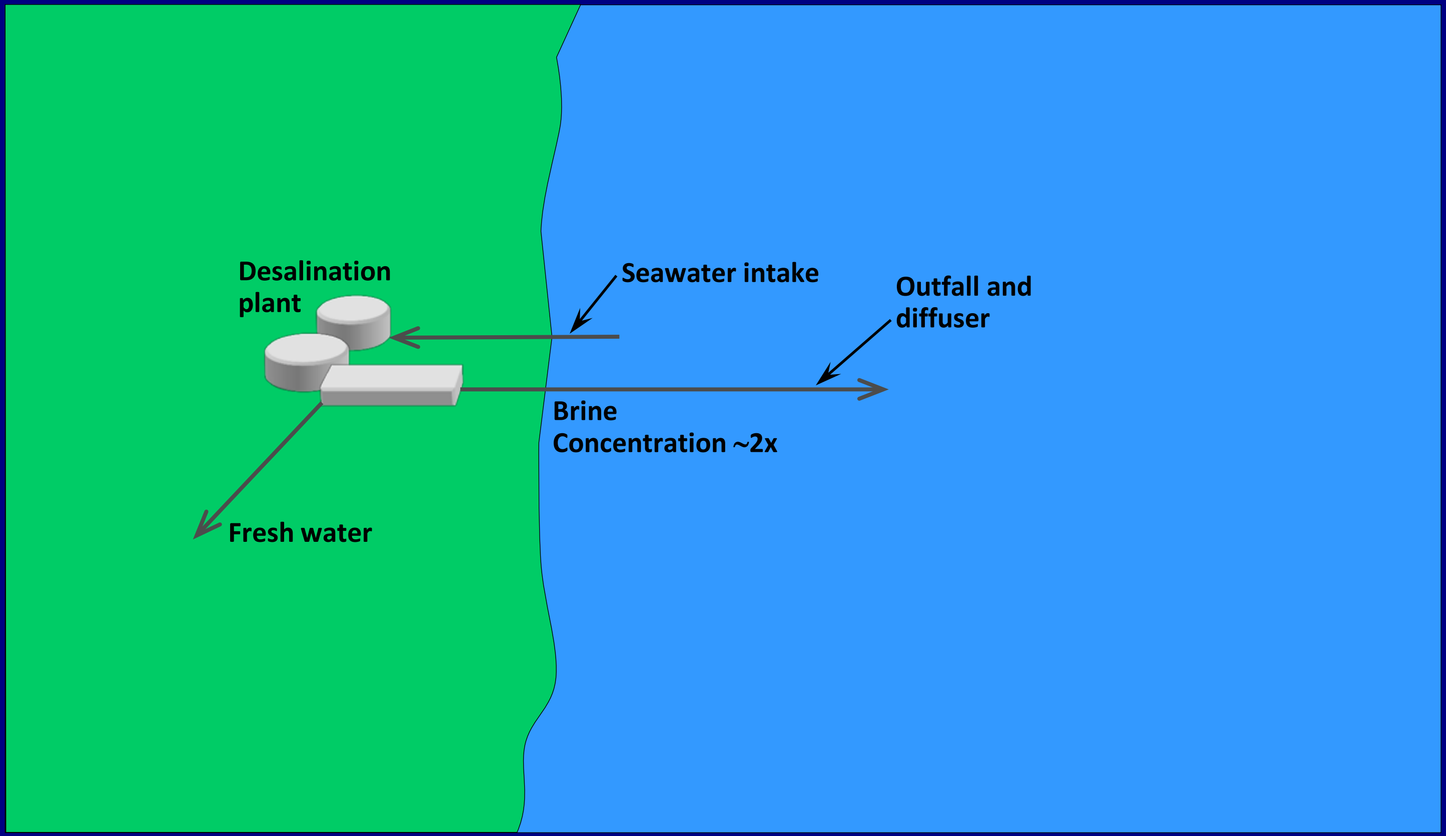
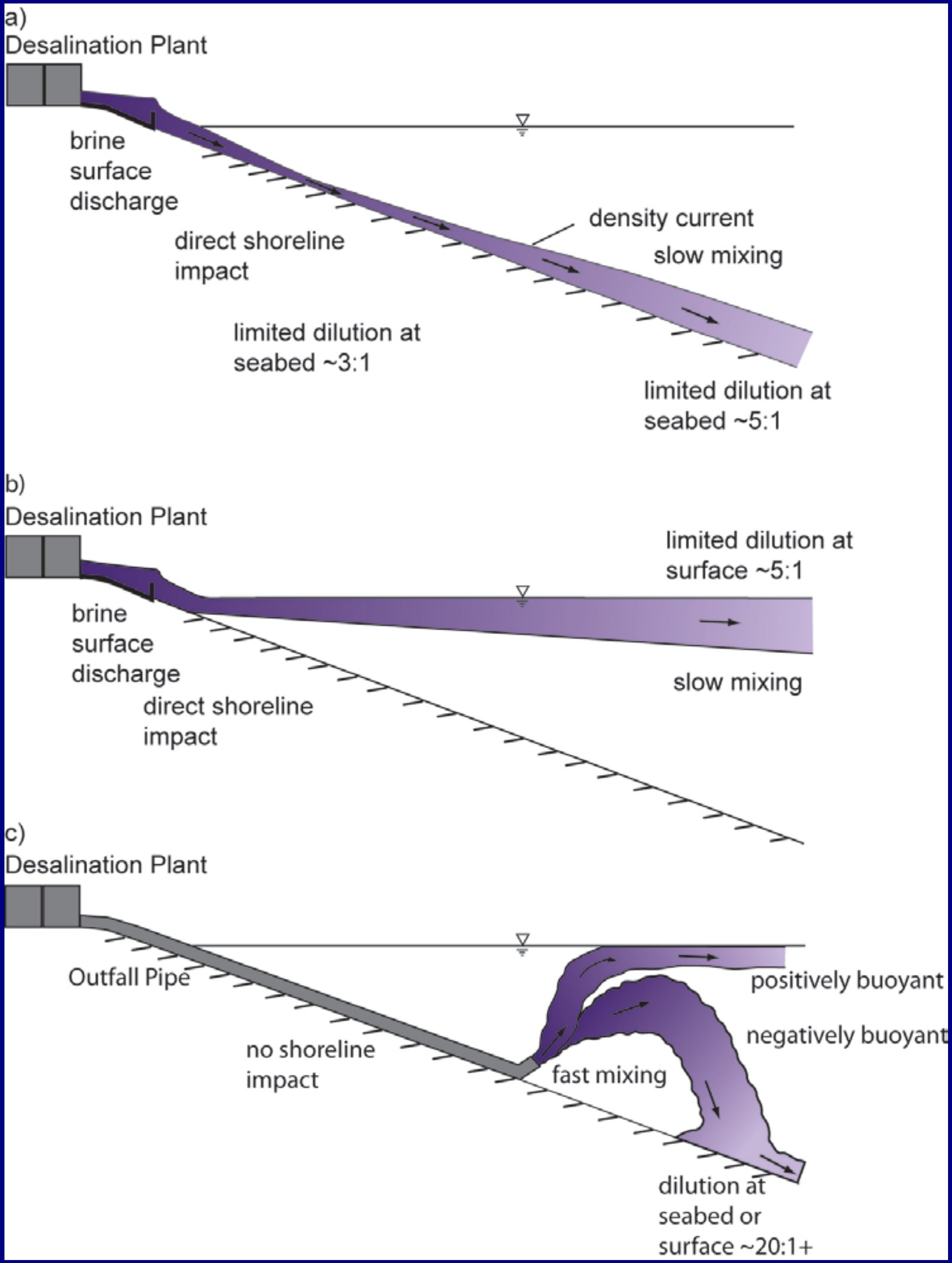
Desalination Plants



Dense jets frequently discharged via diffusers:

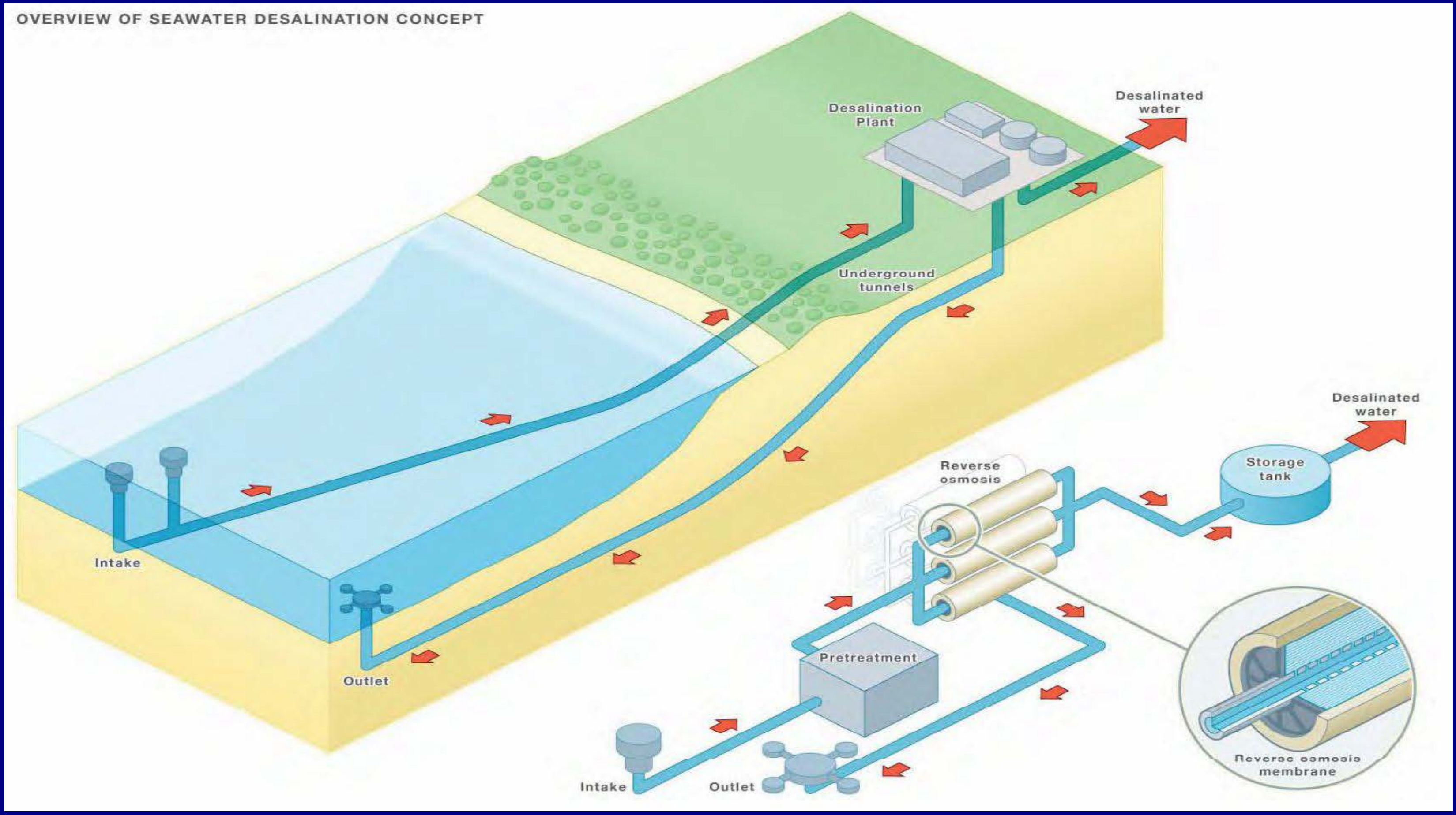
- Desalination plants (brine)
- Liquefied Natural Gas (LNG) terminals (cooled water)
- Water storage tanks
- Other industrial discharges and mine effluents etc
- Research on dense jets is more limited than buoyant
- How to predict?
- How to design outfalls?

Discharge Modes

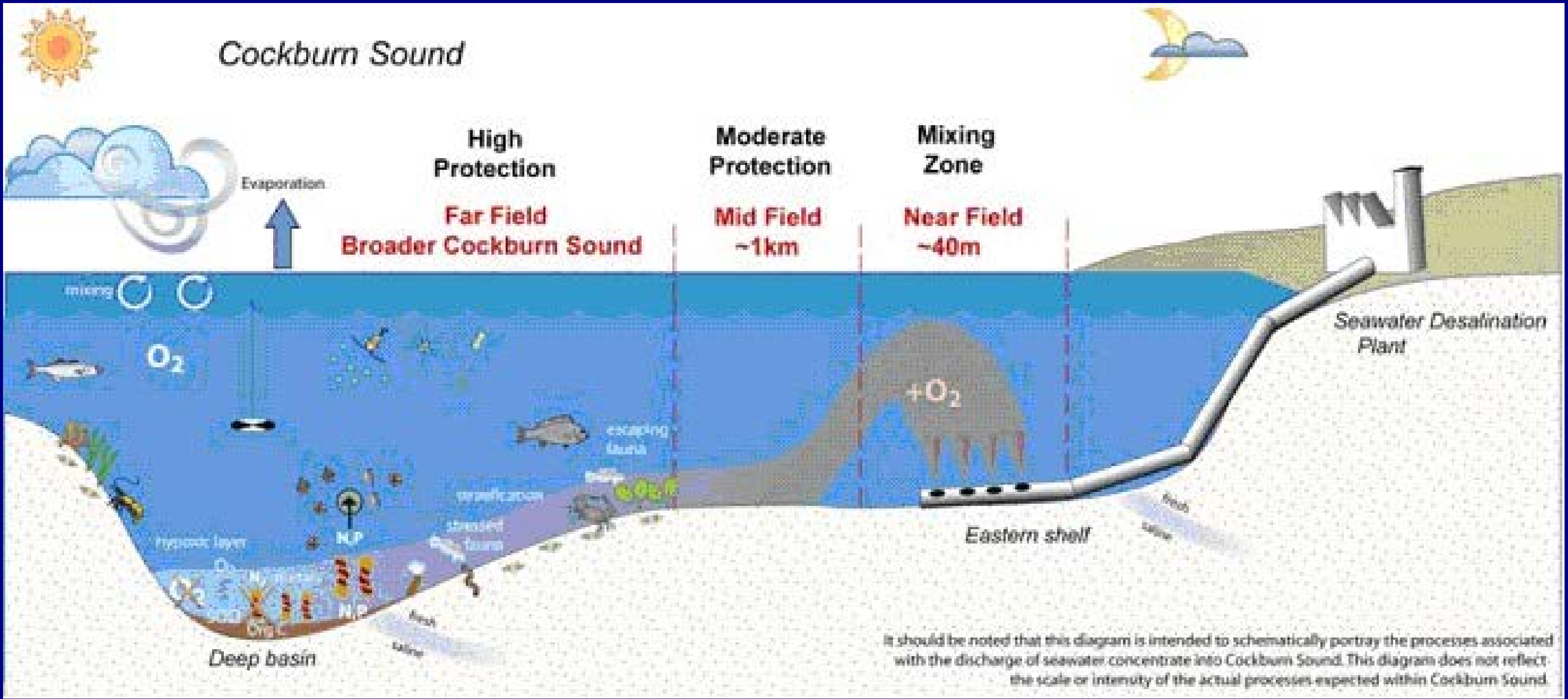


After Bleninger & Jirka (2009)

Overview of Reverse Osmosis Seawater Desalination

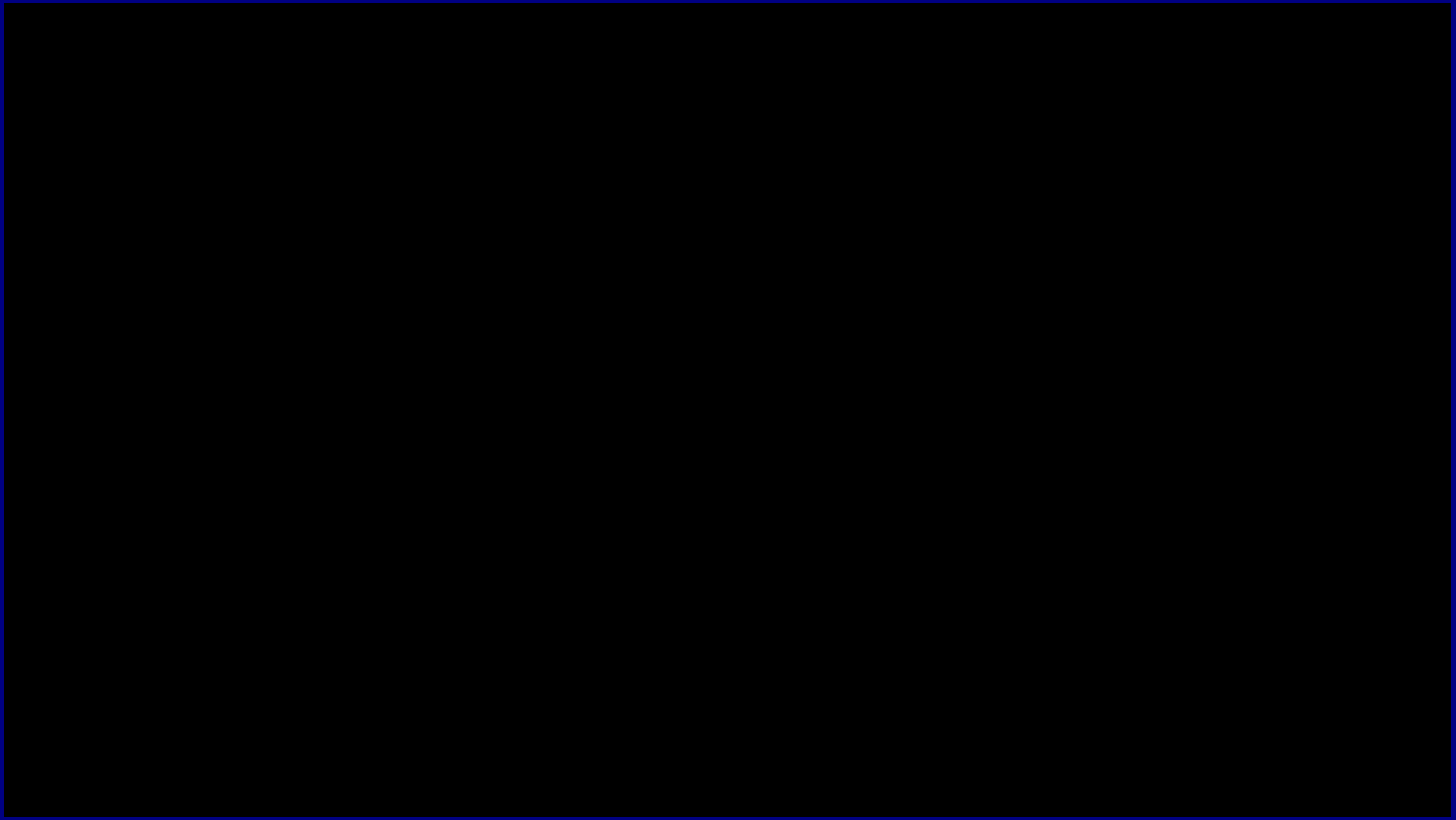


Conceptual Discharge Sketch

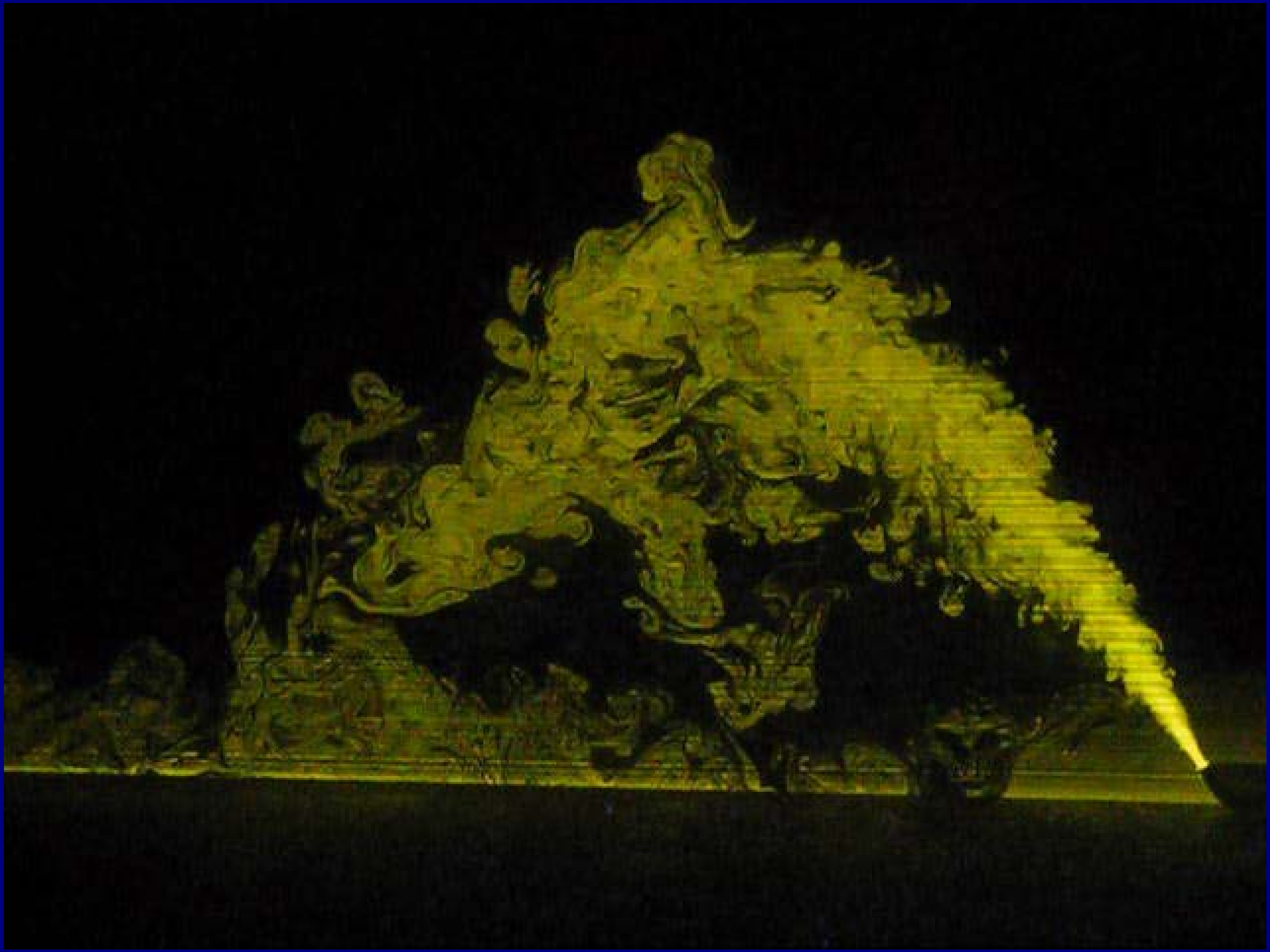


Field Tests on Perth Brine Diffuser

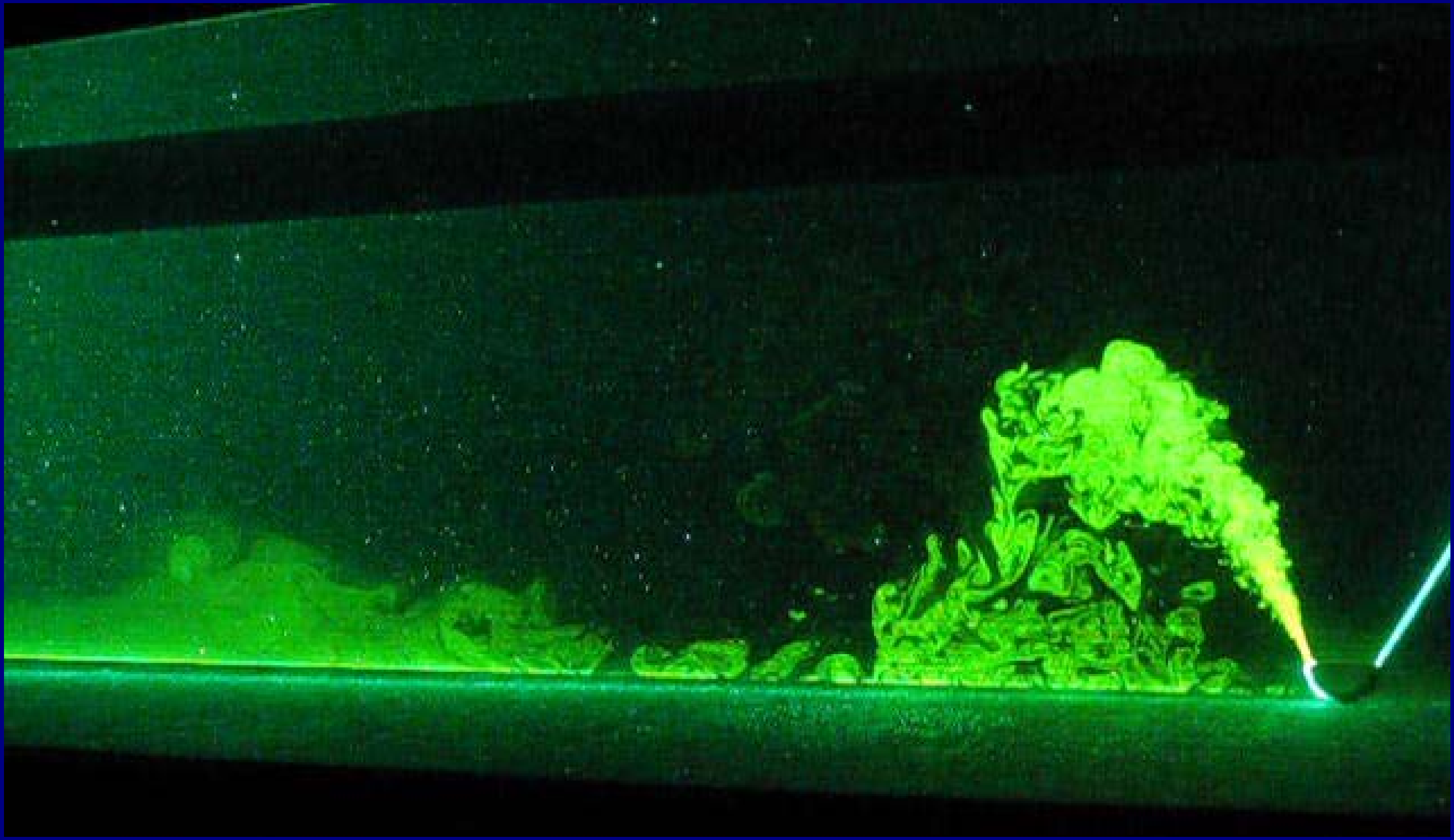
Perth Desalination Plant



LIF Brine Video



LIF Brine Video



Perth Report

A report on the environmental performance of the Perth Seawater Desalination Plant concentrate return system to note 5 years of continuous operation.

March 2012

1. **Dispersion of the brine plume from the plant occurs reliably and independent of temperature and season of the year with return to ambient background salinity levels at 50 m from their release sites.**
2. **Dissolved oxygen levels recorded in waters of Cockburn Sound show little variance from baseline as a result of operation of the Perth plant.**
3. **The plant discharge has shown no significant impact on sensitive, static local species with species survival or reproduction over the 5 years period of operation apparently unchanged. Mobile species that could be impacted do not appear to be affected and could be presumed to move should they find the conditions unacceptable.**
4. **Cumulative long term impacts – such as shorter life span of a species, increased susceptibility to infection – may take time to emerge but there is little evidence, as yet of their likelihood.**

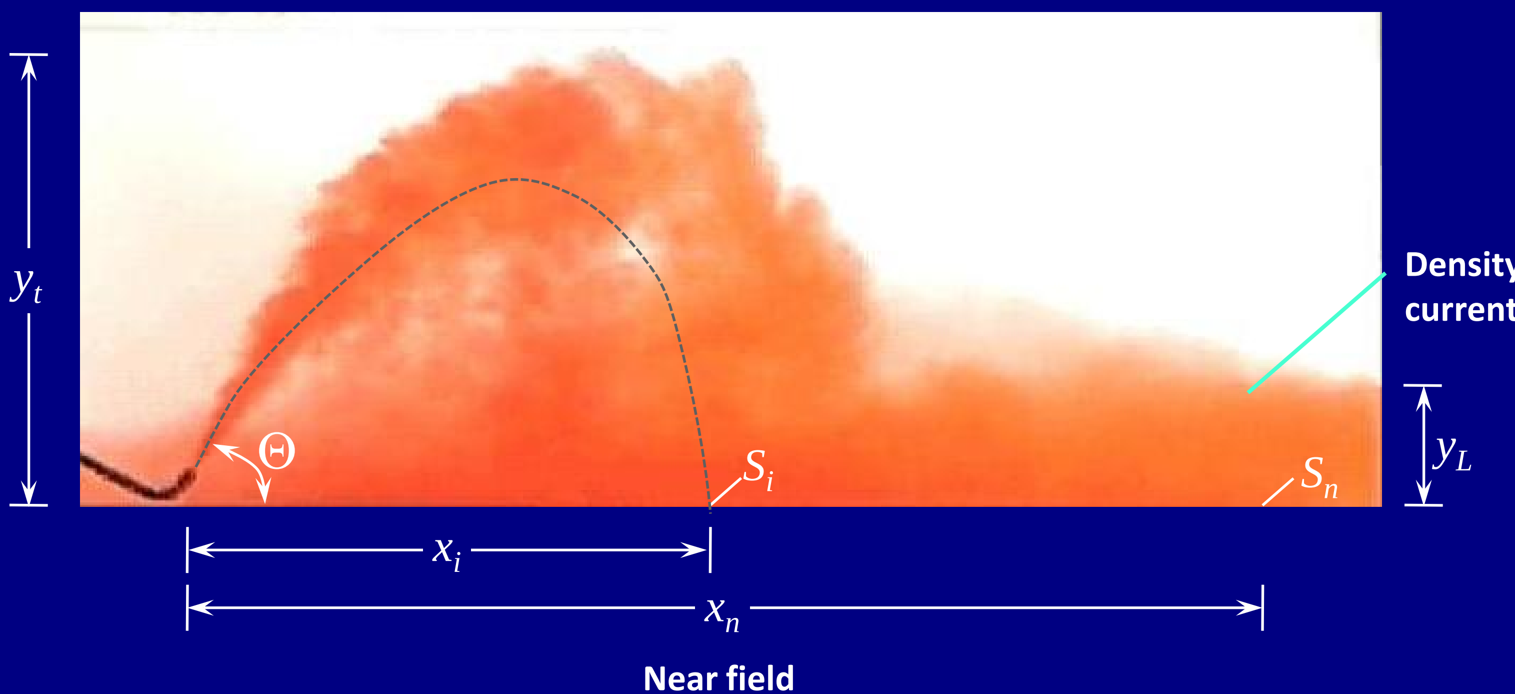
Perth Report

Table A: Marine Species Sensitivity to Salinity (from literature & quoted reports)

Group	***Sensitivity***	***PMDP impacts***
phytoplankton	highly species specific many species tolerance > background most sensitive may be stressed at > 2x background	zooplankton can move if bothered
seagrass	areas of optimal growth may change salinity > 2-5g/L may be a risk possible chronic effects	unchanged
corals	salinity > 2-5g/L likely risk to many species salinity >40g/L show physiological impact	not present in Cockburn area
benthic species	highly species specific	no evidence
fish species *Pagrus auralus* (pink snapper) *Gladioferens imparipes* (copepod)	highly species specific potential impact on larvae form potential impact on reproduction	fish can swim away: copepod bear watching over time

Inclined Dense Jet

Discharge as high velocity jet to achieve high dilution and reduce salinity to safe levels



y_t = Terminal rise height

x_i = Impact point distance to nozzle

x_n = Near-field distance to nozzle

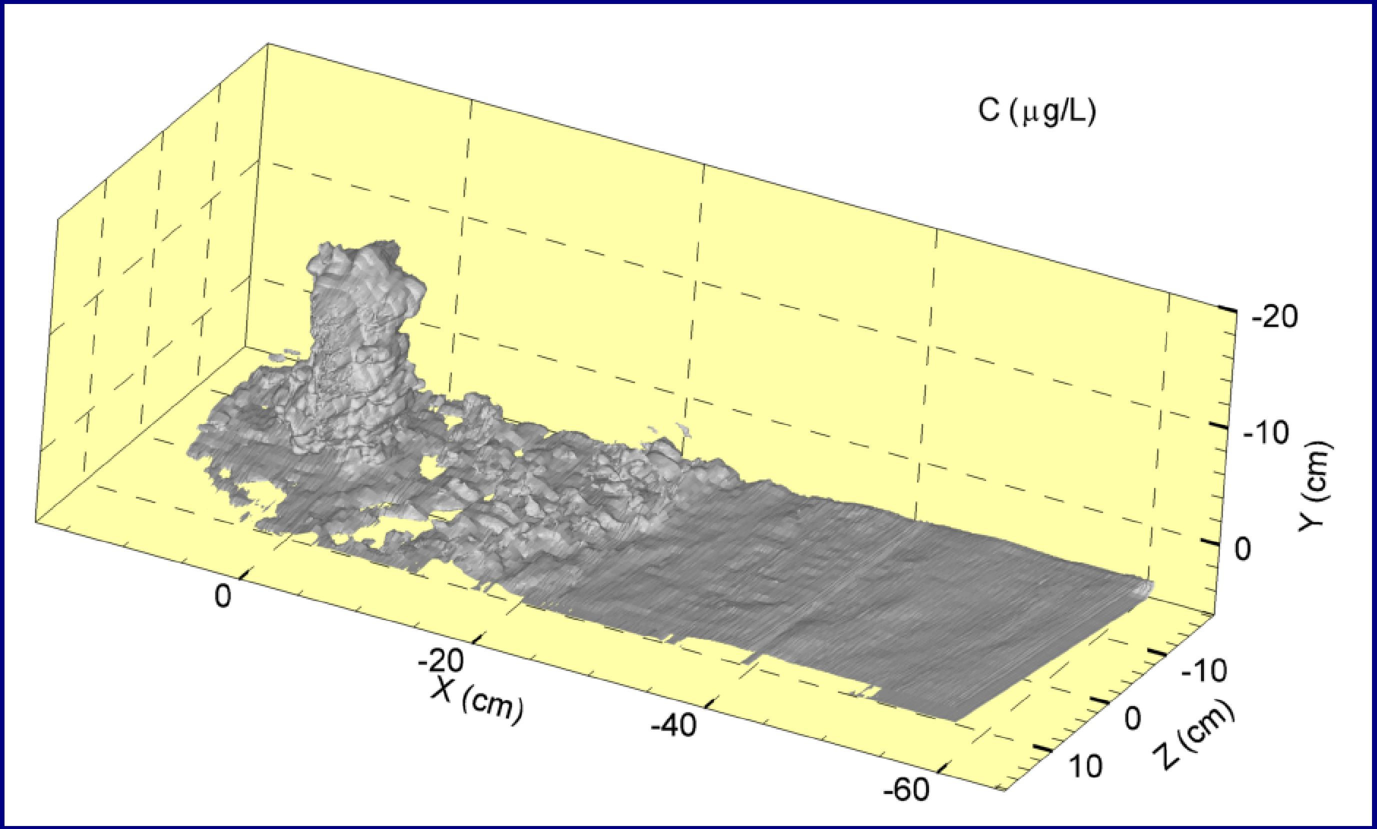
Θ = Upward inclination nozzle angle

y_L = Thickness of bottom layer

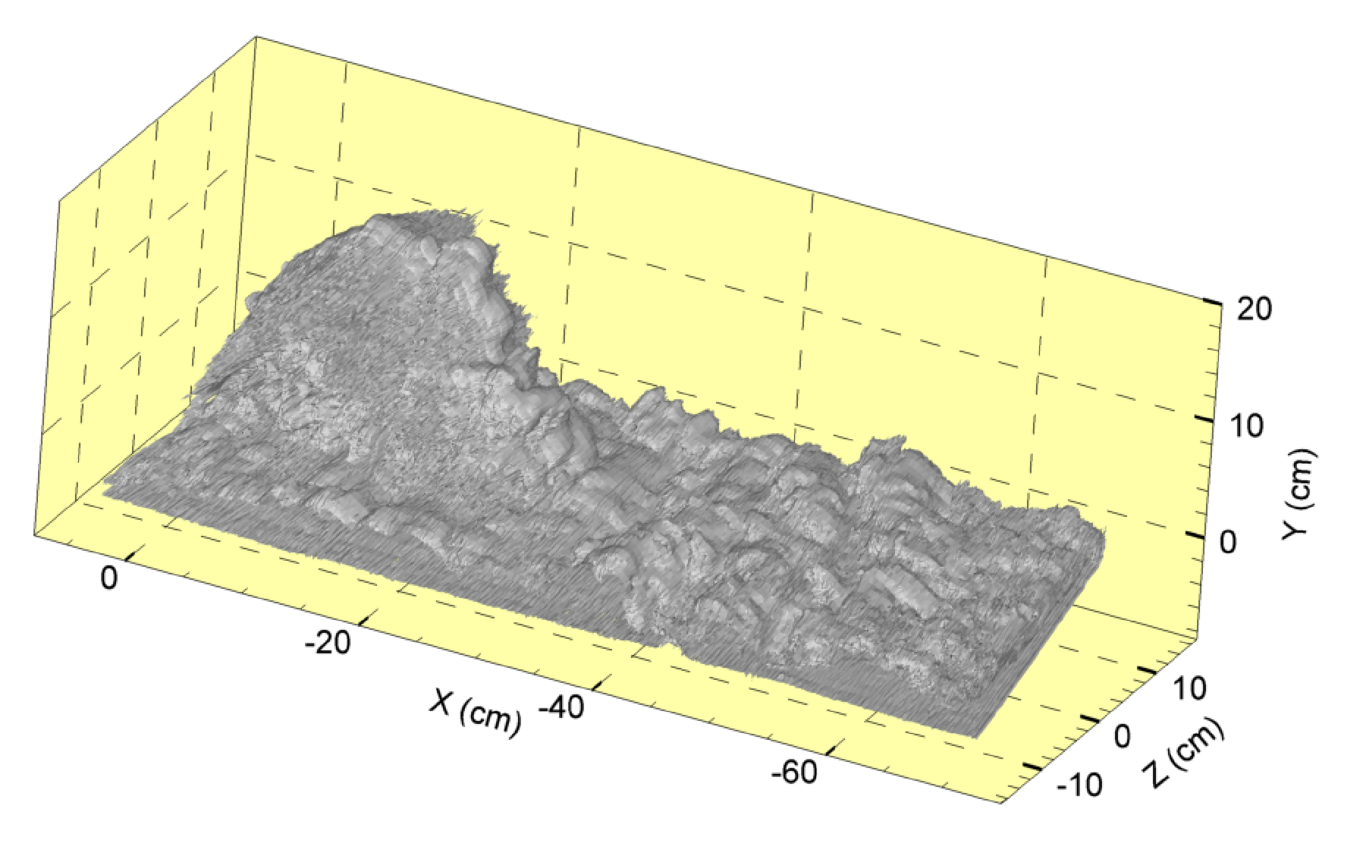
S_i = Impact point dilution

S_n = near field dilution

Vertical Jet (θ = 90°)

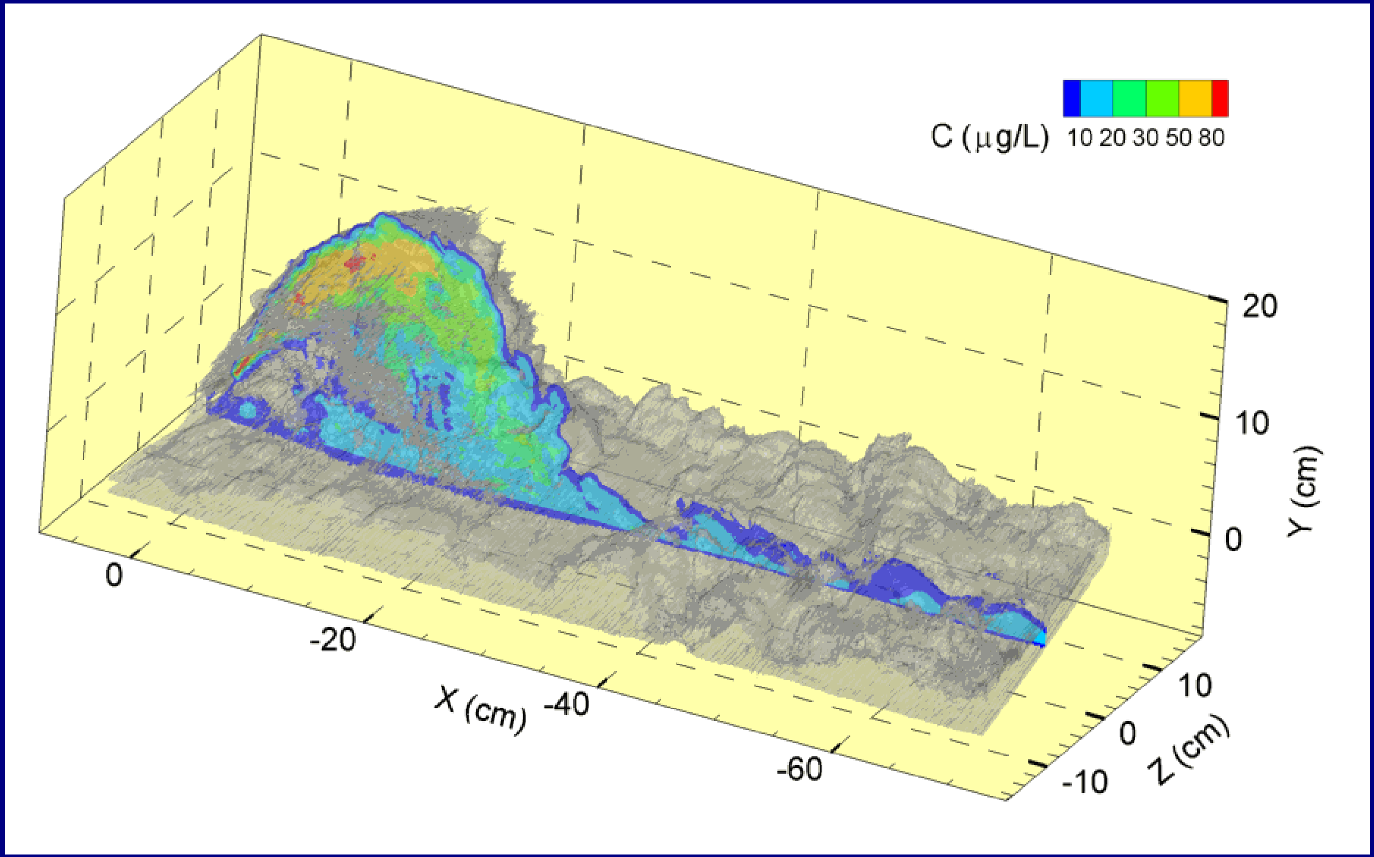


Outer Surface LIF Animation



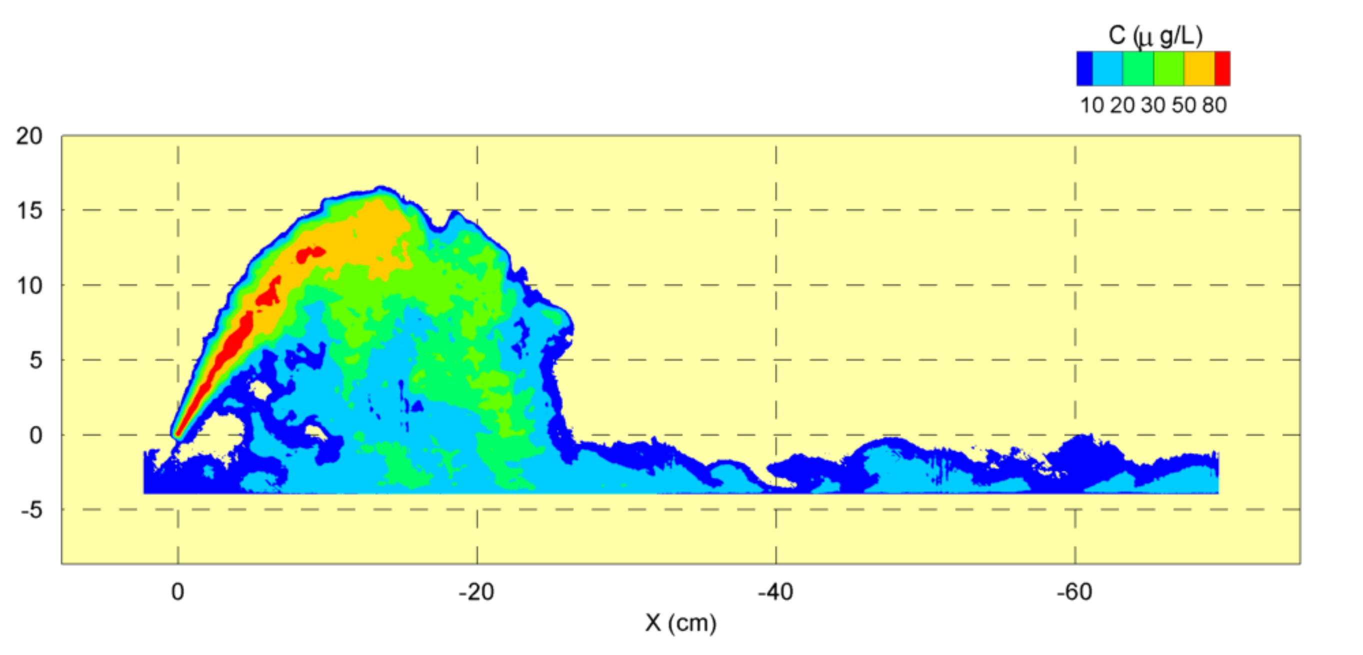
(θ = 60°)

Center Plane LIF Animation



(θ = 60°)

Center Plane LIF Animation



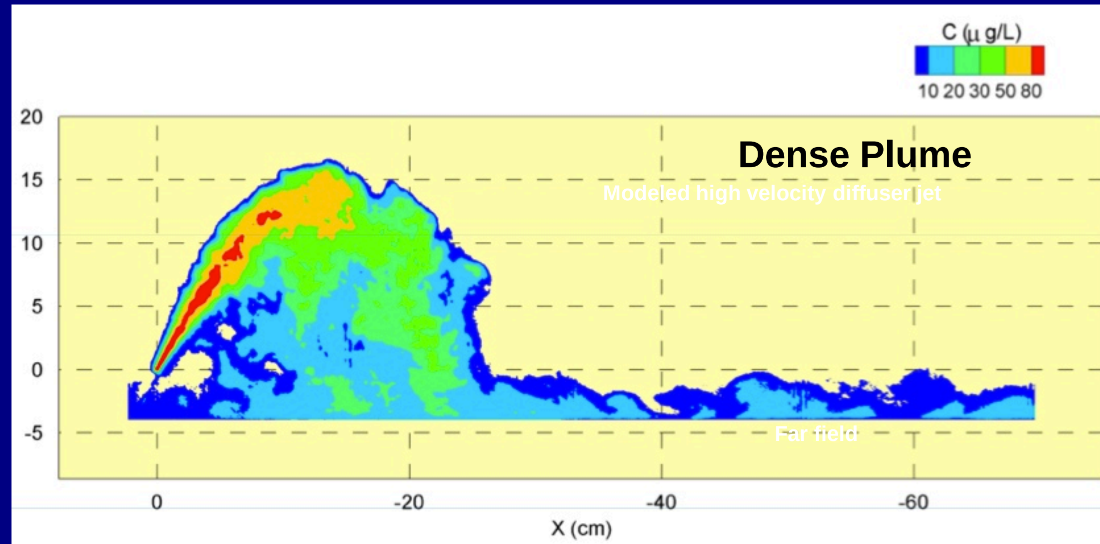
(θ = 60°)

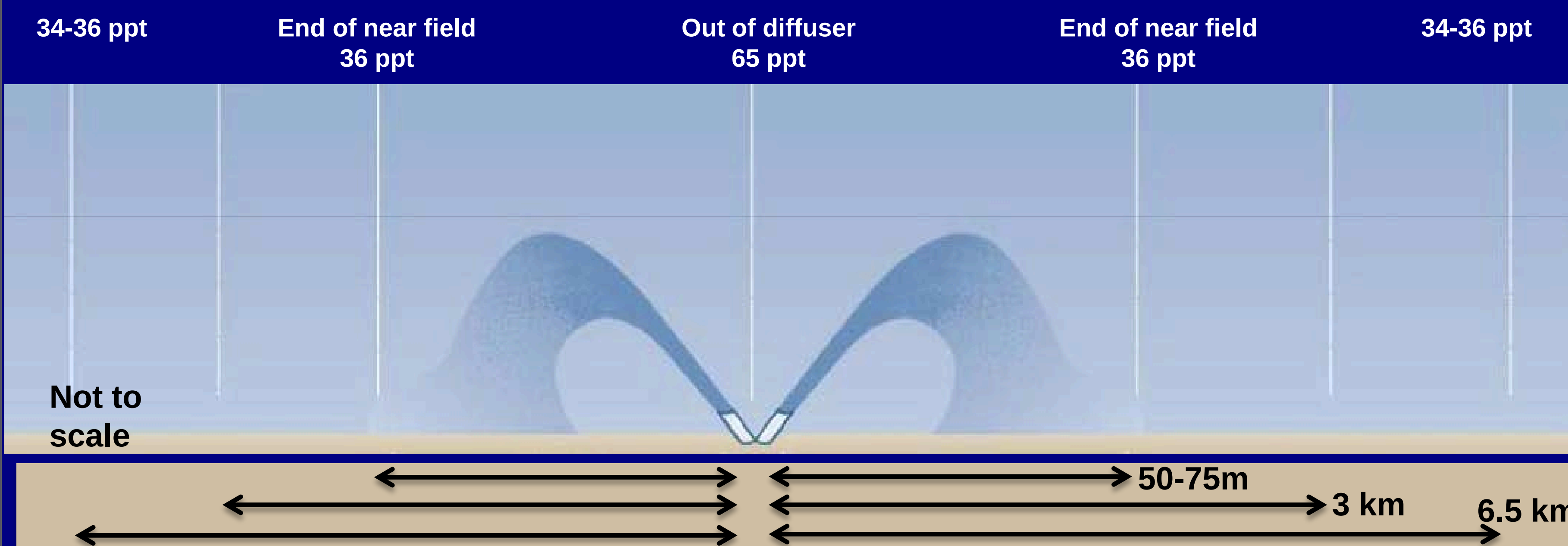
What is ZID?

For dense plumes we need a different definition based on typical extents of near field

Existing engineering models are quite good

Diffuser design and initial momentum are key





Existing Regulations

Region/Authority	Salinity Limit	Compliance Point	Source
US EPA	Increment ≤ 4 ppt		
Carlsbad, CA	Absolute ≤ 40 ppt	1,000 ft	San Diego Regional Water Quality Control Board 2006
Huntington Beach, CA	Absolute ≤ 40 ppt salinity (expressed as discharge dilution ratio of 7.5:1)	1,000 ft	Santa Ana Regional Water Quality Control Board 2012
Western Australia guidelines	Increment < 5%		
Oakajee Port, Western Australia	Increment ≤ 1 ppt		The Waters of Victoria State Environment Protection Policy
Perth, Australia/Western Australia EPA	Increment ≤ 1.2 ppt at 50 m and ≤ 0.8 ppt at 1,000m	50 m and 1,000 m	Wec, 2002
Sydney, Australia	Increment ≤ 1 ppt	50-75 m	ANZECC (2000); Sydney Water et al. (2005).
Gold Coast, Australia	Increment ≤ 2 ppt	120 m	GCD Alliance (2006).
Okinawa, Japan	Increment ≤ 1 ppt	Mixing zone boundary	Okinawa Bureau for Enterprises
Abu Dhabi	Increment ≤ 5%	Mixing zone boundary	Kastner (2008)
Oman	Increment ≤ 2 ppt	300 m	Sultanate of Oman (2005)

Proposed Brines Regulations - I

…mixing zone approach wherein the water quality regulations are met at the mixing zone boundary

…mixing zone should encompass the near field processes…influenced hydrodynamically by the discharge itself

…100 m from the discharge structure in all directions and over the whole water column.

…incremental salinity limit at the mixing zone boundary of less than 5%...will be about 1.7 ppt…dilution of about 20:1.

…dilution is the combination of in-pipe dilution…and near field mixing

….should meet toxicity and other requirements in the Ocean Plan at the edge of the mixing zone.

…(for) positively buoyant…regulatory framework of the Ocean Plan should be sufficient.

Proposed Regulation - II

…preferred methods of discharge are from a multiport diffuser or co-disposal with power plant cooling water or domestic wastewater that results in significant in-pipe dilution…shoreline surface discharge (if positively buoyant) or through an existing multiport diffuser.

Shoreline discharge of raw effluent is discouraged…

In computing near field dilutions of negatively buoyant discharges, conservative assumptions should be applied: that ocean currents do not increase dilution, and the seabed is flat and horizontal.

…estimates of overall flushing of the discharge site should be made to ensure that the dilution requirement…is met.

No specific mathematical models are endorsed…calculations be made using either tested semi-empirical equations available in the literature or by integral mathematical models based on entrainment assumptions. Mathematical models should be validated, and attention should be made to special conditions that occur with typical negatively buoyant discharges such as reduction in dilution due to Coanda effects and jet merging in the case of multiport diffusers.