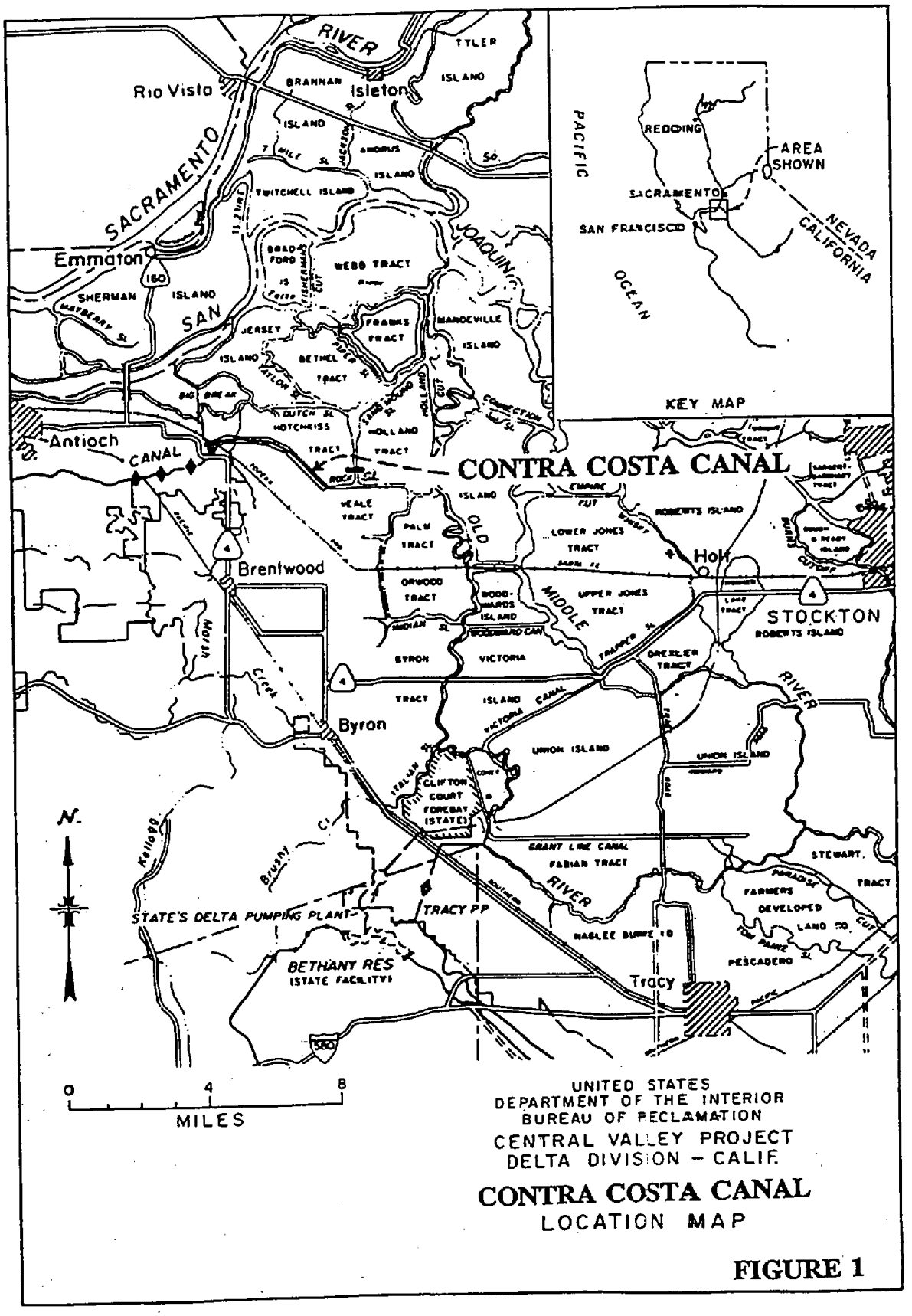
CCWD and the Bureau of Reclamation have initiated planning and predesign activities which will lead to the installation of fish screens at CCWD's Rock Slough Diversion. Fish screens are required per section 3406(b) of the Central Valley Project Improvement Act (CVPIA), and the Los Vaqueros Biological Opinion for Delta Smelt, issued by the Fish and Wildlife Service in September 1993. As a result of these activities, a preferred fish screening site was selected. This site is designated as site B-West on Rock Slough and is the basis for the hydraulic model studies presented herein (figure 2) [1].

Two separate models were used for the CCC fish screen structure investigations. One model was constructed for the purpose of evaluating approach flow conditions and velocity distributions along the length of the structure. A second model was constructed to evaluate the proposed hydrorake system that will be installed at the facility to remove debris from the screens. The background and investigations conducted for each model study are discussed below. The models were constructed in Bureau of Reclamation's Water Resources Research Laboratory in Denver, Colorado.

SCREEN VELOCITY DISTRIBUTION MODEL

Background and Objectives

Fish screening criteria were based on data from the Los Vaqueros Biological Opinion for Delta Smelt issued by the Fish and Wildlife Service along with the National Marines Fisheries Services (NMFS) and California Department of Fish and Game criteria. Fish screens in Rock Slough will be designed to meet 0.20 ft/s approach velocity criteria [NMFS, 1996] based on minimum tide elevation and maximum pumping/canal/slough flow combination. Numerical simulations presently being conducted by the CCWD to evaluate flow conditions indicate that tidal fluctuations could cause flow into the canal to be as high as 600 ft^3/s with corresponding low water surface elevations. The increased flow into the canal increases the velocity through the fish screens and may cause more fish and additional debris to approach the screens. The increase in flow through the fish screens must be considered in screen sizing to prevent exceeding the approach velocity criteria.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Tracy
SACRAMENTO
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CANAL
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MIDDLE
STATE'S DELTA PUMPING PLANT
TRACY PP
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(STATE FACILITY)
CLIFTON COURT FOREBAY (STATE)
GRANT LINE CANAL
FABIAN TRACT
VICTORIA CANAL
UNION ISLAND
WEBB TRACT
BRANNAN ISLAND
TYLER ISLAND
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SHERMAN ISLAND
JERSEY ISLAND
BETHEL TRACT
FRANKS TRACT
MANDEVILLE ISLAND
HOLLAND TRACT
HOTCHKISS TRACT
WEALE TRACT
PALM TRACT
ORWOOD TRACT
BOGARDUS ISLAND
BYRON TRACT
VICTORIA ISLAND
LOWER JONES TRACT
UPPER JONES TRACT
ROBERTS ISLAND
DRESLER TRACT
STEWART TRACT
FARMERS DEVELOPED LAND CO.
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UNITED STATES
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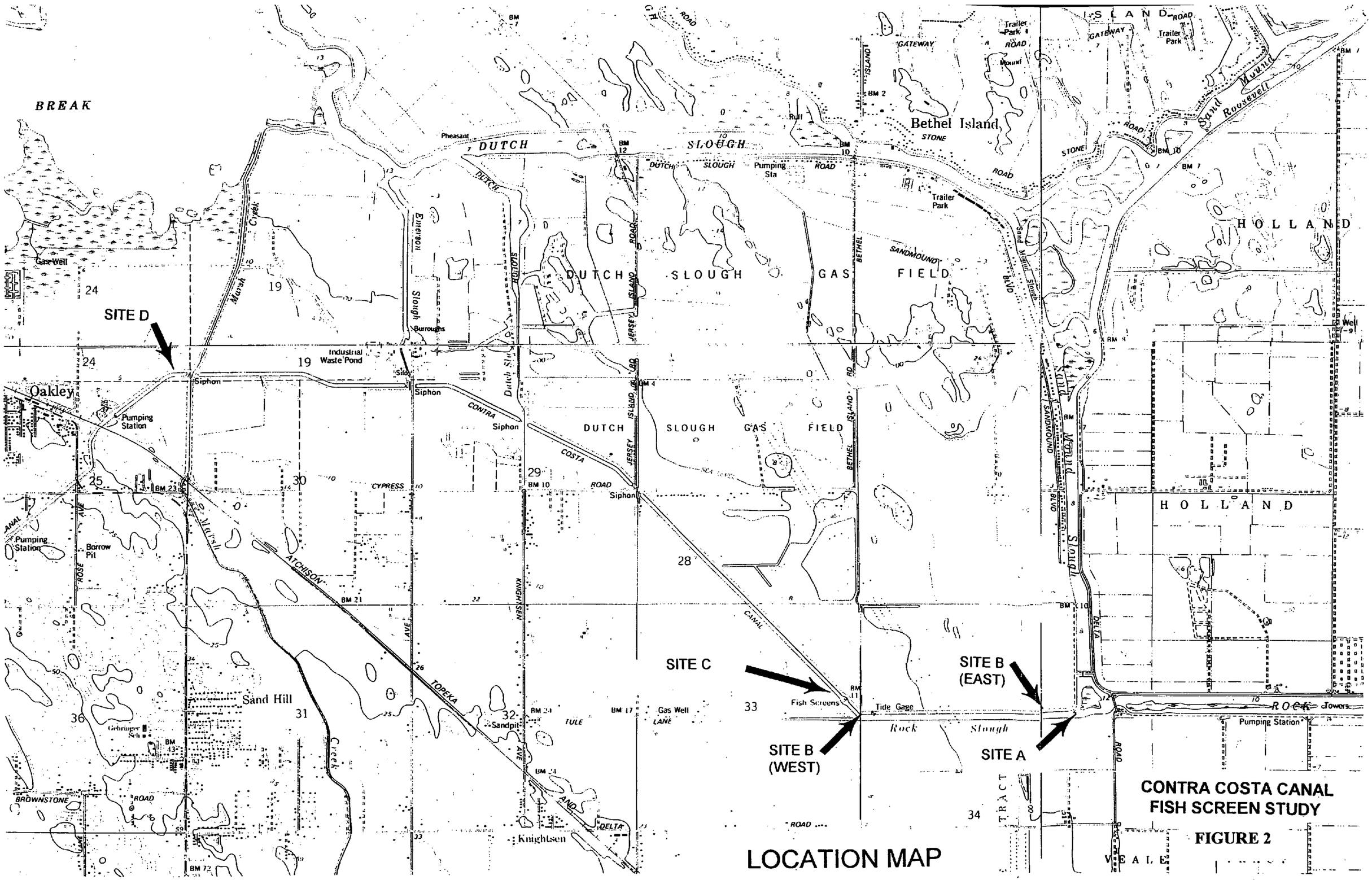
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT
DELTA DIVISION – CALIF.
CONTRA COSTA CANAL
LOCATION MAP

FIGURE 1



LOCATION MAP

CONTRA COSTA CANAL FISH SCREEN STUDY

FIGURE 2

A physical model was used to predict the hydraulic performance of the screen structure in response to a range of flow conditions. To evaluate approach velocity distributions, a physical model of the CCC intake and the B-West fish screen structure on Rock Slough was constructed using a 1:16 geometric scale. Two design alternatives were modeled. The initial design, which will be referenced as Alternative A, was modeled with 11 bays for a total effective length of 372 ft (figure 3a). The second alternative was designed with a shorter effective length of 293 ft and will be referenced as Alternative B (figure 3b). (Note that "effective screen length or area" does not include any support structure and only includes the unobstructed areas of the submerged screen). The objectives of the model study included:

(1) Identifying approach flow patterns, near screen velocities, and uniformity of screen approach velocity for the site B screen structure for the nonbaffled configuration.

(2) Determining the baffle configuration required to produce a uniform velocity distribution along the length of the structure. Note that baffles will be adjustable in the field to obtain optimal velocity distribution on the prototype screen.

(3) Determining the approach velocity distribution to cover a range of flow conditions for the baffled and nonbaffled screen configurations. Note that the range of flow conditions tested include some conditions that are more extreme than what will ever actually occur at the site. The parameters (i.e., discharge (Q), water surface elevation [W.S. El.], and design velocity) were chosen to represent and encompass a range of conditions that may occur at the fish screening site. The results show that the velocity variation (as a percentage of design approach velocity) along the length of the screen is not significantly different for different sets of parameters and therefore provides a reasonable representation of the velocity distribution along the length of the screen.

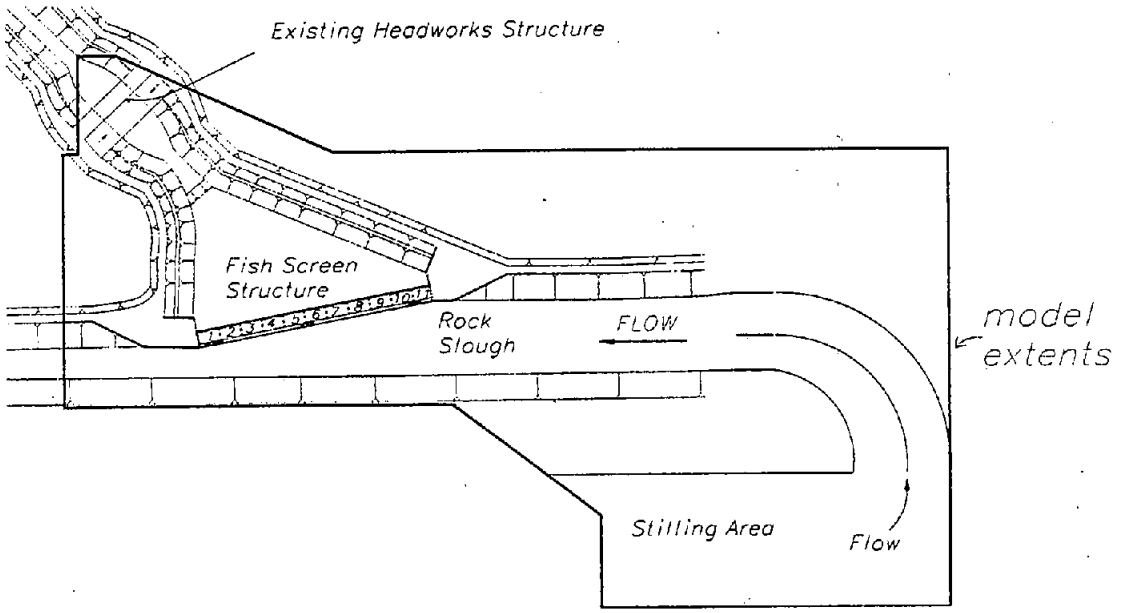
Conclusions

(1) Observations of screen approach flow patterns, indicated by dye traces, showed no unusual flow conditions or areas of flow re-entering the slough through the screen for both alternatives. Therefore, the alignment of the fish screen structure is considered acceptable for either case.

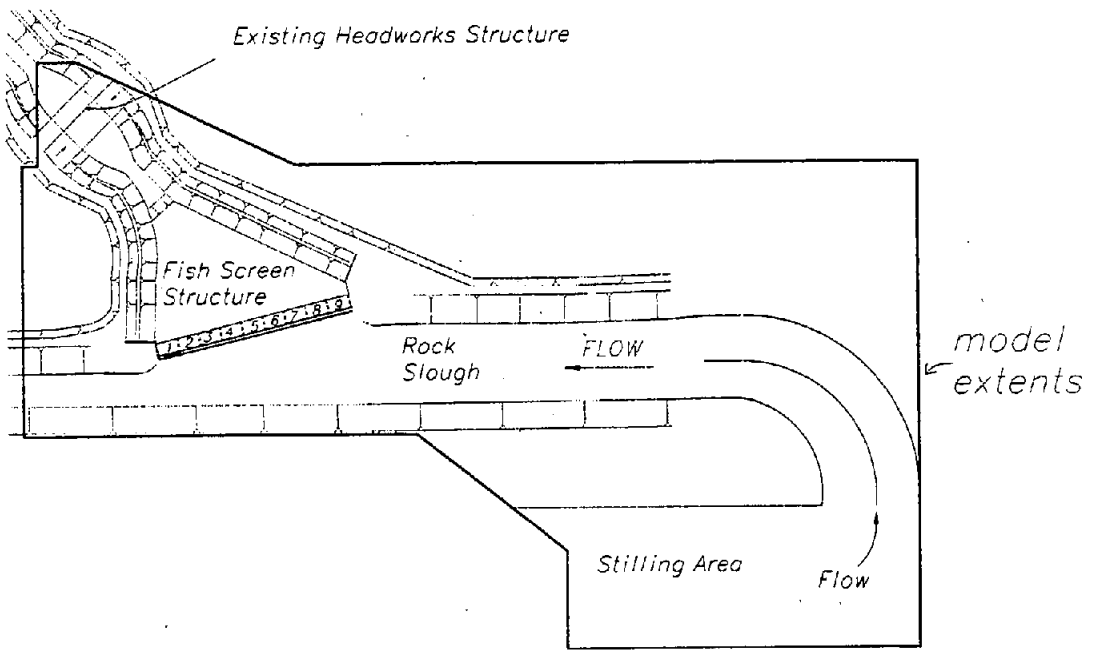
(2) Several areas of stagnant flow were observed. For both alternatives, the area at the extreme downstream end of the structure on the left side of the channel remains fairly stagnant as a result of the reservoir condition that exists immediately downstream from the structure. This is the result of the location of the screen near the end of the slough. This also reduces sweeping velocities at the downstream end of the screen (figures 4a and 4b).

In addition, for Alternative B, a back eddy exists at the upstream end of the structure where the sloped topography meets the vertical sheet pile. However, the effect should be insignificant, considering the nearby slough dead-end. Alternative A was modeled before designers added sloped topography in front of the sheet pile on the approach to the screen; therefore, this condition did not occur.

(3) The following conclusions are described separately for each alternative and are based on the results from its respective study.

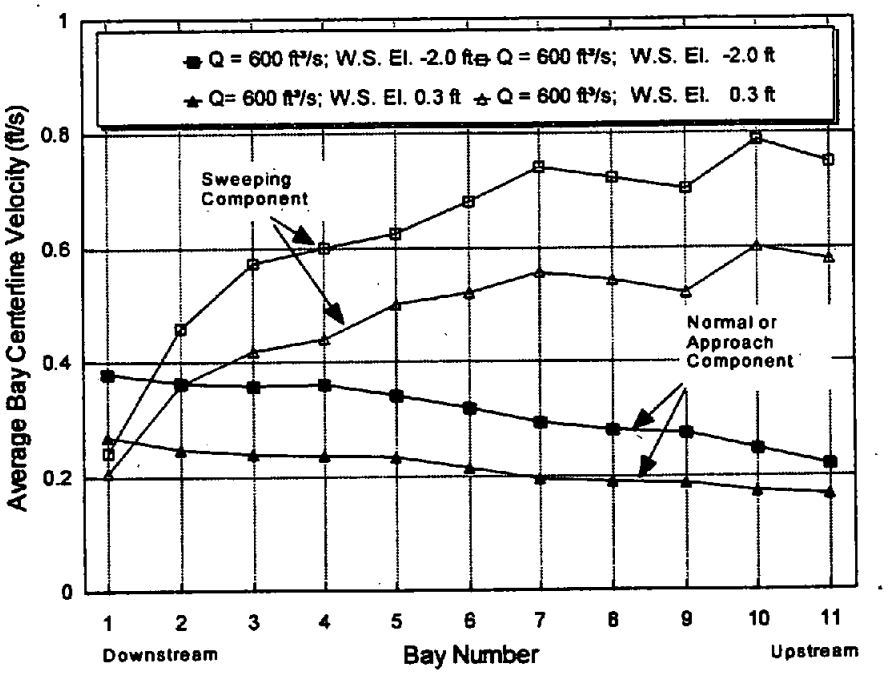


(a)

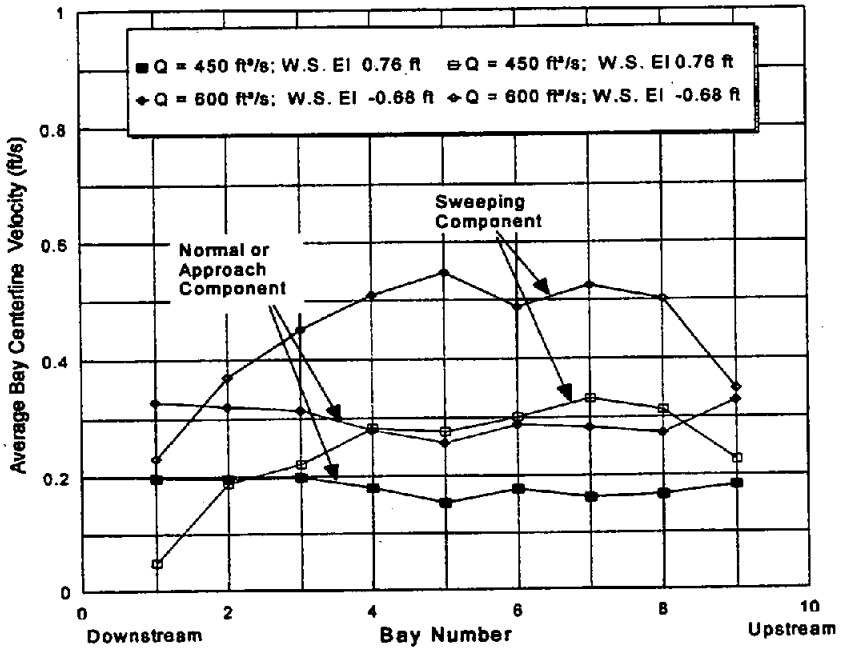


(b)

Figure 3.—Model extents for Contra Costa fish screen structure for (a) an effective screen length of 372 ft and (b) an effective length of 293 ft.



(a)



(b)

Figure 4.—Fish screen approach and sweeping velocities for the nonbaffled screen for (a) Alternative A - 372-ft effective screen length and (b) Alternative B - 293-ft effective screen length.

Alternative A - *Nonbaffled Screen*

- Tests conducted for the nonbaffled screen indicated that approach and sweeping velocity distributions are consistent over the range of flow conditions tested (figure 4a).

- The uniform design velocity, based on a uniform velocity distribution and corresponding to the flow rate and submerged effective screen area (in other words, based on flow continuity) is exceeded by as much as 35 percent at the downstream end of the screen (figure 5).

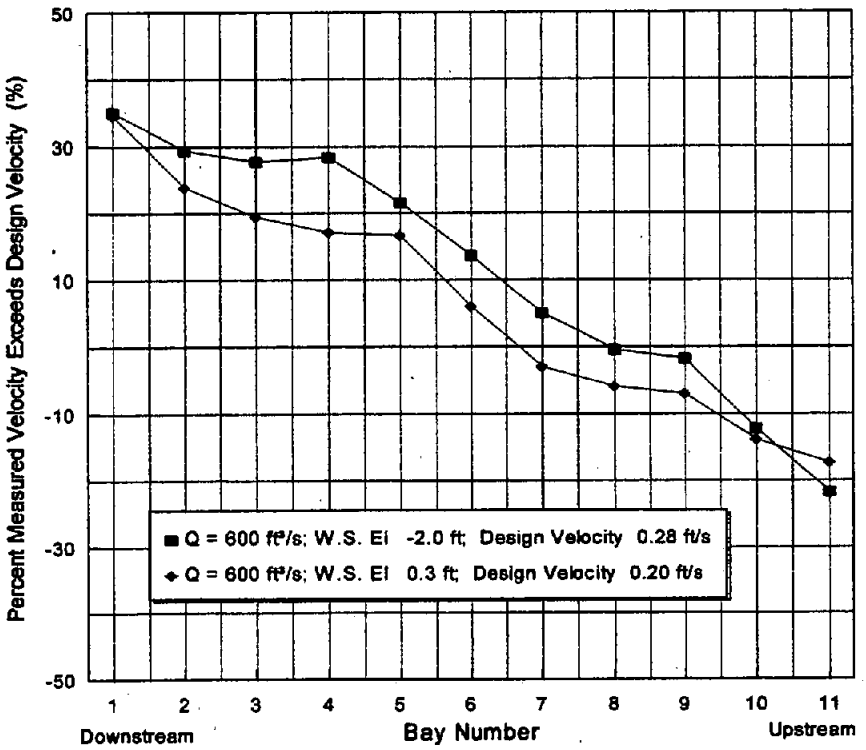


Figure 5.—Percent measured velocity exceeds the uniform design velocity for the 372-ft (effective length) nonbaffled screen for two flow conditions.

Alternative A - *Baffled Screen*

- Baffle requirements to produce uniform velocities along the length of the structure were determined to minimize the screen length required to meet velocity criteria. Baffle requirements were determined based on a division of 11 bays along the length of the structure and the final results, in terms of percent open area per bay, are given in table 1.

- Figure 6 shows the velocity distribution with the final baffle configuration installed in terms of percent of design velocity. The results indicate:

  (a) Adding baffles improves velocity distribution uniformity and reduces maximum approach velocity peaks by about 20 percent (compared to the nonbaffled screen).

Table 1.—Final baffle configuration for 372-ft screen

Bay number	Baffle opening (% open area per bay)
1	55
2	50
3	50
4	47
5	47
6	52
7	54
8	55
9	53
10	67
11	72

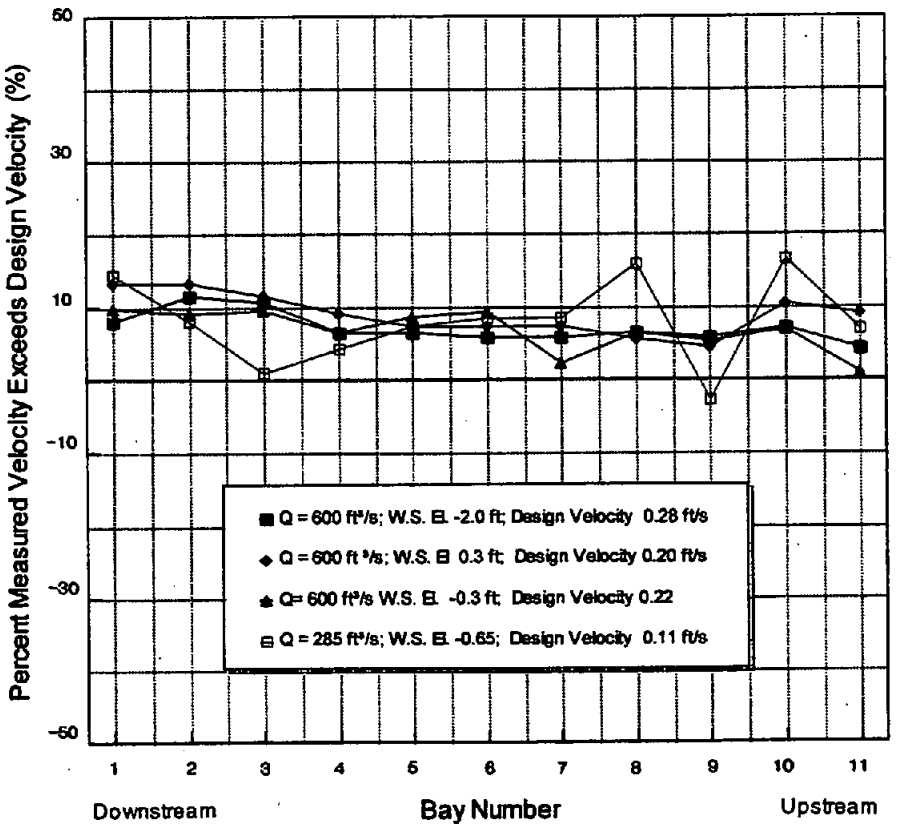


Figure 6.—Percent measured velocity exceeds the uniform design velocity for the baffled 372-ft (effective length) screen for four flow conditions.

(b) The measured velocities for the baffled screen vary within 15 percent of the uniform design velocity (based on continuity).

Alternative B - *Nonbaffled Screen*

Tests conducted for the nonbaffled configuration indicate that velocity distributions are consistent over the range of flow conditions tested (figure 7). However, the measured velocities for the nonbaffled screen exceed the uniform design velocity by as much as 20 percent.

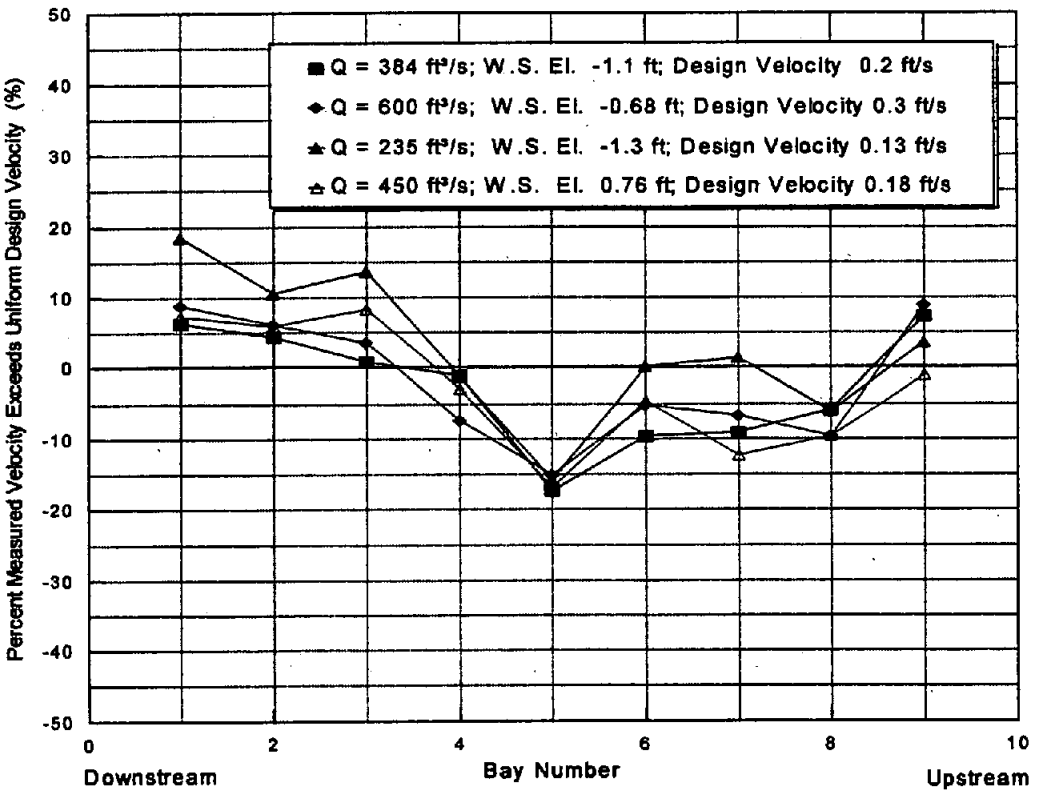


Figure 7.—Percent measured velocity exceeds the uniform design velocity for the 293-ft (effective length) nonbaffled screen for four flow conditions.

Alternative B - *Baffled Screen*

- Figure 8 shows the velocity distribution with the final baffle configuration installed based on a division of nine bays in terms of percent of design velocity. The percent baffle opening (in terms of percent open area per bay) is given for each bay in table 2. The results indicate:

  (a) Adding baffles improves velocity distribution uniformity and reduces maximum approach velocity peaks by about 10 percent (compared to the nonbaffled screen).

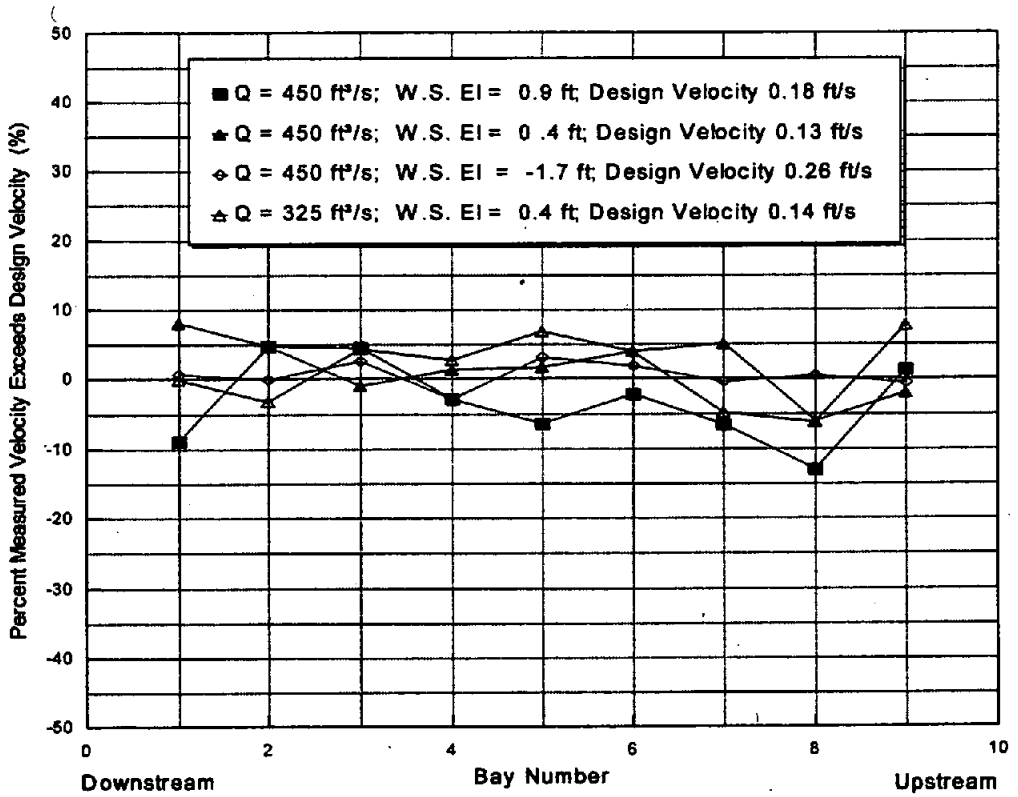


Figure 8. —Percent measured velocity exceeds the uniform design velocity for the 293-ft (effective length) baffled screen for four flow conditions.

Table 2.—Final baffle configuration for the 293-ft (effective length) screen

Bay number	Baffle opening (% open area per bay)
1	64
2	57
3	56
4	57
5	68
6	61
7	57
8	54
9	48

(b) The measured velocities for the baffled screen vary within about 10 percent of the uniform design velocity (based on continuity) for each condition tested.

(4) Site flow conditions are still being evaluated; therefore, the required screen length and the necessity for baffles to meet these criteria will be based on the final assessment of site flow conditions.

(5) Field adjustments of baffle openings may be necessary to accommodate conditions resulting from the as-built design. In addition, later adjustments in baffles may be necessary to accommodate changes in flow conditions as a result of changes in slough geometry or other changes that may affect velocity distribution.

(6) Note that no adjustment can be made in the velocity distribution without baffles (leading to possibly larger variations in velocity should the slough geometry or the as-built design change)

Model Investigations

Scope of the Model

A physical model was used to predict the hydraulic performance of the screen structure in response to a range of flow conditions.

A 1:16 geometric scale was used to model the fish screen structure. Froude scale similitude was used to establish the kinematic relationship between the model and the prototype because hydraulic performance depends predominantly on gravitational and inertial forces. Froude law similitude produces the following relationships between the model and the prototype:

Length ratio $L_r = 1:16$

Velocity ratio $Vr = L_r^{1/2} = 1:4$

Discharge ratio $Q_r = L_r^{5/2} = 1:1024$

Although similitude can be achieved based on Froude number, the viscous effects of flow passing through the fish screen cannot be ignored. Previous studies have shown that prototype size screen can be used in scaled hydraulic models if the model screen Reynolds number is greater than 80 (based on through-screen velocity), so that viscous effects may be considered negligible; thus, achieving similarity of flow patterns and screen approach and sweeping flow velocities. A screen material was chosen for the model that closely matched the percent open area of the screen material to be used at Contra Costa. The minimum Reynolds number for the model screen was 82 throughout the range of conditions tested and was therefore within an acceptable range for achieving similarity of flow conditions. Perforated plate with about 50 percent open area was used in the model to represent the prototype fish screen which will be also have about 50 percent open area (the prototype sreen will be wedgewire with 3/32-inch slot openings).

The approximate extents of the model are shown in figures 3a and 3b for Alternatives A and B respectively. Prototype features modeled included:

- The fish screen structure, including fish screens, and screen baffles
- Approximately 255 ft of intake channel (Rock Slough) upstream of the fish screen structure and about 375 ft of the canal downstream of the structure

The initial fish screen model structure, or Alternative A, was constructed with 11 bays separated by 2-ft-thick piers on 35.83-ft centers for a total effective screen length of 372 ft (figure 3).

To simplify model construction, the same bay width was used for Alternative B for a total of nine bays (instead of prototype configuration of eight wider bays as specified in the design) and an effective screen length of 293 ft. This should not have a significant effect on the prototype velocity distribution along the screen. Reducing the length of the screen strcuture also resulted in a slight rotaion of the structure alignment by about 2 degrees counterclockwise from the centerline of the slough. In addition, a relief panel 9.5 ft in width was added immediately upstream of the screen centerline and 2:1 sloping topography was added in front of the sheet pile at the upstream and downtream ends of the structure for Alternative B.

For both alternatives, Bay 1 is located at the downstream end of the structure, and each bay is numbered consecutively to the upstream end. Also, note that the elevations for the slough invert and the bottom of the fish screen are -8.6 ft and -7.6 ft respectively.

The Investigations

Tests were conducted to evaluate screen velocity distributions and to ensure that velocity criteria [1] was met over the full range of flows expected in the prototype. Actual tidal fluctuations were not simulated in the model. Instead, flow conditions corresponding to instants in the tidal cycle were modeled to cover a range of flow conditions and to show the consistency of the approach velocity distribution over the range tested. Various combinations of discharge and water surface elevation were tested to determine the velocity distribution along the length of the structure over a range of flow conditions for the baffled and nonbaffled screen conditions. The nonbaffled configuration was tested first to determine the velocity distribution and variations along the length of the structure. The results from these tests were then used to help determine the baffle configuration needed to optimize the velocity distribution so that the required screen length to meet velocity criteria could be minimized. In order to determine the consistency in the velocity distribution over a large range of conditions, tests included some flow conditions that may be more extreme than what will actually occur at the site. Approach velocities were measured at the centerline of each bay, normal to the front of the screen, at a prototype distance of 3 inches.

For each flow condition tested, the measured average approach velocity at each bay was compared to the calculated uniform design velocity. The design velocity was calculated based on flow continuity where:

$$V = Q/A$$

V = The uniform design velocity assuming a uniform velocity distribution (ft/s)
Q = Total discharge through the screen(ft^3/s)
A = Submerged effective screen area or [(effective screen length) x (depth of screen submergence)]

The uniform design velocity is the target velocity that would normally be used with known conditions (i.e., a discharge through the screen and corresponding water surface elevation) to size the screen for design conditions. In this case, however, because the screen is already sized, it gives a baseline velocity for each condition tested to compare for uniformity. Velocity distributions measured along the length of the screen are presented in terms of percent of design velocity, for several representative flow conditions, for the nonbaffled and baffled conditions for both alternatives. The parameters (i.e., Q, W.S. El., and design velocity) were chosen to represent and encompass a range of conditions that may occur at the fish screening site. The results show that the velocity variation (as a percentage of design approach velocity) along the length of the screen is not significantly different for different sets of parameters (figures 5 through 8).

Nonbaffled Tests - For each alternative, initial tests were conducted for the nonbaffled configuration to determine if screen structure alignment was adequate. Dye traces injected across the upstream channel of Rock Slough indicated that flow remains fairly well distributed as it enters the screen structure, with the exception of an area at the extreme downstream end of the structure. In this area, portions of the flow on the left side of the channel remain fairly stagnant as a result of the reservoir condition that exists immediately downstream from the structure. This is the result of the nearby slough dead-end. In addition, for Alternative B, a back eddy exists at the upstream end of the structure where the sloped topography meets the vertical sheet pile. Alternative A was modeled before designers added sloped topography in front of the sheet pile on the approach to the screen; therefore, this condition does not occur.

Bay centerline velocities were measured with the Sontek acoustic Doppler velocimeter (ADV) probe (figure 9) to determine velocity distributions along the length of the screen structure. The ADV probe was mounted on a traversing system which allowed the probe to take incremental measurements as it traversed from the water surface to the bottom of the screen and back again at the centerline of each bay. These measurements were then averaged to determine the average centerline velocity for each bay. Figures 3a and 3b show how the bays were referenced in the model, beginning with bay number 1 at the downstream end of the structure. For each alternative sweeping velocities decrease toward the downstream end where more flow enters the screen as a result of the structure location near the end of the slough (figure 4).

Alternative A - *No Baffles*

Figure 4a shows the approach and sweeping velocities for the nonbaffle configuration for the highest flow tested (600 ft^3/s) with corresponding water surface elevations of -2.0 ft and 0.3 ft. This distribution is consistent for each test condition. Figure 5 shows the velocity distribution in terms of percent of design velocity for the nonbaffled screen. In each case, the uniform design velocity, based on continuity, is exceeded by about 35 percent at the downstream end of the screen. This indicates that if the screen length was designed based on a flow condition that would produce a uniform velocity of 0.2 ft/s, the maximum approach velocity along the length of the screen, under this design condition, may be as high as 0.27 ft/s.

Alternative B - *No Baffles*

Tests conducted for the nonbaffled Alternative B configuration indicate that flow distributions are again consistent over the range of flow conditions tested (figure 8). However, the overall distribution changed considerably from Alternative A. This can be attributed to several reasons:

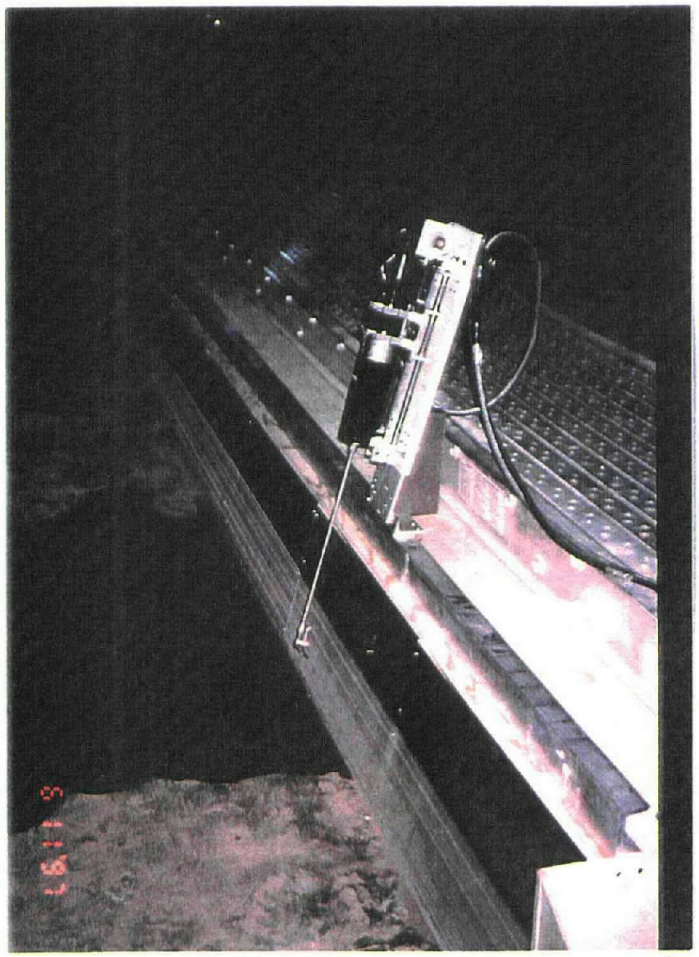


Figure 9.—Sontek ADV probe used for measuring screen approach and sweeping velocities.

- Higher velocities occur at the upstream end of the structure (Bay 9) as the result of adding sloped topogragraphy in front of the sheet pile wall at the upstream approach to the screen. This causes a more direct approach of the flow as it rounds the topography into the screen.

- Lower approach velocities measured at Bay 5 can be attributed to the relief panel installed immediately upstream of bay 5. This causes more flow to sweep past bay 5.

- Screen alignment was rotated by about 2 degrees into the flow for Alternative B.

The measured velocities for the nonbaffled screen exceed the uniform design velocity by as much as 20 percent.

As a result of these investigations, tests with baffles placed behind the screen were conducted to determine if a more uniform velocity distribution along the length of the screen could be achieved for each alternative.

Baffle Requirements - Screen baffles are commonly used behind fish screens to achieve uniformity of flow and therefore minimize the length of screen required to meet velocity criteria. Baffles were installed 4 ft behind the screens in each bay (figure 11). Baffles were modeled with 11 and 9 sets of louvers with adjustable openings for Alternatives A and B respectively (figure 10). Velocity

Figure 10.—Louver used in model to represent baffles.

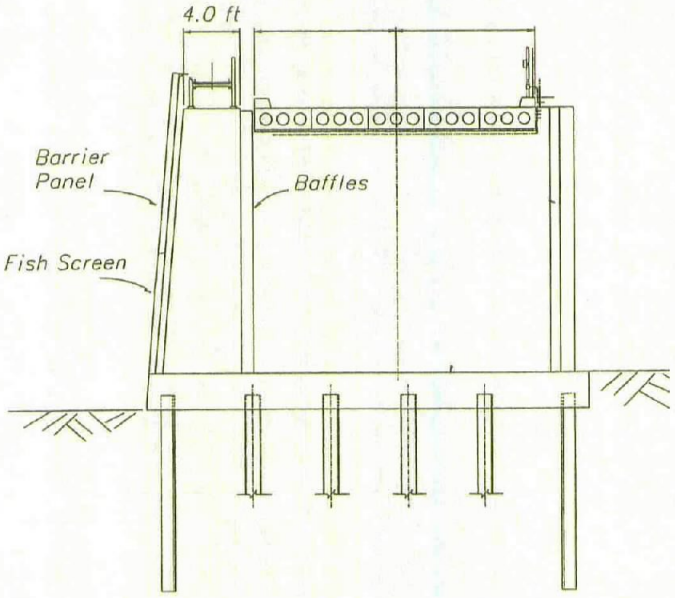


Figure 11.—Fish screen baffle location.

distributions for the no baffle condition were used to determine the initial baffle opening configuration, then adjustments were made until a nearly uniform distribution was obtained along the entire length of the structure. Initial tests were conducted with only the first six to eight bays baffled to determine if uniformity could be achieved. However, this always produced concentrated areas of high velocities into the first unbaffled bay in each case and, therefore, uniformity could not be achieved without adding

baffles to all bays. The final baffle configuration for each alternative (tables 1 and 2) was tested over a range of flow conditions to demonstrate that velocity distributions would remain consistent

Alternative A - *With Baffles*

Baffle requirements to produce uniform velocities along the length of the structure were determined. Baffle requirements were determined based on a division of 11 bays along the length of the structure (figure 3a) and the final results, in terms of percent open area per bay, are given in table 1. Figure 6 shows that although the velocity distribution is uniform within 15 percnet of the design velocity, for a flow of 600 ft^3/s and a water surface elevation of 0.3 ft (which produces a calculated uniform design velocity of 0.2 ft/s) the 0.2-ft/s velocity criteria is exceeded at all locations. This offset may be the result of measuring high velocities through a control volume at a distance of 3.0 inches in front of the screen; therefore, measurements may not be an exact representation of the flow going into the screen. Flow recirculating against the screen or conditions resulting from headloss through the screen may affect velocity measurements. In addition, there may be flow that is unaccounted for, sweeping inside and parallel to the control volume. Figure 6 shows the velocity distribution with the final baffle configuration installed. The results indicate:

(a) Adding baffles improves velocity distribution uniformity and reduces maximum approach velocity peaks by about 20 percent (compared to the nonbaffled screen).

(b) The measured velocities for the baffled screen vary within about 15 percent of the uniform design velocity (based on continuity) (figure 6).

Alternative B - *With Baffles*

Figure 8 shows the velocity distribution with the final baffle configuration installed based on a division of nine bays in terms of percent of design velocity. The baffle opening for each bay is given in table 1.

The results indicate:

(a) Adding baffles improves velocity distribution uniformity and reduces maximum approach velocity peaks by about 10 percent (compared to the nonbaffled screen).

(b) The measured velocities for the baffled screen vary within 10 percent of the uniform design velocity for each of the baffled conditions tested (based on continuity); therefore, the screen can be sized based on a uniform flow distribution (figure 8).

Finally, although the model tests were used to verify the adequacy of screen alignment and determine the overall velocity distribution and baffle arrangement for the screen, it will be necessary to conduct field tests on the prototype structure in order to determine the precise ability of the final arrangement to meet velocity requirements under all operating conditions.

Final adjustments in baffle openings may be necessary in the field to accommodate actual as-built conditions for either alternative.

TRASH RAKE MODEL STUDY

Background and Objectives

Debris is a major concern at the proposed Contra Costa fish screen facilities. Operation and maintenance requirements of the facilities include cleaning fish screens with automatic trash rakes and maintaining a debris removal system. Debris removal and control systems will be built into the screening facilities. A hydrorake system (figure 12) is proposed to clean debris from the fish screen structure, which will be exposed to large quantities of aquatic plant debris. The location of the screen structure at the end of a slough and the absence of a fish bypass require all debris approaching the screen be removed. The performance of the proposed trash rake is proven for removing large debris. However, the system is not designed to effectively remove small material. As a result, tests were conducted to evaluate trash rake performance and to determine any necessary modifications to accommodate removing small debris. In addition, debris transfer from the rake-head to a conveyor system was evaluated, and options to improve debris transfer were identified and tested. A full-scale sectional model of the rake and fish screen was used to evaluate rake performance. Model tests were used to:

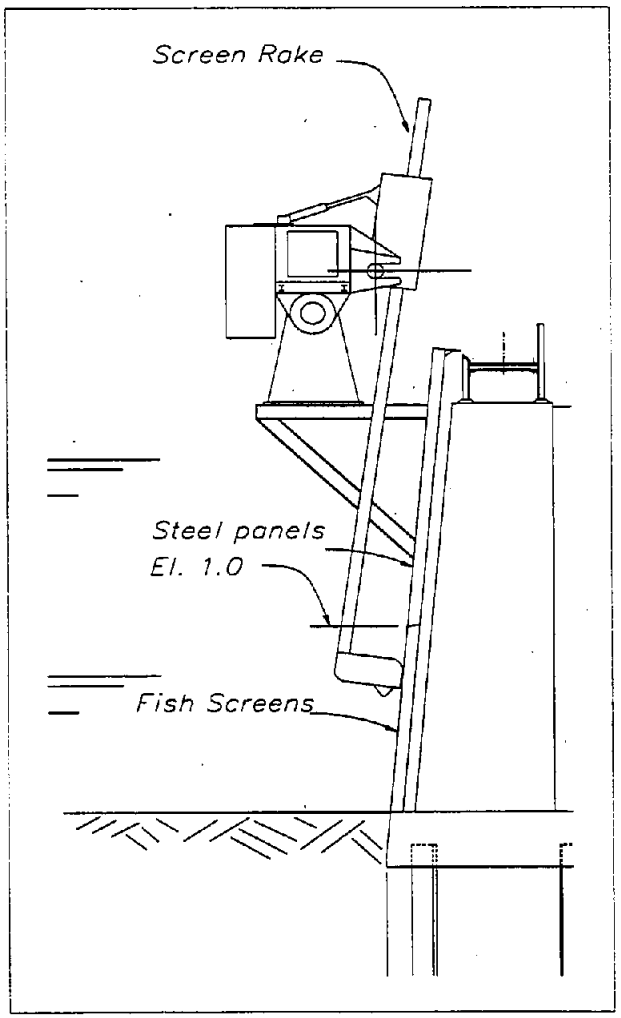


Figure 12.—Hydrorake system profile view.

(1) Determine rake performance for cleaning large- and small-sized prototype debris and determine any necessary modifications.

(2) Evaluate rake performance with the screen profile wires oriented in both the vertical and horizontal directions.

(3) Evaluate cleaning performance and debris release capability with the rake-head force varied over the range specified by the manufacturer (approximately 300 lbs to 500 lbs).

Conclusions

(1) The original rake configuration (figure 13) performed well in removing large debris from the fish screen; however, modifications to the rake were necessary to remove smaller debris.

Figure 13.—Original rake-head configuration.

(2) A raised brush-plate wear bar combination, with the brush mounted about .75 in above the rake surface, was the most effective arrangement tested for removing small debris from the screen (figures 14 and 15). Therefore, this is the recommended configuration. Brushes should be cleaned periodically to maintain the desired flexibility.

(3) The screens should be installed with the profile wires oriented vertically. This will allow the brushes to perform more effectively in cleaning the screen surface and will minimize excessive wear on the scraping bar.

(4) Cleaning performance was good over the full range of rake-head forces tested (300 lbs to 470 lbs). However, a minimum raking force of 425 lbs is recommended to ensure adequate disposal of debris from the rake onto the debris removal system.

The Model

A full-scale sectional model of the fish screen and rake were used to evaluate rake performance. A 4.0-ft by 4.0-ft section of profile wire screen (manufactured by Conn-Weld Industries, Inc.) with 3/32-in slot width and about 50 percent open area was used for the model tests. The screen was installed at an angle of 4 degrees off the vertical axis in a 5-ft-deep by 5.5-ft-wide recirculating flume (figure 16). Flow velocity in the flume was controlled by adjusting gate valves on the piping extending from the prototype recirculating pump and was set for an average screen approach velocity of 0.2 ft/s. A clear Plexiglas viewing window on the flume allowed viewing and videotaping of rake operation and testing. The Hercules Hydrorake rake-head (figure 13) was used for the model tests and was attached to a lever arm which was adjusted with a pneumatic cylinder to exert a constant force of about 470 lbs against the screen throughout the full sweep of the rake from the bottom to the top of the screen. This was the maximum force that could be achieved by the laboratory setup and falls within the 300 to 500 lb range specified by the manufacturer. The model test apparatus is shown in figure 17. During the raking process, the rake was operated at a constant speed of 16.5 ft/s and is considered to be a conservative representation of normal prototype rake operations which are set to a speed of 15 ft/s. The trash rake was tested with prototype debris, including Eurasian Watermilfoil (milfoil), Lemna minor, and Lemna trisulca (duckweed).

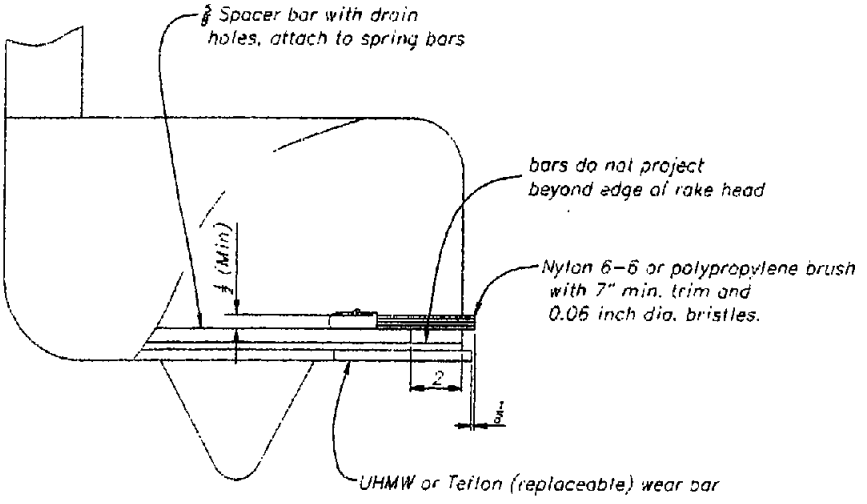


Figure 14.—Profile view of modified rake-head design.

Figure 15.—Final modified rake-head.

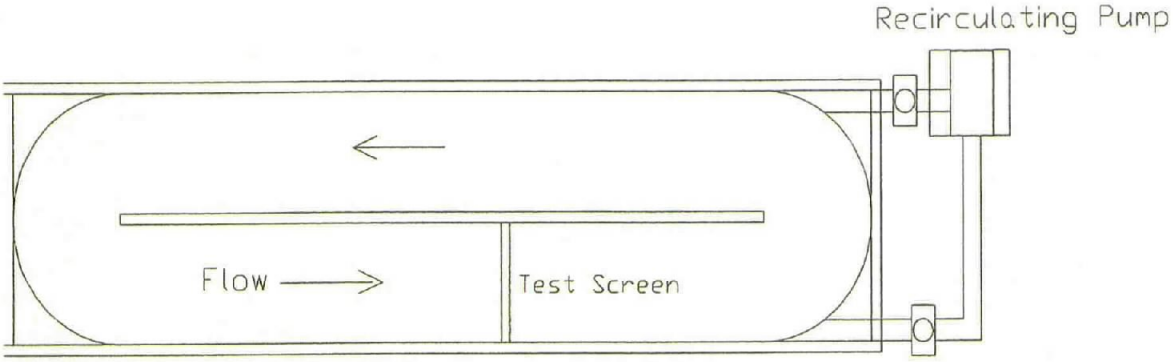


Figure 16.—Layout of fish screen trash rake test facility.

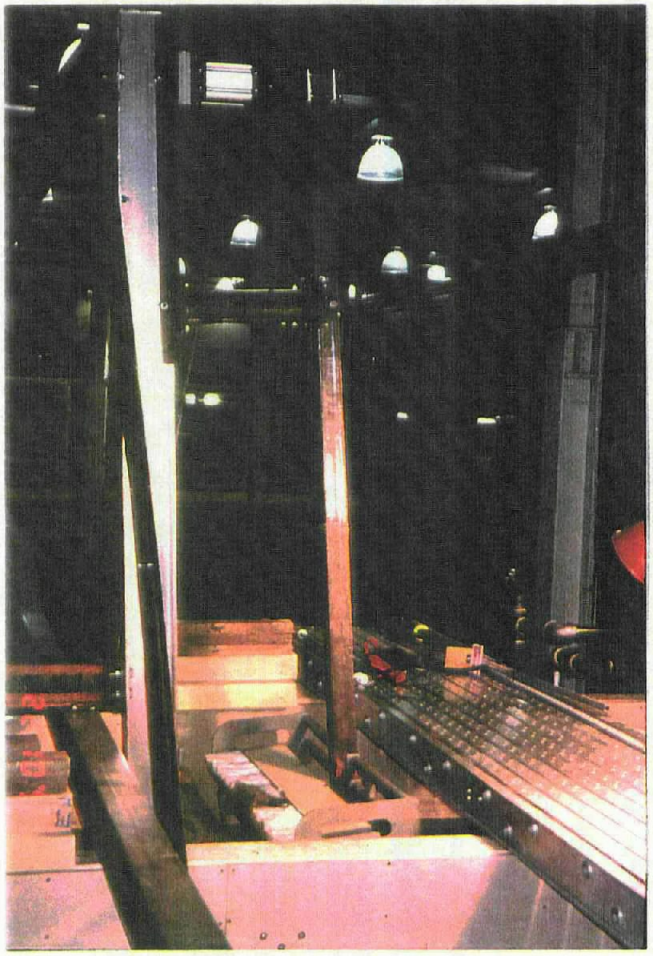


Figure 17.—Trash rake test apparatus.

Trash Rake Model Investigations

Profile Wire - Vertical Orientation

Initial investigations were conducted with the profile wire screen oriented in the vertical direction. An ADV probe was used to measure approach velocities (normal component) in a grid pattern across the screen to confirm the uniformity of velocities. Milfoil was deposited in the recirculating flume and was left to accumulate into a thick mat on the face of the screen (figure 18). The original or as is rake configuration (figure 13) was designed for removing large debris and therefore performed well in removing the milfoil from the screen, with the exception of the right-hand edge which remained loaded with debris (figure 19). This was determined to be the result of the screen being warped by about an eighth of an inch near the right edge of the screen, so no contact was made with the scraping or wear bar. Debris remaining on the bottom of the screen can be ignored since this was the result of the rake not reaching to the bottom of the screen in the test apparatus.

For the next set of tests, the milfoil was removed from the flume and duckweed, which is a much smaller aquatic plant, was deposited into the flume and again left to accumulate into a thick mat on the screen. This time, during the raking process, a significant amount of the debris fell through the forks of the rake and immediately reattached to the face of the screen. As a result, several modifications were investigated

Figure 18.—Screen loaded with milfoil debris.

Figure 19.—Screen after raking milfoil with original rake configurations.

to make the rake more effective in removing this smaller debris. The rake was modified by adding a flat plate over the surface of the rake to prevent debris from slipping between the forks. During raking operations with this configuration, an insignificant amount of debris fell over the edges of the plate and reattached to the screen. This configuration performed well, but again debris remained on the right side of the screen where the screen was warped.

Since screens delivered to field installations may also be warped, the cleaning of these areas presents a potential problem. To address this issue, a flexible brush was attached to the front edge of the flat plate. This arrangement solved the problem by cleaning all areas of the screen; however, there was concern about the durability of the brush being pushed against the screen under such high loads. To remedy this situation, the plate and brush were raised about 3/4 in above the top surface of the wear bar. The brush was again attached to the front of the plate and was extended about 1/8 in horizontally beyond the front surface of the Teflon wear bar (figure 14). This configuration allows the wear bar to carry the load while the brush extends to clean any areas where the screen may be warped. In areas where the screen is not warped, the brush is simply pushed down flush with the wear bar, minimizing wear on the brush. This configuration worked well, and there was little sign of debris left on the screen after raking, including the warped areas which were not previously cleaned with other configurations. Figures 20 and 21 show the screen before and after raking duckweed debris with the raised plate-brush wear bar configuration.

Figure 20.—Screen loaded with duckweed debris.

Figure 21.—Screen after cleaning with raised plate and brush configuration.

Profile Wire - Horizontal Orientation

Since all the tests thus far had been conducted with the profile wires oriented in the vertical direction, the screen was next tested with the profile wires oriented horizontally. The rake was tested with the brush-plate, wear bar configuration, under the same conditions tested earlier. This time, after raking was complete, there was a fair amount of debris left lodged between the horizontal wires. In addition, the wear bar chattered against the horizontal wires as the rake was raised against the screen, potentially leading to excessive wear of the wear bar surface.

As a result of these investigations, the recommended configuration is the raised brush-plate wear bar configuration described above and the profile wire screen installed with a vertical orientation.

Debris Transfer Evaluation

The Hydrorake manufacturer specifies that the force exerted by the rake-head onto the screen be in the range of 300 to 500 lbs. These specifications correspond to the force at the top of the rake stroke since the prototype rake force varies as the rake sweeps from bottom to top. Since all of the tests conducted thus far had used a constant load of 470 lbs, the next step was to test rake performance under lesser loads

down to 300 lbs. These tests were conducted with the screen wires oriented vertically. Tests conducted with the rake-head force reduced demonstrated that cleaning performance remained good even when the rake-head force was reduced to 300 lbs. However, the ability of the rake to transfer debris off the rake at the top of the sweep diminished as the load was reduced. When the rake-head force was set greater than or equal to 450 lbs, there was a noticeable jolt to the springing action at the top of the rake stroke that acts to help spring debris off the rake surface. At forces below 425 lbs, the springing action becomes noticeably slower and may cause a significant amount of debris to remain on the rake.

As a result of these tests, it is recommended that adequate pressure be made available at the installation to produce a minimum raking force of 425 lbs and, if possible, no less than 450 lbs to ensure adequate debris disposal from the rake.

References

[1] Bureau of Reclamation, "Contra Costa Canal Fish Screens, Report 2 (DRAFT)," United States Department of the Interior, January 10, 1997.

[2] Bureau of Reclamation, "Physical Model Studies of the GCID Pumping Plant Fish Screen Structure Alternatives, Progress Report No. 1," United States Department of the Interior, March 1997.

MISSION

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.