PROPOSED HARBOR ISLAND SEAWATER REVERSE OSMOSIS DESALINATION FACILITY

A Prospective Evaluation of Ecotoxicological Risk

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ACRONYMS AND ABBREVIATIONS

POCC	Port of Corpus Christi Authority of Nueces County
TCEQ	Texas Commission on Environmental Quality
MGD	Million gallons per day
ppt	Parts per thousand
CCSC	Corpus Christi Shipping Channel
ERA	Ecological Risk Assessment
COPEC(s)	Contaminant(s) of potential ecological concern
SWRO	Saltwater reverse osmosis
NaOCl	Sodium hypochlorite
UF	Ultrafiltration
RO	Reverse osmosis
BFP	Belt filter press
US	United States
USEPA	US Environmental Protection Agency
ERAGs	Environmental Risk Assessment Guidance
GoM	Gulf of Mexico
MAE	Mission-Aransas Estuary
NRE	Nueces River Estuary
ELS	Early life stage
SAV	Submerged aquatic vegetation
USFWS	US Fish & Wildlife Service
TPWD	Texas Parks & wildlife Department
T&E	Threatened & Endangered
CSM	Conceptual Site Model
TDI	Total Daily Intake
NOM	Natural organic matter
THM	Trihalomethane
ESV	Ecological screening value
PAHs	Polycyclic aromatic hydrocarbons
MAL	Maximum allowable level
EMAP	Environmental Monitoring and Assessment Program
PCBs	Polychlorinated biphenyls
OC	Organochlorine
DDT	Dichloro-diphenyl-trichloroethane
$tPAH_{38}$	Sum concentration of 38 measured PAHs
$tPAH_{50}$	Sum concentration of 50 measured PAHs
EE2	17 α-ethinylestradiol
µg/kg	Micrograms of constituent per kilogram of sediment or tissue
mg/kg	Milligrams of constituent per kilogram of sediment or tissue
mg/L	Milligrams of constituent per liter of water
µg/L	Micrograms of constituent per liter of water
dw	Dry weight
WHO	World Health Organization
LC_{50}	Concentration that is lethal to 50% of organisms
UV	Ultraviolet
ROS	Reactive oxygen species
TRV	Toxicity reference value
NPDES	National Pollutant Discharge Elimination System

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NOEC	No Observed Effect Concentration
LOEC	Lowest Observed Effect Concentration
NOAEL	No Observed Adverse Effect Level
LOAEL	Lowest Observed Adverse Effect Level
IUCN	International Union for Conservation of Nature
DO	Dissolved oxygen
WET	Whole effluent toxicity

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INTRODUCTION

In 2018, the Port of Corpus Christi Authority of Nueces County (POCC) submitted an Industrial Wastewater Permit Application to the Texas Commission on Environmental Quality (TCEQ), which outlines proposed plans to construct a seawater desalination plant capable of generating up to 50 million gallons of potable water per day (MGD) at the former Atofina and Exxon Tank Terminal site on Harbor Island.[1, 2]

In order to operate at full capacity, models indicate that the offshore intake will need to draw in 150.7 million gallons of raw seawater (with an expected salinity range of 32 – 35 parts per thousand [ppt]) each day, approximately 33.2% (equivalent to 50 MGD) of which will be converted to potable water. The vast majority of the unusable fraction of intake water (approximately 63.4% of the total volume of intake water or the equivalent of 95.5 MGD) will be discharged into the Corpus Christi Shipping Channel (CCSC) daily via a multi-port diffuser. Effluent from the facility (i.e., a mixture of membrane reject and water mechanically extracted from sludge) will contain nearly all of the dissolved and suspended constituents present in raw intake media, including chemical toxicants present as source pollution and additional chemicals added as part of the desalination process.[3] The remaining 3.4% of the daily intake water volume (equivalent to 5.1 MGD) will enter a nearby landfill as solid sludge.[1, 2]

Due to the high productivity and ecological value of the habitat in proximity to the site of the proposed facility, it is imperative that all potential ecological risks be thoroughly evaluated prior to project approval and initiation. The potential risks associated with impingement, entrapment and entrainment of aquatic biota (at the seawater intake site), altered hydrodynamics, changes in the transport and settling of larval fishes, and increasing salinity in the CCSC have been evaluated elsewhere. Therefore, the goal of the present report is to prospectively evaluate the potential ecotoxicological risks associated with discharge of effluent from the proposed facility to the CCSC and surrounding habitat.

FRAMEWORK FOR EVALUATING ECOLOGICAL RISK

Standard Ecological Risk Assessment (ERA) practice includes Exposure Assessment, Effects Assessment, and Risk Characterization components. The exposure assessment involves the selection of assessment endpoints, as well as estimating or measuring the cumulative exposure to a given contaminant from all potential sources (e.g., diet, absorption, inhalation). During the Effects Assessment stage, the toxicity values most appropriate for the chemical and receptor combination being evaluated (i.e., intake-based values versus media-based benchmark values), that will be used in the risk characterization step are determined. The Risk Characterization step culminates in a risk estimate that predicts the potential for ecological receptors to be adversely impacted by contaminant exposure and identifies remaining sources of uncertainty that are likely to contribute to overall risk, albeit to an unknown extent.

Generally, ERAs are conducted when a release has already occurred (i.e., site-specific quantitative data can be collected and used to characterize the type and extent of contamination). However, it is possible to prospectively evaluate the potential adverse impacts of an anthropogenic disturbance (e.g., construction of a facility that discharges effluent to the environment) using available surrogate data. As the present report describes potential risk associated with a proposed development project, certain components rely upon previously published datasets and information collected at operational saltwater reverse osmosis (SWRO) desalination facilities (e.g., identification of contaminants of potential ecological concern [COPECs]) and are more qualitative in nature.

For the exposure assessment component of the present report, a combination of peer-reviewed scientific journal articles, reports from various government agencies, technical reports and permitting documents were used to derive a range of surrogate exposure concentrations that could reasonably be expected to occur in environmental media near the outfall. In accordance with standard practice, effect concentrations and toxicity benchmarks for COPECs were also retrieved from various laboratory studies and guidance/regulatory documents where available. It is important to note that Environmental Risk Assessment Guidance documents (ERAGs) published by the United States Environmental Protection Agency (USEPA) state that COPECs should not be "screened out" as potential drivers of risk based on a lack of published effect concentrations/toxicity benchmarks.[4, 5] Rather, the potential ecotoxicological effects associated with such COPECs should be evaluated to the extent possible and included in the Uncertainty Assessment portion of the ERA.[4, 5]

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Moreover, it is well established that exposure to environmental co-stressors (both physical and chemical) play an important role in determining toxic outcomes for ecological receptors exposed to COPECs. Thus, local physical and chemical parameters that can be reasonably expected to exacerbate potential ecological risk will also be discussed as part of Risk Characterization. Similarly, an evaluation of biological parameters (i.e., habitat value, protected status and susceptibility of receptors) that are likely to drive ecological risk associated with the proposed facility is also included, as is standard practice for ERAs.[4-9] The present evaluation concludes with a discussion of sources of uncertainty (which is inherent in every ERA to some extent) that complicate the process of confidently predicting risk at this site, as well as overarching conclusions and recommendations based on the findings described herein.

PROBLEM FORMULATION

Overview of Facility

The design of the proposed facility includes an offshore intake that pumps seawater through course screens to remove large solids. [1, 2] The permit application submitted to TCEQ also states that intake screens would need to be cleared of marine growth using sodium hypochlorite (NaOCl) as needed.[1] From the intake, seawater would move to a mixing unit for the addition of "one or more treatment chemicals," prior to being routed to the clarifier center. [1, 2] A chemical flocculent will be added at this stage, followed by a settling stage to remove suspended solids. [1, 2] Settled solids removed during clarification will eventually be sent to the sludge thickener, while clarified seawater is directed to the Settled Water Clearwell where an oxidizing chemical (NaOCl) is added. [1, 2] From there, seawater will be routed through a strainer where additional NaOCl can be added, and additional solids and debris are removed. [1, 2] Solids removed at this step will also be backwashed to the sludge thickener, while water enters the ultrafiltration (UF) step. During UF, high pressure is used to push water through membranes that remove all particles with a diameter > 0.001 micrometer (μm). [1, 2] Backwashing of membranes (i.e., cleaning mode) must occur relatively frequently, yielding membrane reject that is ultimately sent to the sludge thickener. The desirable permeate water produced during UF is then subject to another round of oxidation by NaOCl, after which, water is pumped through cartridge filters before entering reverse osmosis (RO) units. Particles larger than 0.1 nanometers (nm) will be removed by RO membranes, which will also require a backwashing step that generates a hypersaline brine membrane reject. RO water retained for distribution is highly corrosive due to the repeated addition of NaOCl during the desalination processes. Therefore, the pH of RO water is modified via calcite filtration, prior to chlorination and subsequent distribution as potable water.

Meanwhile, brine (generated during the RO process), solids and sludge (generated as part of the clarification and straining processes) pass into a tank for the addition of chemical coagulants before passing into a sludge thickener where a chemical flocculent facilitates separation of solids from the water. At this stage, the supernatant overflow (i.e., the remaining water portion chemically separated from the sludge) will run into the Outfall Storage Tank, while the solid portion of the sludge from the thickener passes into the belt filter press (BFP). Using a combination of gravity-assisted techniques and mechanical pressing, the BFP extracts and collects water that may be remaining in the sludge in a process known as "dewatering." At this stage, solids remaining in the sludge will be taken to a landfill, and the water will run into the Outflow Storage Tank with the supernatant overflow, and subsequently discharged through an HDPE pipeline to a multi-port diffuser located on the South side of Harbor Island in the CCSC, approximately 300 ft off shore (Figure 1).[1, 2] From the initial point of discharge, tidal influences would then determine whether the effluent flows through Aransas Pass and into the Gulf of Mexico (GoM), or through the CCSC into adjacent bays.[1]

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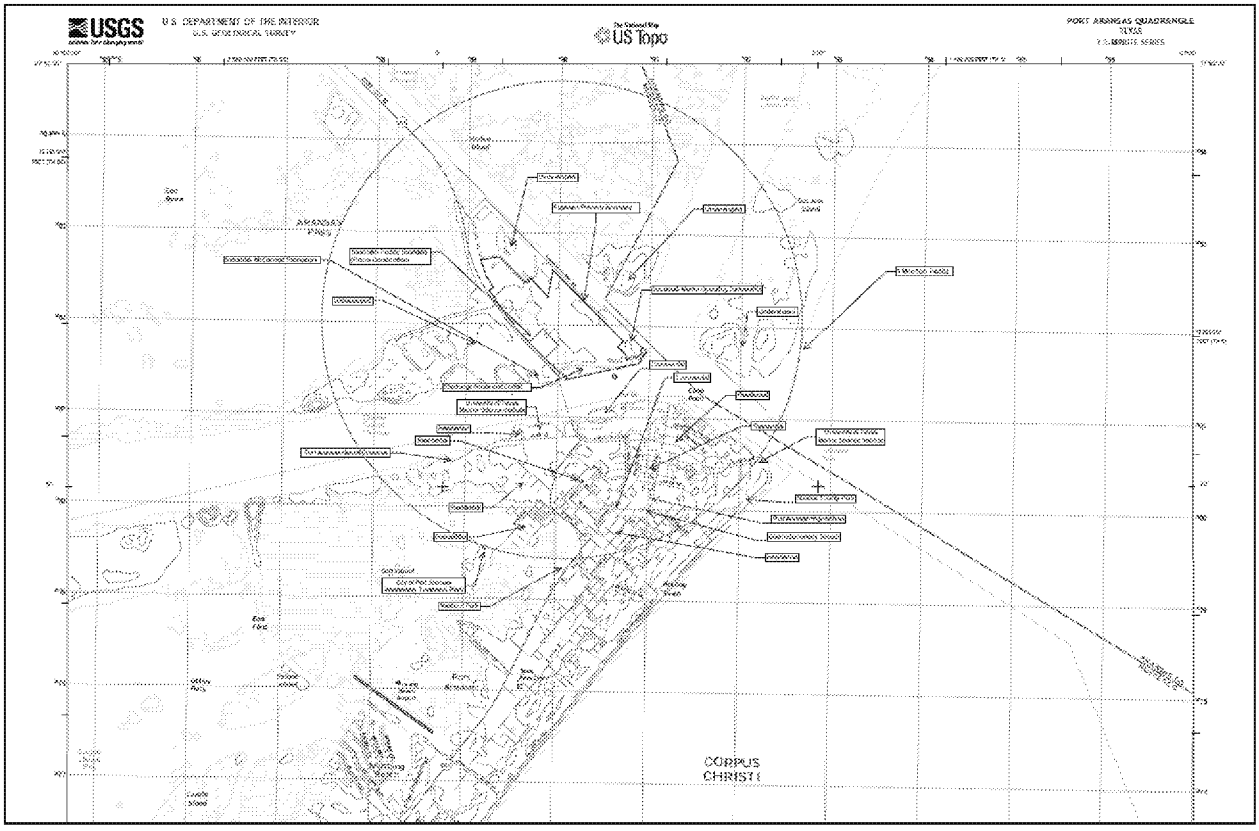

Figure 1. USGS Topographic map (http://eros.usgs.gov/) with facility boundaries indicated in red. The green circle represents a 1-mile radius extending from the proposed project site (i.e., immediate vicinity), as required by TCEQ's permit application.[1]

Site Description

Geography, Hydrology & Climate

Harbor Island is a flood-tidal delta located near the mouth of Aransas Pass, which serves as the only major unobstructed pass between the Mission-Aransas and Nueces River estuaries and the GoM.[10] As such, it is the sole site of water exchange and physical mixing between oceanic waters of the GoM and enclosed estuaries and bays that receive freshwater inflows from the Nueces, Aransas and Mission Rivers and their surrounding coastal basins.[10-13] The Mission-Aransas Estuary (MAE) and Nueces River Estuary (NRE) are both shallow bay systems (mean low water levels range from 0.6 to 3 meters) that are characterized by remarkably low rates of water exchange, with a water turnover cycle of approximately one year.[10] When combined with high average temperatures that facilitate evaporation and a lack of precipitation in the region (outside of major seasonal storm events), these low rates of water exchange/turnover result in gross annual evaporation rates that exceed combined contributions from precipitation and freshwater inflow.[10, 14-16]

Frequent periods of drought, other climate change related factors, and increasing diversion of freshwater inflows due to coastal development also hinder the maintenance of water levels within the MAE and NRE.[10, 16] Additionally, estuarine water quality is being impacted by increasing coastal development, as local military installations, industrial facilities, agriculture and urban centers act as sources of contamination via multiple processes (e.g., air emissions, runoff, discharge of effluents).[10, 11, 13, 15, 17, 18] These issues are of significance, as the climactic and geographic conditions of this bay complex facilitate the accumulation of environmental contaminants released to estuaries, in addition to contributing to hypersaline conditions and predisposing the water column to temperature fluctuations (either of which can cause stratification and hypoxic/anoxic conditions).[14, 19]

Ecology of the Site & Adjacent Habitat

The CCSC and adjacent estuarine and near shore habitats represent highly productive ecosystems that confer an array of ecosystem services to humans (e.g., fisheries, water filtration and detoxification, coastal resiliency and erosion prevention, tourism, recreation), act as essential nursery grounds for early life stage (ELS) aquatic biota, and support complex food webs.[14, 15, 20, 21] A brief overview of the area's ecology is provided below, organized by receptor type.

Aquatic & Emergent Plants

Estuarine emergent wetlands (i.e., salt marshes) are located near freshwater inflows, bays, lagoons, and protected coastlines in the area.[10, 12, 22] Saltwater wetland habitats are also found along much of the area's coastline, with particularly high coverage near Harbor Island (Figure 2).[10] These wetlands are dominated by various grass species, including smooth cordgrass *(Spartina alterniflora)*, turtleweed *(Batis maritima),* dwarf glasswort *(Salicornia bigelovii),* perennial glasswort *(Salicornia perennis),* Gulf cordgrass *(Spartina spartinae),* and saltgrass *(Distichlis spicata)*, which zonate according to salinity.[10]

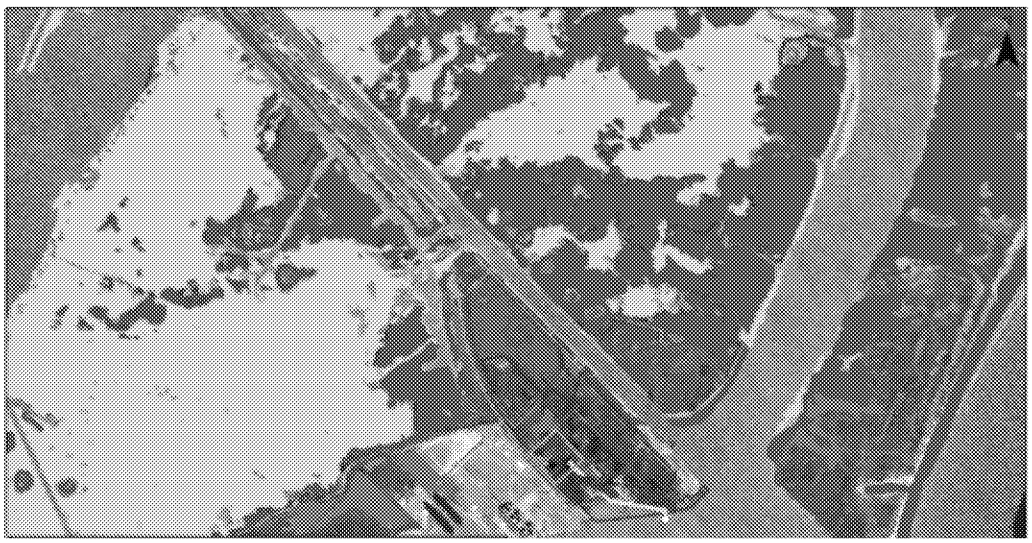

Figure 2. Bright green shading represents local seagrass cover at/near the proposed facility (boundaries in red), while dark green represents estuarine and/or marine wetlands (source: Port Aransas Conservancy, 2019)

Black mangroves (*Avicennia germinans*) have also become established on Harbor Island in recent years, where they provide approximately 600 hectares of highly diverse and productive habitat.[10, 23] Mangroves provide a number of important ecosystem services, including protection against coastal erosion and maintenance of biogeochemical cycles and water quality.[21] Moreover, mangroves act as essential nursery and feeding grounds for a number of native species, including several that are managed and/or protected (Table 1).[10, 23]

Similarly, beds of submerged aquatic vegetation (SAV) constitute critical nursery habitat in the shallow sub-tidal areas around Harbor Island.[10, 24, 25] SAV beds contribute large amounts of organic biomass to coastal food webs, prevent coastal erosion/sedimentation, facilitate biogeochemical cycling and help maintain water quality.[12, 16, 24] Species of SAV native to the Coastal Bend area include widgeon grass *(Ruppia maritima)*, turtle grass *(Thalassia testudinum),* clovergrass *(Halophila engelmannii),* manatee grass *(Syringodium filiformis)* and shoal grass (*Halodule wrightii*) as the most abundant species.[24]

Aquatic Invertebrates

The most abundant invertebrate species within the local saltwater wetlands include the polychaetes *Mediomastus californiensis* and *Streblospio benedicti*.[10] The polychaete species *Paraprionospio pinnata*, *Glycinde solitaria* and *Paraprionospio pinnata* represent the dominate invertebrate within the local bays. Common shellfish include *Macoma mitchelli*, *Mulinia lateralis*, and *Lepidactylus sp.* [10] Common herbivorous invertebrates in the area include the ribbed mussel *(Geukensia demissa),* salt marsh periwinkle (*Littorina irrotata),* blue crab *(Callinectes sapidus),* and fiddler crabs *(Uca pugnax).*[10, 26-30] Each of the aforementioned invertebrate species serve as an important food source for higher level trophic organisms living in nearby coastal habitats.

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Table 1. Threatened (T) and Endangered (E) species that may occupy aquatic habitats in proximity to the proposed facility. Receptors of potential concern for the proposed Harbor Island desalination facility are identified by **bold text.**

Receptor Type	Common Name	Species Name	USFWS	TPWD	Feeding Guild	Local Habitat	Migration Habits
Fish	Opossum pipefish	*Microphis brachyurus*		T	O	Estuaries	R
Amphibians	Black-spotted newt	*Notophthalmus meridionalis*		T	Inv	Coastal wetlands near freshwater inflow	R
Reptiles	Loggerhead sea turtle	*Caretta caretta*	T	T	C	Coastal lagoons, nearshore waters, coastal beaches	P/M
	Hawksbill sea turtle	*Eretmochelys imbricata*	E	E	Inv	Coastal channel jetties, nearshore & open waters	R
	Green sea turtle	*Chelonia mydas*	T	T	O	Coastal channels, estuaries, lagoons, nearshore waters	R
	Kemp's Ridley sea turtle	*Lepidochelys kempii*	E	E	Pis/Inv	Estuaries, near shore waters, coastal beaches	R
	Leatherback sea turtle	*Dermochelys coriacea*	E	E	Inv	Open ocean, coastal beaches	M
Mammals	Atlantic spotted dolphin	*Stenella frontalis*		T	Pis	Pelagic	--
	Rough-toothed dolphin	*Steno bredanensis*		T	Pis	Pelagic	--
	West Indian manatee	*Trichechus manatus*	E	E	H	Seagrass beds	M
Birds	**Piping Plover**	*Charadrius melodus*	E	T	Inv	Coastal beaches, sea grass beds, spoil islands	M
	American Yellow-tailed Kite	*Elanoides forficatus*		T	C/Inv	Coastal woodlands, wetlands	M
	Least Tern	*Sterna antillarum*	E	E	Pis	Estuaries, coastal beaches	M
	Whooping Crane	*Grus americana*	E	E	Pis/Inv	Estuaries, coastal wetlands	M
	Sooty Tern	*Sterna fuscata*		T	Pis	Estuaries, near shore waters, spoil islands	R/M
	Reddish Egret	*Egretta rufescens*		T	Pis	Estuaries, sea grass beds, spoil islands	R
	White-faced Ibis	*Plegadis chihi*		T	Inv/Pis	Low salinity/freshwater wetlands	R/M
	Texas Botteri's Sparrow	*Aimophila botterii texana*		T	Ins	Primarily terrestrial	R
	White-tailed Hawk	*Buteo albicaudatus*		T	C	Primarily terrestrial	M
	Northern Aplomado Falcon	*Falco femoralis septentrionalis*	E	E	C/Inv	Primarily terrestrial	R
	American Peregrine Falcon	*Falco peregrinus anatum*		T	C/Inv	Primarily terrestrial	R
	Rose-throated Becard	*Pachyramphus aglaiae*		T	Ins	Primarily terrestrial	R
	Wood Stork	*Mycteria americana*		T	Pis	Wetlands	M

Definitions

USFWS = US Fish & Wildlife Service
TPWD = Texas Parks & Wildlife Department
E = Endangered

T = Threatened
Pro = Producer
O = Omnivore

Ins = Insectivore
Inv = Invertivore
C = Carnivore

Pis = Piscivore
R = Resident
M = Migratory

Fish

Aransas Pass functions as a critical migratory corridor for aquatic biota that rely upon the specific conditions present in estuaries to complete life history processes and/or developmental stages.[10, 12, 15, 31, 32] These include a number of ecologically and economically valuable estuarine-dependent fish species, such as red drum *(Sciaenops ocellatus),* black drum *(Pogonias cromis),* Southern flounder *(Paralichthys lethostigma),* Atlantic croaker *(Micropogonias undulatus),* spotted seatrout *(Cynoscion nebulosus),* and others (Figure 3).[10, 33, 34]

Figure 3. Yellow crosshatch denotes essential red drum fishing habitat at/near the proposed facility (site boundaries in red; source: Port Aransas Conservancy, 2019)

These high trophic level fishes frequently prey upon small-bodied fish including killifish *(Fundulus sp.),* sheepshead minnow (*Cyprinodon variegatus*), mullet *(Mugil cephalus*), and silversides *(Menidia menidia),* as well as many other fishes and invertebrates.[10, 14, 15, 19] The area is also potential habitat for the threatened opossum pipefish (*Microphis brachyurus*; Table 1).[10]

Aquatic-Dependent Wildlife

The GoM is recognized as one of the most important avian habitats in the world, particularly for waterfowl and shorebirds that forage for food in nearshore habitats.[35, 36] Several species of rails (e.g., Virginia, clapper), egrets (e.g., great, snowy), herons (e.g., great blue, tricolored, reddish), ibises (e.g., white, white-faced), gulls (e.g., laughing, ring-billed) and terns (e.g., caspian, Forster's, royal) are common resident waterfowl and/or shorebirds in the area. Other common migratory/overwintering avian species (i.e., those that forage or nest in the area) include loons, grebes, pelicans, cormorants, ducks, oystercatchers, plovers, curlews, sandpipers and godwits.[10, 37] The area also provides critical habitat for a number of threatened and endangered (T&E) bird species (Table 1), including the piping plover *(Charadrius melodus)*, American yellow-tailed kite *(Elanoides forficatus),* least tern *(Sterna antillarum),* sooty tern *(Sterna fuscata),* reddish egret *(Egretta rufescens),* white-faced ibis *(Plegadis chihi),* wood stork *(Mycteria americana),* and the world's only self-sustaining population of whooping cranes *(Grus americana).*[10, 37-39]

A number of aquatic and aquatic-dependent amphibians and reptiles are also present in coastal habitats on/in proximity to Harbor Island. This list includes several species of sea turtles, five of which are Federally designated as T&E species (Table 1).[19, 40] Texas coastal waters are also home to several species of whales and dolphins (including two that are considered threatened); however, these animals primarily depend on offshore habitat and are not expected to intensively use habitats that may be impacted by the proposed Harbor Island facility. Rare sightings of the endangered West Indian manatee *(Trichechus manatus)* have also occurred in Port Aransas, Corpus Christi, North Padre Island, Goose Island State Park and Copano Bay; however, these sightings are considered anomalies.[10, 40]

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Conceptual Site Model

The conceptual site model (CSM) for the proposed project provides a site-specific framework that guides the remainder of the ecological risk evaluation. Figure 4 provides a visual summary of the CSM, including potential routes of contaminant release to the environment, fate and transport mechanisms that determine the distribution of the COPEC in the environment, potentially complete routes of COPEC exposure, and ecological receptors of potential concern.[4, 5]

Sources of COPECs

Effluents from SWRO facilities typically consist of a mixture of hypersaline brine and membrane reject water that contains chemicals added during the desalination process, as well as those originally present in source water.[41, 42] The draft permit for the Harbor Island facility states that effluent from the facility will be composed of approximately 21.5% (or 20.6 MGD) pre-treatment system reject and 78.5% (or 75 MGD) RO membrane reject, the projected salinity of which is expected to reach 58.5 ppt[a].[1, 43] SWRO effluents are also known to contain (either continuously or intermittently) a complex mixture of chemicals from the following sources:[41, 42, 44-54]

1. Chemicals added during the SWRO process
2. Chemicals originally present in intake media that are concentrated by SWRO and discharged in waste streams

It is also important to note that the construction phase of the proposed project can be expected to lead to an additional degree of environmental contamination; however, the present evaluation will focus largely on COPECs that may be released to the environment as part of normal operations.

Chemicals Added During Operations

In order to generate potable water for human consumption, source water must first be subjected to a sequence of physical and chemical processes that may involve the addition of biocides, antifouling chemicals, coagulants, flocculants, oxidizers and/or reducers and strong acids/bases.[41, 42, 53] The TCEQ permit application references several broad categories of chemicals that will be added during the desalination process, with NaOCl as an explicitly named additive.[1, 2] In the absence of a comprehensive list of chemical additives that may be regularly and/or intermittently used during SWRO operations, it is necessary for the present evaluation to consider chemicals commonly added by operational SWRO facilities as potential COPECs for the proposed Harbor Island facility.

COPECs Present in Intake Media

Contamination present in intake media (e.g., seawater, sediment) at the offshore intake site may be attributed to a number of local or global anthropogenic sources.[14, 15, 19, 55-60] Sources of background contamination relevant to the greater Corpus Christi area include nearby military installations, municipal and industrial discharges/runoff, agricultural runoff, inshore and offshore oil and gas production and exploration, technological disasters/spills, and global atmospheric transport (Figure 4).[11, 13, 15, 17, 18, 26, 56, 59, 61]

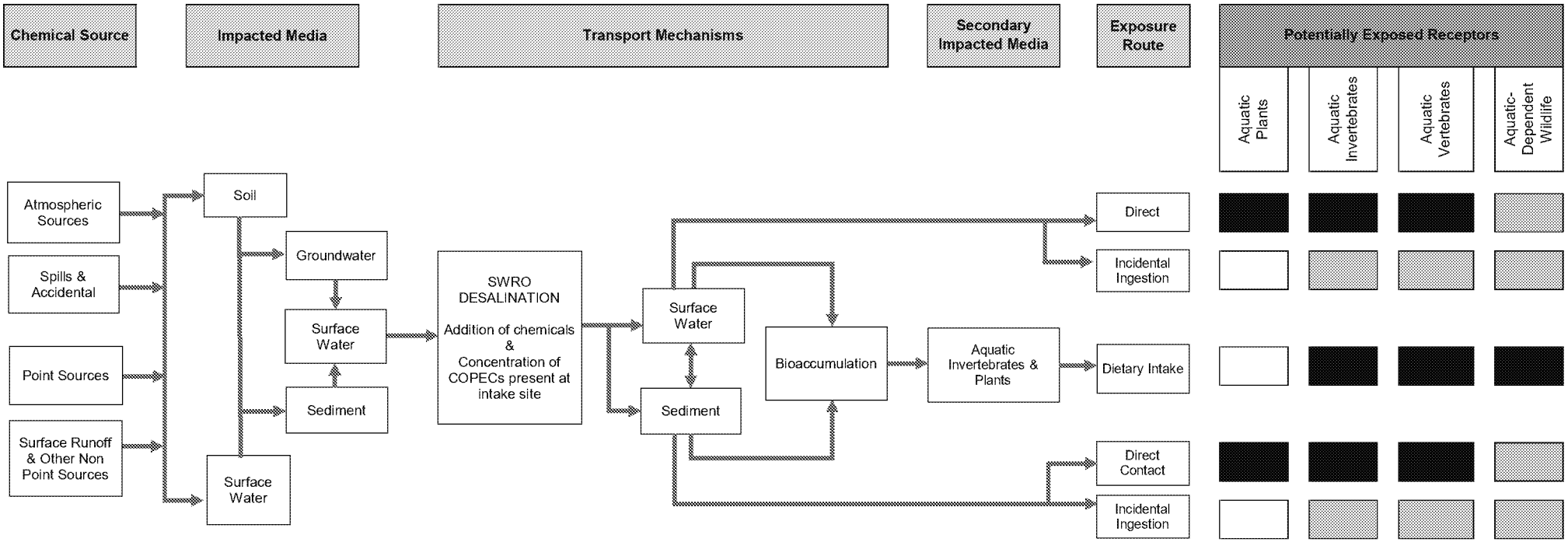
Although the type and extent of contamination initially present in intake media may not be originally attributed to the SWRO facility, both UF and RO are specifically designed to remove and concentrate undesirable constituents present in intake media. Chemicals removed from the desirable permeate water as part of the SWRO process are directed to facility waste streams (i.e., effluent and solid sludge) that are subsequently released to the environment.[44] Thus, the facility must be considered a secondary source of release for all chemicals present as background contamination in intake media, as long as the SWRO process is expected to result in their removal, concentration, and redistribution within the environment.[44]

Fate and Transport of COPECs & Potentially Impacted Media

Once discharged into the aquatic environment, a number of physical, chemical, and/or biological processes will interact to influence the fate and distribution of COPECs in effluent.[45, 46] Common physical processes involved in the distribution of waterborne COPECs include wave action, prevailing currents, tidal influences, physical mixing/water exchange, vessel traffic, and severe weather events.[45, 46, 62, 63] Sediment borne COPECs present in the GoM are also known to be transported away from the site of release via wave-mediated sediment deposition, dredging, vessel traffic, severe weather events (e.g., hurricanes), and other mechanisms.[62-64]

[a] Estimated from a concentration factor of 1.67 (for a 40% recovery operation) and intake salinity of 35 ppt.

Figure 4. Conceptual Site Model (CSM) for the proposed Harbor Island SWRO facility



Less lipophilic COPECs present in effluent (e.g., cationic metals or metalloids) may be present in aqueous compartments (including the water column or pore water) as dissolved constituents, partition to pelagic biota (via direct ingestion, respiration, etc.), undergo transformative processes, or bind to suspended particulates.[5, 45, 65, 66] Once bound, COPECs may be ingested by biota, desorb back to the aqueous phase, or form aggregates that settle out and contaminate surface sediments. COPECs present in surface sediments may be subsequently buried by sedimentation (becoming sequestered in deeper layers), undergo microbial transformation to a form with differential toxicity (e.g., the conversion of inorganic mercury [Hg^{2+}] to methylmercury [MeHg]), and/or they may partition to benthic-associated organisms. [5, 45, 46, 65, 66] The more lipophilic contaminants present in effluent are expected to preferentially partition to the lipid-rich tissues of aquatic biota, and/or sediments. In sediment, lipophilic COPECs may remain sequestered in deeper sediments, they may undergo biotransformation, or they may bioaccumulate in benthic organisms. [5, 45, 46, 65-69]

It is also important to note that a variety of natural and anthropogenic factors can remobilize previously sequestered contamination, such as organism burrowing behaviors, severe weather events, vessel traffic, and dredging.[26, 62, 66, 70] This is particularly true for coastal habitats, such as those in proximity to Harbor Island, as shallow systems (e.g., emergent wetlands, seagrass beds) are more sensitive to the effects of anthropogenic disturbances, severe weather, and coastal erosion.[21, 26, 71] Moreover, these ecosystems are also among the most productive in the world, providing habitat for an array of burrowing organisms and ecosystem engineers.[26, 56, 71-73]

Potential Routes of COPEC Exposure

Aquatic biota and aquatic-dependent wildlife present in proximity to Harbor Island may be simultaneously exposed to facility-associated COPECs via one or more direct or indirect routes (Figure 4). In aquatic ecosystems, direct routes of exposure typically include ingestion and/or absorption of contaminants present in impacted media, while trophic transfer is overwhelmingly the most important route of indirect contaminant exposure.[5, 6, 74, 75] However, the extent to which various exposure routes contribute to an organism's overall exposure to a given contaminant will vary according to several factors, including the organism's life history/behavioral traits, the physico-chemical properties of the COPEC, and various site specific environmental parameters (e.g., salinity, organic carbon content). [76, 77]

Direct uptake/absorption of COPECs present in contaminated water and sediment (including sediment porewater) is expected to contribute to the total daily intake (TDI) of aquatic plants, benthic and pelagic invertebrates, fish, amphibians, and reptiles. [5, 6, 74, 75] Direct ingestion is also expected to be a potentially important exposure route for both pelagic and benthic aquatic consumers. [5, 6, 74, 75] Although direct routes of contaminant exposure remain highly relevant for pelagic biota (especially during sensitive life stages), benthic organisms are typically considered to have a higher relative degree of exposure. This is attributed to life history and behavioral attributes shared by many benthic organisms (e.g., continual direct contact with contaminated sediment/pore water, smaller home ranges, limited mobility), as well as the properties of many persistent and bioaccumulative pollutants that tend to favor accumulation in non-aqueous compartments (e.g., partitioning coefficients that favor lipophilic fractions).[5, 15, 45, 46]

COPECs that are taken up by/bioaccumulate in producers and low trophic level consumers may be subsequently transferred to higher trophic level biota in a process known as biomagnification.[78-84] This indirect path of dietary contaminant exposure constitutes the primary route by which high trophic level aquatic receptors (e.g., piscivorous fishes/reptiles/amphibians, marine mammals) and aquatic-dependent wildlife (e.g., shorebirds and other waterfowl) are exposed to environmental contaminants.[4, 5, 85] As a result of this process, long-lived and high trophic level organisms are known to accumulate potentially toxic body burdens of bioaccumulative contaminants (despite limited contact with impacted water or sediment), potentially exposing sensitive/developmental stage offspring to maternally-derived environmental contaminants.[86-93]

Ecological Receptors of Potential Concern

The CSM for the proposed Harbor Island SWRO facility demonstrates that potentially complete exposure pathways exist for aquatic plants, aquatic invertebrates, aquatic vertebrates, and aquatic-dependent wildlife in proximity to the outfall. Aquatic plants may be exposed to COPECs in effluent via direct contact with impacted environmental media, resulting in uptake/absorption of potentially harmful contaminants. Direct contact may also lead to a substantial proportion of COPEC exposure for aquatic invertebrates. This is particularly true for benthic invertebrates, which are generally less mobile and in continuous contact with sediment borne contaminants that are often bioaccumulative. Pelagic and

benthic invertebrates may also be exposed to COPECs via incidental ingestion of contaminated media; however, many benthic invertebrates also consume large quantities of sediment as a primary source of nutrition. Therefore, ingestion of sediment (i.e., dietary exposure) is expected to be an additional important route of exposure for many low trophic level benthic invertebrates.

Many aquatic vertebrates may also take up a significant proportion of their total COPEC exposure via direct contact with impacted water and/or sediment, depending on their life history traits. Incidental ingestion is expected to contribute to the TDI of these receptors to varying degrees, though it is generally not considered to be a primary source of COPEC exposure relative to other routes. For aquatic biota at higher trophic levels, particularly piscivorous receptors, dietary exposure is expected to be a major source of exposure to bioaccumulative contaminants released in SWRO effluent.

Aquatic-dependent wildlife, such as waterfowl and shorebirds, are expected to experience the bulk of their COPEC exposure via dietary intake of contaminated prey items. Depending on their life history strategies, these receptors may experience some degree of direct contact exposure, though it is not expected to be a major exposure pathway for most wildlife receptors. However, ingestion of contaminated environmental media may meaningfully contribute the TDI of certain aquatic-dependent wildlife depending on their feeding strategies. This is particularly true for receptors that forage in contaminated sediments for benthic dietary items, such as wading waterfowl and shorebirds.

Identification of COPECs

The nature and extent of COPECs that will ultimately be present in effluent from the proposed facility will vary according to a number of factors, including design of the facility, specific operational processes, recovery efficiency, implementation of mechanical and institutional controls (during both the construction and operation phases), COPECs present in intake water, physico-chemical properties of the COPECs themselves (e.g., persistence, partitioning behavior) and a number of other site-specific parameters present at the intake and discharge points (e.g., rates of sediment deposition, freshwater inflow/precipitation, evaporation, rates of flushing/water turnover, natural organic matter [NOM] content, pH, acid-volatile sulfide content, water depth and salinity).[18, 19, 84, 94] As the facility is still in the proposed phase (i.e., effluent was not available for analysis), the COPECs identified below are based on a combination of sources, including planning/application/permitting documents submitted by the POCC and/or their representatives, the scientific literature, and reports from expert panels working on behalf of State, Federal, or International agencies. COPECs attributed to SWRO processes and those attributed to contamination likely to be present in abiotic media present at the intake site are covered in their respective sections below.

Chemicals Added During SWRO

Effluent from SWRO facilities typically includes various chemical antiscalants, coagulants, flocculants, oxidizing/reducing agents, strong acids/bases, and disinfection chemicals that are added as part of the SWRO process (Tables 2-3).[41, 44, 51-53, 95-101] Chemicals added during the SWRO process may also react with constituents present in the aquatic environment (e.g., NOM, bromide, iodide) to yield highly toxic halogenated SWRO by-products. [41, 42, 47-49, 51, 53, 98] As with most other SWRO facilities, the proposed Harbor Island facility plans to chlorinate the permeate water, which is known to correspond with the release of free residual chlorine.[2, 41, 46, 49, 51, 98, 99]

In saltwater environments, free residual chlorine reacts to produce toxic transformation products, including a number of trihalomethanes (THM), haloacetic acids, haloacetonitriles, halonitromethanes, and haloacetamides, which are collectively referred to as disinfection byproducts (Tables 2-3).[41, 42, 47-49, 51, 53, 98] Many disinfection byproducts are known to be carcinogenic/mutagenic and act as reproductive and developmental toxicants, including chloroform and bromoform, which are thought to be the two most common THMs released by SWRO facilities.[44, 51, 99] Brominated byproducts are known to be particularly toxic to biota relative to chlorinated compounds.[44, 51, 95, 98, 99] This is of importance to the proposed facility, as saltwater environments in arid climates that are rich in NOM, those that have existing hydrocarbon contamination and/or those with extensive oil and gas operations (i.e., coastal systems found along the Texas Coast) are known to have especially high bromine concentrations.[11, 13, 51, 99, 102-104]

Chemicals Potentially Present in Intake Media

In addition to chemicals added to effluent as part of the SWRO process, multiple point and non-point sources that contribute to contamination present at the intake site (both presently and in the future) are expected to contribute to

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the presence of COPECs in effluent.[44-46] Existing SWRO facilities are known to discharge a number of multivalent metal ions, high levels of phosphorus and nitrogen containing nutrients, a range of organic compounds, pharmaceuticals and personal care products (and their transformation products), and pathogens in their effluent.[44-46, 105, 106] Therefore, it is reasonable to conclude that contaminants with a mass > 100 Daltons that are commonly associated with local military operations, municipal/urban and industrial discharges/runoff, local agriculture, inshore and offshore oil and gas production and exploration and chemical spills (e.g., the *Deepwater Horizon* oil spill) may be taken up, concentrated, and discharged into the CCSC by the SWRO facility.

Consequently, the following criteria were applied as part of the COPEC selection process:

1. The COPEC can be attributed to known sources of local industrial, military, agricultural and/or urban pollution
2. The COPEC is known to be present in abiotic media from the GoM with a high frequency and abundance
3. The COPEC is expected or known to be removed by the SWRO process and redirected to waste streams

Contaminants from agricultural sources commonly include nitrogen and phosphorus containing nutrients and a range of pesticides and herbicides (Tables 2 -3). Municipal sources also contribute to the presence of the aforementioned COPECs in the aquatic environment, with pharmaceuticals, personal care products, microplastics, plasticizers, halogenated organics and hydrocarbons as additional major sources of contamination (Tables 2-3).[18, 107-117] Multiple industrial and military sources in the region also release large quantities of hydrocarbons, bulk fuels, halogenated organic compounds, pesticides, organotins and heavy metals to water and sediments in nearby coastal systems (Tables 2-3).[17, 58, 66, 84, 118-126]

It should be noted that the goal of the present ERA is not to provide a comprehensive lists of potential COPECs that may be taken in, concentrated and subsequently discharged from the proposed facility, but rather to evaluate those that are considered likely to be present in effluent and/or pose a potential ecotoxicological risk based on the COPEC selection criteria.[15, 19] Chronic ecological screening values (ESVs) recommended for the identification of COPECs that may pose a risk to ecological receptors exposed to effluent-impacted sediment and water are also provided in Tables 2-3. Preference was given to USEPA ESVs; however, refined ESVs were provided for polycyclic aromatic hydrocarbons (PAHs) and phthalates. These alternative ESVs were determined to be most appropriate for evaluating ecological risk related to the proposed ecosystem, due to site-specific factors that favor certain modes of toxic action (i.e., PAH photo-induced toxicity).

Table 2. Ecological screening values (ESVs) for sediments and COPECs identified for the proposed Harbor Island Facility

CASRN	COPEC		Sub-Class	Common Sources	Units	Sediment Screening Criteria			Recommended Screening Value
						USEPA Chronic Saltwater ESV [1]	USEPA Saltwater RSV [1]	Alternate Value	
10222-01-2	**2,2-Dibromo-3-nitrilopropionamide**		Biocides	industrial/military	µg/kg*	3.4	7.1		**3.4**
634-66-2	**1,2,3,4-Tetrachlorobenzene**		Chlorobenzenes	industrial/military	µg/kg*		138	13.8 [4]	**13.8**
95-94-3	**1,2,4,5-Tetrachlorobenzene**		Chlorobenzenes	industrial/military	µg/kg*		135	13.5 [4]	**13.5**
608-93-5	Pentachlorobenzene		Chlorobenzenes	municipal/urban, industrial/military	µg/kg*		36	3.6 [4]	**3.6**
132-64-9	**Dibenzofuran**		Dioxins/Furans	industrial/military	µg/kg*		2313	231.3 [4]	**231.3**
1746-01-6	2,3,7,8-TCDD (Dioxin)		Dioxins/Furans	industrial/military	µg/kg*		0.0005	0.0005	**0.0005**
75-25-2	**Bromoform**		Halogenated Alkanes	Disinfection by-product	µg/kg*	223			**223**
67-66-3	**Chloroform**		Halogenated Alkanes	Disinfection by-product	µg/kg*	291	3352		**291**
ΣPBDE	ΣPBDE	[6]	PBDEs	municipal/urban, industrial/military	µg/kg*				--
2921-88-2	**Chloropyrifos**		Herbicides/Fungicides	agriculture, industrial/military	µg/kg*	0.4	8		**0.4**
333-41-5	**Diazinon**		Herbicides/Fungicides	agriculture, industrial/military	µg/kg*	18	91		**18**
60-51-5	**Dimethoate**		Herbicides/Fungicides	agriculture, industrial/military	µg/kg*		0	0.2 [5]	**0.2**
121-75-5	**Malathion**		Herbicides/Fungicides	agriculture, industrial/military	µg/kg*	0.06	0.42		**0.06**
58-89-9	BHC-gamma (Lindane)		Herbicides/Fungicides	agriculture, industrial/military	µg/kg*	0.6	0.99		**0.6**
2385-85-5	Mirex		Herbicides/Fungicides	agriculture, industrial/military	µg/kg*	3.6	120		**3.6**
8001-35-2	Toxaphene		Herbicides/Fungicides	agriculture, industrial/military	µg/kg*	0.15	54		**0.15**
1582-09-8	Trifluralin		Herbicides/Fungicides	agriculture, industrial/military	µg/kg*		493	49.3 [4]	**49.3**
124-18-5	**Decane**		Hydrocarbons	industrial/military	µg/kg*		65	6.5 [4]	**6.5**
7440-36-0	**Antimony**		Metals	industrial/military	mg/kg dw	2	25		**2**
7440-38-2	**Arsenic**		Metals	industrial/military	mg/kg dw	7.24	41.6		**7.24**
7440-39-3	**Barium**		Metals	industrial/military	mg/kg dw			20 [5]	**20**
7440-41-7	**Beryllium**		Metals	industrial/military	mg/kg dw				--
7440-42-8	**Boron**		Metals	naturally occurring in seawater	mg/kg dw				--
7440-43-9	**Cadmium**		Metals	industrial/military	mg/kg dw	0.68	4.21		**0.68**
7440-47-3	**Chromium**		Metals	industrial/military	mg/kg dw	52.3	160		**52.3**
7440-48-4	**Cobalt**		Metals	industrial/military	mg/kg dw			50 [5]	**50**
7440-50-8	**Copper**		Metals	industrial/military	mg/kg dw	18.7	108		**18.7**
7439-89-6	**Iron**		Metals	industrial/military	mg/kg dw				--
7439-92-1	**Lead**		Metals	industrial/military	mg/kg dw	30.2	112		**30.2**
7439-95-4	**Magnesium**		Metals	industrial/military	mg/kg dw				--
7439-96-5	**Manganese**		Metals	industrial/military	mg/kg dw				--
7439-98-7	**Molybdenum**		Metals	industrial/military	mg/kg dw				--
7440-02-0	**Nickel**		Metals	industrial/military	mg/kg dw	15.9	42.8		**15.9**
7740-22-4	**Silver**		Metals	industrial/military	mg/kg dw				--
7440-24-6	**Strontium**		Metals	industrial/military	mg/kg dw				--
7440-28-0	**Thallium**		Metals	industrial/military	mg/kg dw				--
7440-31-5	**Tin**		Metals	industrial/military	mg/kg dw				--
7440-62-2	**Vanadium**		Metals	industrial/military	mg/kg dw				--
7440-66-6	**Zinc**		Metals	industrial/military	mg/kg dw	124	271		**124**
7439-97-6	Mercury		Metals	industrial/military	mg/kg dw	0.1	0.7		**0.13**
7782-49-2	Selenium		Metals	industrial/military	mg/kg dw				--
239-01-0	**11H-Benzo[a]carbazole**		PAHs	municipal/urban, industrial/military	µg/kg*			[7]	
208-96-8	**Acenaphthylene**		PAHs	municipal/urban, industrial/military	µg/kg*	5.9		[10]	**5.9**
120-12-7	**Anthracene**		PAHs	municipal/urban, industrial/military	µg/kg*	47		[7]	**47**
195-19-7	**Benzo[c]phenanthrene**		PAHs	municipal/urban, industrial/military	µg/kg*			[7]	
192-97-2	**Benzo[e]pyrene**		PAHs	municipal/urban, industrial/military	µg/kg*			[7]	
215-58-7	**Dibenz[a,c]anthracene**		PAHs	municipal/urban, industrial/military	µg/kg*			[7]	
5385-75-1	**Dibenzo[a,e]fluoranthene**		PAHs	municipal/urban, industrial/military	µg/kg*			[7]	
191-68-4	**Dibenzo[g,p]chrysene**		PAHs	municipal/urban, industrial/military	µg/kg*			[7]	
86-73-7	**Fluorene**		PAHs	municipal/urban, industrial/military	µg/kg*	21		[10, 13]	**21**
91-20-3	**Naphthalene**		PAHs	municipal/urban, industrial/military	µg/kg*	35		[10]	**35**
129-00-0	**Pyrene**		PAHs	municipal/urban, industrial/military	µg/kg*	153		[9, 13]	**153**
HMW-PAH	Total High Molecular Weight PAHs	[6]	PAHs	municipal/urban, industrial/military	µg/kg*				--
LMW-PAH	Total Low Molecular Weight PAHs	[6]	PAHs	municipal/urban, industrial/military	µg/kg*	312			**312**
tPAH50	tPAH50	[6]	PAHs	municipal/urban, industrial/military	µg/kg*			1197 [12]	**1197**
56-55-3	Benz(a)anthracene		PAHs	municipal/urban, industrial/military	µg/kg*	75		[9, 13]	**75**
50-32-8	Benzo(a)pyrene		PAHs	municipal/urban, industrial/military	µg/kg*	89		[9, 13]	**89**
205-99-2	Benzo(b)fluoranthene		PAHs	municipal/urban, industrial/military	µg/kg*			190 [5, 9, 13]	**190**
191-24-2	Benzo(g,h,i)perylene		PAHs	municipal/urban, industrial/military	µg/kg*	310		[7]	**310**
207-08-9	Benzo(k)fluoranthene		PAHs	municipal/urban, industrial/military	µg/kg*			240 [5, 13]	**240**
218-01-9	Chrysene		PAHs	municipal/urban, industrial/military	µg/kg*	108		[9, 13]	**108**
53-70-3	Dibenz(a,h)anthracene		PAHs	municipal/urban, industrial/military	µg/kg*	6.2		[9]	**6.2**
206-44-0	Fluoranthene		PAHs	municipal/urban, industrial/military	µg/kg*	113		[7]	**113**
193-39-5	Indeno(1,2,3-cd)pyrene		PAHs	municipal/urban, industrial/military	µg/kg*	340		[9]	**340**
85-01-8	Phenanthrene		PAHs	municipal/urban, industrial/military	µg/kg*	87		[10, 13]	**87**
1336-36-3	Total PCBs	[1,6]	PCBs	industrial/military	µg/kg*	14			**14**
58-90-2	**2,3,4,6-Tetrachlorophenol**		Pesticides	industrial/military	µg/kg*		948	30 [5]	**30**
94-75-7	**2,4-D**		Pesticides	agriculture, industrial/military	µg/kg*	42	436		**42**
554-00-7	**2,4-Dichloroaniline**		Pesticides	industrial/military	µg/kg*		32	3.2 [4]	**3.2**
120-83-2	**2,4-Dichlorophenol**		Pesticides	industrial/military	µg/kg*		1886	57 [5]	**57**
95-95-4	**2,4,5-Trichlorophenol**		Pesticides	industrial/military	µg/kg*	217	1964		**217**
118-79-6	**2,4,6-Tribromophenol**		Pesticides	industrial/military	µg/kg*		308	30.8 [4]	**30.8**
59-50-7	**3-Methyl-4-Chlorophenol**		Pesticides	industrial/military	µg/kg*	1257	2035		**1257**
106-47-8	**4-Chloroaniline**		Pesticides	municipal/urban, industrial/military	µg/kg*	0.9	21		**0.9**
107-02-8	**Acrolein**		Pesticides	agriculture, industrial/military	µg/kg*	0.6	3		**0.6**

CASRN	COPEC		Sub-Class	Common Sources	Units	Sediment Screening Criteria			Recommended Screening Value
						USEPA Chronic Saltwater ESV [1]	USEPA Saltwater RSV [1]	Alternate Value	
1912-24-9	**Atrazine**		Pesticides	agriculture, industrial/military	µg/kg*			0.3 [5]	**0.3**
319-84-6	**BHC (alpha)**		Pesticides	agriculture, industrial/military	µg/kg*	1.3	567		**1.3**
111-44-4	**bis(2-Chloroethyl) Ether**		Pesticides	industrial/military	µg/kg*		8163	816.3 [4]	**816.3**
133-06-2	**Captan**		Pesticides	agriculture, industrial/military	µg/kg*		51	5.1 [4]	**5.1**
63-25-2	**Carbaryl**		Pesticides	agriculture, industrial/military	µg/kg*	0.5	1		**0.5**
1563-66-2	**Carbofuran**		Pesticides	agriculture, industrial/military	µg/kg*	0.4	20		**0.4**
1897-45-6	**Chlorothalonil**		Pesticides	agriculture, industrial/military	µg/kg*	3.9	4		**3.9**
21725-46-2	**Cyanazine**		Pesticides	agriculture, industrial/military	µg/kg*		0	30 [5]	**30**
1918-00-9	**Dicamba**		Pesticides	agriculture, industrial/military	µg/kg*		630	8.4 [5]	**8.4**
2764-72-9	**Diquat**		Pesticides	agriculture, industrial/military	µg/kg*	43	2498		**43**
115-29-7	**Endosulfan**	[2]	Pesticides	agriculture, industrial/military	µg/kg*	0.1	3		**0.1**
1031-07-8	**Endosulfan Sulfate**		Pesticides	agriculture, industrial/military	µg/kg*	0.11	0		**0.11**
33213-65-9	**Endosulfan-beta**		Pesticides	agriculture, industrial/military	µg/kg*	0.14	0		**0.14**
86-50-0	**Guthion**		Pesticides	agriculture, industrial/military	µg/kg*	0.008	0.1		**0.008**
1024-57-3	**Heptachlor epoxide**		Pesticides	agriculture, industrial/military	µg/kg*	0.14	15		**0.14**
94-74-6	**2-methyl-4-chlorophenoxyacetic acid**		Pesticides	agriculture, industrial/military	µg/kg*	2.5	0		**2.5**
527-20-8	**Pentachloroaniline**		Pesticides	agriculture, industrial/military	µg/kg*		621	62.1 [4]	**62.1**
72-54-8	4,4'-DDD		Pesticides	agriculture, industrial/military	µg/kg*	1.2	8		**1.2**
72-55-9	4,4'-DDE		Pesticides	agriculture, industrial/military	µg/kg*	2.1	374		**2.1**
50-29-3	4,4'-DDT		Pesticides	agriculture, industrial/military	µg/kg*		5		
309-00-2	Aldrin		Pesticides	agriculture, industrial/military	µg/kg*	0.1	48		**0.1**
319-85-7	BHC (beta)		Pesticides	agriculture, industrial/military	µg/kg*		567	56.7 [5]	**56.7**
57-74-9	Chlordane		Pesticides	agriculture, industrial/military	µg/kg*	2.7	5		**2.7**
60-57-1	Dieldrin		Pesticides	agriculture, industrial/military	µg/kg*	0.1	4.3		**0.1**
72-20-8	Endrin		Pesticides	agriculture, industrial/military	µg/kg*	0.12	6		**0.12**
76-44-8	Heptachlor		Pesticides	agriculture, industrial/military	µg/kg*	1.5	71		**1.5**
118-74-1	Hexachlorobenzene		Pesticides	industrial/military	µg/kg*	10	23		**10**
77-47-4	Hexachlorocyclopentadiene		Pesticides	agriculture, industrial/military	µg/kg*	1	130		**1**
72-43-5	Methoxtchlor		Pesticides	agriculture, industrial/military	µg/kg*	2.1	59		**2.1**
DDE	Total DDE		Pesticides	agriculture, industrial/military	µg/kg*		13	2.1 [3]	**2.1**
DDD	Total DDD		Pesticides	agriculture, industrial/military	µg/kg*		13	1.2 [3]	**1.2**
DDT	Total DDT		Pesticides	agriculture, industrial/military	µg/kg*	0.7	52		**0.7**
DDx	DDD/DDE/DDT	[6]	Pesticides	agriculture, industrial/military	µg/kg*		44	4.4 [4]	**4.4**
PFAS	PFOA		PFAS	municipal/urban, industrial/military	µg/kg*				--
PFAS	PFOS		PFAS	municipal/urban, industrial/military	µg/kg*				--
ΣPFAS	ΣPFAS	[6]	PFAS	municipal/urban, industrial/military	µg/kg*				--
87-86-5	Pentachlorophenol		Phenols	agriculture, industrial/military	µg/kg*	360	394		**360**
85-68-7	**Butyl benzyl phthalate**		Phthalates	municipal/urban, industrial/military	µg/kg*		481	48.1 [4]	**48.1**
84-74-2	**Di-n-butyl phthalate**		Phthalates	municipal/urban, industrial/military	µg/kg*		319	90 [8]	**90**
117-84-0	**Di-n-octyl phthalate**		Phthalates	municipal/urban, industrial/military	µg/kg*	580	45000		**580**
84-66-2	**Diethyl phthalate**		Phthalates	municipal/urban, industrial/military	µg/kg*	80	1105		**80**
131-11-3	**Dimethyl phthalate**		Phthalates	municipal/urban, industrial/military	µg/kg*	530	2031		**530**
117-81-7	Bis(2-ethylhexyl)phthalate		Phthalates	municipal/urban, industrial/military	µg/kg*	182	2647	100 [8]	**182**

Notes and Definitions

-- indicates ESV is unavailble
CASRN = Chemical Abstract Service Registration Number
COPEC = Constituent of Potential Ecological Concern
mg/kg = milligram of COPEC per kilogram of sediment
µg/kg = microgram of COPEC per kilogram of sediment
dw = dry weight
ESV = Ecological Screening Value
PCB = polychlorinated biphenyl
PAH = Polycyclic aromatic hydrocarbons
PFAS = per- and polyfluoroalkyl substances
Bold Red indicates the COPEC is bioaccumulative
* assuming 1% organic carbon content

[1] Source is USEPA Supplemental ERAGs Guidance [128]
[2] ESV applies to both endosulfan-alpha and -beta
[3] ESVs for 4,4'-DDD and 4,4'-DDE used as a surrogate for total
[4] Value is equivalent to the USEPA Saltwater RSV divided by an uncertainty factor of 10
[5] Freshwater ESV used as a surrogate
[6] Contaminant ESV is applied as a sum value of many COPECs with variable bioaccumulation potentials
[7] Known to exert photo-induced toxicity in the presence of solar radiation - $tPAH_{50}$ ESV applies
[8] Based on a marine species sensitivity distribution calculated by Gao et al., 2019
[9] Sum ESV for High Molecular Weight PAHs applies
[10] Sum ESV for Low Molecular Weight PAHs applies
[11] Sum of 50 PAH compounds
[12] Value from Nielsen et al., 2020

Table 3. Ecological screening values (ESVs) for surface water and COPECs identified for the proposed Harbor Island Facility

CASRN	COPEC	Class	Common Sources	Units	Surface Water Screening Criteria			Recommended Screening Value
					USEPA Chronic Saltwater ESV [1]	USEPA Saltwater RSV [1]	Alternate Value	
127-18-4	**1,1,2,2-Tetrachloroethylene**	Chlorinated Alkenes	municipal/urban, industrial/military	µg/L	8.85	1020		**8.85**
542-75-6	**1,3-Dichloropropene**	Chlorinated Alkenes	agriculture	µg/L	39.5	79		**39.5**
156-60-5	**1,2-trans-Dichloroethylene**	Chlorinated Alkenes	municipal/urban, industrial/military	µg/L	1629	6236		**1629**
65386	**1,1,2-Trichloroethylene**	Chlorinated Alkenes	municipal/urban, industrial/military	µg/L				--
124-48-1	**Dibromochloromethane**	Halogenated Alkanes	Disinfection by-product	µg/L	34	13416	0.8 [2]	**0.8**
67-66-3	**Chloroform**	Halogenated Alkanes	Disinfection by-product	µg/L	471	8150	1.8 [2]	**1.8**
56-23-5	**Tetrachloromethane**	Halogenated Alkanes	municipal/urban, industrial/military	µg/L	4.4	15000		**4.4**
75-25-2	**Bromoform**	Halogenated Alkanes	Disinfection by-product	µg/L	360	1790	18.5 [2]	**18.5**
630-20-6	**1,1,1,2-Tetrachloroethane**	Halogenated Alkanes	municipal/urban, industrial/military	µg/L	360	1376		**360**
71-55-6	**1,1,1-Trichloroethane**	Halogenated Alkanes	municipal/urban, industrial/military	µg/L	1560	3120		**1560**
107-06-2	**1,2-Dichloroethane**	Halogenated Alkanes	municipal/urban, industrial/military	µg/L	5650	11300		**5650**
118-74-1	**Hexachlorobenzene**	Chlorobenzenes	industrial/military	µg/L	0.15	2.8		**0.15**
608-93-5	**Pentachlorobenzene**	Chlorobenzenes	municipal/urban, industrial/military	µg/L	1	11		**1**
108-70-3	**1,3,5-Trichlorobenzene**	Chlorobenzenes	industrial/military	µg/L	5	134		**5**
12002-48-1	**Trichlorobenzene**	Chlorobenzenes	industrial/military	µg/L	5	134		**5**
120-82-1	**1,2,4-Trichlorobenzene**	Chlorobenzenes	industrial/military	µg/L	5.4	134		**5.4**
108-90-7	**Chlorobenzene**	Chlorobenzenes	agriculture, industrial/military	µg/L	25	1360		**25**
106-46-7	**1,4-Dichlorobenzene**	Chlorobenzenes	municipal/urban, industrial/military	µg/L	115	660		**115**
87-86-5	**Pentachlorophenol**	Chlorophenols	agriculture, industrial/military	µg/L	7.9	13		**7.9**
95-95-4	**2,4,5-Trichlorophenol**	Chlorophenols	industrial/military	µg/L	12	259		**12**
58-90-2	**2,3,4,6-Tetrachlorophenol**	Chlorophenols	industrial/military	µg/L	32	120		**32**
59-50-7	**3-Methyl-4-Chlorophenol**	Chlorophenols	industrial/military	µg/L	241	1000		**241**
120-83-2	**2,4-Dichlorophenol**	Chlorophenols	industrial/military	µg/L	790	1352		**790**
68821	**2,4,6-Trichlorophenol**	Chlorophenols	industrial/military	µg/L				--
1897-45-6	**Chlorothalonil**	Herbicides, Fungicides	agriculture, industrial/military	µg/L	0.36	16		**0.36**
1582-09-8	**Trifluralin**	Herbicides, Fungicides	agriculture, industrial/military	µg/L	3	12		**3**
94-74-6	**2-methyl-4-chlorophenoxyacetic acid**	Herbicides, Fungicides	agriculture, industrial/military	µg/L	4.2	40		**4.2**
133-06-2	**Captan**	Herbicides, Fungicides	agriculture, industrial/military	µg/L	18	30		**18**
94-75-7	**2,4-D**	Herbicides, Fungicides	agriculture, industrial/military	µg/L	70			**70**
1918-00-9	**Dicamba**	Herbicides, Fungicides	agriculture, industrial/military	µg/L				--
122-34-9	**Simazine**	Herbicides, Fungicides	agriculture, industrial/military	µg/L		57	5.7	**5.7**
7740-22-4	**Silver**	Metals	industrial/military	µg/L	0.1	1.9		**0.1**
7440-41-7	**Beryllium**	Metals	industrial/military	µg/L	0.13			**0.13**
7439-97-6	**Mercury**	Metals	industrial/military, global emissions	µg/L	0.94	1.8		**0.94**
7740-50-8	**Copper**	Metals	industrial/military	µg/L	3.1	4.8		**3.1**
7740-43-9	**Cadmium**	Metals	industrial/military	µg/L	7.9	33		**7.9**
7439-92-1	**Lead**	Metals	industrial/military	µg/L	8.1	210		**8.1**
7440-02-0	**Nickel**	Metals	industrial/military	µg/L	8.2	74		**8.2**
7440-38-2	**Arsenic**	Metals	industrial/military	µg/L	36	69		**36**
7782-49-2	**Selenium**	Metals	industrial/military	µg/L	71	290		**71**
7740-66-6	**Zinc**	Metals	industrial/military	µg/L	81	90		**81**
7723-14-0	**Phosphorus (elemental)**	Metals	agriculture, municipal/urban	µg/L	100			**100**
7439-96-5	**Manganese**	Metals	industrial/military	µg/L	100			**100**
16065-83-1	**Chromium**	Metals	industrial/military	µg/L	103	515		**103**
7439-89-6	**Iron**	Metals	industrial/military	µg/L	300			**300**
7440-42-8	**Boron**	Metals	naturally occurring in seawater	µg/L	1000			**1000**
7429-90-5	**Aluminum**	Metals	industrial/military	µg/L	1500			**1500**
7440-36-0	**Antimony**	Metals	industrial/military	µg/L	4300			**4300**
7440-48-4	**Cobalt**	Metals	industrial/military	µg/L				--
7439-98-7	**Molybdenum**	Metals	industrial/military	µg/L				--
7440-24-6	**Strontium**	Metals	industrial/military	µg/L				--
7440-31-5	**Tin**	Metals	industrial/military	µg/L				--
7440-62-2	**Vanadium**	Metals	industrial/military	µg/L				--
7440-67-7	**Zirconium**	Metals	industrial/military	µg/L				--
688-73-3	**Tributyltin**	Other	industrial/military	µg/L	0.0074	0.42		**0.0074**
77-47-4	**Hexachlorocyclopentadiene**	Other	agriculture, industrial/military	µg/L	0.07	0.7		**0.07**
87-68-3	**Hexachlorobutadiene**	Other	industrial/military	µg/L	0.3	1.6		**0.3**
124-18-5	**Decane**	Other	industrial/military	µg/L	4	17		**4**
7782-50-5	**Chlorine**	Other	SWRO additive	µg/L	7.5	13		**7.5**
10222-01-2	**2,2-Dibromo-3-nitrilopropionamide**	Other	industrial/military	µg/L	10	40		**10**
91-94-1	**3,3'-Dichlorobenzidine**	Other	industrial/military	µg/L	13	505		**13**
86-30-6	**N-Nitrosodiphenylamine**	Other	industrial/military	µg/L	48	283		**48**
39290-78-3	**Polyaluminum chloride**	Other	SWRO additive	µg/L				--
7681-52-9	**Sodium hypochlorite**	Other	SWRO additive	µg/L				--
118-79-6	**2,4,6-Tribromophenol**	Other Phenols	industrial/military	µg/L	37	140		**37**
132-64-9	**Dibenzofuran**	PAH-like Compounds	industrial/military	µg/L	61	242		**61**
53-70-3	**Dibenz[a,h]anthracene**	PAHs	municipal/urban, industrial/military	µg/L	0.01	0.28		**0.01**
191-24-2	**Benzo[g,h,i]perylene**	PAHs	municipal/urban, industrial/military	µg/L	0.012	0.19		**0.012**
193-39-5	**Indeno[1,2,3-cd]pyrene**	PAHs	municipal/urban, industrial/military	µg/L	0.012	0.27		**0.012**
50-32-8	**Benzo[a]pyrene**	PAHs	municipal/urban, industrial/military	µg/L	0.02	0.64		**0.02**
205-99-2	**Benzo[b]fluoranthene**	PAHs	municipal/urban, industrial/military	µg/L	0.06	1.4		**0.06**
207-08-9	**Benzo[k]fluoranthene**	PAHs	municipal/urban, industrial/military	µg/L	0.06	1.3		**0.06**
129-00-0	**Pyrene**	PAHs	municipal/urban, industrial/military	µg/L	0.11	0.45		**0.11**
56-55-3	**Benzo[a]anthracene**	PAHs	municipal/urban, industrial/military	µg/L	0.35	4.6		**0.35**
218-01-9	**Chrysene**	PAHs	municipal/urban, industrial/military	µg/L	0.35	4.2		**0.35**
120-12-7	**Anthracene**	PAHs	municipal/urban, industrial/military	µg/L	0.43	1.8		**0.43**
206-44-0	**Fluoranthene**	PAHs	municipal/urban, industrial/military	µg/L	0.82	3.4	0.6 [6]	**0.6**

CASRN	COPEC		Class	Common Sources	Units	Surface Water Screening Criteria			Recommended Screening Value
						USEPA Chronic Saltwater ESV [1]	USEPA Saltwater RSV [1]	Alternate Value	
198-55-0	**Perylene**		PAHs	municipal/urban, industrial/military	µg/L	0.9		[13]	**0.9**
91-20-3	**Naphthalene**		PAHs	municipal/urban, industrial/military	µg/L	1.4	780		**1.4**
85-01-8	Phenanthrene		PAHs	municipal/urban, industrial/military	µg/L	4.6	7.7		**4.6**
83-32-9	**Acenaphthene**		PAHs	municipal/urban, industrial/military	µg/L	15	320		**15**
86-73-7	**Fluorene**		PAHs	municipal/urban, industrial/military	µg/L	24	82		**24**
208-96-8	**Acenaphthylene**		PAHs	municipal/urban, industrial/military	µg/L	28	291		**28**
90-12-0	**1-Methylnaphthalene**		PAHs	municipal/urban, industrial/military	µg/L	52	157		**52**
91-57-6	**2-Methylnaphthalene**		PAHs	municipal/urban, industrial/military	µg/L	52	150		**52**
HMW-PAH	**Total HMW-PAHs**	[3]	PAHs	municipal/urban, industrial/military	µg/L				--
LMW-PAH	**Total LMW-PAHs**	[3]	PAHs	municipal/urban, industrial/military	µg/L				--
239-01-0	**11H-Benzo[a]carbazole**		PAHs	municipal/urban, industrial/military	µg/L			[13]	--
194-59-2	**7H-Dibenzo[c,g]carbazole**		PAHs	municipal/urban, industrial/military	µg/L			[13]	--
195-19-7	**Benzo[c]phenanthrene**		PAHs	municipal/urban, industrial/military	µg/L			[13]	--
215-58-7	**Benzo[b]triphenylene**		PAHs	municipal/urban, industrial/military	µg/L			[13]	--
225-51-4	**Benzo[c]acridine**		PAHs	municipal/urban, industrial/military	µg/L			[13]	--
192-97-2	**Benzo[e]pyrene**		PAHs	municipal/urban, industrial/military	µg/L			[13]	--
225-11-6	**Benzo[a]acridine**		PAHs	municipal/urban, industrial/military	µg/L			[13]	--
92-82-0	**dibenzo[a,c]phenazine**		PAHs	municipal/urban, industrial/military	µg/L			[13]	--
5385-75-1	**Dibenzo[a,e]aceanthrylene**		PAHs	municipal/urban, industrial/military	µg/L			[13]	--
191-68-4	**Dibenzo[g,p]chrysene**		PAHs	municipal/urban, industrial/military	µg/L			[13]	--
tPAH50	tPAH50	[3]	PAHs	municipal/urban, industrial/military	µg/L			0.25 [5]	**0.25**
8001-35-2	Toxaphene		Pesticides	agriculture, industrial/military	µg/L	0.0002	0.21		**0.0002**
2385-85-5	Mirex		Pesticides	agriculture, industrial/military	µg/L	0.001	0.001		**0.001**
60-57-1	Dieldrin		Pesticides	agriculture, industrial/military	µg/L	0.002	0.71		**0.002**
72-20-8	Endrin		Pesticides	agriculture, industrial/military	µg/L	0.002	0.04		**0.002**
57-74-9	Chlordane		Pesticides	agriculture, industrial/military	µg/L	0.004	0.09		**0.004**
76-44-8	Heptachlor		Pesticides	agriculture, industrial/military	µg/L	0.004	0.05		**0.004**
1024-57-3	Heptachlor Epoxide		Pesticides	agriculture, industrial/military	µg/L	0.004	0.05		**0.004**
2921-88-2	**Chloropyrifos**		Pesticides	agriculture, industrial/military	µg/L	0.006	0.011		**0.006**
1031-07-8	Endosulfan Sulfate		Pesticides	agriculture, industrial/military	µg/L	0.009	0.03		**0.009**
50-29-3	4,4'-DDT		Pesticides	agriculture, industrial/military	µg/L	0.01	0.13		**0.01**
86-50-0	**Azinphos-methyl (Guthion)**		Pesticides	agriculture, industrial/military	µg/L	0.01	0.19		**0.01**
58-89-9	BHC-gamma		Pesticides	agriculture, industrial/military	µg/L	0.02	0.16		**0.02**
72-43-5	Methoxychlor		Pesticides	agriculture, industrial/military	µg/L	0.03			**0.03**
319-84-6	BHC (beta)		Pesticides	agriculture, industrial/military	µg/L	0.046	--		**0.046**
72-54-8	4,4'-DDD		Pesticides	agriculture, industrial/military	µg/L	0.084	0.35		**0.084**
121-75-5	**Malathion**		Pesticides	agriculture, industrial/military	µg/L	0.1	1		**0.1**
72-55-9	4,4'-DDE		Pesticides	agriculture, industrial/military	µg/L	0.14	0.7		**0.14**
63-25-2	**Carbaryl**		Pesticides	agriculture, industrial/military	µg/L	0.29	1.6		**0.29**
1563-66-2	**Carbofuran**		Pesticides	agriculture, industrial/military	µg/L	0.29	1.2		**0.29**
333-41-5	Diazinon		Pesticides	agriculture, industrial/military	µg/L	0.82	0.82		**0.82**
30560-19-1	**Acephate**		Pesticides	agriculture, industrial/military	µg/L	1.5	28		**1.5**
8065-48-3	Demeton		Pesticides	agriculture, industrial/military	µg/L				--
959-98-8	Endosulfan-alpha		Pesticides	agriculture, industrial/military	µg/L				--
33213-65-9	Endosulfan-beta		Pesticides	agriculture, industrial/military	µg/L				--
309-00-2	Aldrin		Pesticides	agriculture, industrial/military	µg/L	0.0001	1.3		**0.0001**
1912-24-9	**Atrazine**		Pesticides	agriculture, industrial/military	µg/L				--
21725-46-2	**Cyanazine**		Pesticides	agriculture, industrial/military	µg/L		61	6.1 [7]	**6.1**
1763-23-1	Perfluorooctanesulfonic acid		PFAS	municipal/urban, industrial/military	µg/L			2.57 [4]	**2.57**
335-67-1	Perfluorooctanoic acid		PFAS	municipal/urban, industrial/military	µg/L				--
117-81-7	Bis(2-ethylhexyl)phthalate		Phthalates	municipal/urban, industrial/military	µg/L	6	605		**6**
85-68-7	**Butylbenzyl Phthalate**		Phthalates	municipal/urban, industrial/military	µg/L	18	38		**18**
84-74-2	**Di-n-Butyl Phthalate**		Phthalates	municipal/urban, industrial/military	µg/L	27	102		**27**
84-66-2	**Diethyl Phthalate**		Phthalates	municipal/urban, industrial/military	µg/L	59	2139		**59**
131-11-3	**Dimethyl Phthalate**		Phthalates	municipal/urban, industrial/military	µg/L	3295	16500		**3295**

Notes and Definitions

USEPA = United States Environmental Protection Agency
-- indicates value is unavailble
CASRN = Chemical Abstract Service Registration Number
µg/L= micrograms of COPEC per liter of water
ESV = Ecological Screening Value
Bold Red indicates the COPEC is bioaccumulative

[1] USEPA National Recommended Water Quality Criteria from supplemental ERAGs [128]
[2] Retrieved from Boudjelleba et al., 2016
[3] Summed contaminants with variable bioaccumulation potentials
[4] Retrieved from Conder et al., 2019
[5] Based on photoinduced toxicity of crude oil to ELS speckled seatrout [185] & red drum [186]
[6] Based on phototoxic NOEC for early life stage mysid shrimp [187]
[7] Value is equivalent to the USEPA Saltwater RSV divided by an uncertainty factor of 10

EXPOSURE ASSESSMENT

To evaluate the potential for COPECs to occur in effluent and receiving waters near the Harbor Island facility outfall, data on the presence/concentrations of COPECs released from existing SWRO facilities were used as surrogate values. This data was augmented by contaminant data collected as part of local field monitoring studies conducted by the National Oceanic and Atmospheric Administration (NOAA).

Chemicals Added During SWRO

Studies conducted at existing SWRO facilities report free residual chlorine near outfalls at concentrations ranging from 70 to 500 µg/L, with concentrations between 20–180 µg/L measured in mixing zone water.[47, 51] These concentrations exceed both the acute and chronic saltwater screening values for the protection of aquatic life established by the US Environmental Protection Agency (Tables 2-3).[127, 128] Of the THMs formed at the outfall of SWRO facilities, bromoform and chloroform tend to be the most commonly occurring.[47, 49, 51, 104] To our knowledge, the TCEQ permit application submitted by the POCC does not identify expected concentrations of free residual chlorine or halogenated disinfection byproducts; however, TCEQ establishes maximum allowable levels (MALs) for a number of COPECs in the draft permit. [1, 2] Given that several modeling parameters, as well as the ability of the diffuser design to meet the TCEQ MALs have been called into question by recent expert testimony, the MALs appear to provide a reasonable numerical starting point with which to evaluate potential exposure to some of the more prevalent SWRO additives.

Saeed et al.[129] reported concentrations of bromoform in SWRO effluent, as well as in paired water and sediment samples collected from the mixing zone and intake sites at existing facilities. These values can be used to numerically estimate the degree to which bromoform present in SWRO effluent can be expected to accumulate in abiotic media present in receiving waters over time. When the TCEQ maximum allowable effluent concentration for bromoform (presented in the draft permit) is multiplied by the accumulation factors estimated using the Saeed et al.[129] data, we find that the even the low range of predicted sediment concentrations for most COPECs evaluated exceed the USEPA's chronic ecological screening level values for the protection of marine/estuarine aquatic life (Table 4).[128]

The study authors also measured concentrations of four metals (iron, nickel, copper, and chromium) in water, sediment, and fish tissues collected near SWRO intake and outfall sites (Table 4).[129] These metals were selected for analysis based on their status as known chemical additives (iron) and/or their frequency of detection in SWRO effluents at operation facilities. Paired intake and outfall values for each media type were similarly used to estimate accumulation factors of these metals over time. Results suggest that long term discharge of SWRO effluent may lead to concentrations of nickel, copper and chromium in environmental media that exceed ESVs established by the USEPA for the protection of saltwater aquatic life (Table 4). A range of predicted iron concentrations were also estimated using this approach; however, the USEPA has not established recommended screening values for iron in saltwater. Although the lack of a screening value for iron makes it more difficult to evaluate potential direct toxic effects of iron to aquatic biota, studies have shown that excessive release of iron in SWRO effluent may lead to adverse effects on aquatic biota via indirect mechanisms. Effects of other COPECs added during the SWRO process, including phosphate-based antiscalants, have also been shown to lead to adverse effects via indirect mechanisms. In accordance with standard ERA practice (as dictated by USEPA ERAGs) the potential for these COPECs to cause adverse effects on ecological receptors should not be discounted based on a lack of screening values. Therefore, potential risk associated with these COPECs remains a source of uncertainty for the proposed facility, although they will be qualitatively evaluated to the extent possible in the Effects Assessment portion of the present evaluation.

Cumulatively, these findings suggest that receptors of potential concern may experience meaningful exposure to COPECs added or generated as part of the SWRO process itself. Therefore, potential effects of free residual chlorine, THMs, and indirect effects of antiscalants and coagulants will be carried forward for further evaluation.

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Table 4. Range of mean COPEC concentrations reported in environmental samples collected near exisiting SWRO facilities and/or their paired intake sites. "Relative Increase at Outfall" represents the relative degree to which the process of SWRO has been shown to concentrate and redistribute low level environmental contamination present at the intake site. "Accumulation Factors" represent the relative degree to which COPECs present in effluent may accumulate in water, sediment and biota near the outfall over time. Accumulation factors (calculated using data collected at operational SWRO facilities) were then used to estimate a range of COPEC concentrations that may accumulate in water and sediment at Harbor Island over time, assumuing effluent concentrations are equivalent to the maximum allowable levels in the Harbor Island draft permit. **Bold red text** indicates that the COPEC is predicted to exceed USEPA's ecological screening values established for the protection of marine/estuarine aquatic life over time, assuming similar parameters at the Harbor Island facility.

CASRN	COPEC	Medium		Mean in Effluent	Mean in Mixing Zone	Mean at Intake Site	Relative Increase at Outfall [mixing zone] / [intake]	Mixing Zone Accumulation Factors [media] / [effluent]	TCEQ MAL HI Effluent [a]	Predicted Concentration in Media at HI [MAL] * Accumulation Factor		Ecological Screening		
				Low High	Low High	Low High	Low High	Low High		Low High		ESV [b]	Exceed Low [Predicted]	Exceed High [Predicted]
7439-89-6	Iron	Water	µg/L	14 - 25	25 - 27	0.01 - 5.5	5 - 2700	1 - 2	7,000	7,000 - 13,500		--		
		Sediment	mg/kg*		2590 - 2639	230 - 287	9 - 11	103,600 - 188,500		725,200,000 - 1,319,500,000		--		
		Fish muscle	mg/kg*		4.3 - 9.3	3.73 - 8.39	1 - 2	172 - 664		1,204,000 - 4,650,000		--		
		Fish liver	mg/kg*		11.98 - 41.6	12.99 - 39	0 - 3	479 - 2,971		3,354,400 - 20,800,000		--		
7440-02-0	Nickel	Water	µg/L	*0.05 - 0.05*	0.1 - 1.5	*0.05 - 0.05*	2 - 30	2 - 30	2	4 - 60		8.2	NO	YES
		Sediment	mg/kg*		10 - 14	4 - 8	0 - 9	200,000 - 280,000		400,000 - 560,000		15.9	YES	YES
		Fish muscle	mg/kg*		0.2 - 1.73	0.2 - 1.69	0 - 1	4,000 - 34,600		8,000 - 69,200		--		
		Fish liver	mg/kg*		0.96 - 1.04	0.89 - 3.86	1 - 4	19,200 - 20,800		38,400 - 41,600		--		
7440-50-8	Copper	Water	µg/L	0.1 - 0.3	2 - 5	1 - 3	1 - 5	7 - 50	2	13 - 100		3.1	YES	YES
		Sediment	mg/kg*		0.36 - 0.48	1 - 1.8	1 - 2	1,200 - 4,800		2,400 - 9,600		18.7	YES	YES
		Fish muscle	mg/kg*		3.1 - 14	0.32 - 0.4	0 - 5	10,333 - 140,000		20,667 - 280,000		--		
		Fish liver	mg/kg*		13 - 15	2.9 - 12.81	7 - 15	43,333 - 150,000		86,667 - 300,000		--		
7440-47-3	Chromium [c]	Water	µg/L	*0.05 - 0.05*	1 - 2	*0.05 - 0.05*	20 - 40	20 - 40	3	60 - 120		103	YES	YES
		Sediment	mg/kg*		10.2 - 15.4	3 - 4.5	2 - 5	204,000 - 308,000		612,000 - 924,000		52.3	YES	YES
		Fish muscle	mg/kg*		0.001 - 0.001	*0.0005 - 0.0005*	2 - 2	20 - 20		60 - 60		--		
		Fish liver	mg/kg*		*0.0005* - 0.001	*0.0005* - 0.001	1 - 2	10 - 20		30 - 60		--		
75-25-2	Bromoform [d]	Water	µg/L	25 - 35	22 - 28	1 - 1	22 - 28	1 - 1	10	6 - 11		18.5	NO	NO
		Sediment	mg/kg*		0.32 - 0.39	0.03 - 0.03	13 - 15	9 - 15		91 - 154		223	YES	YES

Notes and Definitions:

Italicized values respresent non-detects estimated as 1/2 the COPEC's detection limit [4,5,128]

-- value not available

µg/L - micrograms of COPEC per liter of water

mg/kg - milligrams of COPEC per dry weight kilogram of sediment or tissue

HI - Harbor Island

ESV - Ecological screening value

* dry weight

[a] According to the Harbor Island Draft Permit

[b] USEPA Ecological Screening Values for seawater and marine sediments (Tables 2 & 3) [128]

[c] Value for Chromium III used for saltwater ESV. Total chromium ESV used for sediment.

[d] Bromoform was the primary THM detected at all sites

Chemicals Present in Intake Media

Texas has historically discharged more toxic chemicals into the GoM than any other Gulf state, thus it is reasonable to expect that intake media will contain at least some degree of background contamination.[19] Field data collected by the USEPA's Environmental Monitoring and Assessment Program (EMAP) from 1991- 2006 revealed that concentrations of PAHs and polychlorinated biphenyls (PCBs) in estuarine sediments throughout the GoM exceeded sediment quality guidelines that are used to predict toxicological risks to aquatic biota.[14, 15, 19] This includes the bays of the Texas Coastal Bend, whose sediment quality ratings were considered poor, with estuarine quality similarly rated as poor for 38% of areas.[130] Accordingly, fish from impacted estuarine/nearshore habitats in Texas and Louisiana alone accounted for 89% of contaminant associated gross pathologies observed.[14, 15]

Concentrations of sediment associated COPECs at the proposed intake site are presently unavailable; however, NOAA's National Status and Trends Program maintains a searchable ecotoxicological database that contains the results of the agency's sediment and tissue monitoring efforts.[131] Data on COPECs present in sediment, oysters, and fish liver were available for the Corpus Christi, Aransas, and Copano Bays. Data for a subset of COPECs known to be prevalent in the GoM were analyzed for each medium, including dioxins/furans, PCBs, metals, organochlorine (OC) pesticides, and PAHs. JMP (version 14.2) was used to generate summary statistics for local data, which informed the present evaluation (Table 5).

Results indicate that constituents from each of the contaminant classes included in the analysis occur with a high frequency and abundance in local bays. Where paired sediment and tissue data were available for COPECs, tissue concentrations typically exceeded those present in sediments, indicating that many of these COPECs are bioavailable and present in the local food web (Table 5). Thus, the potential for intake, concentration, and redistribution of these COPECs to the CCSC and proximal habitat via SWRO effluent exists. Results for each class of contaminants are discussed in their respective sections below.

Metals

The maximum detected sediment concentrations of arsenic, copper, chromium, nickel, zinc, and lead all exceeded USEPA ESV's, although mean predicated concentrations did not (Table 5). Mercury and Cadmium were present at levels just below their ESVs, indicating that even small increases in the concentrations of these COPECs via SWRO effluent may have implications for the health of aquatic biota. Co-occurring metals were ubiquitously detected in sediment samples, indicating that local aquatic biota are likely to experience simultaneous exposure to multiple metals. Given the findings of previous studies (described previously), the SWRO process is expected to contribute an additional degree of metals contamination to the CCSC. Thus, it is reasonable to suggest that facility operations may lead to mean sediment concentrations of these metals that exceed ESVs over time (i.e., present a potential risk to ecological receptors).

Polychlorinated Biphenyls

Mean total PCBs in sediments were approximately equivalent to/very slightly exceeded sediment ESVs (Table 5), indicating that exposure to PCBs may already pose a risk to sensitive receptors at some locations. Detection frequencies were congener-dependent, with more persistent congeners demonstrating detection rates as high as 96%. Given the mean concentration and high frequency of detection, it is reasonable to suggest that media at the intake site may be impacted by PCB contamination, potentially leading to their redistribution to the CCSC via SWRO effluent. Consequently, PCBs are considered a likely risk to ecological receptors in proximity to the outfall.

Organochlorine Pesticides

Mean sediment concentrations of aldrin, dieldrin and total dichloro-diphenyl-trichloroethanes (DDTs) also exceeded sediment ESVs, with detection frequencies ranging between 23% and 41% (Table 5). Though positive detections for these three COPECs occurred with a somewhat lower relative frequency in sediment samples, several other OC pesticides (which commonly co-occur) were detected with a frequency of up to 70%. Moreover, the maximum concentrations of two additional COPECs in this class also exceeded the sediment ESVs, introducing the potential for additive or potentiating effects (i.e., increasing overall risk). Given the number of COPECs that occur above ESVs in this class, along with the frequencies with which OC pesticides are detected in local bays, it is reasonable to suggest that impacted media present at the intake site may result in the presence of one or more of these COPECs in SWRO effluent.

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Table 5. Summary statistics for COPECs present in sediment, oyster, and fish liver samples from Corpus Christi, Aransas, and Copano Bays

CASRN	COPEC	UNITS (dw)	SEDIMENT N	SEDIMENT Detection Rate	SEDIMENT Mean [a]	SEDIMENT SD	SEDIMENT Max	ESV [b]	OYSTER N	OYSTER Detection Rate	OYSTER Mean [a]	OYSTER SD	OYSTER Max	FISH LIVER N	FISH LIVER Detection Rate	FISH LIVER Mean [a]	FISH LIVER SD	FISH LIVER Max
Dioxins/Furans and PCBs																		
132-64-9	Dibenzofuran	µg/kg	3	100%	2.03	2.22	4.60	231.3	11	100%	7.6	4.6	16.7					
1336-36-3	total PCBs	µg/kg	21	varies [c]	14.16	--	--	14	50	varies [c]	39.4	--	--	2	varies [c]	215.33	--	--
Metals																		
7439-97-6	Mercury	mg/kg	21	100%	0.04	0.03	0.11	0.13	57	100%	0.1	0.05	0.3	4	100%	0.5	0.2	0.8
7440-43-9	Cadmium	mg/kg	21	100%	0.27	0.18	0.61	0.68	57	100%	5.8	3.1	15.3	4	100%	1.1	1.0	2.6
7440-38-2	**Arsenic**	mg/kg	21	100%	4.6	1.67	8.5	**7.24**	57	100%	9.0	3.0	17.1	4	100%	8.1	2.4	10.5
7440-02-0	**Nickel**	mg/kg	21	100%	11.3	5.23	20.0	**15.9**	57	100%	1.8	0.9	4.4	4	100%	0.5	0.3	0.7
7440-50-8	**Copper**	mg/kg	21	100%	10.1	5.34	27.1	**18.7**	57	100%	153.1	85.9	339.0	4	100%	50.7	22.4	79.3
7440-47-3	**Chromium**	mg/kg	21	100%	36.7	11.75	60.7	**52.3**	57	82%	0.7	0.6	3.8	4	75%	0.0	0.0	0.0
7439-92-1	**Lead**	mg/kg	21	100%	18.9	13.85	72.1	**30.2**	57	100%	1.1	2.3	18.2	4	100%	0.1	0.0	0.1
7440-66-6	**Zinc**	mg/kg	18	100%	71.7	39.47	159.0	**124**	57	100%	2786.8	2060.6	7031.0	4	100%	126.1	6.8	133.7
	Mean total metals	mg/kg			153.6						2958.44					187.14		
Organochlorine (OC) Pesticides																		
1024-57-3	**Heptachlor Epoxide**	µg/kg	23	17%	0.13	0.18	0.4	**0.14**	51	63%	1.1	0.9	3.3	5	20%	0.3	--	0.3
76-44-8	Heptachlor	µg/kg	23	17%	0.21	0.31	0.7	1.5	53	38%	0.4	0.4	1.8					
60-57-1	Dieldrin	µg/kg	22	23%	0.26	0.34	0.8	0.1	50	92%	2.4	3.1	20.0	5	20%	3.3	--	3.3
2385-85-5	Mirex	µg/kg	23	35%	0.50	0.77	2.3	3.6	46	41%	0.5	0.5	2.0					
57-74-9	Chlordane	µg/kg	23	39%	0.99	0.37	2.6	2.7	56	96%	5.9	0.9	56.6	5	40%	4.9	2.0	6.3
309-00-2	Aldrin	µg/kg	20	40%	0.26	0.36	1.1	0.1	59	36%	1.4	1.5	5.0					
DDT	DDT	µg/kg	22	41%	0.77	0.02	3.0	0.7	49	69%	1.2	0.0	5.0	5	20%	3.3	--	3.3
DDE	DDE	µg/kg	23	70%	0.45	0.28	1.4	2.1	58	100%	3.5	1.4	15.0	5	100%	35.6	17.1	77.1
DDD	**DDD**	µg/kg	22	45%	0.94	0.66	4.7	**1.2**	51	88%	5.8	1.1	50.1	5	40%	23.2	5.7	33.1
DDx	**DDx**	µg/kg			2.16		9.1	**4.4**			10.5		70.0		--	62.1	--	113.5
	Mean total OC Pesticides	µg/kg			4.52						22.13					70.70		
Polycyclic Aromatic Hydrocarbons (PAHs)																		
90-12-0	1-Methylnaphthalene	µg/kg	8	50%	3.8	4.6	10.3		34	100%	9.5	5.9	24.1					
91-57-6	2-Methylnaphthalene	µg/kg	9	67%	4.8	5.8	16.3		35	100%	15.2	11.3	47.2					
83-32-9	Acenaphthene	µg/kg	8	38%	4.7	4.6	9.3		32	97%	6.7	5.7	24.2					
208-96-8	**Acenaphthylene**	µg/kg	8	63%	3.5	4.1	8.9	**6**	27	89%	4.0	3.1	10.9					
120-12-7	Anthracene	µg/kg	10	70%	25.2	42.9	118.1	47	31	100%	14.0	13.3	46.5					
56-55-3	**Benzo[a]anthracene**	µg/kg	11	73%	52.5	109.6	316	**75**	30	93%	29.7	36.6	147.1					
50-32-8	**Benzo[a]pyrene**	µg/kg	12	83%	57.5	125.9	399	**89**	34	76%	4.4	3.7	14.7					
205-99-2	**Benzo[b]fluoranthene**	µg/kg	10	90%	66.6	133.9	403	**190**	36	86%	15.2	16.2	56.0					
91-20-3	**Benzo[e]pyrene**	µg/kg	12	83%	33.3	66.2	211	**35**	35	86%	11.8	12.8	44.8					
191-24-2	**Benzo[g,h,i]perylene**	µg/kg	9	78%	50.0	90.0	240	**310**	29	76%	3.6	3.6	15.6					
207-08-9	Benzo[k]fluoranthene	µg/kg	9	78%	33.2	63.8	173	240	32	84%	10.9	15.9	61.7					

CASRN	COPEC	UNITS (dw)	SEDIMENT N	SEDIMENT Detection Rate	SEDIMENT Mean [a]	SEDIMENT SD	SEDIMENT Max	ESV [b]	OYSTER N	OYSTER Detection Rate	OYSTER Mean [a]	OYSTER SD	OYSTER Max	FISH LIVER N	FISH LIVER Detection Rate	FISH LIVER Mean [a]	FISH LIVER SD	FISH LIVER Max
218-01-9	**Chrysene**	µg/kg	12	75%	48.4	110	334	**108**	33	94%	42.9	54.9	231.3	Not Reported				
	Chrysenes (C1)	µg/kg	5	100%	48.0	75.1	176		35	37%	28.7	36.1	103.7					
	Chrysenes (C2)	µg/kg	5	80%	24.2	29.4	64.5		37	24%	33.0	40.0	110.9					
	Chrysenes (C3)	µg/kg	12	29%	12.7	13.8	22.4											
	Chrysenes (C4)	µg/kg	9	43%	17.1	13.2	26.6											
53-70-3	**Dibenzo[a,h]anthracene**	µg/kg	10	70%	14.4	23.0	63.7	**6**	29	59%	1.1	0.8	2.6					
206-44-0	**Fluoranthene**	µg/kg	12	75%	90.6	169.2	514	**113**	31	100%	89.8	99.7	340.0					
	Fluoranth/Pyrenes (C1)	µg/kg	12	100%	46.5	72.5	180		39	56%	76.2	86.6	286.6					
	Fluoranth/Pyrenes (C2)	µg/kg	12	100%	33.7	55.9	98											
	Fluoranth/Pyrenes (C3)	µg/kg	12	33%	39.8	--	40											
86-73-7	**Fluorene**	µg/kg	9	44%	3.9	4.2	9	21	30	100%	8.3	6.8	28.2					
	Fluorenes (C1)	µg/kg	9	57%	3.4	2.9	7		31	65%	13.7	13.1	56.5					
	Fluorenes (C2)	µg/kg	9	71%	6.7	5.8	16		41	51%	47.6	71.6	265.8					
	Fluorenes (C3)	µg/kg	9	57%	12.7	9.7	23		42	38%	108.8	166.1	577.3					
193-39-5	Indeno[1,2,3-cd]pyrene	µg/kg	10	80%	52.7	109.9	315	340	29	72%	3.4	3.9	13.5					
91-20-3	**Naphthalene**	µg/kg	9	78%	10.3	16	46.3	**35**	38	100%	14.6	7.4	33.3					
	Naphthalenes (C1)	µg/kg	9	100%	3.1	2.3	5.3		28	100%	23.3	16.2	68.7					
	Naphthalenes (C2)	µg/kg	9	100%	3.5	2.9	9.3		29	79%	22.2	14.7	59.6					
	Naphthalenes (C3)	µg/kg	9	100%	6.5	4.9	15.6		30	70%	34.9	36.0	158.6					
	Naphthalenes (C4)	µg/kg	9	71%	5.9	4.8	14.1		28	50%	62.2	80.2	273.3					
198-55-0	Perylene	µg/kg	12	83%	17.9	25.6	84.9		25	80%	5.6	5.6	18.9					
85-01-8	**Phenanthrene**	µg/kg	12	75%	55.1	113.8	346.7	**87**	40	100%	34.7	37.3	153.8					
	Phenan/Anthracenes (C1)	µg/kg	12	100%	16.2	27.6	74.3		29	76%	51.2	76.0	370.5					
	Phenan/Anthracenes (C2)	µg/kg	12	86%	16.9	26.1	65.8		32	75%	83.0	166.9	794.2					
	Phenan/Anthracenes (C3)	µg/kg	12	86%	12.2	15.2	36.2		39	46%	123.6	235.5	735.1					
	Phenan/Anthracenes (C4)	µg/kg	12	71%	7.9	8.4	17.7		39	31%	106.6	167.5	453.1					
129-00-0	**Pyrene**	µg/kg	12	92%	78.6	145.5	461	**153**	31	100%	56.4	63.0	241.2					
	Mean total PAHs				1023.9	--	--	1197			1196.6							

Notes and Definitions

COPEC - contaminant of potential environmental concern
CASRN - chemical abstract service registration number
SD - standard deviation
N - number of samples tested
mg/kg - milligram of COPEC per kilogram of sediment
µg/kg - microgram of COPEC per kilogram of sediment
dw - dry weight
ESV - Ecological Screening Value

PAH - Polycyclic aromatic hydrocarbons
PCB - polychlorinated biphenyl
Bold red - current levels may be sufficient to exert toxic effects
Bold black- maximum measured concentrations exceed ESV
[a] Mean concentration of positive detections
[b] Per USEPA ERAGS, the maximum is used when 10 or fewer data points are available [128]
[c] Congener dependent detection rates: sediment, 15 - 96%; oyster, 20 - 100%; fish liver, 50 - 100%

Polycyclic Aromatic Hydrocarbons (PAHs)

Data for 38 PAHs were reported for Corpus Christi, Aransas and Copano bays, with summary statistics revealing an estimated mean sum concentration (i.e., $tPAH_{38}$) of approximately 1,024 - µg/kg in sediment samples (Table 5). Of note, these concentrations represent those present in local sediments prior to the *Deepwater Horizon* oil spill in 2011, which released enormous quantities of PAHs into the GoM. This is of note, as recalcitrant PAHs have been shown to contaminate sediments decades after an oil spell (i.e., long after water returns to background concentrations).[132, 133]

The USEPA provides sediment ESVs for sixteen of the PAHs included in NOAA's database. Concentrations of nearly all of these PAHs exceed their sediment ESVs in local bays. Maximum concentrations of eleven compounds exceeded their sediment ESVs, with two more (anthracene and dibenzo[a,h]anthracene) present at sufficiently high mean concentrations to exceed ESVs. Co-occurring PAHs were detected ubiquitously in sediment samples, which is unsurprising given that all of these compounds are constituents of crude oil (the extraction, refinement, and transport of which constitutes a considerable proportion of local industry). These findings, combined with the frequency and scale of oil spills/accidental releases that impact the Texas Gulf Coast annually, the historical use of the proposed site (i.e., former Tank Terminal), and ongoing extensive vessel traffic in the CCSC, indicate that oil-related contamination will almost certainly be present in facility effluent to some degree. Thus, this class of COPECs is expected to be one of the key drivers of ecological risk associated with the proposed facility, despite the following assertion put forth in the TCEQ draft permit/application.[1, 14, 19, 43, 44, 55-59, 98, 132, 134-136]

> "A priority watershed of critical concern has been identified in Segment No. e48r in Nueces County. The piping plover, *Charadrius melodus*, a threatened aquatic-dependent species, has been determined to occur in the watershed of Segment No. z48r; <u>however, the facility is not a petroleum facility and its discharge is not expected to have an effect on the piping plover</u>."

According to desalination experts at the World Health Organization (WHO), there is "a significant potential for anthropogenic contamination of source waters, <u>particularly seawater and estuarine waters</u>" to be present in RO membrane reject (a major constituent of SWRO effluent that would be released into the CCSC).[44] The WHO also explicitly states that there is "a significant potential for contamination by petroleum hydrocarbons, <u>particularly in regions where there is substantial oil extraction activity</u>," such as the Corpus Christi area and elsewhere along the Texas Coast. Additional scientific studies also report the presence of source contamination in SWRO effluent, in support of the WHO's findings.[3, 14, 19, 44, 60, 106]

Pharmaceuticals and Personal Care Products

Pharmaceuticals and their biotransformation/degradation product are continually discharged by wastewater treatment facilities, often leading to a state of pseudo-persistence for widely prescribed compounds.[110, 137, 138] Pharmaceuticals are generally present at lower concentrations in the marine environment relative to other types of environmental contaminants.[108, 110, 139] However, due to their potency and specificity, environmentally relevant concentrations of a growing number of pharmaceuticals are being found to exceed effects concentrations in non-target aquatic biota, particularly when exposure occurs during development.[137, 140-143]

Despite their confirmed prevalence in the freshwater environment, studies rarely characterize the presence of pharmaceutical compounds in saltwater systems.[130, 144] Nevertheless, the available data show the presence of over a hundred pharmaceuticals in coastal water and sediment samples at measurable concentrations, the majority of which exceed previously predicted environmental concentrations.[144, 145] Antibiotics, hypertension medications, painkillers, and certain synthetic sex steroids have been identified as pharmaceuticals present in nearshore sediment and water samples with the highest frequency and abundance (up to 2,000 mg/kg wet weight in some instances), particularly in samples collected in proximity to urbanized coastal areas that receive effluent from wastewater treatment plants (like the Corpus Christi bay complex). Many of these compounds are thought to pose an important ecotoxicological risk to biota in estuarine systems, as they're routinely measured at concentrations exceeding their known 50% effect concentrations for aquatic organisms.[111, 144, 146]

With regard to SWRO operations, the potential presence of synthetic sex steroids (including their metabolically active degradation/transformation products) in effluent is of particular concern, as many of these widely prescribed

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compounds are known to be potent endocrine disruptors. The synthetic sex steroid 17 α-ethinylestradiol (EE2) is currently the most abundant synthetic steroid detected in estuarine/marine systems, with studies reporting concentrations of up to 0.130 mg/kg (or 130,000 ng/kg) in sediment and 38 ng/L in water samples. [144, 147, 148] As with other COPECs of comparable size that are commonly present as source contamination, the SWRO process may result in the redistribution of EE2 and other sex steroids/metabolites to the CCSC and surrounding aquatic habitats. As current data suggest that estuarine receptors in proximity to urban centers (like Corpus Christi) experience at least some degree of ongoing low-level exposure to EE2, remobilization of this compound to the CCSC is likely to exacerbate existing exposure scenarios for local aquatic biota.

To our knowledge, there are no data describing current environmental concentrations of EE2 or other synthetic sex steroids in the Corpus Christi bay complex. Similarly, the sensitivity of local aquatic receptors of potential concern has not yet been evaluated for these COPECs. However, laboratory studies using small bodied fish models have observed reproductive toxicity following waterborne exposure to concentrations of EE2 as low as 2 ng/L.[147, 148] These remarkably low effect concentrations are further supported by the results of field studies, with one particularly robust multi-year whole lake study reporting a complete population collapse (driven by male intersex/feminization) of a prevalent small bodied fish species following chronic exposure to only 5 ng/L EE2.[149] Though direct reproductive toxicity is likely to occur at higher (albeit, still in the ng/L range) EE2 exposure concentrations for larger aquatic biota, it is important to note that direct effects on the reproduction of low trophic level organisms (e.g., small bodied prey fish) can have important downstream implications for food abundance, food web structure and/or community composition. Thus, even seemingly negligible increases in exposure (on the order of a single ng/L) of EE2 and/or related compounds can be sufficient to cause ecosystem-wide impacts.

The ecotoxicological risks associated with the potential presence of synthetic sex steroids in SWRO effluent are also not expected to be confined to habitat in the immediate vicinity of the outfall, due to a combination of factors. For example, many of these compounds degrade relatively slowly in the marine environment, during which time they're known to be transported miles away from point sources of emission.[111, 144, 147, 148, 150, 151] Moreover, other industrial compounds present in local bay systems that are likely to be present in SWRO effluent (e.g., PCBs, OC pesticides, phthalates, PAHs) are also known to exhibit estrogenic activity (i.e., act as endocrine disruptors) in aquatic receptors. The prevalence and abundance of many of these compounds in local bays indicate that there is a high potential for multiple endocrine disrupting compounds to be simultaneously present in SWRO effluent at any given point in time. Consequently, there exists a high potential for additive or more than additive effects on the reproductive success of local aquatic biota.

The scarcity of toxicity reference values (TRVs) for estuarine biota combined with the lack of site-specific data on the presence of pharmaceuticals in environmental media near the intake site precludes a quantitative or semi-quantitative evaluation of the potential risk that these compounds may pose to aquatic and aquatic-dependent wildlife (therefore, pharmaceuticals and personal care products are not included in Tables 2 - 3). However, given the high level of urbanization surrounding the Corpus Christi Bay complex, SWRO operations are almost certain to lead to some (additional) degree of chronic exposure for biota in proximity to the outfall. Because of the high ecological value of the habitat (particularly for ELS and T&E aquatic biota), the high potential for mixture interactions that modify toxicity (particularly when multiple compounds with similar modes of action are present), the long water residence time in the area, the intended potency of these COPECs, and the propensity for highly prevalent pharmaceuticals to act as endocrine disruptors and/or reproductive toxicants in non-target aquatic organisms, the potential ecotoxicological effects of this large group of COPECs should not be discounted.[110, 144, 152, 153] Therefore, potential adverse effects of pharmaceutical exposure in effluent remains an additional source of uncertainty for the proposed project.

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EFFECTS ASSESSMENT & RISK ESTIMATION

Chronic exposure to mixtures of COPECs that exert sublethal effects (e.g., reduced reproductive capacity/biomass, developmental abnormalities) are typically expected to drive ecotoxicological risk for sensitive receptors at sites of this nature (i.e., sites where effluent is discharged under an NPDES permit), rather than acute mortality from single COPEC exposures.[4, 88, 89, 154-164] Adverse effects may occur through either direct toxic mechanisms or through indirect pathways. For example, COPECs that exert direct toxic effects on the reproduction of low trophic level organisms may lead to a decreased availability of prey that indirectly impacts higher trophic level biota by preventing them from meeting energetic needs. [88, 89, 154, 160-164]

Unfortunately, there remains a paucity of data describing the sublethal effects of chronic exposure to whole SWRO effluent on aquatic and aquatic-dependent receptors, as the majority of laboratory studies on this topic report short term mortality following acute exposures to high salinity conditions.[45, 46] Field studies examining the effects of SWRO effluent tend to be highly qualitative in nature, lack replication/reproducibility, are conducted at already-degraded sites, and/or report analytical data for only very limited number of physical/chemical parameters. Despite these data gaps, results of studies at other SWRO discharge sites provide sufficient evidence to suggest that SWRO effluent may present serious ecotoxicological risks to sensitive aquatic biota that rely on the CCSC and proximal habitats to complete key life processes, with implications for biodiversity and community structure.[44, 50, 97, 98, 136, 165]

It is also important to note that a number of sources explicitly state that the ecological impacts of SWRO operations are expected to be amplified at estuarine discharge sites that experience low rates of water exchange and poor flushing, such as the bay complex connected to the GoM via the CCSC.[45, 46, 49, 136] The aforementioned conditions are also known to further facilitate the accumulation of a variety of COPECs (e.g., metals, OC pesticides, PCBs, PAHs), which may contribute to the intensified effects observed in such systems. [10, 44, 50, 98, 136, 165]

In the present evaluation, assessment endpoints were selected based on a combination of factors, including the overall potential for exposure and the expected sensitivity of the receptor. The modest amount of toxicity data available for receptors of potential concern exposed to whole SWRO effluent is briefly reviewed below by receptor type. However, due to the scarcity of whole effluent data, it was necessary to perform much of the remaining evaluation using an approach that considers COPECs individually. Due to the large number of chemicals that were identified as potential COPECs, those that are expected to be present in effluent as a result of the SWRO process itself and those that are known to be present in local environmental media above the USEPA's (2018) Marine/Estuarine Sediment ESVs and the Chronic Saltwater ESVs were prioritized for evaluation. Potential effects of these COPECs on previously identified receptors of potential concern are discussed below in their respective sections.

Benthic Assemblages

Benthic organisms are responsible for a number of critical roles that maintain the health of estuarine systems, including recycling organic detritus, redistributing sediments, promoting bacterial transformation in the sub-surface, and facilitating recruitment of other ELS organisms through ecosystem engineering processes that modify the benthos/create habitat.[26, 45, 46, 130, 166] Energy transfer from the benthos also supports estuarine food webs, with microphytobenthic organisms serving as primary producers and other benthic infaunal and epifaunal organisms acting as key dietary items for a variety of aquatic consumers and aquatic dependent wildlife (e.g., shorebirds and waterfowl), while also acting as a vector of contaminant mobilization from the sediment into the food web . [50, 51 166] Because contamination of and/or adverse effects on benthic assemblages can have important ecosystem-wide implications for food availability, habitat creation, recruitment of ELS biota, and trophic transfer of contaminants, impacts of SWRO effluent on benthic community structure was determined to be an important assessment endpoint for the proposed facility.

Changes in benthic assemblages are regarded as a sensitive measure of sediment contamination, due to the sustained and direct exposure to lipophilic contaminants that many of these organisms experience via multiple routes.[3, 45, 46, 98, 167] Moreover, more than 20% of benthic communities along the Gulf coast are estimated to be already degraded by sediment contamination and hypoxia, with habitat near urban and industrial centers exhibiting the most severe

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impacts.[14, 15, 19, 130] Thus, additional co-stressors associated with SWRO operations may lead to disproportionately intense effects if benthic communities are already approaching their tolerance threshold.

These findings are highly relevant to the proposed project, as SWRO operations are known to contribute an additional degree of contamination to aquatic sediments and exacerbate hypoxia, particularly in enclosed bays and estuaries like the Corpus Christi bay complex.[15, 19, 48, 49, 96, 97, 130] Community level effects of SWRO effluent reported in the literature include a complete absence of some (previously abundant) benthic micro- and macrofaunal organisms, altered species composition, and reduced benthic biodiversity. [3, 45, 46, 52, 98, 167, 168] These adverse outcomes have been attributed to a combination of very mild increases in salinity (on the order of a few ppm or less) in combination with effluent borne COPECs, with impacts typically decreasing in severity as distance from the outfall increases.[3, 41, 45, 46, 49, 52, 54, 96, 97, 168] Based on the number of studies reporting direct impacts of whole SWRO effluent on benthic assemblages at relatively low exposure concentrations, the Harbor Island facility is likely to pose a considerable risk to benthic assemblages near the outfall.

Seagrasses

Seagrasses are known to be particularly sensitive to habitat disturbances, including physical disturbances, nutrient loading, and pollution. Consequently, their biomass and productivity serves as a key indicator of the extent to which anthropogenic impacts are degrading the health of estuarine systems.[14, 15, 41, 169] Seagrass coverage in the GoM has been steadily declining for decades, with location-dependent differences in the severity of habitat loss that range from 20% to 100%.[12, 14, 15, 22] In fact, surveys conducted by NOAA and EPA found that 95% of all remaining seagrass coverage in the GoM was located within just two coastal habitats, one of which is the Laguna Madre/Copano-Aransas area (including Harbor Island).[12, 14, 15, 22] Despite constituting a significant portion of the Gulf's remaining seagrass coverage, landscape analyses indicate that local seagrass coverage is also in decline, with significant losses reported for Harbor Island.[13]

Moreover, SAV beds have been designated as essential fish habitat (EFH) by all three Gulf State regional fishery management councils,[b] with others classifying them as "Habitat Areas of Particular Concern" (a special designation of EFH reserved for ecologically valuable, rare, and at-risk habitats).[25, 169] These habitats serve as vital nursery/breeding grounds for many species of economically and ecologically important fishes and invertebrates, and also support several species of T&E waterfowl and sea turtles. Aquatic vegetation also influences important physical processes that are needed to maintain the health of estuarine systems, including nutrient and contaminant cycling, erosion control, and water quality maintenance.[12, 16, 24] Therefore, potential effects on the growth and biomass of SAV represent important assessment endpoints for the present ERA.

The literature identifies aquatic plants as being among most sensitive receptors with regards to prolonged SWRO effluent exposure.[3, 41, 45, 46, 54, 98, 100, 101, 170] Adverse effects of SWRO effluent on SAV include reduced growth, shoot abundance, length, survival and biomass, altered community structure, and increased occurrence of necrotic lesions and epiphytes. [3, 48, 54, 100, 101, 170] Severity of effects decreased with increasing distance from the outfall, and impacts were present even when changes to salinity were negligible (i.e., less than 3 ppt). [3, 98-101, 106] Where impacts on salinity were observed, the severity of effects could not be explained by hypersaline conditions alone.[3, 48, 54, 100, 101, 170] Cumulatively, these findings indicate that COPECs in effluent are likely to be an important determinant of the degree of impacts to SAV habitats in proximity to the outfall. [54, 98, 100, 101, 170]

Given the high ecological value of the habitat provided by this already stressed receptor, the demonstrated sensitivity of SAV to SWRO effluent and the low rate of water exchange/flushing in the area (which is expected to amplify adverse effects), the Harbor Island facility is likely to pose a considerable risk to the biomass and growth of SAV in proximity to the facility/outfall.

Early Life Stage Fish & Shellfish

It is widely accepted that ELS organisms, regardless of taxa, demonstrate increased sensitivity to the adverse effects of toxicant exposures, as well as to other types of environmental stressors.[141, 170-179] Thus, reduced survival of embryo-larval stages of estuarine and estuarine-dependent fish and shellfish are considered an important ERA assessment endpoint for the proposed Harbor Island facility. A modest number of studies have examined the toxicity of desalination effluent to developing aquatic biota; however, studies tend to be acute in nature, use invertebrate freshwater or marine (i.e., not

[b] Under the Magnuson-Stevens Act, EFH is "...waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity."

estuarine models), and focus largely on the toxic effects of hypersalinity.[3, 41, 42, 45, 46, 48-50, 53, 54, 96, 100, 101, 170] Furthermore, few studies have addressed sublethal impacts of whole desalination effluent on developing organisms, with laboratory studies focusing on mortality following single constituent exposures.[180, 181] The small number of studies that have investigated the effects of whole effluent exposure on ELS fish and shellfish report impacts on the growth, hatching success, survival, behavior, and immune function.[3, 182]

In acute toxicity tests involving exposure to THMs, ELS shellfish demonstrated considerable sensitivity to brominated THMs relative to other test species, with an acute LC_{50} for chloroform and bromoform of approximately 1,000 µg/L. However, these organisms demonstrated a stress response at much lower exposure concentrations and other sublethal effects were not investigated.[3, 46, 98, 99] Moreover, the study authors found accumulation of some THMs in study organisms, indicating the potential for latent sublethal effects that may impact fitness and survival. It has been suggested that chronic THM exposure may lead to effects at much lower exposure concentrations; however, chronic TRVs have not yet been established for ELS aquatic organisms exposed to THMs.[3, 46, 98, 99]

PAHs are a highly toxic and lipophilic component of crude oil that readily bioaccumulate in aquatic biota that come into contact with impacted water and sediment.[87, 133, 183, 184] A subset of PAHs are photodynamic and can absorb energy from certain wavelengths of solar radiation (typically in the ultraviolet [UV] wavelengths). This is of toxicological significance, as ELS organisms often lack complete pigmentation, thus allowing penetrating UV to interact with PAHs present in their tissues.[87, 133, 184, 185] Many estuarine and estuarine-dependent fish and shellfish species that are native to local bays and estuaries exhibit positively phototactic behaviors during early life stages, which exposes them to intense incident UV radiation during the summer months in the GoM.[87, 133, 183, 184, 186] When ELS biota are co-exposed to intense UV and photodynamic PAHs, reactive oxygen species (ROS) are rapidly generated, leading to oxidation of biomolecules and severe tissue damage at exposure concentrations well below those known to exert toxicity via other mechanisms.[87, 133, 183-185, 187] Thus, transparent/translucent ELS aquatic biota are vulnerable to the effects of photo-induced toxicity, particularly in areas with naturally occurring oil seeps or known anthropogenic sources of oil (e.g., the Texas coast).[171, 188]

As previously stated, the CCSC functions as a critical migratory corridor for a number of regionally important estuarine-dependent fish and shellfish species that rely upon local shallow water habitats (e.g., estuaries, bays, lagoons, passes) to carry out life history processes essential to their survival (e.g., spawning, development, foraging). Many species of adult estuarine-dependent fish species spawn offshore, with embryo-larval stages of offspring passively transported via coastal/tidal currents to protected nursery grounds, where they remain through the juvenile/sub-adult stage.[10, 34, 189] As such, a large proportion of the local ELS fish and shellfish population drift through the CCSC every spawning season, where the (tidally-influenced) outfall will also be located, making exposure to effluent highly probable.[1, 2]

Given the near certain likelihood of at least some degree of PAH contamination near the intake (Table 5), the molecular weight of photodynamic PAHs, and the findings of the WHO regarding the presence of petroleum contamination in SWRO effluent, it is reasonable to assume that PAHs will be present in effluent that is being routinely discharged into the CCSC. Red drum, speckled seatrout, blue crab and fiddler crab are known to utilize habitat in proximity to the outfall and all demonstrate considerable sensitivity to photo-induced toxicity. In fact, studies have shown that ELS red drum and speckled seatrout both experience significant mortality following waterborne exposures to less than one per billion (µg/L) $tPAH_{50}$ (i.e., the sum of 50 PAH analytes).[183, 184]

Moreover, fiddler crab larvae exposed to oiled sediments containing 1,197 µg/L $tPAH_{50}$ *in ovo* experienced significant mortality following exposure to UV after hatch in clean seawater, indicating that photo-induced toxicity may also have serious implications for survival of benthic biota with planktonic larval stages.[87] Monitoring data indicates that estimated mean sediment PAH concentrations were 1,024 µg/L for the sum of 38 PAHs (i.e., $tPAH_{38}$) in 2010. Though a direct comparison between the photo dynamicity of measured $tPAH_{50}$ and estimated $tPAH_{38}$ concentrations is not possible, it is reasonable to suggest that any additional inputs of PAHs to the CCSC (via SWRO effluent) may have significant impacts on the survival of ELS aquatic biota in proximity to the outfall.

Threatened & Endangered Receptors

Title 16, Section 1538 of the United States (US) Endangered Species Act (ESA) expressly forbids the *taking* (i.e., harassing, harming, pursuing, wounding, killing, or capturing) of any listed endangered species by all entities subject to U.S. jurisdiction (e.g., individuals, businesses, and government entities). The ESA also forbids Federal agencies from funding,

authorizing, or conducting any actions that may jeopardize the continued existence of a listed species by adversely modifying their designated critical habitat.[190] The ESA is also quite specific as to the definition of critical habitat; defining it as [b]:

> *"...the specific areas within the geographical area occupied by the species, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations."* [190]

From a biological perspective, the features that are considered essential to the conservation of T&E species include those needed to:

- Ensure successful reproduction
- Carry out key aspects of the species' life history
- Allow for typical behavior
- Allow for growth at the individual and population levels
- Meet the species' shelter, food, water, air, light, mineral, nutritional, or other physiological requirements
- Provide suitable habitat for breeding and rearing of offspring, germination, or seed dispersal
- Provide protection from disturbances
- Provide habitat that is representative of the species' historical, geographical, and ecological distribution

A number of Federal, State, and working group guidance documents underscore the importance of evaluating potential risk with an added level of conservativism when T&E species are present or potentially present at a site. [4, 7, 74, 191-194] Thus, the threshold for classifying ecological risk as "unacceptable" is considerably lower at sites that may provide critical habitat to T&E receptors [c]. The same is true for ecosystems with high conservation value, such as the MAE, NRE and the Aransas Pass system, which has been designated as an estuary of national significance (in addition to its classification as EFH under the Magnuson-Stevens Act).[6, 15, 53]

In instances where an ecological risk assessor must evaluate potential risk to T&E receptors/habitats of high conservation value, it is standard practice to use much more conservative parameters that afford additional protections.[4-7, 193-195] This practice is based on the premise that toxicants that reduce the reproductive capacity (a standard direct effects assessment endpoint for ERAs) of individual animals or the biomass/growth of standing crops of aquatic plants, are essentially exerting population level effects where T&E receptors are concerned, due to limited numbers/biomass of breeding age individuals and dwindling genetic diversity. [4, 74, 196] This added degree of conservatism is generally accomplished using the following approaches: [4, 6, 74, 75, 197, 198]

- Use of a No Observed Effect Concentration (NOEC) as the TRV for aquatic biota (in place of the Lowest Observed Effect Concentration (LOEC)
- Use of a No Observed Adverse Effect Level (NOAEL) as the TRV for aquatic-dependent wildlife (in place of the Lowest Observed Adverse Effect Level (LOAEL)
- Use of Uncertainty Factors in the derivation of TRVs, especially when incomplete toxicity data are available for a given COPEC
- Affording protection to individual organisms (rather than populations)
- For ecosystems of high conservation value, protection should be afforded to 95% to 100% of species present at the site
- Standard benchmark screening values should be used with great caution and toxicity values for the most sensitive species tested within the T&E receptor's taxonomic group should be used to evaluate risk
- COPEC screening is performed using the assumption that aquatic receptors (e.g., fish, aquatic invertebrates) exclusively and permanently occupy the water body being modeled for potential impacts

It is also important to note that regulatory precedent dictates that decision-making should be based on scenarios that are likely to overestimate (rather than underestimate) risk to T&E receptors when there are insufficient toxicity data/benchmark values available to confidently evaluate potential risk.[5, 6, 74, 193-195, 198] Table 1 identifies aquatic and aquatic-dependent T&E receptors that may occupy habitats in proximity to the proposed facility. Three species of T&E sea turtles (hawksbill, green, and Kemp's Ridley) and three avian T&E species (piping plover, whooping crane and reddish egret) were determined to be receptors with high risk profiles with regard to the proposed Harbor Island SWRO facility. This determination was made based on a combination of their habitat preferences, migratory habits, feeding guild, degree of dependence on local habitat, number of breeding age individuals remaining in the population, as well as the expected nature/composition of the facility's effluent (discussed further below).

Therefore, the potential ecotoxicological risk that the proposed project may present to the above identified T&E receptors should be extensively evaluated using reproduction and survival as assessment endpoints.[5, 74] Due to the degree of extrapolation that would be required to generate food web models for aquatic-dependent receptors in the absence of site-specific measured data, the remaining discussion will be qualitative in nature to avoid providing an erroneous estimation of risk.

Aquatic-Dependent T&E Receptors

As previously stated, the GoM provides critical habitat for a number of T&E shorebirds and waterfowl that forage for food in shallow and/or nearshore habitats.[35, 36] Aquatic dependent avian receptors, particularly non-migratory resident species, commonly exhibit some of the highest risk profiles at contaminated sites with impacted surface water. [5, 6, 74, 75, 199] This is due to a combination of factors, including their high site fidelity, relatively small home ranges, high food consumption rate, and habitat use strategies that lead to bioaccumulative COPEC exposure via multiple routes.[5, 6, 75] Piscivorous and/or omnivorous waterfowl/shorebirds are often concurrently exposed to COPECs through incidental ingestion of contaminated environmental media (e.g., water and sediment) and consumption of contaminated dietary items, with the latter generally contributing to overall COPEC exposure to the greatest extent. [5, 6, 75]

Reddish Egret

The reddish egret is currently listed as threatened in Florida and Texas, while the International Union for Conservation of Nature (IUCN) has assigned this species a global designation of "Near Threatened."[200-202] There are estimated to be between 1,500 and 2,000 nesting pairs of reddish egrets remaining in the United States, most of which are found along the Texas Gulf Coast, including a resident population in the Corpus Christi bay system.[10, 37, 200] The reddish egret prefers to forage for sheepshead minnows, killifish, and small mullet in the shallow waters of protected bays/estuaries, though they occasionally consume crustaceans (i.e., incidental ingestion of sediment is a potentially significant route of COPEC exposure). Of note, young birds are fed via regurgitation, introducing the potential for sensitive early life stage (ELS) chicks to be exposed to bioaccumulative contaminants present in adult dietary items. Moreover, the reddish egret demonstrates high ecological specificity, forages within a small home range, and exhibits low fecundity and delayed sexual maturity.[200, 201] In combination with the reddish egret's high potential for dietary exposure to bioaccumulative COPECs (many of which act as reproductive and developmental toxicants), the degree of risk associated with the Harbor Island facility is considered high for this receptor.

Piping Plover

Piping plovers are a Federally and State listed (Threatened) small foraging shorebird species that overwinter on GoM beaches, sand flats, mudflats, emergent sea grass beds, and spoil islands. Current population estimates suggest that less than 6,000 breeding age birds remain in North America, approximately 44% of which are thought to overwinter along the Texas coast/barrier islands, where they forage for food in soft mud and/or sand. Feeding is particularly active during low tide, when polychaetes (their primary dietary item) are easily retrieved from the benthos. Their reliance of polychaetes is important to note, as benthic assemblages are known to be among the most sensitive to SWRO effluent exposure, indicating that indirect effects (i.e., decreased food abundance) of the facility may adversely impact the survival of the plover. Aside from marine worms, piping plovers also consume crustaceans, mollusks, and other small marine animals, all of which are known to act as vectors of dietary COPEC exposure.

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Although plovers are a migratory species, this species exhibits site fidelity and remains at wintering grounds for over 70% of the year, indicating that local sources of environmental contamination (e.g., including those released by the proposed facility) may lead to chronic exposure scenarios for these receptors. Habitat destruction via contamination, coastal development, increasing recreational use of beach habitats, noise pollution from vehicular traffic and accelerated coastal erosion have been identified as primary drivers of population declines.[203, 204] As all of the aforementioned stressors are associated with the construction and operation of the proposed facility, it is possible that this development project may directly contribute to local population declines. In combination with the high potential for dietary COPEC exposure and the potential indirect effects on its food supply, the risk associated with the Harbor Island facility is considered high for the piping plover.

Whooping Crane

Whooping cranes are Federally and State listed (Endangered) large migratory waterfowl that overwinter in coastal marshes and estuaries along the Texas Gulf coast/barrier islands where they forage for benthic invertebrates in brackish bays, marshes, and salt flats.[10, 38, 39, 205] Their reliance on benthic food sources is of significance for several reasons. Firstly, benthic invertebrates act as an important vector of dietary exposure to sediment borne COPECs, and secondly, benthic assemblages are known to be among the most sensitive to SWRO effluent exposure. Thus, the whooping crane is expected to have a complete route of COPEC exposure (via contaminated benthic dietary items and incidental sediment ingestion), while decreased food abundance may also indirectly impact the flock.

Moreover, this species demonstrates extremely high site fidelity, with small flocks of birds (i.e., 7 or less individuals) generally returning to established overwintering grounds in/around the Aransas National Wildlife Refuge [c] each year.[10, 38, 39, 205] As a result, whooping cranes are particularly susceptible to adverse effects on the quality and/or abundance of their food supply, which may occur through several mechanisms. The first, is through the release of contaminants into the aquatic environment that reduce the quality and/or availability of prey items preferred by cranes. The second, is through exposure to bioaccumulative COPECs released in effluent that may impact the fitness of the cranes themselves. The third, is by exacerbating drought conditions and high salinity conditions in the Coastal Bend tidal basins and estuaries during times of drought.

Although strong homing instincts preclude paired adult birds from dispersing to new habitat, younger birds who have not yet paired with a mate may venture much further from the refuge to establish their overwintering territory. Consequently, confirmed sightings of overwintering breeding age whooping cranes have been documented throughout the Corpus Christi bay system (including near Harbor Island) and elsewhere along the Gulf Coast as recently as February 2021 (Figure 5).[38, 39, 206] Thus, it is reasonable to suggest that unpaired whooping cranes may currently use, or will use Harbor Island as overwintering habitat.

Although ERAs typically focus on evaluating risk for resident receptors, the extremely small number of adult whooping cranes remaining in the wild (approximately 504 adults as of 2020), their remarkably high site fidelity/ecological specificity, increasing anthropogenic stress (e.g., habitat loss/degradation, contamination) and sediment intrusive feeding strategy indicate that the risk profile for this species may be higher than for other migratory avian receptors in proximity to the proposed project site. [10, 38, 39, 205] Moreover, the known terrestrial impacts of desalination facility construction (e.g., piping, removal of vegetation, excavations, noise pollution, vibrations) and operation may disrupt social behaviors, limit foraging activities, and result in displacement of cranes from nearby bay and marsh habitats [39, 207] Pollution, habitat destruction/degradation, and noise pollution have all been identified as factors that have contributed to the whooping cranes decline. Thus, the Harbor Island facility may pose a direct risk to the local whooping crane population.

[c] The Aransas National Wildlife Refuge was designated as critical whooping crane habitat under the ESA in 1978.

Figure 5. Verified whooping crane sightings reported to the Texas Parks & Wildlife Department between November 2012 and February 2021.

Aquatic T&E Receptors

Sea turtles in the GoM are highly vulnerable to extinction, due to a combination of their life history traits (e.g., long-juvenile stage, delayed sexual maturation) and the prevalence of anthropogenic stressors in the GoM (e.g., pollution, climate change, natural resource extraction, fishing, vessel traffic, coastal development, technological disasters).[19, 208] All five protected species of sea turtles native to the GoM, including the hawksbill *(Eretmochelys imbricate)*, green *(Chelonia mydas)*, loggerhead *(Caretta caretta)*, leatherback *(Dermochelys coriacea)*, and Kemp's Ridley (*Lepidochelys kempii*), use local aquatic and terrestrial (i.e., beach) habitats as foraging and/or breeding grounds,.[14, 15, 19, 209-212]

Anthropogenic threats to sea turtle survival and reproduction that are relevant to the proposed facility include the following:[213, 214]

- Exposure to COPECs present in effluent and/or runoff from site
- Exposure to physical/chemical pollutants during construction
- Entrainment at the intake site
- Indirect effects via impacts to SAV (e.g., turbidity feedback loop)
- Indirect effects via altered hydrology (e.g., foraging, orientation)
- Indirect effects via artificial lighting (e.g., ELS photo-behaviors)

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Figure 6. Current local habitat range of the (A.) green sea turtle, (B.) Kemp's Ridley sea turtle, and (C.) hawksbill sea turtle, according to the US Fish and Wildlife Service's Endangered Species Database

Both the construction and operation of the proposed SWRO facility presents a potential ecotoxicological risk to all native sea turtle species to some extent, as T&E species should be protected at the individual level.[5, 74] However, the risk profile is considered greatest for the green and Kemp's Ridley sea turtles. This is largely attributed to their high dependence on local neritic zone habitat (e.g., shallow bays, estuaries, lagoons, passes) to carry out key aspects of their life history and successfully reproduce, as well as their time of residence in local bays and estuaries.[208, 213-215] As both species are generally considered to be resident or seasonally resident in habitats in proximity to the proposed facility (Figure 6), these species are expected to experience exposure to facility-associated hazards (e.g., physical and chemical contamination) to a greater extent than other native sea turtle species.[14, 15, 19, 208-212]

Green Sea Turtle

Green sea turtles are State and Federally listed as Threatened in the GoM, though they are listed as Endangered elsewhere in the US and globally.[210, 213, 216] In recent years, this species has increasingly relied upon local protected beaches as reproductive habitat, a trend that is attributed to the availability of relatively unaltered/protected barrier island shoreline. [208, 209] Local seagrass beds, such as those in proximity to Harbor Island, have also been identified as critical foraging and development grounds for juvenile green sea turtles (Figure 6A), which is known to be a particularly vulnerable life stage for this species.[12, 16, 24, 208, 209] This is of note, as seagrasses have also been identified as a receptor of potential ecological concern for the proposed project, indicating that physical and chemical pollution attributed to the facility may adversely affect the survival and reproduction of green sea turtles via both direct and indirect mechanisms.[12, 16, 24]

Kemp's Ridley Sea Turtle

The Kemp's Ridley sea turtle – the smallest and most endangered sea turtle in the world – is listed as Endangered in the US and Critically Endangered globally.[211, 216] The range of the remaining members of this species include sheltered coastal areas and barrier islands in Texas, including local bays and estuaries (Figure 6B), where they forage for crabs (their primary dietary item), as well as other aquatic invertebrates (both benthic and pelagic) and dead fish/bycatch.[211, 215] As previously discussed, the facility poses a high degree of risk to ELS crab populations, indicating that the food supply of these receptors may be adversely impacted by COPECs released to the environment surrounding the outfall.

The primary breeding ground of this species is located near Rancho Nuevo, Tamaulipas (Mexico); however, several South Texas beaches are increasingly being utilized as major secondary breeding grounds.[209, 211] Confirmed nesting sites include South Padre Island, North Padre Island, Corpus Christi Bay, Mustang Island, San Jose Island, Matagorda Island, Matagorda Peninsula, among others. Consequently, the USFWS is currently evaluating a petition to classify undeveloped beaches in these areas as critical habitat under the ESA (decision pending).[214] Collectively, the habitat range of this species (as determined by the USFWS; Figure 6B) and spatial configuration of the aforementioned nesting sites suggests that beaches in proximity to Harbor Island may be used as reproductive habitat for this critically endangered species. Moreover, females are known to migrate between breeding and foraging grounds through shallow neritic corridors,[209, 214, 215] which is likely to include aquatic habitat in proximity to the facility and/or the effluent outfall. Thus, the Harbor Island SWRO facility may contribute to habitat destruction and degradation of the Kemp's Ridley sea turtle.

Generalized & Indirect Effects on Receptors of Concern

Effluent released from the proposed Harbor Island desalination plant into the CCSC also introduces the potential for ecosystem level impacts via several indirect mechanisms.[39] For example, COPECs that are directly toxic to primary producers (e.g., SAV, microphytobenthic biota) also have clear implications for food abundance and food web structure.[98, 166] THMs are known to be directly toxic to a number of primary producers at exposure concentrations that are below those measured at existing SWRO outfalls (up to a full order of magnitude lower in some cases).[47, 99] Iron based coagulants present in effluent have also been shown to reduce primary productivity in laboratory and field studies, via decreased penetration of SAV and settling over benthic producers. [47, 98, 99] Moreover, phosphate based antiscalants have been shown to contribute to eutrophication and hypoxic/anoxic conditions that are already known to occur in local bays and estuaries.[10, 47, 102] Similarly, SWRO effluent is known to lead to an influx of phosphorus and nitrogen-containing inorganic nutrients from multiple locally-occurring sources (e.g., municipal, agricultural), further increasing the potential for eutrophication and depleted dissolved oxygen (DO) in aquatic habitats in proximity to the outfall.

Other Significant Drivers of Ecotoxicological Risk

Although the individual chemicals present in brine effluents from desalination facilities are not typically found at acutely toxic concentrations, it is important to note that the chronic toxicity of the entire mixture to local species (which exhibit variable sensitivities) will ultimately determine the degree to which the ecosystem is impacted. This includes not only the various chemical interactions that are known to alter the toxicity of mixtures to aquatic biota, but also the physical parameters of the brine itself (e.g., salinity, DO, temperature), the rate of dispersion of the effluent, as well as the various environmental co-stressors (e.g., UV, temperature, ocean pH, sea level, circulation patterns, vessel traffic, severe weather) that have the potential to exacerbate the toxic effects of effluents to aquatic biota.[8, 185, 217-220] It is of note that SWRO effluents themselves may also drive changes in many of the aforementioned physical parameters (e.g., temperature, DO, salinity), though the potential for impacts varies according to facility design and discharge location.[41]

Both the MAE and NRE experience remarkably low rates of water exchange and insufficient freshwater inflow to replace evaporation during the arid summer months/periods of drought, which are common in the region (and expected to increase in intensity/frequency in coming decades).[10, 16, 102] This is of note from an ecotoxicological and ecological risk perspective, as drought conditions are associated with rapidly rising water temperatures/depressed DO and hypersaline conditions (particularly in these shallow systems), the combination of which facilitates the accumulation of environmental contaminants in sediments and exacerbates the toxicity of COPECs present in the aquatic environment to biota.[10, 16, 41, 42, 45, 46, 49, 102, 207]

Elevated salinity is frequently cited as the most obvious adverse ecological consequence of SWRO operations, particularly where enclosed bays and estuaries are concerned. [41, 42, 45, 46, 49, 207] This is primarily presented in the context of osmotic imbalance; however, there are also indirect mechanisms by which even slight increases in salinity may exert adverse effects on aquatic biota. For example, hypersaline conditions are known to influence the fate and transport of many contaminants in the aquatic environment (including many expected to be present in SWRO effluent), as well as exposure, bioavailability/accumulation, and toxicity of COPECs to a range of aquatic organisms.[41, 42, 45, 46, 180, 181, 207] Changes in the relative proportions of various ionic compounds present in the water column are also sufficient to cause osmotic imbalance, which is a widely accepted potentiator of toxicity for many COPECs.[41, 42, 45, 46, 49, 207] This indicates that

models and/or engineering interventions that aim to maintain total salinity in the CCSC are not sufficient to mitigate potential risk to aquatic biota in proximity to the outfall.[41, 42, 45, 46, 49, 106, 207] Therefore, it is reasonable to suggest that rapid mixing and/or dilution of SWRO effluent may not be sufficient to avoid toxic effects on sensitive biota, even under ideal conditions. This is largely due to the expectation that seawater pulled into the facility by the offshore intake will have a different ionic content from that in proximity to the discharge site, which effectively lowers the effect concentration of many effluent-associated COPECs (via induction of osmotic stress). [20, 24, 45, 46, 180, 221]

SWRO facilities are also known to depress DO content when sufficient mixing or dilution of hypersaline effluent does not occur – the risk of which is increased when enclosed bays and estuaries are selected as a site of discharge.[41, 45, 46, 49, 98] As previously stated, depressed DO can affect contaminant fate and transport, bioavailability, and lead to a variety of adverse outcomes for aquatic biota. This includes changes in gene expression, immune function, metabolism, locomotion, behavior, growth and development, oxidative stress, and mass mortality events.[19, 45, 46, 102, 222, 223] Annual recurrent cycles of hypoxia are well documented within area bays and estuaries,[10, 102] indicating that any additional suppression of DO by SWRO facility operations (e.g., via insufficient dilution/mixing of hypersaline effluent, discharge of excessive nutrients, etc.) may lead to significant impacts on the health and survival of aquatic organisms in proximity to the proposed facility during these cycles, particularly those within/passing through the effluent mixing zone.

The above-described issues have important implications for the survival of even the most tolerant estuarine biota, as adverse effects may occur via a variety of direct and indirect toxic mechanisms (e.g., potentiation of COPEC toxicity, food web impacts). This is particularly true, given that the TCEQ permit application states that the intended purpose of the proposed project is to "...provide a sustainable supply of potable water for the Corpus Christi area that is not dependent upon rain water," (i.e., production will be unaffected by drought conditions).[1, 2]

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Uncertainty Assessment

Uncertainty is inherent in all risk assessments to some degree, due to a wide range of factors. As uncertainty increases, the type and magnitude of potential ecosystem impacts becomes increasingly hard to predict. With regard to the proposed Harbor Island development project, several important sources of uncertainty exist that are expected to lead to risk estimates that are biased low (i.e., actual risk is likely to be higher than estimated risk). Some of the more evident sources of uncertainty are discussed in their respective sections below.

Impacts of Construction & Technological Disasters

Although the ecological risks associated with SWRO are primarily discussed in the context of normal facility operations herein, impacts anticipated during the construction phase, as well as potential risks associated with technological disasters should be thoroughly evaluated prior to project initiation.[45, 46] Ecosystem impacts attributed to the construction phase of coastal development projects that should be thoroughly evaluated include vibration/noise pollution, solid waste deposition, coastal erosion and increased turbidity/sedimentation due to sediment intrusive activities (e.g., digging, laying pipe, pumping). Moreover, the latter is associated with remobilization of previously sequestered legacy contamination (e.g., hydrocarbons, persistent organic pollutants, heavy metals), which is exacerbated by onsite vehicular and heavy machinery operations and use of certain construction materials.[45, 46] Increasing turbidity from sedimentation and seabed disturbances during construction also has the potential to increase the bioavailability of sediment-associated contaminants, and act as a physical co-stressor that exacerbates toxic effects of COPEC exposure. [22, 221, 224, 225] With regard to ecological risk associated with technological disasters, it is imperative that risk related to both facility malfunctions, as well as other large-scale disasters (e.g., oil spills) that have the potential to deposit contamination at the intake site be considered prior to initiation of the project.

Lack of Site-Specific Data

As discussed previously, potentially important data gaps exist regarding the presence of pharmaceuticals and their transformation products in SWRO effluent, with potentially important implications for reproductive and developmental toxicity. Additionally, SWRO facilities use variable designs, proprietary chemical formulations, differing institutional and mechanical controls, etc., the details of which are not yet fully publicly available for the proposed Harbor Island project.[1, 43, 45, 46]

Sufficient/current site specific COPEC data is also not available for the planned site of intake; therefore, it is difficult to predict the type and degree of contamination that intake media may contribute to facility effluent with any degree of confidence. Unfortunately, collection of current COPEC data is also not sufficient to exclude the potential for substantial future contamination at the site of intake, which could result in a large influx of contamination to the CCSC via effluent. Future oil spills are of particular concern in this regard, given the prevalence of fossil fuel exploration, extraction, transportation and refining operations present in the greater Corpus Christi area (and throughout the GoM).[10, 14] Therefore, unless sufficient contingency and mitigation measures can be implemented that will ensure that future impacts to nearshore environments do not result in an influx of contaminants to the CCSC via effluent, it is not plausible to provide a confident prediction of future ecotoxicological risk. This is of concern, given the high ecological value of the habitat and the potential presence of T&E receptors in proximity to the facility.[12, 14, 24, 45, 102, 226]

Lack of Representative Toxicity Values

Where sufficient data are available, State and Federal regulatory authorities (TCEQ and USEPA, respectively) derive and/or enforce numeric water and sediment quality criteria to protect aquatic life from the adverse effects of COPECs and/or changes in physical parameters (e.g., temperature and salinity) of the environment.[5, 227] However, such criteria are not available for all COPECs that may be present in effluent from the proposed facility, and for those that do, it is common for criteria to be based on data generated by toxicity tests that utilize model organisms that inhabit either marine or freshwater environments.[20] As estuarine systems are characterized by natural salinity gradients, there is a high degree of uncertainty associated with the use of marine or freshwater criteria for the protection of estuarine aquatic biota.[20, 45, 46, 221, 228] Moreover, TCEQ has not yet established water quality criteria to protect aquatic life from anthropogenic effects on estuarine salinity gradients, which many native biota depend on to complete certain life history processes. This is of ecotoxicological significance, given that changes in salinity are known to be an important co-stressor that exacerbates the toxicity of many COPECs to aquatic biota. [20, 45, 46, 221, 228, 229]

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It is also important to note the considerable degree of uncertainty surrounding the effects of whole effluent exposure on sensitive embryo-larval stages of fish and shellfish, particularly when exposures are chronic in nature, involve mixtures of COPECs with similar mechanisms of toxic action, when one or more physical co-stressors are present under acute exposure conditions (e.g., ELS organisms drift through the mixing zone), when effects are sub-lethal and/or latent in nature, and when exposure to effluent occurs during critical windows of development.[3, 45, 46] Other understudied topics of considerable relevance to the proposed project include exposure scenarios that occur in aquatic habitats with low rates of water exchange/mixing (e.g., habitat near Harbor Island), and potential effects of effluent discharge on organisms with very specific salinity requirements during developmental stages.[3, 41, 49]

Increasing Anthropogenic Pressures

Estuarine communities are increasingly stressed by a combination of intensifying anthropogenic impacts, such as coastal development, physical and chemical pollution, and a myriad of climate change associated effects (e.g., increasingly intense severe weather events, temperature stress, accelerated coastal erosion/increasing turbidity, changes in the quantity/timing/location of freshwater inflows, hypersaline conditions, and a loss of biodiversity).[10, 13, 19, 49] Many of these changes have important ecological and toxicological implications in estuarine systems. For example, climate change driven hypersalinity (attributed to a combination of decreasing precipitation/freshwater inflow and increased evaporation) may be exacerbated by facility operations, resulting into significant effects on estuarine and estuarine-dependent species that rely upon salinity gradients to complete key aspects of their life history.[3, 49]

In addition to acting as important physical co-stressors that exacerbate toxicity, many of the above listed anthropogenic stressors are also known to facilitate the accumulation of environmental contaminants in shallow bays and estuaries.[63, 117, 230, 231] Cumulatively, these relatively minor chemical and physical perturbations may lead to unpredictable and disproportionately severe effects on the health of estuarine biota already near their stress tolerance limit.[49] Thus, it has been acknowledged that many of the toxic effects of desalination effluent are likely to be considerably underestimated by standard whole effluent toxicity (WET) testing approaches.[3, 21]

Unknown Toxicity of Mixtures

The toxicity of whole effluent from SWRO facilities to aquatic biota varies considerably according to many factors related to facility design (e.g., proprietary mixture of chemicals used, mechanical/institutional controls, degree/rate of effluent dilution), biological characteristics of the study organisms (e.g., trophic level, water column position, inherent variations in species/life stage sensitivities) and the ecosystem (e.g., degree of flushing, NOM content, depth, temperature, substrate), as well as the source of intake water (e.g., proximity to urban centers, salinity).[45, 46, 49, 53] Moreover, interactions between the various constituents present in complex mixtures (e.g., desalination effluent) are known to modify toxic outcomes for exposed aquatic biota, often resulting in more than additive effects.[137, 232-234] Thus, it is necessary to perform an extensive array of chronic and acute WET tests on the most sensitive life stage of a number of regionally important species that represent different trophic levels and vertical positions in the water column (i.e., benthic organisms vs pelagic organisms) to make predictions about potential risks related to a project of this scale in one of only five major channels that facilitate water exchange between closed bay systems and the GoM.[53] This is especially true given the sensitivity, productivity and high ecological value of the habitat in proximity to the proposed facility/site of discharge, as well as the presence of a number of T&E species.[10-12, 16, 24, 38, 205, 208, 213-215]

Model Representativeness

A number of issues have been raised regarding the model parameters (e.g., intake speed and location) used to predict the composition and expected concentration of effluent at the outfall, which formed the basis for the draft permit approved by TCEQ.[1, 2] Recent expert testimony indicates that, given the updated parameters, the current design of the diffuser may not be able to achieve the degree of mixing/dilution necessary to meet preliminary limits approved by TCEQ.[1, 43, 227] This source of uncertainty may have considerable implications for the overall degree of risk to receptors, even when exposure is transient or acute.[1, 43]

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CONCLUSIONS AND RECOMMENDATIONS

The proposed development project poses a highly uncertain and potentially severe degree of ecotoxicological risk to habitat of high ecological value, which is also known to support multiple T&E receptors.[10, 19, 25, 169, 210-212] Moreover, aquatic systems adjacent to the discharge site experience remarkably low rates of water exchange/flushing, which is known to facilitate the accumulation of contaminants (including those known to be released in desalination effluents) and is widely recognized as a primary determinant of ecological risk associated with SWRO operations.[10, 49, 98, 221] Moreover, facility operations may exacerbate drought conditions, recurrent cycles of hypoxia and hypersalinity that further facilitate COPEC accumulation and potentiate toxicity of many contaminants to aquatic biota.[50, 102, 221-223]

Therefore, due to the extremely high level of uncertainty, the potentially significant and severe consequences of underestimating ecological risk in an ecosystem with the previously described attributes, and the findings/recommendations of multiple experts that have evaluated desalination projects elsewhere, it is strongly recommended that the POCC not proceed with current plans to discharge SWRO effluent into the CCSC. [41, 42, 44, 46, 47, 49, 53, 98, 207] Should the POCC decide to proceed with the project as planned (i.e., locate the outfall in the CCSC), a full environmental impact assessment is urgently needed for both the construction and operation phases of the proposed facility, to include an evaluation of potential impacts from future technological disasters or spills. At a minimum, the following data is needed to reduce the degree of uncertainty associated with the potential impacts of the project on local biological resources.[45, 46]

- Accurate and up to date models predicting the rate of effluent dilution, degree of mixing, and anticipated salinity (including the relative ionic composition) at the diffuser and within the mixing zone. In accordance with established recommendations for evaluating risk to T&E receptors and/or habitat of high ecological value (both of which apply to the proposed development project), model parameters should be based on a worst case scenario (e.g., drought conditions, flow of effluent into the bay), for the protection of individual T&E receptors and/or 95-100% of species[6, 8, 9, 25, 74, 169]
- Acute and chronic toxicity data for a range of native estuarine and estuarine-dependent species (of varying life-stages, trophic levels, and life history traits) exposed to full strength effluent under environmentally relevant exposure conditions. Testing conditions should represent a worst case drought scenario for the protection of individual T&E receptors, and the protection of 95-100% of species.[6, 8, 9, 25, 74, 169] In accordance with standard ERA practice, reproduction and survival should be preferentially used as assessment endpoints.[5, 74, 159, 199]
- Site specific data on the physico-chemical properties and current contaminant concentrations present in aquatic or terrestrial environmental media that may be disturbed or impacted by construction and/or operation of the proposed facility. This should include (at a minimum) sampling near the proposed intake and outfall sites, the construction site, and any nearby habitats that may receive runoff from the construction site or future impervious surfaces at the facility.[5, 6, 74, 191, 192, 199, 235]
- Predicted total daily exposure concentrations (from all direct and indirect sources) for the most highly exposed resident receptors. Cumulative risk from co-exposure to all COPECs reasonably expected to be present in effluent should be considered, along with any potentiating effects of physical co-stressors present in the aquatic environment (e.g., drought conditions).[5, 6, 12, 74, 181, 186, 221, 225, 235]

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