ISOS|2023

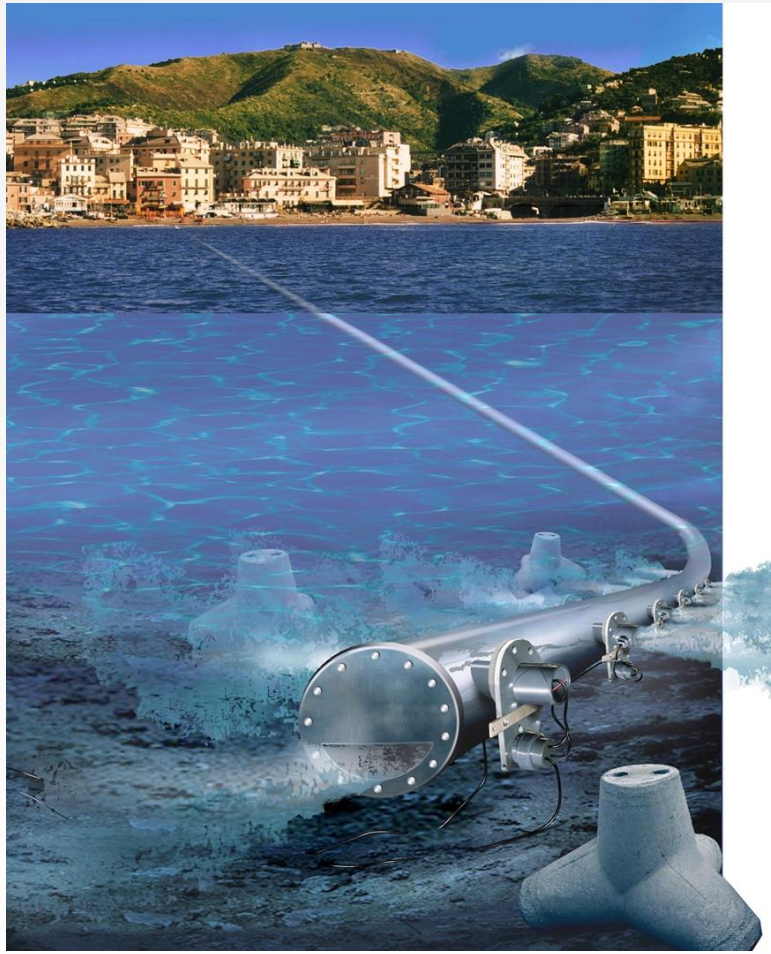
Simposio Internacional sobre Sistemas de Emisarios 2023

International Symposium on Outfall Systems 2023

Outfall modelling for Mixing Zone definition

PROF. DR.-ING. TOBIAS BLENINGER (FEDERAL UNIVERSITY OF PARANÁ, UFPR, BRAZIL)

CONTENT



- Problem and context: Coastal Water Quality
- Outfall Systems
- Design criteria
- Case study: São Paulo Coast
- Conclusions

Problem?

TABLE 1
NEED FOR FERTILISERS (NITROGEN, POTASSIUM AND PHOSPHORUS) TO PRODUCE 250 KG OF CEREALS AND THE CONTENT IN (SWEDISH) FAECES AND URINE

Important nutrients	Urine 500 l/yr	Faeces 50 l/yr	Total	Nutrient need for 250 kg cereals
Nitrogen (N)	4.0 kg, 88%	0.5 kg, 12%	4.5 kg, 100%	5.6 kg
Phosphorus (P)	0.4 kg, 67%	0.2 kg, 33%	0.6 kg, 100%	0.7 kg
Potassium (K)	0.9 kg, 71%	0.3 kg, 29%	1.2 kg, 100%	1.2 kg
Total amount of N+P+K	5.3 kg	1.0 kg	6.3 kg	7.5 kg

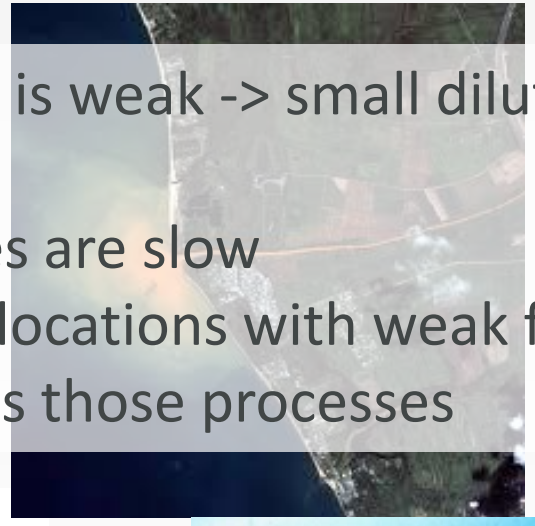
Sources: SEPA, 1995 and Wolgast, 1993

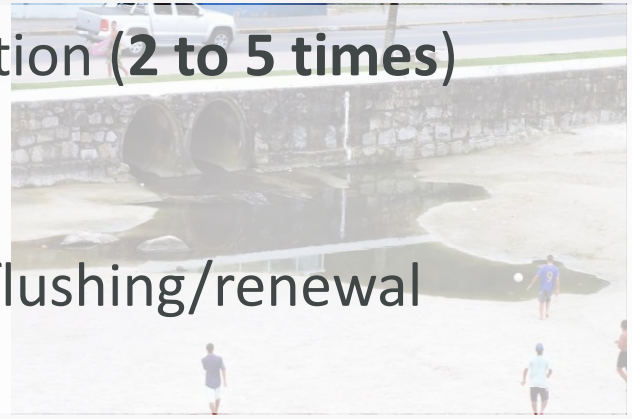
- Everything ok?

Natural and anthropogenic nutrients vs. contaminants

Mixing Processes:

$$\text{Dilution} = \frac{\text{efluente concentration}}{\text{ambient concentration (limit)}}$$





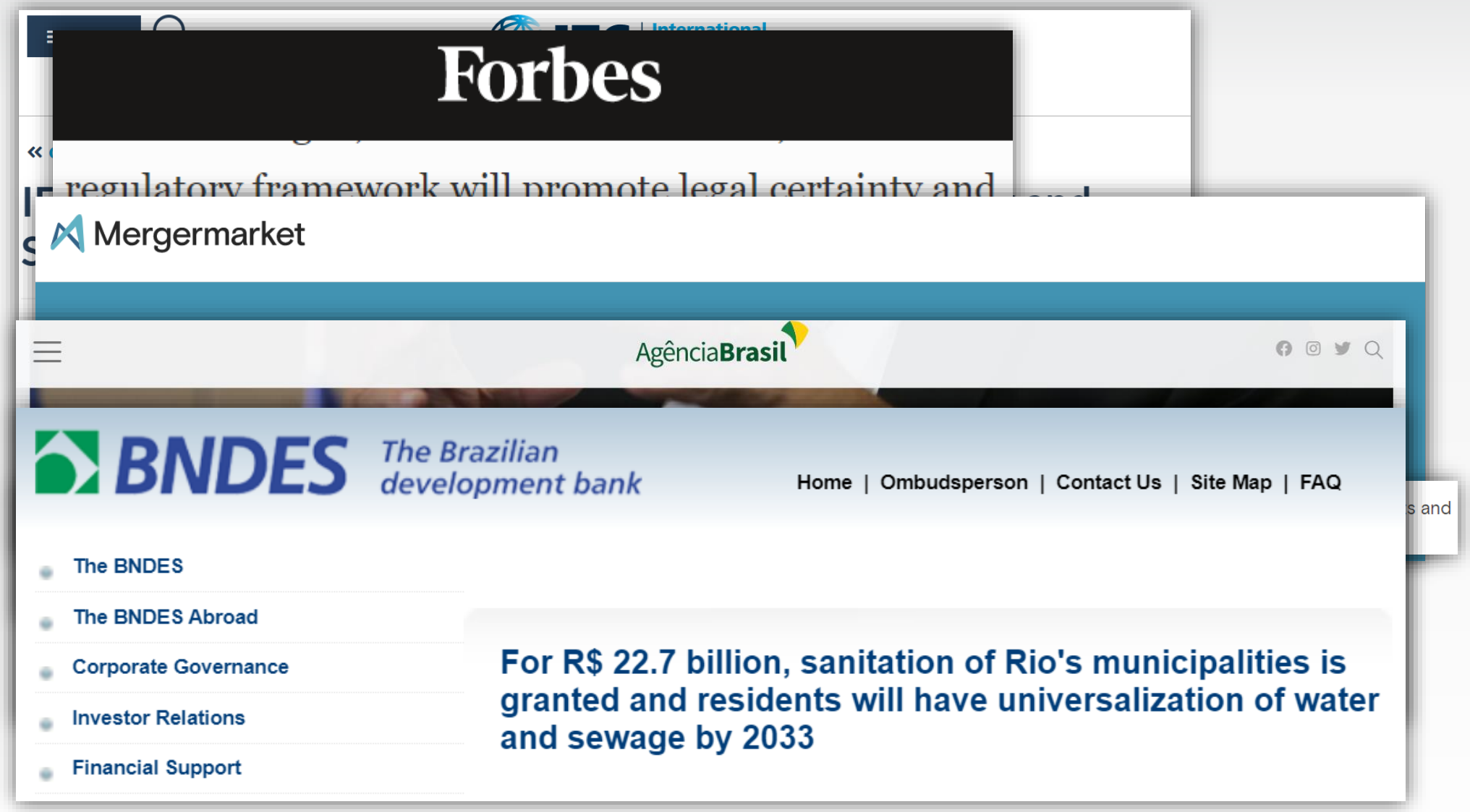
Passive ambient mixing is weak -> small dilution (**2 to 5 times**)

Biodegradation:

- Assimilative capacities are slow
- Especially at shallow locations with weak flushing/renewal
- Treatment accelerates those processes

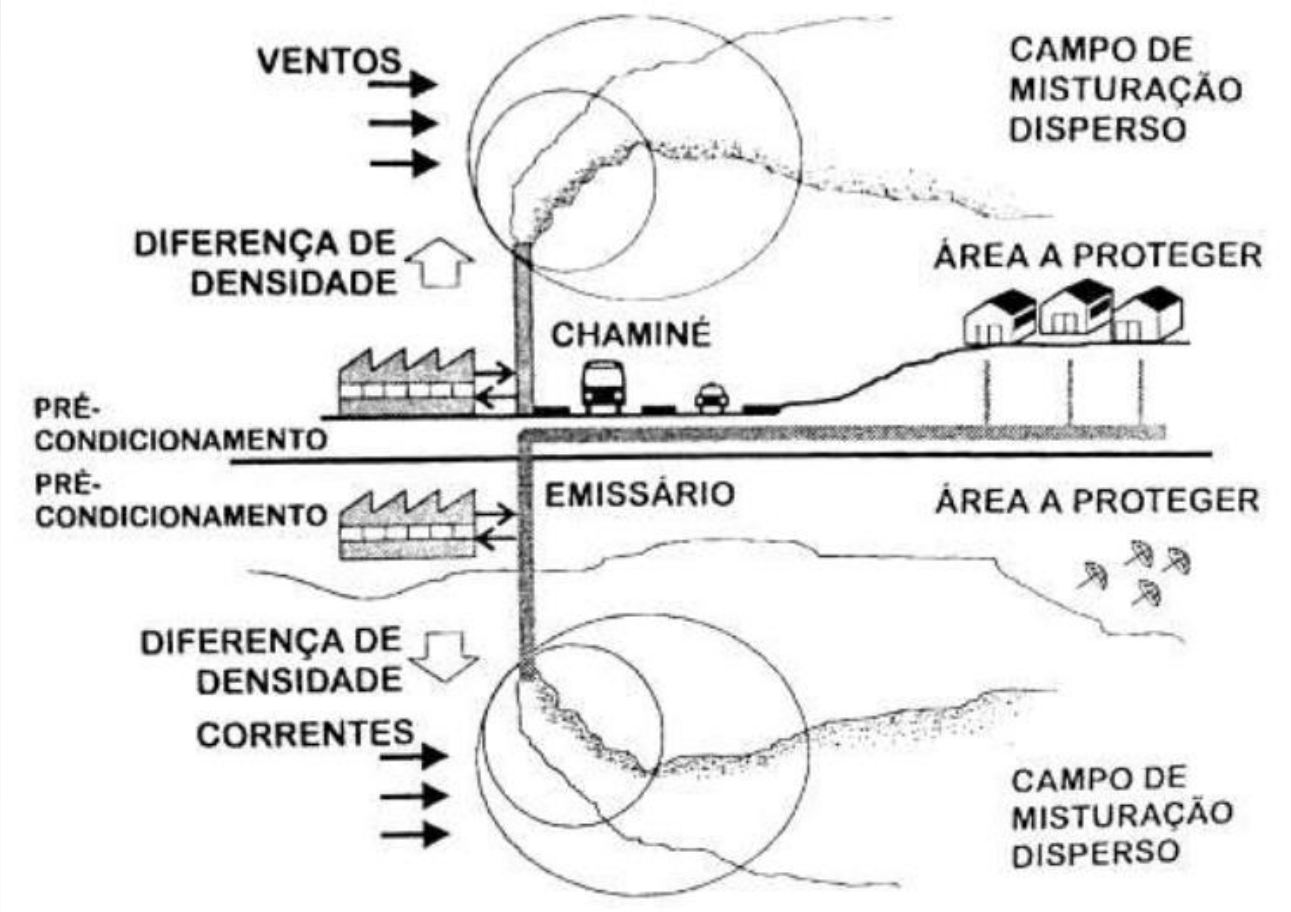
Outfalls (**active mixing**) is more efficient (**100 or more times**)

Megaprojects - megainvestments



IAHR LAD é superimportante - interação com outras associações

Different perceptions



Consequences:

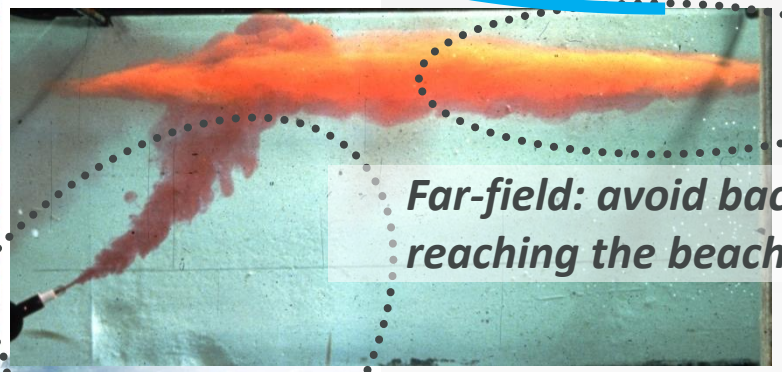
- **Expensive WWTP**, not solving water quality problems;
- **Missing integrated analysis** (treatment and disposal)
- **Not considering all sources** (drainage, diffuses pollution, etc.)

- **Society does not seem to accept/understand ocean discharge systems though accepts atmospheric discharges**

Fonte: Botafogo e Pereira (1997)

Mixing processes

(courtesy of Paolo Domenichini, Italy)

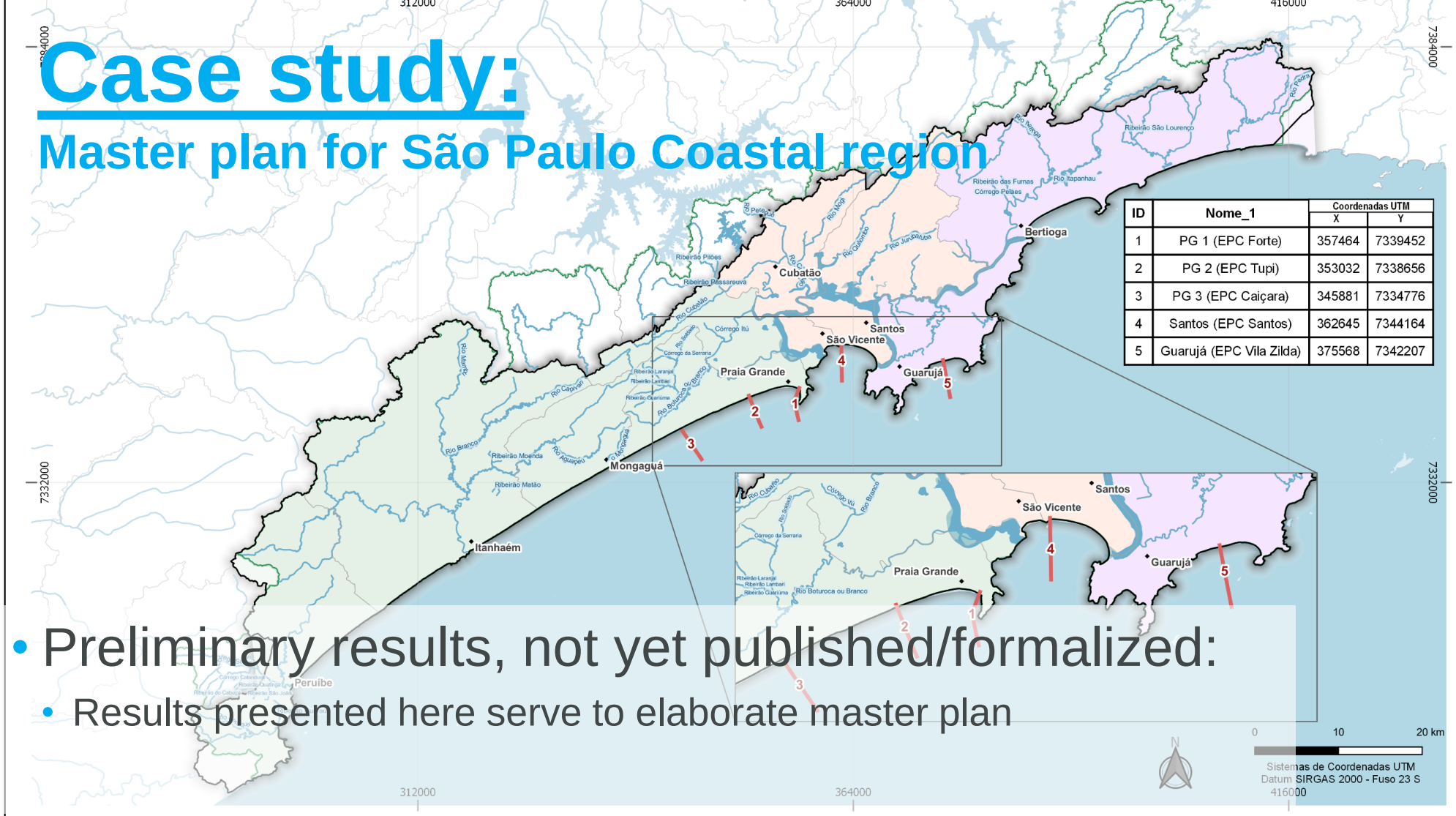


Far-field: avoid bactéria reaching the beaches

Near-field: achieve concentration limits of nutrientes in limited region (mixing zone)

Case study:

Master plan for São Paulo Coastal region



ID	Nome_1	Coordenadas UTM	
		X	Y
1	PG 1 (EPC Forte)	357464	7339452
2	PG 2 (EPC Tupi)	353032	7338656
3	PG 3 (EPC Caiçara)	345881	7334776
4	Santos (EPC Santos)	362645	7344164
5	Guarujá (EPC Vila Zilda)	375568	7342207

- Preliminary results, not yet published/formalized:
  - Results presented here serve to elaborate master plan

Legenda

- Sedes Municipais
- Hidrografia
- Reservatórios
- Unidade Negócios Baixada Santista
- Região Metropolitana da Baixada Santista
- Limite da UGRHI 07 - Baixada Santista
- Emissários

Regiões de Planejamento

- Norte
- Centro
- Sul

Revisão e Atualização do Plano Diretor de Abastecimento de Água e Elaboração do Plano Diretor de Esgotamento Sanitário da Baixada Santista - PDAAES - RMBS

Escala: 1:450.000 Elaborado em: Agosto/2021

Fontes: Fontes: Hidrografia - ANA (2017) / COBRAPE (2020); Reservatórios - ANA (2017); Unidade de Negócios da Baixada Santista - SABESP (2020); Limites Municipais - IGC (2015); Sedes Municipais - IGC (2010); Limite UGRHI 07 - DAEE (2019); Regiões de Planejamento - COBRAPE (2020); Emissários - COBRAPE (2021).

CONSÓRCIO **INTEGRAÇÃO** CAGM

Metropolitan region of BAIXADA SANTISTA

Existing Outfalls

Pretreatment and desinfection

Unidade	Guarujá	PG1	PG2	PG3	Santos
Capacity (L/s)	1.450	1.200	1.200	1.400	5.300
Extension (m)	4.200	3.350	3.350	3.675	4.000
Diffuser(m)	300	650	650	420	425
Depth (m)	14	14	14	13	11,5
Risers	75	80	80	84	79

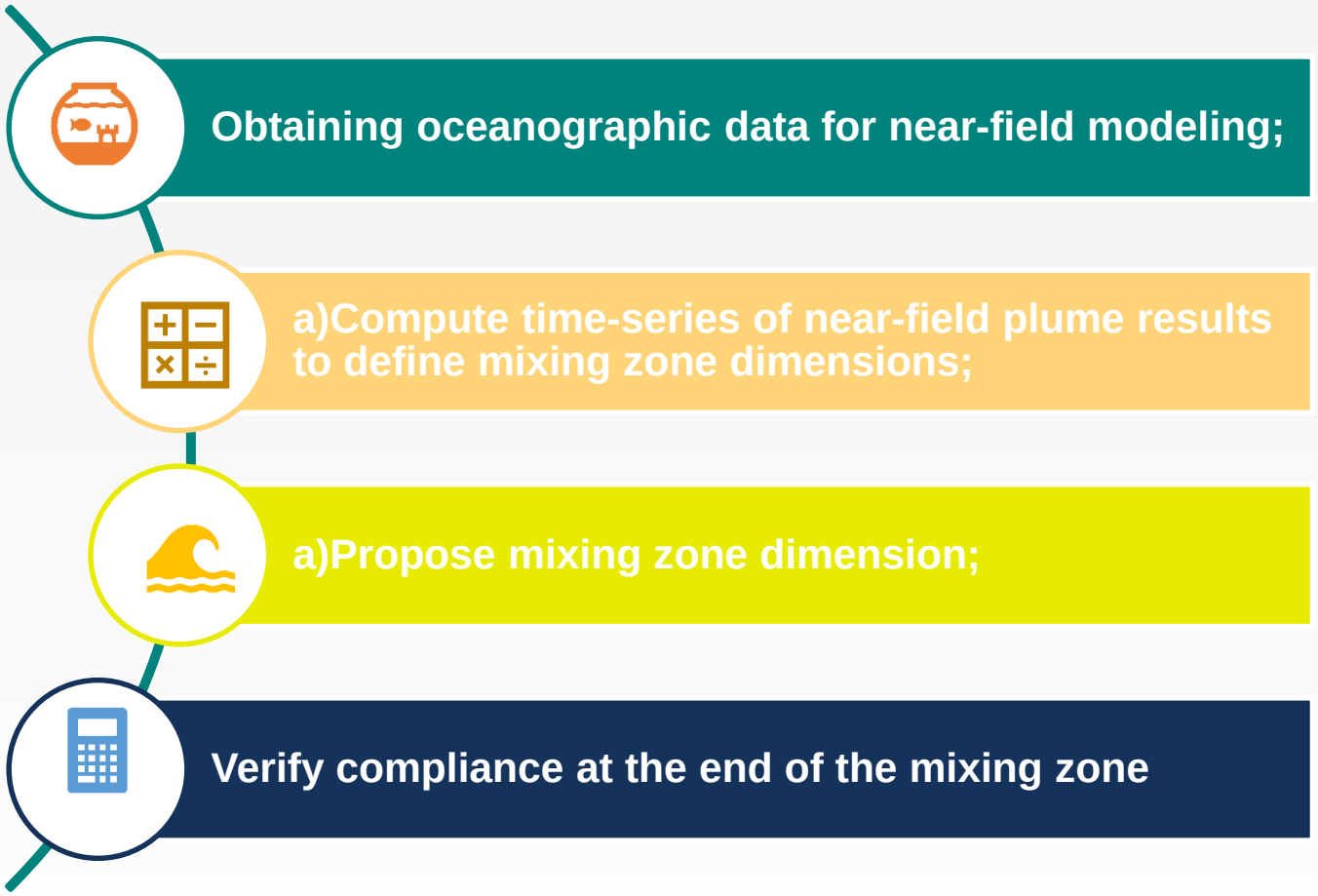
Substances: enterococos, coliforms, total organic carbon, nitrogen, total phosphorous, total suspended solids

River and channel discharges: Salinity, loads

Oceanographic data: physical, biological, chemical

Meteorological data: winds, radiation, temperature

First step: Near-field modeling

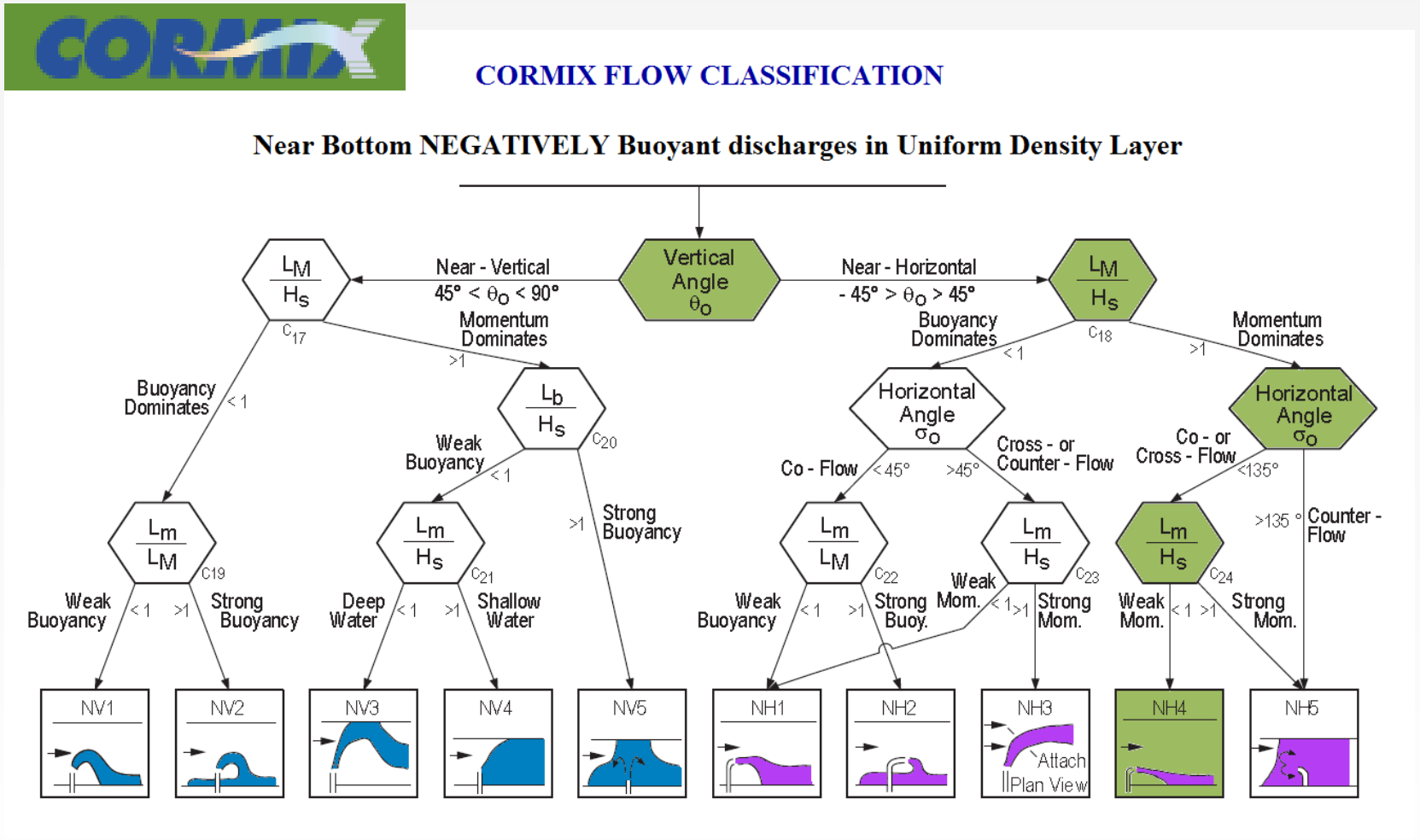


Required dilutions

Outfall	Parameter	Maximum dilution requirement		Minimum dilution requirement	
		Classe 1	Classe 2	Classe 1	Classe 2
Guarujá (EPC Vila Zilda)	E-Coli (NMP/100mL)*	68.700**	6.870**	47.992**	4.799**
	Carbono Orgânico Total (mg/L)*	36	22	27	16
	Nitrogênio Amoniacal (mg/L*	94	54	73	41
	Fósforo Total (mg/L*	150	100	97	65
	Enterococos (UFC/100mL)	18.800**		5.612**	
Emissário Forte (Subsistema 1)	E-Coli (NMP/100mL))	73.350**	7.335**	38.992**	3.899**
	Carbono Orgânico Total (mg/L)	37	22	29	17
	Nitrogênio Amoniacal (mg/L)	83	47	52	30
	Fósforo Total (mg/L)	134	89	82	54
	Enterococos (UFC/100mL)	18.800**		4.510**	
Emissário Tupi (Subsistema 2)	E-Coli (NMP/100mL)	86.645**	8.665**	26.360**	2.636**
	Carbono Orgânico Total (mg/L)	31	19	25	15
	Nitrogênio Amoniacal (mg/L)	80	45	55	32
	Fósforo Total (mg/L)	154	103	75	50
	Enterococos (UFC/100mL)	18.800**		4.521**	
EPC Caiçara (Subsistema 3)	E-Coli (NMP/100mL)	95.900**	9.590**	39.451**	3.945**
	Carbono Orgânico Total (mg/L)	32	19	24	14
	Nitrogênio Amoniacal (mg/L)	90	52	62	35
	Fósforo Total (mg/L)	126	84	82	55
Santos	E-Coli (NMP/100mL)	68.700**	6.870**	47.992**	4.799**
	Carbono Orgânico Total (mg/L)	36	22	27	16
	Nitrogênio Amoniacal (mg/L)	94	54	73	41
	Fósforo Total (mg/L)	150	100	97	65

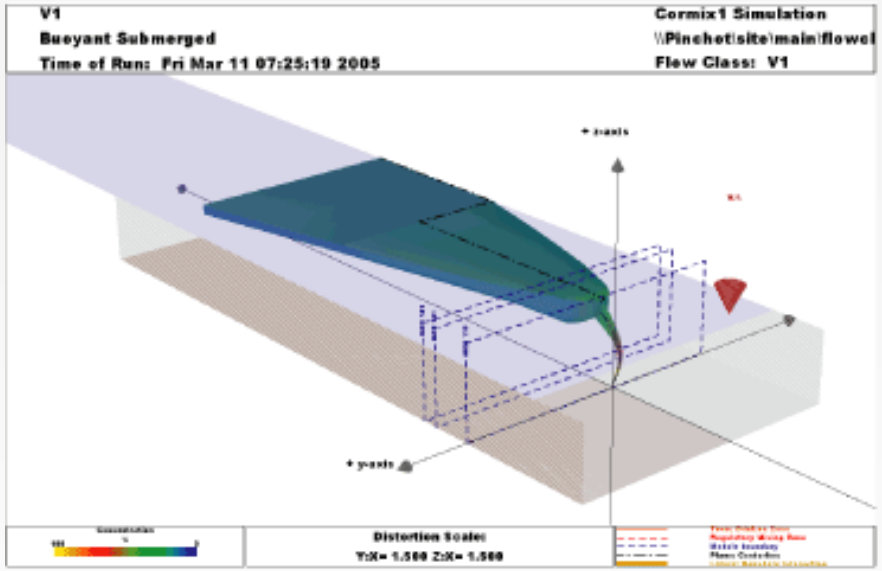
Near-field model

- **CORMIX** V12.0.0.0 (Jirka et al., 1996; MixZon, 2017)

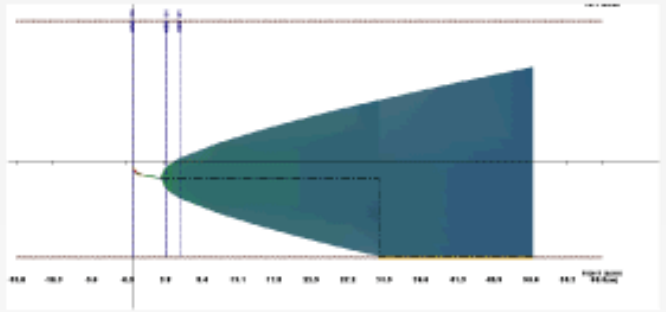


CorTime: quasi unsteady approach

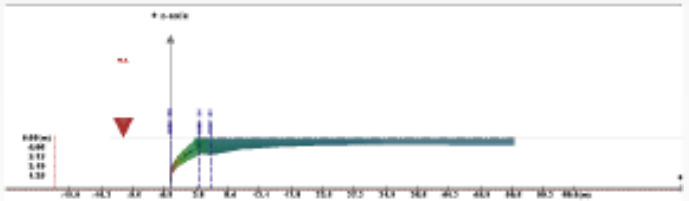
3D View



Plan View

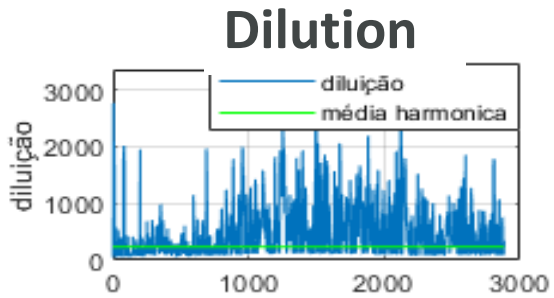


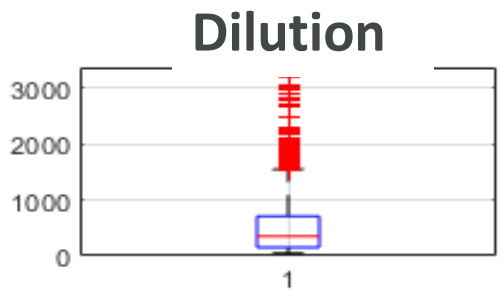
Side View

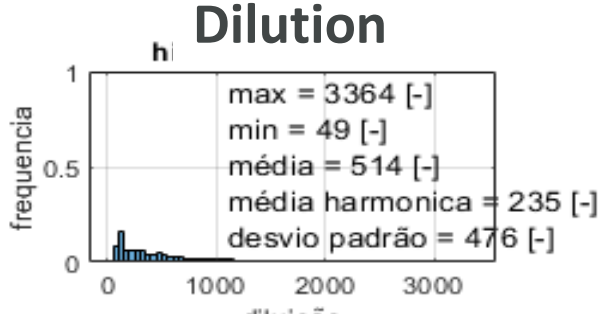


- **3.000 simulations to cover a 1 year period (3h time step)**
- **Considering changing discharge, currents, stratification, water level**

Results


Dilution
diluição
média harmonica
diluição
3000
2000
1000
0
0
1000
2000
3000


Dilution
3000
2000
1000
0
1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min = 49 [-]
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média harmonica = 235 [-]
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frequencia
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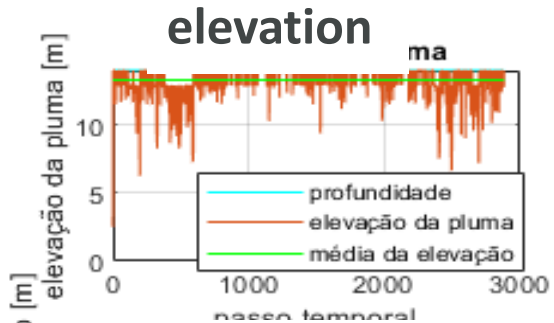
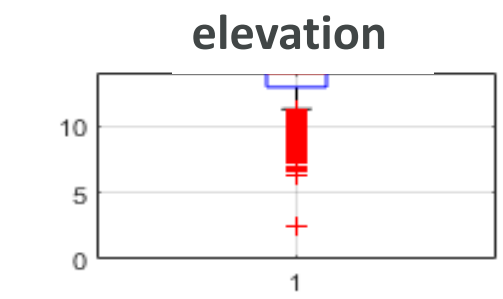
0.5
0
0
1000
2000
3000


elevation
elevação da pluma [m]
profundidade
elevação da pluma
média da elevação
10
5
0
0
1000
2000
3000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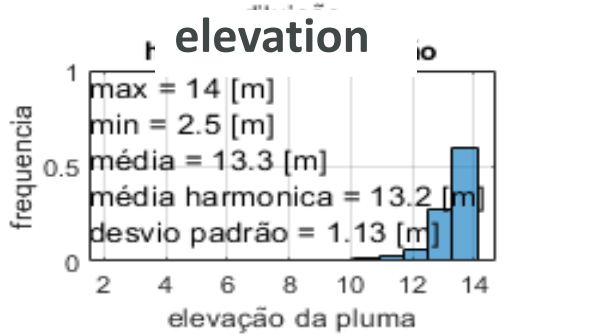
10
5
0
1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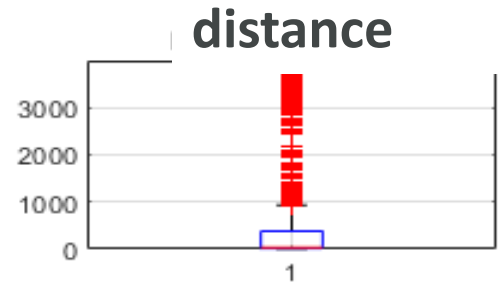
média = 13.3 [m]
média harmonica = 13.2 [m]
desvio padrão = 1.13 [m]
frequencia
1
0.5
0
2
4
6
8
10
12
14
elevação da pluma


distance
distancia final campo proximo [m]
3000
2000
1000
0
0
1000
2000
3000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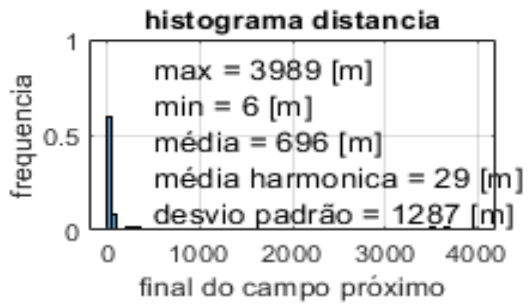
2000
1000
0
1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frequencia
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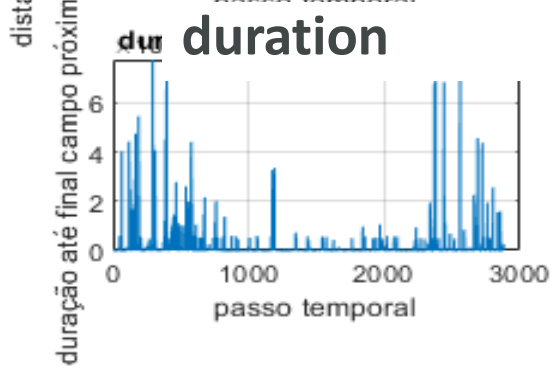
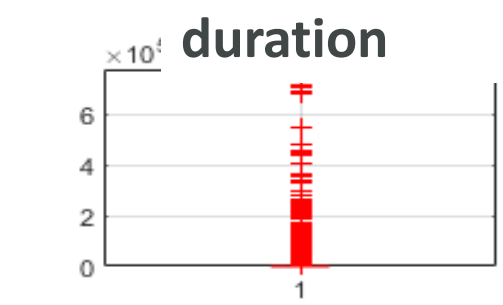
0.5
0
0
1000
2000
3000
4000
final do campo próximo


duration
duração até final campo próximo [s]
6
4
2
0
0
1000
2000
3000
passo temporal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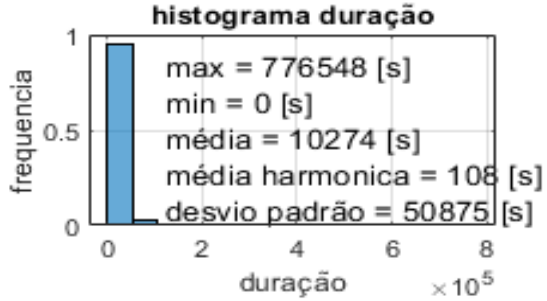
×10
6
4
2
0
1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média harmonica = 108 [s]
desvio padrão = 50875 [s]
frequencia
1
0.5
0
0
2
4
6
8
duração
×10^5

Proposed regulatory mixing zone dimensions

Outfall	Maximal discharge [m³/s]	Hydrodynamic mixing zone dimension [m]	Duration of plume reaching end [s]	Regulatory mixing zone [m]
Santos	5,300	218	83	200
PG1	1,200	30	59	50
PG2	1,200	27	57	50
PG3	1,400	33	73	100
Guarujá	1,450	166	395	200

- Preliminary proposal, yet to be discussed in master plan

2	PG 2 (EPC Tupi)	353032	7338656
3	PG 3 (EPC Caiçara)	345881	7334776
4	Santos (EPC Santos)	362645	7344164
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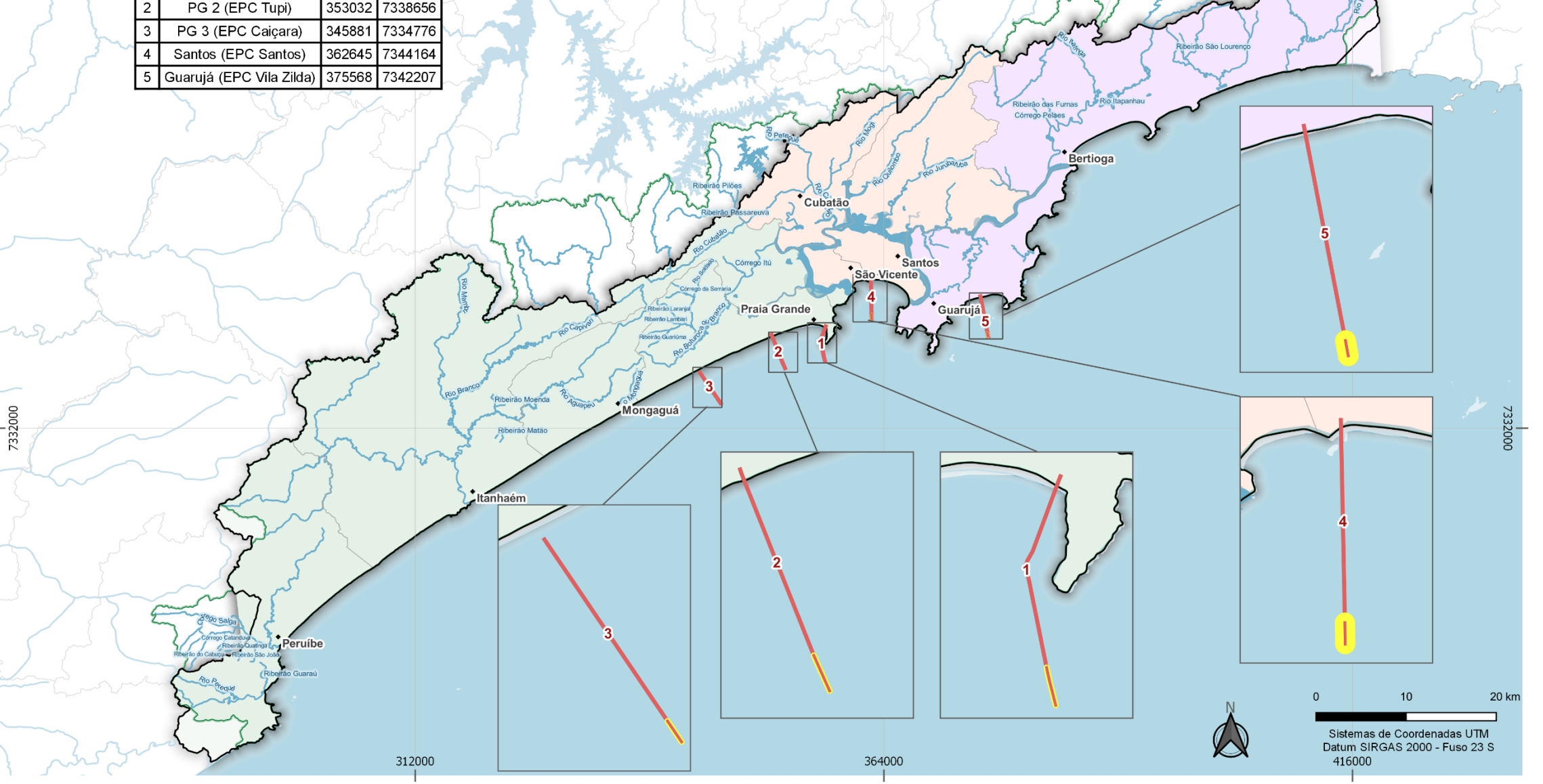

Mapa de Localização

Legenda

- Sedes Municipais
- Hidrografia
- Reservatórios
- Unidade Negócios Baixada Santista
- Região Metropolitana da Baixada Santista

Regiões de Planejamento

- Centro
- Norte
- Sul

- Emissários
- Zona de Mistura

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Compliance?

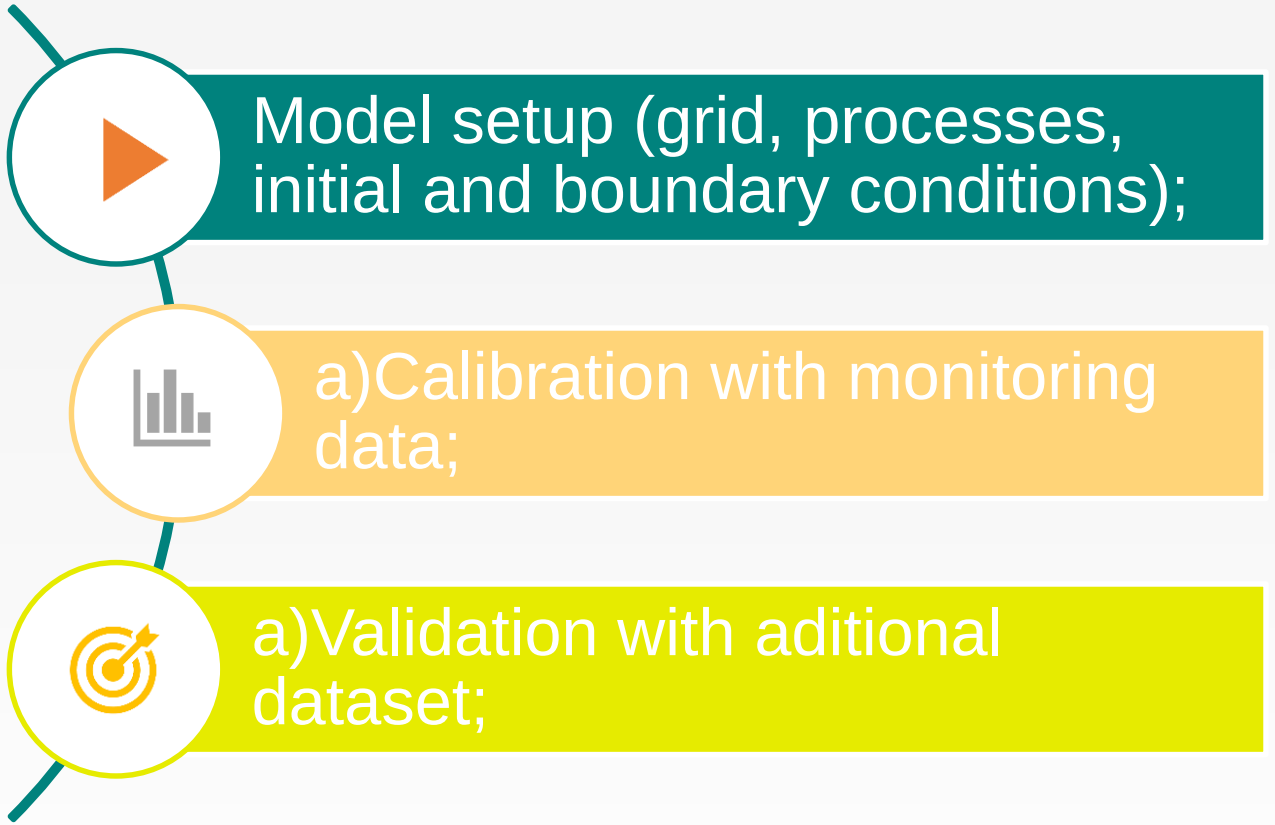
Outfall	Santos		PG1		PG2		PG3		Guarujá	
Scenario	2012	2019	2012	2019	2012	2019	2012	2019	2012	2019
Dilution end of initial mixing	60	73	235	220	196	238	1036	690	258	327
Dilution end of legal zone	60	76	215	207	183	224	812	561	250	371
Percentil dos menores 5% da diluição (diluição mínima) na ZML	26	28	79	79	74	83	265	172	80	86
								900	1530	1890
								0	0	0
								0	13	11
								,4/13	12,15/14	13/14
								,4/13	12,15	13/14
								172	155	143
								214	217	186

- Compliance at end of regulatory mixing zone for all substance, except bacteria
- If effluent chlorinated, also in compliance within mixing zoon
- Without chlorination:
  - → Far-field analysis

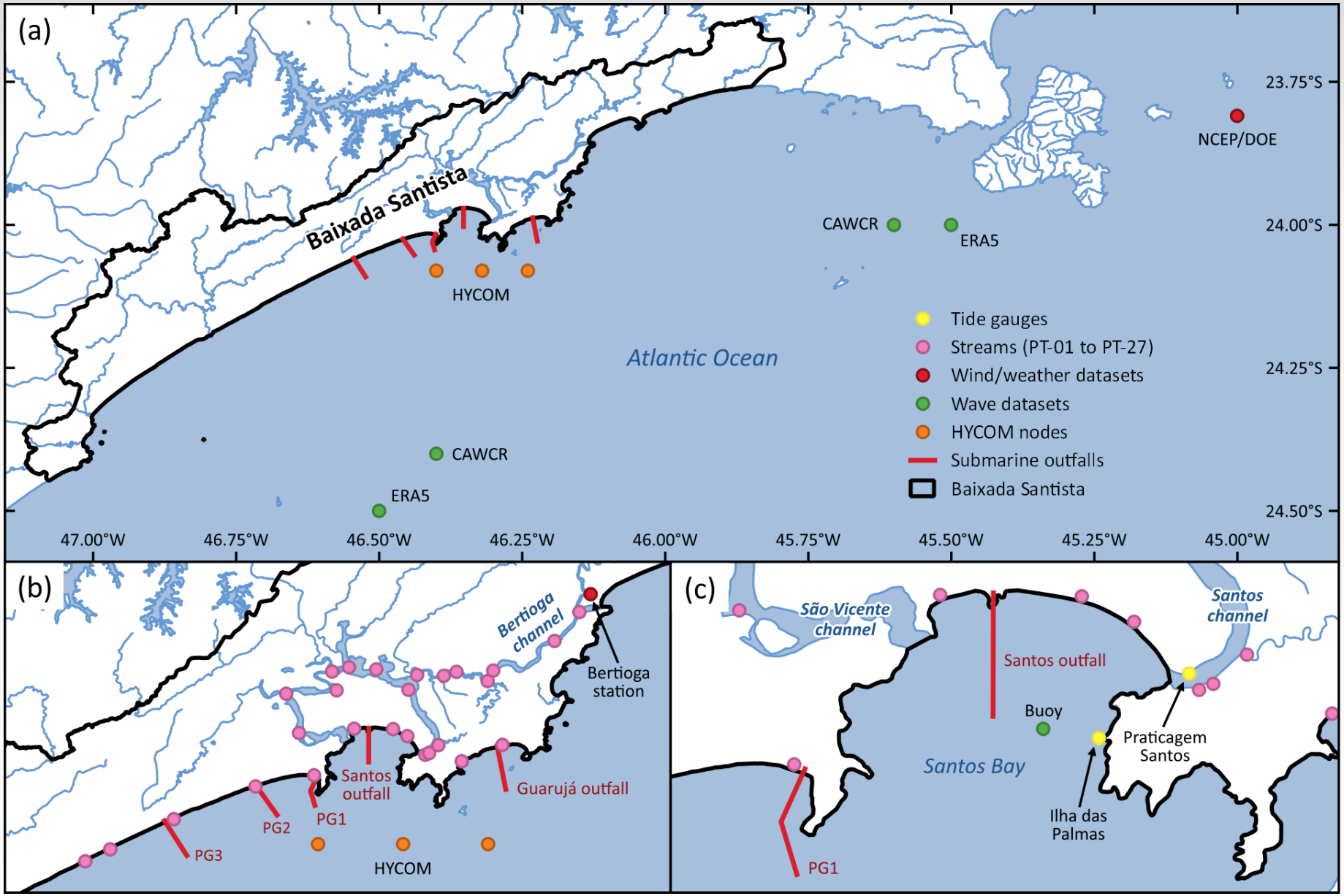
Step 2:

Far-field hydrodynamic and water quality modeling

Delft3D 4
Open Source

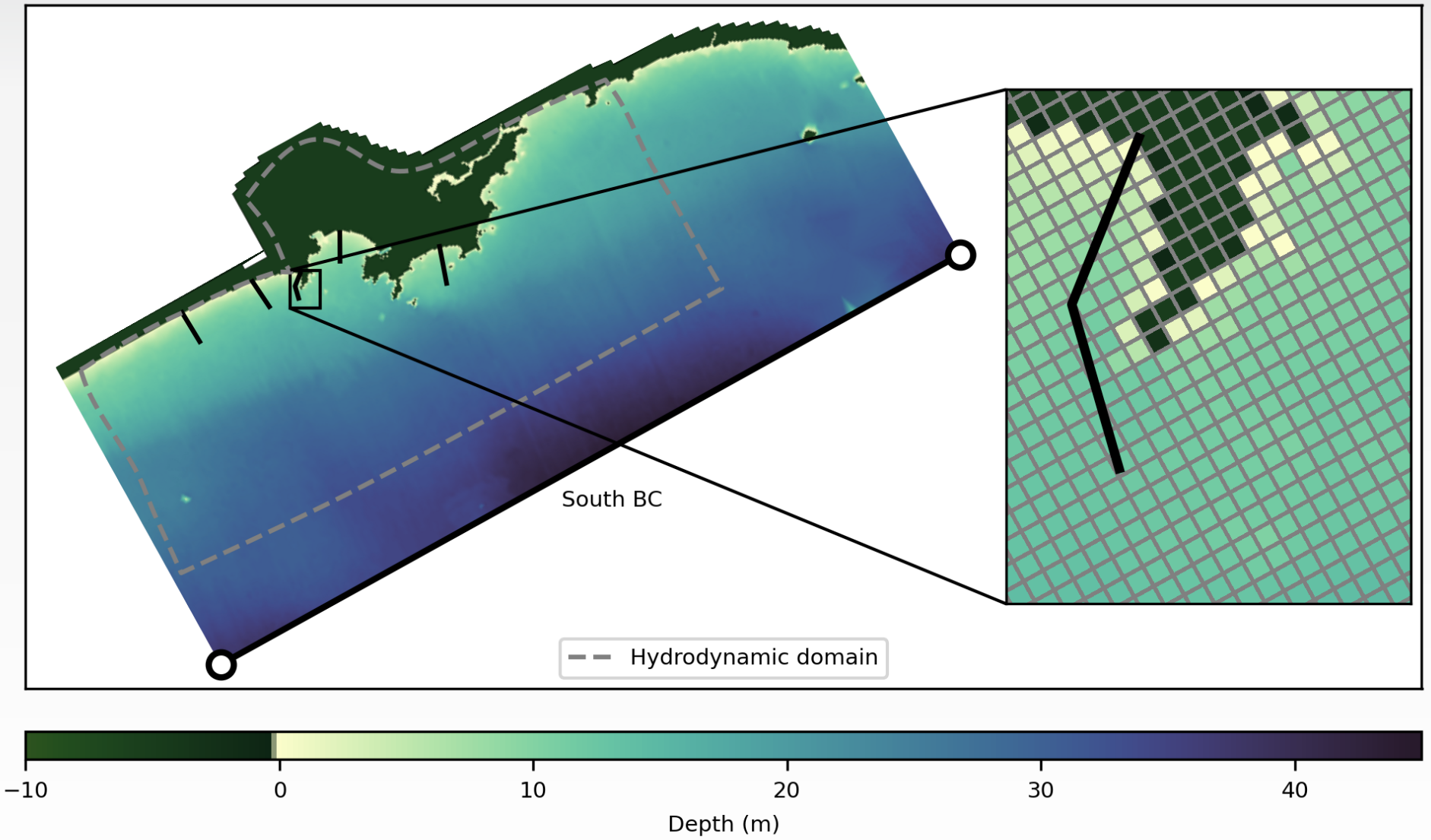


Delft3D-FLOW and WAQ version 4.04.01.



Diego Casas, UFPR

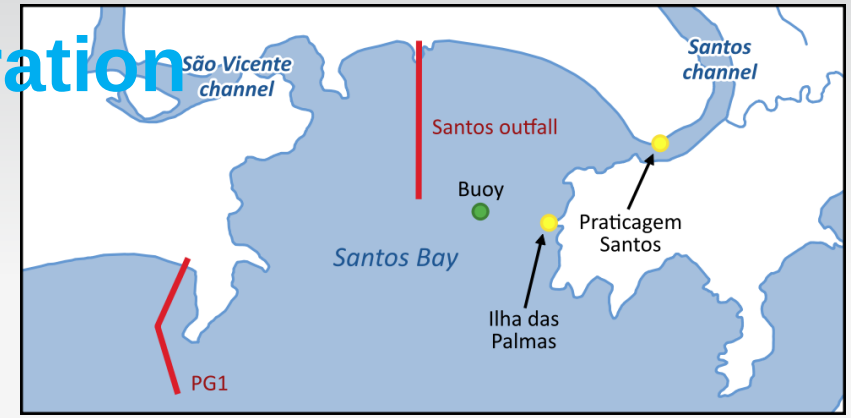
Modelagem de campo afastado - hidrodinâmica e qualidade



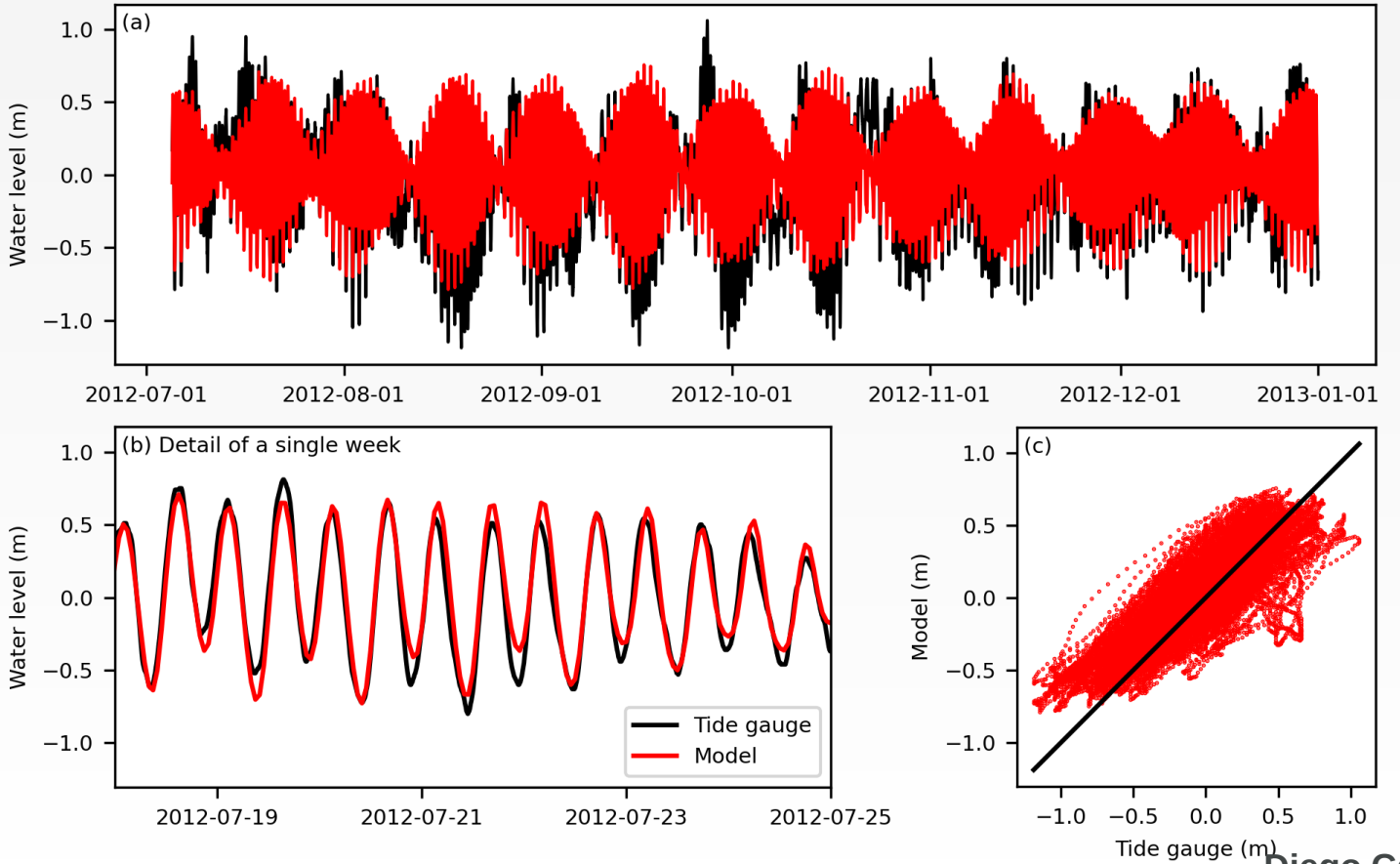
Hydrodynamic model calibration

- July–December 2012
- Willmott's index* = 71%

* Index of model performance by Willmott et al. (2011)

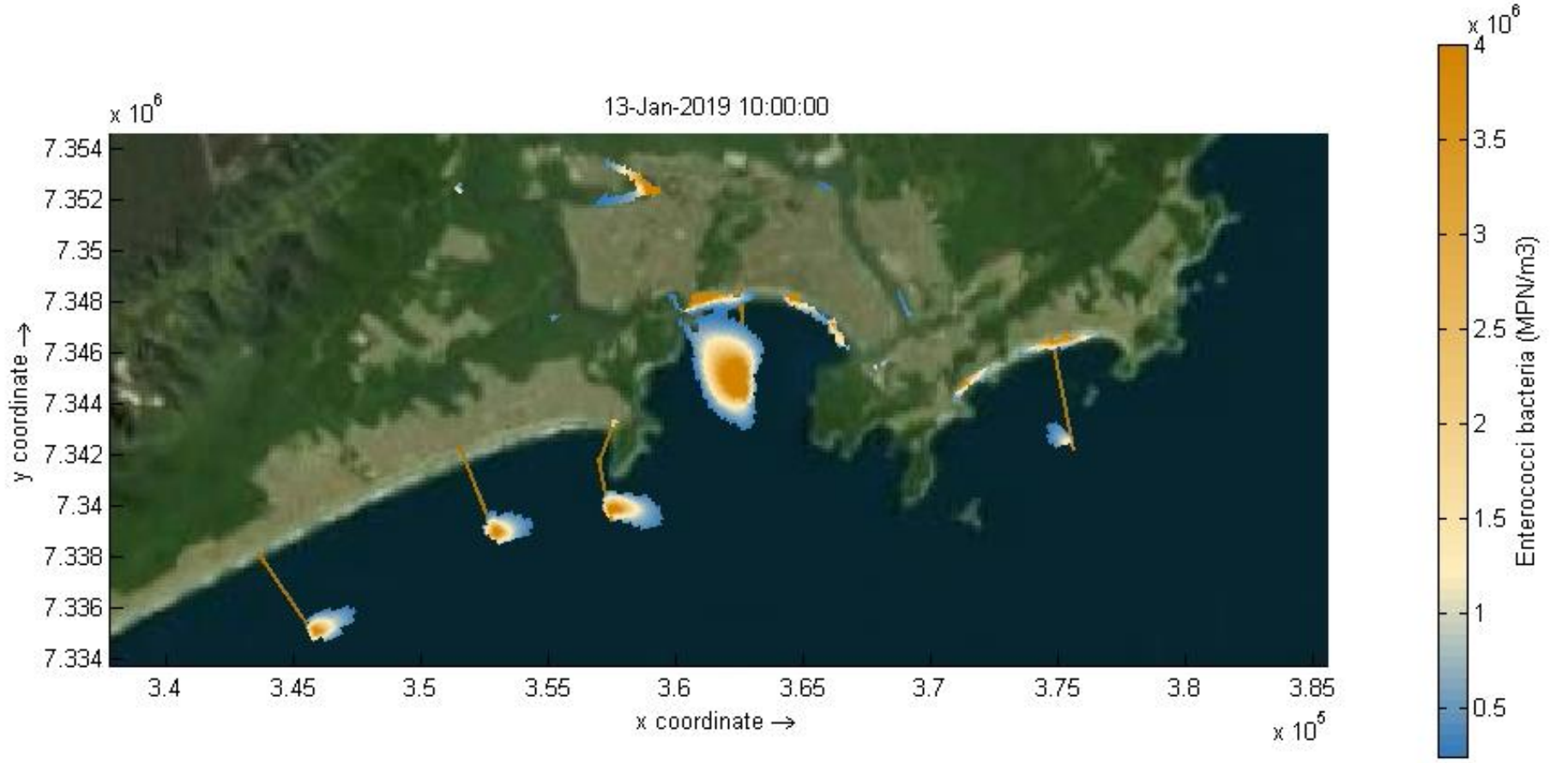


Praticagem Santos

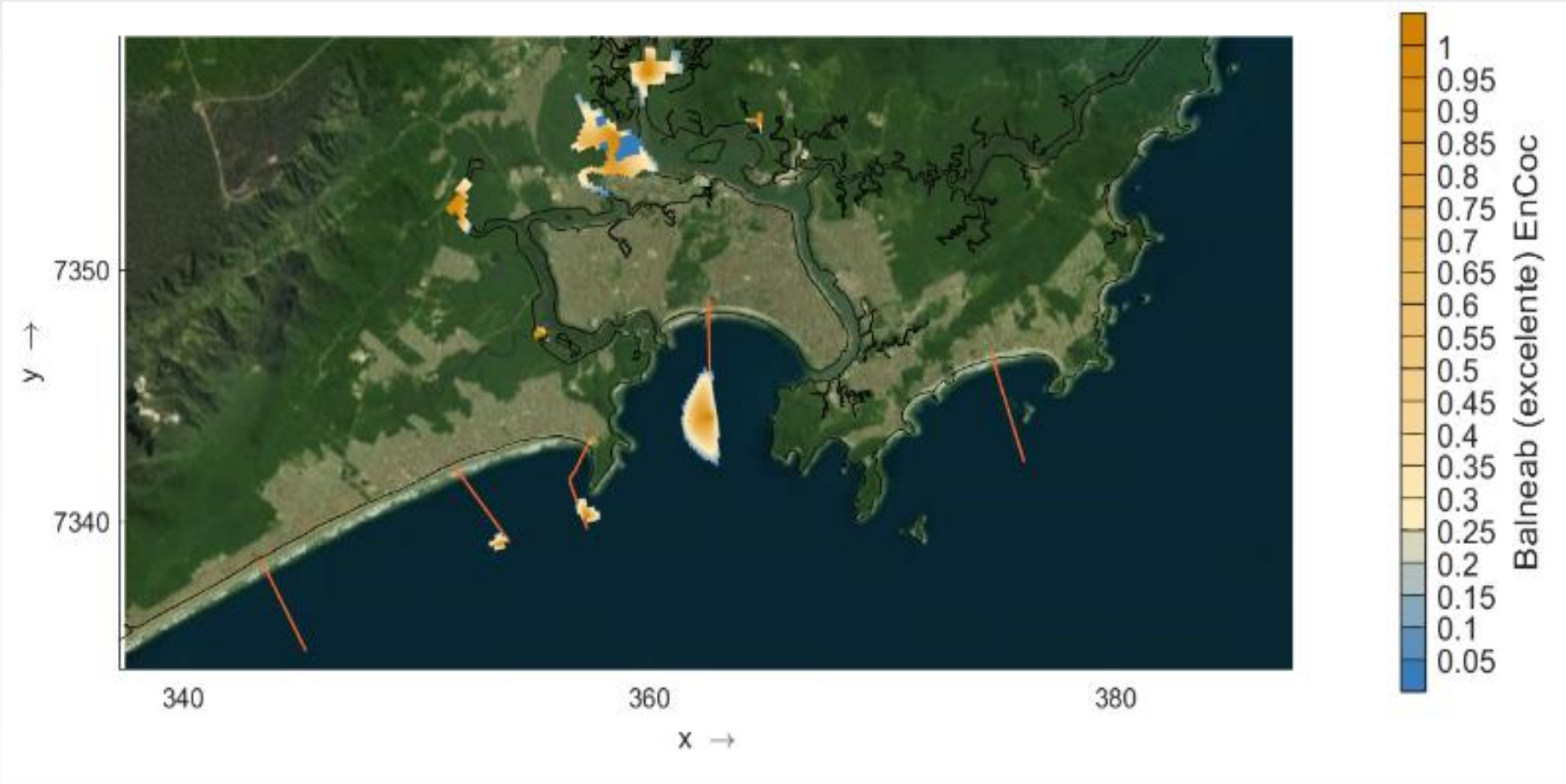


Results

Enterococos concentrations – maximum discharge



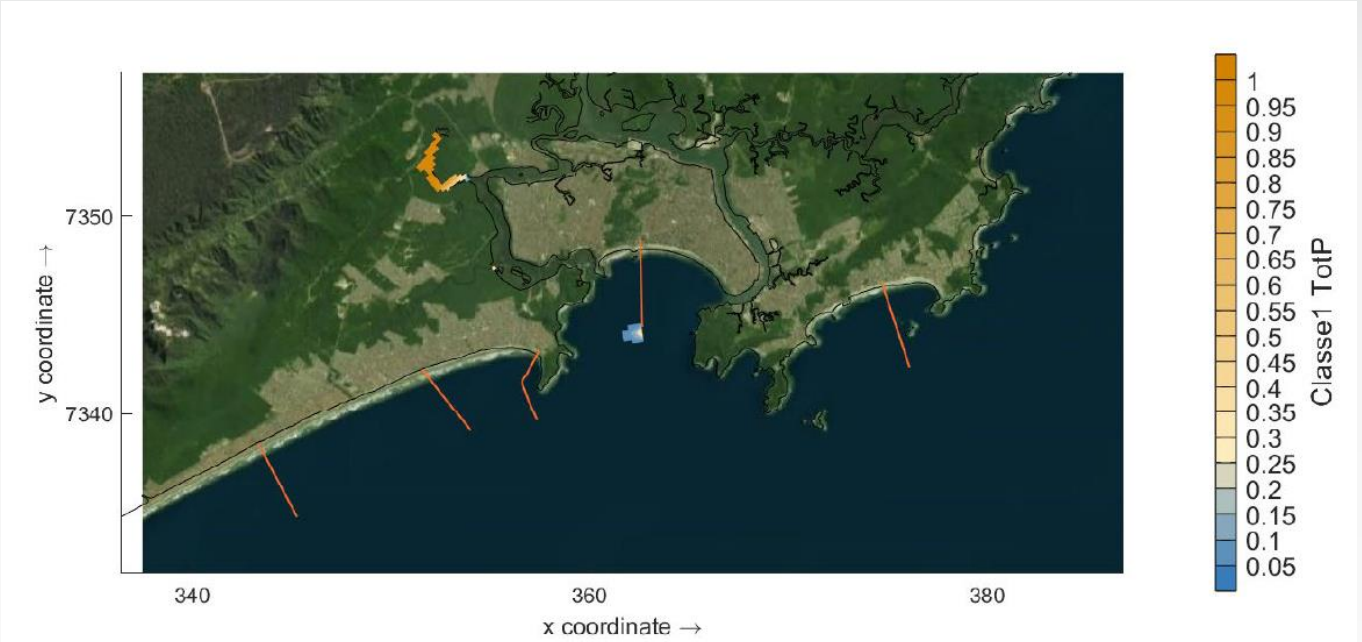
Results

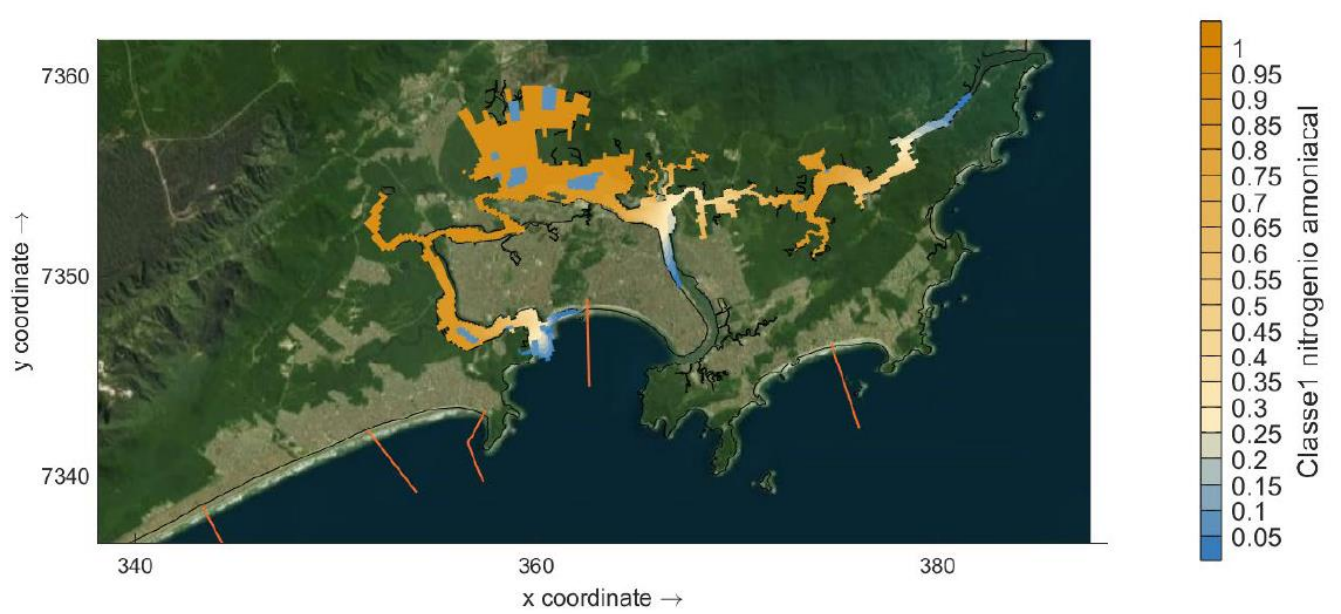


Exceedance Frequency of excelente beach water quality above 5% probability (CONAMA 274/00)

Results

Ammonia:
Exceedance frequency of class 2 water body

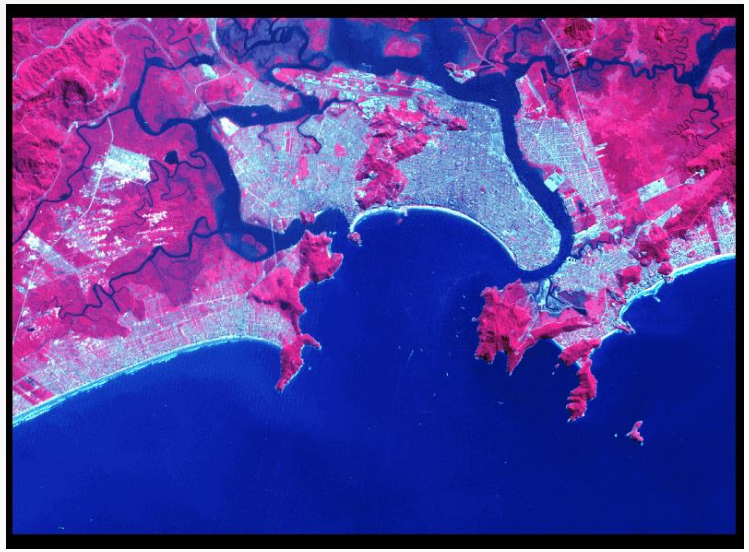


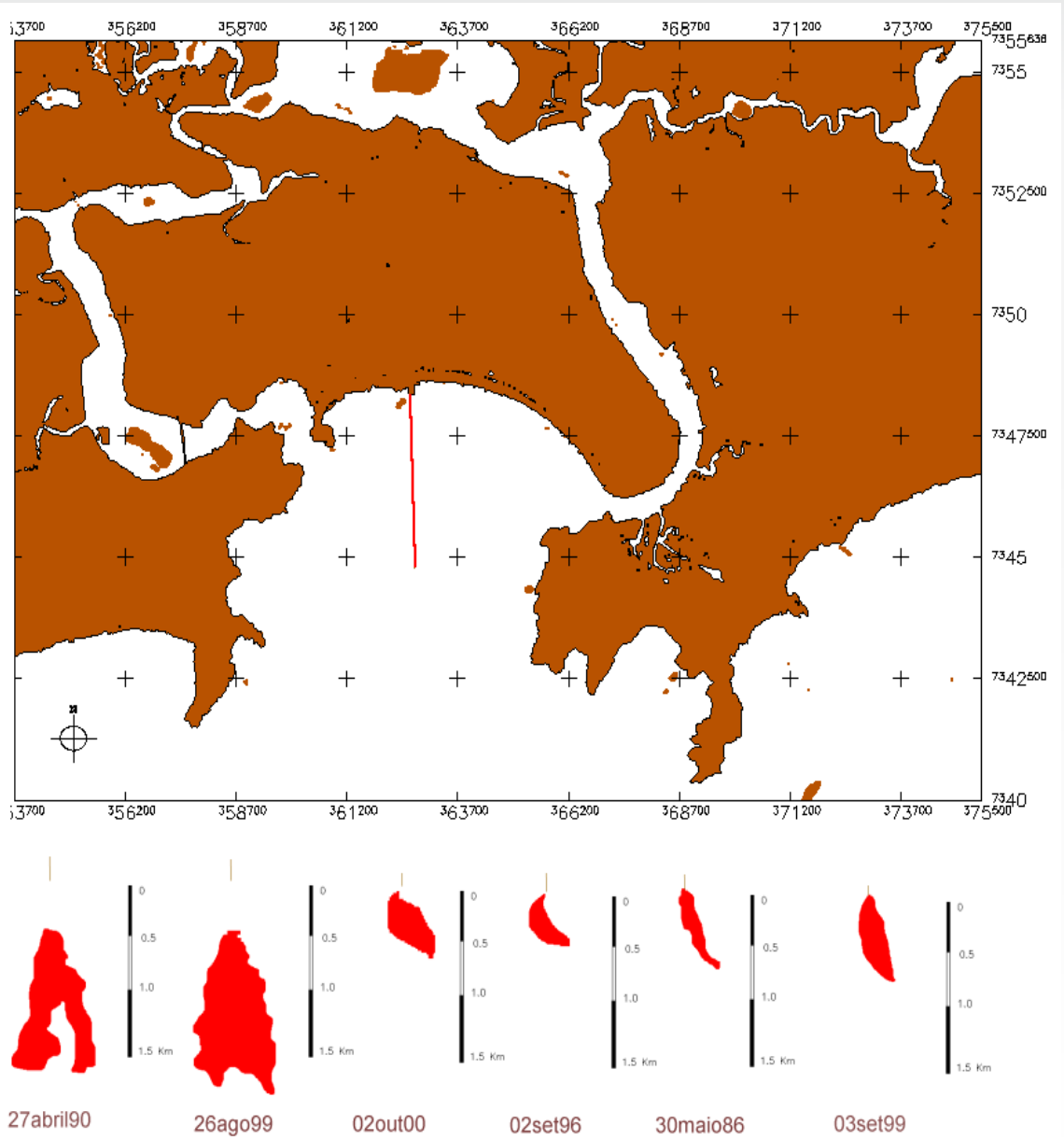


Total Phosphorous:
Exceedance frequency of class 2 water body

Innovative monitoring of outfall plume

- Remote sensing by satellite





Conclusions

- **Near-field:** nutrient concentrations below limit
- **Far-field:**
  - no substance accumulation observed due to outfalls (no risk of eutrofication)
  - Outfalls do not cause bacterial pollution at beaches
  - Suspended sediment deposits Around Santos outfall -> monitoring!
- **Integrated approach and master plan:**
  - Considering all sources for improving investments
  - Significant pollution from rivers and channels
- **Paradigme change:**
  - Previous sanitation solutions considered only intake to discharge, but not receiving Waters as a whole
- **Knowledge exchange:**
  - **Community models** (http://www.d3d-baydelta.org/; http://www.agmcommunity.org/)
  - **Universal repositories** (Hycom, TPXO, GEBCO)

ACKNOWLEDGEMENTS

IAHR / IWA Committee on Marine Outfall Systems:

www.iahr.org → Committees

www.iwa-network.org → Communities → Specialist Groups

Models:

- CORMIX, www.cormix.info
- Delft3D, www.deltares.nl

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IAHR AIRH International Association for Hydro-Environment Engineering and Research
Hosted by Spain Water and IWHR, China

IWA the international water association

ISOS|2023

Simposio Internacional sobre Sistemas de Emisarios 2023

International Symposium on Outfall Systems 2023

aysa Lo bueno del agua llega.

COFES

Ministerio de Obras Públicas Argentina