FUTURE SUPPLY ACTIONS PROGRAM

WEBINAR SERIES

One Water

THE METROPOLITAN WATER DISTRICT of SOUTHERN CALIFORNIA

Development of an Approach for the Evaluation of Brine Diffuser Shear Mortality

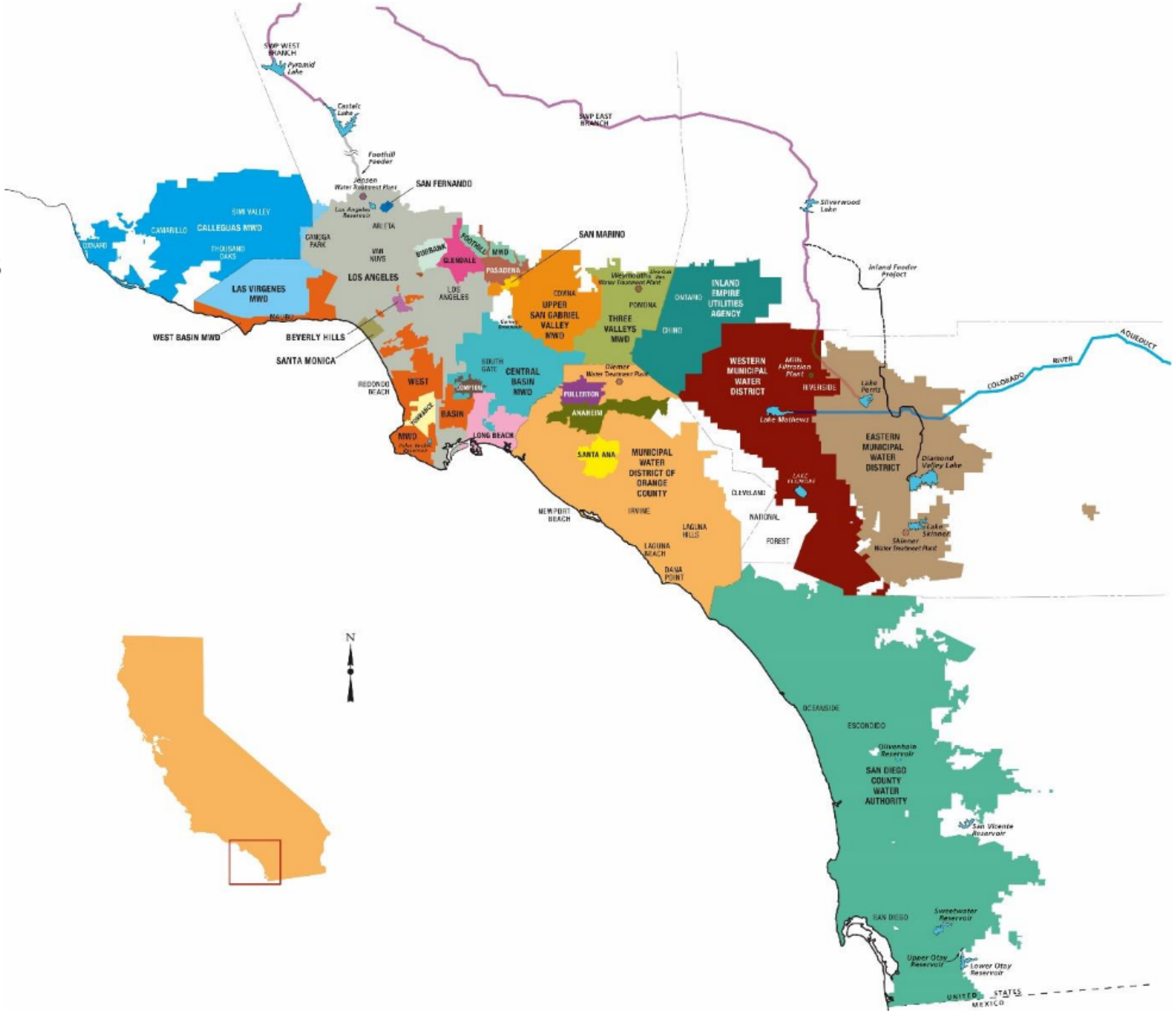
May 12, 2022

Agenda

- Welcome & Introductions
- Presentation
- Questions & Answers

The Metropolitan Water District of Southern California

- Nation's largest wholesale water provider
- Service area: 19 million people/5,200 square miles/parts of six counties
- 26 member agencies
- Supports $1 trillion regional economy
- Imports water from Northern Sierra and the Colorado River, invests in local projects



Metropolitan's Role for Southern CA

Future Supply Actions Funding Program

Future Supply Actions established in 2010 IRP

Drive innovation

Pilot new approaches and technologies	**Remove barriers** to supply development	**Benefit the region**

Local Resources

Groundwater	**Stormwater**	**Reuse**	**Desalination**

Current Program

Member Agency

- 14 studies
- $3.1 million

Water Research Foundation

- 6 potable reuse studies
- 1 agricultural reuse study
- $975k

Speaker Spotlight

Al Preston, Ph.D., P.E.

Geosyntec

Mine Berg, Ph.D.

Environmental Science Associate

Alejandra Cano

West Basin Municipal Water District

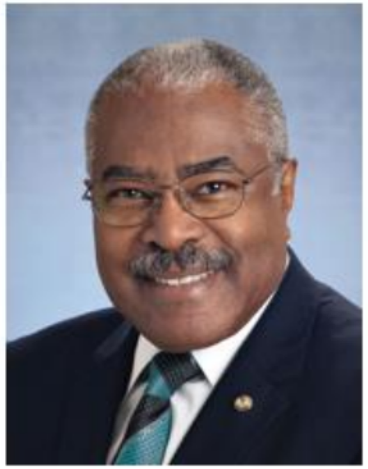
Presentation Outline

- ❑ West Basin Municipal Water District
- ❑ Project Team
- ❑ Background
- ❑ Study Goals
- ❑ Overview of the Study
- ❑ Computational Fluid Dynamics Model
- ❑ Mortality Literature Review
- ❑ Challenges
- ❑ Case Studies
- ❑ Key Lessons Learned
- ❑ Recommendations

Mission

Provide a **safe** and **reliable** supply of **high-quality water** to the communities we serve.

Board of Directors



Division I

Harold C. Williams
Immediate Past President

Division II

Gloria D. Gray
Secretary

Division III

Desi Alvarez
Treasurer

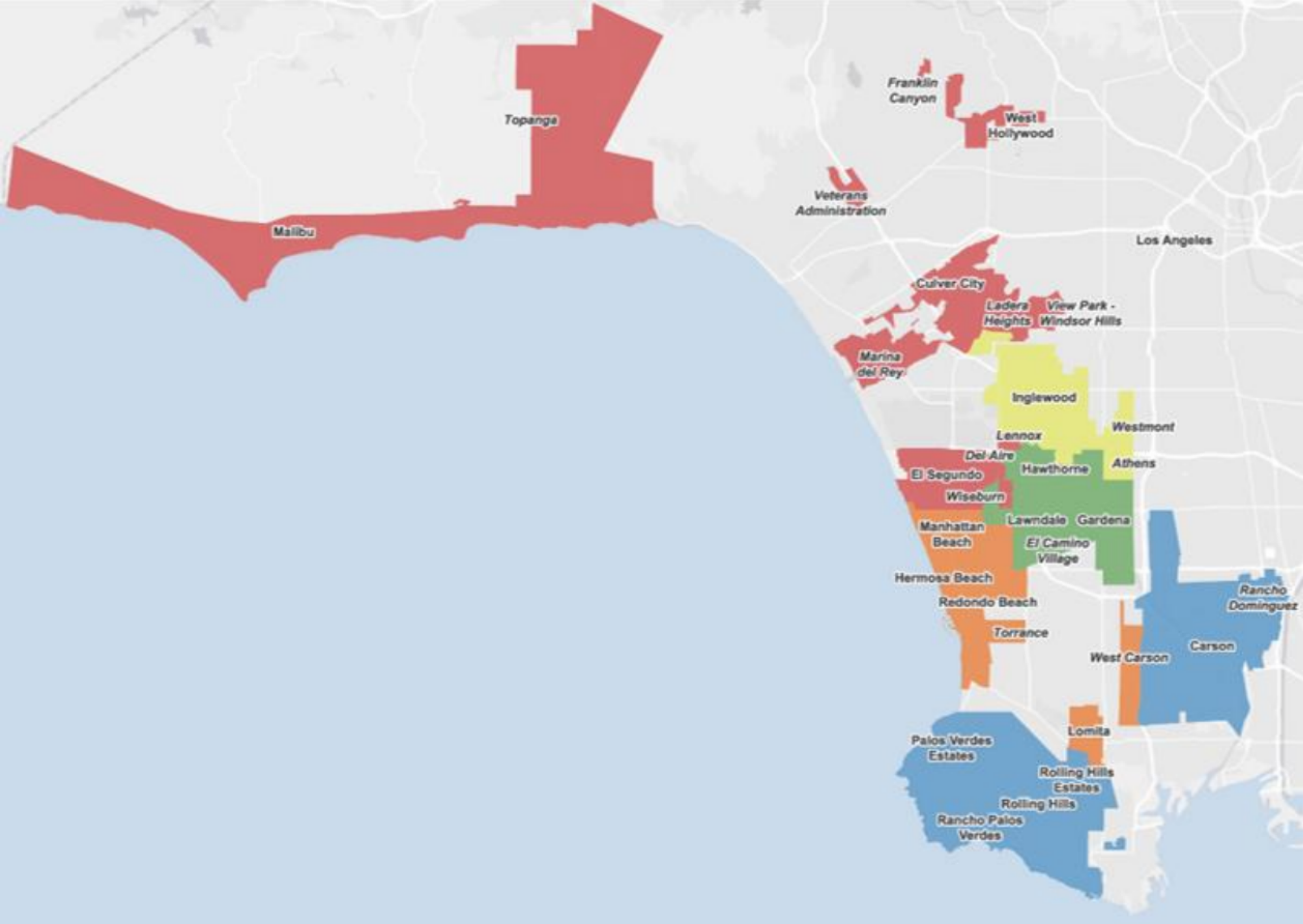
Division IV

Scott Houston
Vice President

Division V

Donald L. Dear
President

Service Area



Division I
Carson, Palos Verdes Estates, Rancho Palos Verdes, Rolling Hills, Rolling Hills Estates, and unincorporated LA County areas of Rancho Dominguez

Division II
Inglewood, and unincorporated LA County areas of Lennox, South Ladera Heights, West Athens, and Westmont

Division III
Hermosa Beach, Lomita, Manhattan Beach, Redondo Beach, portion of Torrance and West Carson

Division IV
Culver City, El Segundo, Malibu, West Hollywood, and unincorporated LA County areas of Del Aire, Lennox, Marina del Rey, North Ladera Heights, Topanga, View Park - Windsor Hills and Wiseburn

Division V
Gardena, Hawthorne, Lawndale, and unincorporated LA County area of El Camino Village

Project Team

Alejandra Cano

Project Advisory Committee

- **Dr. Phil Roberts**
- **Dr. Bryan Gaylord**

Dr. Al Preston, PE

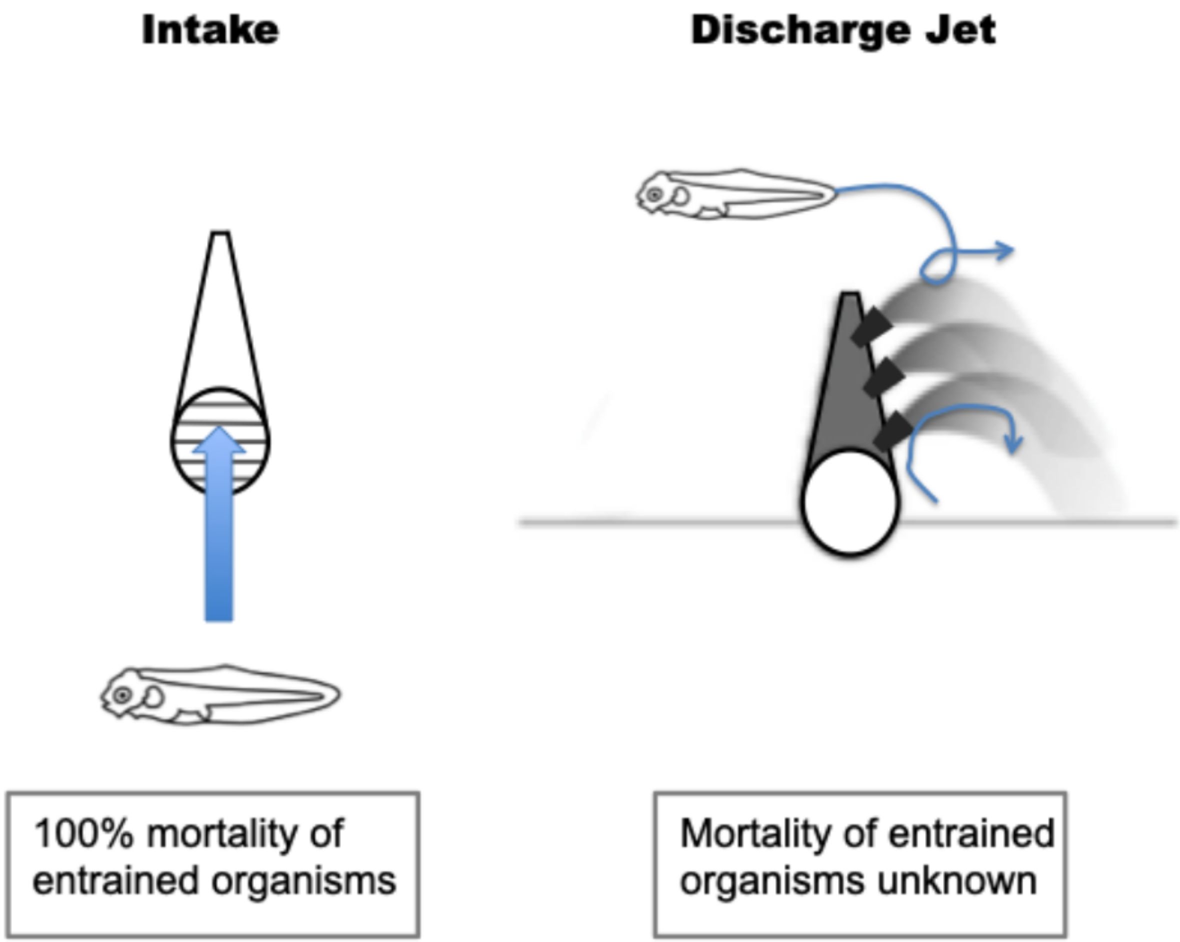
Dr. Mine Berg

Eric Zigas

Alex Wesner, PE

Background

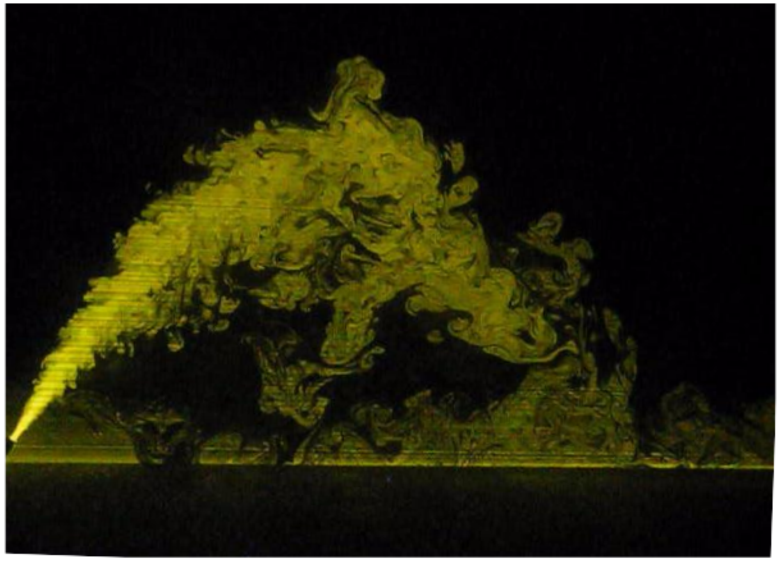
Background



Blue arrows: entrained water

Background

How to Quantify Turbulence and Shear Effects on Living Organisms?



Video by Dr. Phil Roberts

Current Approach:

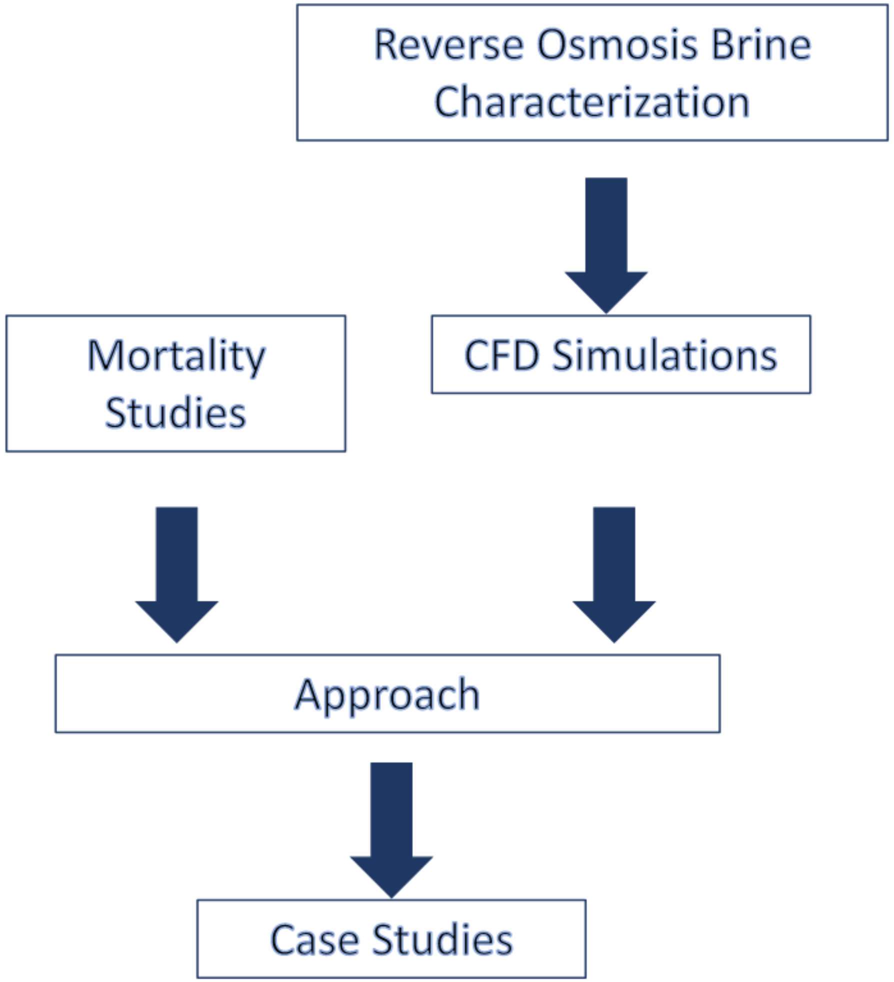
- Estimate entrainment of organisms to the apex
- Assume 100% mortality

Study Goals

- Improve the characterization of the shear and turbulence properties in a brine discharge jet/plume
- Have a better understanding of the relationship between discharge jet/plume characteristics and shear mortality
- Provide a methodology based upon sound science to enable more realistic estimates of shear mortality
- Help inform improved designs of diffuser systems to minimize mortality, while still meeting California Ocean Plan dilution requirements.

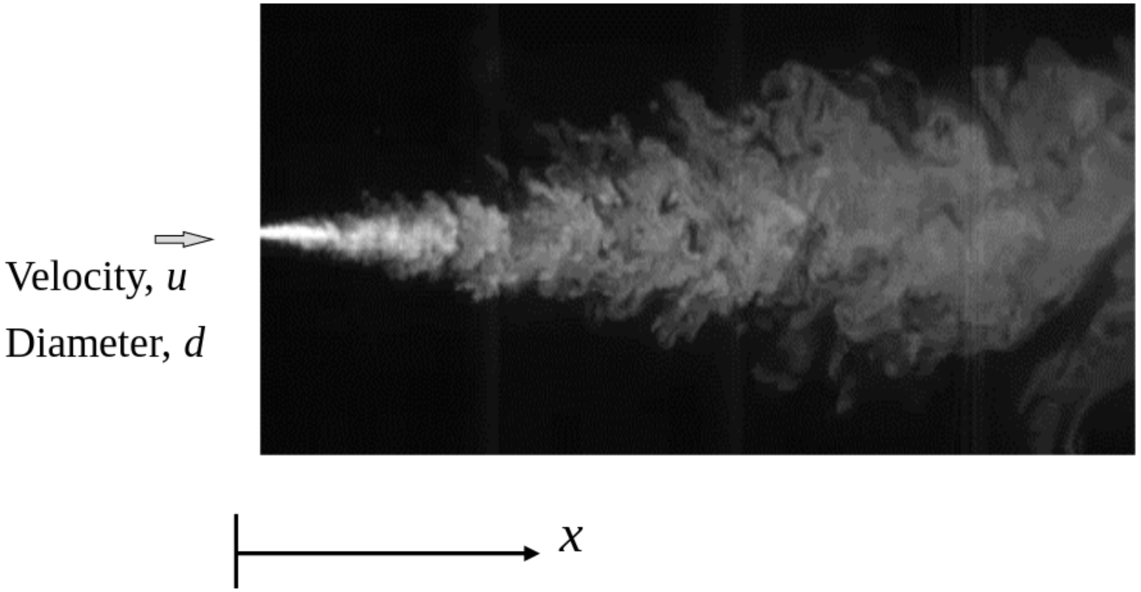
Overview of the Study

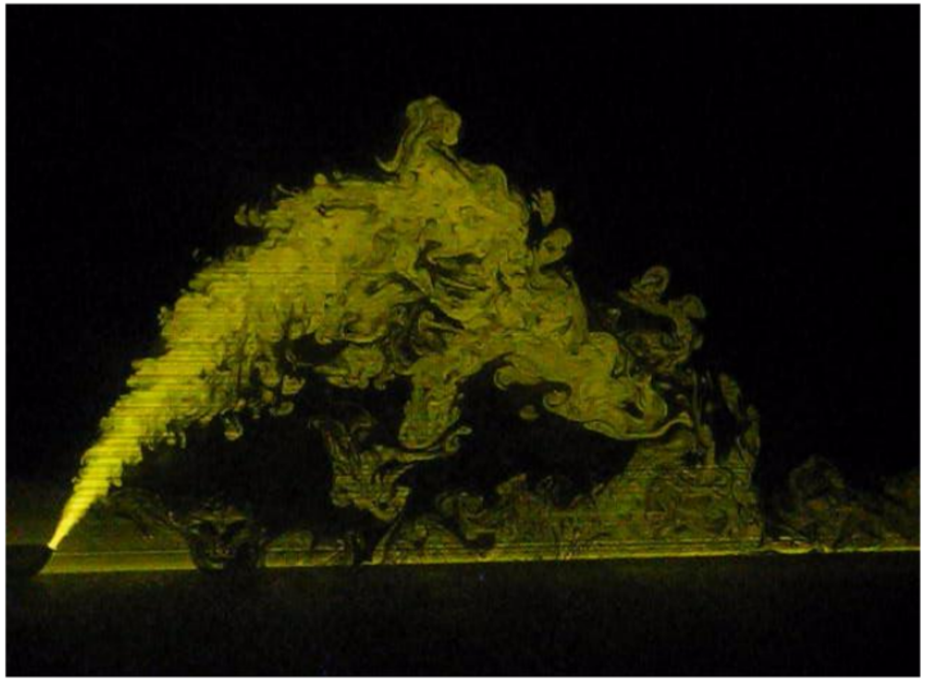
- Computational Fluid Dynamics (CFD) Model (Development, Validation and Results)
- Mortality Literature Review
- Develop an Approach
- Case Studies



Computational Fluid Dynamics (CFD) Model

Jet/Plume Turbulence





Kolmogorov scale = smallest length scale in flow

Kolmogorov scale on centerline:

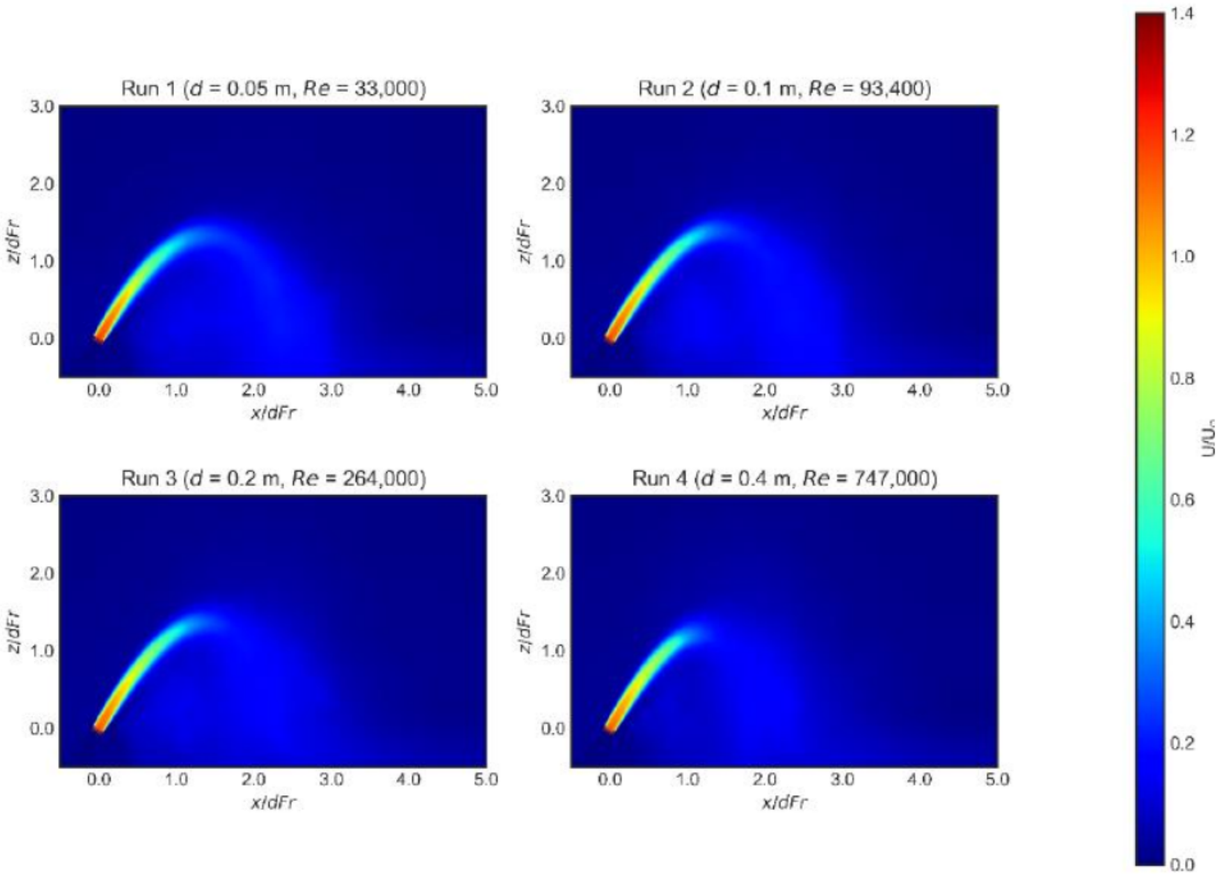
$$\frac{\eta_c}{x} = 0.24\,\mathrm{Re}^{-3/4} \qquad \mathrm{Re} = \frac{ud}{\nu}$$

CFD Parameterizations

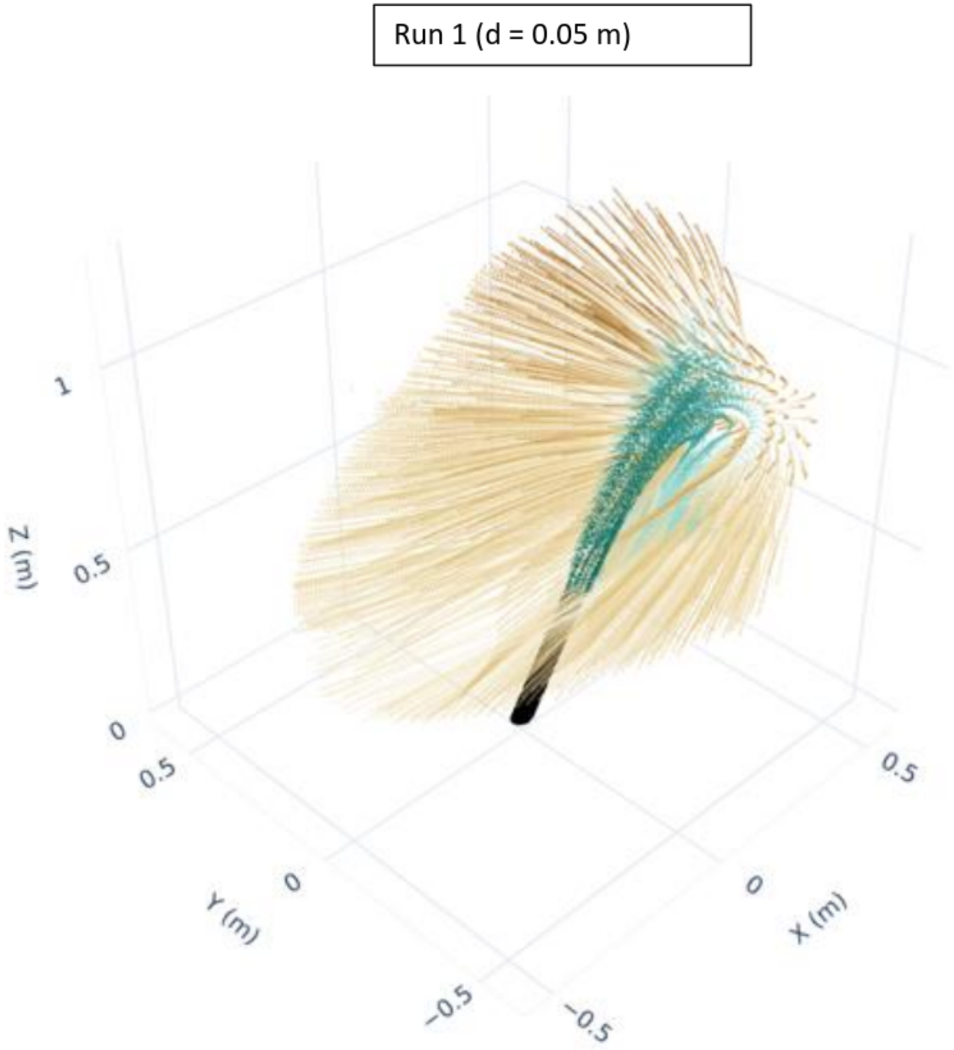
Table 1. Simulation Parameters

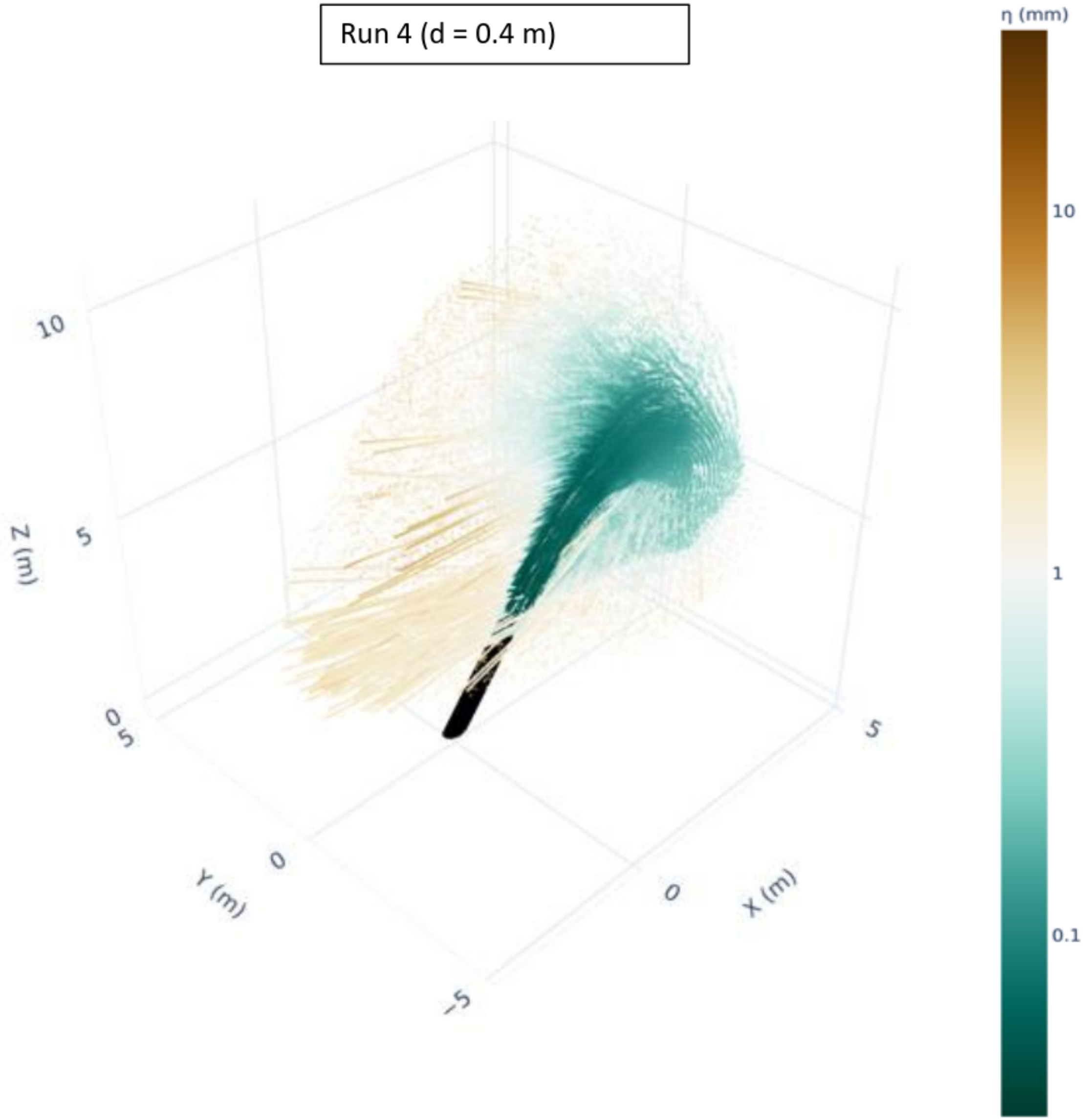
#	Description	Port diameter, d (m)	Ambient salinity, S_a (ppt)	Discharge salinity, S_0 (ppt)	Salinity increment, ΔS (ppt)	Ambient density, ρ_a (kg/m^3)	Discharge density, ρ_0 (kg/m^3)	Froude number, Fr	Port velocity, u (m/s)	Reynolds number, Re
0	Validation	0.00429	0	33	33	997	1030	20	0.75	3,200
1	Vary Re – 1	0.05	33	66	33	1023.2	1048.6	6.35	0.70	33,000
2	Vary Re – 2	0.1	33	66	33	1023.2	1048.6	6.35	0.99	93,400
3	Vary Re – 3	0.2	33	66	33	1023.2	1048.6	6.35	1.40	264,300
4	Vary Re – 4	0.4	33	66	33	1023.2	1048.6	6.35	1.98	747,400
5	Vary S_a	0.1	34	67	33	1024.0	1049.4	6.35	0.99	93,400
6	Vary S_0 – 1	0.1	33	60	27	1023.2	1044.0	5.19	0.73	69,100
7	Vary S_0 – 2	0.1	33	72	39	1023.2	1053.3	7.50	1.27	120,200
8	Blended – 1	0.1	33	50	17	1023.2	1036.3	3.27	0.37	34,500
9	Blended – 2	0.1	33	40	7	1023.2	1028.6	1.35	0.10	9,100
10	Neutrally Buoyant*	0.1	33	33	0	1023.2	1023.2	undefined	0.99	93,400

* The neutrally buoyant simulation is used for comparison purposes only. The current project only considers negatively buoyant jets/plumes.

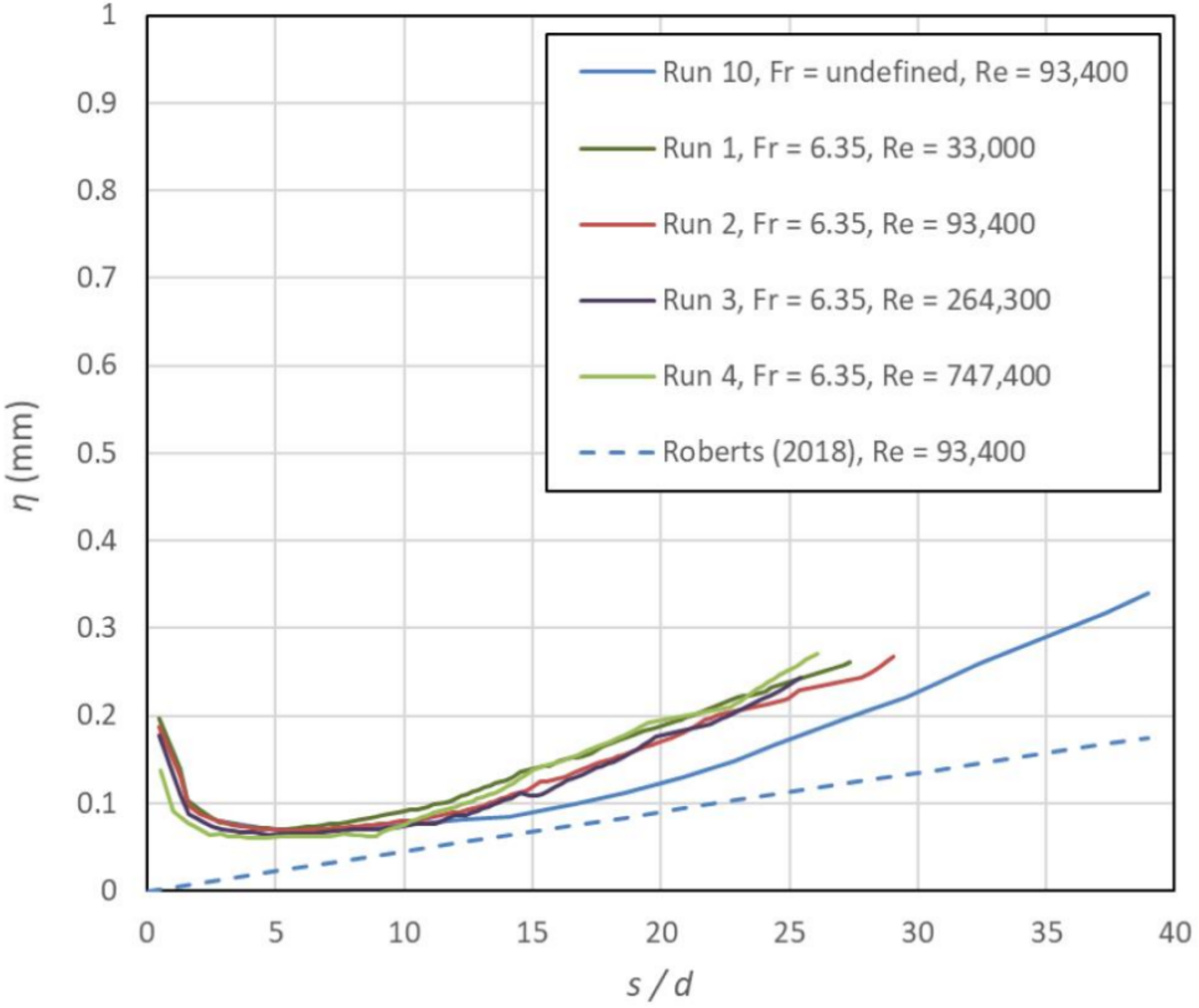


CFD Results - Trajectories





CFD Results – Kolmogorov Length Scale



1	Negative buoyancy slightly reduces turbulence intensity the rising portion of the plume compared to a neutrally-buoyant jet
2	For typical diffuser designs the Kolmogorov scales remain below 0.5 mm throughout the rising portion of the plume
3	Results are consistent with the general approach of Roberts (2018) in terms of estimating the Kolmogorov scale in the rising portion of the plume

CFD Simulation Conclusions

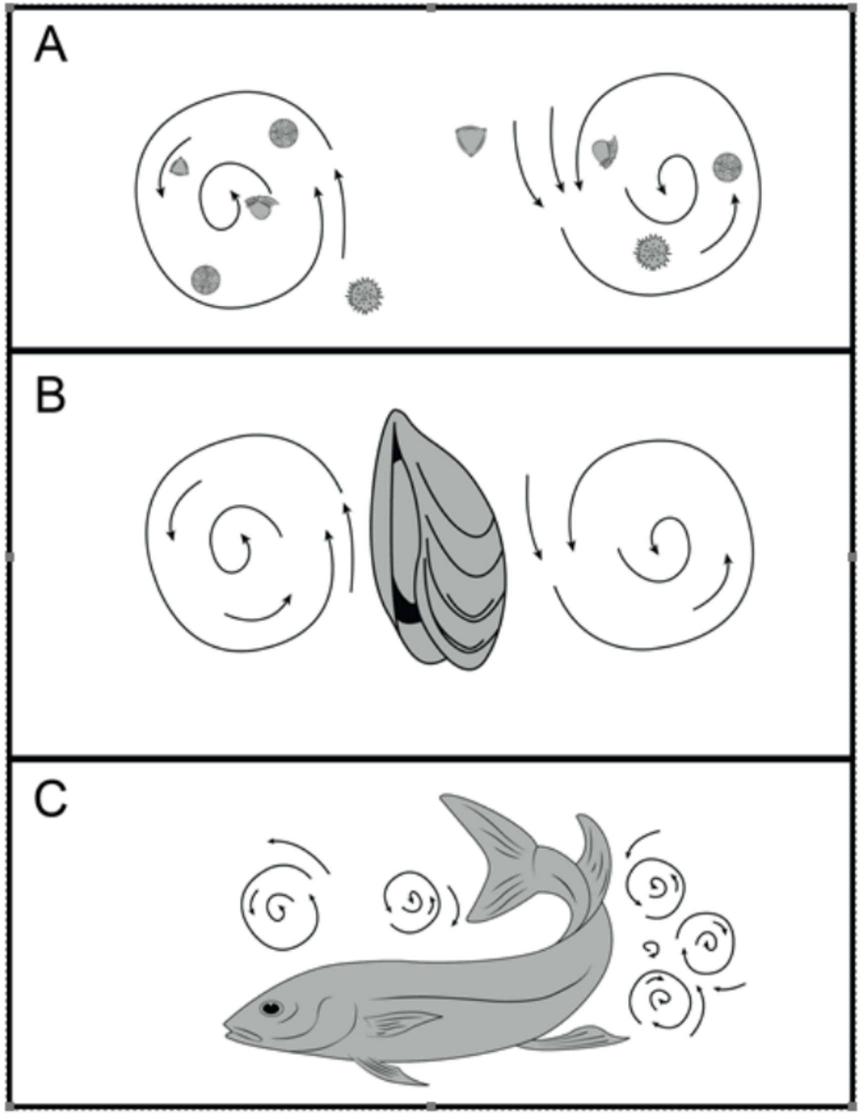
1	Negative buoyancy slightly reduces turbulence intensity the rising portion of the plume compared to a neutrally-buoyant jet
2	For typical diffuser designs the Kolmogorov scales remain below 0.5 mm throughout the rising portion of the plume
3	Results are consistent with the general approach of Roberts (2018) in terms of estimating the Kolmogorov scale in the rising portion of the plume
4	CFD results can provide a wealth of other information (statistics, durations, time histories, trajectories, entrainment velocities, entrainment volumes)

Mortality
Literature Review

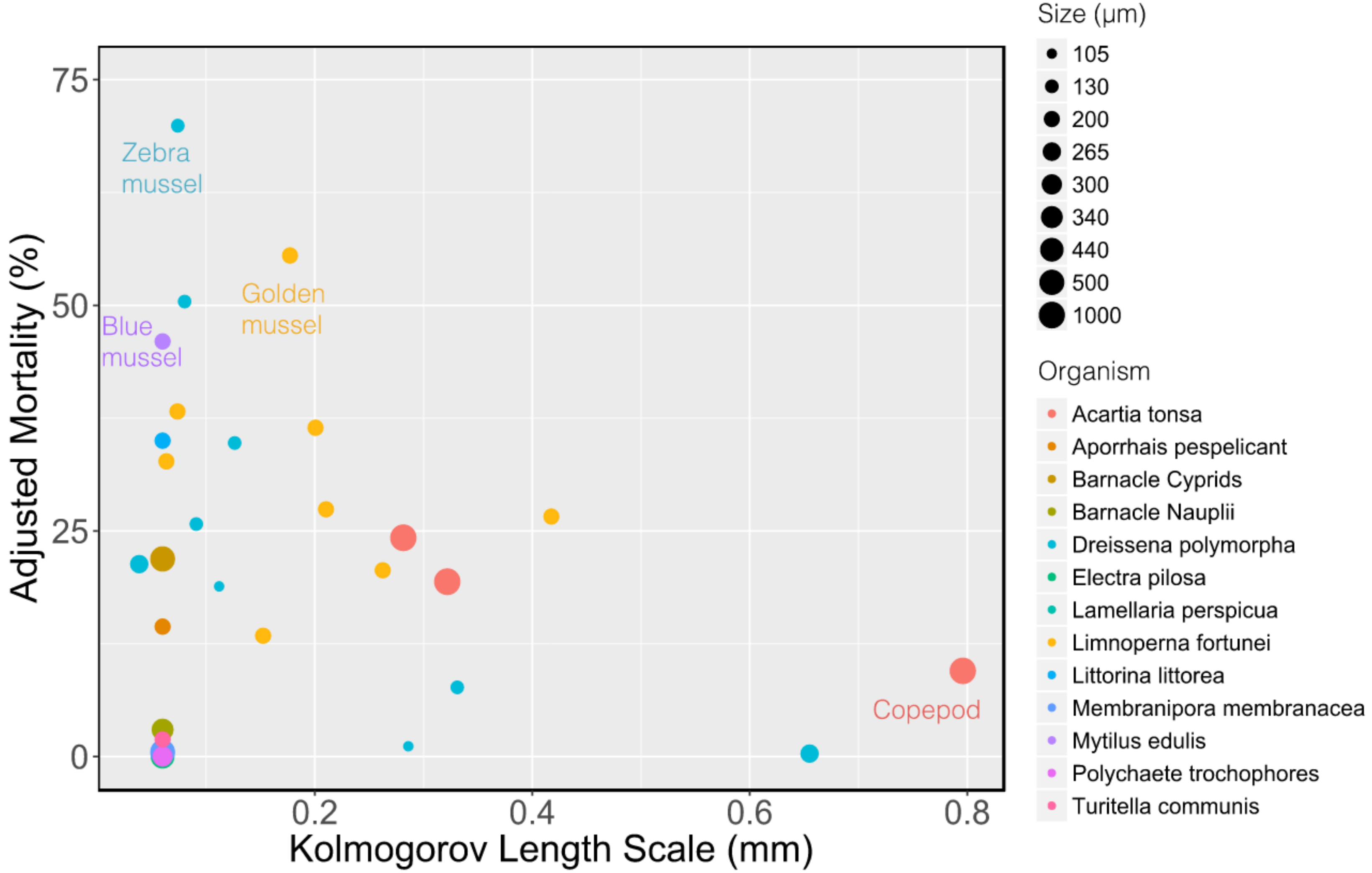
Mortality and Size Relative to Kolmogorov Length Scale

1

Mortality is greatest when size of organism is comparable to that of the smallest turbulent eddies



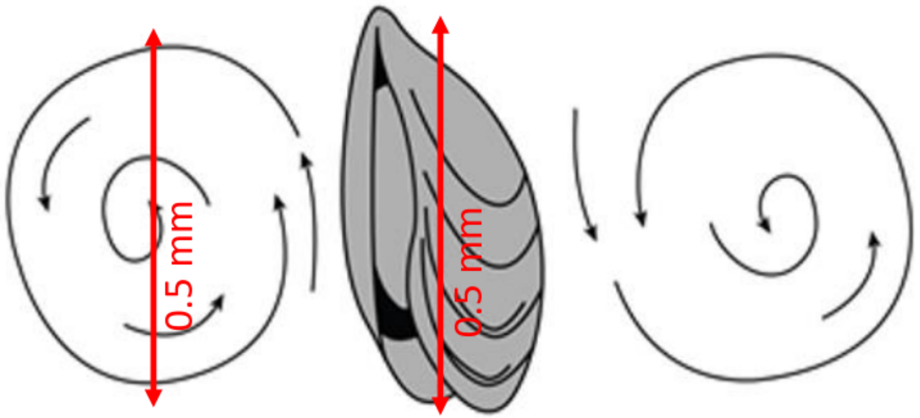
Relationship Between Kolmogorov Length Scale and Mortality



Maximum Mortality at Kolmogorov Scale < 0.5 mm

2

Mortality of larval organisms would most likely be limited to the region of the jet where the Kolmogorov length scale < 0.5 mm



Mortality greatest to organisms with size similar to most damaging Kolmogorov length scale, i.e. 0.5 mm and smaller

Larval Mortalities Differed by Taxonomic Group

3

Maximum mortalities differed by taxonomic groups. No commercially important larval populations (such as fish) were included in the review

Taxonomic Group	Maximum Adjusted Mortality (%)	Species Examined in Group
Bivalves	70	*Dreissena polymorpha* *Limnoperna fortunei* *Mytilus edulis*
Gastropods	35	*Littorina littorea,* *Aporrhais pespelicant* *Turitella communis* *Lamellaria perspicua*
Copepods	24	*Acartia tonsa*
Barnacles	22	*Barnacle nauplii and cyprids*
Bryozoans	0.5	*Membranipora membranacea* *Electra pilosa*
Polychaetes	0	*Polychaete trochophores*

Overall Mortalities

4

The 90th percentile of the combined data from all the reviewed studies (11 total) had a mortality of 50% or lower

Maximum mortality = 70% (24 hr)

Short duration mortality < 50% (<5 min)

Median mortality = 20%

Shear Mortality Literature Review Conclusions

1	Mortality of small marine organisms from turbulence increases sharply when their size is comparable to that of the smallest turbulent eddies
2	Mortality of larval organisms is most likely limited to the region of the jet where the Kolmogorov length scale < 0.5 mm
3	Maximum mortalities differ by taxonomic groups
4	Short term mortality is less than 50%

Challenges Faced in the Study

On mortality of fish larvae data

Larvae reviewed in literature:

- Zebra mussels
- Golden mussels
- Gastropods
- Copepods
- Eggs

Larvae emphasized in impact calculation:

- Fish
- Shellfish

One study of fish larvae examined their response to laminar flow could not be compared to turbulence fields or energy dissipation rates

Turbulence mechanism

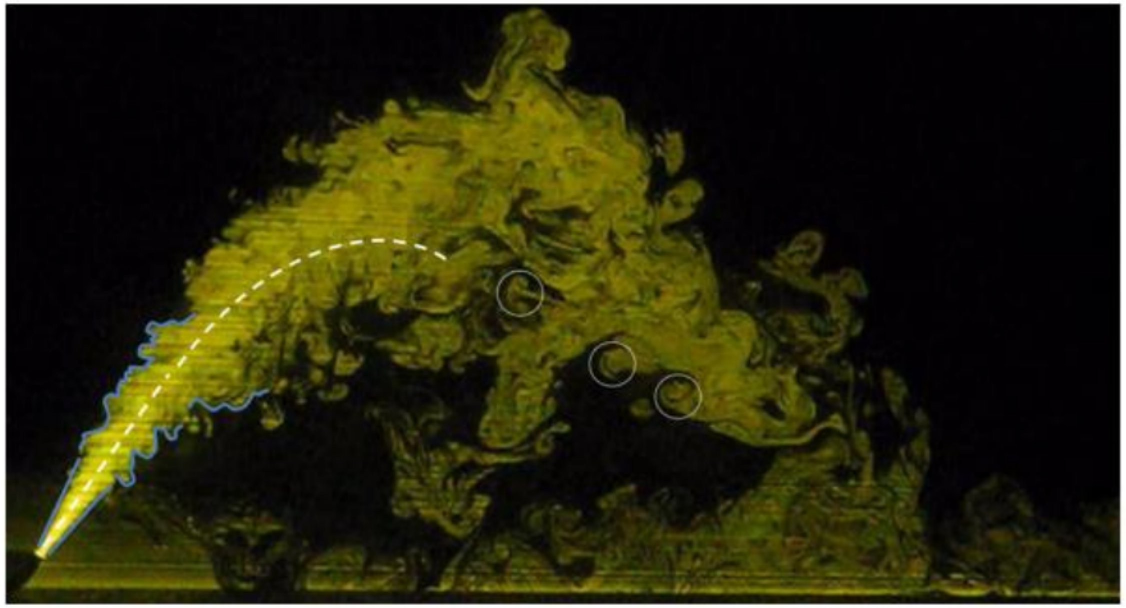
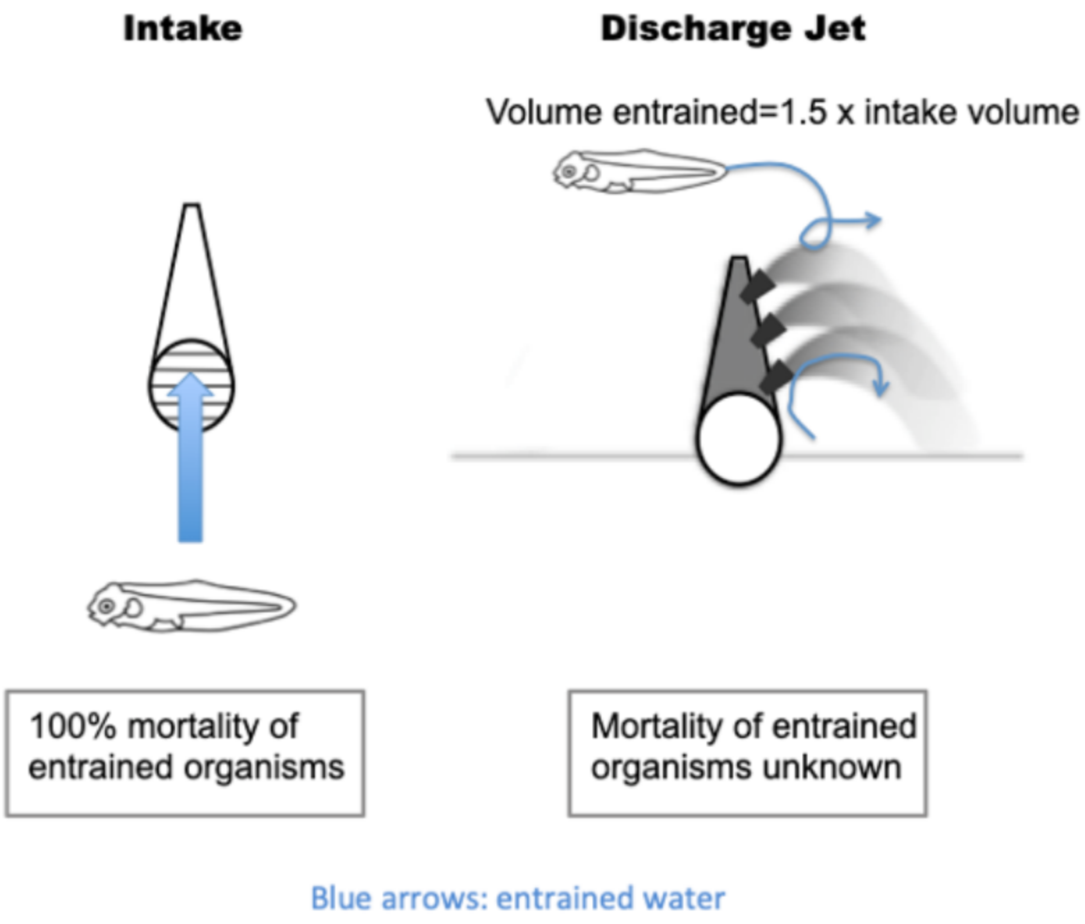


Image of high velocity brine jet/plume flow entraining surrounding water. Dashed white line represents the centerline of the rising jet/plume where eddy sizes are smallest and viscous shear stresses are potentially damaging to marine organisms.

Case Studies

Case Studies



Discharge calculations for West Basin and Huntington Beach:

- Use 1 mm size exclusion threshold
- Use 50% mortality

Area Production Foregone (APF) Calculation

APF = Proportional Mortality (P_M) x $Area_{SW}$

P_M's for target fish larvae calculated via ETM* by:

- Focusing on fish larvae 1 mm size or smaller
- Assigning 50% mortality to fish larvae 1 mm size or smaller

**ETM = Empirical Transport Model*

Application to West Basin's Ocean Water Desalination Project (OWDP)

Target Larvae	A_{SW} (acres)	P_M-in	F_V (volume scaling factor)	F_S (size scaling factor)	F_M (mortality scaling factor)	P_M-dis1	P_M-dis2
Sea basses	30,305	5.00×10^{-3}	0.2985	0.07	0.5	1.49×10^{-3}	5.22×10^{-5}
Combtooth blennies	1,356	4.00×10^{-3}	0.2985	0	0.5	1.19×10^{-3}	0
CIQ goby complex	1,356	2.21×10^{-2}	0.2985	0	0.5	6.60×10^{-3}	0
Diamond turbot	1,356	3.09×10^{-2}	0.2985	0	0.5	9.23×10^{-3}	0
N. anchovies	292,775	2.20×10^{-3}	0.2985	0.01	0.5	6.57×10^{-4}	3.28×10^{-6}
Silversides	22,573	3.19×10^{-2}	0.2985	0	0.5	9.52×10^{-3}	0
White croaker	131,435	4.20×10^{-3}	0.2985	0.04	0.5	1.25×10^{-3}	2.51×10^{-5}
Queenfish	86,049	5.00×10^{-4}	0.2985	0	0.5	1.49×10^{-4}	0
Unid. croakers	52,114	6.80×10^{-3}	0.2985	0.23	0.5	2.03×10^{-3}	2.33×10^{-4}
Sanddabs	36,616	1.50×10^{-3}	0.2985	0.59	0.5	4.48×10^{-4}	1.32×10^{-4}
California halibut	65,246	2.40×10^{-3}	0.2985	0.025	0.5	7.17×10^{-4}	8.96×10^{-6}
English sole	55,964	1.10×10^{-3}	0.2985	0	0.5	3.28×10^{-4}	0

$F_V = OWDP_{entrain}/ESGS_{intake}$=116 MGD/398.6 MGD=0.2985
$F_S = Larvae_{<1mm}/Larvae_{ALL}$
F_M=0.5
P_M-dis1=P_M-in x F_V
P_M-dis2=P_M-in x F_V x F_S x F_M

Application to Huntington Beach Desalination Plant (HBDP)

Target Larvae	A_{SW} (acres)	P_M-in	F_V (volume scaling factor)	F_S (size scaling factor)	F_M (mortality scaling factor)	P_M-dis1	P_M-dis2
Combtooth blennies	75,243	2.75×10^{-3}	0.2795	0	0.5	7.44×10^{-4}	0
CIQ goby complex	15,815	1.35×10^{-3}	0.2795	0	0.5	7.68×10^{-4}	0
Diamond turbot	20,880	1.01×10^{-3}	0.2795	0.17	0.5	2.83×10^{-4}	2.41×10^{-5}
Sand crabs	32,741	1.74×10^{-3}	0.2795	1.00	0.5	4.87×10^{-4}	2.43×10^{-4}
N. anchovies	88,958	2.25×10^{-3}	0.2795	0	0.5	6.28×10^{-4}	0
Spotfin croaker	20,880	5.21×10^{-4}	0.2795	0.11	0.5	1.46×10^{-4}	8.01×10^{-6}
White croaker	59,058	1.50×10^{-3}	0.2795	0.01	0.5	4.19×10^{-4}	2.09×10^{-6}
Queenfish	104,896	1.20×10^{-3}	0.2795	0	0.5	3.36×10^{-4}	0
California halibut	38,178	8.29×10^{-4}	0.2795	0.36	0.5	2.32×10^{-4}	4.17×10^{-5}

$F_V = HBDP_{entrain}/HBGS_{intake}$ = 168 MGD/601.1 MGD = 0.2795

$F_S = Larvae_{<1mm}/Larvae_{ALL}$

$F_M = 0.5$

P_M-dis1 = P_M-in x F_V

P_M-dis2 = P_M-in x F_V x F_S x F_M

Preliminary Discharge APF Calculations

Project	Intake Volume (MGD)	Entrained Volume (MGD)	APF_{IN} (acres)	APF_{DIS} (acres)
WBD	41	116	47.5	1.6
HBDP	100	285*	78.1	9.2

$APF = A_{sw} \times P_M$

APF_{IN}=100% mortality of all entrained target species larval size classes

APF_{DIS}=50% mortality of ≤ 1 mm size entrained target larval species

*Estimated based on entrained/intake volume multiplier of WBD Project

Key Lessons Learned and Recommendations

Key Lessons Learned

CFD Modeling

- Negative buoyancy attenuates turbulence intensity
- However, turbulence on the rising portion is potentially damaging

Mortality Literature Review

- Use 1 mm size exclusion threshold
- Use 50% mortality

Recommendations

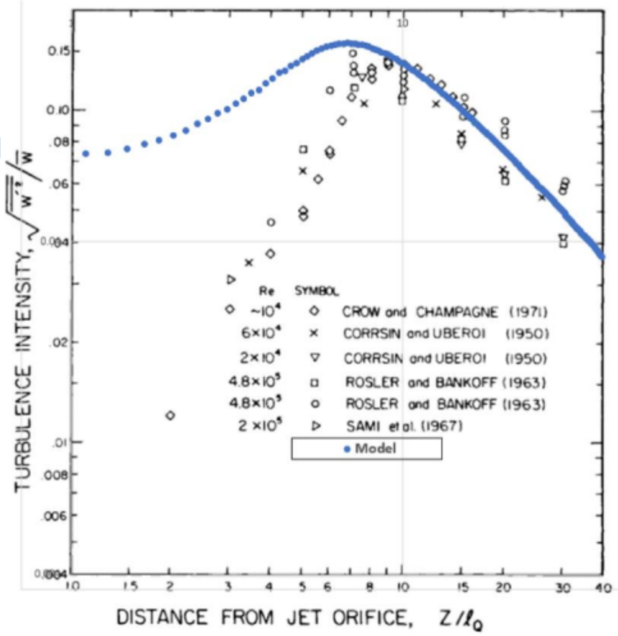
For future experimental studies, it is recommended:

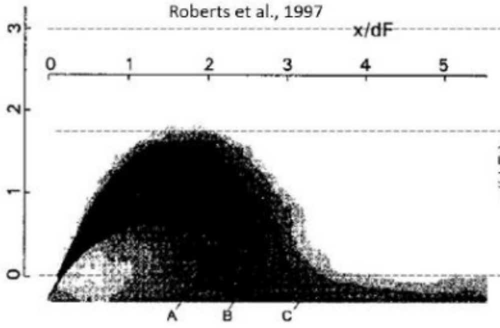
- Target species are used to test vulnerability of larvae to turbulence
- Turbulence is generated using a jet stream.

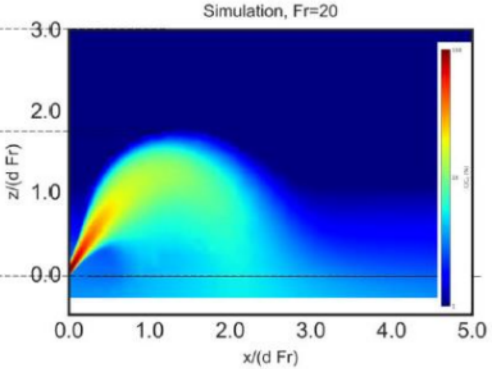
Q&A Discussion

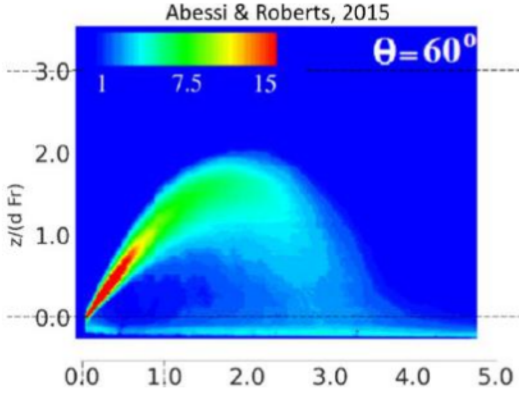
CFD Validation

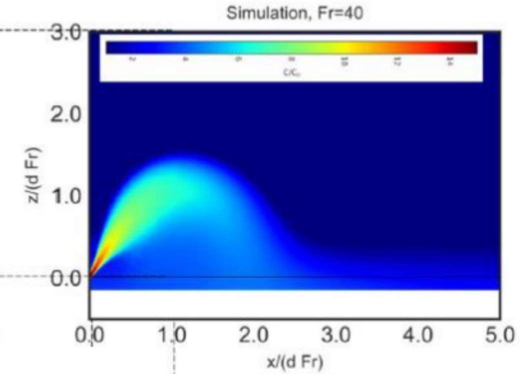
- Validated CFD results against experiments
    - Neutrally buoyant jets
    - Length scales
    - Dilutions
    - Concentration profiles

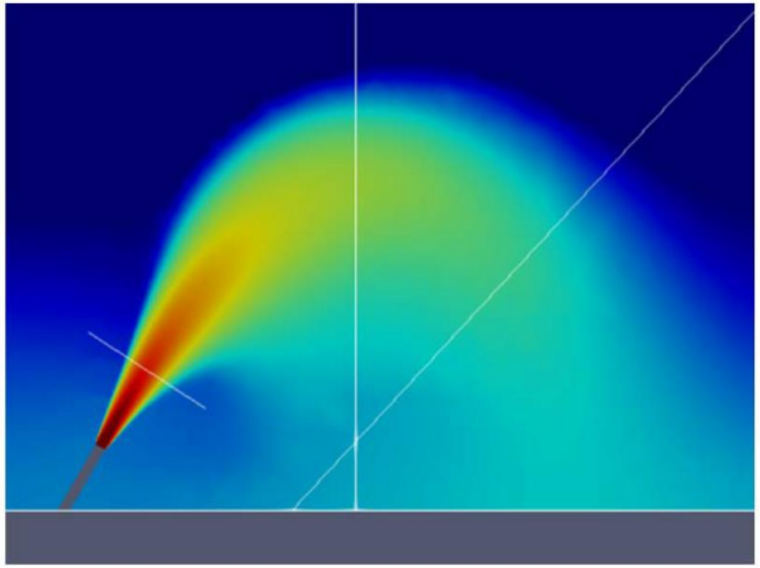


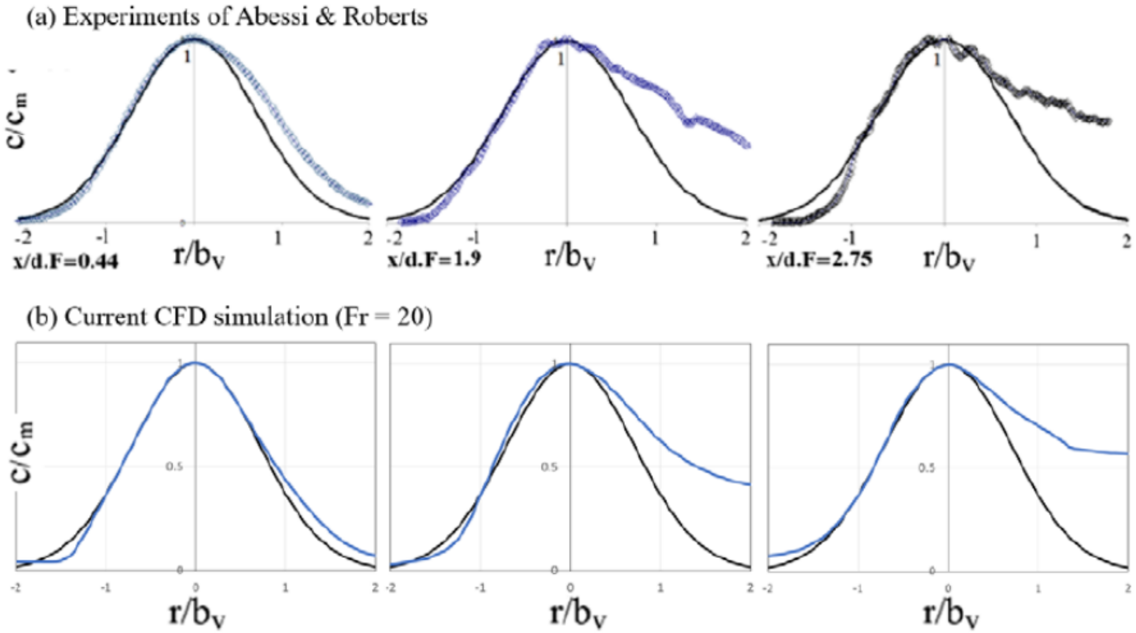




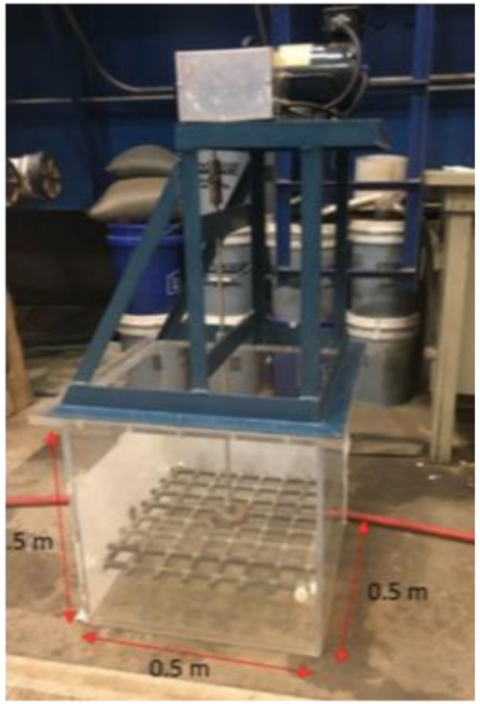




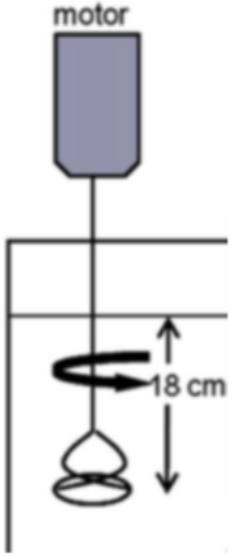




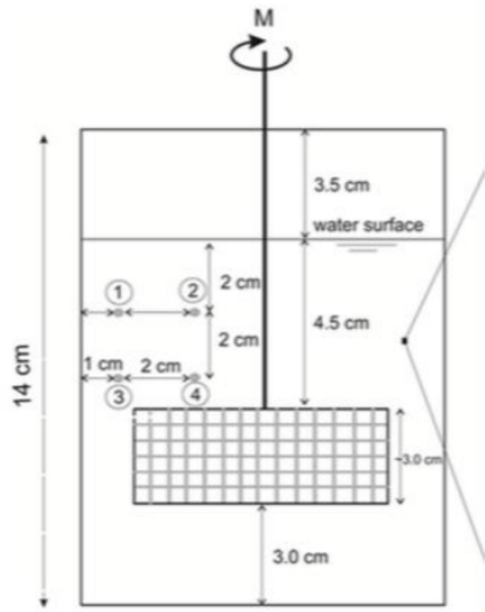
Turbulence mechanism



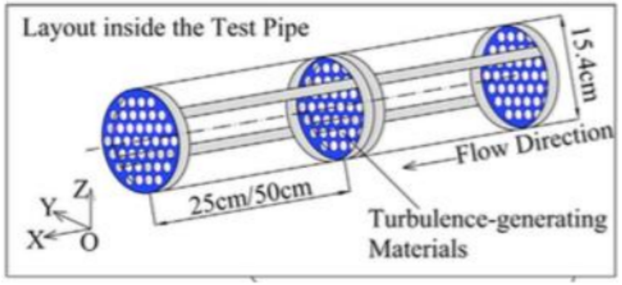
Vertically oscillating grid



Rotating Stirrer

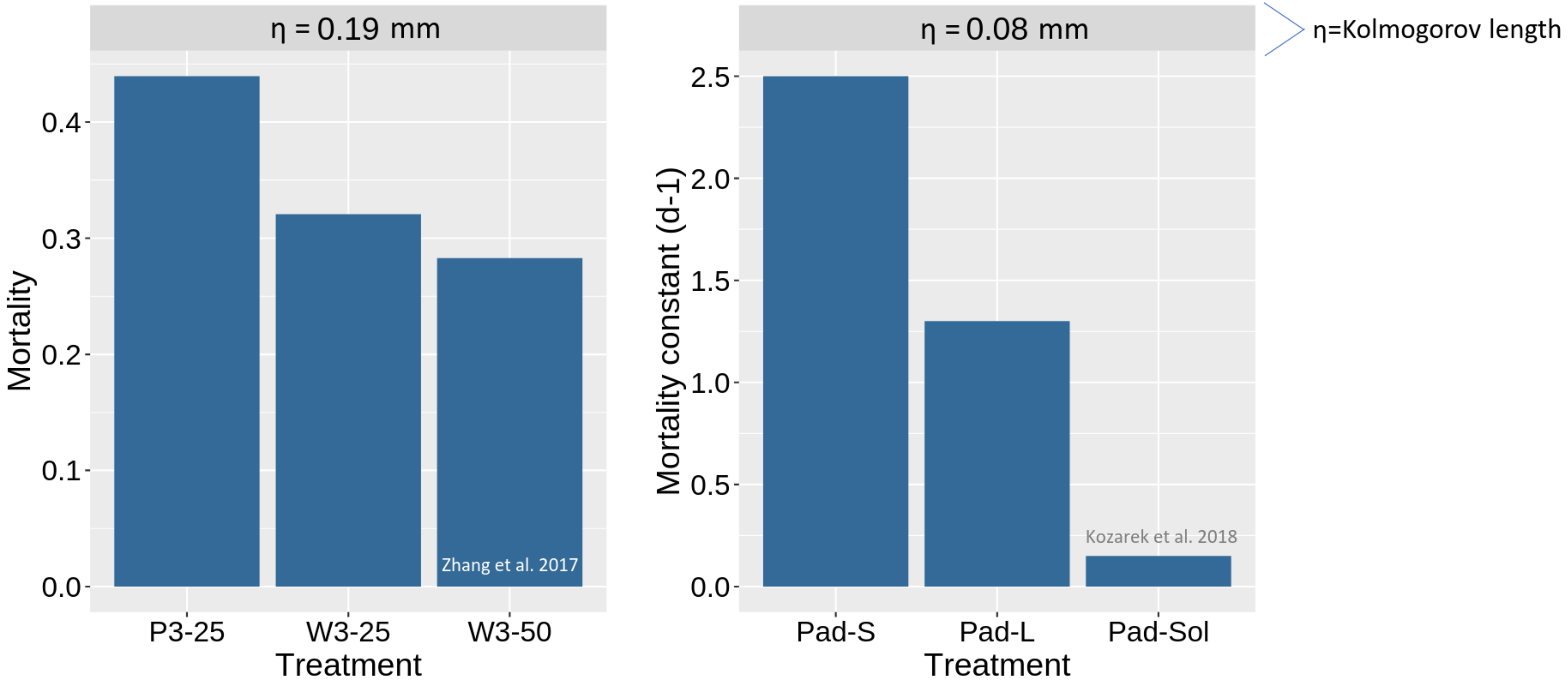


Rotating Paddle



Flow through perforated plates in pipe

Mortality variation depending on turbulence mechanism



At the Kolmogorov scale, turbulence is isotropic, i.e. its properties do not depend on how it is generated, therefore should give the same results in terms of mortality