State of California
The Resources Agency
Department of Water Resources
Division of Environmental Services, Fish Facilities Section

A Pilot Study on the Bio-fouling Resistance of 304 and 316 Stainless Steels and Copper Nickel Metal.

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Introduction

Background

In recent years there has been an increase in the use of cylindrical and flat plate screens for the protection of endangered fish species. Present criteria require the screens to have 1.75 mm openings and meet an approach velocity of 0.2 fps. The screens are typically constructed of stainless steel in the form of welded wedgewire, woven wire mesh or perforated plate. Stainless steel, specifically 304 and 316, have been the material of choice for construction of the screens. The use of stainless steel in fish screens can be attributed to the materials strength, affordability, and corrosion resistance. These steels however, are not resistant to biofouling and require cleaning on a regular basis. Biofouling and clogging is a primary issue of concern when utilizing fish screens at water diversion facilities. Experience at existing facilities shows that as aquatic organisms and plants grow on the screens, a head loss develops across the screen causing inefficiencies in water diversion and areas of high approach velocities (hot spots). As the water velocities increase through the hot spots, there is a potential for fish impingement on the screens.

The State currently operates a number of small cylindrical screens that range in size from 8 cfs to 10 cfs and are constructed of 304 stainless steel mesh. The screens utilize water pressure to minimize biofouling, but this technology has not been successful. What was designed as a self cleaning screen now has to be cleaned by divers on a regular basis. Some screens have imploded due to the severe head loss caused by the excessive biofouling/clogging. Other cleaning systems such as brush systems that travel along the face of the screen have been more effective, but only clean the face of the screen and not the backside where biofouling also occurs.

Biofouling is also an issue of concern at facilities that utilize louvers to screen diverted water. Louvers are used at both the State Water Project (SWP) and Central Valley Project (CVP) water diversion facilities. Biofouling of the existing louvers at both of these facilities is a maintenance issue that is time consuming and requires specialized equipment to pull and clean the louvers. At the (SWP) facility the louvers are cleaned weekly and at the (CVP) facility the louvers are cleaned daily.

Technologies such as growth inhibiting alloys have been considered, but have not been deployed in the Delta because of their cost. One such alloy is Copper-Nickel (CuNi). The literature suggests that when submerged in water, a copper patina forms on the alloy that aquatic organisms find inhospitable. Price inquiries indicate that the cost of copper-nickel is two to three times that of stainless steel ($200-$300 per square foot). The cost difference is due to the fact that many companies do not have the machinery and tools to work with copper since its demand is limited.

Purpose

This pilot study was conducted to determine if there is a difference in biofouling resistance among welded wedge wire (3mm openings) screen coupons constructed of 304 and 316 stainless steels and 90/10 Copper Nickel (90% Copper and 10% Nickel). The information gathered could help State and Federal agencies select a material for future screened facilities or the retrofit of existing facilities within the Sacramento - San Joaquin Delta. Improved biofouling resistance at screened facilities would reduce facility maintenance and downtime, and improve system efficiency by reducing head loss through the screens or louvers.

Study Areas

Four locations within the Sacramento-San Joaquin Delta were selected for the study (Figure 1). Site selection was based on accessibility, distribution within the Delta and flow conditions at each site. Chosen sites were distributed throughout the Delta to encompass the variation in environmental conditions within the Delta. Sites with visible sweeping flows were chosen in order to limit sediment buildup on the screens. The sites are 1) Los Vaqueros intake structure on Old River, 2) water quality monitoring station RSAC 142 on the Sacramento River in the town of Hood, 3) Sherman Island water diversion structure at Horseshoe Bend, and 4) the water quality monitoring station S37 in Suisun Slough (Suisun Marsh).

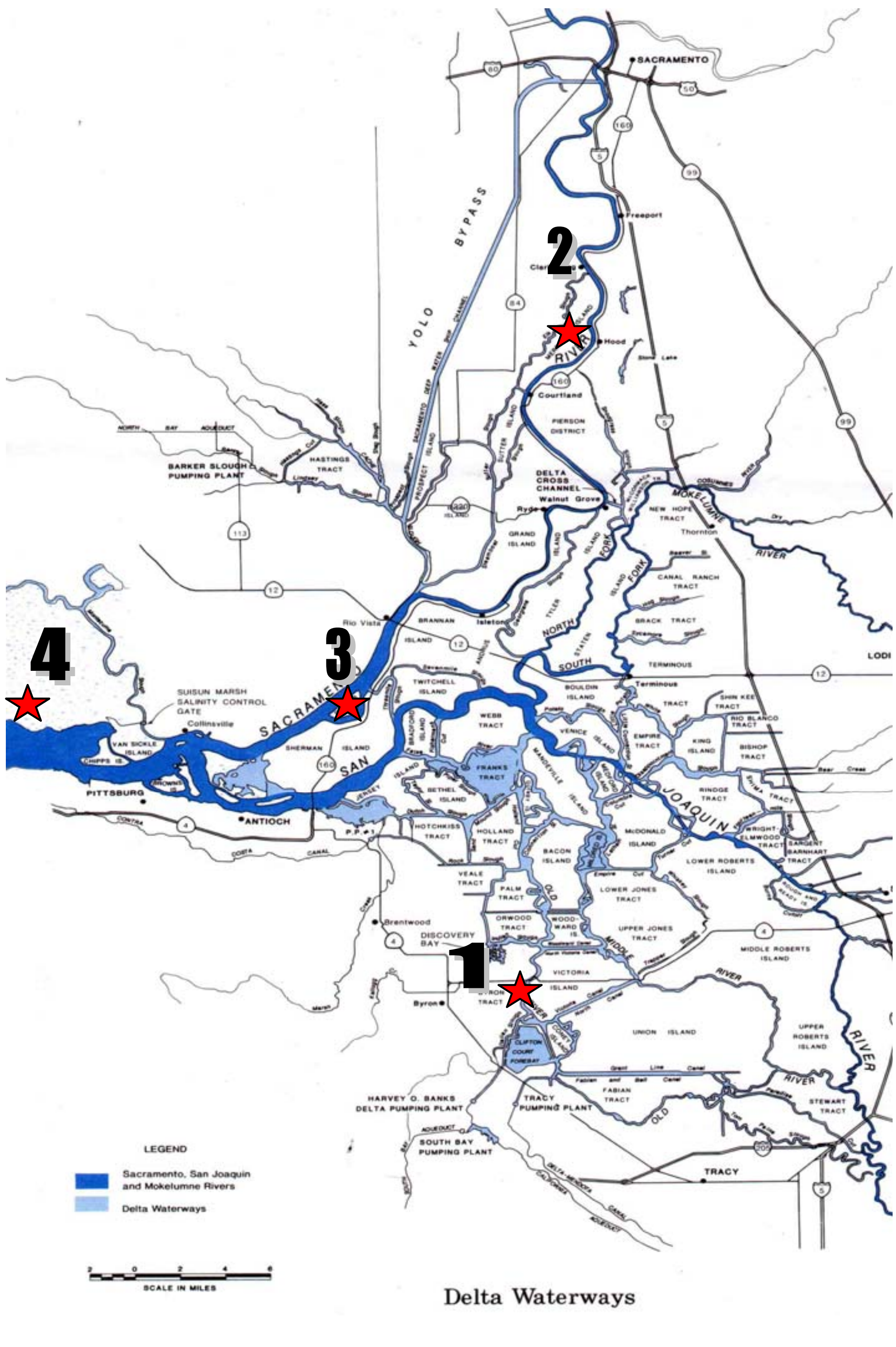


Figure 1. Location of Study Sites (Site four is at Suisun Slough which is further east off the map).

Figure 2. Los Vaqueros Intake and location of screen coupons.

The Los Vaqueros Intake facility is owned and operated by the Contra Costa Water District (CCWD) and is part of the Los Vaqueros Reservoir Project. The facility is located along Old River just south of the Highway 4 Bridge in Contra Costa County, CA. This facility is located approximately 1.5 miles downstream of Clifton Court Forebay and the SWP fish salvage facility. The track system and screen material were installed adjacent to the existing facility screens. The facility sits on an outside bend and provides good visible sweeping flows. The screens are also protected from large floating debris by an existing debris boom installed to protect the facility and its screens. With planning in progress to replace or rework the intake facility to Clifton Court Forebay, this study site could provide valuable information for selecting a screen material that helps the new or reworked facility meet its diversion needs.

Figure 3. Hood Monitoring Station RSAC 142 and location of screen coupons.

The Hood monitoring station is located just south of the town of Hood along the Sacramento River approximately 18 miles south of Sacramento. The track system and screen material were installed on the back side of the facility. Initial plans called for the screen coupons to be installed on the front of the facility where they would be exposed to sweeping flows in the channel, but due to water quality equipment already in place, the screens were installed on the back-side of the facility where sweeping flows were less prevalent. The site and screens were accessed by boat.

Figure 4. Location of Horseshoe Bend screen coupons.

The Horseshoe Bend fish screen facility is located on Sherman Island on the Sacramento River approximately 6 miles South of Rio Vista. This site contains two cylindrical stainless steel woven wire screens with a diversion capacity of 30 cfs. The screens utilize an internal rotating backwash system for cleaning. There are 11 other screened sites on the Island that are fitted with 10 cfs cylindrical screens. All the screened sites on the Island, including Horseshoe Bend, have experienced operational problems due to severe biofouling. The existing biofouling problems make this an ideal test site. The screens at Horseshoe Bend are set off of a 90-ft long walkway that extends into the Sacramento River. The track system and screen material were installed off the end of this walkway in an area with visible sweeping flows. The site and screens were reached by boat.

Figure 5. Water Quality Monitoring Station S37 and location of screen coupons.

Water quality monitoring station S37 (Morrow Island) is located in Suisun Marsh at the entrance to Suisun Slough on a private duck club property. The site is currently used by the Suisun Marsh Compliance and Monitoring Branch to monitor Electrical Conductivity (EC). This site was selected for its proximity to Grizzly Bay and its saline environment in which to test the screen materials. The track system and screen material were installed off the front of the facility which exposed the screens to sweeping flows in the Slough.

Methods

Test Apparatus

A steel track system was fabricated for each site to facilitate lifting and lowering of the screen coupons during sampling (Figure 6). The track system was constructed of steel and designed to attach to existing piles with fabricated pile-clamps. Three pile-clamps were installed per site; two were installed above the water surface and one below the water surface. The Los Vaqueros track system was designed differently to fit the facility wing wall because no piles were present at the site (Figure 7). The depth to which the tracks were installed was determined by reviewing site plans and historical tide data for each site. The depth of the tracks placed the top of the screen coupons 1.5 ft below the lowest tide recorded in the past fifteen years, ensuring that the coupons remained submerged throughout the study. The track system was fabricated by the South Delta Field Division (DFD), and installed with the assistance of DWR divers. The divers installed the pile-clamp positioned under water, and verified that track system was installed at the proper depth.

Poly Vinyl Chloride (PVC) pipe (schedule 40) and heavy duty PVC glue were used to construct the frames holding the screen coupons in place (Figure 6). PVC was used to eliminate the possibility of dissimilar metal corrosion by serving as an insulator between the different screen metals. The use of PVC also made the frame lightweight which aided in lifting the screen coupons out of the water during sampling. The frame was designed to ride up and down the track system to aid in sampling and to make repairs if necessary.

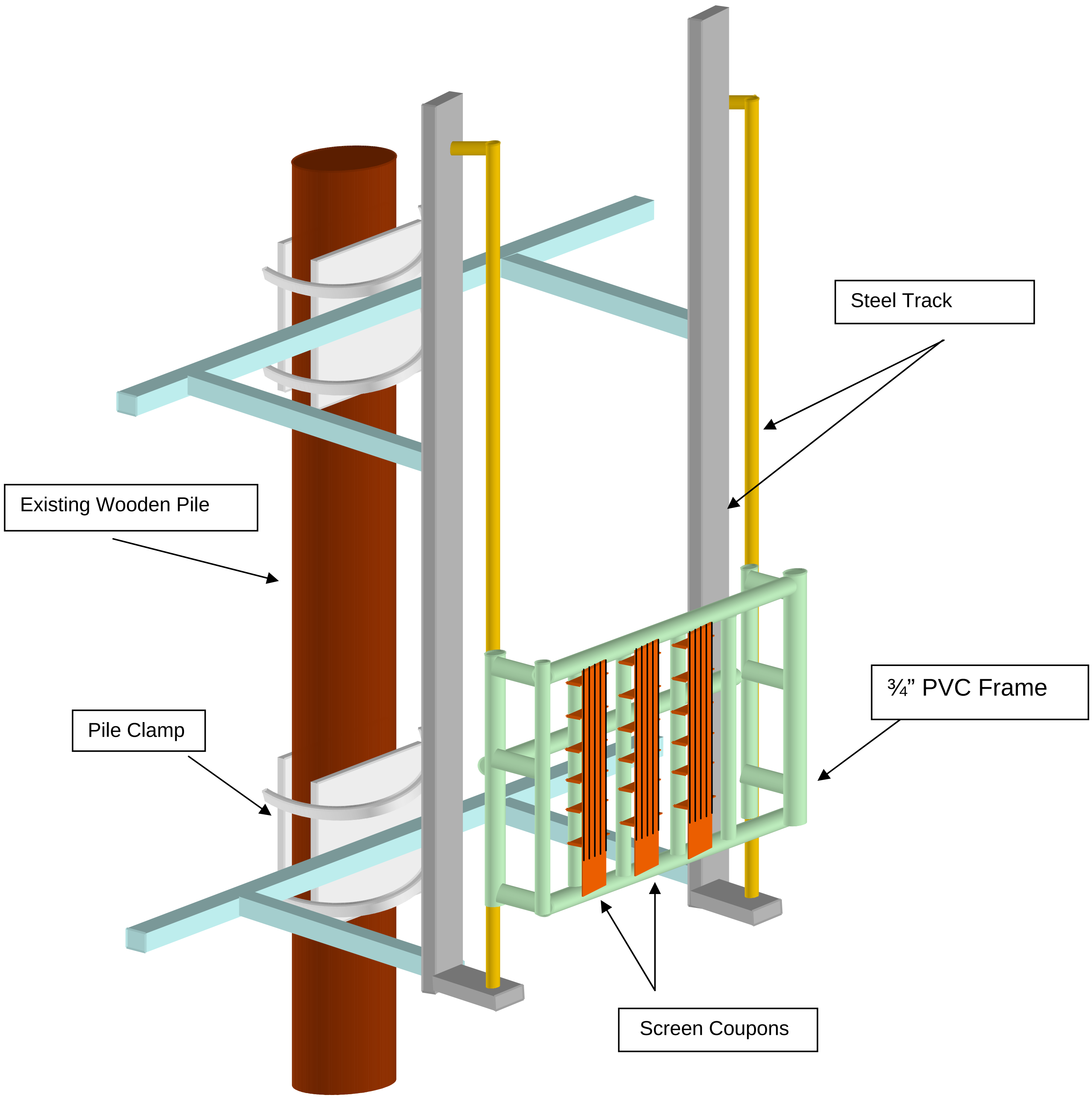


Figure 6. Track System for Sites 2, 3, and 4.

Figure 7. Screen Track System for Site 1 (Los Vaqueros Site).

Screen Placement

Track systems and PVC frames were installed three weeks prior to beginning the sampling period to allow for any modifications or adjustments if needed. The screen coupons were installed at the beginning of the sampling period. The study start dates for the different sites are shown in Table 1. The time needed to install the screen coupons, and the travel time between sites did not permit all screens to be installed on the same day.

Table 1. Study start dates (date screens were deployed)

Los Vaqueros	Hood	Horseshoe Bend	Suisun Marsh
July 7, 2002	June 26, 2002	June 27, 2002	June 26, 2002

At each site five coupons of each material (304 and 316 stainless steel and 90/10 Copper-Nickel) measuring 3 in x 12 in (7.6 cm x 30.5 cm) were attached to the PVC frame. All coupons had wedgewire openings of 3 mm. The coupons at each site were installed in an alternating sequence of 304, Copper-Nickel and 316 (Figure 8). Nylon zip-ties rated at 50 psi each were used to secure the screens to the frame. The zip-ties provided adequate holding strength, and facilitated easy removal and replacement of the coupons. An alternating sequence was used to equally expose all coupons to the environmental factors present at each site. Coupons were installed with the wedge wire running in the vertical direction. All screen coupons were weighed and numbered prior to installation and a master sheet for each site was created to document the location of each screen coupon on the PVC frame.

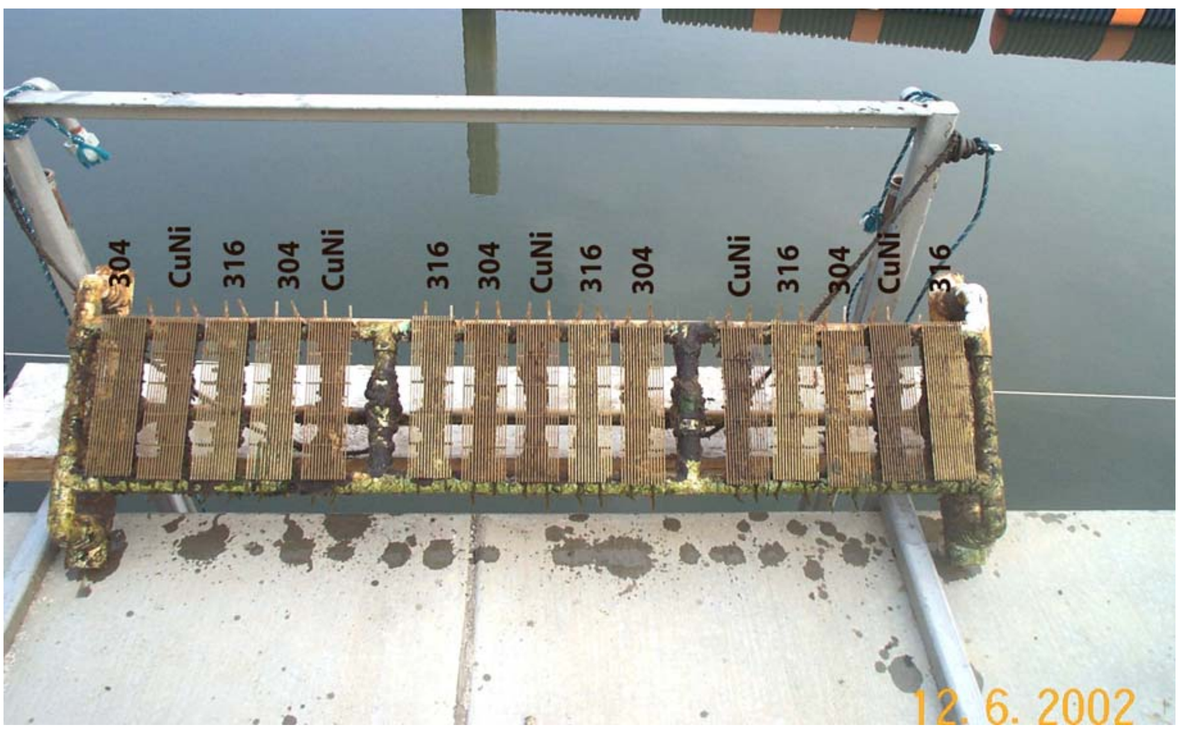


Figure 8. Screen Placement on PVC Frame

Midway through the study, a fabric material was installed alongside the metal coupons (Table 2). The fabric, according to the manufacturer, is resistant to aquatic biofouling and could be an alternative to using conventional screens at intakes. A 3-inch by 12-inch section of the material (same as coupons) was installed onto the PVC frame. One section of fabric was installed per site to observe and compare the materials biofouling resistance to that of the different screen metals.

Table 2. Fabric Material Installation Dates

Los Vaqueros	2/11/03
Hood RSAC 142	2/28/03
Horseshoe Bend	2/28/03
Morrow Island	2/7/03

Data Collection Dates

Monthly data collection was originally planned, but the first site visit revealed that a two month sampling interval would be necessary to obtain the amount of biological growth needed for quantitative analysis. In the latter part of the study the sampling interval was increased to observe biofouling with a reduction in cleaning frequency. Data collection dates, which occurred at the end of each sampling interval, are shown in Table 3.

Table 3. Data Collection Dates

	Data Collection Dates					
Los Vaqueros	**8/2/02**	**10/9/02**	**12/6/02**	**2/11/03**	**5/27/03**	**11/4/03**
Hood RSAC 142	**8/6/02**	**10/7/02**	**12/5/02**	**2/28/03**	**5/30/03**	**9/25/03**
Horseshoe Bend	**8/1/02**	**10/9/02**	**12/6/02**	**2/28/03**	**5/27/03**	**10/9/03**
Morrow Island	**8/2/02**	**10/7/02**	**12/5/02**	**2/7/03**	**5/30/03**	**9/25/03**

Biomass/Data Collection

Biomass samples for each screen material were collected for qualitative analysis only. Three screen coupons at each site, one for each screen material (304, 316, and CuNi), were designated for collection of the material sample. For simplicity, the first three coupons (from the left side of the PVC frame) at each site were designated for qualitative analysis. The same three coupons were used throughout the study for collection of the qualitative samples. Samples were collected by scraping the screen coupon face with a plastic spatula. This type of analysis required a small sample and did not require all material to be collected. Samples were deposited into collection jars containing a solution of 5 ml of water and 25 ml of Lugol's that served as a stain and preservative. Collected samples were marked for identification and stored in an ice chest for transportation. When possible the samples were delivered to DWR's Bryte Laboratory the same day of collection or they were stored in a refrigerator and delivered the next day possible. Organisms present in the collected samples were identified to the lowest taxonomic group practical. Prior to collecting samples, the screen coupon arrangement was photographed with a digital camera to establish a visual record of the biofouling.

The original plan called for biomass samples from the remaining twelve coupons for quantitative analysis. However, the first sampling episode revealed the difficulty in collecting all of the accumulated material from the coupons. The many surface faces, angles on the screen material, and crevices made it difficult and time consuming to collect the material from the entire coupon. The sampling method was modified to collect samples only from the face of the coupons for the analysis. This method did not work either; the collection process was pushing material back through the wedgewire and producing a sample unrepresentative of the material on the coupon face. Upon further review of the sampling methods, a decision was made to use visual analysis in determining the effectiveness of the screen material in resisting biofouling. Visual analysis was used for quantifying biofouling on intake screens in a similar study conducted by Weirsema, et.al (1979) on biofouling in Galveston Bay, Texas.

Visual Inspection

The visual analysis for this study consisted of dividing the screen coupon face into five sections, each representing 20% of the coupon. Each section was then visually inspected to estimate the wedgewire surface face percent coverage and coupon open area occlusion (Figure 9). The percentages for each section were then totaled to obtain a percent coverage and percent occlusion for the screen coupon. With this type of analysis, a coupon could have 100% coverage of the wedgewire surface face, and minimal obstruction of its open area. An example would be a very thin layer of algae covering the entire wedgewire surface. The analysis did not differentiate between materials growing or caught on the coupons. All materials found on the coupon face were included in estimating percent coverage. Digital photos of the coupons were also taken to document the coverage. The screen coupons were thoroughly cleaned during each sampling event to expose a clean surface face for the next sampling period. The screen coupons were removed from the PVC frame two at a time and cleaned thoroughly with nylon brushes. The screens coupons were then reattached to the PVC frame with the new nylon zip-ties.

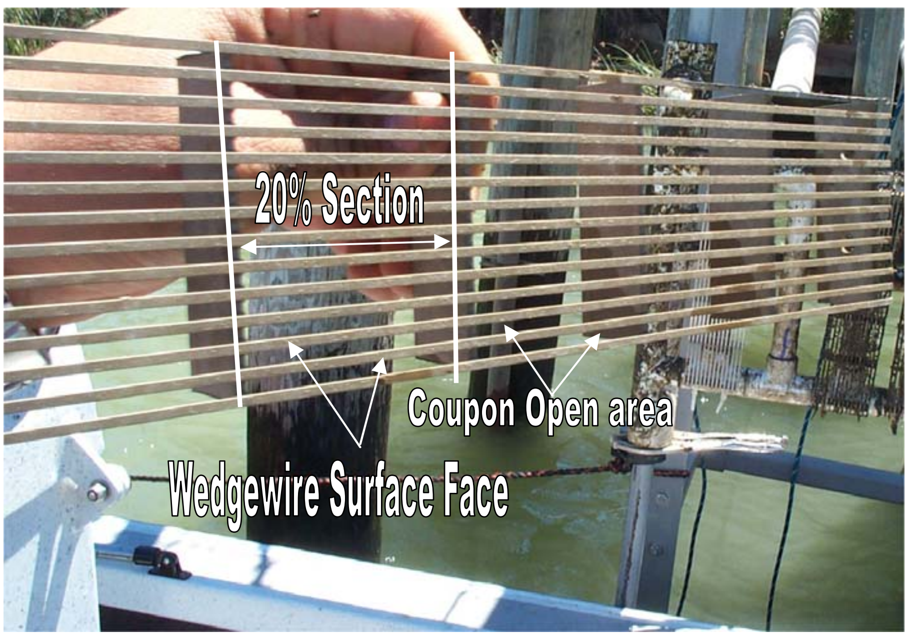


Figure 9. Coupons were divided into five 20% sections. Each section was analyzed to determine the percent of wedgewire surface face biofouling (coverage) and coupon open area occlusion.

Water Quality Data

Water quality data such as water temperature, dissolved oxygen, electrical conductivity and salinity were also collected at the end of each sampling episode using an YSI 85 water quality probe. Due to inconsistent sampling intervals and the small number of samples, no statistical analysis was done. Water Quality results can be found in the appendix.

Percent Wedgewire Coverage and Open Area Occlusion

Los Vaqueros Site

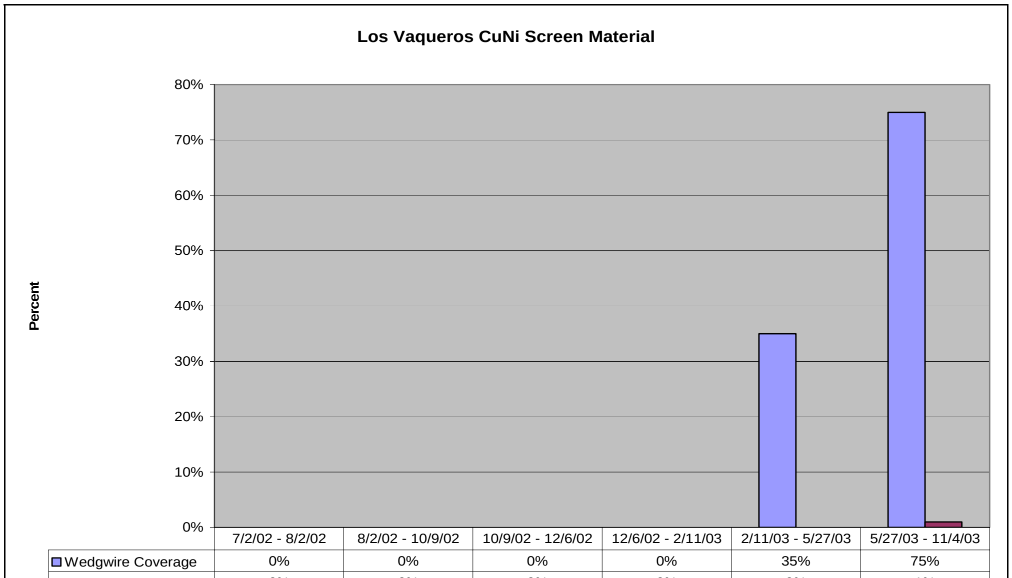
The sampling intervals, wedgewire surface face percent coverage and open area occlusion for this site are shown in Charts 1 through 3. The charts show a sample interval of two months in the beginning of the study, and an increase to four and five month sample intervals at the end of the study. The intervals were increased to evaluate biofouling with a reduction in cleaning frequency.

CuNi

Very little material was visible on the CuNi screen coupons throughout the study (Chart 1). Of the six sample intervals, only two produced biofouling on the CuNi screen coupons. The fouling consisted of a very thin layer of black algae (see taxonomic table for identification). Thirty five percent coverage of the wedgewire face and 0% open area occlusion occurred during the sample interval of February 11, 2003 and May 27, 2003. The sample interval of May 27, 2003 through November 4, 2003 produced 75% wedgewire face coverage and 1% open area occlusion. The biofouling was easily rubbed off and did not block or obstruct the open area of the screen. Minimal effort was needed to clean the screens thoroughly. See photos in Appendix.

Stainless Steel

The 304 and 316 coupons did not perform as well as the CuNi coupons. Biofouling was observed on the 304 and 316 coupons for all sample intervals (Charts 2 and 3). The highest percent coverage occurred during the sampling interval of February 11, 2003 to May 27, 2003. This sample interval produced 100% coverage of the wedgewire surface face for both 304 and 316 coupons. The coupons were 5% covered with sponge and 95 percent covered with a thin brown layer of algae. Although the coverage was very high during this interval, the open area occlusion was only 7%. The greatest percentage of open area occlusion occurred during the interval of May 27, 2003 through November 4, 2003. This interval produced 70% wedgewire face coverage and 60% open area occlusion (Figure 10). The high percentage of occlusion can be attributed to the large quantity of fresh water sponge on the coupons. This site consistently produced sponge growth on the coupons and visual inspections throughout the study indicate that the sponge first set hold on the wedgewire support members and then spread throughout the screen if given enough time. In the early stage of sponge establishing itself on the screens, it was found only on the wedgewire supports members. There was no visible difference in the amount of fouling between the 304 and 316 coupons. Light to moderate scrubbing with a plastic spatula and nylon brush was necessary to remove the biofouling from the coupons.



	7/2/02 - 8/2/02	8/2/02 - 10/9/02	10/9/02 - 12/6/02	12/6/02 - 2/11/03	2/11/03 - 5/27/03	5/27/03 - 11/4/03
Wedgwire Coverage	0%	0%	0%	0%	35%	75%
Open Area Occlusion	0%	0%	0%	0%	0%	1%

Chart 1. Los Vaqueros site - Percent wedgewire surface face coverage and coupon open area occlusion for CuNi metal.

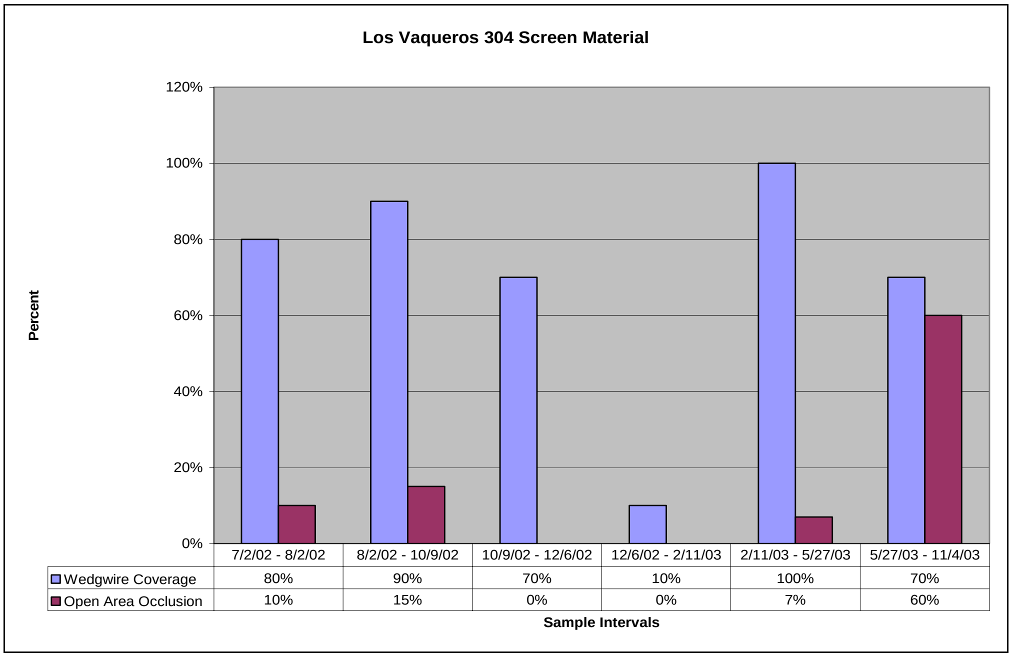


Chart 2. Los Vaqueros site – Percent wedgewire surface face coverage and coupon open area occlusion for 304 stainless steel.

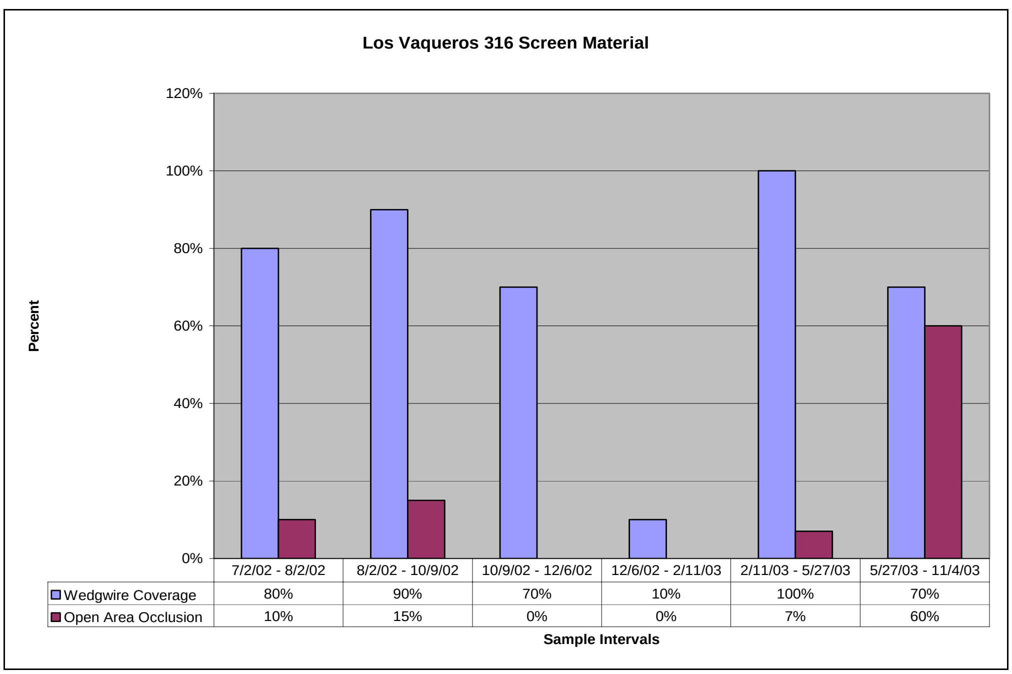


Chart 3. Los Vaqueros site - Percent wedgewire surface face coverage and coupon open area occlusion for 316 stainless steel.

Figure 10. Los Vaqueros Biofouling for sample interval 5/27/03 – 11/4/03.

Horseshoe Bend Site

Sampling intervals, wedgewire surface face percent coverage and open area occlusion for this site are shown in Charts 4 through 6. The charts show a sample interval of two months in the beginning of the study, and an increase to three and four month sample intervals at the end of the study. The intervals were increased, as they were at the Los Vaqueros site, to evaluate biofouling with a reduction in cleaning frequency.

CuNi

Similar to the Los Vaqueros site, only two sample intervals (February 28, 2003 through May 27, 2003 and May 27, 2003 through October 9, 2003) caused biofouling on the CuNi screens (Chart 4). The biofouling consisted of a thin layer of black algae and was very similar to that of the Los Vaqueros site. The taxonomic tables in the appendix show that the CuNi coupons from both sites had some of the same algae present. This alga was very easily cleaned off with light rubbing/scrubbing with a nylon brush. The coupons remained very clean throughout the study and required little cleaning between intervals. See photos in appendix for visual information.

Stainless Steel

In contrast to the CuNi, for all intervals biofouling was present on the 304 and 316 coupons. The biofouling at this site was much more filamentous and embedded with silt when compared to the Los Vaqueros site. The highest wedgewire face coverage (95%) for the 304 and 316 coupons occurred during the sampling interval of August 1, 2002 through October 9, 2002 (Figure 11). The coverage consisted of filamentous brown algae embedded with silt. The filamentous alga appears to aid in the build-up of sediment on the coupons. This is evident from photos showing the CuNi wedgewire supports clean with no silt build-up, and the wedgewire supports on the 304 and 316 coupons with fibrous algae and heavy sediment build-up (see photos in appendix). The highest percentage (40%) of open area occlusion occurred during the sample interval of May 27, 2003 through October 9, 2003. The higher percent of open area occlusion is due to the presence of fresh water sponge on the coupons during this interval. It is the only sample interval at this site that produced fresh water sponge. Similar to the Los Vaqueros site, the sponge appears to have originated on the wedgewire supports. The lowest percent (20%) of wedge wire coverage occurred during the sampling interval of October 9, 2002 to December 6, 2002. Filamentous algae were the primary fouling source during this interval. Moderate scrubbing/scraping with a nylon brush and plastic spatula were necessary to remove the filamentous algae from the 304 and 316 coupons.

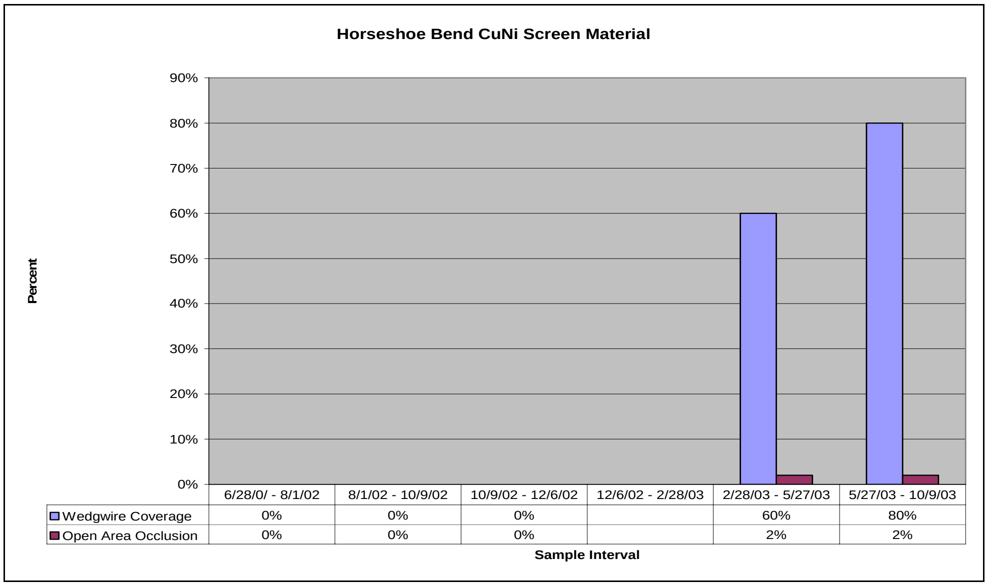


Chart 4. Horseshoe Bend site - Percent wedgewire surface face coverage and coupon open area occlusion for CuNi metal.

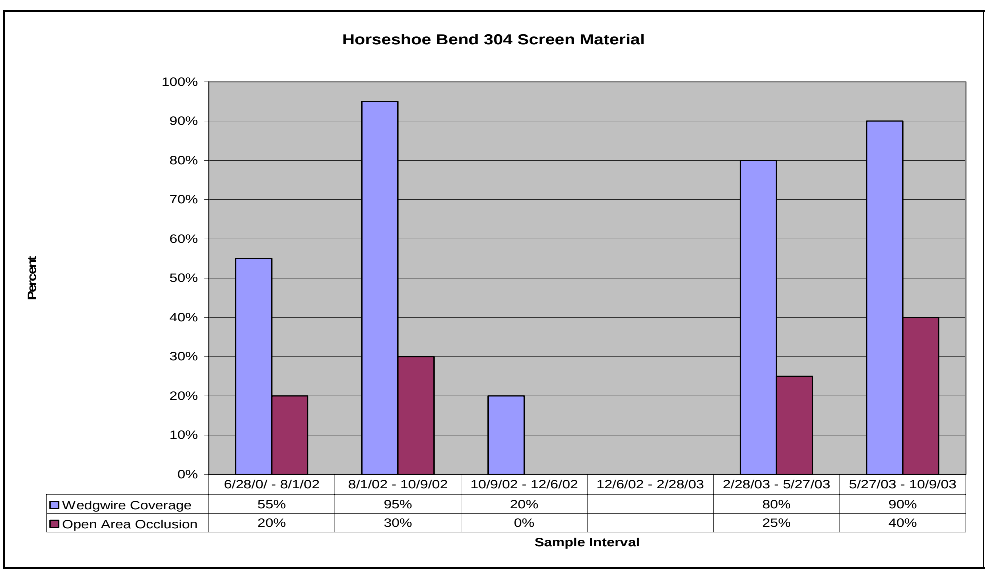


Chart 5. Horseshoe Bend site – Percent wedge wire surface face coverage and coupon open area occlusion for 304 stainless steel.

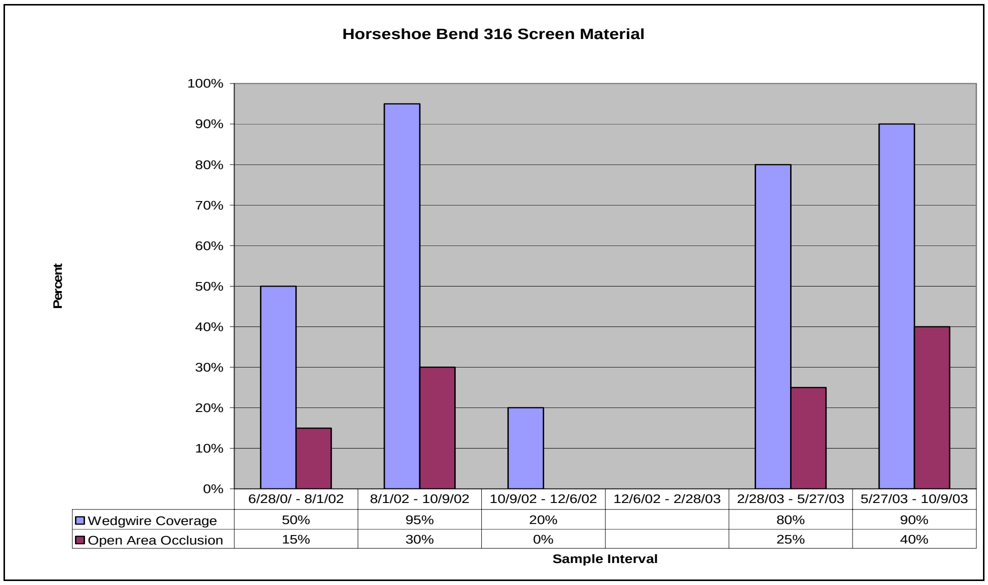


Chart 6. Horseshoe Bend site – Percent wedge wire surface face coverage and coupon open area occlusion for 316 stainless steel.

Figure 11. Horseshoe Bend biofouling for sample interval 8/1/02 – 10/9/02.

Morrow Island Site

The sampling intervals, wedgewire surface face percent coverage and open area occlusion for this site are shown in chart 7 through 9. The charts show a sample interval of two months at the beginning of the study, and an increase to four month sample intervals at the end of the study. The intervals were increased, as they were at the Los Vaqueros and Horseshoe Bend sites to evaluate biofouling with a reduction in cleaning frequency.

CuNi

The CuNi coupons did an excellent job resisting biofouling and remained free of barnacles and algal growth for the duration of the study (Chart 7). They required very little scrubbing only to remove light sediment build-up on the wedgewire support members.

Stainless Steel

For all sample intervals, biofouling was present on the 304 and 316 coupons (Charts 8 and 9). The primary biofouling agents at this site were barnacles and calcareous algae. Most of the barnacles on the screen coupons were attached to the wedgewire supports with only a few attaching to the wedgewire itself. The prevalence of the barnacles on the wedgewire supports could be in part due to larger surface area that is provided by the supports. At this site two intervals, February 7, 2003 through May 30, 2003 and May 30, 2003 through September 25, 2003, produced 100% coverage of the wedgewire surface face. The type of biofouling was very different for both sample intervals. The sample interval of February 7th through May 30th of 2003 produced a web of algae and heavy sediment that covered the 304 and 316 screen coupons (Figure 12). Some barnacles were found attached to the wedgewire under the web of algae. This sample interval also had the highest percentage of open area occlusion at 70%. The very dense web of biofouling blocked the majority of the open area on some of the 304 and 316 coupons. For the sample interval of May 30th through September 25th of 2003, the 304 and 316 coupons were covered with calcareous algae and some barnacles, the same type of biofouling produced during the other sample intervals. Although this interval also had 100% wedgewire face coverage, the biofouling only produced a 15% occlusion of the 304 and 316 coupon open area. The 304 and 316 coupons required heavy scraping/scrubbing with plastic spatulas and nylon brushes to remove the biofouling.

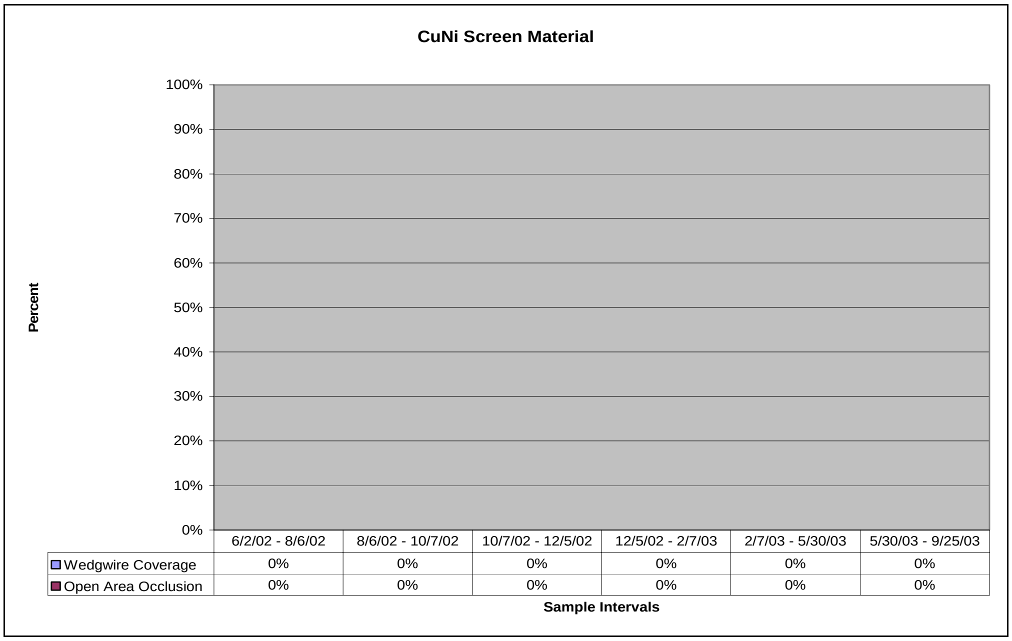


Chart 7. Morrow Island site – Percent of wedgewire surface face coverage and coupon open area occlusion for CuNi metal. Coupons remained free of biofouling for the duration of the study.

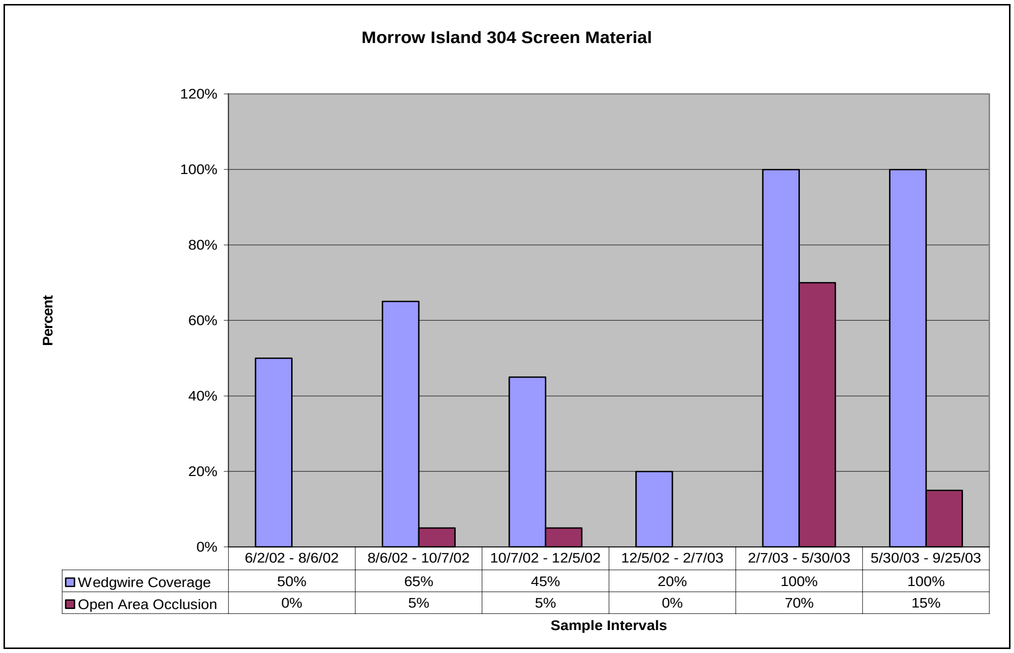


Chart 8. Morrow Island site – Percent of wedgewire surface face coverage and coupon open area occlusion for 304 stainless steel.

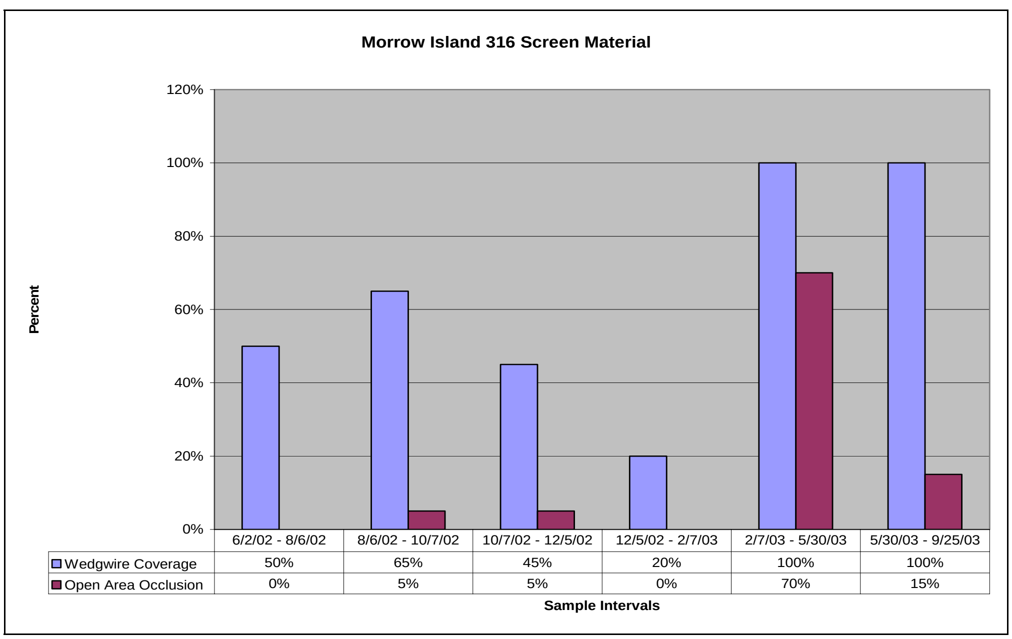


Chart 9. Morrow Island site – Percent of wedgewire surface face coverage and coupon open area occlusion for 316 stainless steel.

Figure 12. Morrow Island Biofouling for sample interval 2/7/03 – 5/30/03.

Hood Site

The sampling intervals, percent coverage of wedgewire surface face and open area occlusion for this site are shown in charts 10 through 12. The chart shows a sample interval of two months at the beginning of the study, and an increase to three and four month sample intervals at the end of the study. The intervals were increased, as they were at the other three sites, to evaluate biofouling with a reduction in cleaning frequency. Conditions at Hood caused a gelatinous mixture of entrapped silt and debris on all three coupon materials throughout most of the study. In 1977 a similar study conducted at this site also noted a gelatinous mixture of sediment and debris on the screens (Smith 1977).

CuNi

Hood is the only site where visually biofouling material was present on the CuNi coupons throughout the study. Visually, the amount of biofouling on the CuNi was much less than the stainless steels. The biofouling was also easier to clean off of the CuNi coupons. Qualitative analysis of the material from all three metals revealed similar biofouling species (see taxonomic tables). The CuNi coupons were stained a dark brown early in the study. It is unknown what caused the staining, and unclear whether it promoted biofouling by inhibiting the CuNi from forming its protective anti-biofouling patina. The coupon open area occlusion caused by the CuNi biofouling was minimal (1%) for all sample intervals. Floating debris such as twigs and grasses were consistently present on all coupons.

Stainless Steel

All sample intervals produced a high percentage of wedgewire surface face coverage on the 304 and 316 coupons. A total of three intervals produced 90% wedgewire surface face coverage on the 304 and 316 coupons (Charts 10-11). The gelatinous mixture of biofouling was very dense and blocked 50% of the 304 and 316 coupon open area for the interval of August 6, 2002 to October 7, 2002. The second highest percent (40%) of open area occlusion occurred during the interval of October, 7, 2002 through December 5, 2002. Floating debris such as grasses and twigs were consistently present on all coupons, including the CuNi coupons. The heavy silt load and how it accumulates on the screens can be seen in Figure 13.The coupons during the intervals that produced the lowest percent coverage had area with a thin layer of green algae and floating debris (twigs, grasses, leaves,). Floating debris was consistently present on all the coupons at this site. This is a site that had very high silt content, which is evident from the photos taken at the site that show heavy silt buildup on the coupons. The 304 and 316 coupons required moderate scrubbing with a nylon brush to remove the material.

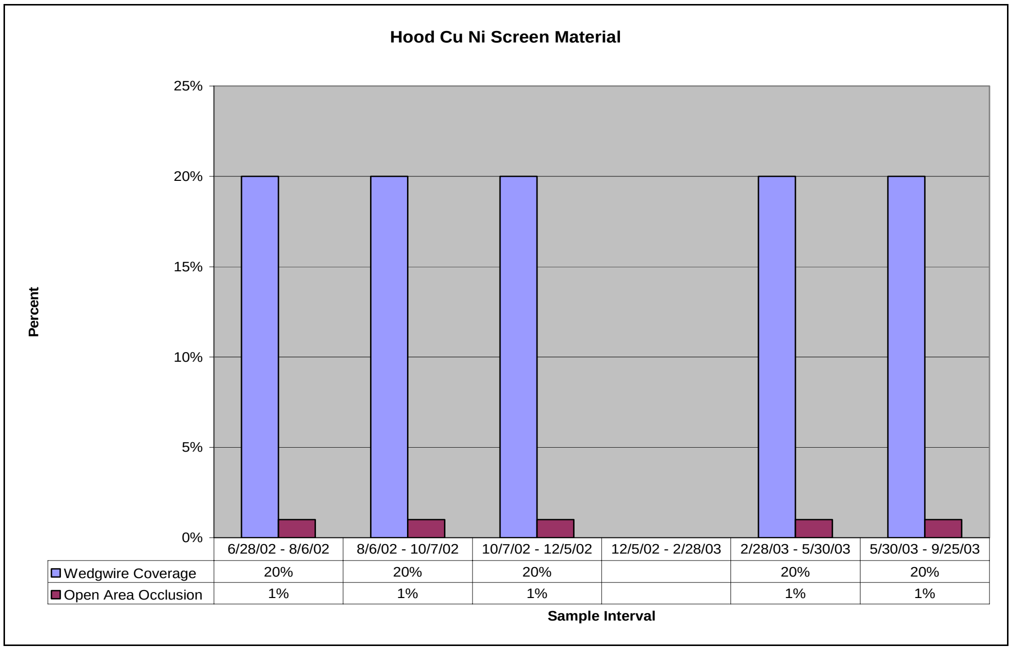


Chart 10. Hood site – Percent of wedgewire surface face coverage and coupon open area occlusion for CuNi metal.

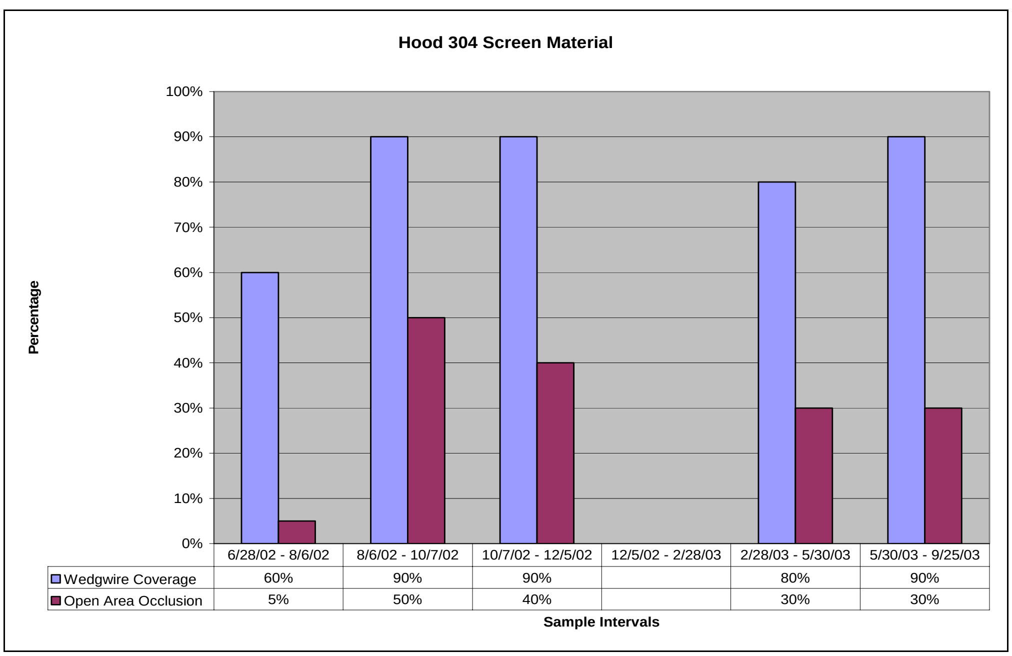
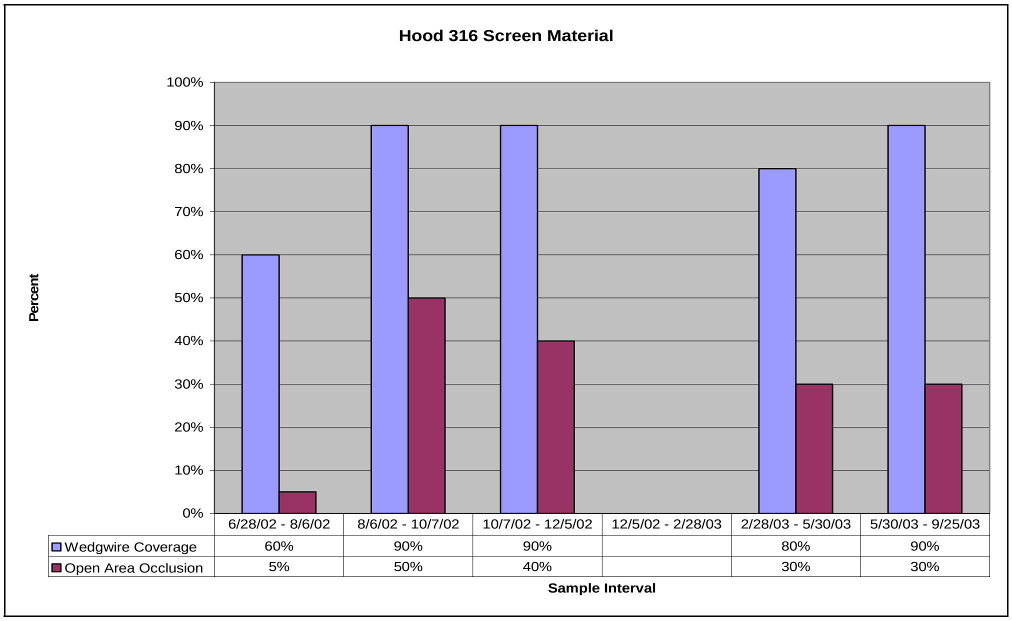


Chart 11. Hood Site – Percent coverage of Wedgewire surface face coverage and coupon open area occlusion for 304 stainless steel.



	6/28/02 - 8/6/02	8/6/02 - 10/7/02	10/7/02 - 12/5/02	12/5/02 - 2/28/03	2/28/03 - 5/30/03	5/30/03 - 9/25/03
Wedgwire Coverage	60%	90%	90%		80%	90%
Open Area Occlusion	5%	50%	40%		30%	30%

Chart 12. Hood Site – Percent of wedgewire surface face coverage and coupon open area for 316 stainless steel.

Figure 13. Hood Site - Biofouling for sample interval 10/7/02 – 12/5/02.

Biofouling Observations of Fabric

The fabric material was installed midway through the study (Figure 14) and was subjected to two sample intervals, which were the last and longest intervals of the study. The fabric was cut into sections with the same dimensions as the metal coupons, and one section was installed per site. Similar to the 304 and 316 coupons, the fabric had biofouling on all sample intervals at all the sites. Barnacles were the only organism found on the 304 and 316 coupons that were not observed on the fabric. We found the fabric easier to clean than the 304 and 316 coupons. Most of the biofouling came off by vigorously shaking the fabric under water.

Figure 14. Fouling on fabric material.

Taxonomic Results

All samples collected were qualitatively analyzed for taxonomic composition by biologists at DWR's Bryte Laboratory. The most abundant forms identified at the different sites are listed below.

- Los Vaqueros (*Syndera, Navicual, Cocconeis, Achnanthes,* and *Rhoicoshpenia curvata*)
- Hood (*Syndera, Navicual, Achnanthes, Diatoma* and *Melosira*)
- Horseshoe Bend (*Navicual, Achnanthes, Cocconeis* and *Fragilaria*)
- Suisun Marsh (*Cymbella*)

The Los Vaqueros, Horseshoe Bend and Hood had some of the same species of algae present. See tables 8 through 11 for a complete listing of all the alga species identified at the test sites.

Table 4. Taxonomic Composition for Los Vaqueros

Los Vaqueros Site	Taxonomic Composition of Samples																	
Sample date	8/2/02			10/9/02			12/6/02			2/11/03			5/27/03			11/5/03		
Material	304	316	CuNi	304	316	CuNi	304	316	CuNi	304	316	CuNi	304	316	CuNi	304	316	CuNi
Algae:																		
Synedra	X			X									X	X			X	X
Lyngbya													X					
Navicual	X	X		X	X								X	X			X	X
Bacillaria paxillifer					X													
Cocconeis	X	X		X	X		X	X					X	X				
Cosinodiscus		X																
Aphanizomenon flos-aquae				X														
Achnanthes	X	X		X	X		X	X					X	X	X			X
Ankistrodesmus					X													
Ankistrodesmus falcatus					X													
Nitzschia																X		
Hydrosera whampoensis				X	X													
Gyrosigma	X			X	X												X	X
Nitzschia apiculata				X														
Nitzxshia tryblionella				X														
Nitzschia sigmoidea				X														X
Cymbella	X				X													
Gomphonema													X					
Oscillatoria							X	X					X					
Biddulphia laevis				X														
Rhoicoshpenia curvata	X	X		X	X		X	X					X	X		X		
Pseudanabaena														X		X	X	
Pleurocapsa																	X	
Bacillaria								X										
Diatoma													X					
Stephanodiscus niagarae				X														
Cymatopleura	X				X													
Closterium		X																
Gloeothece							X	X										
Coleochaete							X	X										
Microcystis															X			
Microspora							X											

Table 5. Taxonomic Composition for Hood

Hood Monitoring Site	Taxonomic Composition of Samples																	
Sample date	8/6/02			10/7/02			12/5/02			2/28/03			5/30/03			9/25/03		
Material	304	316	CuNi	304	316	CuNi	304	316	CuNi	304	316	CuNi	304	316	CuNi	304	316	CuNi
Algae:																		
Synedra	X	X	X	X	X		X	X		X	X	X	X	X	X	X	X	X
Terpsinoe																X		
Terpsinoe musica																	X	
Navicual	X	X	X	X	X	X	X	X			X		X	X	X	X	X	X
Bacillaria paradoxa																	X	
Bacillaria paxillifer					X													
Cocconeis				X			X	X										
Cocconeis placentula																X	X	
Achnanthes		X	X	X	X	X	X	X	X					X		X	X	X
Nitzschia							X								X	X	X	
Hydrosera whampoensis				X	X	X	X	X									X	
Hydrosera		X																
Hyalotheca			X															
Gyrosigma		X		X	X	X	X	X									X	X
Nitzschia sigmoidea													X				X	
Nitzschia tryblionella	X		X															
Cymbella		X					X	X								X		X
Melosira							X	X		X	X	X	X	X	X	X		X
Melosira granulata	X	X	X															
Gomphonema							X											X
Pennate diatom																		X
Closterium														X				
Cosmarium																		X
Oscillatoria						X	X									X		
Biddulphia											X							
Biddulphia laevis				X	X											X		
Fragilaria							X			X	X	X	X	X	X			
Rhoicoshpenia curvata							X	X										
Stauroneis														X				
Pediastrum duplex															X			
Pseudanabaena											X							
Bacillaria																		
Diatoma	X	X	X	X	X	X	X	X	X	X		X			X			
Spirogyra							X											
Cyclotella								X										
Surirella			X		X													
Ulothrix														X				
Microspora							X	X	X									

Table 6. Taxonomic Composition for Horseshoe Bend

Horseshoe-Bend Site	Taxonomic Composition of Samples																	
Sample date	8/1/02			10/9/02			12/6/02			2/28/03			5/27/03			10/9/03		
Material	304	316	CuNi	304	316	CuNi	304	316	CuNi	304	316	CuNi	304	316	CuNi	304	316	CuNi
Algae:																		
Synedra	X									X	X		X	X			X	
Synedra actinastroides	X																	
Synedra ulna	X	X																
Terpsinoe musica																		
Navicual	X			X			X			X	X		X	X	X	X	X	X
Bacillaria paxillifer											X							
Cocconeis		X		X				X					X	X				
Cosinodiscu		X																
Cocconeis placentula	X															X		
Achnanthes	X	X		X				X		X	X			X	X	X	X	X
Amphora ovalis								X					X	X				
Ankistrodesmus falcatus											X							
Nitzschia		X		X						X			X	X				
Hydrosera whampoensis		X		X														
Gyrosigma	X	X												X			X	
Nitzschia sigmoidea					X													
Cymbella		X								X				X		X		
Melosira granulata	X	X																
Melosira										X	X		X	X	X			
Gomphonema																	X	
Cosmarium																		
Oscillatoria							X									X	X	
Biddulphia laevis	X	X												X				
Fragilaria		X			X								X	X			X	
Rhoicoshpenia curvata													X	X		X		
Stauroneis																X		
Pleurocapsa				X														
Bacillaria		X																
Diatoma Vulgare	X										X			X				
Spirogyra																		
Thalassiosira eccentrica																		
Cyclotella					X								X					
Aulacoseira granulata				X	X		X											
Trachelomonas															X			
Microcystis																		
Microspora																		
Surirella								X										

Table 7. Taxonomic Composition for Suisun Marsh

Suisun Marsh Site S37	Taxonomic Compostion of Samples																	
Sample date	8/2/02			10/7/02			12/5/02			2/7/03			5/30/03			9/25/03		
Material	304	316	CuNi	304	316	CuNi	304	316	CuNi	304	316	CuNi	304	316	CuNi	304	316	CuNi
Algae:																		
Synedra																		
Terpsinoe																		
Terpsinoe musica																		
Thalassiosira eccentrica					X													
Navicual																		
Bacillaria paradoxa																		
Cocconeis																		
Cocconeis placentula																		
Cryptomon					X													
Achnanthes					X													
Achnanthes gibberula											X							
Amphoriprora														X				
Ankistrodesmus falcatus																		
Nitzschia																		
Hydrosera whampoensis																		
Gyrosigma																	X	
Nitzschia sigmoidea																		
Cymbella	X																X	
Melosira																		
Gomphonema																		
Pennate diatom																		
Cosmarium																		
Oscillatoria																		
Biddulphia laevis																		
Fragilaria																		
Rhoicoshpenia curvata																		
Stauroneis																		
Pseudanabaena																		
Pleurocapsa																		
Chlamydomonas							X											
Bacillaria																		
Diatoma																		
Spirogyra																		
Cyclotella																		
Aulacoseira granulata																		

Conclusions

The fabric material was only installed for two sample intervals and biofouling samples were not obtained for analysis. During the two sample intervals, it was just as prone to biofouling as the 304 and 316 stainless steels. Photos show the fabric with the same type of biofouling as the stainless steel coupons. Barnacle were never observed on the fabric, but were present on the metal coupons at some of the sites. The fabric was easier to clean, requiring only vigorous shaking in the water and no scrubbing to clean. More data is needed to fully understand the biofouling characteristics of the fabric.

Stainless steels

There was no visible difference in the biofouling resistance of 304 and 316 stainless steels at all test sites. Visually the amount and distribution of the biofouling at each individual test site was the same for both metals. There was also no difference in the effort required to remove the biofouling from either the 304 or 316 coupons. During the extended sample intervals biofouling caused as much as 50% occlusion of the coupons open area. Both metals required moderate to heavy scrubbing to clean the coupons after sampling. Calcareous algae and barnacles at the Morrow site and filamentous algae at the Los Vaqueros and Horseshoe Bend sites were difficult to remove from the stainless steels. The difficulty was in removing the algal from in-between the wedgewire. Heavy scrubbing with a nylon brush and plastic spatula was necessary to remove the biofouling from the 304 and 316 coupons.

CuNi

In contrast the copper nickel coupons were very effective at resisting biofouling. This is evident by the lack of biofouling on the CuNi coupons throughout most the study. The biofouling that did occur on the CuNi was very small in quantity, was easily cleaned off, and did not cause blockage of the coupons' open area. The CuNi material resisted barnacles, fresh water sponge and filamentous algae, the type of biofouling most frequently found on the stainless coupons. The Hood test site was the site that visually produced biofouling on the CuNi for all sample intervals. The CuNi coupons at this site were stained a dark brown early on in the study. It is unclear if the staining inhibited the CuNi from forming its protective patina, thereby causing the biofouling observed during the study. Staining did not occur at the other sites.

All coupons were installed with the orientation of the wedgewire in the vertical direction. This orientation placed the wedgewire support members in the horizontal direction. Observations indicate that the larger horizontal surface area of these wedgewire supports provided an area ideal for biofouling on the stainless steel coupons and is the area were barnacles, fresh water sponge and filamentous algae first set in. This area around the wedgewire supports (backside of screen coupons) consistently had larger amounts of biofouling material (Figure 13). It is unknown if positioning the wedgwire horizontally (support members vertically), would produce the same biofouling results. The larger surface area and not the orientation of the wedgewire supports may be what is facilitating more biofouling.

Current cylindrical and flat plate screen cleaning technologies such as water pressure and rotating nylon brushes do not address control or removal of backside biofouling. Internal Water pressure systems due not provide the force needed to remove the material and rotating nylon brush systems only clean the face of the screen. As a result, constant maintenance and manual cleaning of some facilities is needed to address the problem. The study clearly shows an advantage to using CuNi over stainless steel to resist biofouling. It is a more expensive material, but its biofouling resistance could substantially reduce costs associated with maintenance, downtime and reduced system efficiency, potentially offsetting the initial higher cost of the material. The figure below (Figure 14) further supports considering the use of CuNi for building or retrofitting screen facilities.

Figure 15. Photo shows Backside of Coupons at the Los Vaqueros site prior to cleaning. The CuNi coupon is free of biofouling after being in the water for five months. (Sample interval from 5/27/03 – 11/4/03)

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Appendix

Water Quality Charts

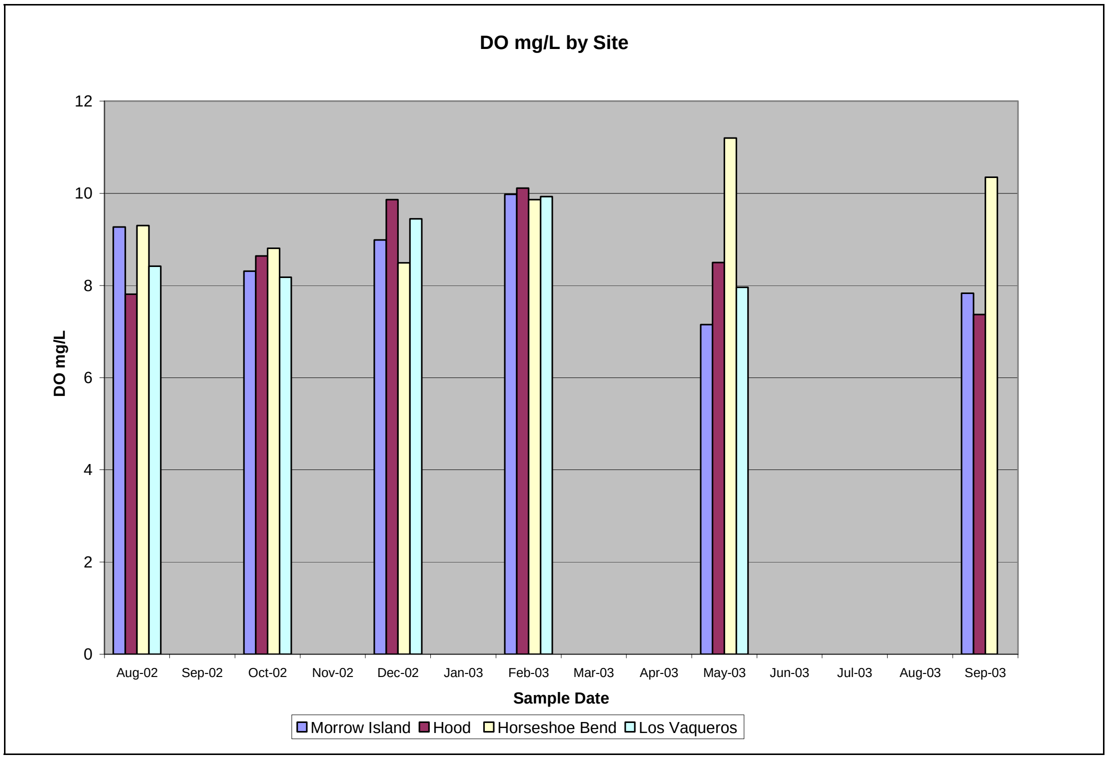

Chart A1. Dissolved Oxygen levels for all four sites. Dissolved Oxygen readings were not all collected on the same day of the month.

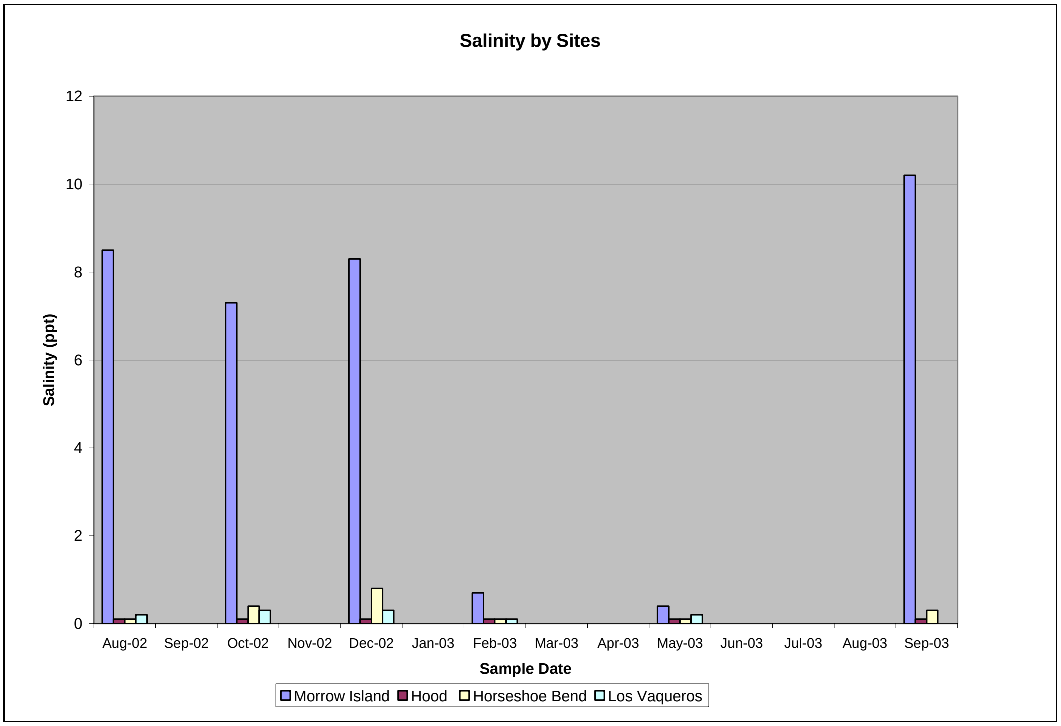

Chart A2. Salinity of the four sites for during study. Not all salinity readings were collected on the same day of the month.

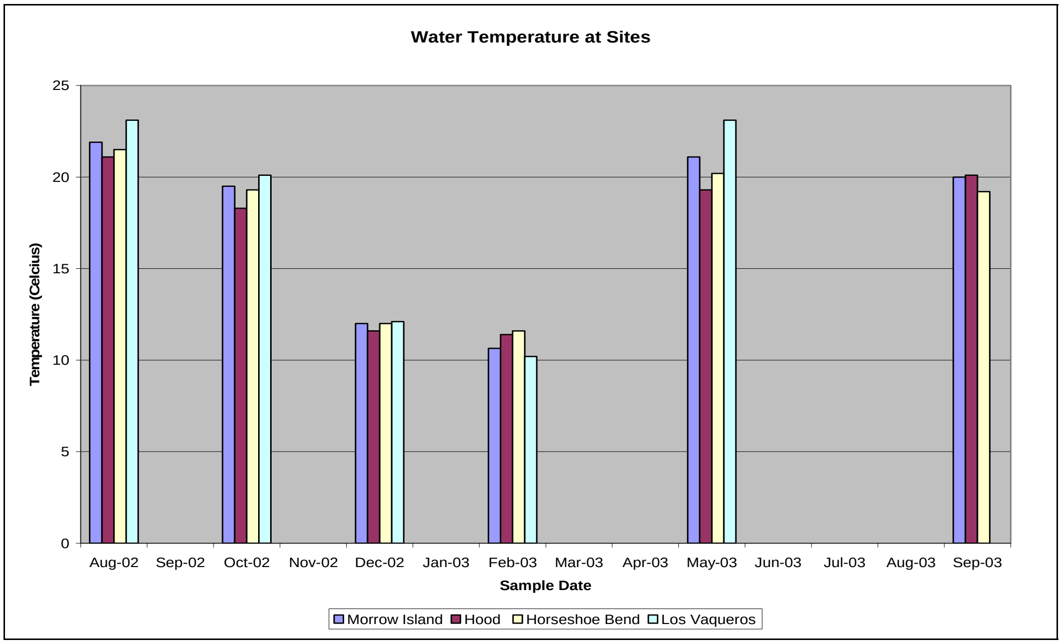

Chart A3. Water Temperature of four sites during the study. Not all water temperature readings were collected on the same day.

Study site photos are available on CD

Los Vaqueros Site Photos

Hood Site Photos

Horseshoe Bend Site Photos

Morrow Site Photos