# Intake Design for Minimising Debris Blockages and Impacts to Fish

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## ABSTRACT

Seawater desalination intake systems must be designed to provide access to a reliable quantity of high quality feedwater. In addition, it is critical that the intake system be adequately designed to prevent blockages to flow and impacts to the marine organisms in the source waterbody. Operational impacts from these blockages include equipment damage, facility outages and plant safety concerns. These operational impacts can ultimately translate to system reliability problems and declines in plant revenue. Selecting the best intake technology for minimizing these risks is a site-specific exercise that requires consideration of the unique site conditions, such as the design flow required, ambient hydraulics, presence and type of debris, site bathymetry, competing uses of the source waterbody, the value of the organisms in the source waterbody, the regulatory requirements, and the social aspects. This paper outlines a comprehensive protocol for selecting the proper intake technology and best management practices (BMPs) for a given site. It describes the process by which intake blockages can be minimized as well as how to address common environmental concerns over potential impacts to marine organisms. A Chilean case study is provided to illustrate the steps involved in assessing an existing intake's vulnerability to intake blockages and which modifications or BMPs would minimize the risk.

## 1.0 INTRODUCTION

Seawater intake systems are critical to the desalination and power generation industries. Intakes are designed to provide a reliable supply of consistent quality seawater with minimal environmental impact. Intakes also provide a means to protect downstream process equipment from damage or clogging by debris. Therefore, the design and operation of seawater intake systems is critical to ensure proper operational and environmental performance. Selection of the proper intake system is also critical for economic reasons, as a state-of-the-art intake can represent a substantial proportion of the total capital costs of a project. Developing a reliable method for selecting the best intake technology is good practice for developers in the water-use industries. Furthermore, it is important for existing facilities to understand how best to operate, maintain, or modify existing intake technologies to minimize intake blockages and impacts to marine life.

## 2.0 METHODOLOGY

The success of an intake can be measured by its ability to prevent the passage of debris and marine life into the downstream process equipment. Therefore, in order to determine the potential success of a planned intake or the success of an existing intake, it is necessary to consider various engineering and biological aspects. The sections below present descriptions of the types of intake systems available, standard approaches for selecting the best intake technology for new facilities and for assessing the performance of intakes at existing facilities. Detail is provided on both engineering and biological components that contribute to an optimized seawater intake system. Lastly, a case study is provided for a Chilean power plant that underwent an intake assessment to determine the best alternatives to address a recurring debris issue.

### 2.1 Intake Technologies

The various intake technologies available to developers can be broadly grouped into four main categories based on how they operate to minimize debris and marine life impacts: behavioural systems, exclusion systems, collection systems, and diversion systems (EPRI 2007). The following presents a brief description of each of the intake categories.

*Behavioural systems* function on the premise that some fish species can be repelled from an intake or attracted to a safe location away from the intake by various stimuli. Behavioural systems are designed solely to reduce impacts to marine organisms and do not address debris issues. Examples of behavioural technologies that have been researched include sound, strobe lights, and air bubble curtains (Figure 1). *Exclusion systems* function on the premise that a screen will physically exclude debris and organisms equal to or greater than its mesh size. For optimal debris performance, provisions (mechanical or otherwise) are incorporated to keep the screening surface clean. Examples of exclusion technologies include cylindrical wedgewire screens (Figure 2) and conventional travelling water screens. *Collection systems* are designed to actively collect organisms and debris and return them to the source waterbody. The modified travelling water screen is one of the most popular collection technologies used at cooling water intake structures in the power industry. This type of screen differs from a conventional travelling water screen in that it includes buckets on the ascending face of the screen which collect marine life and debris, a spraywash system which rinses marine organisms and debris into troughs that return the collected material back to the source waterbody (Figure 3). Diversion systems are designed to passively divert debris and fish to bypasses for return to the source waterbody. An example of a diversion system is and angled screen with a bypass at the end (Figure 4).

**Figure 1** Laboratory evaluation of an air bubble curtain used as a behavioural technology for preventing entrainment of fish (courtesy Alden Research Laboratory)

**Figure 2** Cylindrical wedgewire screen used as an exclusion technology (courtesy We Energies)

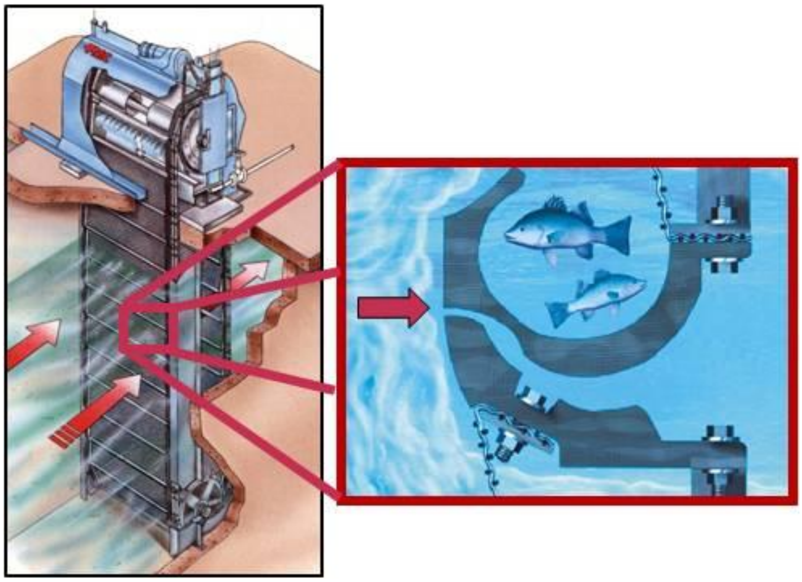

**Figure 3** Modified travelling water screen used as a collection technology (courtesy Siemens)

**Figure 4** Angled screen diversion system (courtesy US Filter)

## 2.2 Intake Selection/Assessment Process

To determine which intake alternatives have the greatest potential to minimize debris blockages and reduce potential impacts to marine life, numerous site-specific criteria should be considered (EPRI 2000). The relative advantages and disadvantages of each alternative can aid in screening the various options down to those with the greatest potential to meet performance and economic criteria. The best intake alternatives will meet the following general criteria:

- Alternatives should function under expected debris loading and hydraulic conditions in the source waterbody.
- Alternatives should provide effective protection from debris throughout the entire water column.
- Alternatives should be designed to minimize impingement and entrainment of marine organisms or improve the survival of those organisms impinged.
- Alternatives should not adversely impact sensitive benthic habitat (e.g., coral reefs).
- Alternatives should not adversely impact navigation.
- Alternatives should meet worker and public safety requirements.
- Alternatives should be compatible with recreational uses of the region.

After the intake alternatives have been screened according to the criteria listed above, the remaining options can be further limited according to the following criteria:

- The intake technology is available and does not require extensive engineering development.
- The intake technology has engineering and/or biological advantages over the other technologies evaluated.
- The technology has proven effectiveness for minimizing debris blockages and impacts to marine life.

Although the selection process is as objective as possible, it is also necessary to incorporate best professional judgment based on experience to determine how well a particular technology may perform at a given site. If engineering data exist in sufficient detail to develop a conceptual design and/or if the technology has been constructed at another site, it can be considered an available technology from an engineering perspective. If test data (preferably from a full-scale application) are available that document a technology's biological effectiveness with one or more of the species present at a given site (or similar species), it can be considered and available technology from a biological perspective. In addition, one technology may hold an advantage over another if the civil/structural requirements for its installation are substantially less.

There are a number of other site-specific engineering and biological details that can impact the intake technology selected for a given site. For instance, it is helpful to have good baseline *biological information* describing the species, sizes, distribution, seasonality, and density of marine organisms and algae that are present at the intake location. These details are useful in determining the optimal location, intake technology, screening mesh size, and operational schedule of the intake. Similarly, it is helpful to have good baseline *oceanographic information* describing the tidal ranges, tidal velocities, ambient currents, and wave characteristics.

## 2.3 Debris Management

After an intake technology has been installed, keeping it clean and operating as designed is necessary for obtaining a reliable supply of consistent quality seawater. While the protection of fish and other marine organisms constitutes a significant environmental and regulatory challenge to the operation of large seawater intakes in many countries, the management of debris constitutes the most significant operational challenge. Debris can be comprised of nearly any marine component including seagrasses and algae, leaves, trash, floating wood, sediment/sand, fish, jellyfish, crabs, and clams/mussels.

The management of debris at large industrial water intakes is a global challenge. Intake blockages can create significant safety- and reliability-related issues at nuclear and fossil-fuelled power plants. The industry typically addresses debris-related intake blockages either proactively before a problem arises or reactively after a blockage has occurred or through some combination of both. The approaches for minimizing/mitigating intake blockages can be broadly categorized into preventive and corrective actions. *Preventive actions* include developing best management practices (BMP), maintaining standard operating procedures (SOP), using early warning plans, and constructing an historical database of previous intake blockage events to analyze the conditions under which future events could be expected (EPRI 2009). *Corrective actions* include flow reductions, increased screen rotation, increased raking of trash rack, modification of screening device, use of a skimmer wall or debris boom, injection of heated water for ice, use of anti-biofouling coating on submerged intake components, divers for cleaning, and seasonal net deployment for reducing algae ingress (EPRI 2009).

As mentioned above, many facilities choose to address debris issues by modifying the intake; however, there are also newer technologies available that may provide protection against debris-related intake blockages. These technologies include debris deflector groins, porous dikes, floating barriers, barrier nets, trash racks with automated cleaning systems, travelling water screens with features that eliminate/reduce potential for debris carryover and increased debris removal efficiency, passive wedgewire screens with an integrated cleaning system (pressurized air backwash or mechanically brushed), and the use of water jets to displace debris (EPRI 2009).

## 3.0 Case Study – AES Gener Ventanas Generating Station

Alden Research Laboratory (Alden) completed an evaluation of debris-related issues associated with the cooling water intake system at AES Gener's Ventanas Generating Station (Ventanas). The following presents this evaluation as a brief case study on the alternative solutions to Ventanas' debris issues. This case study presents information relative to a power plant cooling water intake system. Flow rates for seawater intakes used at mining facilities are likely to be less, making other potential intake technologies viable.

Ventanas is a base-loaded, coal-fired power plant that uses a once-through cooling water system. The station is located in the north of Quintero Bay, 41 kilometers north of Valparaíso City and 160 kilometers from Santiago, Chile, as shown on Figure 5. The plant has two units producing an output of 340 MW.

Cooling water for Ventanas is withdrawn from Quintero Bay through two intake siphon pipes attached to a ship pier at the north end of the bay. The circulating water systems for each unit are independent with the sealed siphon pipes located on each side of the ship unloading dock. In each intake structure, cooling water is screened by trash racks, stationary screens, and travelling water screens. Unit 1 is designed to operate at ocean levels ranging from low water El. -2.18 m to high water El. 1.47 m. Unit 2 is designed to operate at ocean levels ranging from low water El. -2.69 m to high water El. 1.47 m.

Currents in the bay follow a clockwise circular pattern, entering the bay from the north and following the coastline to the south before turning north at the southeastern end. The water is discharged through separate discharge pipes back into the bay.

**Figure 5** Location of the Ventanas Generating Station (courtesy http://www.bing.com/maps/)

Ventanas has experienced significant debris issues in the past. Algal clogging problems on the intake structures' bar racks and travelling water screens and debris carryover to the condenser tube sheets were the focus of this study. Debris that carries over the screens allows dirty water to enter the spraywash pumps, service water pumps, and circulating water pumps. The strainers on the spraywash pumps clog with debris thus reducing the ability of the spraywash system to clean the travelling water screens. The circulating water pumps convey dirty unscreened water to the condensers which clog and reduce the performance of the condensers. In addition, excessive head loss across the travelling water screens reduces the operating water level for the pumps which may affect pump performance due to insufficient pump submergence.

At times, the accumulation of algae on the screens is so great that the differential pressure created a large gap between the screen mesh frame and the guide seal plates through which debris passed. In addition to the algal clogging, a site inspection revealed sediment deposition in the intake siphon pipes and intake structures; therefore, an evaluation was also done to alleviate this problem.

**Figure 6** Algae removed from the trash rack at Ventanas (courtesy Alden Research Laboratory)

The debris and sediment management alternatives were screened for applicability at Ventanas and options were identified to:

- Reduce algal loading at the siphon bell inlets
- Increase debris removal capacity at the bar racks
- Eliminate carryover at the travelling water screens
- Reduce condenser cleaning efforts

The options evaluated for the *siphon bell inlet* included the use of physical barriers to prevent the ingress of algae and other debris. Although some physical barriers have potential to reduce algal loadings on the intake screens, in the absence of performance data, physical barriers at the siphon bell inlets were not considered viable for Ventanas.

The options evaluated for the *bar racks* included new trash rakes, new stationary trash rakes for each screen bay, 25-mm spaced bar racks, and bar screens. A new bar rack and rake were chosen for further consideration.

The options evaluated for the *travelling water screens* were intended to eliminate the potential for carryover of algal debris (carryover was noted as the primary problem at Ventanas). The options were comprised of modifications to the existing screens and the installation of newer, state-of-the-art travelling water screens. The modifications that were considered for the existing screens included:

- Additional or new spraywash pumps with increased pressure
- Additional strainers for spraywash pumps
- Optimization of spraywash header angles to effectively clean screens and reduce carryover
- Additional back side spraywash headers and trough
- Increased screen rotation speeds (may require new screen drive unit)
- Replacement of screen wire mesh panels with molded polyurethane mesh with round, tapered holes to reduce debris stapling effect and aid in effective cleaning
- Screen control system

The options evaluated to reduce *sediment deposition* included: modifying the geometry of the bell inlets to reduce the relatively high intake velocities, installing a deflector wall to reduce the potential for shipping traffic to suspend sediment with “propeller wash”, installing spargers or high pressure water jets in the intake bays to keep sediments in suspension, modifying the intake bay geometry to eliminate low velocity areas where sediment builds up, and installing permanent dredgers and/or augers to remove sediment as it builds up.

### *Debris Management Recommendations*

While it was recommended that AES Gener make improvements to both the bar racks and the travelling water screens, Alden recommended that the primary initial focus be on replacing the existing travelling water screens with new screens that prevent carryover. Alden recommended Passavant Geiger MultiDisc screens (Figure 7) due to their proven performance, greater effective screening area, lower through-screen velocity, and lower clean screen head loss when compared to other travelling water screen designs.

Once the travelling water screens are replaced, Alden recommended making improvements to increase debris removal capacity at the bar racks upstream of the travelling water screens. Replacing the existing bar racks Passavant Geiger Revolving Chain Screens with 25-mm spaced bars would significantly increase debris removal capacity at both units.

Prior to implementing any sediment management strategies, Alden recommended that AES Gener conduct a detailed investigation to determine particle sizes for sediment accumulated in the intake bays, on the beach, and near the intake siphon bell mouths; the source of the suspended sediment; and the rate of sediment accumulation in the intake bays.

**Figure 7** Passavant Geiger MultiDsic travelling water screen (courtesy Alden Research Laboratory)

## REFERENCES

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