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Draft White Paper
Port of Corpus Christi
Intake Structures for Proposed Desalination Plants
LaQuinta and Harbor Island
December 11, 2018

1.0 Introduction

This white paper provides a detailed overview of the proposed intake structures intended for two desalination plants currently in the permitting process by the Port of Corpus Christi Authority of Nueces County (POCCA). POCCA is undergoing this effort to support the City of Corpus Christi in their effort to design and construct one or more desalination plants. If constructed, these plants would enhance the Cities ability to provide a sustainable water supply to the Region's water portfolio, which currently draws from fresh water surface water sources (Grimsbo, 2018). The proposed site locations are PCCA-owned properties located in La Quinta and on Harbor Island.

2.0 General Desalination Plant Configuration Details

A desalination plant essentially removes the salt and other components from seawater providing a very high purity water suitable for industrial or potable water purposes. The process used to remove the salts and other components is a multi-phase filtering process that ends with reverse osmosis. Reverse osmosis utilizes an ultra-fine membrane technology through which water is forced through membranes under high pressure. Reverse osmosis desalination is different than the more traditional Multi-Stage Flash Distillation in that the latter uses heat to evaporate water and leaves behind the salt, and is typically paired with a large water consuming plant with ample waste heat. The proposed desalination technology discussed by stakeholders for Corpus Christi and the PCCA permit applications is based on reverse osmosis. A good review of the reverse osmosis desalination process can be found at https://adventure.howstuffworks.com/survival/gear/reverse-osmosis-desalinators3.htm.

3.0 Intake Structures

A wide variety of intake structures have been utilized at desalination plants, power plants, and other facilities requiring large withdrawals from water sources across the world. Choices of intakes depend upon site conditions, typically focusing on the most cost effective solution that is reasonably protective of the environment. The choice of intake structure is a key component of a desalination plant design, since required intake flow is approximately three times the volume of the filtered water produced. This intake volume must be removed from its source in a safe, cost effective and reasonably environmentally friendly manner.

The primary issues related to designing an adequate intake structure are how the structure minimizes *impingement* and possibly *entrainment* impacts. *Impingement* occurs when organisms sufficiently large to avoid going through the screens are trapped against the screens by the force of the incoming source water. *Entrainment* occurs when marine organisms are drawn into the desalination plant intake and pass through the treatment facilities. These issues have been largely addressed by regulations covering cooling water intakes, which are found in Section 316(b) of the Clean Water Act (CWA). The intent of the Section 316(b) Rule when it comes to impingement is to ensure that the location, design, construction and capacity of the cooling water intake structure reflects the best technology available. The intent of the 316(b) Rule when it comes to entrainment to compare the cost to implement the best technology available, on a site-specific basis, vs the cost benefit of protecting the species at risk. It is important to note that these regulations do not apply to municipal desalination plants, but impingement protection is considered a best practice for large intake structures. It is likely that the state level permitting process will require some level of impingement protections. The EPA only considers requiring entrainment protection after a detailed study of the cost to implement the technology vs. the benefit, in dollars, of the species being protected. POCCA, on the grounds of stewardship, may voluntary attempt to provide entrainment protections. It is expected that an attempt to provide entrainment protection will have an order of magnitude effect on project execution cost.

The withdrawal of water removes billions of aquatic organisms from waters of the U.S. each year, including fish, fish larvae and eggs, crustaceans, shellfish, sea turtles, marine mammals, and many other forms of aquatic life. Most impacts are to early life stages of fish and shellfish. The quantity of water withdrawn is directly proportional to the number of organisms entrained or impinged.

Intakes in coastal waters, estuaries, and tidal rivers tend to have greater ecological impacts than those in freshwater lakes and offshore ocean intakes, since these areas are usually more biologically productive and have more aquatic organisms in early life stages.

Plants across the world have used a variety of structures and strategies to address these issues. The structures can be divided into two categories: *surface* and *subsurface.*

3.1 Surface Structures

3.1.1 Shoreline Intake: The most common intake structure is a shoreline intake. This approach is consistent with electric power generation plants for condenser cooling water where a bar screen prevents entry of larger objects and one or more traveling screens or mechanically cleaned bar screens remove progressively smaller objects. Typically, the screening chamber is located on or near shore. In other cases, intake pipe(s) may extend out a considerable distance into the sea.

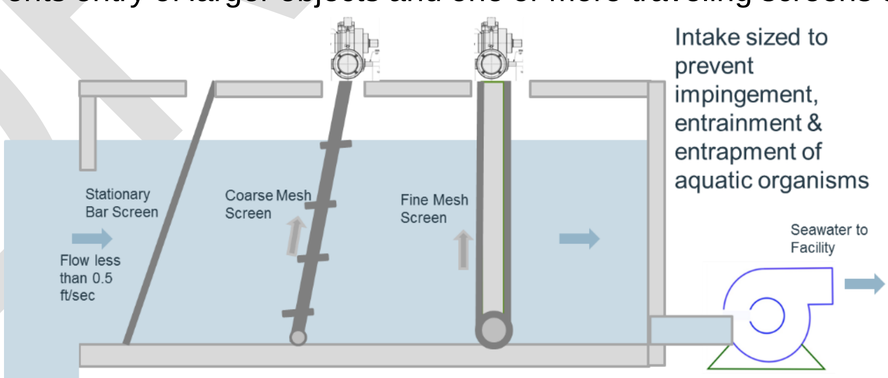


Figure 1: Typical Shoreline Intake

A variety of screens and nets have been utilized to support shoreline intakes (Pankratz, 2011). These are discussed below.

3.1.1.1 Traveling Water Screens: Traveling Water Screens are an industry standard for seawater intakes. The screens consist of revolving wire mesh panels with coarse or fine mesh depending upon the application. As the wire mesh panels revolve out of the water, a high-pressure water spray removes accumulated debris, washing it into a trough for disposal. The screens can be located within a channel (see **Figure 1** above) with access to deeper water or at the end of a pipe that extends out into the sea utilizing a Velocity Cap (described below).

3.1.1.2 Ristroph Screen: A Ristroph screen *(*See **Figure 2***)* is a modified traveling water screen. Panels are fitted with fish buckets and lift fish out of the water where they are gently sluiced away from the screen and back to the source waterbody prior to screen debris removal with a high pressure spray. Ristroph modifications have improved *impingement* survival 70-80% among various species. *Entrainment* is not improved.

Figure 2: Ristoph Screen Curtesy of Evoqua

3.1.1.3 Fine Mesh Screens: Final Mesh screens have successfully reduced *entrainment* of eggs, larvae, and juvenile fish. The fine mesh 0.5 mm to 2 mm is placed on traveling water screens, reducing entrainment by up to 80%, but without the benefit of survival. In order to improve survivability of eggs and larvae research has shown that through screen velocity must be kept at or below 0.5 fps and even that does not guarantee effective reduction in entrainment losses. Fine mesh screens may result in operational problems due to the high screen clogging rate from fine debris. Some applications have been seasonal applications during periods of egg and larval abundance.

3.1.1.4 Through-Screen Velocity: One of the most critical aspects for design of a surface intake is the speed at with water passes through the screens. For design of a new intake facility the best practice available is to size the intake structure so that water withdrawal rates can be achieved with through-screen velocities that are at or below 0.5 fps. Research indicates that when this velocity is achieved survivability for impingement and entrainment is highest. When through-screen velocity is 0.5 fps there is no need for additional impingement protection technologies (i.e. fish baskets and fish return system).

3.1.1.5 Filter Net Barriers: *Filter net barriers consist of* full-depth filter fabric with openings ranging from 0.4mm to 5mm placed around an intake structure. The barrier is suspended by a floating boom and anchored to the seabed. The surface area is sized for sufficient throughput of water to operate the plant and a flow velocity low enough to avoid *impingement* of marine life or debris. *Entrainment* is significantly minimized, since the filter net barrier flow through can be set up to be less than the current, allowing small marine life to be carried by the current past the intake. These types of barriers are often used seasonally, depending upon local conditions.

3.1.2 Off-Shore Intakes: Two common off-shore intake structures are velocity caps and passive screens.

3.1.2.1 Velocity Cap: A cover placed over the vertical suction pipe of an offshore intake is called a velocity cap (***Figure 3***). The cover converts vertical flow into horizontal flow at the intake entrance to reduce fish entrainment. Fish will avoid rapid changes in horizontal flow and velocity cap intakes have been shown to provide 50 to 60% reduction in fish *impingement,* depending upon location and species present (EPA 821-R-04-007, 2004).

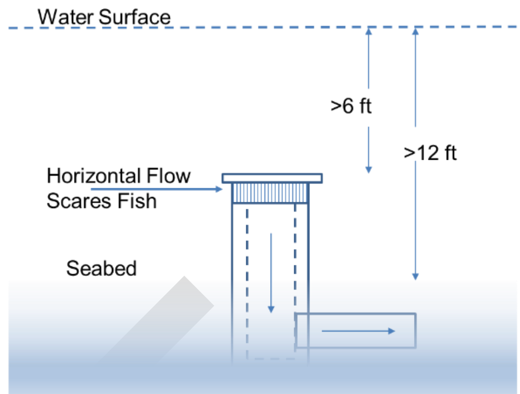


Figure 3: Velocity Cap

It has been shown that the relationship of the vertical opening to the length of horizontal entrance can be optimized to create a uniform flow and improve a fish's ability to react. As with all intake configurations, there are many design issues that must be considered, and the performance of a velocity cap may vary in still water versus areas subject to tidal cross-flows.

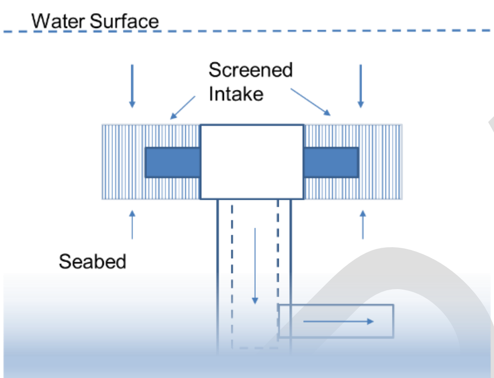


Figure 4: Wedgewire Screen

3.1.2.2 Passive Screens: Wedgewire screens (**Figure 4**) provide a screened intake at the source location, providing an advantage over velocity caps, in that this design prevents marine life from becoming *entrained* and *entrapped* in long piping systems. The screens are typically cylindrical in design with 0.5 millimeters (mm) to 10 mm mesh typically oriented horizontally. Screen mesh is project specific depending upon its protection standard. Surface area is based on maintaining a velocity through the mesh of less than 0.5 feet per second to minimize debris and marine life *impingement*. Passive screens are best-suited for areas where an ambient cross-flow current is present. An air backwash system on a timer clears the screens to prevent buildup of marine life and debris.

3.2 Subsurface Intakes

Seawater collected by subsurface intakes is naturally pretreated via slow filtration through the typically sandy ocean floor. As such, the collected flow usually contains low levels of solids, slit, oil & grease, natural organic contaminants, and aquatic organisms. These conditions essentially pre-treat the seawater, minimizing on shore pre-treatment.

When subsurface intakes collect water from an on-shore coastal aquifer, this water is often of lower salinity than ambient seawater. If a subsurface intake collects source water from an alluvial aquifer, however, such water could have very low oxygen concentration and could contain high level of manganese, iron, hydrogen sulfide, and other constituents that can have an adverse impact on desalination plant RO membrane performance, water production costs, and discharge water quality.

A variety of systems have been tested and/or utilized with varying degrees of success. These systems are summarized below.

3.2.1 *Vertical Wells:* Vertical beach wells have typically found an application for supplying source water to relatively small seawater desalination plants (1 MGD or less). A vertical beach well (***Figure 5***) consists a non-metallic casing, well screen, and vertical turbine pump. Site suitability is determined by drilling test wells and conducting a detailed hydrogeologic investigation to determine the formation transmissivity and substrate characteristics. It is preferred to locate beach wells as close to the coastline as possible. Maximum yield from individual wells range from 0.1 to 1.0 mgd.

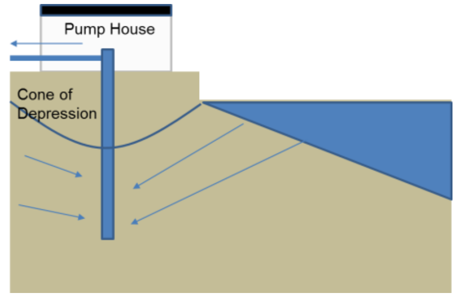


Figure 5: Vertical Beach Well

Experience with beach wells for seawater desalination in California and at the largest beach-well seawater desalination plant on the Pacific coast in Salina Cruz, Mexico indicate potential for elevated concentrations of manganese and/or iron in the intake water. This issue requires green sand pretreatment filters or UF membrane pretreatment system to protect the RO membranes, both of which are common RO pre-treatment steps. Open seawater intakes typically do not tend to have iron and manganese source water quality related problems.

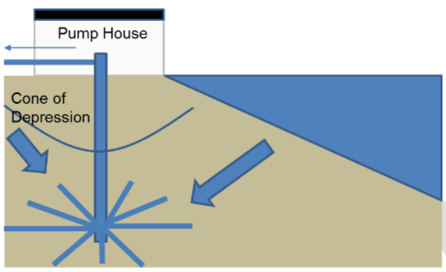


Figure 6: Ranney Type Collector

3.2.2 Horizontal Wells: Horizontal wells are more suitable for larger seawater desalination plants and are applied in two configurations: radial *Ranney-type collector wells* (**Figure 6**) and horizontal wells with *Directionally drilled (HDD) collectors* (**Figure 7**), such as those developed and installed by Neodren (http://www.catalanadeperforacions.com/en/neodren). These types of wells, in particular HDD collectors, have already found full-scale applications worldwide. According to literature published by IntakeWorks, a license provider for Neodren, the technology has been used as the intake system for five desalination plants in Spain with intakes ranging in size from 1.8 to 21.9 mgd.

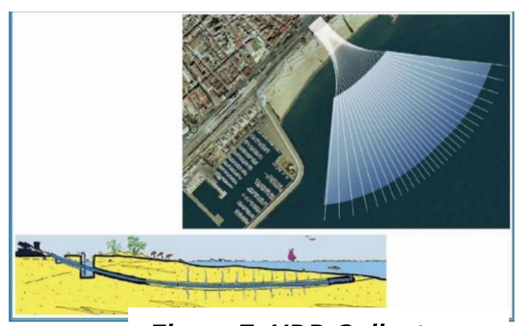


Figure 7: HDD Collectors Curtesy of Neodren

The 34 mgd San Pedro Del Pinatar (Cartagena) plant in Spain is the largest seawater desalination plant in the world today utilizing subsurface intakes (HDD wells). While the HDD wells have performed adequately for the initial 17 mgd project phase, site specific hydrogeological constraints have limited their use for the plant expansion to 34 MGD, and a new 17 mgd open water intake system was ultimately constructed to provide the necessary flow.

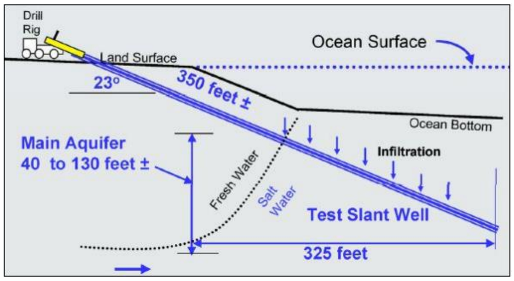


Figure 8: Slant Well Curtesy of Geoscience

Slant wells use vertical well drilling technology to install inclined source water collectors under the ocean floor (**Figure 8**). Geoscience (https://gssiwater.com) is a leader in this approach. An intake is currently under development for Municipal Water District of Orange County (MWDOC) in Dana Point, California. The pilot well was installed in 2006 and successfully removed 3 mgd for 2 years. Reports indicate a significant reduction in performance over time. The technology is now being scaled up with the hope of a 30 mgd feed water supply from seven 800 ft wells and 2 standby wells.

Subsurface infiltration gallery intake systems (also known as under-ocean floor seawater intakes or seabed infiltration systems) consist of a series of man-made submerged slow sand media filtration beds located at the bottom of the ocean in the near-shore surf zone (**Figure 9**). As such, seabed filter beds are sized and configured using the same design criteria as slow sand filters. Currently, such intake system is undergoing long-term testing by the Long Beach Water Department in California.

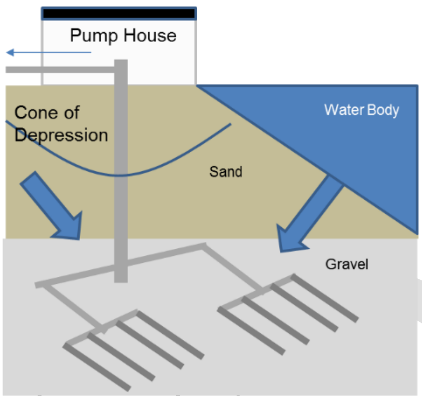


Figure 9: Subsurface Infiltration Gallery

At present, the largest seawater desalination plant in the world using an infiltration gallery type of subsurface intake is located in Fukuoka, Japan. The plant has capacity of 13.2 MGD, and has been in operation since 2006. This plant pretreats the source seawater collected by the infiltration gallery using ultrafiltration (UF) membranes, primarily for metals removal.

4.0 Proposed Approach

The two planned desalination plants require approximately 100 to 150 mgd of seawater. The intake structures ultimately chosen for the two facilities must meet a basic criteria of delivering the required flow and water quality necessary for efficient and sustainable operation.

As discussed above, POCCA intends to permit desalination plants in two locations, Harbor Island and LaQuinta. Each location is unique and will require an intake strategy suitable to its location.

4.1 Harbor Island Approach: The intake strategy for a 150 mgd *surface* intake at Harbor Island is relatively straightforward. Adequate shore line in an area that can be dredged and maintained is available in an area immediately north of the Ferry landing. The approach would consist of a shoreline intake structure similar to **Figure 1** consisting of three intakes, each 10 ft wide and 40 ft deep, and is based on using a screen mesh of

¼-in by ¼-in with 64% open area. The dredged area would open up to naturally deep water with a consistent tidal current.

As shown in **Figure 10**, the intake design would limit inlet velocities to 0.3 ft/s, well below the recommended 0.5 ft/sec limit required by the 316(b) regulations. Modeling of the intake demonstrates inlet flow rates decrease to 0.05 ft/sec at a distance of 30 ft from the intake bar screened entrance, and 0.01 ft/sec 200 ft from the intake bar screen.

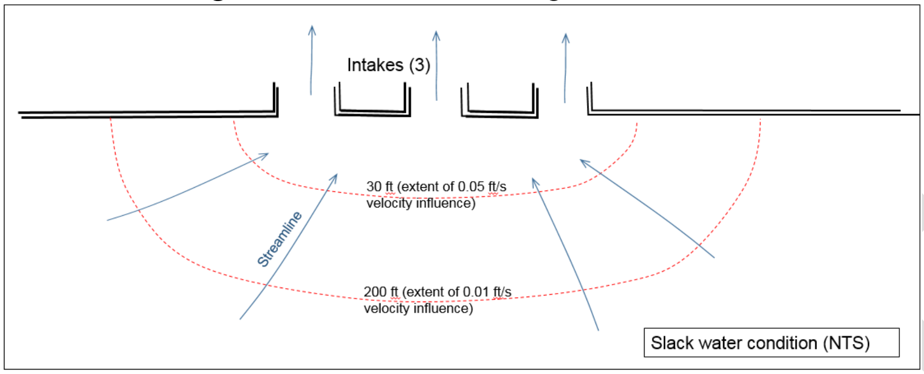


Figure 10: Velocity Gradients toward Intake Structure

Cooling water intake structures with flows greater than 125 mgd are also required to provide *entrainment* reduction or protection per the 316(b) rule. If this requirement was considered in the Harbor Island design, *entrainment* could potentially be mitigated using several approaches.

Based on a surface water intake scenario, options are limited to use of a filter net barrier. Based on the rapid flow typical of the Corpus Christi Channel, a barrier approximately 30 ft from the intake would be within a velocity range toward the intake of 0.05 ft/sec, well below the observed velocities of +3 ft (ebb tide) and -3 ft/sec (flood tide), and modeled tidal peak velocities of +5.5 ft/s (ebb tide) and -4 ft/s (flood tide). Therefore, it is not expected that *impingement* of small marine life on the barrier would be a significant issue. However, mortality would likely be high for marine species that would come into contact with the barrier, and maintenance and sustainability of the barrier would be a significant issue. The filter net barrier mesh size would be determined through study of marine species in the area. It is likely that its use would be seasonal, however this consideration would be based on year around evaluation of marine species in the Corpus Christi Channel.

Subsurface intake concepts were evaluated as an alternative to the surface intake. Based on its location within busy shipping lanes, and planned use for surrounding land, the most promising option is an intake collector system off shore as shown in **Figure 7** using HDD technology.

Sources of available data were reviewed to better understand local seabed soil quality. In general, bottom soil consisting primarily of sand is optimal. The off shore grain size distribution is best represented by the ***Entrance*** data from **Table 1** below (USACE, 2017).

Location	Physical Parameter				
	% Gravel	% Sand	% Silt	% Clay	D50 (mm)
Entrance	0.0	56.6	25.1	19.2	0.251
Inner Basin to La Quinta	0.0	80.5	11.7	9.1	0.201
La Quinta to BCN 82	0.0	6.9	45.7	47.4	0.014
BCN 82 to Viola TB (Inner Harbor)	0.0	27.2	35.3	37.5	0.046
La Quinta	0.0	25.3	54.9	19.8	0.036
Rincon	0.0	53.2	26.3	20.6	0.254
Maintenance ODMDS*	0.3	98.1	0.5	1.4	--
New Work ODMDS*	0.0	51.5	30.8	17.0	--
Reference Area*	0.0	50.7	26.7	21.2	--
CEWSG long term averages from 1977 to 2016					
* EPA 2015 monitoring data					

Table 1: Grain Size Analysis from Dredge Material

Based on this data, it appears that the local Gulf bottom sediments have high concentrations of silts and clays. If this data is consistent for the Gulf in the vicinity of the Aransas Inlet, use of the seabed soils for infiltration would be challenging. Since such an intake would need to produce ten times the volume of water of the largest system currently in use, it is expected that such a system would not be economically viable. Further challenges include the -75 ft dredge planned for the Harbor Island area and the 2 mile pipeline required to access the Gulf.

Due to these constraints and the availability of a viable *surface* intake concept, it appears a sub*surface* intake would be cost prohibitive, and would be very challenging to construct.

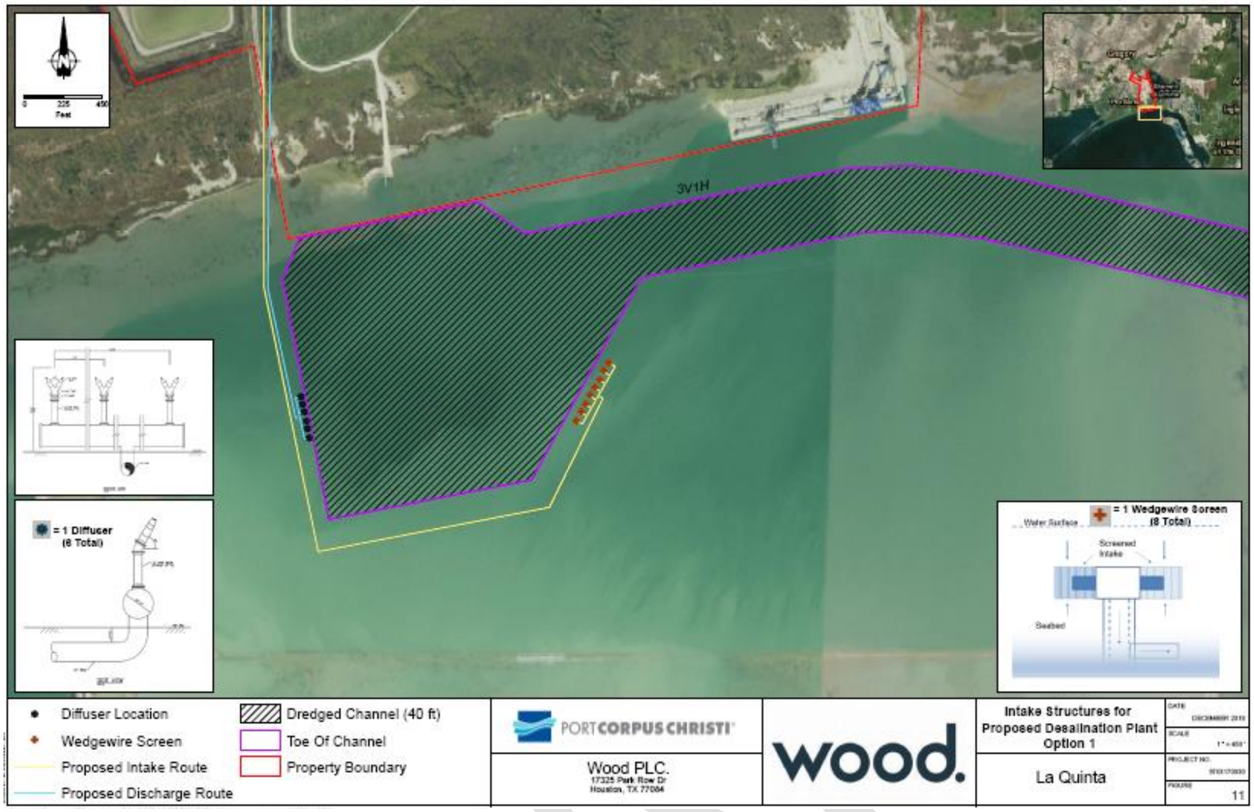
4.2 LaQuinta Approach: The intake strategy for the 100 mgd LaQuinta site is constrained by very limited shore line availability. Therefore, the approach described for Harbor Island is not available.

The LaQuinta site opens up to the San Patricio Turning Basin, an area approximately 1000 ft long and 1500 ft wide dredged to approximately 40 ft. The initial *surface* intake concept places the intake and discharge diffuser at opposite ends of the Turning Basin, on the upslope and at the furthest point from the shore based marine berth and the associated Navigation Channel (See **Figure 11**).

A hydrodynamic model was utilized to evaluate this scenario for potential recycle of higher salinity water resulting from a buildup of salinity from the discharge diffuser. This model indicated an approximately 5 ppt buildup, which is an undesirable scenario, effectively eliminating this area from consideration (Wood, 2018).

Based on this finding, we again looked for open water that may be available for a surface intake system. One concept that has promise would be to place a shallow intake system in approximately 10 ft of water immediately south of the barrier island known as Beneficial Use Area No. 6 (See **Figure 12**).

The two technologies designed for such an installation are Wedgewire screens and velocity caps. Although both are viable options, the Wedgewire screen appears to be the most viable option since it also prevents *entrapment* of marine life within the intake piping.


3V1H
= 1 Diffuser (8 Total)
= 1 Wedgewire Screen (8 Total)
Water Surface
Screened Intake
Seabed
Diffuser Location
Wedgewire Screen
Proposed Intake Route
Proposed Discharge Route
Dredged Channel (40 ft)
Toe Of Channel
Property Boundary
PORTCORPUSCHRISTI
Wood PLC.
17325 Park Row Dr
Houston, TX 77084
wood.
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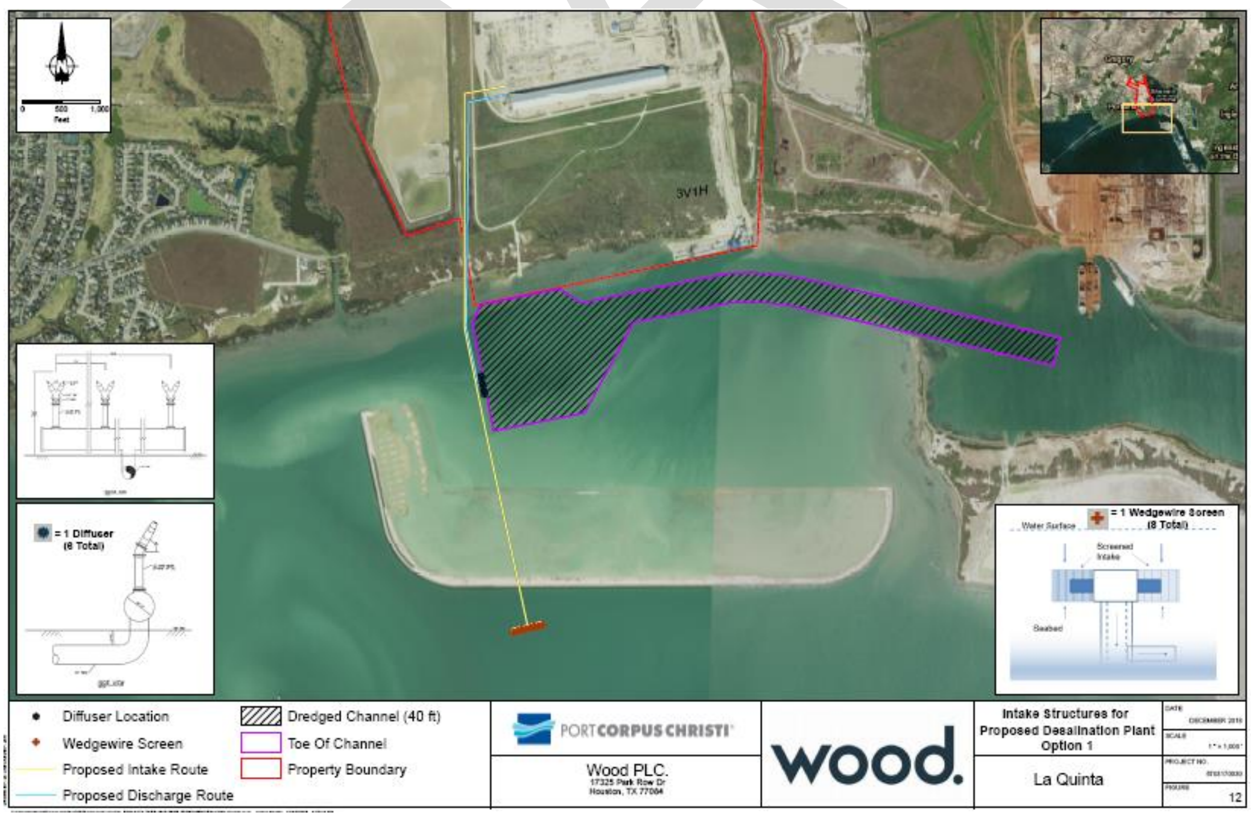
3V1H
= 1 Diffuser (8 Total)
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Water Surface
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Seabed
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Dredged Channel (40 ft)
Toe Of Channel
Property Boundary
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wood.
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Wedgewire screens are designed to be placed in a water body where prevailing ambient cross flow current velocities (≥ 1 ft/sec) exist. This high cross-flow velocity allows organisms that would otherwise be *impinged* on the Wedgewire screen intake to be carried away with the flow.

An integral part of a typical Wedgewire screen system is an air burst back-flush system, which directs a charge of compressed air to each screen unit to blow-off debris back into the water body, where they are carried away from the screen unit by the ambient cross-flow currents.

Based on the 100 mgd intake flow required for the desalination plant, preliminary calculations indicated a series of four intake pipes would be required each with 25 ft of two 24-in diameter screen based on the ¼-in by ¼-in screen size. Appropriately sized screens would not only address *impingement*, but would also minimize *entrainment* of smaller marine species. Any smaller species buildup on the screen would be freed periodically through use of the above mentioned air burst system. However, similar to the Harbor Island scenario described above, mortality of smaller species that come in contact with the screen would likely be high.

Subsurface intake systems were reviewed for viability. We again looked for open water that may be available for an infiltration system. One concept that has promise would be an HDD based infiltration system in the area discussed above, south of Beneficial Use Area No. 6. As discussed above, such a system would be five times the size of the largest system currently in use. The data in **Table 1** was again consulted (See ***LaQuinta*** line item) to evaluate whether the area identified would have a desirable high sand content.

Similar to the Harbor Island findings, the area in the vicinity of ***LaQuinta*** is high in silts and clays, making such a concept very challenging. However, the open water is within a half mile, and a viable pipeline route is available around the west side of the Turning Basin. Therefore, it would be prudent to collect sediment samples in the area south of the barrier island to evaluate suitability for such a system.

5.0 Permitting

Permits necessary for the intake construction and operation include:

- TCEQ Water Rights Permits (Texas Water Code Chapters 5, 11, and 12) for withdrawal of surface water for any purpose.
- U.S. Army Corp of Engineers (COE) Section 404 Standard Permit, Section 10 of the Rivers and Harbors Act of 1899 for structures in water of the United States.

PCCA and Wood began meeting with the Texas Parks & Wildlife Department (TPWD) and other stakeholders to discuss the permit applications. Planning for the final location of and correct type of intake structure was initiated in June with the approval of the contract with Wood by the Port Commission. Wood is explicitly tasked with identifying design alternative(s) that will avoid significant impacts to bay flora, fauna, and habitats. This process is ongoing and will conclude with the development of the water rights permit application and the information necessary to start the COE permit application process.

Given the potential concerns with the intake structure development, PCCA and Wood have held meetings with TPWD, University of Texas Marine Science Institute, and the

Coastal Bend Bays & Estuaries Program and are currently coordinating meetings with others such as the Harte Research Institute, Coastal Conservation Association, and Saltwater-Fisheries Enhancement Association. The intent of these meetings is to get input in the design of the intake structure prior to developing the permit applications. The Port is committed to incorporating the best available science from the local research community into the planning and design of this facility.

Some additional considerations for mitigation measures include preventative measures for red tide occurrences caused by red algal blooms. Red tide outbreaks in the bay system could create potential health exposure issues if drawn in through the intake structure. This is typically mitigated operationally through shut down of the plant during red tide outbreaks.

6.0 Next Steps

PCCA and Wood will also continue to reach out to stakeholders to identify the concerns related to the intake structure and obtain available research and studies. This information will inform the development of the proposed intake structures and subsequent water rights permit application to the TCEQ. The coordination with stakeholders on the intake structures for both La Quinta and Harbor Island is expected to continue through mid-December with final development of the draft permit applications shortly thereafter. As before with the discharge permits, the draft permit applications will be reviewed with key stakeholders prior to submittal to the TCEQ.

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