

Environmental Impact Assessment

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MLD: Greater Malé Waste-to-Energy Project – Waste to Energy Plant PART C

Table 2.1: Directional Distribution of Wind Statistics (Percentage Occurrence for Wind Speed vs Wind Direction)

Dir (Deg N) Speed (m/s)	0 -- 10	10 -- 20	20 -- 30	30 -- 40	40 -- 50	50 -- 60	60 -- 70	70 -- 80	80 -- 90	90 -- 100	100 -- 110	110 -- 120	120 -- 130	130 -- 140	140 -- 150	150 -- 160	160 -- 170	170 -- 180	180 -- 190	190 -- 200	200 -- 210	210 -- 220	220 -- 230	230 -- 240	240 -- 250	250 -- 260	260 -- 270	270 -- 280	280 -- 290	290 -- 300	300 -- 310	310 -- 320	320 -- 330	330 -- 340	340 -- 350	350 -- 360	Total
0 – 1	0.03	0.06	0.06	0.05	0.06	0.07	0.06	0.04	0.09	0.03	0.03	0.05	0.04	0.06	0.05	0.04	0.05	0.08	0.03	0.06	0.07	0.06	0.06	0.06	0.07	0.06	0.11	0.03	0.08	0.07	0.08	0.06	0.07	0.06	0.06	0.03	2.07
1 – 2	0.17	0.24	0.20	0.21	0.24	0.26	0.21	0.19	0.20	0.14	0.14	0.14	0.10	0.12	0.10	0.10	0.11	0.12	0.11	0.16	0.19	0.18	0.24	0.21	0.23	0.24	0.30	0.23	0.30	0.23	0.27	0.29	0.27	0.24	0.23	0.18	7.07
2 – 3	0.29	0.38	0.43	0.48	0.44	0.45	0.43	0.35	0.34	0.23	0.19	0.16	0.15	0.14	0.13	0.11	0.11	0.13	0.12	0.17	0.19	0.28	0.32	0.49	0.51	0.53	0.64	0.53	0.64	0.54	0.48	0.45	0.39	0.34	0.31	0.29	12.16
3 – 4	0.31	0.40	0.57	0.67	0.67	0.72	0.60	0.49	0.42	0.24	0.19	0.16	0.13	0.10	0.09	0.09	0.09	0.08	0.08	0.16	0.22	0.27	0.44	0.65	0.73	0.96	1.10	0.95	1.13	0.92	0.77	0.58	0.41	0.38	0.35	0.26	16.39
4 – 5	0.26	0.38	0.58	0.86	1.03	1.05	0.90	0.61	0.37	0.20	0.10	0.08	0.07	0.03	0.04	0.04	0.05	0.09	0.08	0.13	0.20	0.31	0.48	0.75	0.97	1.26	1.48	1.36	1.31	1.11	0.82	0.55	0.38	0.29	0.21	0.19	18.62
5 – 6	0.10	0.19	0.42	0.68	0.99	1.13	1.00	0.59	0.30	0.16	0.06	0.05	0.03	0.03	0.03	0.01	0.04	0.05	0.04	0.07	0.11	0.21	0.41	0.70	1.07	1.40	1.63	1.45	1.51	1.15	0.75	0.48	0.23	0.14	0.09	0.08	17.39
6 – 7	0.02	0.04	0.09	0.26	0.69	0.90	0.72	0.39	0.19	0.08	0.05	0.03	0.02	0.01	0.00	0.01	0.02	0.01	0.03	0.04	0.06	0.11	0.20	0.40	0.76	1.24	1.56	1.49	1.43	0.98	0.57	0.25	0.12	0.07	0.03	0.02	12.89
7 – 8	0.00	0.01	0.03	0.08	0.23	0.47	0.35	0.18	0.08	0.03	0.03	0.02	0.01	0.01				0.01	0.02	0.02	0.02	0.06	0.09	0.21	0.50	0.90	1.16	1.07	0.98	0.62	0.33	0.15	0.05	0.03	0.00	0.01	7.78
8 – 9		0.00	0.03	0.02	0.05	0.12	0.11	0.04	0.01	0.01	0.02	0.00							0.01	0.00	0.01	0.02	0.04	0.09	0.25	0.52	0.65	0.62	0.43	0.30	0.14	0.04	0.03	0.02		3.60	
9 – 10				0.02	0.04	0.05	0.03	0.00	0.00	0.00	0.00										0.00	0.01	0.01	0.02	0.12	0.21	0.24	0.28	0.21	0.08	0.04	0.01	0.00			1.39	
10 – 11						0.00	0.01																			0.01	0.02	0.06	0.13	0.12	0.06	0.02	0.02	0.00			0.47
11 – 12																										0.01	0.02	0.06	0.04	0.02	0.01	0.00	0.01				0.18
12 – 13																										0.01	0.01	0.04	0.01	0.01	0.01	0.00					0.09
13 – 14																											0.01	0.01									0.02
14 – 15																											0.00										0.00
15 – 16																												0.00									0.00
Total	1.18	1.70	2.42	3.33	4.44	5.22	4.42	2.86	2.00	1.12	0.81	0.69	0.54	0.51	0.44	0.41	0.47	0.58	0.51	0.81	1.08	1.53	2.28	3.60	5.26	7.42	9.13	8.22	8.09	6.03	4.27	2.89	1.95	1.56	1.28	1.06	100

3 WAVE CLIMATE MODELLING

3.1 Introduction

Wave climate condition is one of main input parameter for the hydrodynamic model. Therefore it is required to develop wave climate conditions for different monsoons in order to set up the hydrodynamic model. The wave data is not available for the desired location on the sea fit for usage. Most of the time wave data measured point is far away from the project location and it has to be transformed to a desired location by a model. In this case, MIKE 21 numerical wave model was used for wind wave generation and transformation process. The objectives of the wave climate modelling of this scheme is establishing nearshore wave climate at the site.

3.2 Model Used – MIKE 21 SW Model System

MIKE 21 SW includes a new generation spectral wind-wave model based on unstructured mesh. The model simulates the growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas. It includes two different formulations, namely, directional decoupled parametric formulation and fully spectral formulation. The directional decoupled parametric formulation is based on a parameterization of the wave action conservation equation. The parameterization is made in the frequency domain by introducing the zeroth and first moment of the wave action spectrum as dependent variables. The fully spectral formulation is based on the wave action conservation equation, where the directional-frequency wave action spectrum is the dependent variable.

The basic conservation equations are formulated in either Cartesian co-ordinates for small-scale applications or Polar Spherical co-ordinates for large-scale applications.

MIKE 21 SW includes the following physical phenomena:

- Wave growth by action of wind
- Non-linear wave-wave interaction
- Dissipation due to white capping
- Dissipation due to bottom friction
- Dissipation due to depth induced wave breaking
- Refraction and shoaling due to depth variation
- Wave-current interaction
- Effect of time varying water depth and flooding and drying

The discretization of the governing equation in geographical and spectral space is performed using cell-centered finite volume method. In the geographical domain, an unstructured mesh

technique is used. The time integration is performed using a fractional step approach where a multi-sequence explicit method is applied for the propagation of wave action.

3.3 Model Setup

MIKE 21 SW model was used to generate waves and transfer them to the proposed site location base on UKMO wind data. All data set obtained from UKMO; i.e. 3 hour interval data from 1986 to 2016 were transferred to the site location.

The model was established by digitizing from the Admiralty charts No. 1013 & 3323, and near shore bathymetry data which were provided by WS. The preparation of model bathymetry was completed using flexible mesh as a requirement of SW model with reference to the Mean Sea Level. Figure 3.1 shows the regional model bathymetry of MIKE 21 SW model.

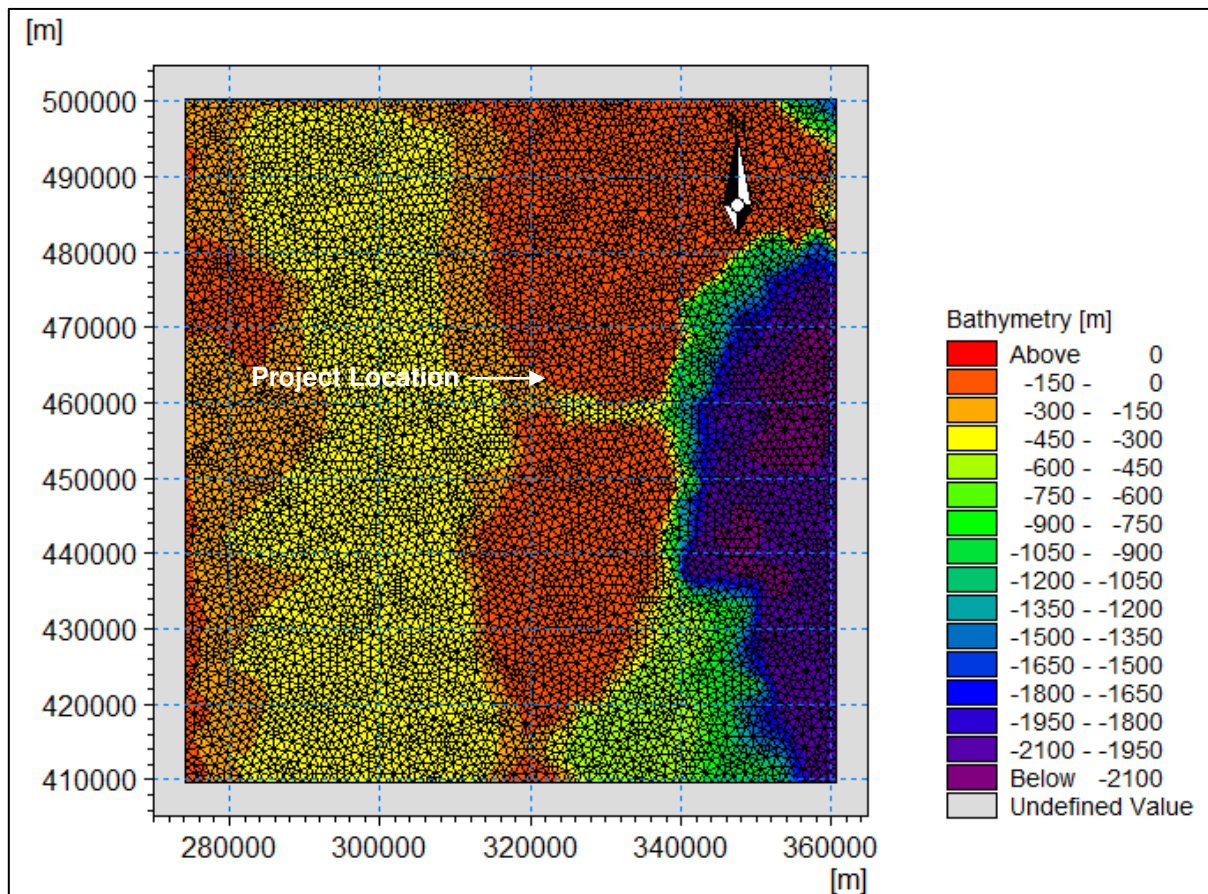


Figure 3.1: Wave Model Bathymetry - Regional

Additionally, a local model was also incorporated to improve the performance and accuracy of results. Then deep sea wind generated waves were transferred to 300m depth by regional model and then analysed wave data were further transferred to the site location by local model. The selected local model which the offshore boundary laid on around 300m depth is shown in Figure 3.2.

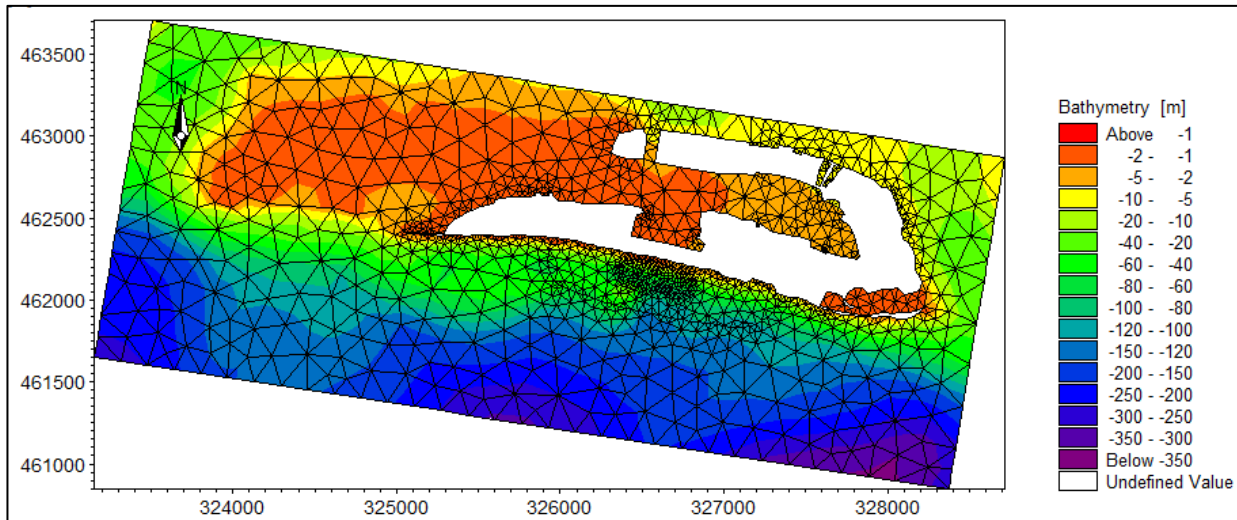


Figure 3.2: Wave Model Bathymetry - Local

3.4 Model Results

The wave analysis details of results obtained from the regional model at 300m depth are given below. The extracted results were analysed considering different seasons such as annual, South-West and North-East monsoon periods. South West monsoon was considered as from May to November while North East as from December to April. Tables 3.1 to 3.6 indicate the percentage of occurrence of waves, and their average peak wave period corresponding to the wave height and direction while Figures 3.3 to 3.5 graphically illustrate the wave height distribution patten in 360° angle.

Table 3.1: Annual Directional Distribution of Wave Height at 300m Depth (Percentage of Occurrence)

Dir (Deg.N) Hs (m)	0 -- 10	10 -- 20	20 -- 30	30 -- 40	40 -- 50	50 -- 60	60 -- 70	70 -- 80	80 -- 90	90 -- 100	100 -- 110	110 -- 120	120 -- 130	130 -- 140	140 -- 150	150 -- 160	160 -- 170	170 -- 180	180 -- 190	190 -- 200	200 -- 210	210 -- 220	220 -- 230	230 -- 240	240 -- 250	250 -- 260	260 -- 270	270 -- 280	280 -- 290	290 -- 300	300 -- 310	310 -- 320	320 -- 330	330 -- 340	340 -- 350	350 -- 360	Total		
0 -- 0.2	0.71	0.88	0.99	1.17	1.36	1.30	1.30	1.05	0.80	0.67	0.47	0.41	0.32	0.33	0.28	0.26	0.25	0.28	0.29	0.36	0.43	0.53	0.62	0.78	0.89	1.01	1.10	1.31	1.20	1.14	1.11	0.98	0.83	0.81	0.73	0.69	27.64		
0.2 -- 0.4	0.19	0.32	0.49	0.99	1.73	2.78	3.30	2.53	1.47	0.76	0.43	0.27	0.23	0.17	0.15	0.13	0.14	0.13	0.15	0.18	0.25	0.37	0.58	1.03	1.52	2.41	2.93	2.76	2.04	1.27	0.72	0.46	0.28	0.19	0.16	0.16	33.67		
0.4 -- 0.6		0.00	0.01	0.02	0.09	0.44	1.06	0.90	0.41	0.18	0.11	0.07	0.03	0.02	0.01	0.01	0.01	0.02	0.02	0.05	0.12	0.22	0.59	1.59	3.40	4.53	4.29	2.76	1.31	0.41	0.14	0.05	0.01	0.01			22.88		
0.6 -- 0.8			0.00	0.00	0.01	0.01	0.03	0.03	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.15	0.52	2.17	3.58	2.84	1.15	0.30	0.04	0.00	0.00	0.00	0.00			10.95		
0.8 -- 1			0.00	0.00	0.00		0.00	0.00	0.00	0.00			0.00		0.00	0.00						0.00	0.03	0.13	0.81	1.56	0.97	0.19	0.03	0.00		0.00		0.00				3.75	
1 -- 1.2			0.00	0.00	0.00	0.00										0.00		0.00					0.00	0.01	0.18	0.42	0.19	0.03	0.00		0.00		0.00					0.85	
1.2 -- 1.4		0.00	0.00		0.00	0.00										0.00	0.00	0.00								0.02	0.11	0.04						0.00	0.00			0.17	
1.4 -- 1.6					0.00			0.00	0.00																	0.00	0.01	0.00			0.00	0.00	0.00	0.00					0.03
1.6 -- 1.8				0.00		0.00	0.00		0.00						0.00												0.00	0.00	0.00		0.00	0.00		0.00					0.01
1.8 -- 2					0.00			0.00													0.00		0.00																0.01
2 -- 2.2					0.00	0.00		0.00	0.00										0.00	0.00											0.00			0.00					0.01
Above 2.2		0.00	0.00		0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00				0.00				0.00		0.00	0.00							0.00		0.00					0.02	
Total	0.90	1.20	1.49	2.19	3.19	4.53	5.69	4.52	2.68	1.61	1.02	0.74	0.58	0.52	0.44	0.39	0.41	0.43	0.46	0.59	0.82	1.15	1.97	4.06	8.98	13.64	12.36	8.20	4.87	2.85	1.97	1.49	1.12	1.02	0.90	0.85	100.00		

Table 3.2: Annual Directional Distribution of Peak Wave Period at 300m Depth

Dir (Deg.N) Hs (m)	0 -- 10	10 -- 20	20 -- 30	30 -- 40	40 -- 50	50 -- 60	60 -- 70	70 -- 80	80 -- 90	90 -- 100	100 -- 110	110 -- 120	120 -- 130	130 -- 140	140 -- 150	150 -- 160	160 -- 170	170 -- 180	180 -- 190	190 -- 200	200 -- 210	210 -- 220	220 -- 230	230 -- 240	240 -- 250	250 -- 260	260 -- 270	270 -- 280	280 -- 290	290 -- 300	300 -- 310	310 -- 320	320 -- 330	330 -- 340	340 -- 350	350 -- 360	Average		
0 -- 0.2	1.8	1.9	1.9	1.9	2.0	2.0	2.0	2.0	1.9	2.0	1.9	1.8	1.9	1.9	1.8	1.8	2.1	1.9	1.9	1.8	1.7	1.7	1.8	1.8	1.8	1.8	1.9	1.9	1.9	1.9	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.9	
0.2 -- 0.4	2.3	2.5	2.5	2.5	2.5	2.6	2.7	2.7	2.7	2.7	2.7	2.8	2.8	2.8	2.8	3.0	3.1	3.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	2.8	2.7	2.6	2.5	2.4	2.4	2.4	2.4	2.8	
0.4 -- 0.6		9.1	7.8	7.0	3.2	3.0	3.1	3.1	3.1	3.2	3.4	3.5	3.3	4.3	7.6	8.5	4.8	8.8	3.6	3.6	3.7	3.8	3.8	3.8	3.8	3.7	3.7	3.6	3.5	3.3	3.4	3.2	3.6	4.9				3.6	
0.6 -- 0.8			11.6	10.9	12.4	8.7	7.3	5.3	6.4	5.2	3.5	6.5	13.3	11.5	13.4			19.9	4.0	9.7	4.2	4.2	4.3	4.3	4.2	4.2	4.1	4.0	3.9	3.7	8.9	14.7	13.5	12.9				4.2	
0.8 -- 1			13.0	14.1	14.7		10.7	12.2	11.0	12.7			11.8	19.4	7.9	7.0							4.7	5.3	4.6	4.6	4.5	4.4	4.3	4.2	4.1		14.2		12.4				4.5
1 -- 1.2			12.3	10.9	15.9	12.2										12.1		12.3					5.0	5.0	4.9	4.8	4.7	4.6	10.9		13.0		16.3					5.1	
1.2 -- 1.4		13.5	12.7		16.6	13.8										13.1	9.8	14.4								5.2	5.1	5.0						14.4	14.0				6.0
1.4 -- 1.6					16.7			14.1	12.8																	5.5	5.3	5.2			11.8	14.3	18.8	18.0					9.2
1.6 -- 1.8				13.0		14.2	11.2		14.5						21.2											5.4	5.4	11.6		13.6	16.0		15.8					13.4	
1.8 -- 2					15.6			13.0													12.7		18.8																14.8
2 -- 2.2					12.8	13.4		14.7	16.9										10.9	12.2											19.8			14.2					15.3
Above 2.2		17.7	15.1		10.1	12.8	16.4	12.8	15.6	19.6		16.8	13.1				20.9				16.4		15.3	15.4							16.2		15.3					16.3	
Average	1.9	2.1	2.3	2.2	2.4	2.5	2.6	2.6	2.6	2.5	2.4	2.3	2.4	2.3	2.5	2.4	2.5	2.5	2.3	2.3	2.4	2.6	3.0	3.3	3.7	3.7	3.5	3.2	2.9	2.5	2.3	2.1	2.0	2.0	1.9	1.8	3.0		

Table 3.3: Directional Distribution of Wave Height for South-West Monsoon at 300m Depth (Percentage of Occurrence)

Dir (Deg.N) Hs (m)	0 -- 10	10 -- 20	20 -- 30	30 -- 40	40 -- 50	50 -- 60	60 -- 70	70 -- 80	80 -- 90	90 -- 100	100 -- 110	110 -- 120	120 -- 130	130 -- 140	140 -- 150	150 -- 160	160 -- 170	170 -- 180	180 -- 190	190 -- 200	200 -- 210	210 -- 220	220 -- 230	230 -- 240	240 -- 250	250 -- 260	260 -- 270	270 -- 280	280 -- 290	290 -- 300	300 -- 310	310 -- 320	320 -- 330	330 -- 340	340 -- 350	350 -- 360	Total
0 -- 0.2	0.09	0.09	0.08	0.06	0.07	0.03	0.04	0.05	0.07	0.09	0.08	0.08	0.15	0.21	0.24	0.20	0.25	0.31	0.38	0.49	0.60	0.74	0.84	1.13	1.18	1.17	1.19	1.32	1.04	0.79	0.68	0.45	0.30	0.21	0.19	0.10	15.00
0.2 -- 0.4	0.00		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.08	0.13	0.15	0.21	0.22	0.27	0.35	0.45	0.65	1.10	1.88	2.55	3.87	4.13	3.52	2.08	1.11	0.57	0.27	0.13	0.04	0.03	0.02	23.96
0.4 -- 0.6			0.01	0.00	0.00		0.01	0.00		0.00	0.00	0.00		0.01	0.01	0.01	0.02	0.03	0.05	0.10	0.23	0.37	1.07	3.00	6.42	8.04	7.35	4.46	2.04	0.66	0.24	0.06	0.00	0.00			34.20
0.6 -- 0.8			0.01	0.01	0.01	0.01								0.00	0.00				0.00	0.00	0.02	0.08	0.31	1.03	4.22	6.25	4.86	1.94	0.57	0.09	0.01					19.41	
0.8 -- 1				0.00	0.00	0.00	0.01						0.00			0.00						0.00	0.04	0.22	1.24	2.47	1.63	0.33	0.07	0.01						6.03	
1 -- 1.2			0.01	0.00	0.00	0.00												0.00					0.00	0.02	0.19	0.49	0.33	0.05	0.01				0.00			1.10	
1.2 -- 1.4			0.00		0.00											0.00		0.01								0.01	0.11	0.07									0.21
1.4 -- 1.6											0.01															0.01	0.02	0.01				0.00	0.00				0.05
1.6 -- 1.8				0.00			0.00		0.00																		0.00	0.00	0.00								0.02
1.8 -- 2					0.01			0.00																													0.01
2 -- 2.2						0.00			0.00										0.00	0.00																	0.01
Above 2.2			0.00		0.00	0.00			0.00														0.00														0.01
Total	0.09	0.09	0.12	0.08	0.10	0.05	0.07	0.07	0.09	0.11	0.10	0.10	0.18	0.30	0.37	0.37	0.49	0.58	0.70	0.95	1.30	1.85	3.36	7.28	15.82	22.44	19.56	11.61	5.80	2.65	1.49	0.79	0.44	0.25	0.22	0.12	100.00

Table 3.4: Directional Distribution of Peak Wave Period for South-West Monsoon at 300m Depth

Dir (Deg.N) Hs (m)	0 -- 10	10 -- 20	20 -- 30	30 -- 40	40 -- 50	50 -- 60	60 -- 70	70 -- 80	80 -- 90	90 -- 100	100 -- 110	110 -- 120	120 -- 130	130 -- 140	140 -- 150	150 -- 160	160 -- 170	170 -- 180	180 -- 190	190 -- 200	200 -- 210	210 -- 220	220 -- 230	230 -- 240	240 -- 250	250 -- 260	260 -- 270	270 -- 280	280 -- 290	290 -- 300	300 -- 310	310 -- 320	320 -- 330	330 -- 340	340 -- 350	350 -- 360	Average
0 -- 0.2	1.4	2.5	4.8	2.1	2.4	2.4	1.3	1.4	2.7	1.6	1.8	1.7	2.1	1.9	1.9	1.8	1.8	1.9	1.8	1.8	1.8	1.8	1.8	1.8	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.8	1.7	2.0	1.6	1.6	1.9
0.2 -- 0.4	2.2		5.3	4.1	6.1	8.6	3.7	10.3	11.5	7.9	2.5	3.7	2.7	2.7	2.8	3.0	2.9	3.1	3.1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.9	2.9	2.8	2.7	2.5	2.4	2.4	2.4	3.0	
0.4 -- 0.6			11.7	9.3	10.1		12.2	7.9		7.9	15.7	8.1		6.8	3.3	5.9	3.8	3.5	3.5	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.7	3.7	3.6	3.5	3.4	3.2	3.1	3.1	13.0		3.7
0.6 -- 0.8			11.5	9.0	9.9		12.7							11.5	17.2				4.0	4.2	4.2	4.2	4.3	4.2	4.2	4.2	4.1	4.0	3.9	3.7	3.6					4.2	
0.8 -- 1				14.1	16.1		10.7	12.2								7.9							4.6	4.7	4.6	4.6	4.5	4.4	4.3	4.2	4.1						4.5
1 -- 1.2			12.3	10.3	13.1	13.0													12.3				4.9	5.0	4.9	4.8	4.7	4.6	10.9				18.7			5.1	
1.2 -- 1.4			12.7		16.6											13.1		13.5								5.2	5.1	5.0								5.9	
1.4 -- 1.6											14.3															5.5	5.3	5.2			11.8	13.6				8.6	
1.6 -- 1.8				13.0			11.2		14.5																		5.4	5.4	11.6							11.1	
1.8 -- 2					15.6			13.0																												14.7	
2 -- 2.2						13.4			13.1										10.9	12.2																12.6	
Above 2.2			15.8		10.1	12.8			20.0														15.3													11.5	
Average	1.5	2.5	6.8	4.0	6.2	7.1	6.0	4.4	5.8	2.6	3.5	2.0	2.4	2.3	2.3	2.6	2.4	2.5	2.5	2.5	2.6	2.7	3.1	3.3	3.7	3.7	3.6	3.3	3.0	2.7	2.4	2.1	2.0	2.2	1.7	1.7	3.4

Table 3.5: Directional Distribution of Wave Height for North East Monsoon at 300m Depth (Percentage of Occurrence)

Dir (Deg.N) \ Hs (m)	0 -- 10	10 -- 20	20 -- 30	30 -- 40	40 -- 50	50 -- 60	60 -- 70	70 -- 80	80 -- 90	90 -- 100	100 -- 110	110 -- 120	120 -- 130	130 -- 140	140 -- 150	150 -- 160	160 -- 170	170 -- 180	180 -- 190	190 -- 200	200 -- 210	210 -- 220	220 -- 230	230 -- 240	240 -- 250	250 -- 260	260 -- 270	270 -- 280	280 -- 290	290 -- 300	300 -- 310	310 -- 320	320 -- 330	330 -- 340	340 -- 350	350 -- 360	Total	
0 -- 0.2	1.31	1.73	2.15	2.52	2.85	2.81	2.76	2.01	1.42	1.01	0.65	0.53	0.31	0.28	0.18	0.12	0.16	0.08	0.07	0.07	0.15	0.12	0.07	0.13	0.16	0.20	0.27	0.31	0.33	0.48	0.70	0.87	0.85	0.98	1.04	1.18	30.86	
0.2 -- 0.4	0.62	0.98	1.59	3.31	5.87	9.57	11.03	7.95	4.07	1.84	0.87	0.60	0.33	0.22	0.12	0.07	0.04		0.02	0.01	0.02	0.03	0.02	0.07	0.11	0.20	0.31	0.49	0.55	0.51	0.45	0.53	0.43	0.42	0.42	0.46	54.14	
0.4 -- 0.6		0.01	0.01	0.07	0.34	1.67	4.06	3.32	1.42	0.62	0.33	0.20	0.05	0.01	0.03	0.01			0.00		0.01	0.02	0.00	0.04	0.20	0.21	0.30	0.17	0.13	0.10	0.07	0.03	0.02	0.01		0.01	13.49	
0.6 -- 0.8					0.01	0.01	0.10	0.11	0.01	0.01	0.02	0.00	0.00									0.01	0.00		0.11	0.33	0.18	0.03	0.00		0.00		0.00				0.95	
0.8 -- 1																							0.02	0.02	0.16	0.18	0.02							0.00			0.41	
1 -- 1.2				0.00											0.00											0.01	0.06	0.01			0.00						0.10	
1.2 -- 1.4		0.00																								0.00											0.01	
1.4 -- 1.6																																	0.00	0.00				0.01
1.6 -- 1.8															0.00																0.00	0.00					0.01	
1.8 -- 2																																			0.00			0.00
2 -- 2.2																																						0.00
Above 2.2								0.00	0.00	0.00							0.00																					0.02
Total	1.94	2.73	3.75	5.89	9.08	14.06	17.95	13.40	6.93	3.48	1.87	1.33	0.69	0.52	0.34	0.20	0.20	0.08	0.10	0.09	0.19	0.17	0.13	0.26	0.79	1.13	1.08	1.00	1.02	1.09	1.23	1.44	1.31	1.43	1.45	1.64	100.00	

Table 3.6: Directional Distribution of Peak Wave Period for North East Monsoon at 300m Depth

Dir (Deg.N) \ Hs (m)	0 -- 10	10 -- 20	20 -- 30	30 -- 40	40 -- 50	50 -- 60	60 -- 70	70 -- 80	80 -- 90	90 -- 100	100 -- 110	110 -- 120	120 -- 130	130 -- 140	140 -- 150	150 -- 160	160 -- 170	170 -- 180	180 -- 190	190 -- 200	200 -- 210	210 -- 220	220 -- 230	230 -- 240	240 -- 250	250 -- 260	260 -- 270	270 -- 280	280 -- 290	290 -- 300	300 -- 310	310 -- 320	320 -- 330	330 -- 340	340 -- 350	350 -- 360	Average	
0 -- 0.2	1.8	1.9	1.9	1.9	2.0	2.0	2.0	2.0	1.9	2.1	1.8	1.8	1.8	1.8	2.2	1.8	2.4	2.1	2.8	1.9	2.0	1.5	1.9	1.9	1.6	1.8	1.7	1.8	1.9	1.9	1.9	1.8	1.7	1.8	1.8	1.8	1.8	1.9
0.2 -- 0.4	2.3	2.4	2.4	2.4	2.5	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.9	2.8	2.8	2.9	3.1		2.5	2.6	2.9	2.8	3.1	2.8	3.0	2.9	3.0	2.9	2.9	2.8	2.7	2.6	2.5	2.4	2.4	2.3	2.6	
0.4 -- 0.6		6.5	5.0	2.9	3.0	3.0	3.0	3.1	3.1	3.1	3.2	3.2	3.3	3.2	7.4	7.2			7.6		3.8	3.9	3.7	3.7	3.8	3.7	3.6	3.5	3.4	3.3	3.7	3.1	3.0	2.9		2.8	3.1	
0.6 -- 0.8					3.2	3.3	3.4	3.6	3.4	8.7	3.5	3.6	14.2									4.3	4.5		4.3	4.2	4.1	3.9	3.8		10.0		13.5				4.1	
0.8 -- 1																							6.9	4.8	4.6	4.5	4.4								12.4		4.8	
1 -- 1.2				14.5												12.1										4.9	4.9	4.9			13.0							6.1
1.2 -- 1.4		13.5																																			9.3	
1.4 -- 1.6																																		18.8	18.0		18.4	
1.6 -- 1.8															21.2																13.6	13.3					16.0	
1.8 -- 2																																			14.2		14.2	
2 -- 2.2																																					17.5	
2.2 -- 2.4								12.8	11.1	19.6							20.9																					17.5
Average	2.0	2.1	2.2	2.2	2.4	2.5	2.6	2.7	2.6	2.7	2.5	2.5	2.5	2.2	3.1	2.8	3.0	2.1	3.0	2.0	2.2	2.1	3.2	2.7	3.6	3.5	3.1	2.7	2.6	2.4	2.4	2.2	2.1	2.1	1.9	1.9	2.5	

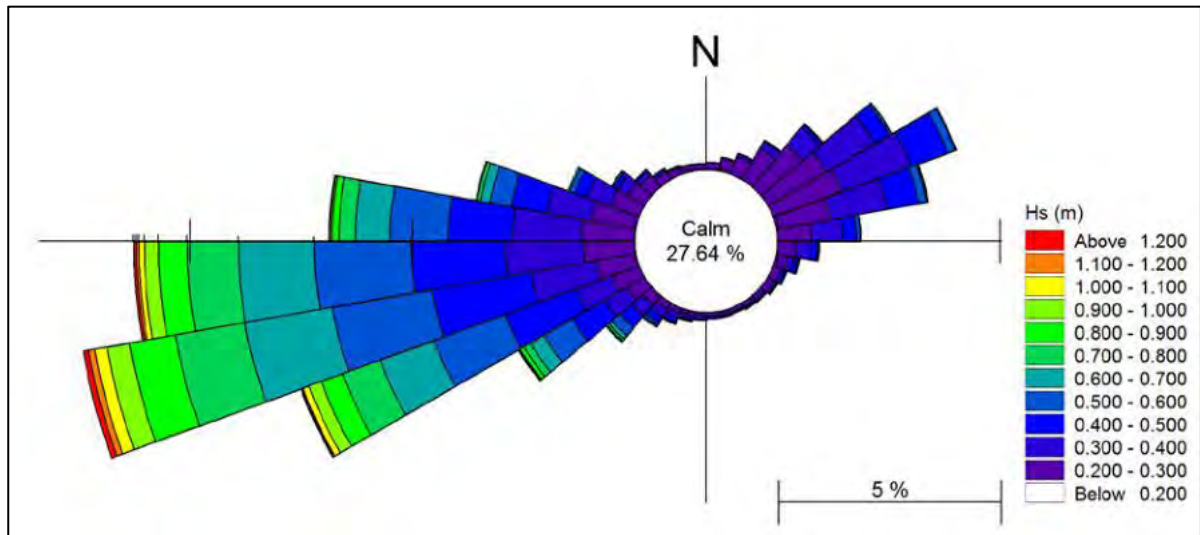


Figure 3.3: Annual Wave Height Distribution at 300m Depth

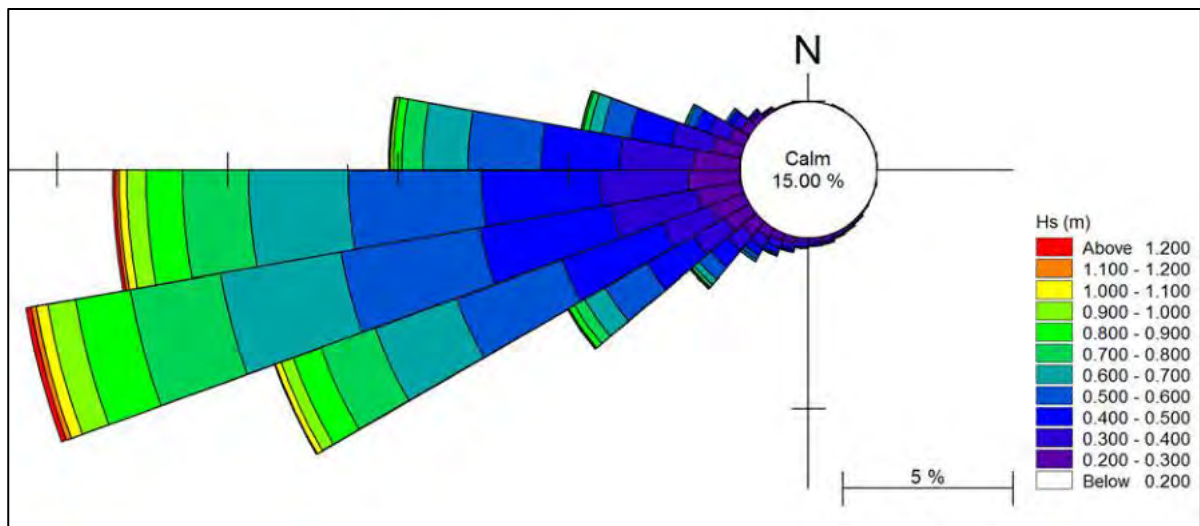


Figure 3.4: Wave Height Distribution for South-West Monsoon at 300m Depth

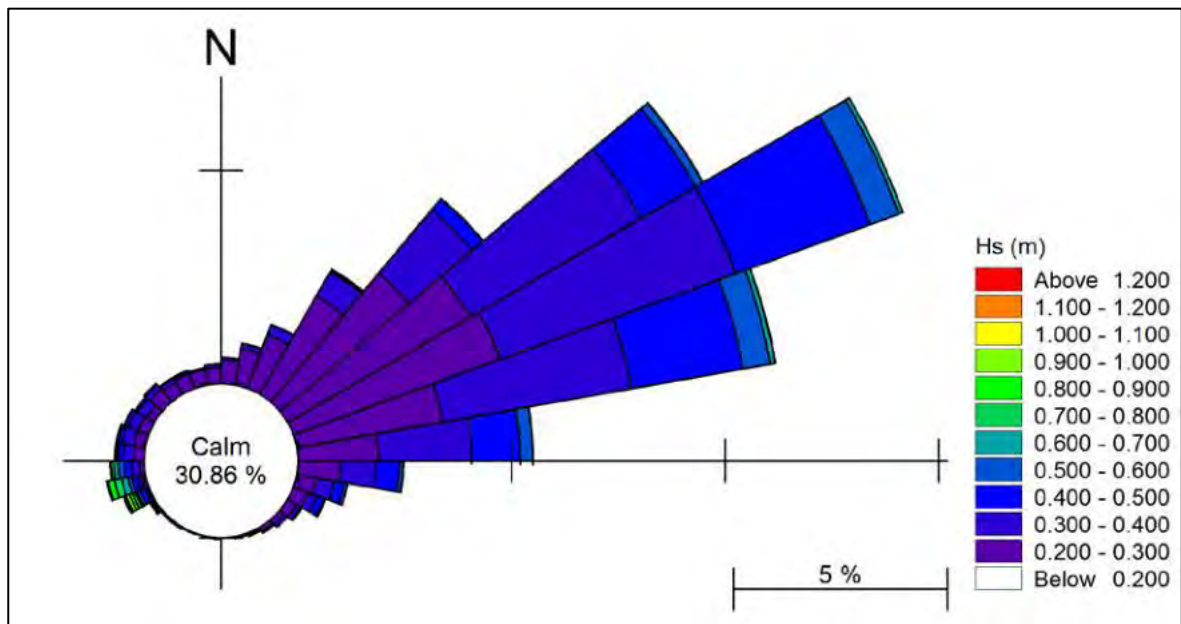


Figure 3.5: Wave Height Distribution for North-East Monsoon at 300m Depth

4 HYDRODYNAMIC MODELLING

In order to compute water circulation with effect of tidal flow, wave and wind in and around the study area, a hydrodynamic model required to be carried out. Hence, the numerical model, MIKE 21 HD was used in this process.

4.1 MIKE 21 Hydrodynamic Model System

MIKE 21 HD (Flexible Mesh) model developed by Danish Hydraulic Institute was used for the simulation. It is a modelling system for 2D free-surface flows and applicable to the simulation of hydraulic and environmental phenomena in lakes, rivers, estuaries, bays, coastal areas and seas in response to a variety of forcing functions including tide, wind, wave and river flow. The HD module allows you to specify a variety of hydrographic boundary conditions, initial conditions, bed resistance and wind forcing. It also allows you to include different types of sources and sinks as well as a number of different structures. It provides the hydrodynamic basis for the computations performed in the environmental hydraulics and sediment transport modules.

4.2 MIKE 21 HD Model Set Up

4.2.1 Model Bathymetry

Same as the wave model, Admiralty charts and bathymetry data provided by the client were used for the development of model bathymetry. Since tidal variation would be applied as main boundary condition for the regional model, availability of tidal data was considered when setting up the model. Tidal boundaries were developed using MIKE 21 Toolbox Tide developer considering 25km away from Thilafushi in North and South directions, and 45km in West and East direction. Therefore the regional model covers the model area of 50km in north-south way and 90km east-west way. Figure 4.1 illustrates the bathymetry of regional model and position of the local model on it. Local model was selected considering the bathymetry, and kept offshore boundary at 300m depth.

Triangular flexible mesh was generated by MIKE 21 Bathymetry Creator Tool while considering finer mesh size for more concern area. The UTM 43 coordinate system was used for (x, y) coordinates and Mean Sea Level (MSL) was used as the elevation datum. The local bathymetry with mesh is given in Figure 4.2.

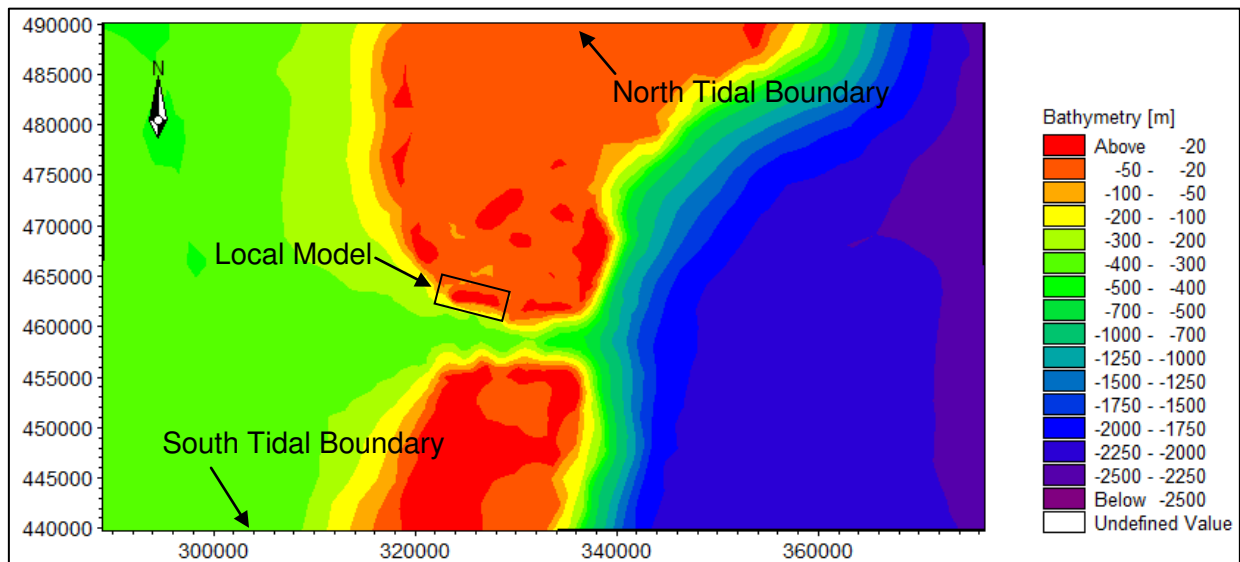


Figure 4.1: Bathymetry for Regional Hydrodynamic Model

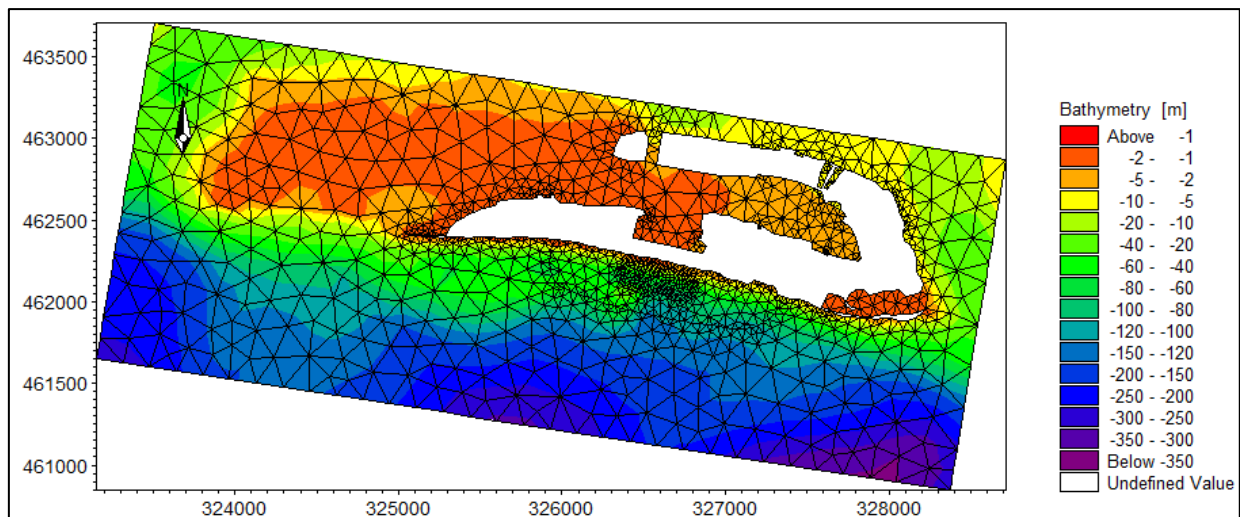


Figure 4.2: Bathymetry for Local Hydrodynamic Model

4.2.2 Simulation Period

The regional model was run for one month period for each South-West and North-East monsoon and the local model was run for three days for each monsoon which covering spring and neap tide. The regional model was run with the time step of 3s and the local model with 1s.

4.2.3 Boundary Conditions

The tide levels of the boundaries are used as boundary conditions for regional model. Time series of water levels were predicted using MIKE 21 Toolbox Tide developer for north and south tidal boundaries as indicated in Figure 4.1. Representative predicted tidal plots in north and south boundaries for few days in South-West Monsoon are shown in Figures 4.3 and 4.4.

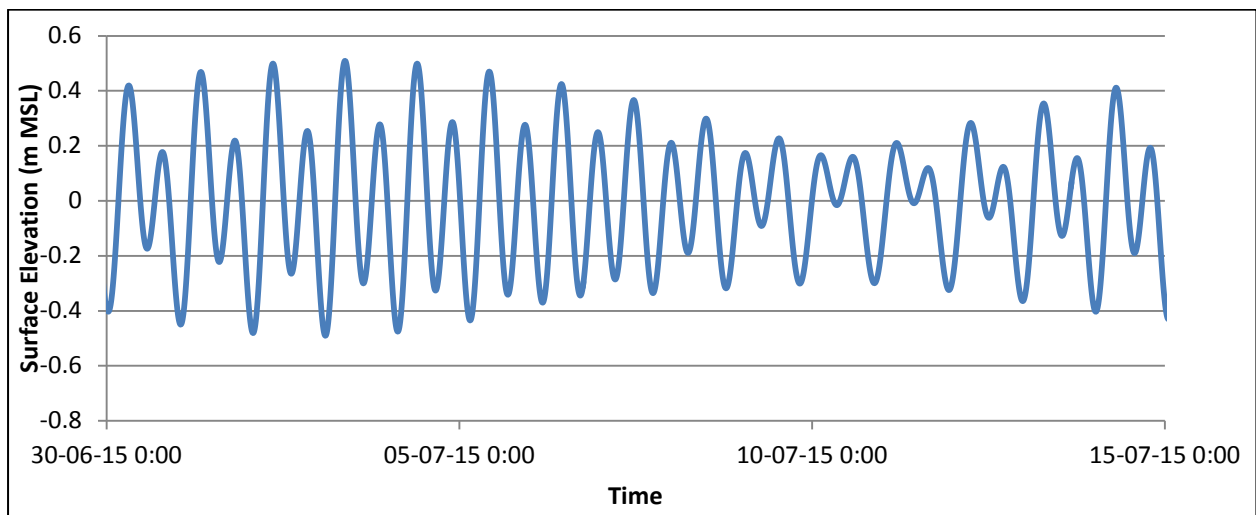


Figure 4.3: Predicted Tide in North Boundary

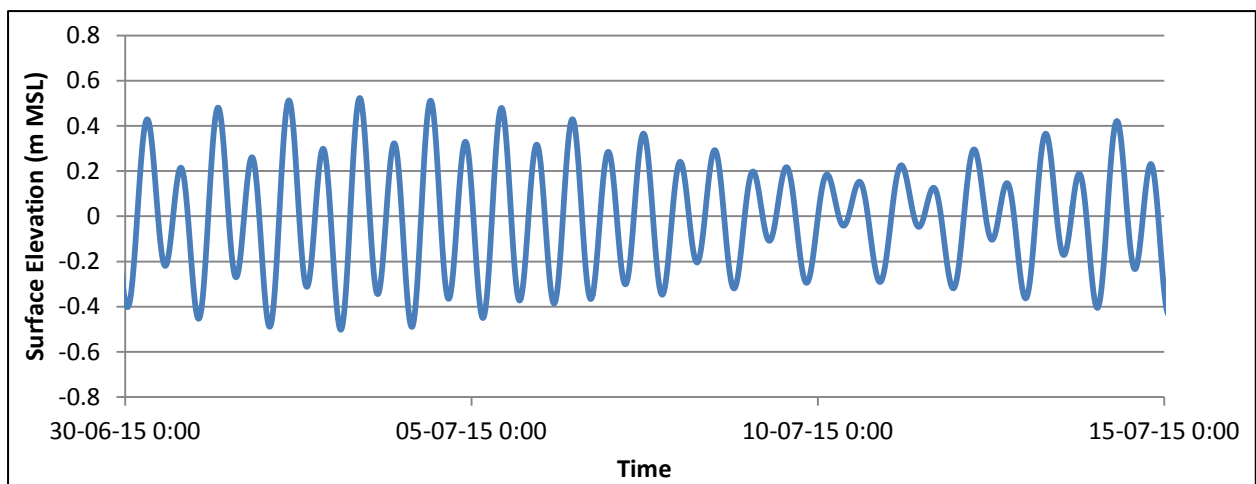


Figure 4.4: Predicted Tide in South Boundary

Water levels and discharges extracted from regional model at the boundaries of the local model were used as boundary conditions for the local model.

4.2.4 Wave and Wind Conditions

Local model was run for average wave/wind condition for both monsoons. The average condition was selected considering 50% of occurrence line of wave height of the wave data extracted at 300m depth from wave transformation model (MIKE 21 SW). In this process, most dominant directional bands were selected for the calculations (as coloured in Table 3.3 to 3.6). Same as wave, 50% of occurrence line of wind speed of UKMO wind data was selected to obtain corresponding wind speed. The selected wave and wind conditions are given in following table and both wind and wave conditions were applied at the same time in the model for each monsoon.

Table 4.1: Applied Wave/Wind Conditions for the Local Hydrodynamic Model

Monsoon	Wave Condition			Wind Condition	
	Hs (m)	Tp (s)	Direction (deg)	Speed (m/s)	Direction (deg)
SW	0.49	3.6	260	5.75	270
NE	0.26	2.4	60	5.02	55

4.3 MIKE 21 HD Model Calibration

Calibration was done for predicted tide levels at Male considering the variation of surface elevations. Figure 4.5 shows the water level comparison between model values and predicted tide at male. The bed roughness was used as the calibration parameter and Manning’s Number of 32 was set as the suitable values for the calibration.

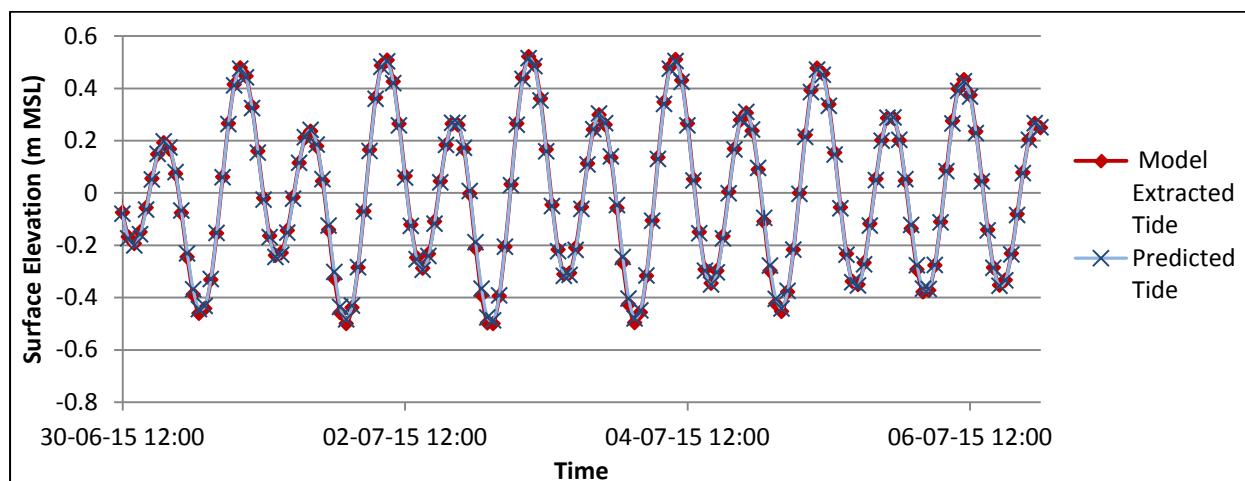


Figure 4.5: Calibration with Predicted Tide at Male

4.4 MIKE 21 HD Results

The main objective of the HD modelling is to observe the flow pattern in the site area and find out the effective current flow for thermal dispersion at outfall. Hence current speeds and directions were extracted at the outfall location (Figure 4.6) for both monsoon periods and spring and neap tidal conditions. The average current speed and direction for different conditions are given in Table 4.2. Further variations of current pattern at outfall area are given in Annex A.

According to the results, it can be observed that the wave condition is not significantly affected for the current at outfall location; it is basically tide dominant. The direction of current varies almost 180 degree with ebb and flood conditions, but Table 4.2 gives direction values only considering westward current flow condition.

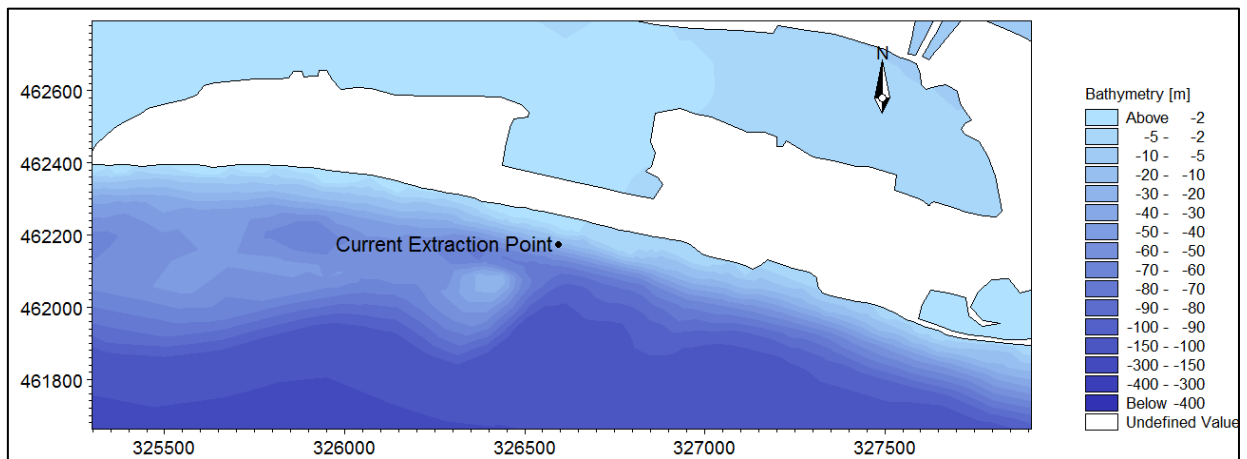


Figure 4.6: Current Extracted Points

Table 4.2: Average Current Condition at Extracted Point

Monsoon	Tidal Condition	Current Speed (m/s)	Direction (deg)
SW	Neap Tide	0.10	277
	Spring Tide	0.22	280
NE	Neap Tide	0.10	280
	Spring Tide	0.20	271

5 THERMAL DISPERSION MODELLING

5.1 Introduction

The proposed incinerator will use sea water as the coolant and discharge hot water back to the sea. Inevitably, the temperature of water discharged is above the ambient. As temperature is one of the most important environmental variables, discharging water of such temperature will have significant impact to the aquatic organisms and to the local biological and biogeochemistry of the ocean. Impacts of high water temperature discharge are such as:

- Coral bleaching
- Reduction of dissolved oxygen level
- Stimulation of phytoplankton and benthic algal growth
- Alteration in ecosystem which affects the mortality and reproduction
- Alteration of thermal structure of the ocean, current patterns, surface wave patterns

In this modelling process, initial dilution is estimated using a near field model (CORMIX). Thereafter using its results depth average diluted thermal factors are obtained and fed them to a far field model (MIKE 21 HD Thermal Dispersion). Finally spreading of thermal plume in 2D plain can be obtained.

5.2 Simulation Scenarios

Three different flow rates for three different excess temperature are required to consider in the simulations. In order to find out best location (depth) for the outfall, three different depths are proposed for the simulations. In addition, two different monsoon and tidal conditions are also considered. Therefore all together 36 number of scenarios are required to simulate. All simulation scenarios are given in the following table.

Table 5.1: Simulation Scenarios

Sc. ID	Monsoon	Tide	Excess Temperature (°C)	Flow Rate (m ³ /h)	Depth at Discharge (m)
NE_S_01	North-East	Spring	2.5	16.56	10
NE_S_02					20
NE_S_03					30
NE_S_04			5	8.28	10
NE_S_05					20
NE_S_06					30
NE_S_07			10	6.21	10
NE_S_08					20
NE_S_09					30
NE_N_01		Neap	2.5	16.56	10
NE_N_02					20
NE_N_03					30
NE_N_04			5	8.28	10
NE_N_05					20
NE_N_06					30
NE_N_07			10	6.21	10
NE_N_08					20
NE_N_09					30
SW_S_01	South-West	Spring	2.5	16.56	10
SW_S_02					20
SW_S_03					30
SW_S_04			5	8.28	10
SW_S_05					20
SW_S_06					30
SW_S_07			10	6.21	10
SW_S_08					20
SW_S_09					30
SW_N_01		Neap	2.5	16.56	10
SW_N_02					20
SW_N_03					30
SW_N_04			5	8.28	10
SW_N_05					20
SW_N_06					30
SW_N_07			10	6.21	10
SW_N_08					20
SW_N_09					30

5.3 Near Field Modelling

The given outfall pipe diameter is 300mm. Accordingly discharge velocity of plume is between 0.065m/s and 0.0244m/s which are significantly low compared to the sea current at location. It will be released close to the sea bottom. Since the density of the heated plume is less it will act as negatively buoyant discharges and tends to move upwards. The initial momentum of the discharge will lead to a very turbulent flow that will attempt to mix the fluid over the full depth available. This mixing will be resisted by the fact that the discharge is buoyant. The mixing will also cause ambient fluid to be entrained into the jet, reducing its momentum and temperature. This initial momentum is very important and generally reduces the excess temperature by a factor of 2 to 3 over a distance of a few meters. Once the discharge momentum has been reduced below a certain limit due to the dilution, the mixing will cease to be the dominant factor and the discharge will transform into what is generally known as a plume. After this the discharge enters the far field. To examine the near field behaviour of the heated plume CORMIX mixing zone model is used.

5.3.1 Cormix Modelling System

The CORMIX is a mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones resulting from continuous point source discharges (Doneker & Jirka 2007). It is a computer-aided-design (CAD) developed by the Defrees Hydraulic Laboratory at Cornell University, Ithaca, New York, in cooperation of USEPA for studying aqueous pollutant discharges into a range of water bodies, design and mixing zone analysis (Doneker & Jirka 2007). The role of boundary interaction is the emphasis of the system for predicting steady-state mixing behaviour and plume geometry (Doneker & Jirka 2007).

Simulation model selection in CORMIX is controlled by the Graphical user interface (GUI) and mixing zone rule-based expert systems technology. Description of discharge and ambient conditions are specified as input data in the GUI. Based on the inputs, the most appropriate hydrodynamic simulation model is determined. CORMIX employs the length-scaled rule-based system for classification of flow regimes and uses the length scale for predicting the initial dilution. CORMIX simplifies the characteristics of each stage in the steady-state condition and predicts the plume dilution by using some empirical equations (Etemad-Shahidi & Azimi 2007).

CORMIX is applicable to wide range of problems from a simple single submerge pipe discharge into a small stream with rapid cross-sectional mixing to a complicated multiport diffuser installation in deeply-stratified coastal water. However, there is lack of applicability in highly unsteady ambient flow conditions that are prone to locally recirculating flows (Doneker & Jirka 2007).

The main aim is to obtain an estimation of spreading of heated plume around the discharge. The model set up used the excess temperature as a tool to access the change in temperature

level. Based on the requirement, four different water depths were considered for outfall and simulations were carried out accordingly for considering all the relative environmental conditions.

5.3.2 Model Simulations

As discussed earlier dilution process can be divided into a primary jet dilution in the so-called **near-field** and a subsequent natural dilution in the **far-field**. The natural dilution (far field) is influenced by waves, currents and environment conditions.

In general near field of an outfall is governed by the initial jet characteristics of the plume and outfall geometry. In this case, horizontal single port discharge is considered in the modelling simulations. The density of effluent was varied from 1017m³/kg to 1020m³/kg according to the excess temperature and the ambient density of the sea water is considered as 1025m³/kg. Ambient temperature level is assumed as 28°C. Simulations were carried out for list of scenarios given in Table 5.1.

5.3.3 CORMIX Model Results

Visualization of the effluent discharged from the port and rising to the surface in a cross flow at near-field region is given below for the simulation of North-East monsoon with neap tide and excess temperature 10°C and depth of discharge 10m (Sc. ID: NE_N_07). Both plan view and the elevation of the plume of for this scenario are given below and 3D view plots for rest of simulations are given in Annex B.

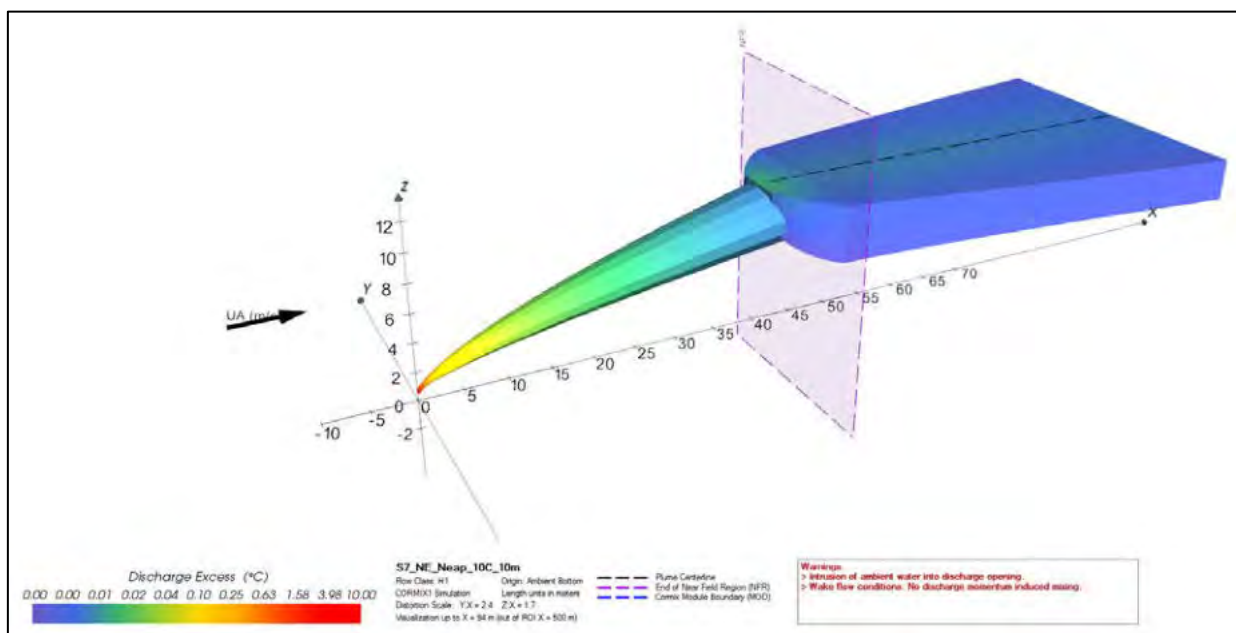


Figure 5.1: Visualization of the Effluent Discharged from the Port and Rising to the Surface at Near-Field Region (3D View)

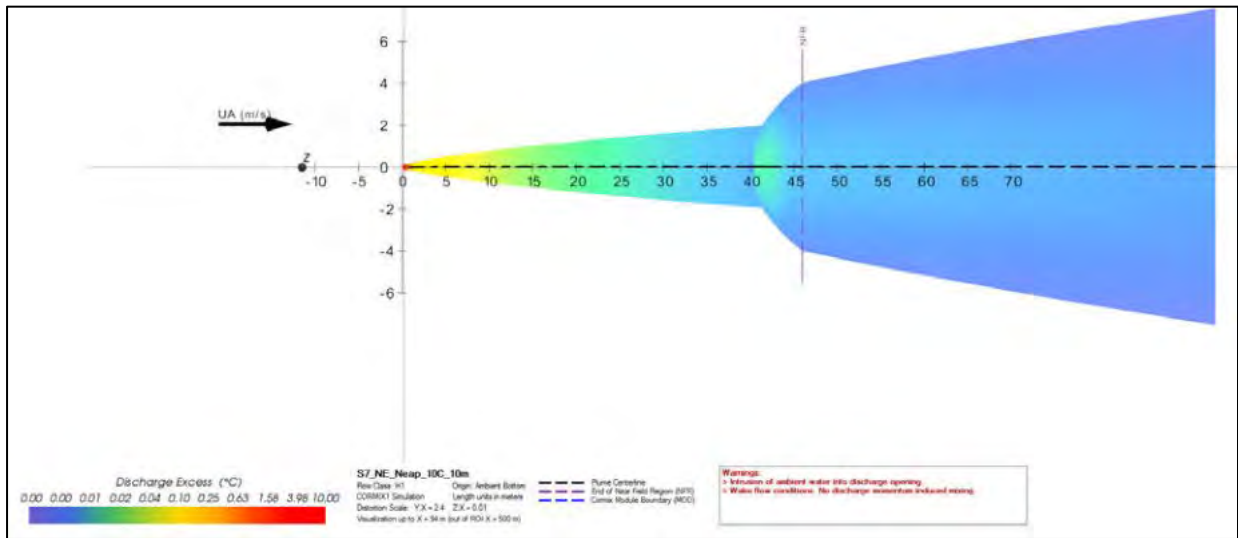


Figure 5.2: Visualization of the Effluent Discharged from the Port and Rising to the Surface in a Cross Flow at Near-Field Region. (Plan View)

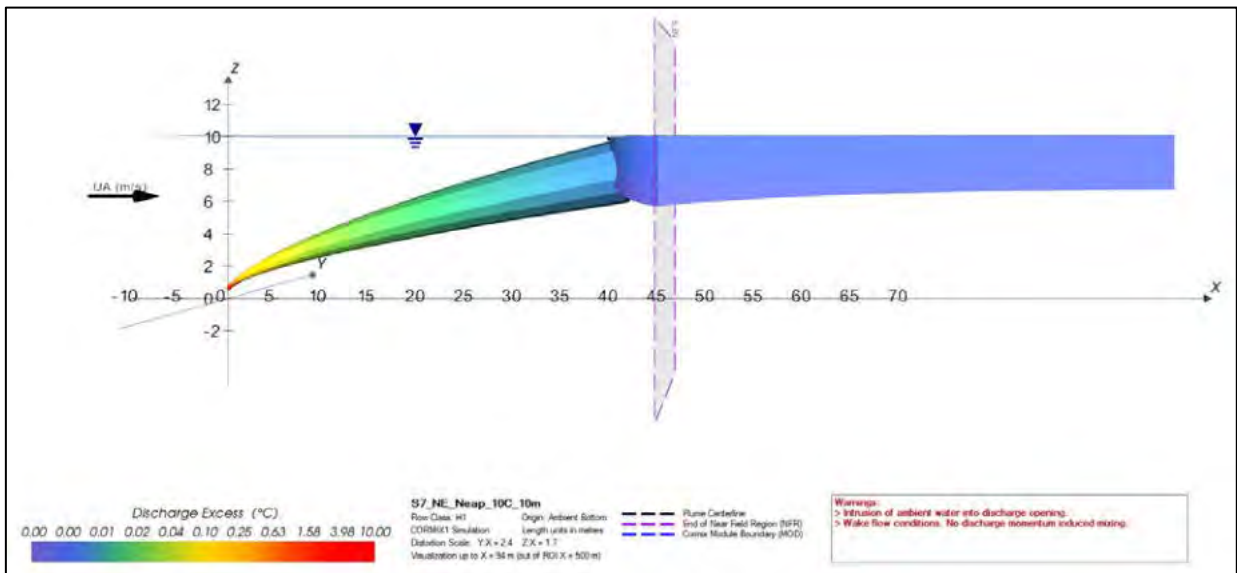


Figure 5.3: Visualization of the Effluent Discharged from the Port Spreading at Near-Field Region. (Elevation)

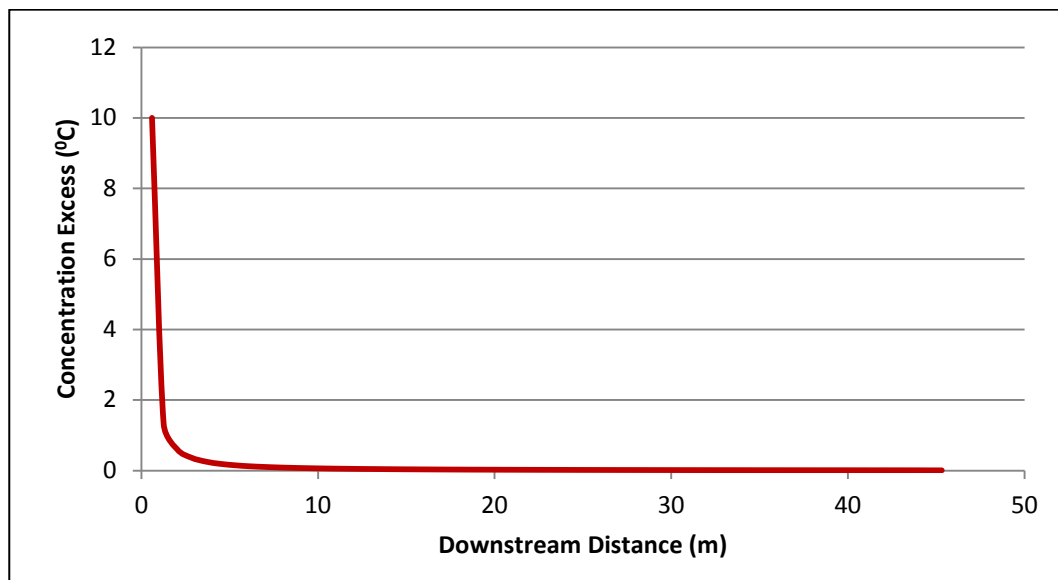


Figure 5.4: Excess Concentration vs. Downstream Distance

5.3.4 Discussion

According to the results of above scenario, relatively high influence can be observed with low depth release, high temperature plume and low current speed. Hence plume discharge at 10m depth with 10°C excess temperature at neap tidal condition is the most influence scenario in near-field modelling. There are two scenario which satisfy these condition; scenario IDs of those are **NE_N_07** and **SW_N_07**. Hence the above selected scenario is one of most influential condition among all scenarios. Even with this most influential condition, high dilution can be observed due to low flow rate of effluent. The excess temperature reduces to less than 1°C within few meters of downstream distance. Therefore effect on coastal environment with this discharge is negligible.

5.4 Far Field Modelling

As discussed earlier two models were used to assess the dispersion pattern of the heat plume, one for the near field and one for the far field. The use of the semi-empirical length scale model, CORMIX, for the near field is described in Section 5.3.

As the turbulent plume travels further away from the discharge location, the jet characteristics become less important and three dimensional treatment of thermal dispersion is nearly changed to two dimensional treatments. Then in order to simulate the current phenomena, it is possible to use two-dimensional models. MIKE 21 Hydrodynamic Model combine with Thermal Dispersion Tool has been used for hydrodynamic and thermal dispersion simulation in far field region.

5.4.1 Input Data

All input parameters used in local hydrodynamic model (as given in Chapter 4) are used for thermal dispersion modelling. Therefore two different monsoon conditions (South-West and North-East) and two different tidal conditions (Spring and Neap) are taken into consideration in the simulation. In addition, heat plume discharge boundary for far-field simulation is established using the near-field model (CORMIX) results. The excess temperature was extracted in mean water depth from CORMIX model and given as an input data for MIKE 21 HD thermal dispersion model. The excess temperature extracted for different scenarios are given in Table 5.2.

Table 5.2: Input Excess Temperature for Far-Field Model

Sc. ID	Monsoon	Tide	Excess Temperature (°C)	Flow Rate (m ³ /h)	Depth at Discharge (m)	Excess Temperature at Average Depth(°C)		
NE_S_01	North-East	Spring	2.5	16.56	10	0.015		
NE_S_02					20	0.002		
NE_S_03					30	0.001		
NE_S_04			5		8.28	10	0.006	
NE_S_05						20	0.002	
NE_S_06						30	0.001	
NE_S_07			10			6.21	10	0.011
NE_S_08							20	0.004
NE_S_09							30	0.002
NE_N_01		Neap	2.5	16.56			10	0.015
NE_N_02							20	0.004
NE_N_03							30	0.002
NE_N_04			5		8.28		10	0.016
NE_N_05							20	0.004
NE_N_06							30	0.002
NE_N_07			10			6.21	10	0.024
NE_N_08							20	0.005
NE_N_09							30	0.002
SW_S_01	South-West	Spring	2.5	16.56			10	0.007
SW_S_02							20	0.002
SW_S_03							30	0.001
SW_S_04			5		8.28		10	0.005
SW_S_05							20	0.001
SW_S_06							30	0.001
SW_S_07			10			6.21	10	0.007
SW_S_08							20	0.002
SW_S_09							30	0.001
SW_N_01		Neap	2.5	16.56			10	0.016
SW_N_02							20	0.004
SW_N_03							30	0.002
SW_N_04			5		8.28		10	0.016
SW_N_05							20	0.004
SW_N_06							30	0.002
SW_N_07			10			6.21	10	0.024
SW_N_08							20	0.005
SW_N_09							30	0.002

5.4.2 Model Results and Discussion

Since the discharge flow rate is considerably low, high dilution can be observed at outfall area. Hence the mean depth excess temperature is very low. However the extracted values were added to the far-field model and obtained the results.

High influence can be observed at low depth discharge same as near-field model, but high heat distribution can also be observed for high effluent flow rate condition even it has low excess temperature. As an example Sc. ID: NE_S_01 has excess temperature 2.5°C in the effluent, but it has 16.56m³/h flow rate which is comparatively high. Therefore results of this scenario shows high heat distribution. Further scenarios with neap tidal condition shows higher influence with its low current speed than spring tide. According to these conditions high influence scenarios are;

- a) NE_S_01
- b) NE_N_01
- c) NE_N_07
- d) SW_S_01
- e) SW_N_01
- f) SW_N_07

As an example Sc. ID: NE_N_07 has been used for further discussion which was critical in near-field model too. Figure 5.5 and 5.6 show the temperature variation in 2D plain for this high influence scenario when current directed westward and eastward respectively. According to the results, the excess temperature level reduces 5×10^{-6} °C within the 90m range from the discharge point for both cases. However 5×10^{-6} °C excess temperature is very low temperature and negligible in coastal environment. Therefore thermal dispersion is very high even in a high influence scenario and it will be a very low effect to the coastal environment. Thermal dispersion plots for all scenarios are given in Annex C.

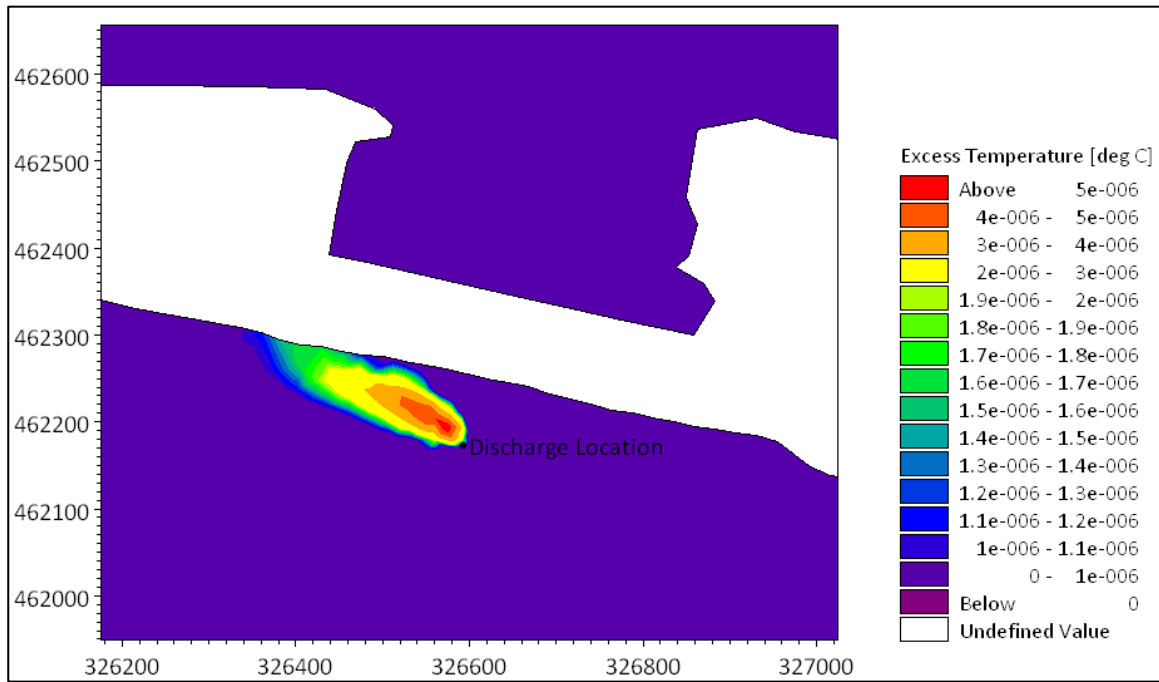


Figure 5.5: Thermal Dispersion towards West at Scenario NE_N_07

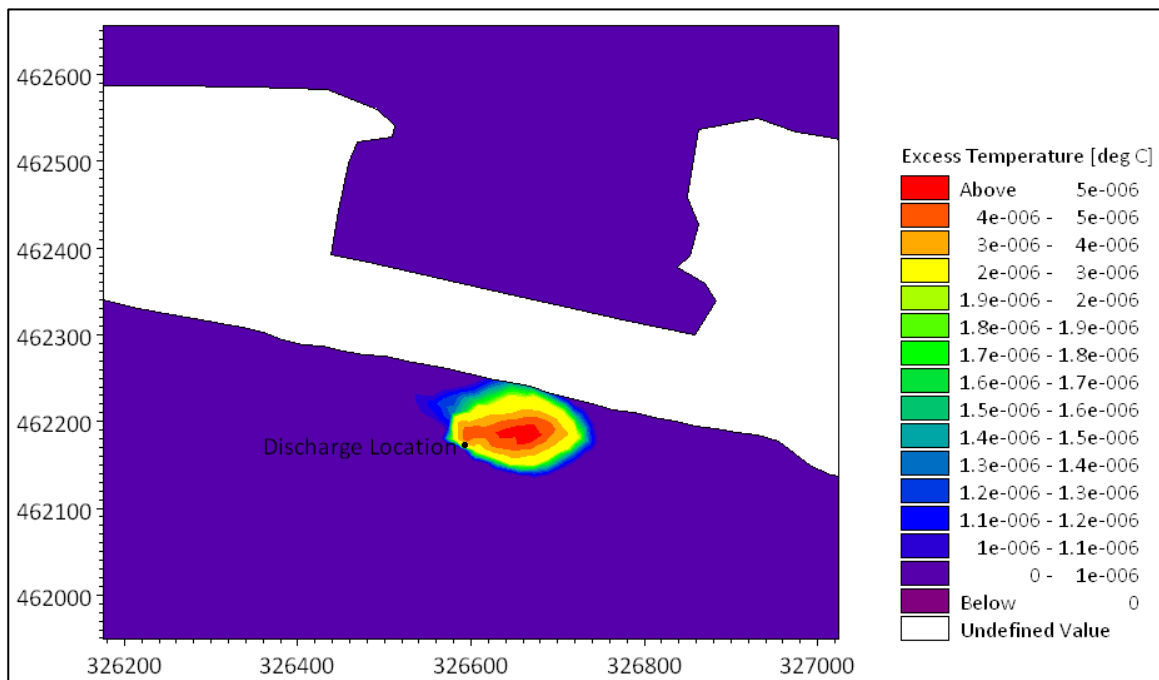


Figure 5.6: Thermal Dispersion towards East at Scenario NE_N_07

6 SUMMARY AND CONCLUSION

- In order to find out thermal dispersion in coastal environment for outfall of hot water plume of a proposed incinerator at Thilafushi Island, a set of numerical model simulation was carried out for different design conditions and seasonal conditions.
- Measured data as well as reliable predicted data were utilized as model inputs, and analysed them before applied to the model.
- MIKE 21 SW model was used to establish the wave condition at site for different monsoon periods (South-West and North-East) and MIKE 21 HD model was used to obtain the current condition at discharge location. Further both spring and neap tidal conditions were simulated separately; and about 0.2m/s and 0.1m/s average current speed were obtained at the discharge point for spring and neap tide respectively. Wave condition was not significantly affected on current condition at discharge point.
- Two modelling system were used thermal dispersion modelling, namely CORMIX model for **near-field** dispersion and MIKE 21 HD coupled with thermal dispersion tool for **far-field** dispersion.
- According to near-field model results,
 - High dilution can be observed due to low flow rate of effluent.
 - High temperature reduction was observed within few meters from released point. Even in one of most influential scenario (Sc. ID: NE_N_07) which has low depth of discharge (10m), high excess temperature (10°C) and low current speed (0.1m/s), temperature reduces to 1°C within 3m of range.
- Results obtained from near-field model were used as input parameter for far-field model.
- Far-field model results represent the temperature spreading in 2D plain for different scenarios.
- According to far-field model results,
 - High heat distribution can be observed with high effluent flow rate, but excess temperature is very low and negligible in coastal environment.
 - Same as the near-field model low depth discharge creates some influence comparative to the other conditions.

ANNEX A

Current Speed Vector Plots

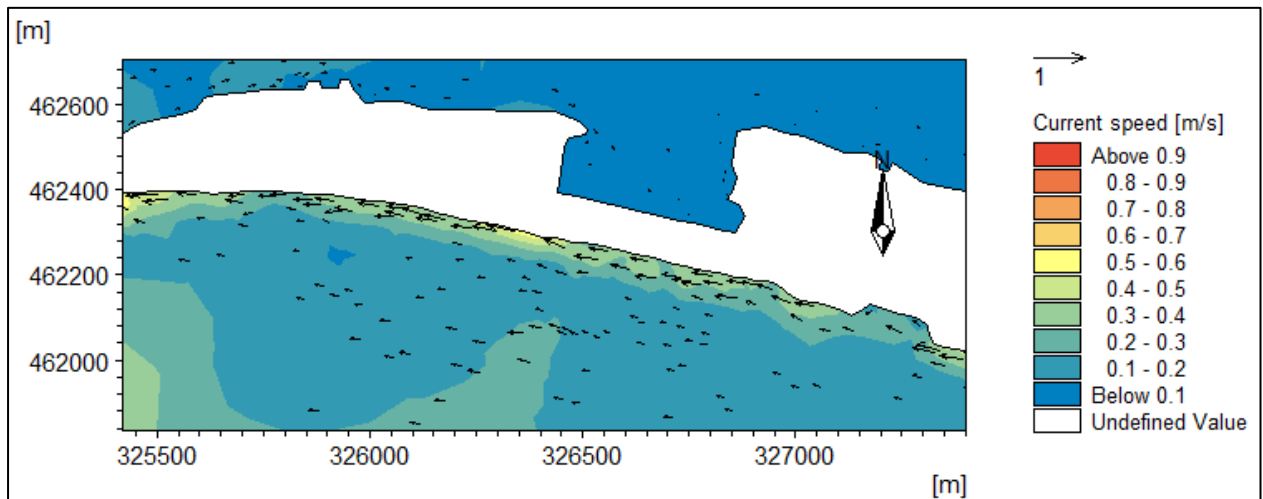


Figure A.1: SW Monsoon, Spring Tide, Average Condition

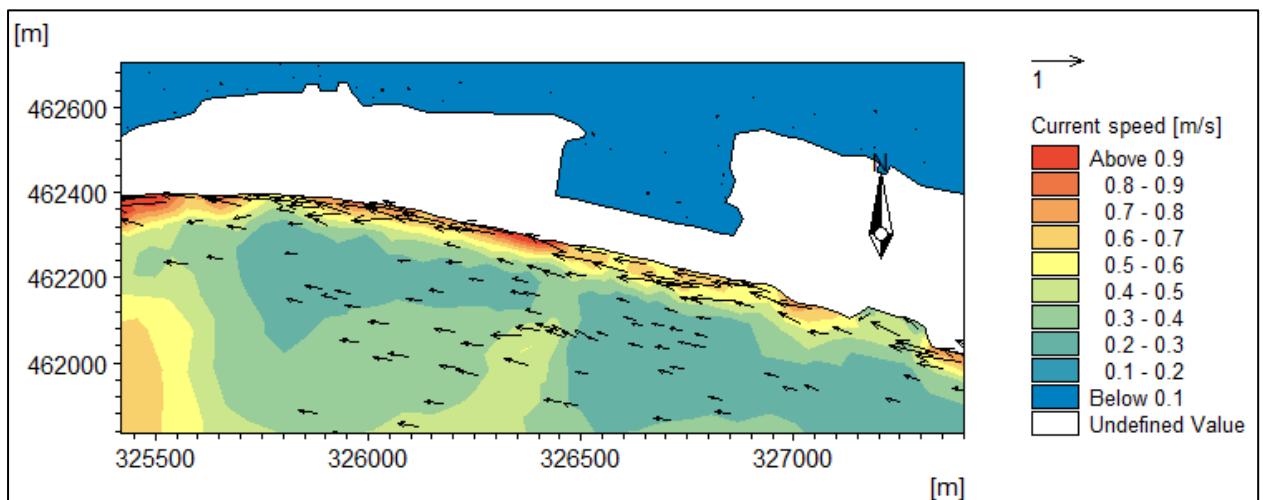


Figure A.2: SW Monsoon, Spring Tide, Maximum Condition

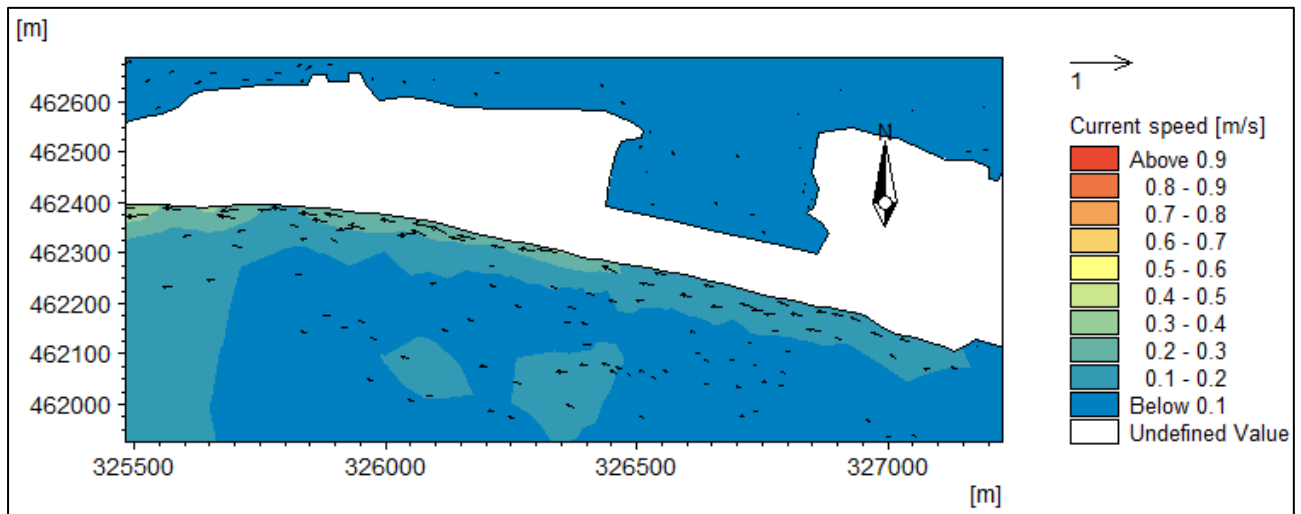


Figure A.3: SW Monsoon, Neap Tide, Average Condition

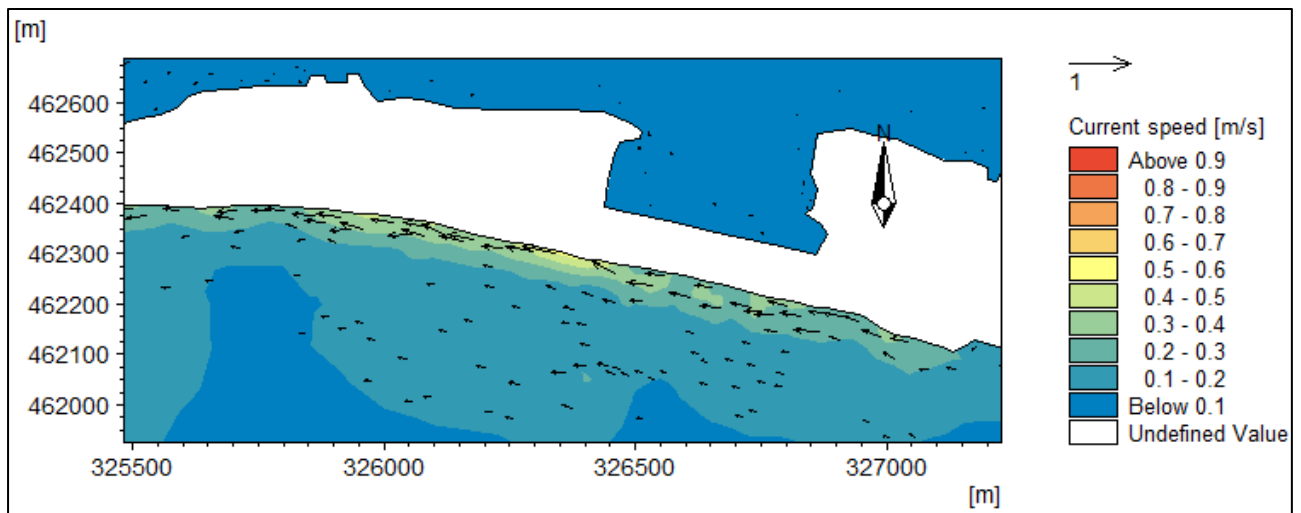


Figure A.4: SW Monsoon, Neap Tide, Maximum Condition

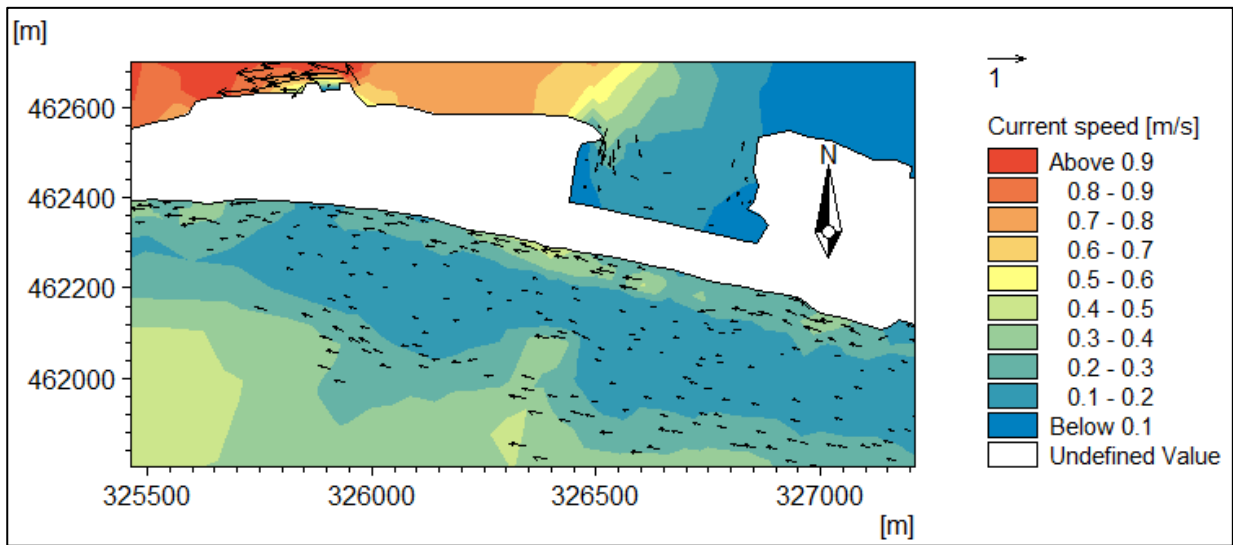


Figure A.5: NE Monsoon, Spring Tide, Average Condition

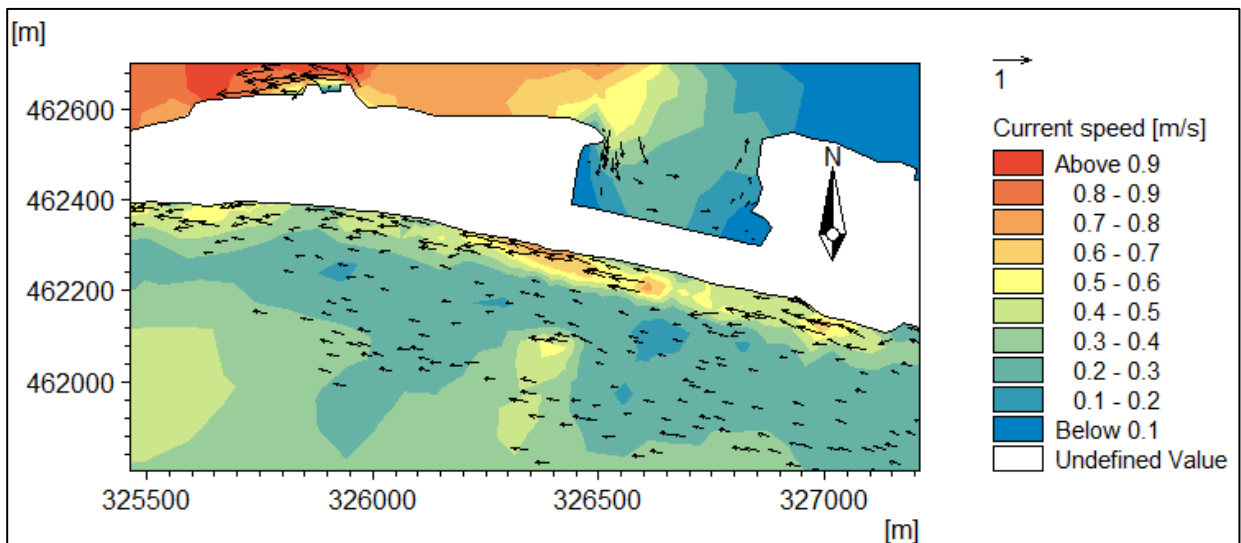


Figure A.6: NE Monsoon, Spring Tide, Maximum Condition

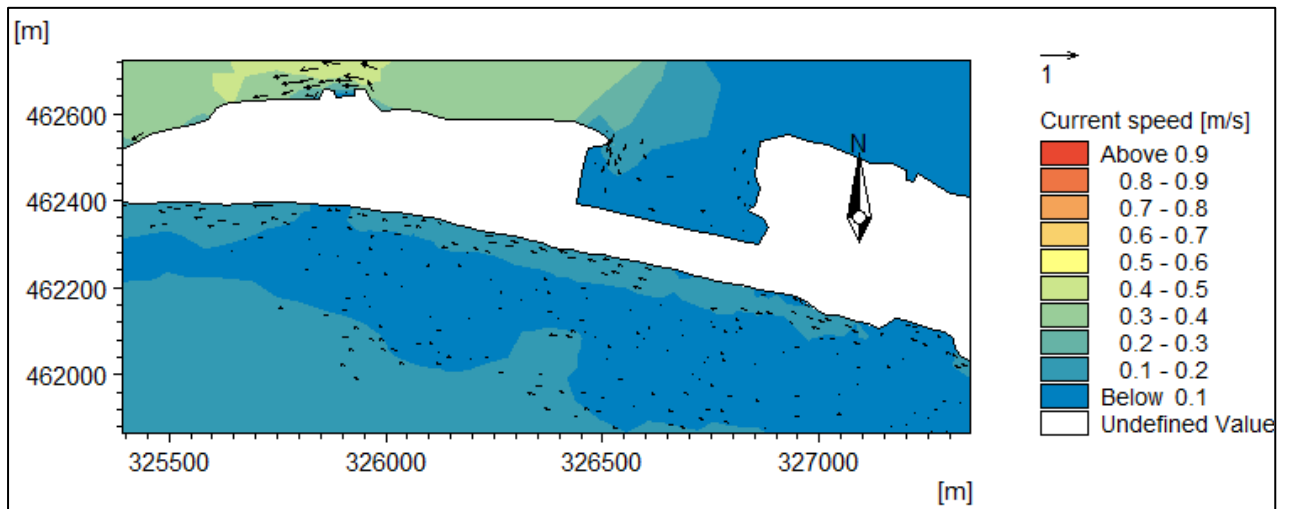


Figure A.7: NE Monsoon, Neap Tide, Average Condition

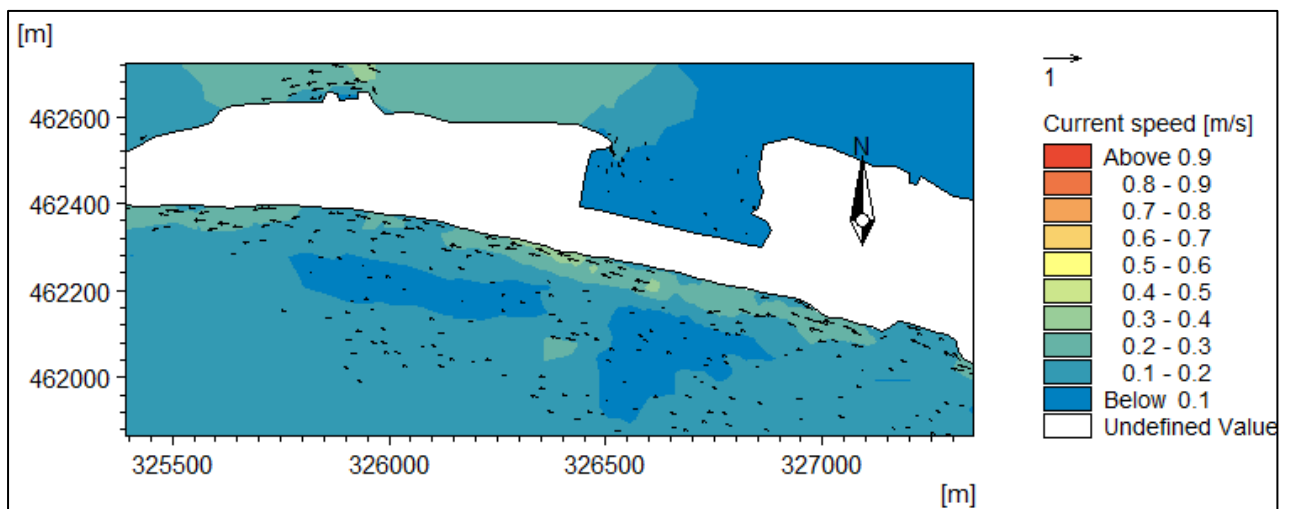


Figure A.8: NE Monsoon, Neap Tide, Maximum Condition

ANNEX B

Heat Dissipation in Near Field (CORMIX)

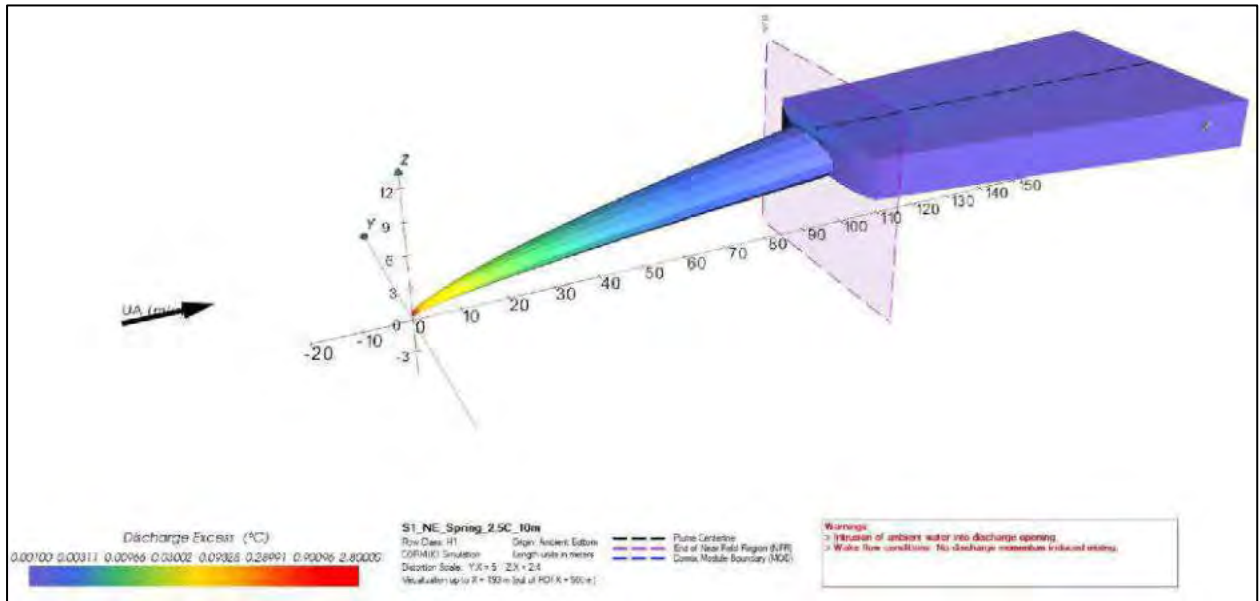


Figure B1: NE_S_01_ (Ex. Temp.=2.5°C, Flow Rate=16.56 m³/h, Depth=10m)

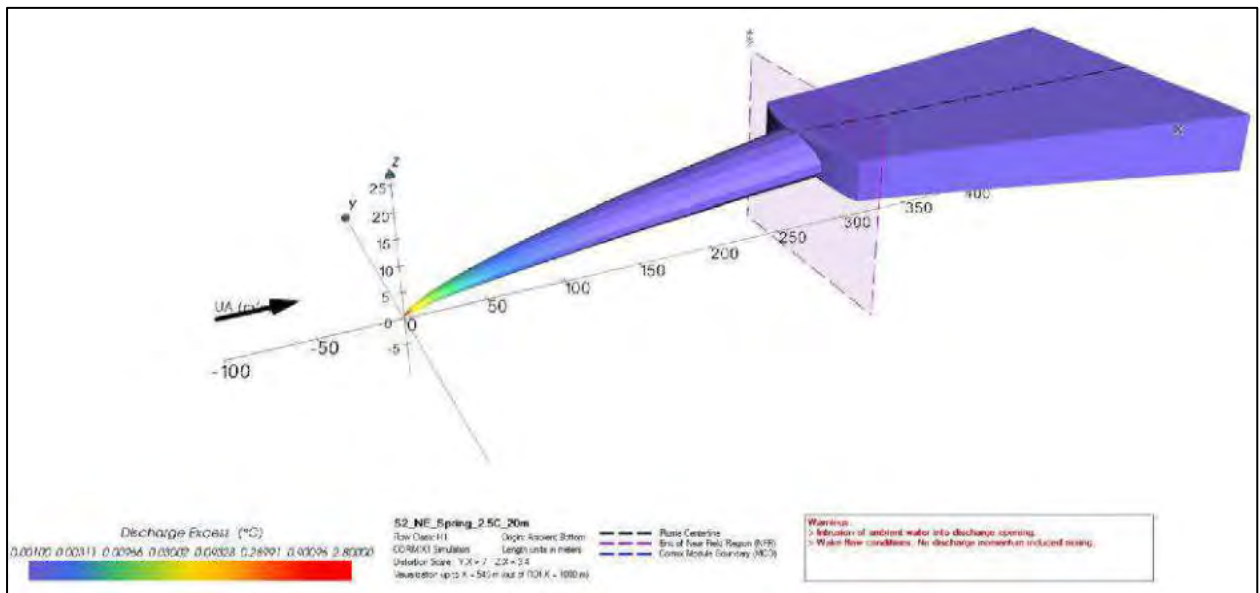


Figure B2: NE_S_02_ (Ex. Temp.=2.5°C, Flow Rate=16.56 m³/h, Depth=20m)

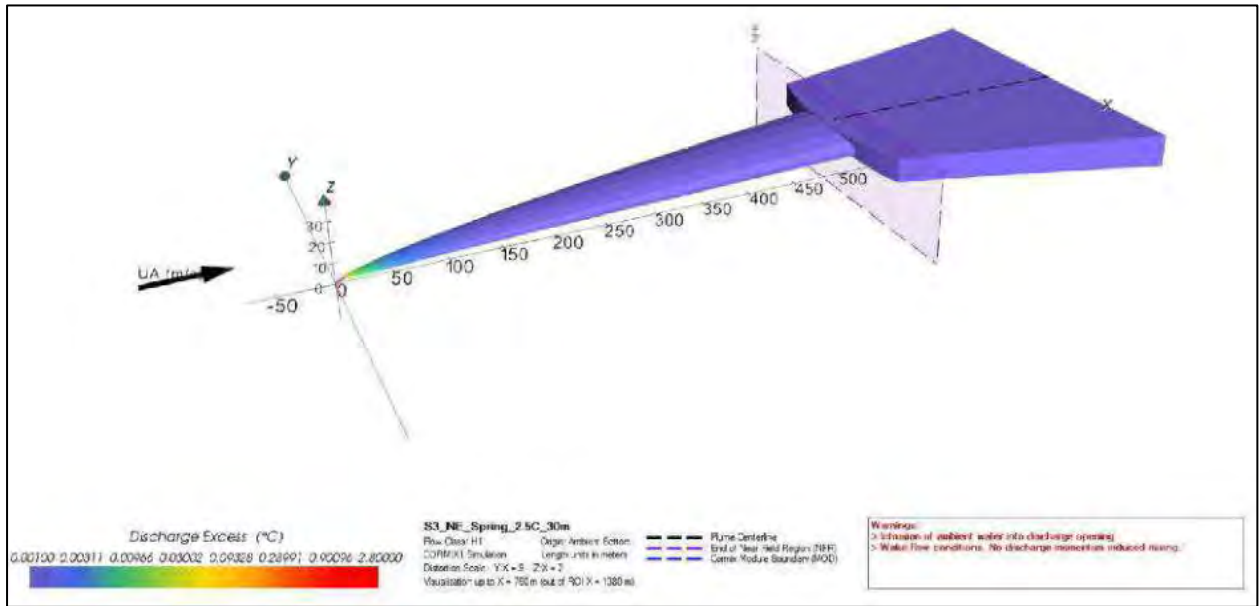


Figure B3: NE_S_03_ (Ex. Temp.=2.5°C, Flow Rate=16.56 m³/h, Depth=30m)

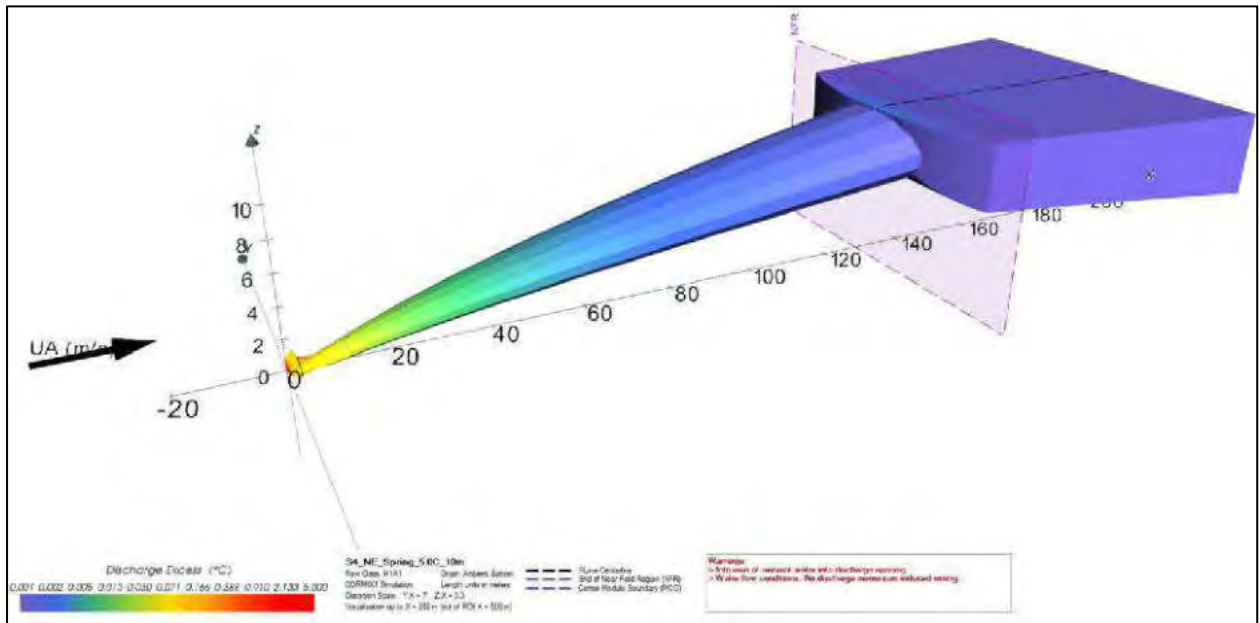


Figure B4: NE_S_04_ (Ex. Temp.= 5°C, Flow Rate=8.28 m³/h, Depth=10m)

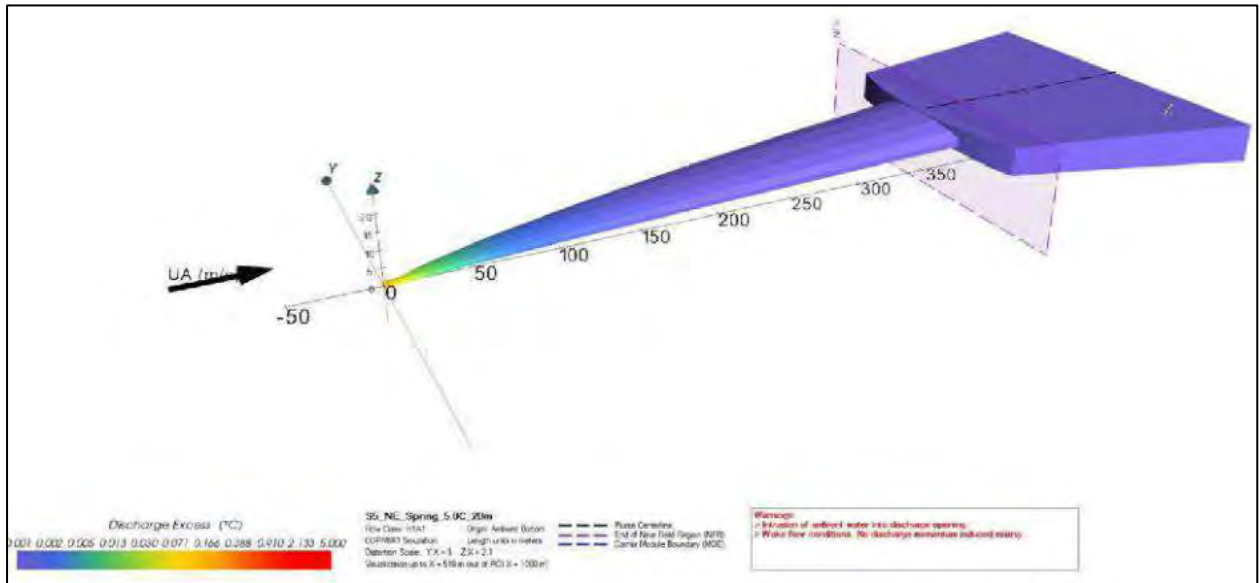


Figure B5: NE_S_05_ (Ex. Temp.= 5°C, Flow Rate=8.28 m³/h, Depth=20m)

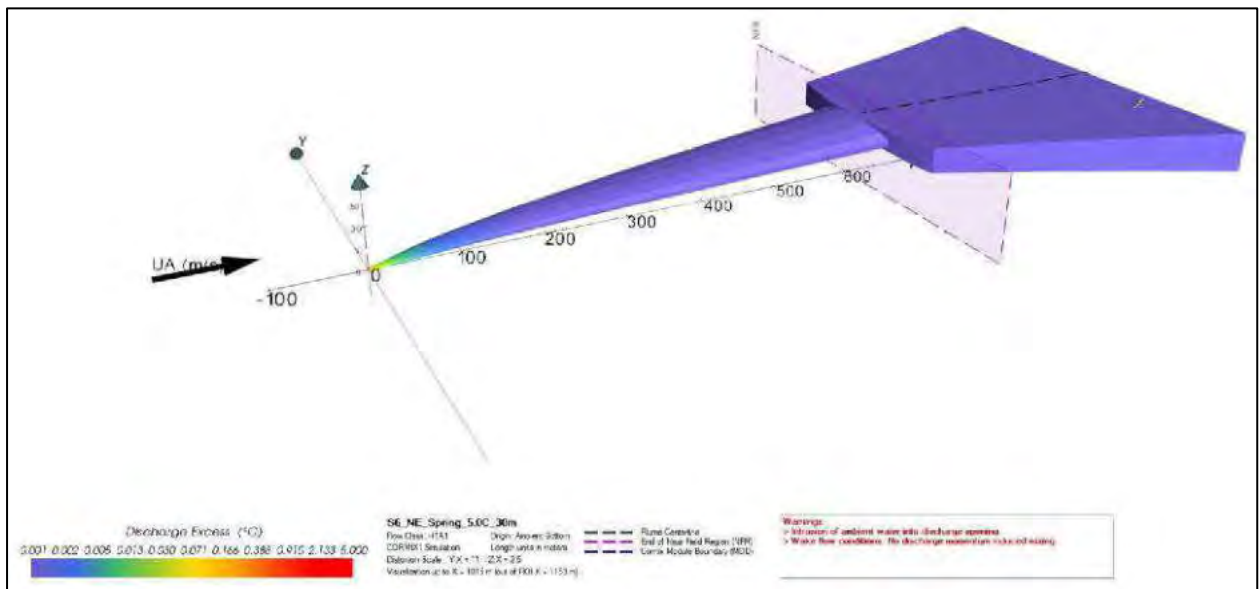


Figure B6: NE_S_06_ (Ex. Temp.= 5°C, Flow Rate=8.28 m³/h, Depth=30m)

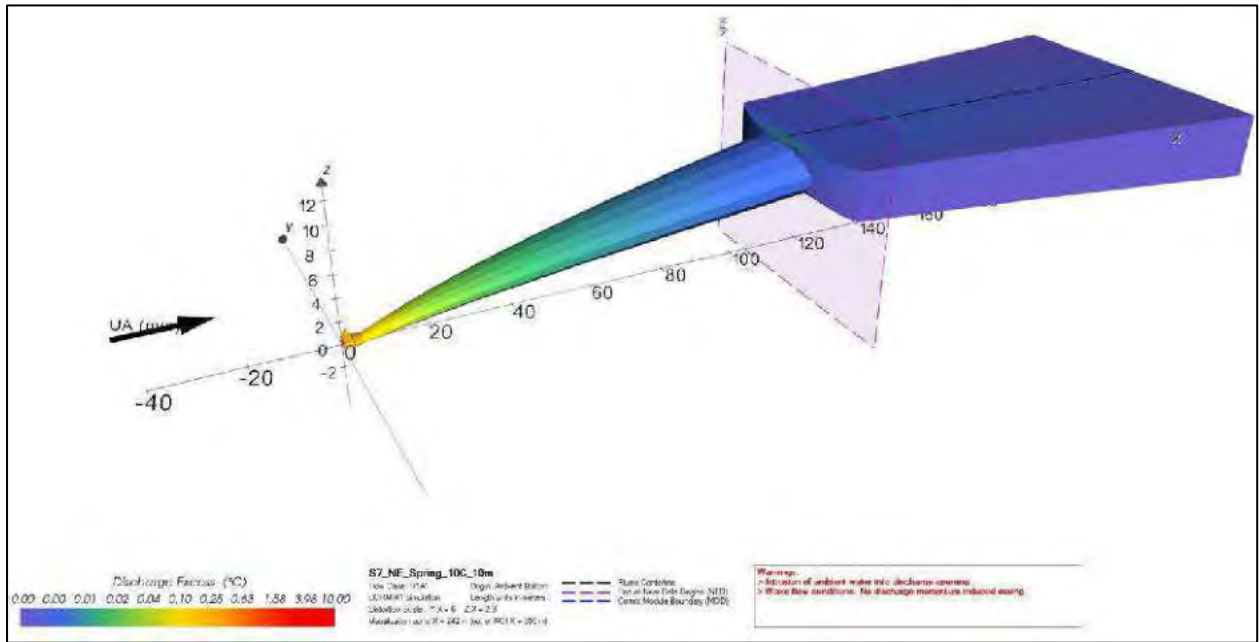


Figure B7: NE_S_07_ (Ex. Temp.= 10°C, Flow Rate=6.21 m³/h, Depth=10m)

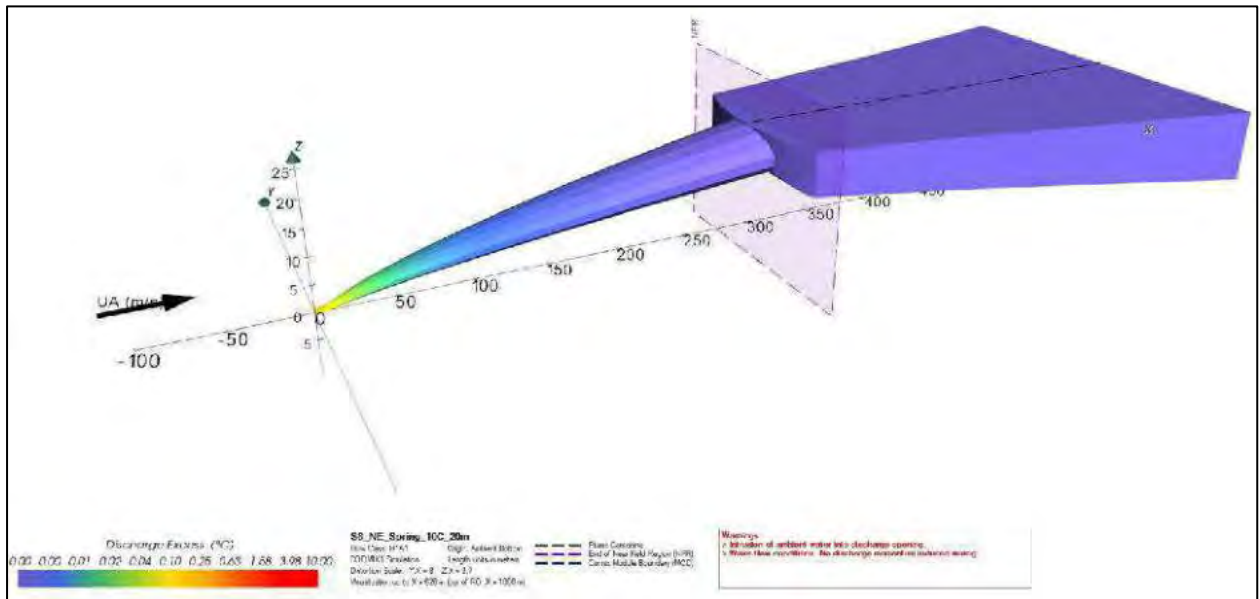


Figure B8: NE_S_08_ (Ex. Temp.= 10°C, Flow Rate=6.21 m³/h, Depth=20m)

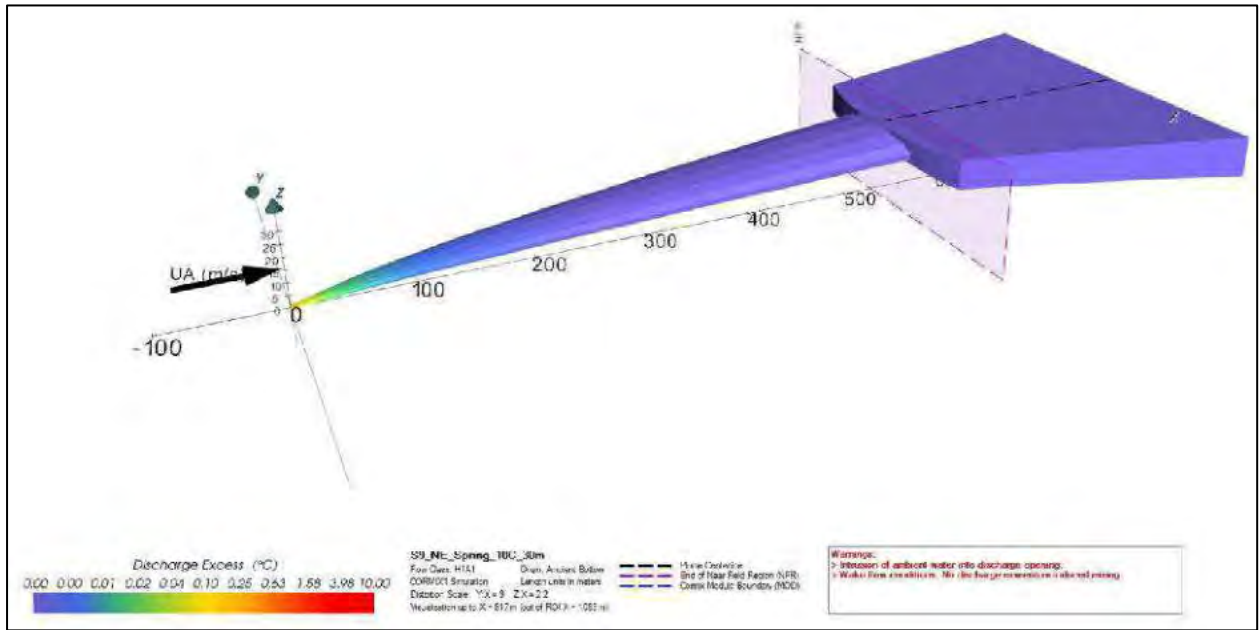


Figure B9: NE_S_09_ (Ex. Temp.= 10°C, Flow Rate=6.21 m³/h, Depth=30m)

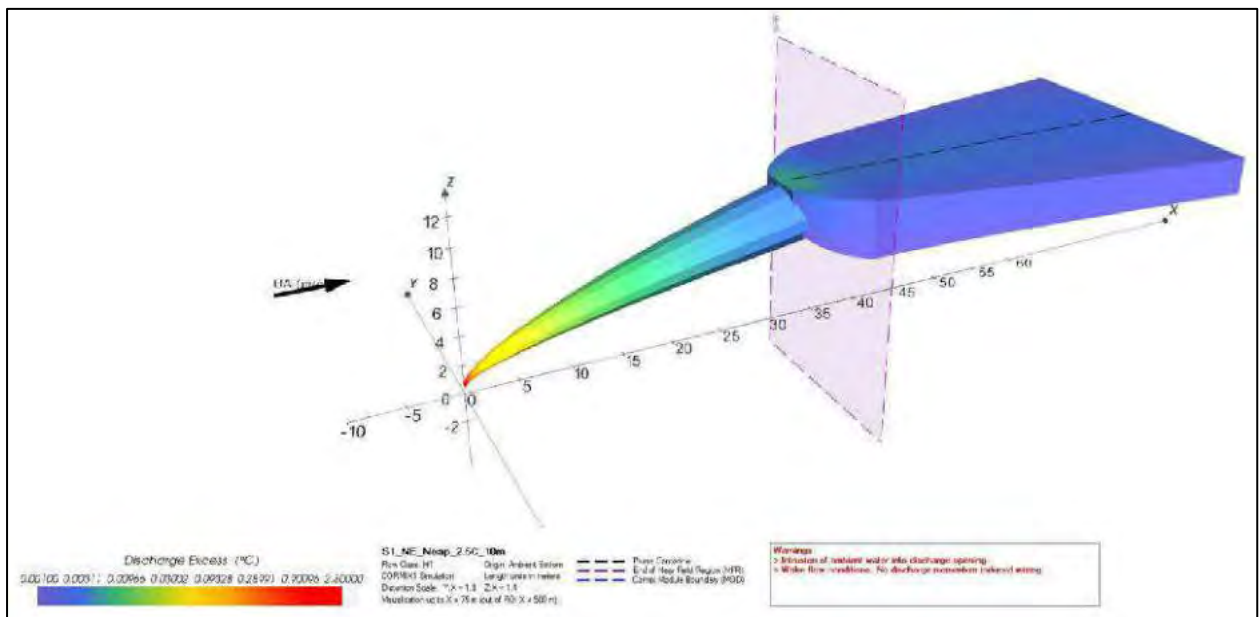


Figure B10: NE_N_01_ (Ex. Temp.= 2.5°C, Flow Rate=16.56 m³/h, Depth=10m)

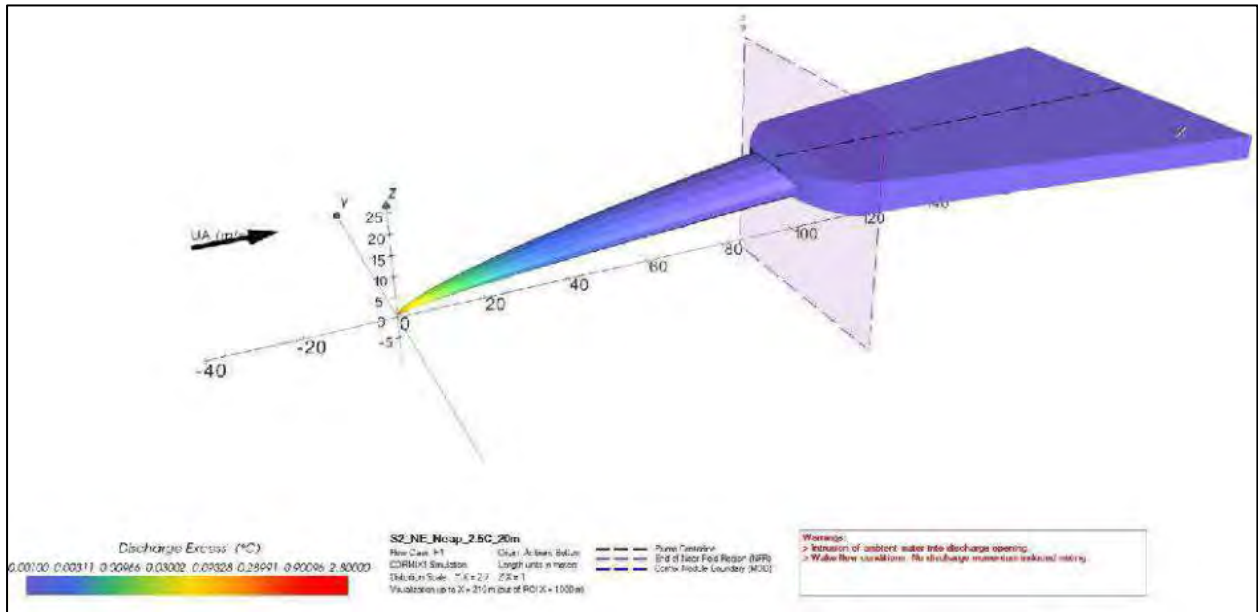


Figure B11: NE_N_02_ (Ex. Temp.= 2.5°C, Flow Rate=16.56 m³/h, Depth=20m)

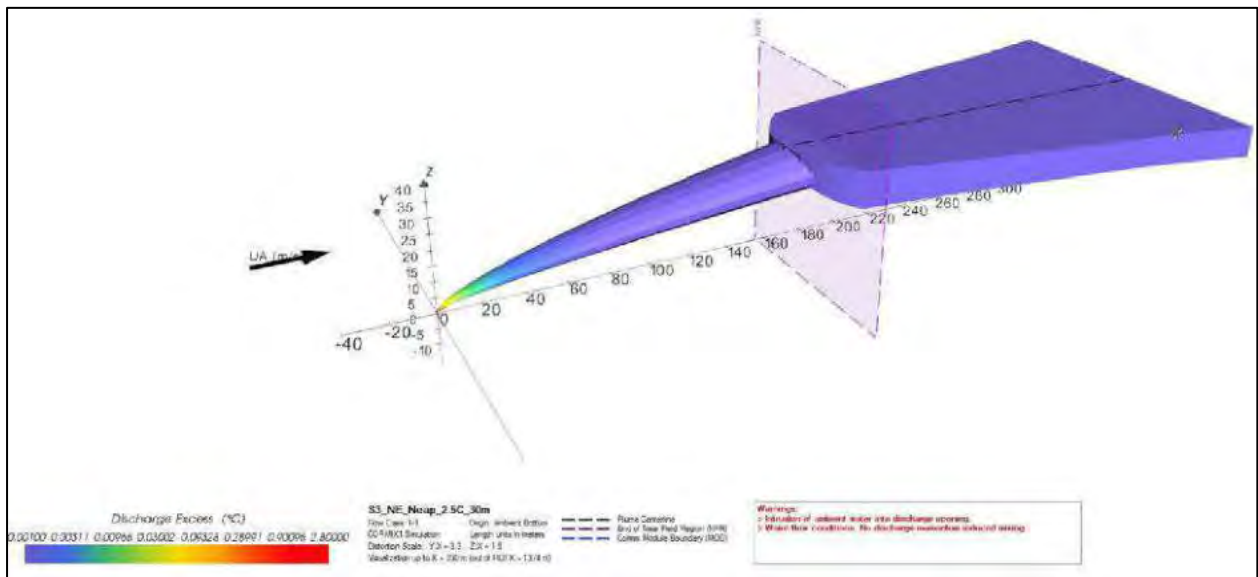


Figure B12: NE_N_03_ (Ex. Temp.= 2.5°C, Flow Rate=16.56 m³/h, Depth=30m)

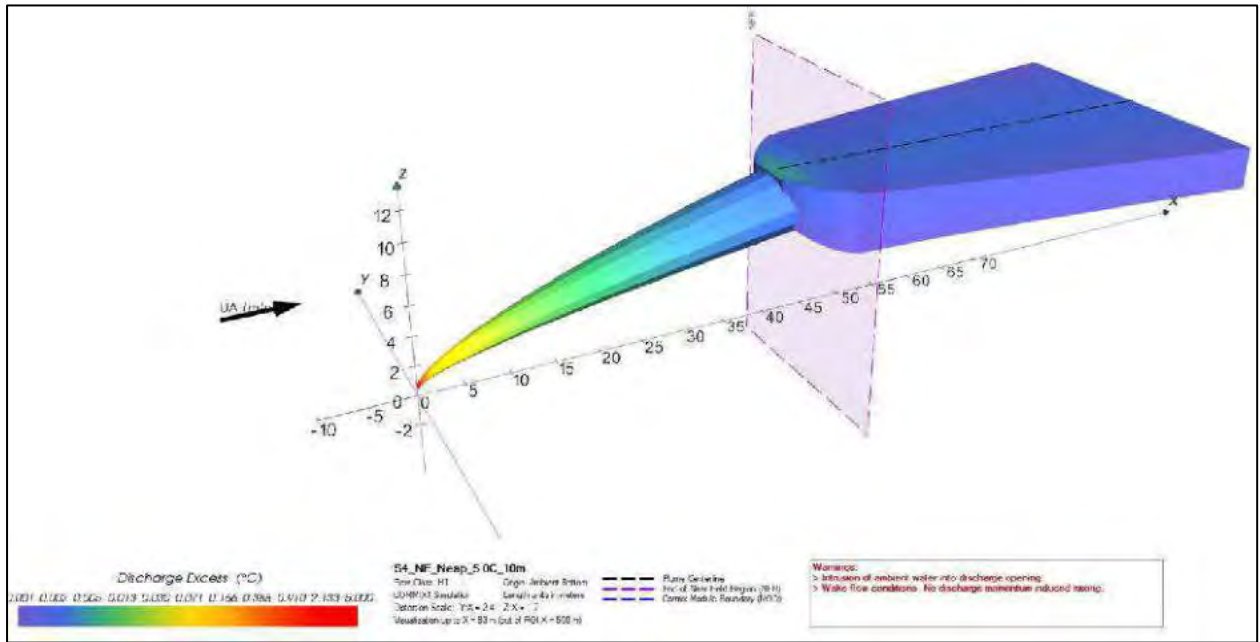


Figure B13: NE_N_04_ (Ex. Temp.= 5°C, Flow Rate=8.28 m³/h, Depth=10m)

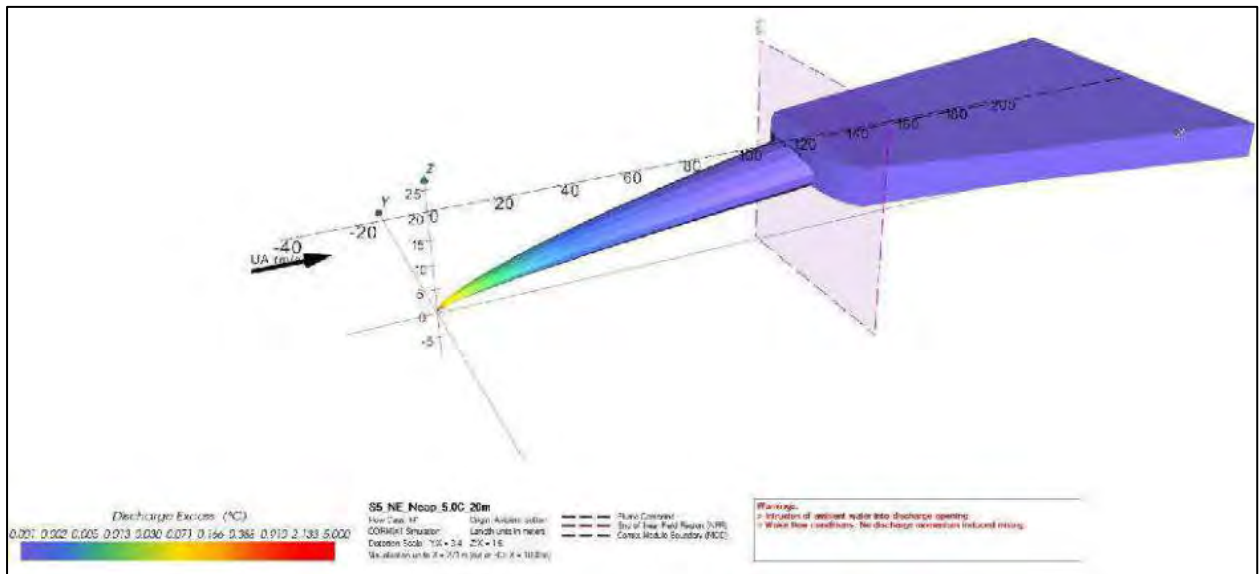


Figure B14: NE_N_05_ (Ex. Temp.= 5°C, Flow Rate=8.28 m³/h, Depth=20m)

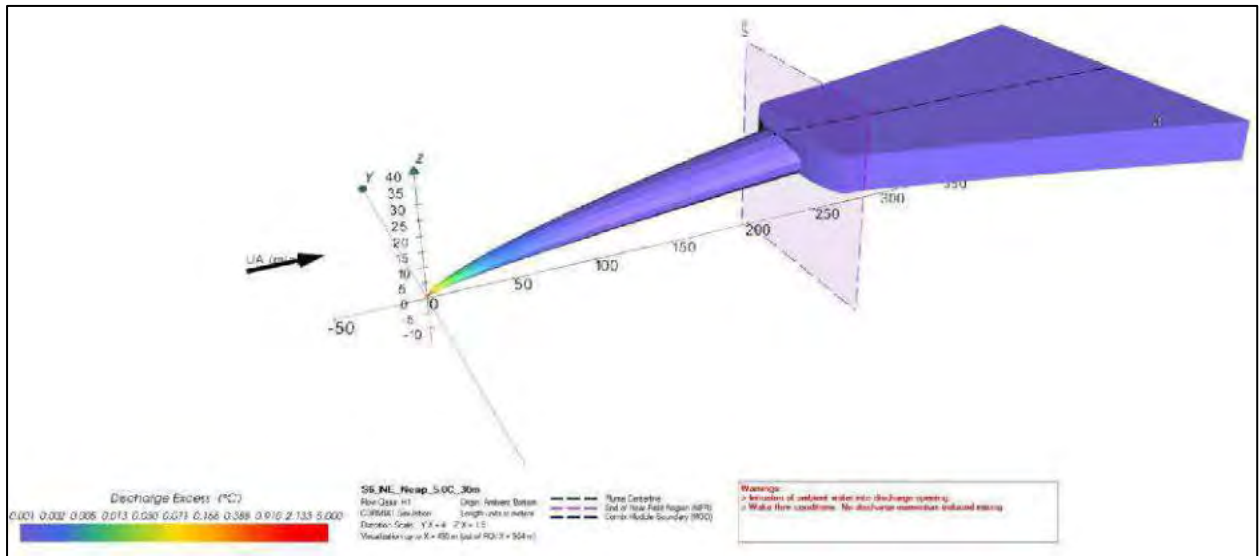


Figure B15: NE_N_06_ (Ex. Temp. = 5°C, Flow Rate=8.28 m³/h, Depth=30m)

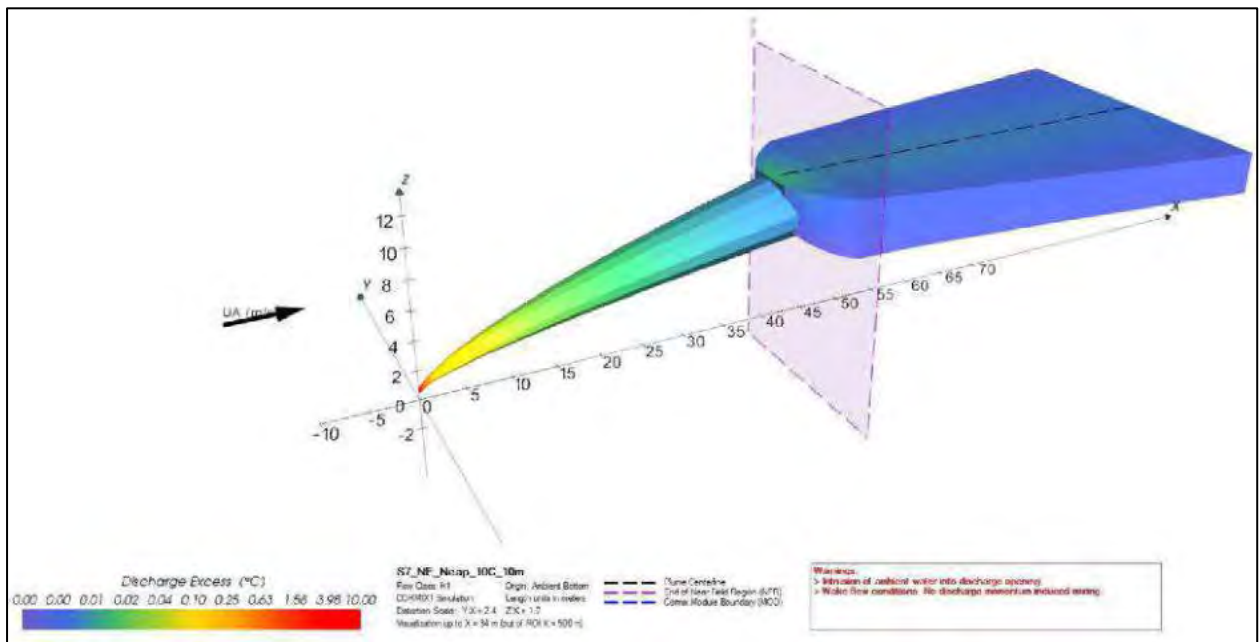


Figure B16: NE_N_07_ (Ex. Temp. = 10°C, Flow Rate=6.21 m³/h, Depth=10m)

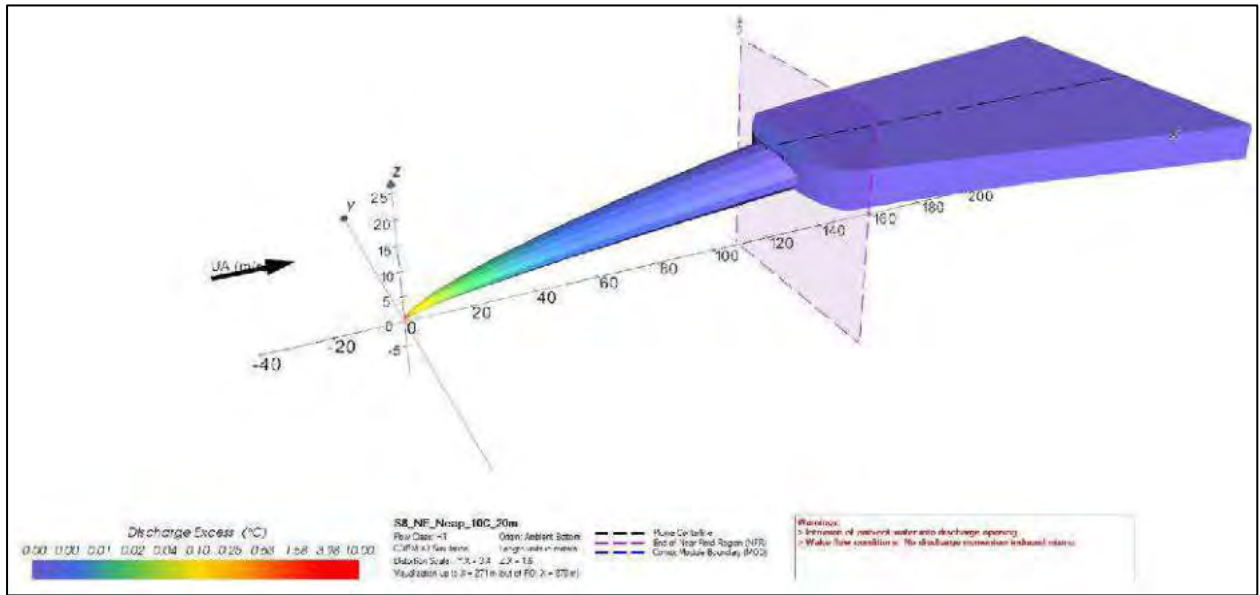


Figure B17: NE_N_08_ (Ex. Temp. = 10°C, Flow Rate=6.21 m³/h, Depth=20m)

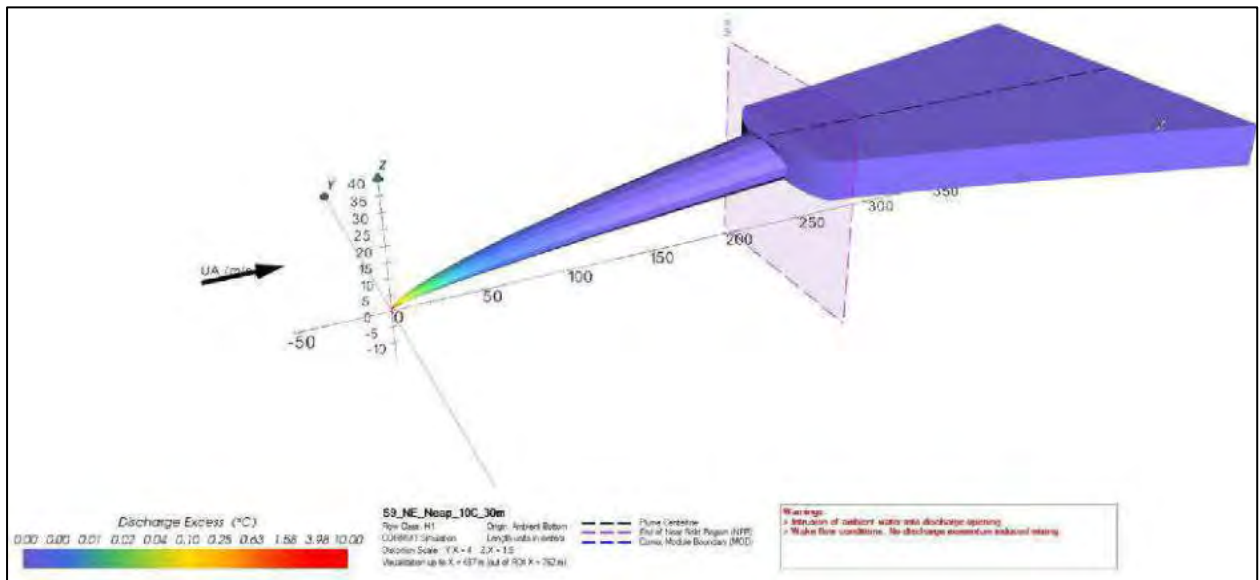


Figure B18: NE_N_09_ (Ex. Temp. = 10°C, Flow Rate=6.21 m³/h, Depth=30m)

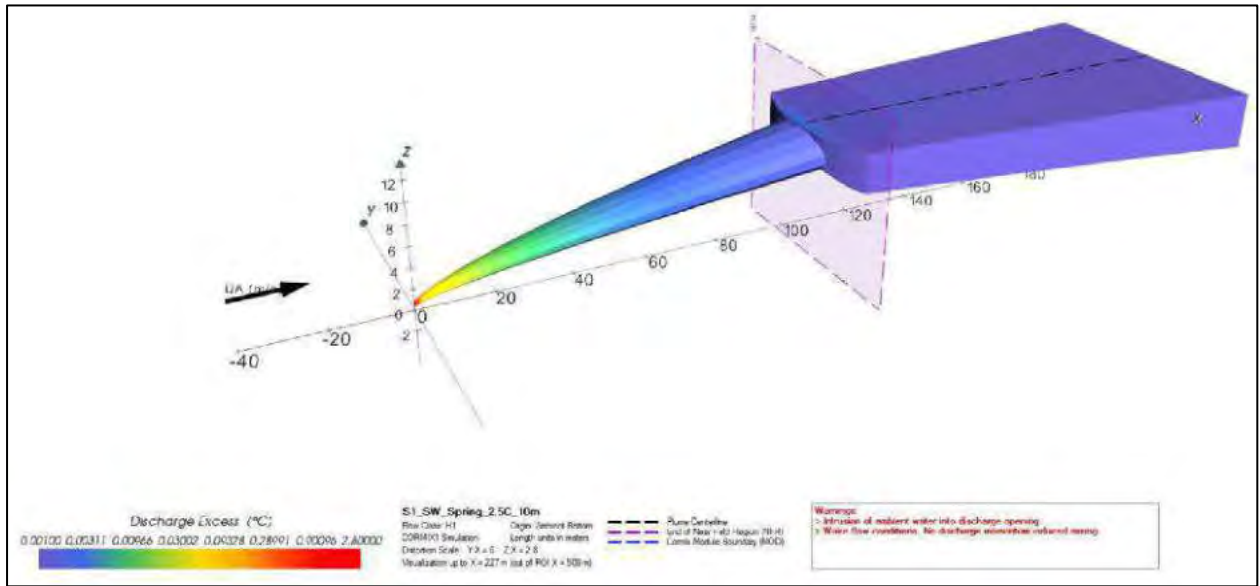


Figure B19: SW_S_01_ (Ex. Temp. = 2.5°C, Flow Rate=16.56 m³/h, Depth=10m)

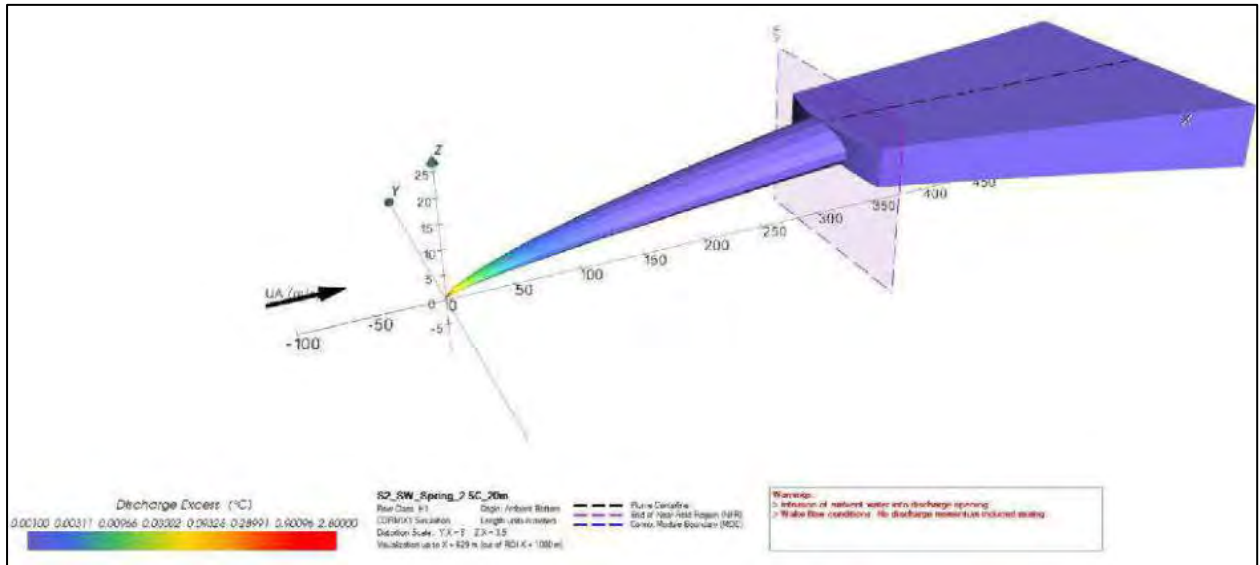


Figure B20: SW_S_02_ (Ex. Temp. = 2.5°C, Flow Rate=16.56 m³/h, Depth=20m)

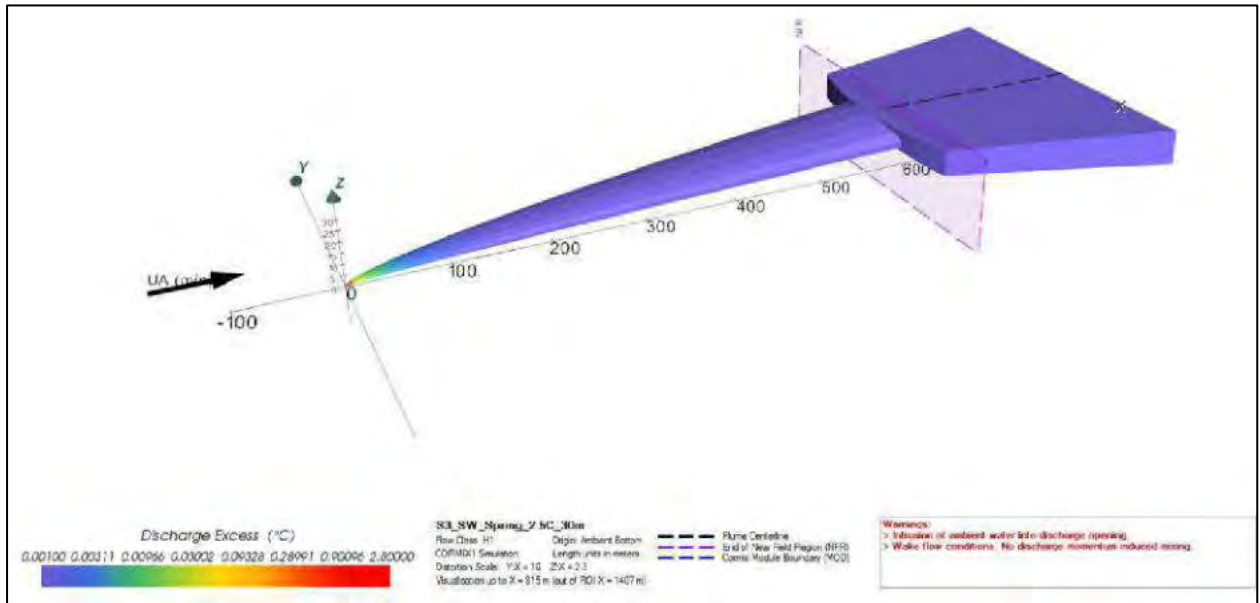


Figure B21: SW_S_03_ (Ex. Temp. = 2.5°C, Flow Rate=16.56 m³/h, Depth=30m)

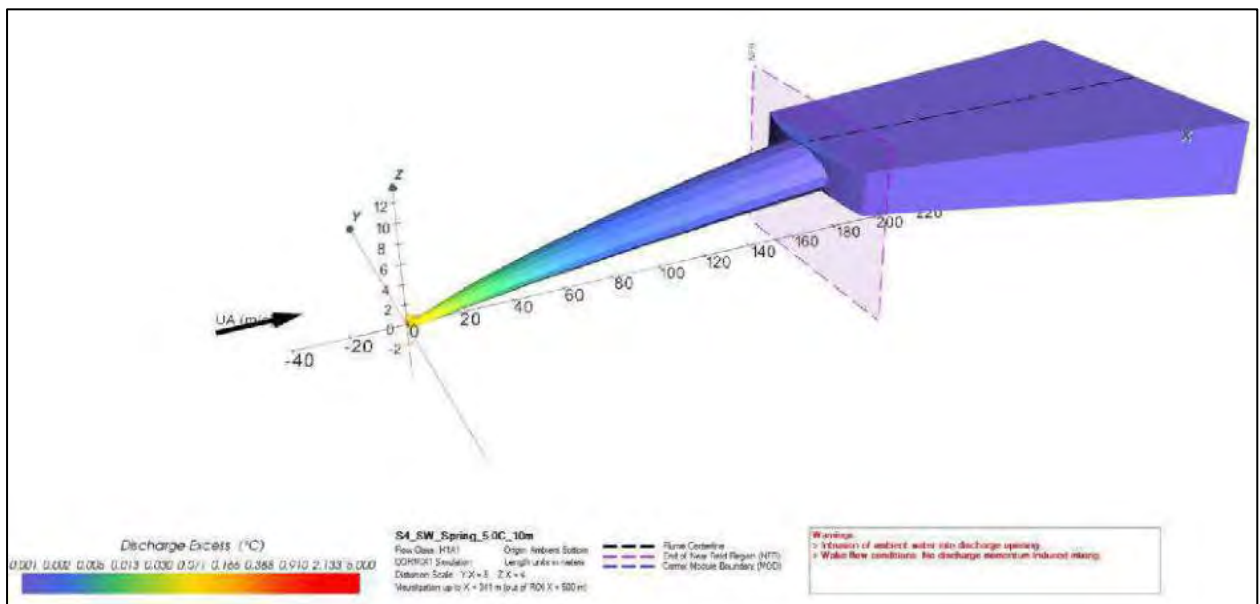


Figure B22: SW_S_04_ (Ex. Temp. = 5°C, Flow Rate=8.28 m³/h, Depth=10m)

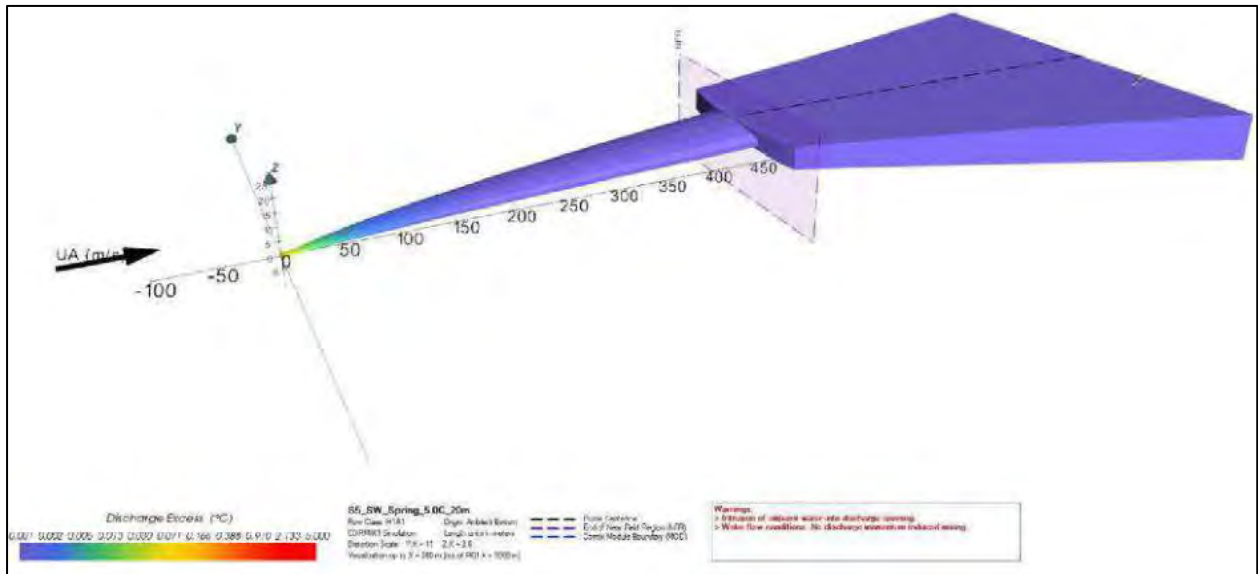


Figure B23: SW_S_05_ (Ex. Temp. = 5°C, Flow Rate=8.28 m³/h, Depth=20m)

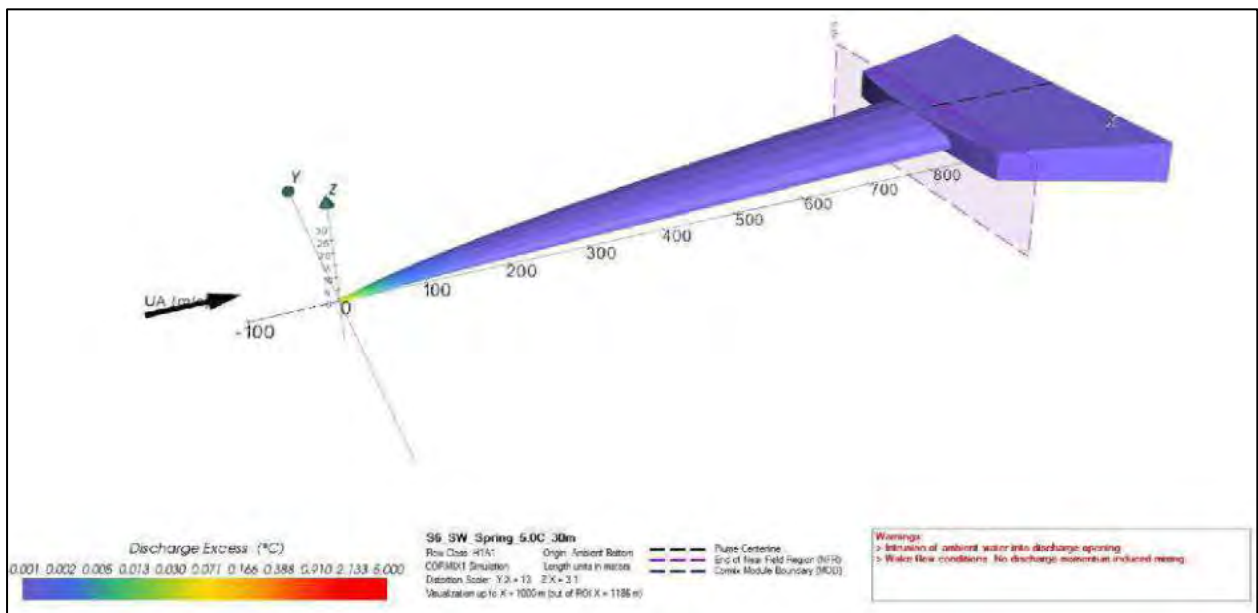


Figure B24: SW_S_06_ (Ex. Temp. = 5°C, Flow Rate=8.28 m³/h, Depth=30m)

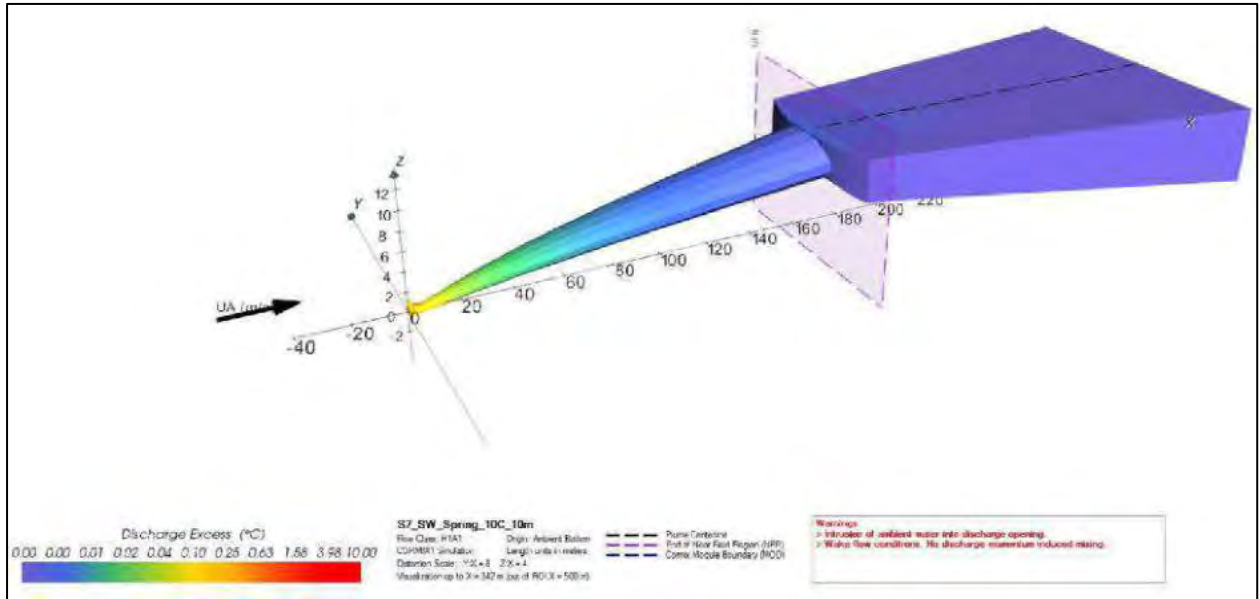


Figure B25: SW_S_07_ (Ex. Temp. = 10°C, Flow Rate=6.21 m³/h, Depth=10m)

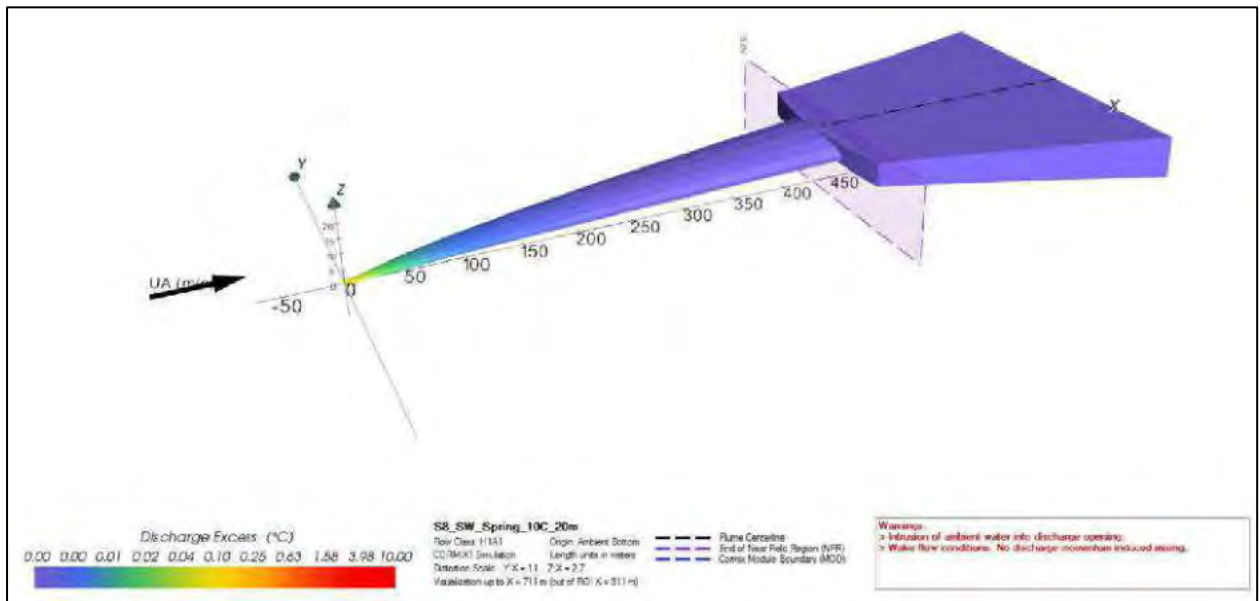


Figure B26: SW_S_08_ (Ex. Temp. = 10°C, Flow Rate=6.21 m³/h, Depth=20m)

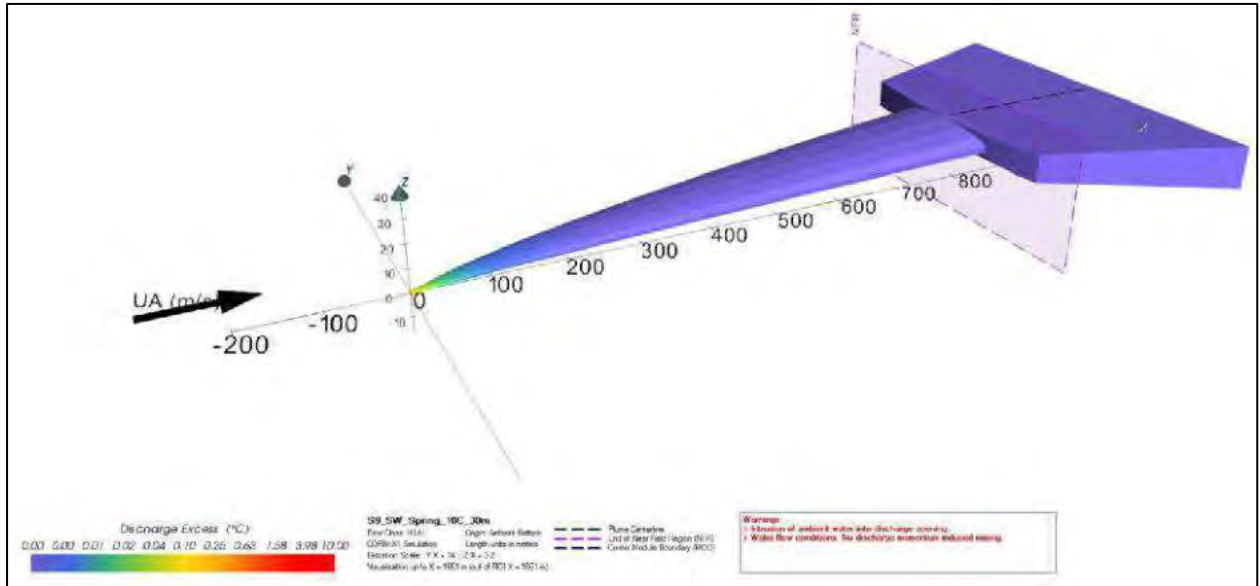


Figure B27: SW_S_09_ (Ex. Temp. = 10°C, Flow Rate=6.21 m³/h, Depth=30m)

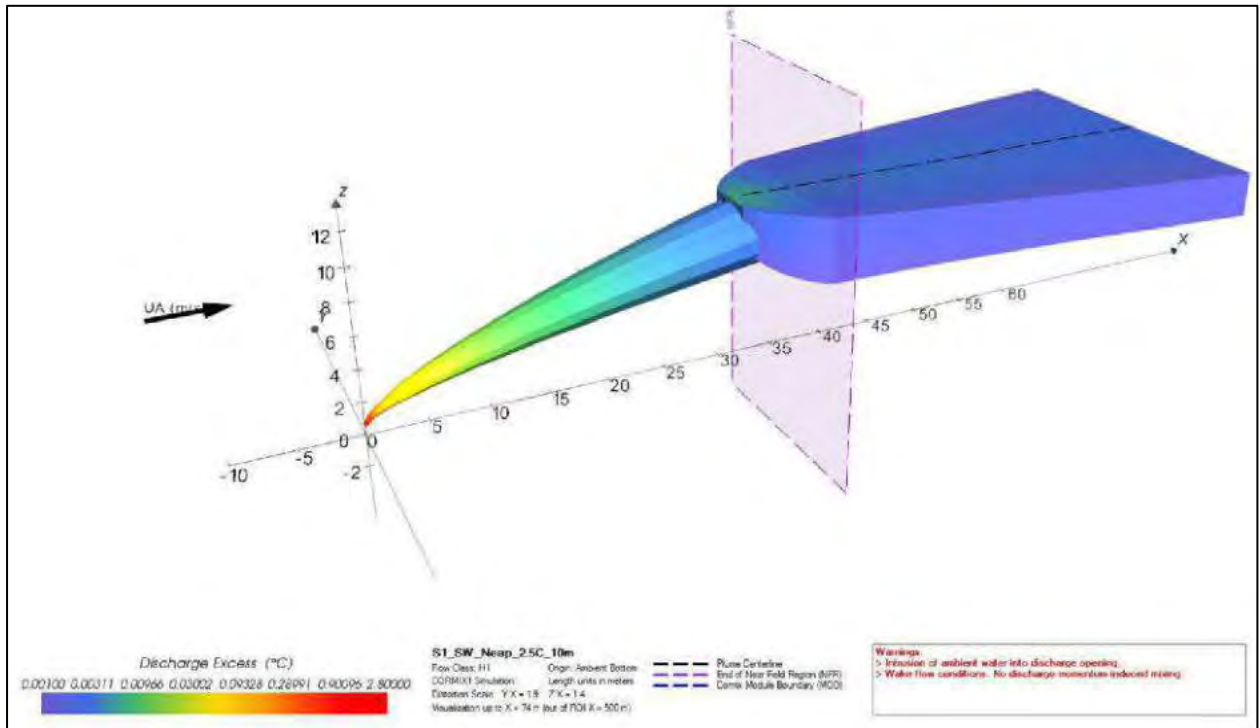


Figure B28: SW_N_01_ (Ex. Temp. = 2.5°C, Flow Rate=16.56 m³/h, Depth=10m)

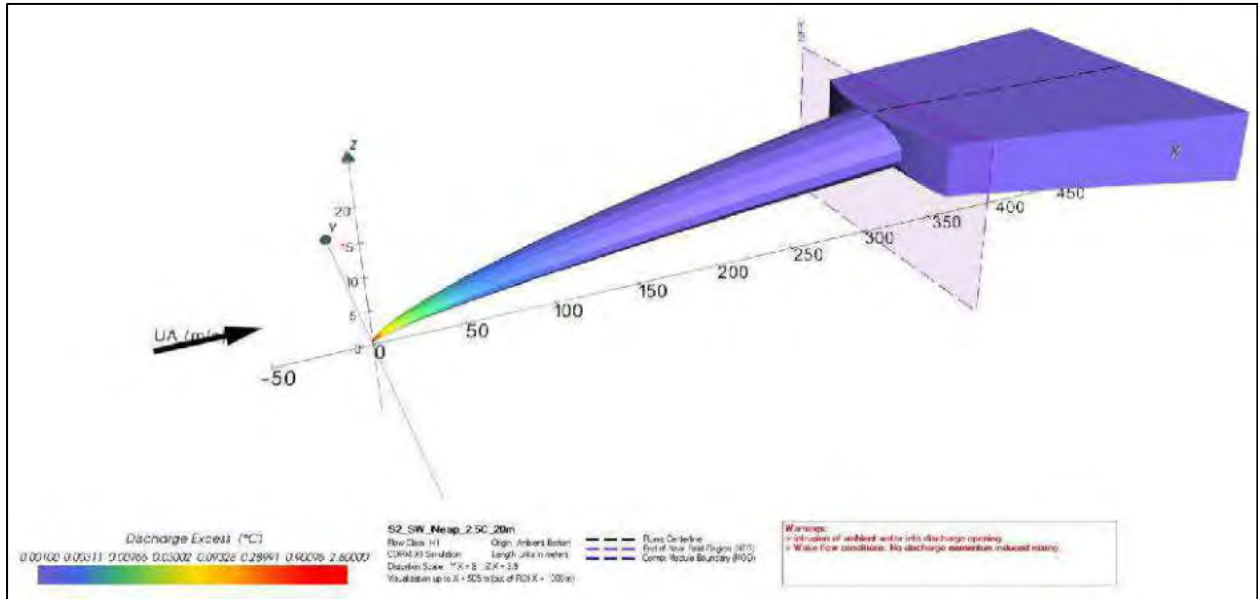


Figure B29: SW_N_02_ (Ex. Temp. = 2.5°C, Flow Rate=16.56 m³/h, Depth=20m)

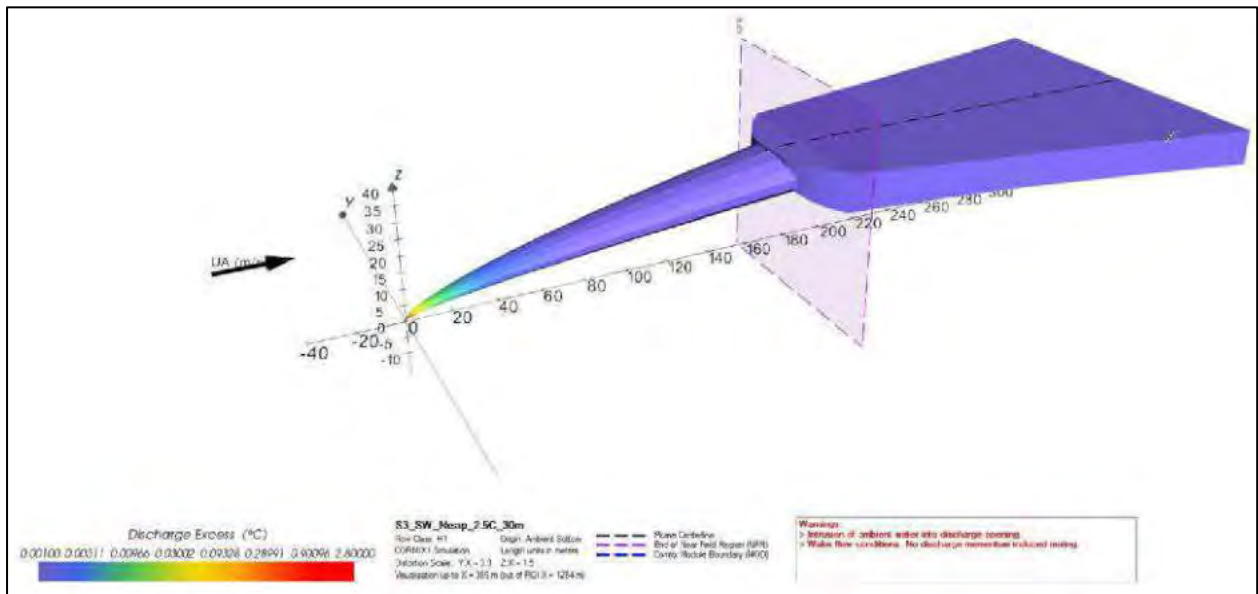


Figure B30: SW_N_03_ (Ex. Temp. = 2.5°C, Flow Rate=16.56 m³/h, Depth=30m)

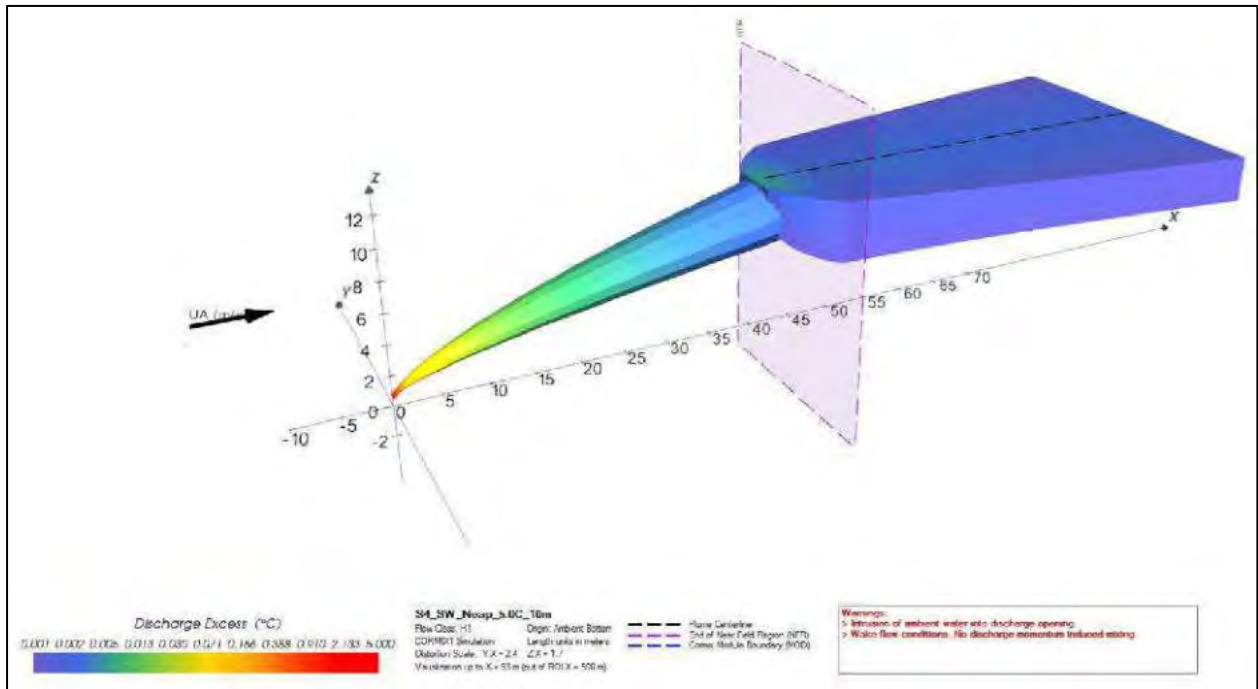


Figure B31: SW_N_04_ (Ex. Temp. = 5°C, Flow Rate=8.28 m³/h, Depth=10m)

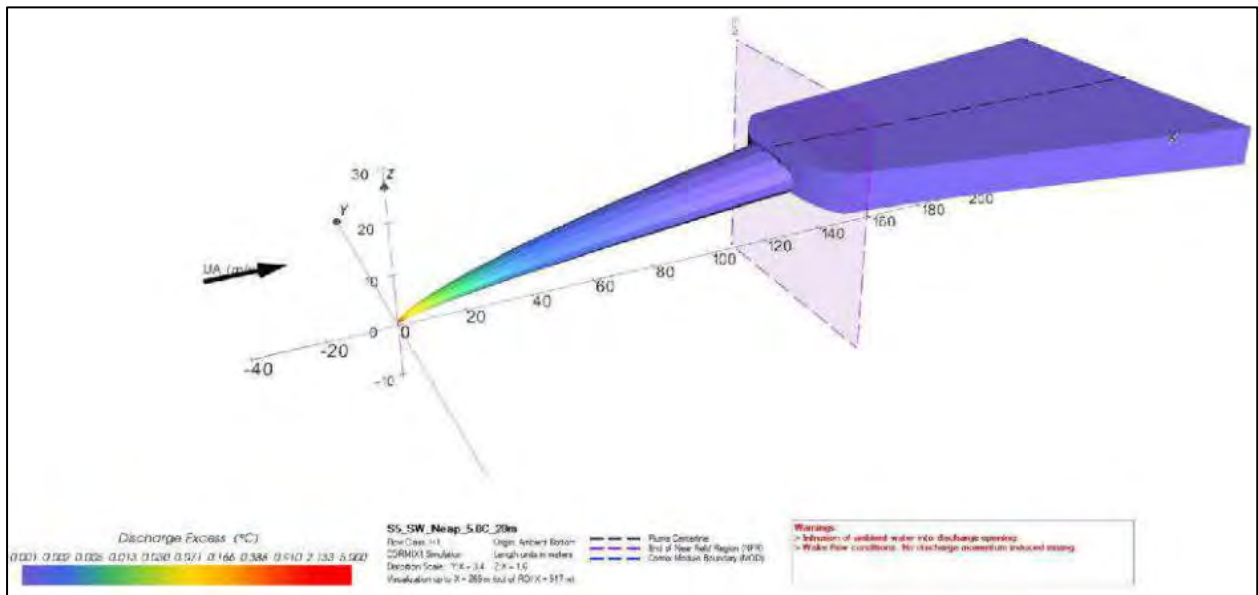


Figure B32: SW_N_05_ (Ex. Temp. = 5°C, Flow Rate=8.28 m³/h, Depth=20m)

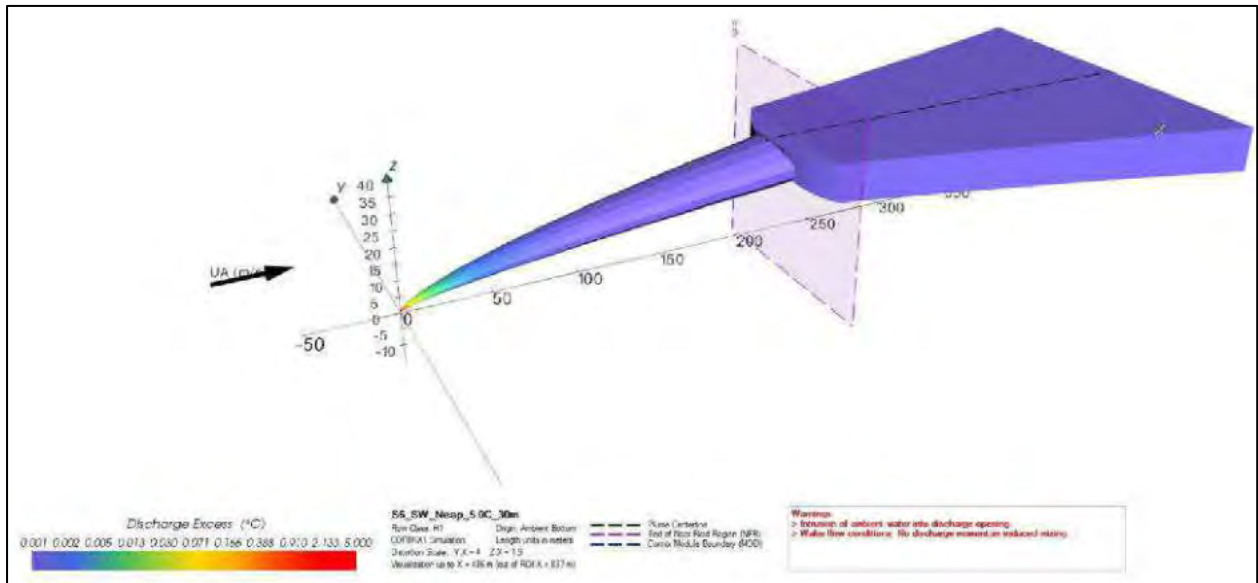


Figure B33: SW_N_06_ (Ex. Temp. = 5°C, Flow Rate=8.28 m³/h, Depth=30m)

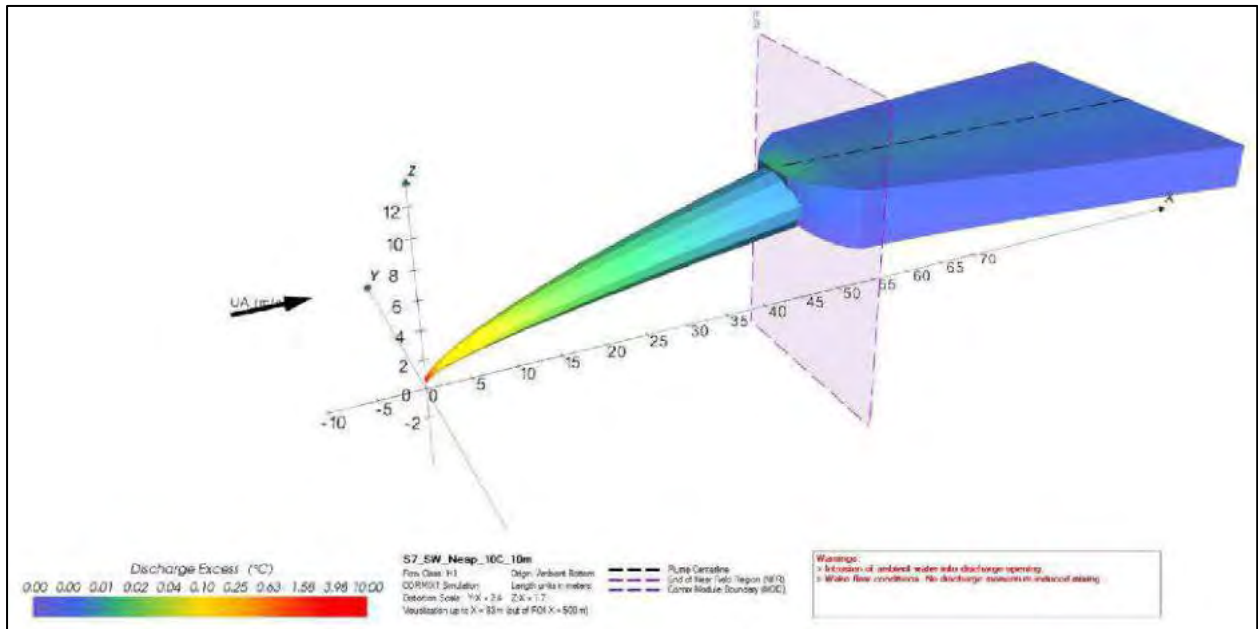


Figure B34: SW_N_07_ (Ex. Temp. = 10°C, Flow Rate=6.21 m³/h, Depth=10m)

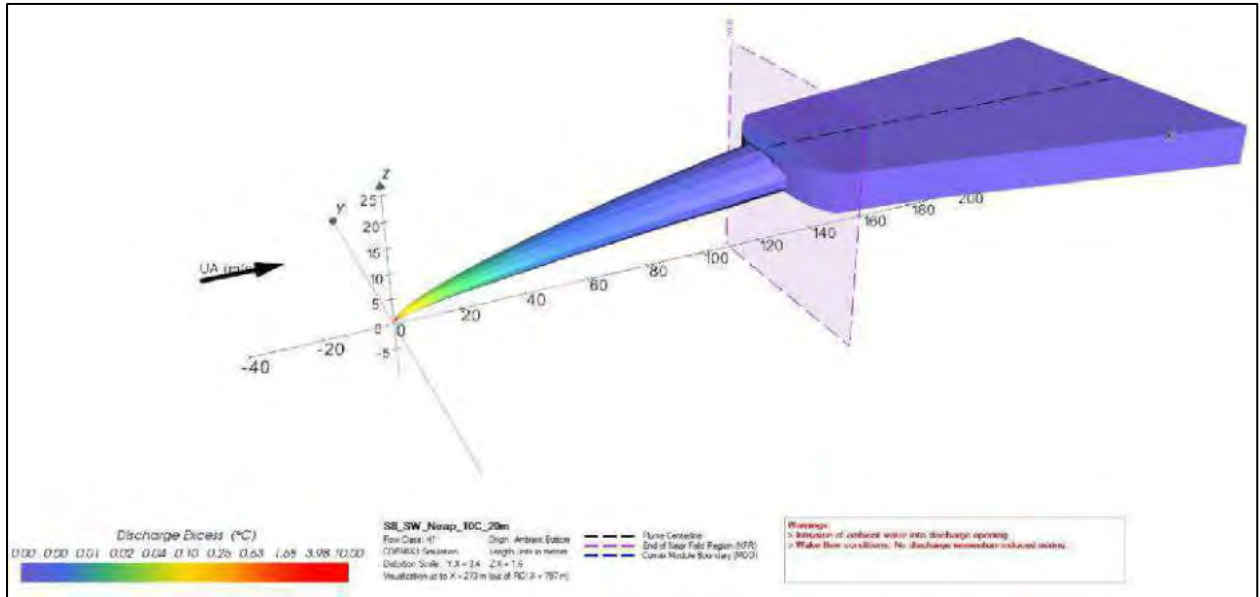


Figure B35: SW_N_08_ (Ex. Temp. = 10°C, Flow Rate=6.21 m³/h, Depth=20m)

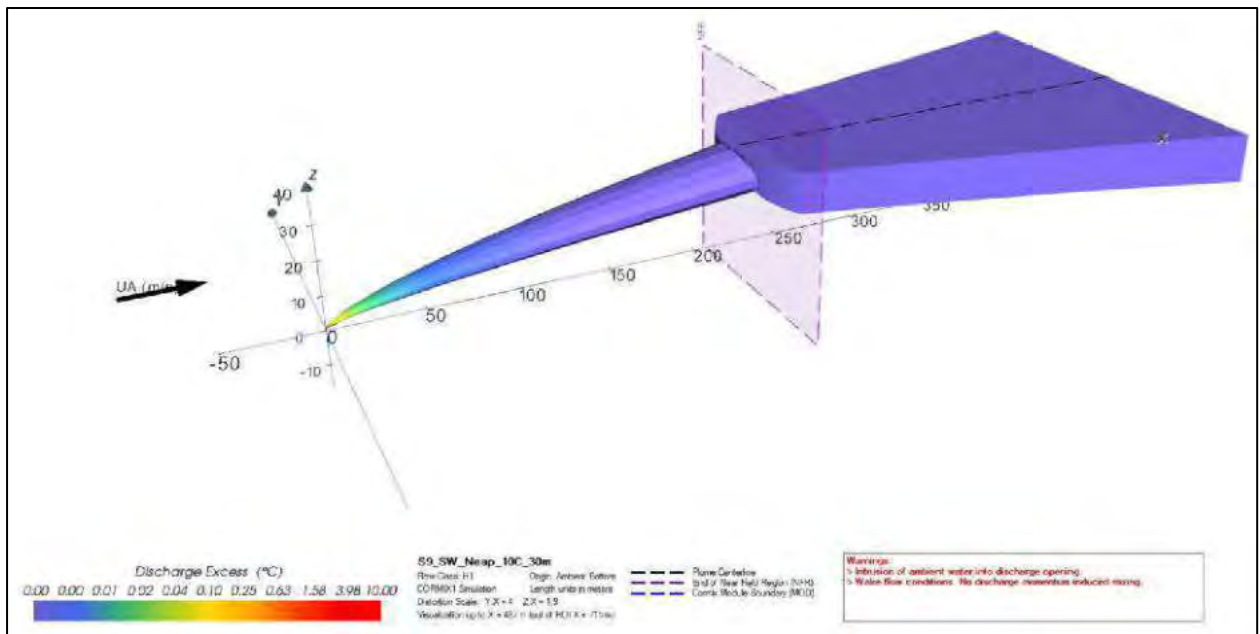


Figure B36: SW_N_09_ (Ex. Temp. = 10°C, Flow Rate=6.21 m³/h, Depth=30m)

ANNEX C

Heat Dissipation in Far Field (MIKE 21 HD)

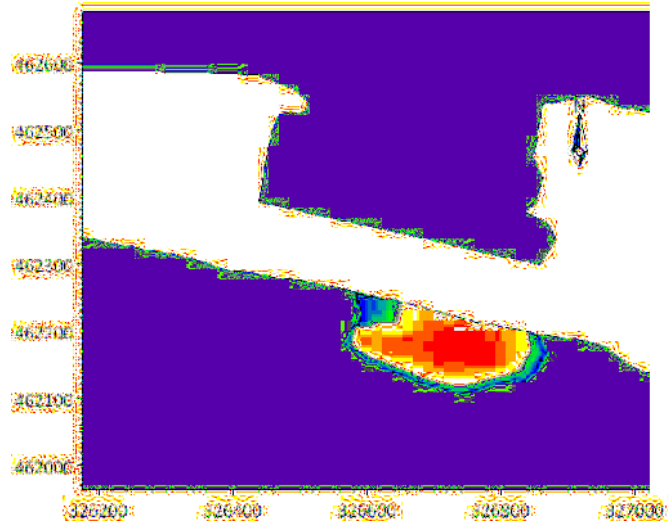


Figure C.01: NE_S_01_Eastward Flow

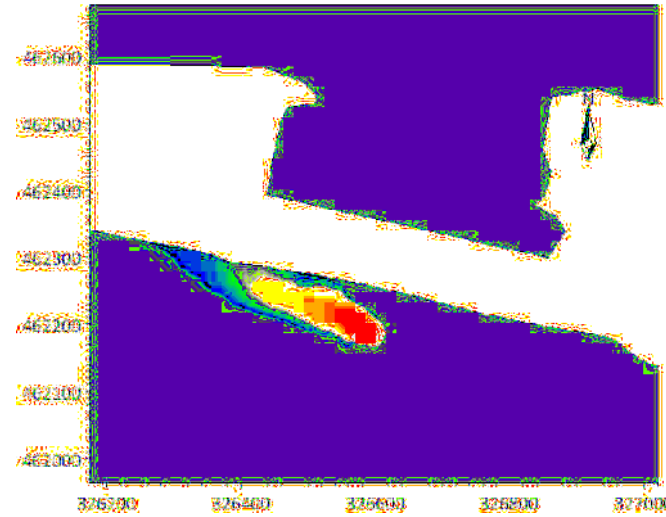


Figure C.02: NE_S_01_Westward Flow

Excess Temperature [deg C]

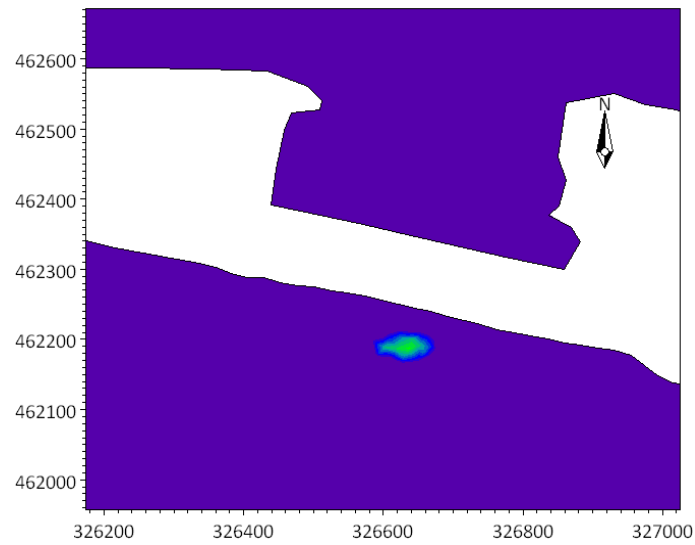
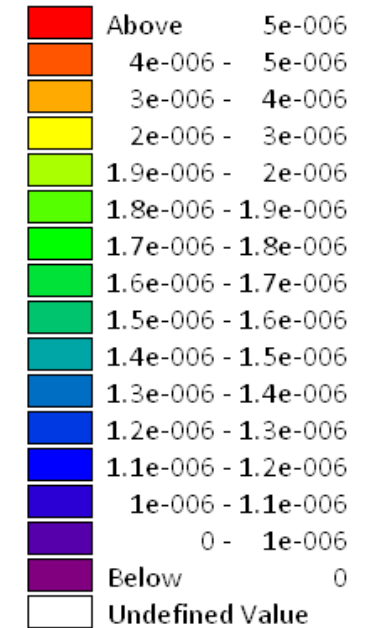


Figure C.03: NE_S_02_Eastward Flow

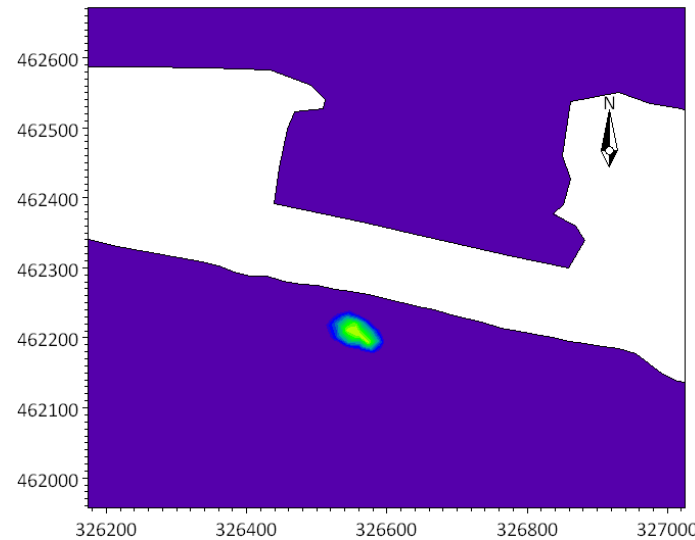


Figure C.04: NE_S_02_Westward Flow

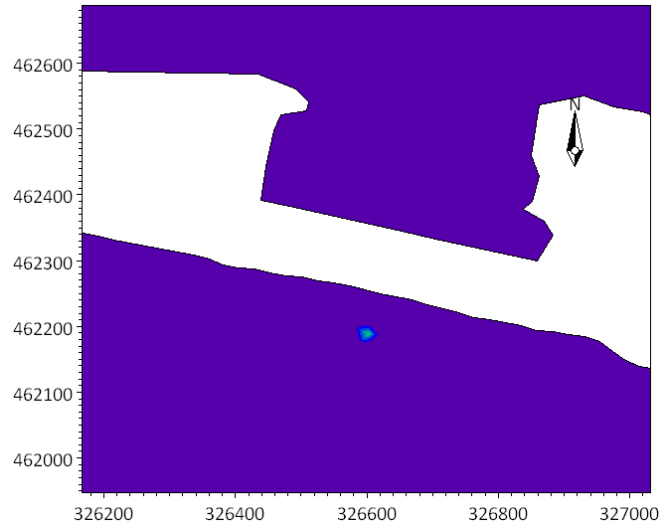


Figure C.05: NE_S_03_Eastward Flow

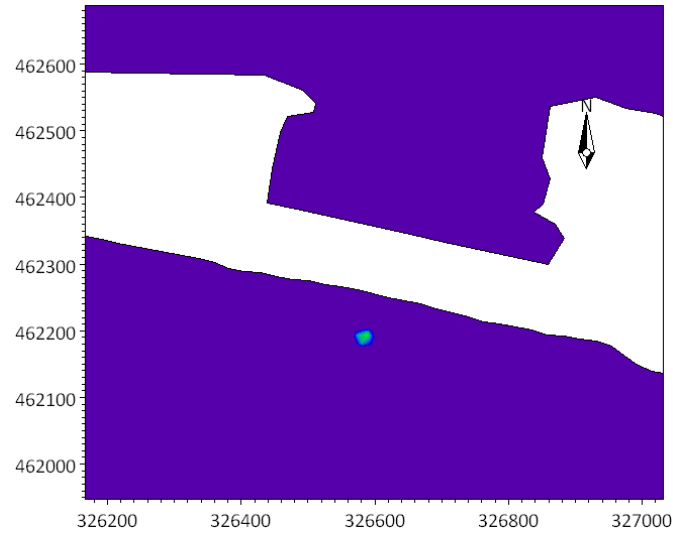


Figure C.06: NE_S_03_Westward Flow

Excess Temperature [deg C]

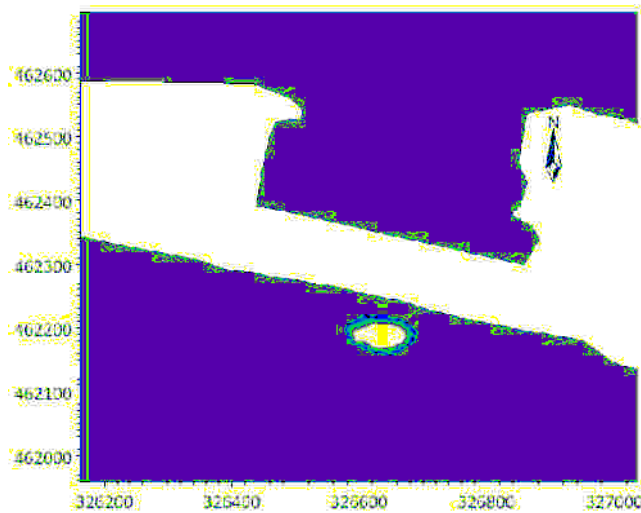
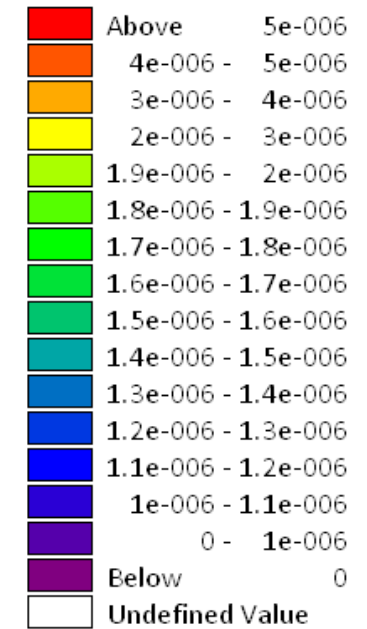


Figure C.07: NE_S_04_Eastward Flow

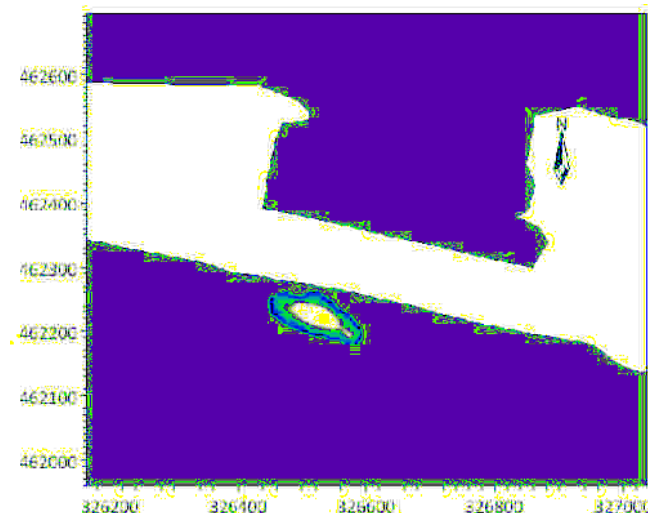


Figure C.08: NE_S_04_Westward Flow

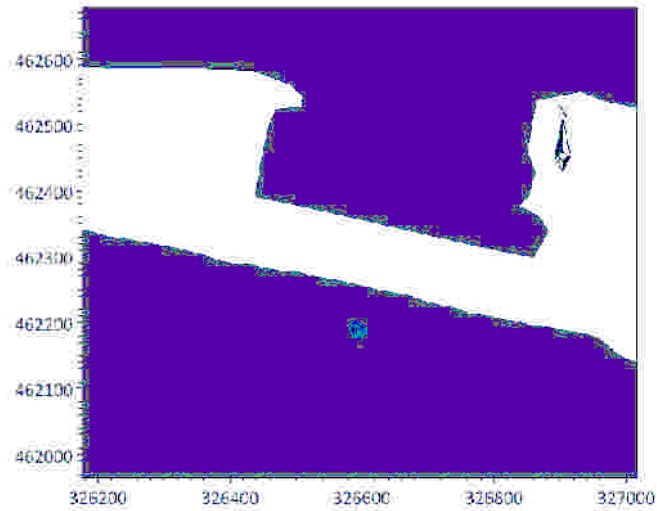


Figure C.09: NE_S_05_Eastward Flow

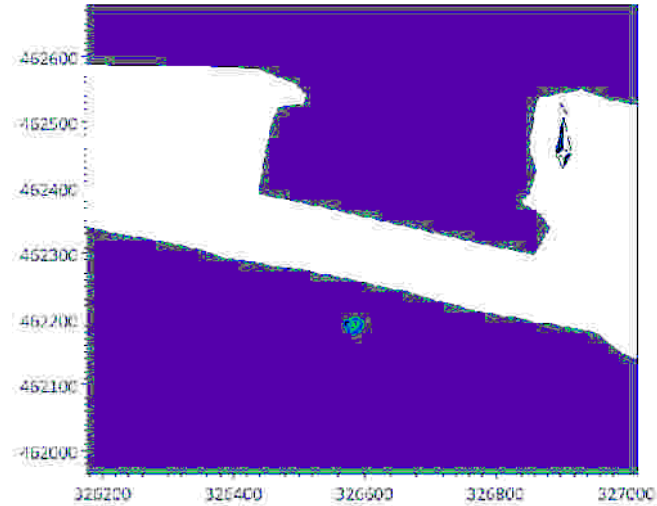


Figure C.10: NE_S_05_Westward Flow

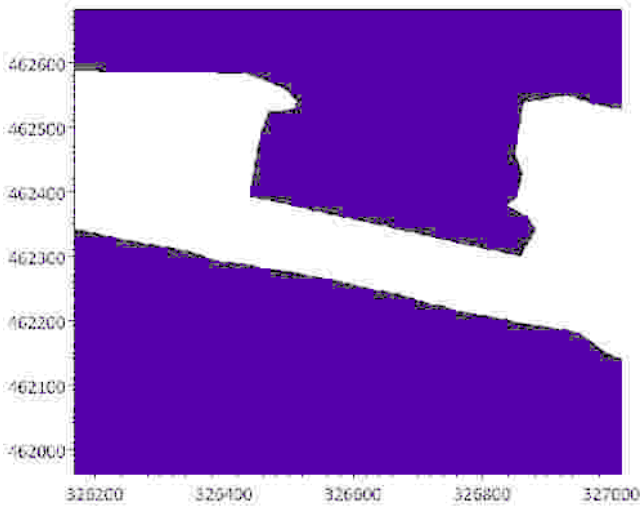


Figure C.11: NE_S_06_Eastward Flow

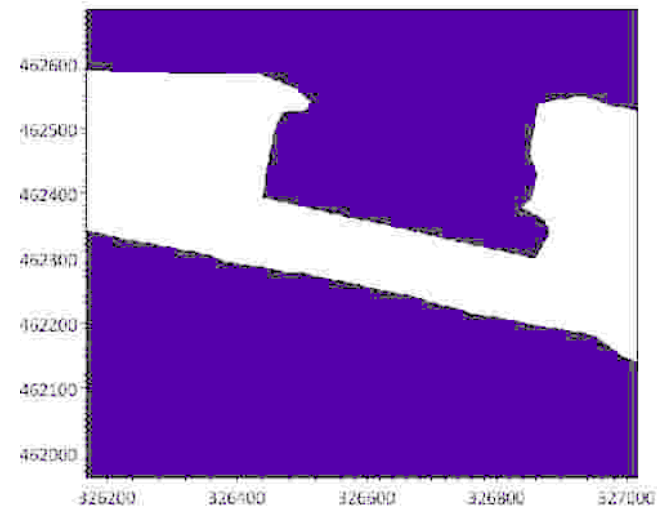
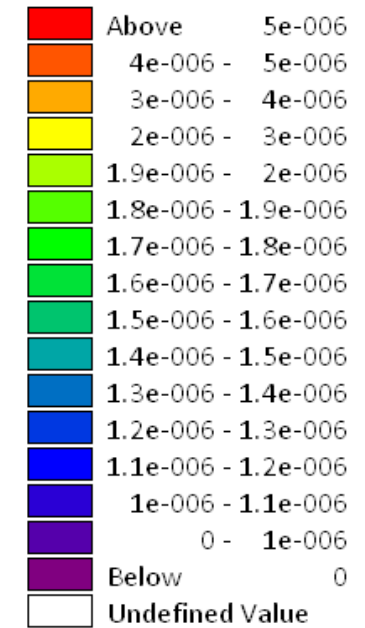


Figure C.12: NE_S_06_Westward Flow

Excess Temperature [deg C]



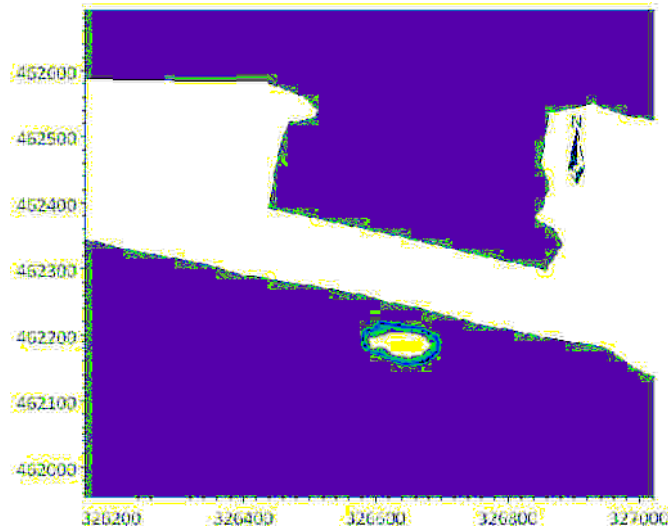


Figure C.13: NE_S_07_Eastward Flow

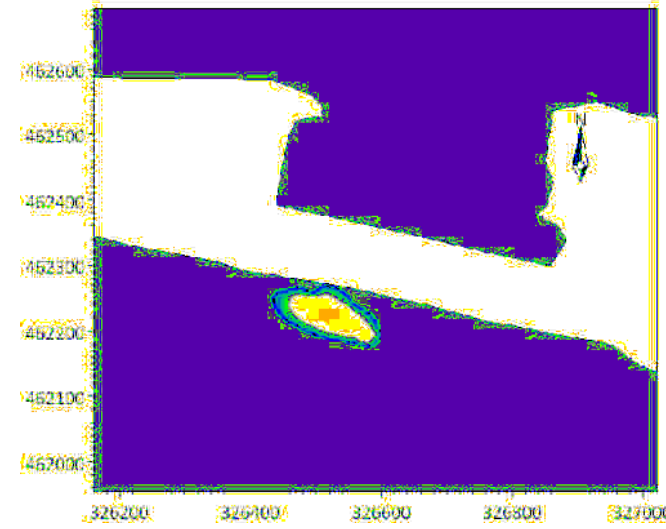


Figure C.14: NE_S_07_Westward Flow

Excess Temperature [deg C]

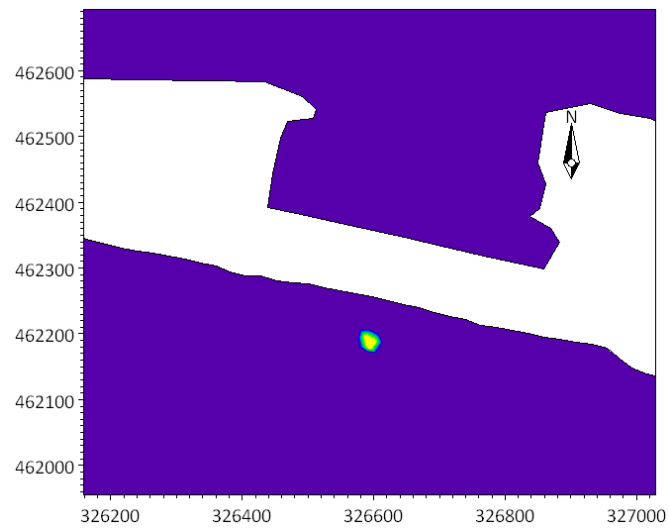
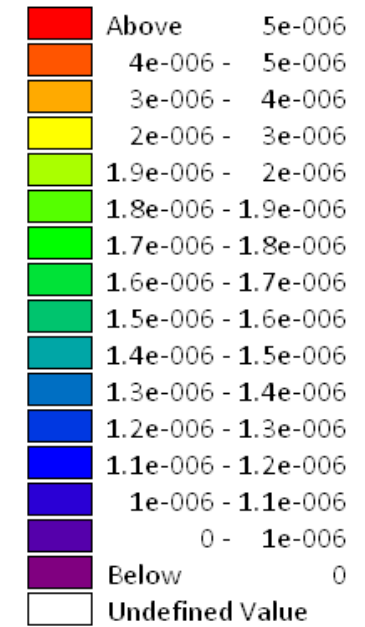


Figure C.15: NE_S_08_Eastward Flow

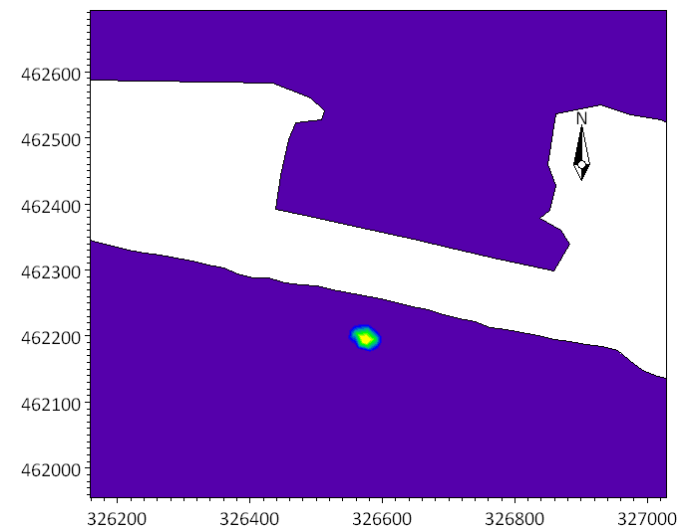


Figure C.16: NE_S_08_Westward Flow

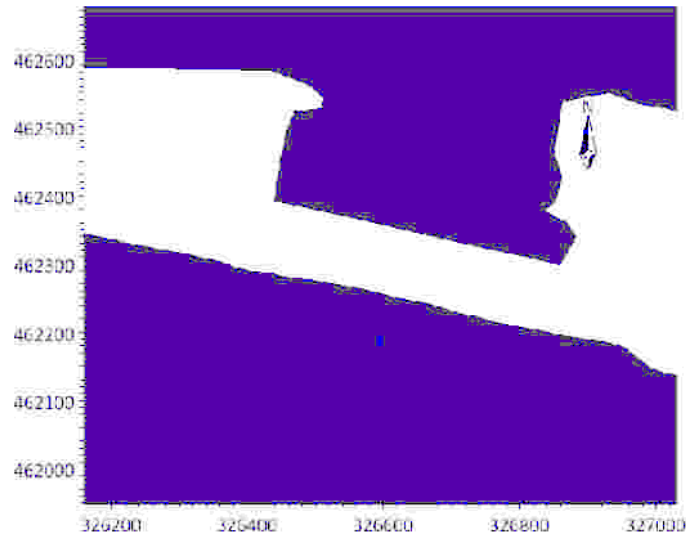


Figure C.17: NE_S_09_Eastward Flow

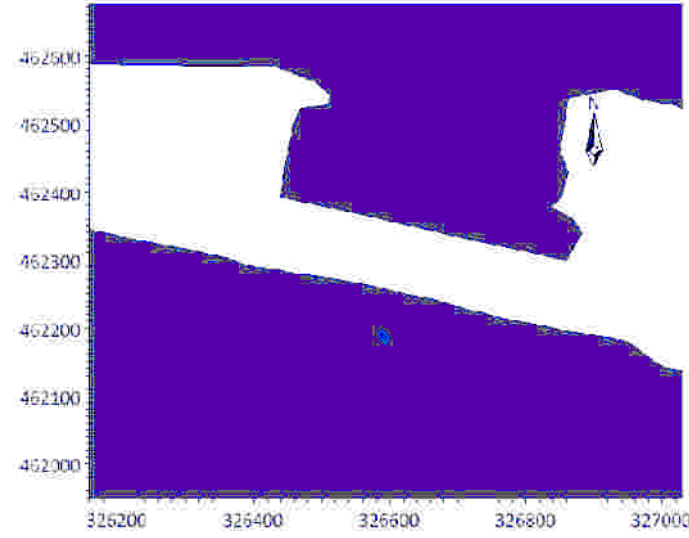


Figure C.18: NE_S_09_Westward Flow

Excess Temperature [deg C]

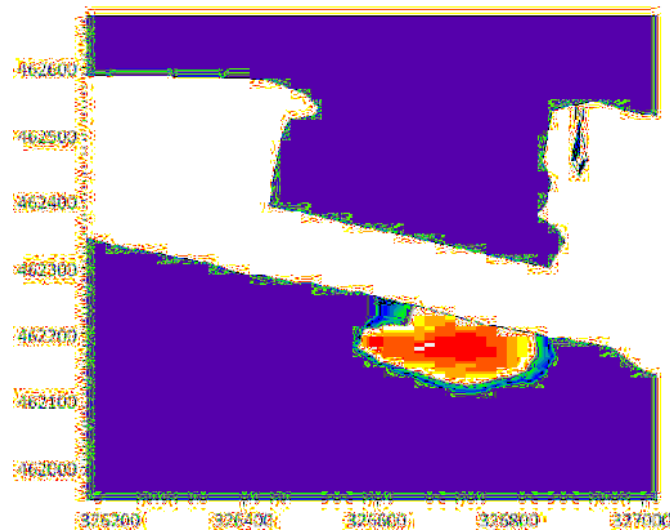
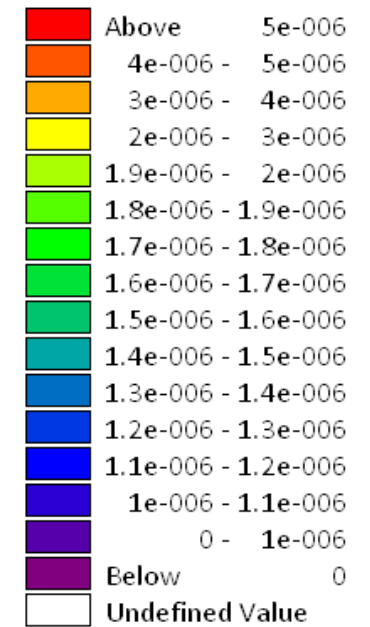


Figure C.19: NE_N_01_Eastward Flow

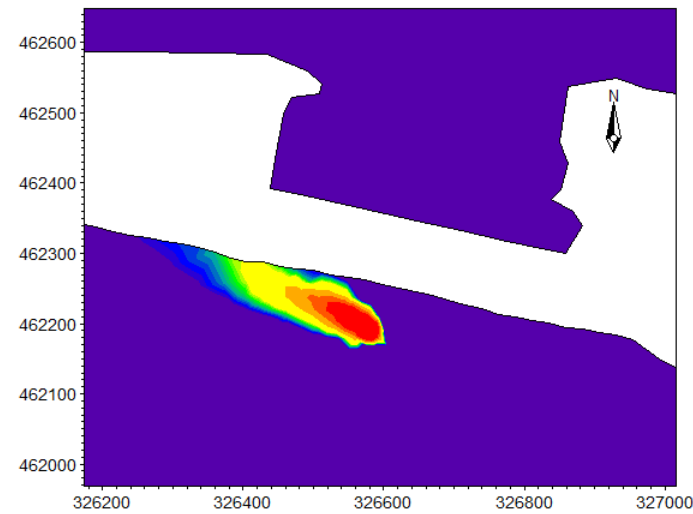


Figure C.20: NE_N_01_Westward Flow

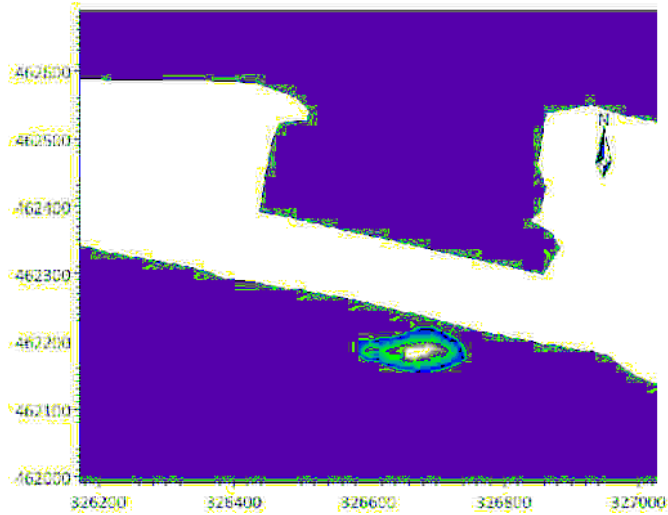


Figure C.21: NE_N_02_Eastward Flow

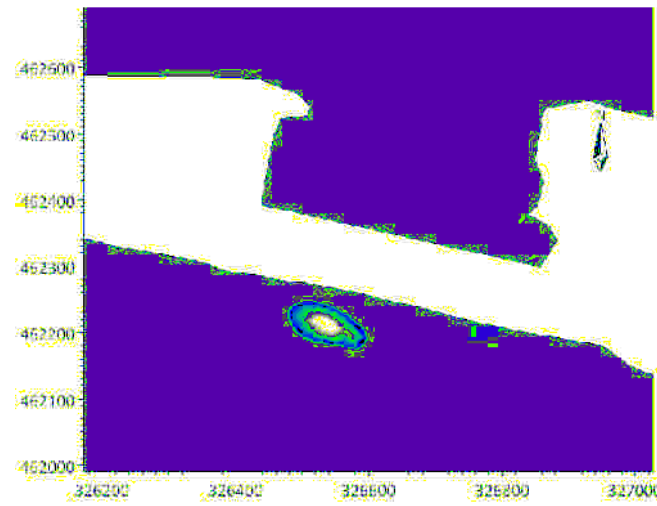


Figure C.22: SW_N_02_Westward Flow

Excess Temperature [deg C]

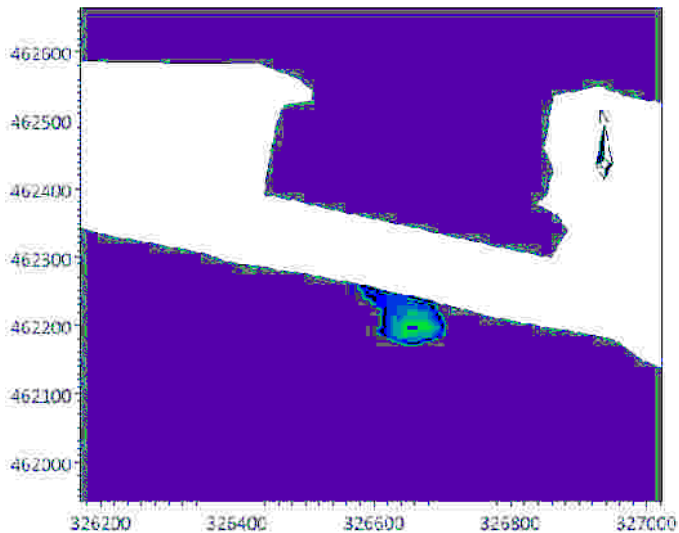
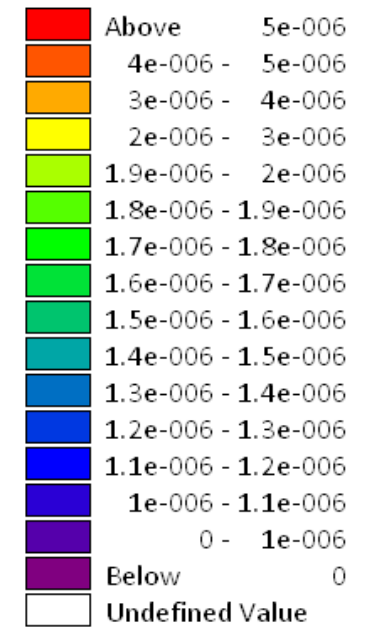


Figure C.23: NE_N_03_Eastward Flow

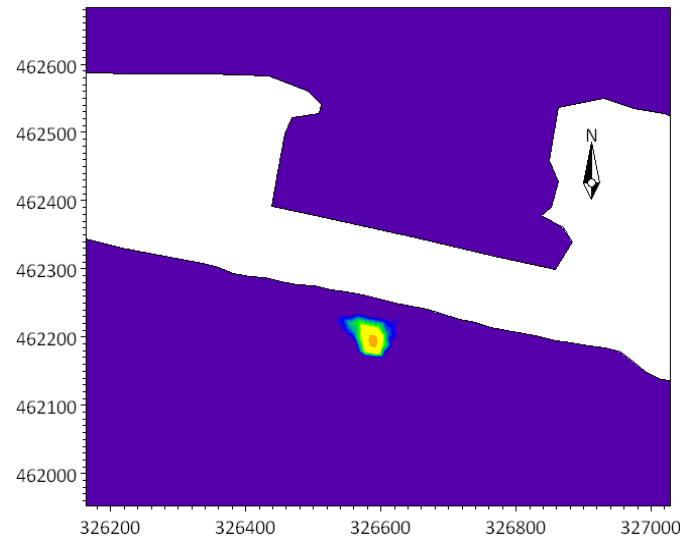


Figure C.24: NE_N_03_Westward Flow

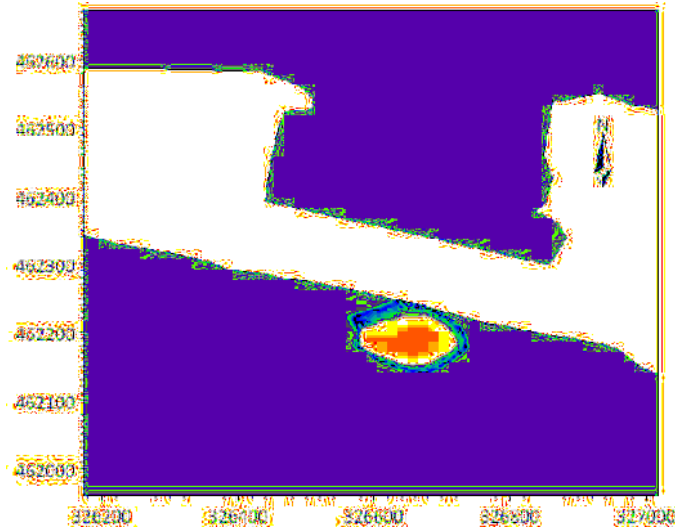


Figure C.25: NE_N_04_Eastward Flow

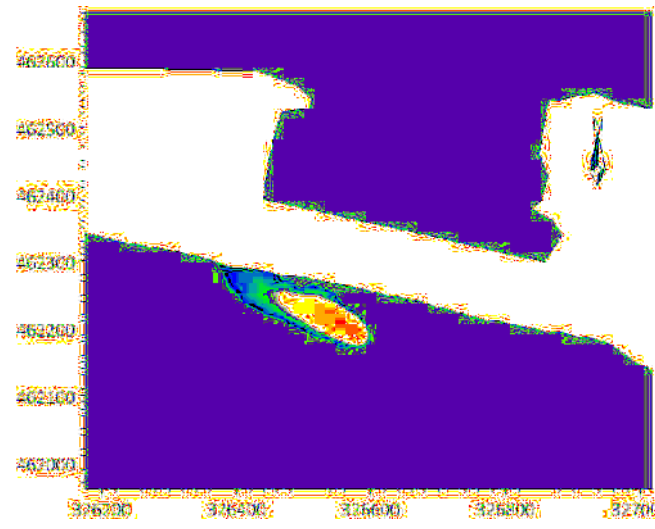


Figure C.26: SW_N_04_Westward Flow

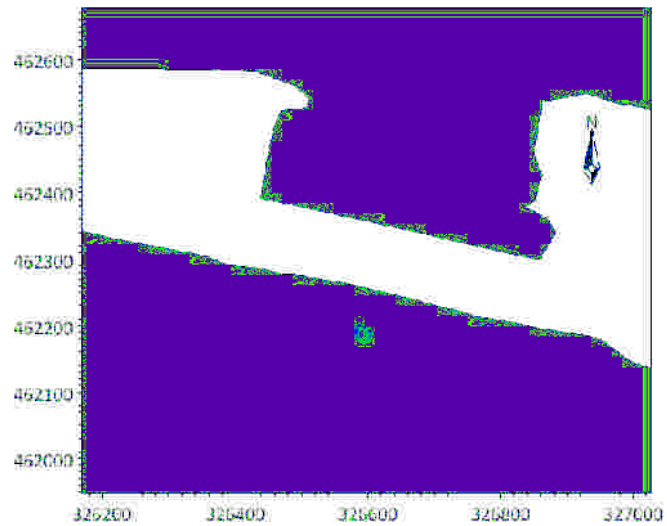
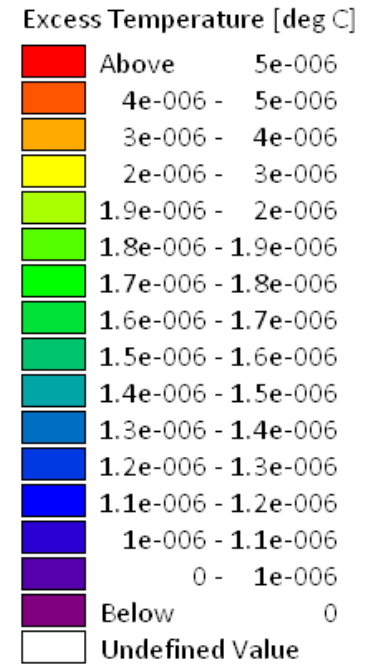


Figure C.27: NE_N_05_Eastward Flow

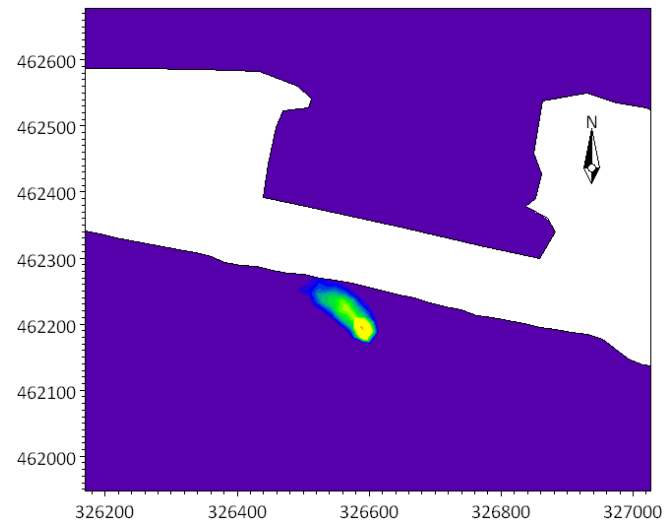


Figure C.28: NE_N_05_Westward Flow

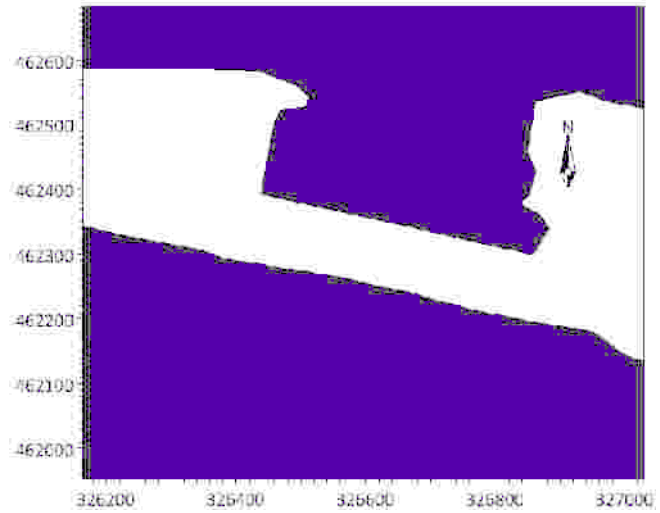


Figure C.29: NE_N_06_Eastward Flow

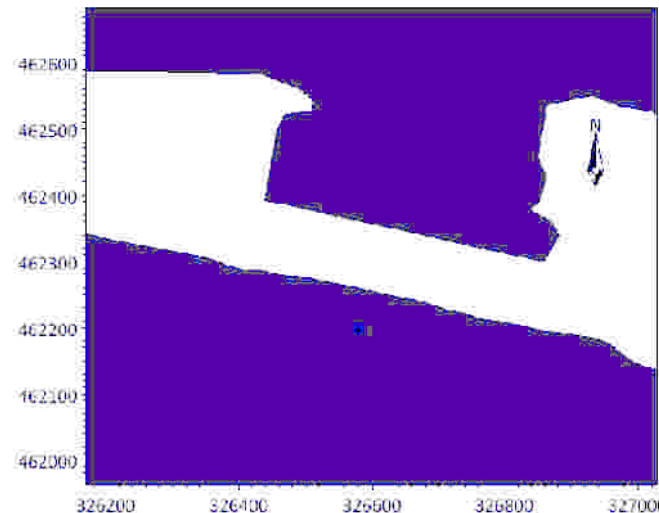


Figure C.30: NE_N_06_Westward Flow

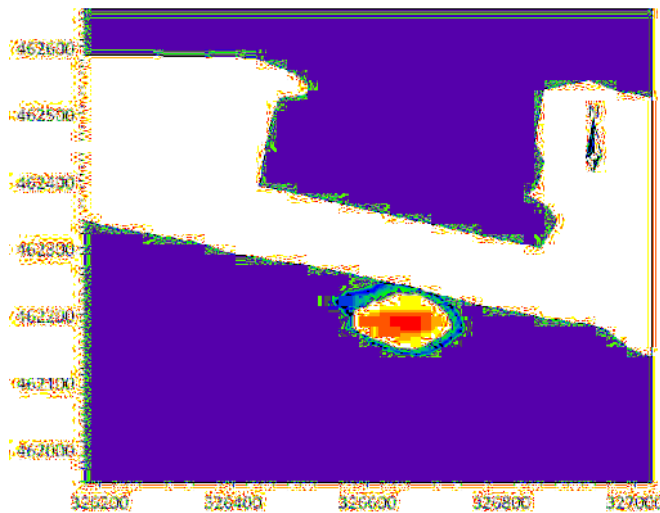
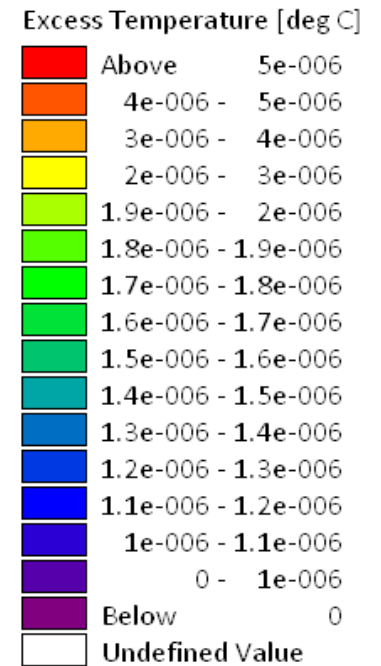


Figure C.31: NE_N_07_Eastward Flow

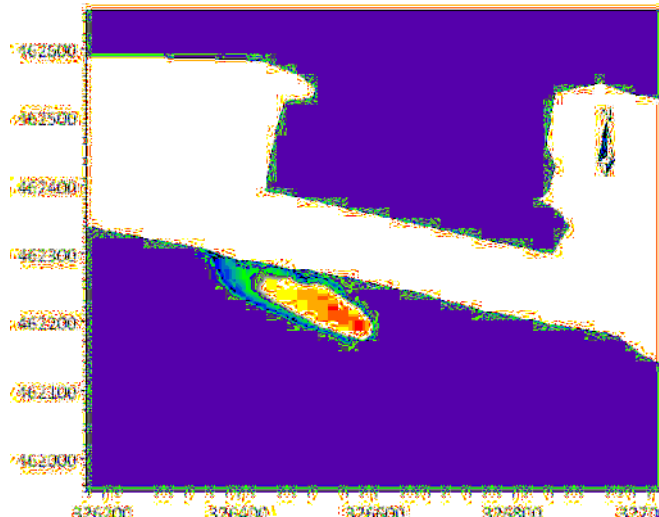


Figure C.32: NE_N_07_Westward Flow

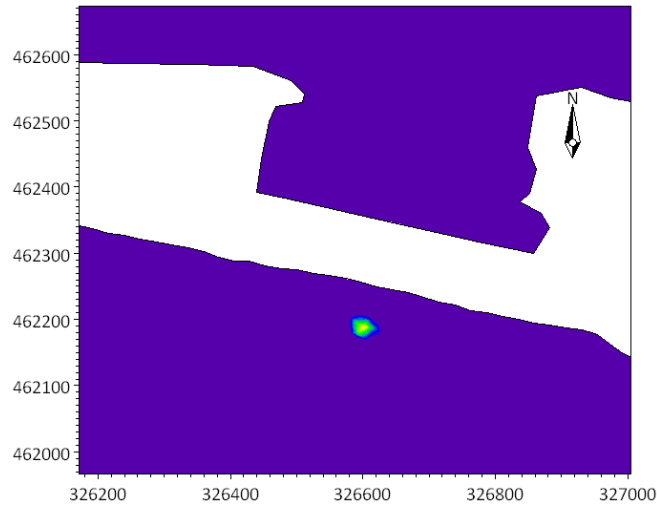


Figure C.33: NE_N_08_Eastward Flow

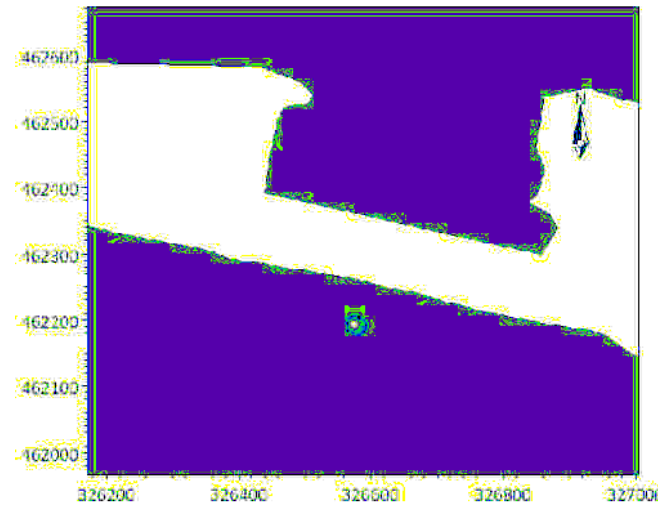


Figure C.34: NE_N_08_Westward Flow

Excess Temperature [deg C]

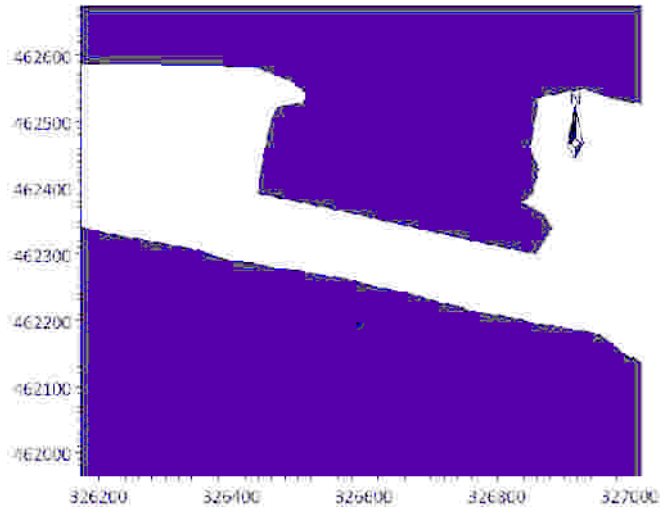
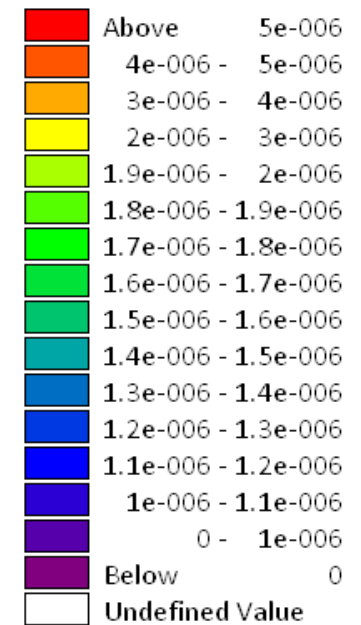


Figure C.35: NE_N_09_Eastward Flow

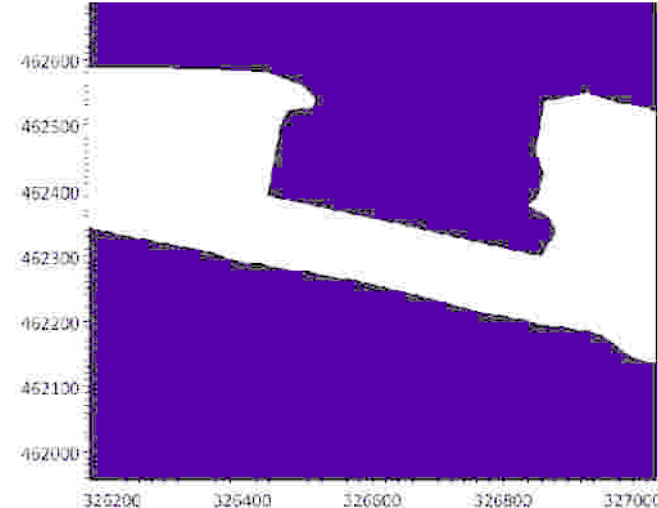


Figure C.36: NE_N_09_Westward Flow

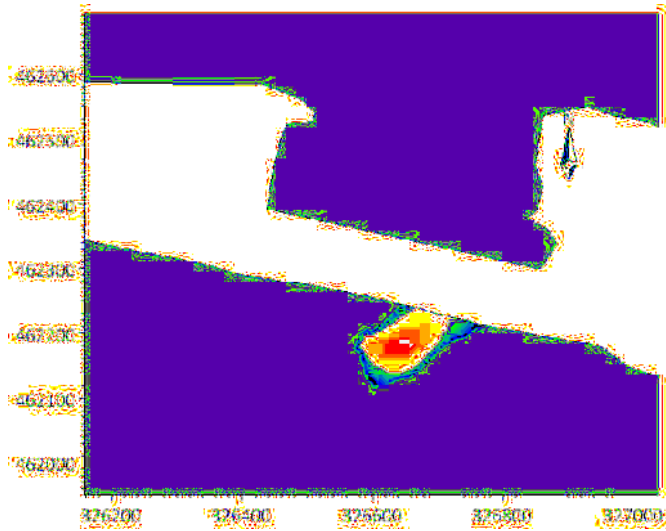


Figure C.37: SW_S_01_Eastward Flow

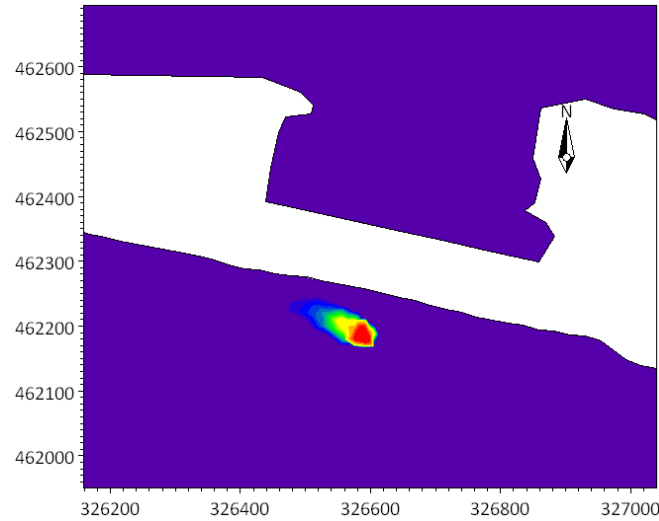


Figure C.38: SW_S_01_Westward Flow

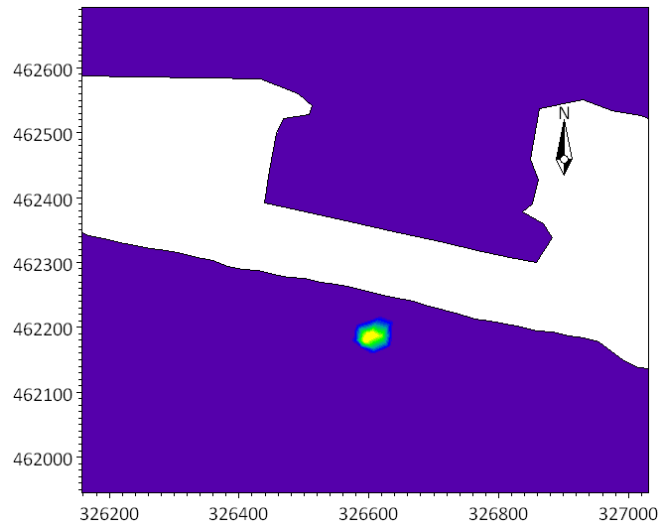
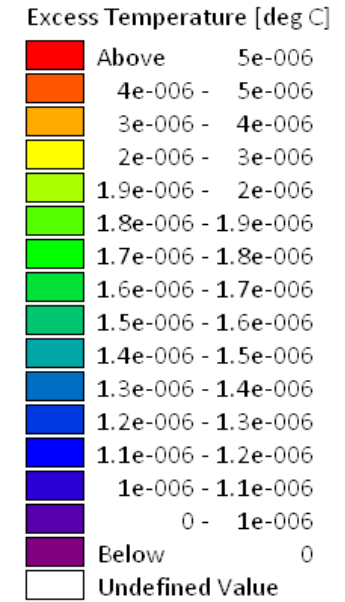


Figure C.39: SW_S_02_Eastward Flow

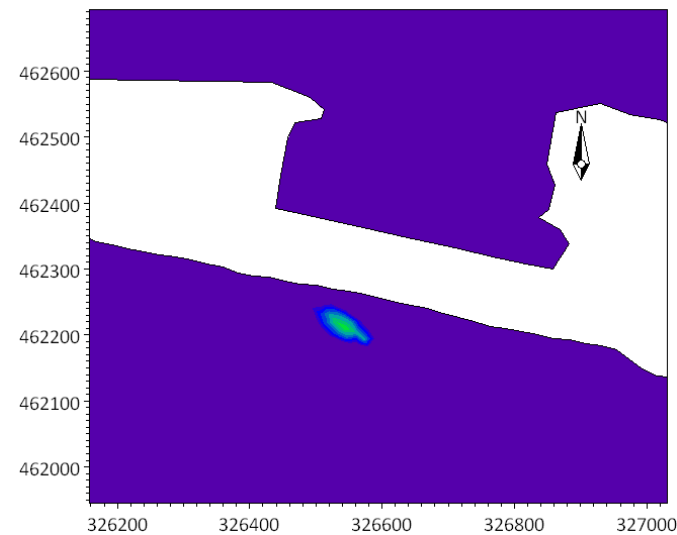


Figure C.40: SW_S_02_Westward Flow

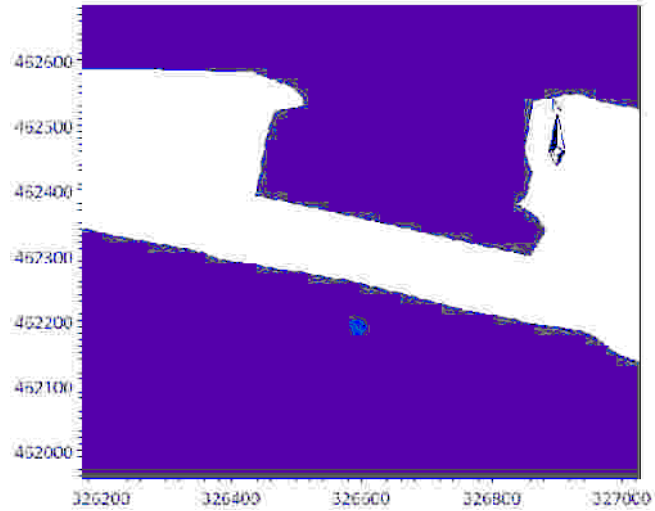


Figure C.41: SW_S_03_Eastward Flow

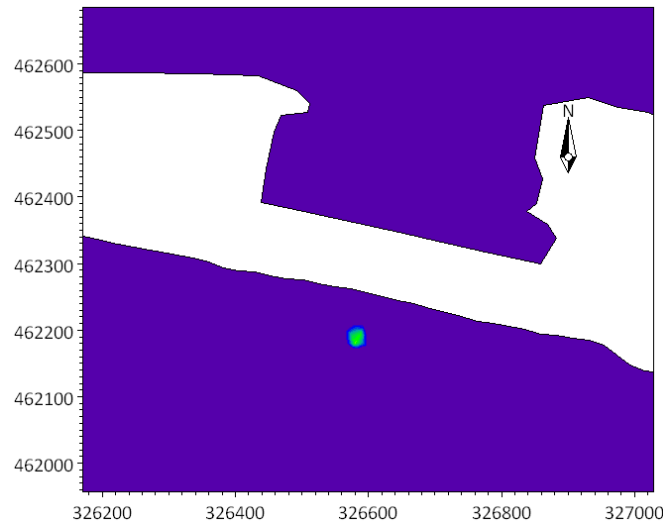


Figure C.42: SW_S_03_Westward Flow

Excess Temperature [deg C]

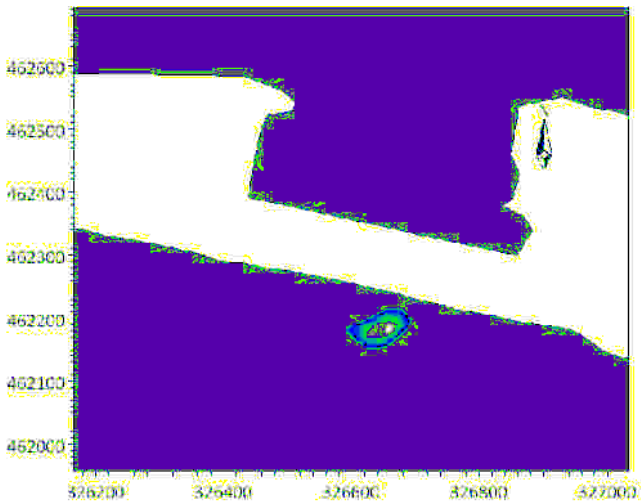
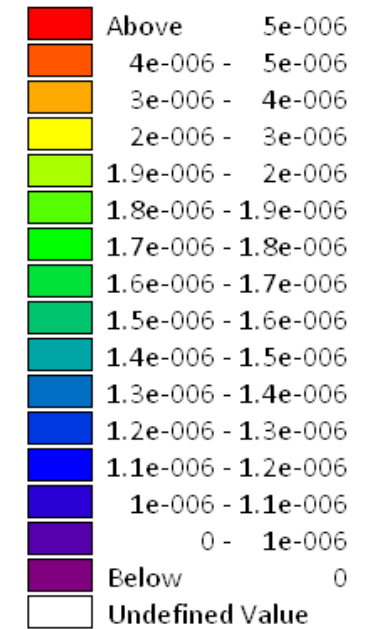


Figure C.43: SW_S_04_Eastward Flow

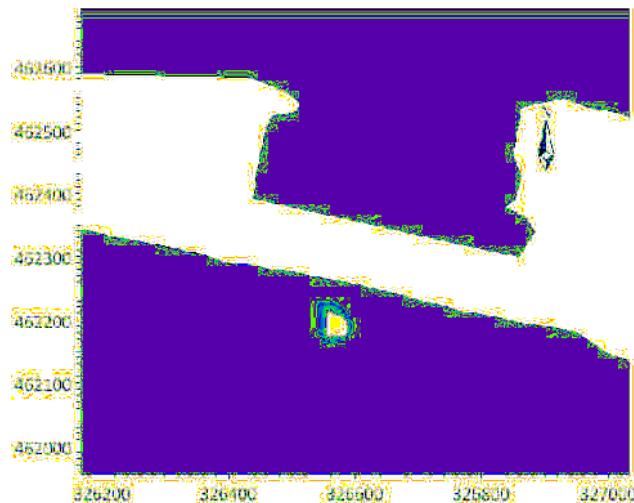


Figure C.44: SW_S_04_Westward Flow

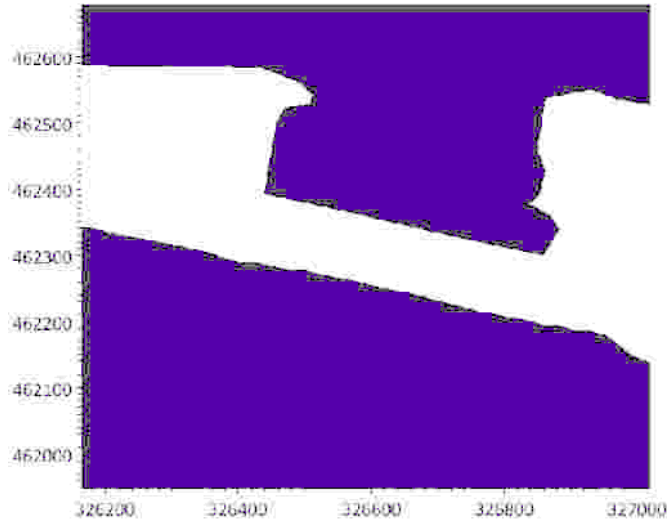


Figure C.45: SW_S_05_Eastward Flow

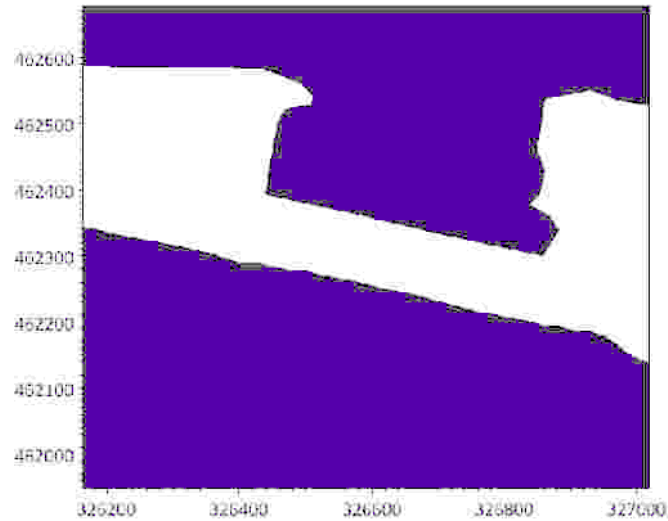


Figure C.46: SW_S_05_Westward Flow

Excess Temperature [deg C]

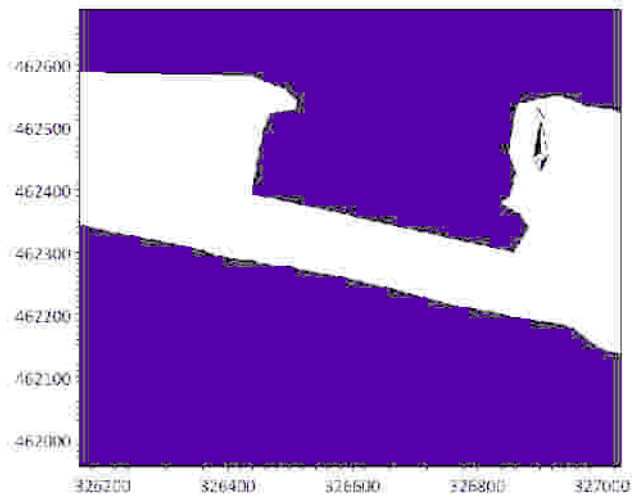
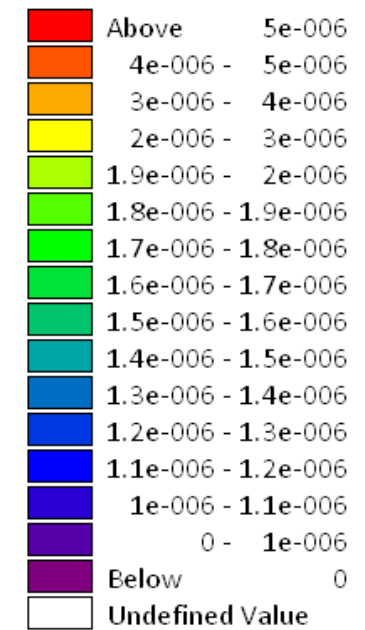


Figure C.47: SW_S_06_Eastward Flow

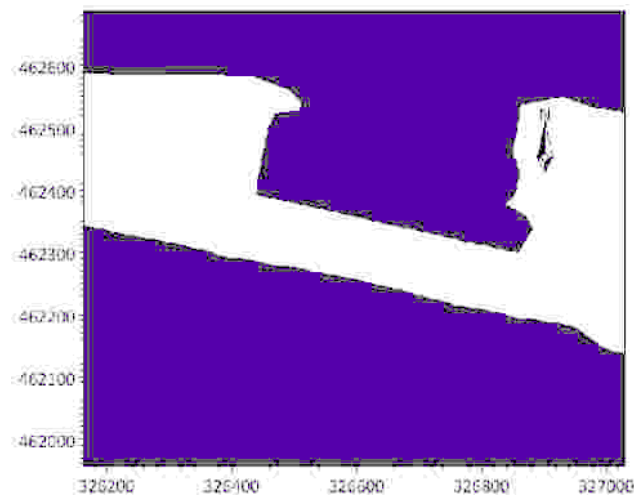


Figure C.48: SW_S_06_Westward Flow

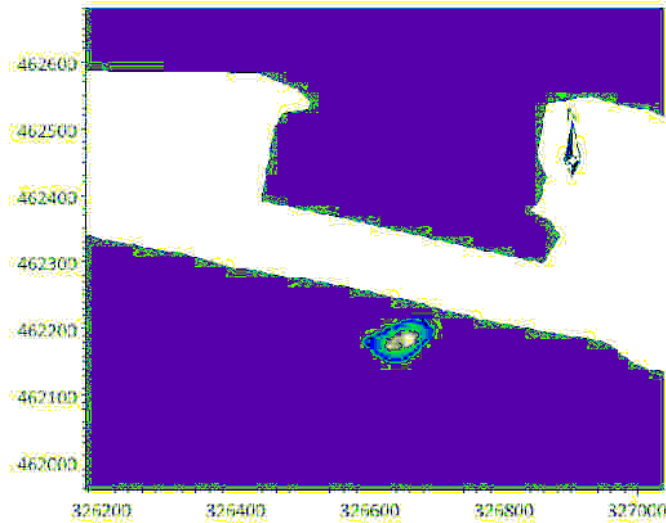


Figure C.49: SW_S_07_Eastward Flow

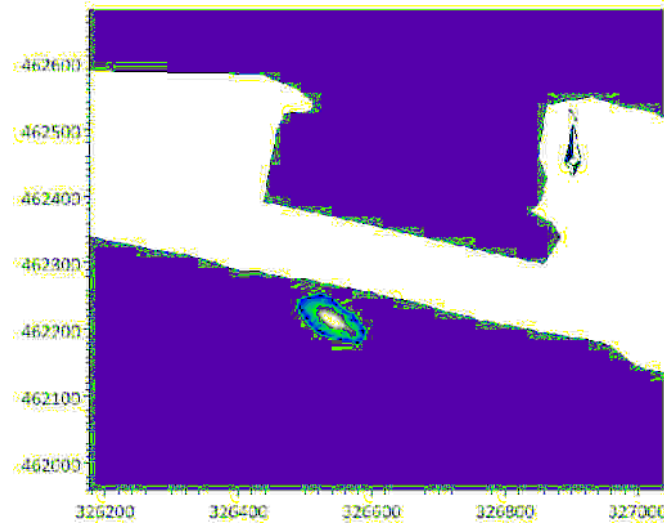


Figure C.50: SW_S_07_Westward Flow

Excess Temperature [deg C]

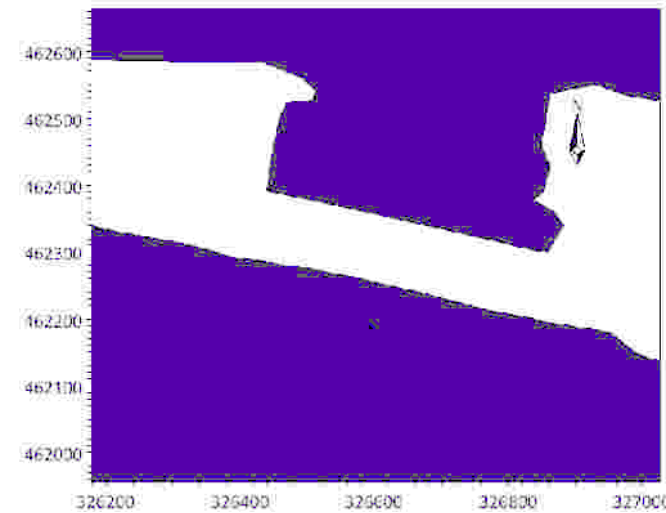
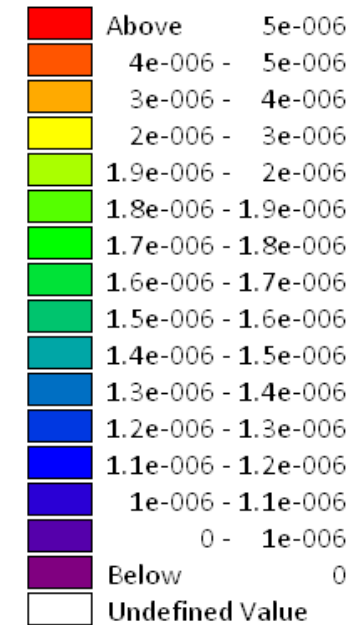


Figure C.51: SW_S_08_Eastward Flow

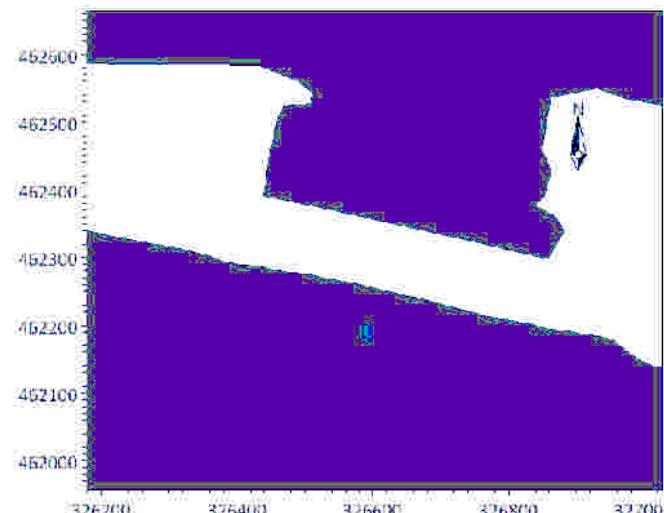


Figure C.52: SW_S_08_Westward Flow

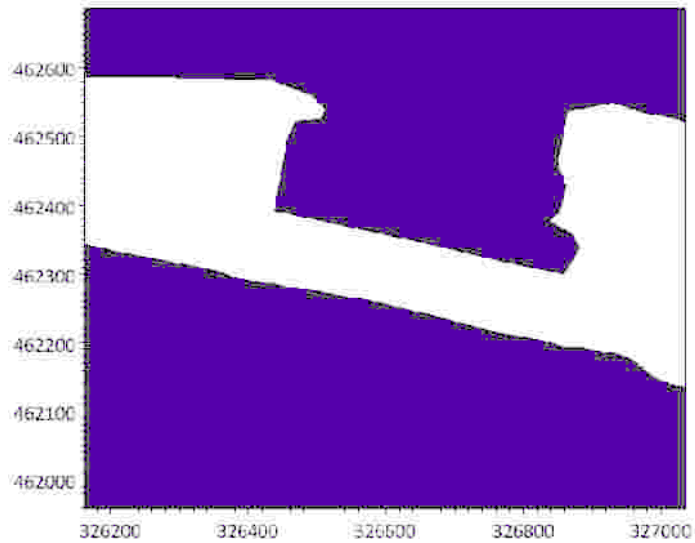


Figure C.53: SW_S_09_Eastward Flow

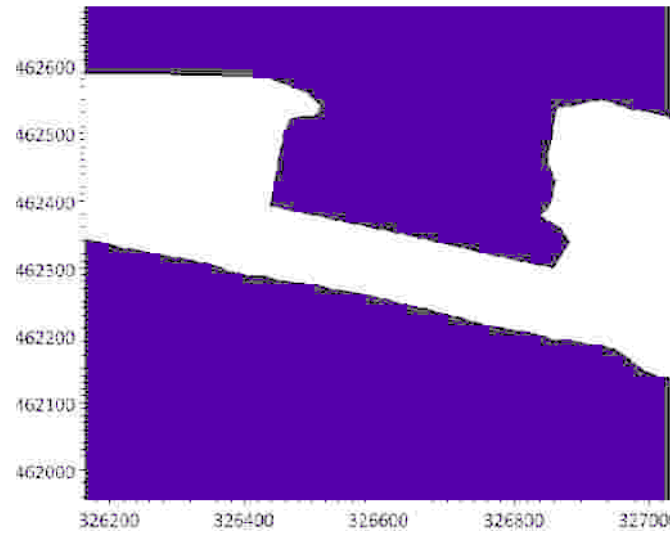


Figure C.54: SW_S_09_Westward Flow

Excess Temperature [deg C]

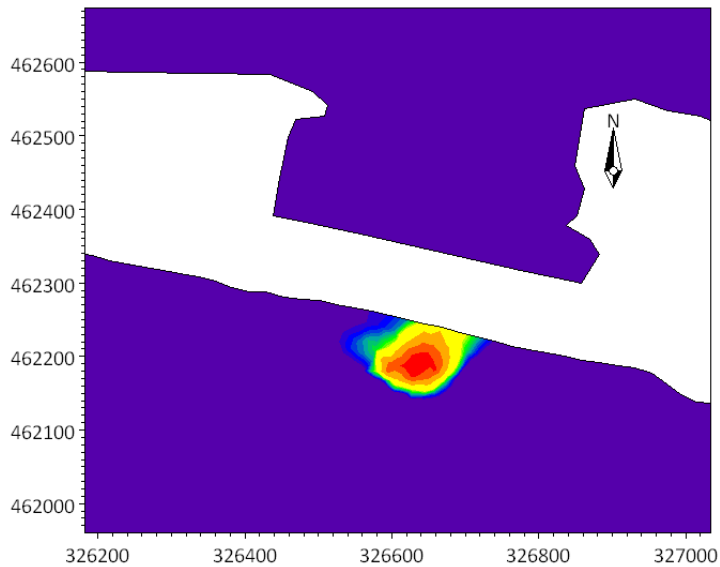
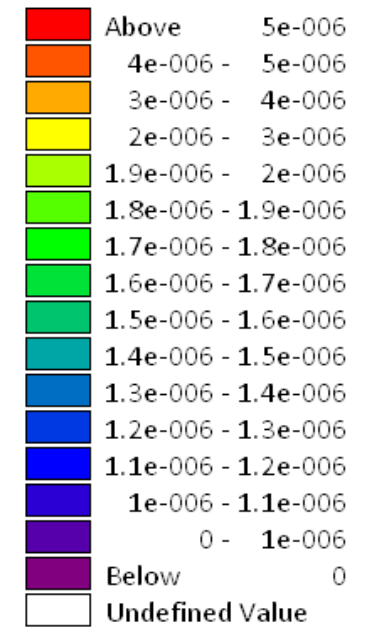


Figure C.55: SW_N_01_Eastward Flow

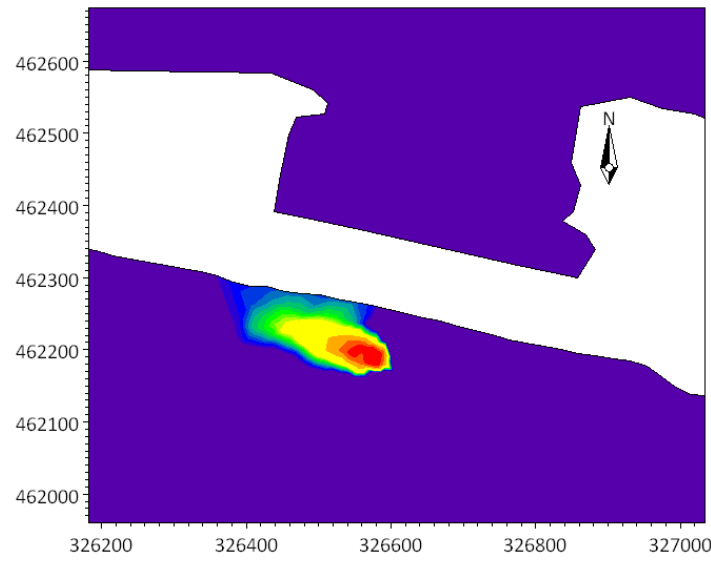


Figure C.56: SW_N_01_Westward Flow

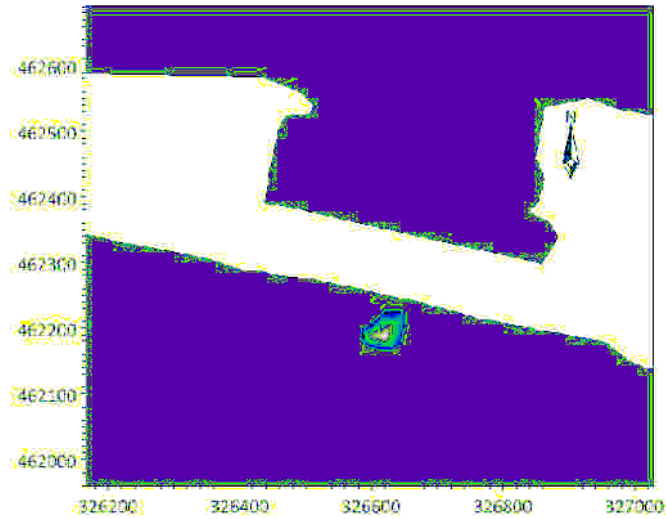


Figure C.57: SW_N_02_Eastward Flow

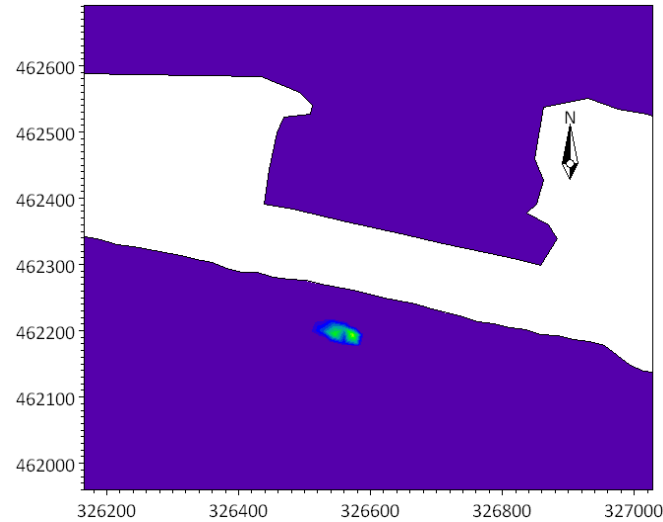


Figure C.58: SW_N_02_Westward Flow

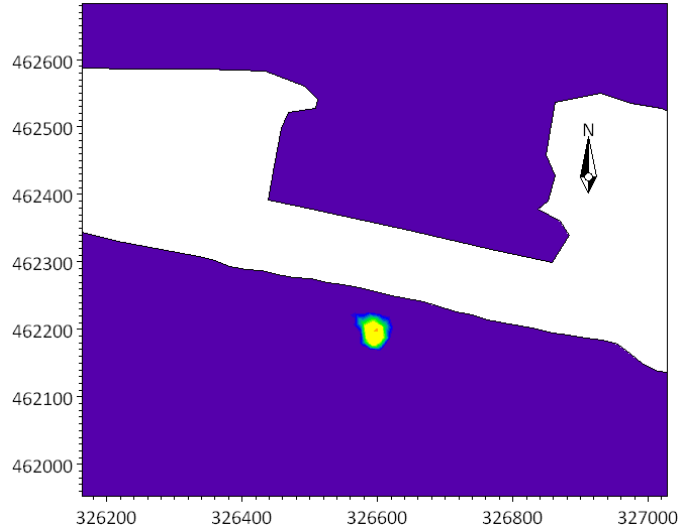
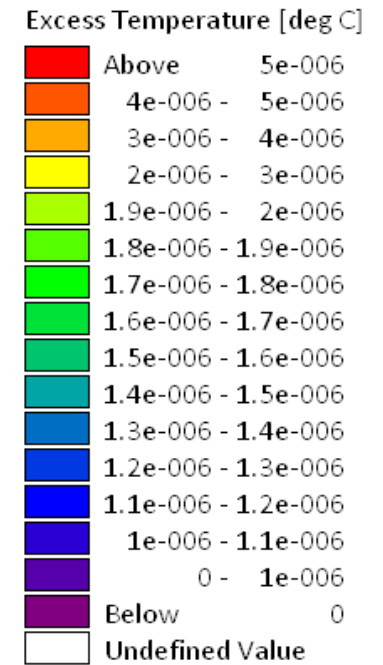


Figure C.59: SW_N_03_Eastward Flow

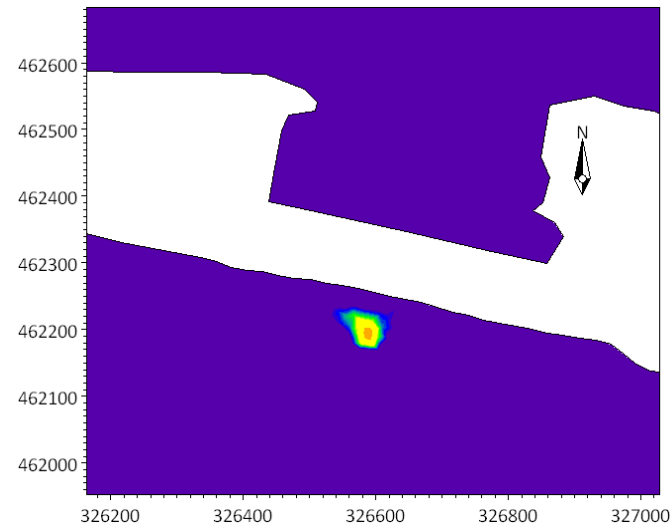


Figure C.60: SW_N_03_Westward Flow

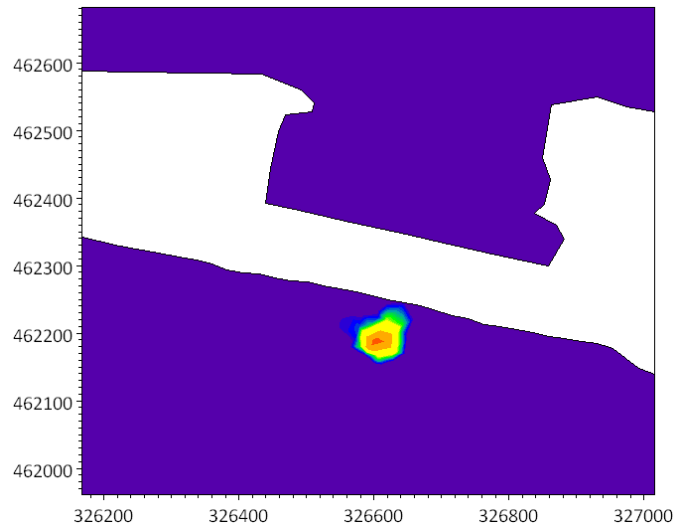


Figure C.61: SW_N_04_Eastward Flow

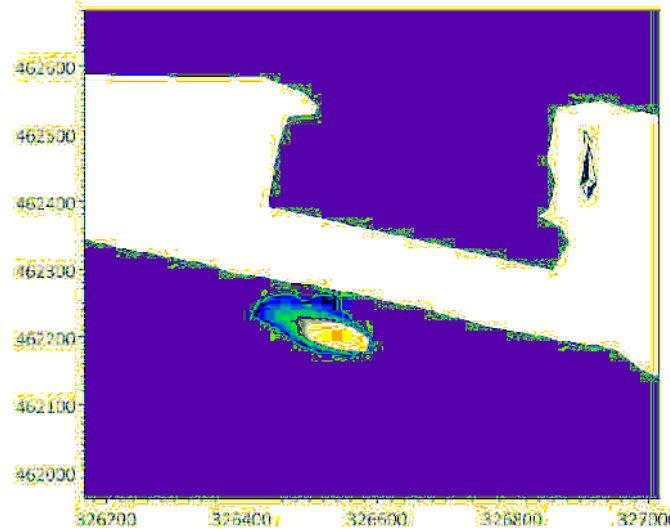


Figure C.62: SW_N_04_Westward Flow

Excess Temperature [deg C]

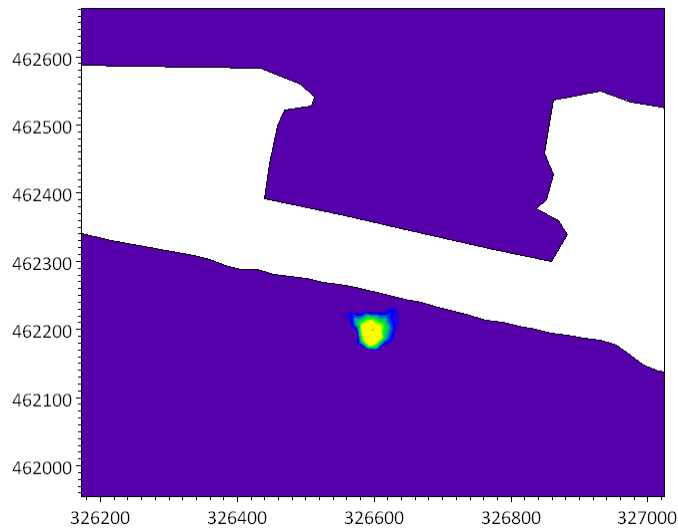
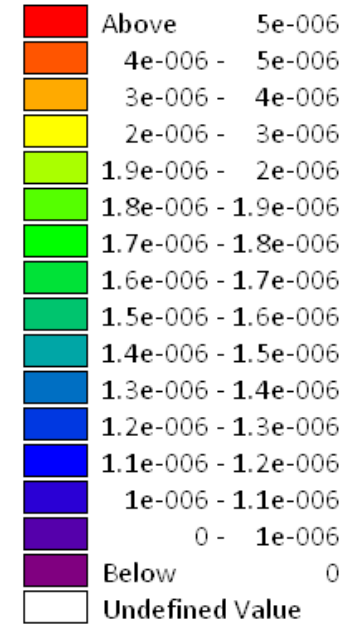


Figure C.63: SW_N_05_Eastward Flow

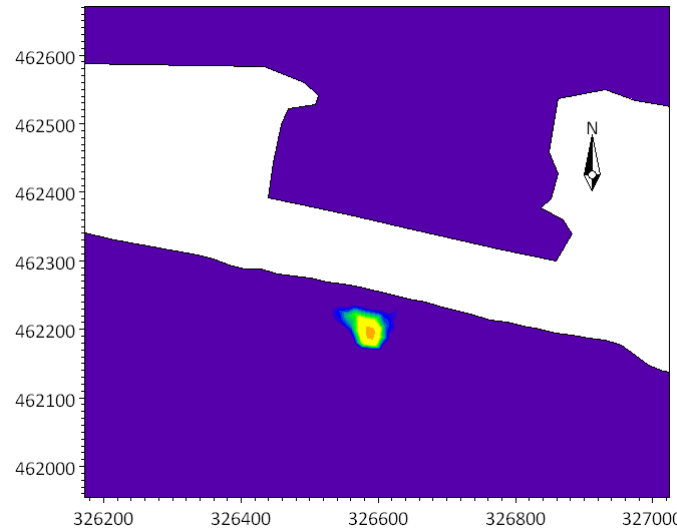


Figure C.64: SW_N_05_Westward Flow

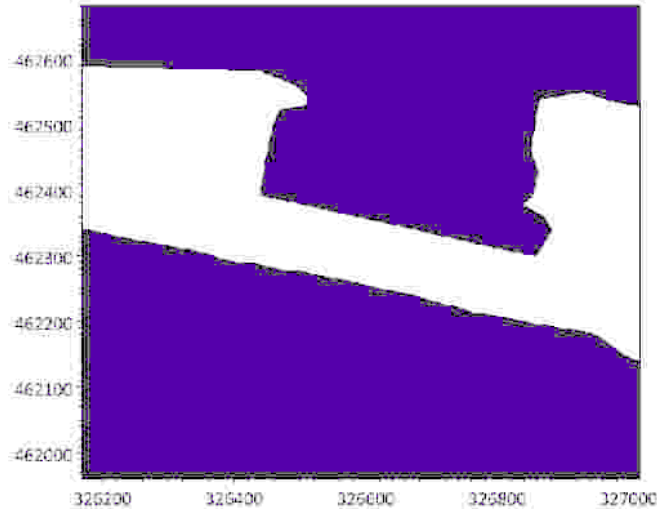


Figure C.65: SW_N_06_Eastward Flow

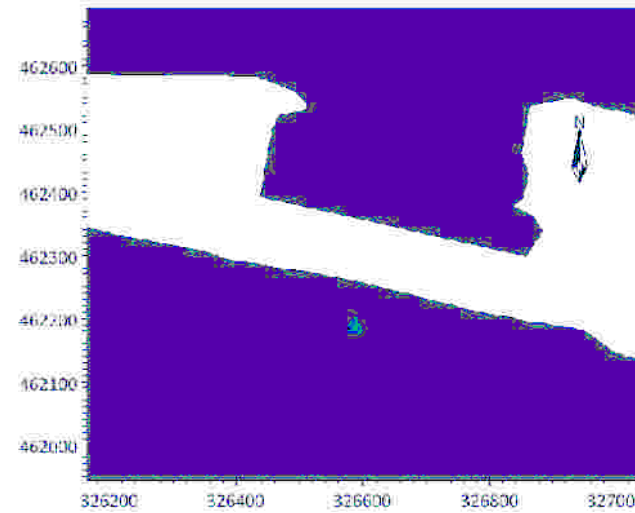


Figure C.66: SW_N_06_Westward Flow

Excess Temperature [deg C]

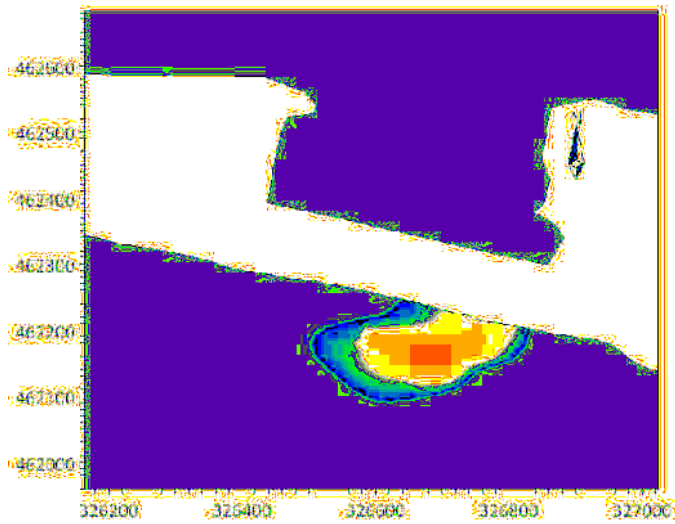
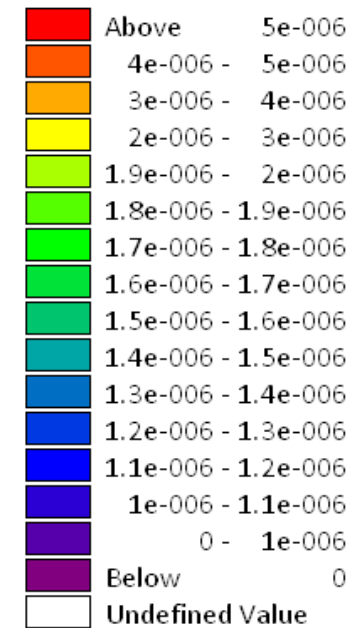


Figure C.67: SW_N_07_Eastward Flow

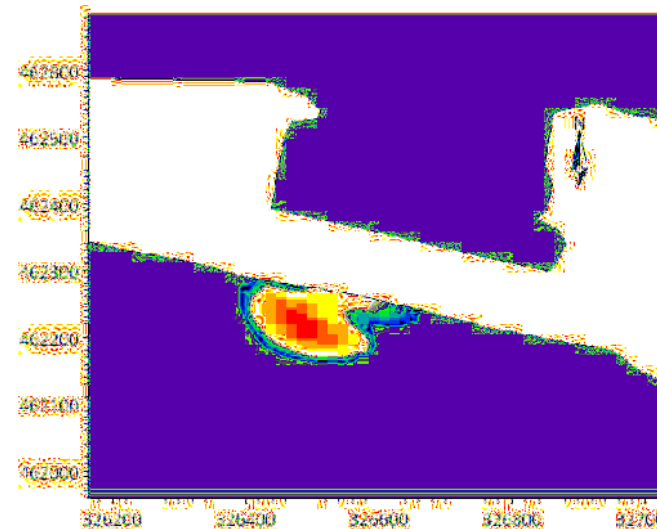


Figure C.68: SW_N_07_Westward Flow

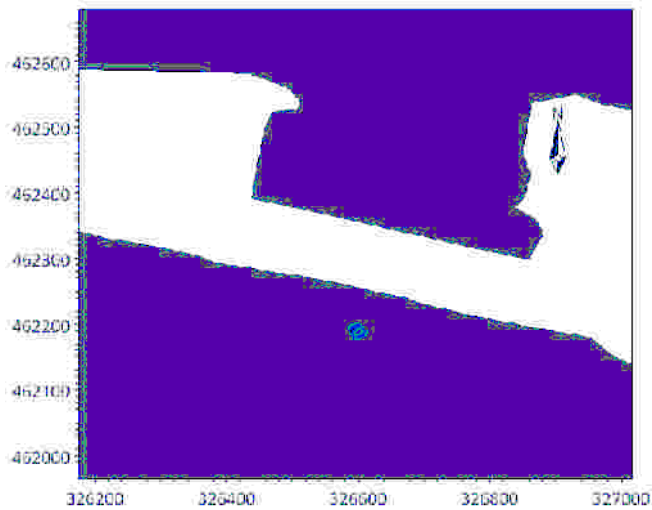


Figure C.69: SW_N_08_Eastward Flow

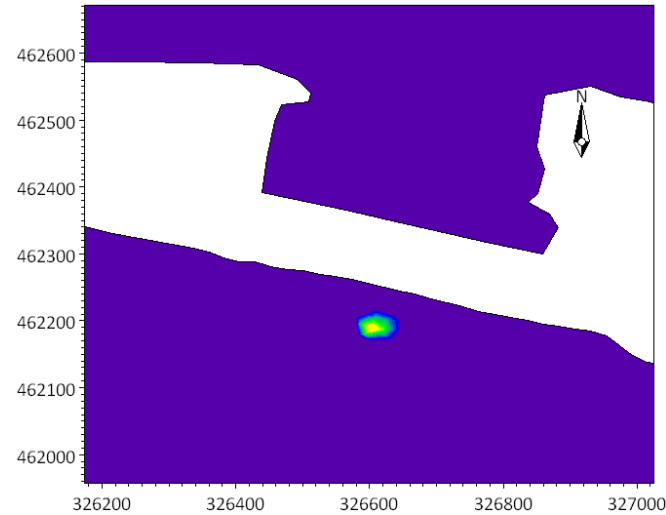


Figure C.70: SW_N_08_Westward Flow

Excess Temperature [deg C]

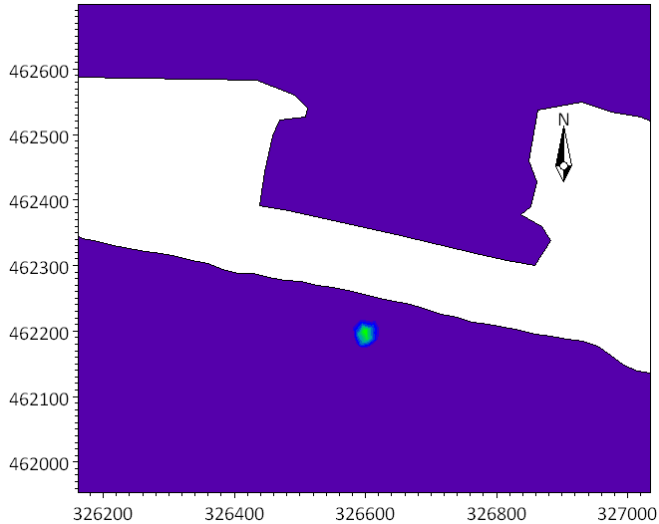
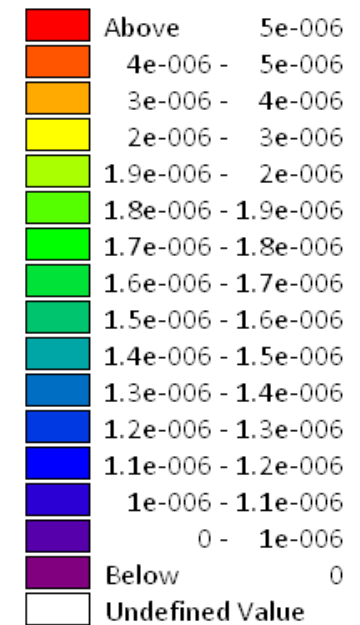


Figure C.71: SW_N_09_Eastward Flow

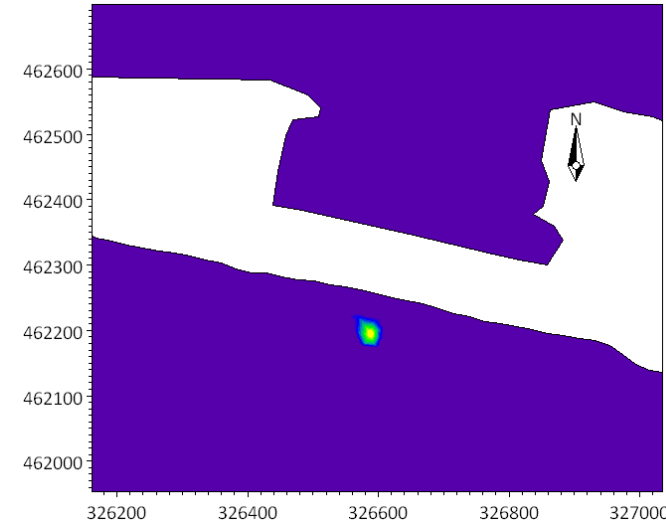


Figure C.72: SW_N_09_Westward Flow

Environmental and Social Impact Assessment for the Regional Solid Waste Management Facility (RSWMF) Thilafushi

Noise Level Measurement

Prepared by: Abdul Aleem (EIA P03/2019)



23rd September 2019

Noise Level Measurement

Noise level was measured to establish baseline at five locations: NQ1, NQ2, NQ3, NQ4 and NQ5 by Water Solutions on 25th August 2019 using hand held sound level meter at Thilafushi. Ambient noise levels were measured during the day time from 10:00 am to 12:00 pm and during the night from 10:00 pm to 12:00 pm at 5 locations (see map). The day time was considered as 7:00 a.m. to 10:00 p.m, while the night time was considered as 10:00 p.m. to 7:00am.

Station Name	Station Coordinates	Monitoring rationale
NQ1 (Thilafushi)	4°10'26.4 N 73°28'59.9 E	The station was selected as it represents a major industrial location of the island and is also located close to the harbour. The location lies north of the proposed facility on the opposite side of the lagoon.
NQ2 (Thilafushi)	4°10'56.6 N 73°26'53.3 E	The station was selected as it represents a major industrial location of the island. The location lies east of the proposed facility on the opposite side of the lagoon. The location has various industrial activities in its proximity
NQ3 (Thilafushi)	4°10'58.3 N 73°26'09.6 E	This station was selected as it is located near the boundary of the proposed WTE facility.
NQ4 (Thilafushi)	4°10'57.3 N 73°25'59.4 E	This station was selected as it is located west of proposed WTE facility. The area has less development and less activity during the day time.
NQ5 (Thilafushi)	4°10'57.3 N 73°26'14.4 E	This station was selected as it is located at the proposed WTE facility.



Figure: Locations where noise was monitored for the baseline assessment.

Table: Summary of Noise Quality Results for Thilafushi

S. No	Locations	Noise Level dB (A) Day Time	Noise Level dB (A) Night Time
NQ1	Thilafushi	65.1	53.7
NQ2	Thilafushi	64.2	51.8
NQ3	Thilafushi	56.3	50.0
NQ4	Thilafushi	56.0	48.9
NQ5	Thilafushi	54.6	49.0

The ambient noise levels were moderate to high considering the international standards. The higher background noise can be attributed to the roar from the sea, windy conditions and closely packed industrial areas and movement of boats. Thilafushi was quieter during the night as there are no activity on the island.

Environmental and Social Impact Assessment for the Regional Solid Waste Management Facility (RSWMF) Thilafushi

Noise Level Measurement (Additional Measurements)

Prepared by: Abdul Aleem (EIA P03/2019)



24th October 2019

Noise Level Measurement

Additional Noise level was measured at two locations: NQ3 and NQ4 by Water Solutions on 6th and 7th October 2019 using hand held sound level meter at Thilafushi. Ambient noise levels were measured every hour for 24 hours at each locations.

Station Name	Station Coordinates	Monitoring rationale
NQ3 (Thilafushi)	4°10'58.3 N 73°26'09.6 E	This station was selected as it is located near the boundary of the proposed WTE facility.
NQ4 (Thilafushi)	4°10'57.3 N 73°25'59.4 E	This station was selected as it is located west of proposed WTE facility. The area has less development and less activity during the day time.

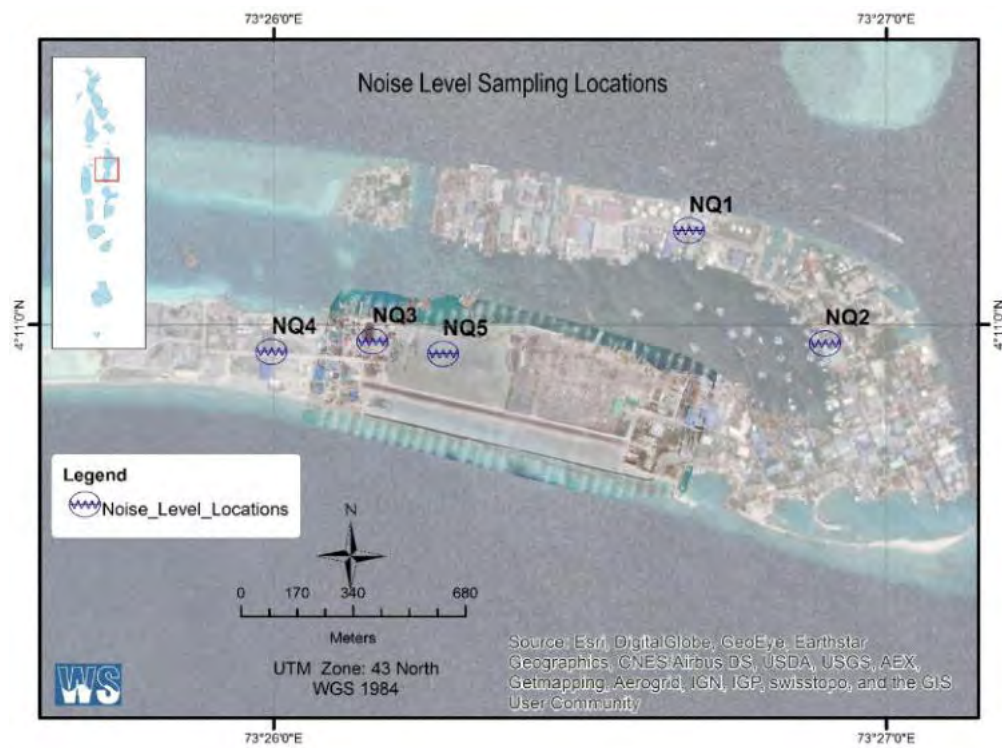


Figure: Locations where noise was monitored for the baseline assessment.

Table: Noise Measurement Results for Thilafushi

Date	Time	Noise Level dB (A)	
		NQ3	NQ4
6/10/2019	7:00	50.1	52.4
6/10/2019	8:00	54.4	54.3
6/10/2019	9:00	55.7	56.2
6/10/2019	10:00	56.5	56.8
6/10/2019	11:00	57.1	55.4
6/10/2019	12:00	56.8	57.4
6/10/2019	13:00	57.4	56.4
6/10/2019	14:00	57.3	55.9
6/10/2019	15:00	56.7	55.4
6/10/2019	16:00	56.8	56.1
6/10/2019	17:00	51.3	54.3
6/10/2019	18:00	49.4	49.4
6/10/2019	19:00	50.1	48.9
6/10/2019	20:00	49.6	48.6
6/10/2019	21:00	49.3	48.3
6/10/2019	22:00	50.1	48.5
6/10/2019	23:00	50.3	48.3
7/10/2019	0:00	50.1	48.1
7/10/2019	1:00	50.1	48.1
7/10/2019	2:00	50.3	48.3
7/10/2019	3:00	50.8	47.8
7/10/2019	4:00	50.2	48
7/10/2019	5:00	49.5	49.1
7/10/2019	6:00	49.8	49.3

The ambient noise levels were low considering the international standards. The background noise can be attributed to the roar from the sea, windy conditions areas and movement of boats. Thilafushi was quitter during the night as there are no activity on the island.



TEST REPORT



Report No:

(7419)080-0561A(S)

May 16, 2019

Page 1 of 4

Attn: Mr. Nashfa Nashidh

Customer:

Water Solutions (Pvt) Ltd

Address :

MA. Faseri, 1st Floor, Ameenee Magu, Male, Maldives

Date of Sample Received:

Apr 03, 2019

Date of Testing Started:

Apr 03, 2019

Date of Report Modified:

May 16, 2019

Date of Testing Completed:

May 16, 2019

Sample Description:

Sample Received as:

Approximately 500ml x 3 Nos. of Water sample contained in two sealed plastic bottles & one glass bottle respectively

Sample Identified by the Client as:

Ground Water

Thilafushi GW 1

Sample Drawn By BVCPS

NO

Photo of the Samples Submitted



Bureau Veritas Consumer Products Services Lanka (Pvt) Ltd.

No. 570, Galle Road, Katubedda, Moratuwa, Sri Lanka
Tel: (9411) 2350111-115 (dedicated lines), Fax: (9411) 112622198 & 199
Email: bvcp.lanka@lk.bureauveritas.com

This report is governed by, and incorporates by reference, the Conditions of Testing as posted at the date of issuance of this report at <http://www.cps.bureauveritas.com> and is intended for your exclusive use. Any copying or replication of this report to or for any other person or entity, or use of our name or trademark, is permitted only with our prior written permission. This report sets forth our findings solely with respect to the test samples identified herein. The results set forth in this report are not indicative or representative of the quality or characteristics of the lot from which a test sample was taken or any similar or identical product unless specifically and expressly noted. Our report includes all of the tests requested by you and the results thereof based upon the information that you provided to us. You have 60 days from date of issuance of this report to notify us of any material error or omission caused by our negligence; provided, however, that such notice shall be in writing and shall specifically address the issue you wish to raise. A failure to raise such issue within the prescribed time shall constitute your unqualified acceptance of the completeness of this report, the tests conducted and the correctness of the report contents.

TEST REPORT



Report No:

(7419)080-0561A(S)

May 16, 2019

Page 2 of 4

TEST RESULTS

No.	Parameters	Results	LOQ	Unit	Test Method
1	Turbidity*	1.3	-	NTU	APHA 23rd ed: 2017: 2130 B
2	pH at 25°C*	7.3	-	-	APHA 23rd ed: 2017 :4500H ⁺
3	Iron (as Fe)*	0.4	-	mg/l	APHA 23rd ed: 2017: 3125 B
4	Manganese (as Mn)	0.02	-	mg/l	APHA 23rd ed: 2017: 3125 B
5	Arsenic (as As)	ND	0.001	mg/l	APHA 23rd ed: 2017: 3125 B
6	Total Dissolved Solids*	794	-	mg/l	APHA 23rd ed: 2017: 2540 C
7	Electrical Conductivity at 25°C*	1.39	-	mS/cm	APHA 23rd ed: 2017; 2510 B
8	Cadmium (as Cd)*	ND	0.0001	mg/l	APHA 23rd ed: 2017: 3125 B
9	Lead (as Pb)*	ND	0.001	mg/l	
10	Mercury (as Hg)	ND	0.00005	mg/l	
11	Polynuclear Aromatic Hydrocarbons*				
a	Naphthalene	ND	1.0	µg/l	CPSD –AN-00576
b	Acenaphthylene	ND	1.0	µg/l	CPSD –AN-00576
c	Acenaphthene	ND	1.0	µg/l	CPSD –AN-00576
d	Fluorene	ND	1.0	µg/l	CPSD –AN-00576
e	Phenanthrene	ND	1.0	µg/l	CPSD –AN-00576
f	Anthracene	ND	1.0	µg/l	CPSD –AN-00576
g	Fluoranthene	ND	1.0	µg/l	CPSD –AN-00576
h	Pyrene	ND	1.0	µg/l	CPSD –AN-00576
i	Benzo[a]anthracene	ND	1.0	µg/l	CPSD –AN-00576
j	Chrysene	ND	1.0	µg/l	CPSD –AN-00576
k	Benzo[a]pyrene	ND	1.0	µg/l	CPSD –AN-00576
l	Benzo[e]pyrene	ND	1.0	µg/l	CPSD –AN-00576
m	Indeno[1,2,3-cd]pyrene	ND	1.0	µg/l	CPSD –AN-00576
n	Dibenzo[a,h]anthracene	ND	1.0	µg/l	CPSD –AN-00576
o	Benzo[g,h,i]perylene	ND	1.0	µg/l	CPSD –AN-00576
p	Benzo[b]fluoranthene	ND	1.0	µg/l	CPSD –AN-00576
q	Benzo[j]fluoranthene	ND	1.0	µg/l	CPSD –AN-00576
r	Benzo[k]fluoranthene	ND	1.0	µg/l	CPSD –AN-00576

TEST REPORT



Report No: (7419)080-0561A(S)

May 16, 2019

Page 3 of 4

(*)Indicates- ISO 17025: 2005 accredited test.

Remark:

The test report (7419)080-0561A has been replaced with the test report (7419)080-0561A(S) in order to add test results of Heavy metals.

NOTE:

APHA: American Public Health Association,
SLS: Sri Lanka Standard, ND: Not Detected,
LOQ: Limit of Quantification, mg/l: milligrams per liter,
°C :Celsius, NTU: Nephelometric Turbidity Units,
mS/cm : milliSiemens per centimeter.

Contact Information for this report (Technical and General Inquiries and Feedback)

GENERAL INQUIRIES:		
IROSHA UDUGAMPALA	TEL: +94 768 229 528	E-MAIL: Irosha.Udugampala@lk.bureauveritas.com
TECHNICAL INQUIRIES:		
ROHITHA GUNARATHNA	TEL: +94 774 151 768	E-MAIL: rohitha.gunarathna@lk.bureauveritas.com
FEED BACK:		
KUMUDINI RATHNAYAKE	TEL: +94 768 229 455	E-MAIL: kumudinie.rathnayake@lk.bureauveritas.com

REVIEWED BY: SHYAMIKA WICKRAMASINGHE

BUREAU VERITAS CONSUMER PRODUCTS SERVICES LANKA (PVT) LTD.

AUTHORIZED SIGNATORY

ROHITHA GUNARATHNA

MANAGER-
ANALYTICAL LABORATORY

TEST REPORT



Report No:

(7419)080-0561C(S)

May 16, 2019

Page 4 of 4

CPS CONDITIONS OF SERVICE

The party that submits a completed service request form to Company or signs a quotation issued by the Company for its performance of services ("Services") is the "Client" under these Conditions of Service. The entity within the Bureau Veritas Consumer Products Services division accepting the service request form and issuing the Report documenting the results of those Services is the "Company" under these Conditions of Service. Company and Client are, together, the "Parties" and each is a "Party". A request for Services constitutes a legally binding agreement on both Parties when such a request is accepted by the Company ("Agreement") under the following terms and conditions (collectively, "Conditions").

1. Services. (a) The completion of the Services shall be evidenced by the Company's issuing to Client a written report setting forth the results of the Services based upon the properly accepted request, applicable protocols, written information, and where applicable, the product sample provided by Client to Company ("Report"). Company may delegate/assign the performance of all or a portion of the Services to an affiliate of Company or to an agent or subcontractor. Client shall provide to Company on a timely basis, all documents and information necessary to enable Company to properly perform the Services. Company may, in its sole discretion, dispose of product samples furnished to Company for the Services that were not destroyed in the course of performance of the Services. (b) Client represents and warrants to Company that (i) each product sample is not submitted in violation of a third party's intellectual property rights; (ii) Client will not use and rely upon Company's Report for any product whose properties differ from the sample(s) upon which the Report is based; and (iii) any goods subject to inspection will be completely prepared for the type of inspection booked for the specified date, and (c) Client accepts sole responsibility and liability for the accuracy of documents submitted to government or other regulatory bodies, including certificates of compliance required under the US Consumer Product Safety Improvement Act and EU requirements under REACH regulations. Client's responsibility and liability for accuracy shall apply even where Company has provided assistance to Client in preparation of such documentation.

2. Report. (a) The Report shall (i) constitute the sole deliverable for the Services, (ii) relate solely to the facts and circumstances as observed and recorded by Company at the time of performance of the Services within the limits of written information and instructions received from Client. Company shall have no obligation to update the Report after its issuance. Where the Services include testing or inspection: (i) the Report will set forth the findings of Company solely with respect to the product samples identified therein and (ii) the results set forth in the Report are not to be construed as indicative or representative of the quality or characteristics of the lot from which a product sample was taken for Company's performance of Services. (b) The Report is issued solely by Company, is intended for the exclusive use of Client and its affiliates and, except as required by a regulatory body, shall not be published, used for advertising purposes, copied or replicated for distribution or publicly disclosed without Company's prior written consent. Company is not responsible for any third party's interpretation of the Report. (c) Client shall not request a Report for purposes of litigation, nor shall it list Company, its affiliates or employees as an expert in any proceeding without Company's prior written consent. If Client anticipates producing or otherwise using the Report in any legal proceedings, it shall so notify Company prior to submitting the Report in such proceeding.

3. Representations and Warranties. (a) Company undertakes due care and ordinary skill in the performance of its Services. (b) Client agrees that Company is neither an insurer nor a guarantor and does not take the place of Client or the third parties that it retains, including designers, manufacturers, agents, buyers, distributors, and transportation or shipping companies; Company disclaims all liability in such capacities. Client understands that, if it seeks to protect itself from claims of loss, damage or injury, it should obtain appropriate insurance. (c) Company does not warrant or guarantee Client's products, and Company's Report does not represent a warranty of merchantability, a warranty of fitness for a particular purpose, or any other warranty or guarantee.

4. Payment. Payment in full shall be due 30 days after the date of invoice, failing which Company may revoke any credit extended to Client. Client shall reimburse Company for (i) collection on overdue amounts from the due date until paid at an interest rate of 1.5% per month and (ii) any other costs Company incurs in collecting past due amounts, including court, attorneys and collection agencies' fees.

5. Intellectual Property. The names, service marks, trademarks and copyrights of Company and its affiliates (collectively, the "Marks") are and remain the sole property of Company and shall not be used by Client. Client shall not contest the validity of the Marks or take any action that might impair the value or goodwill associated with the Marks or the image or reputation of Company or its affiliates. Client understands that any information or samples submitted to Company is a license for Company to use the same in the performance of Services.

6. Relationship. (a) Nothing herein creates a partnership, agency or joint venture between the Parties. (b) The failure to require strict observance or performance of any provision of these Conditions shall not be construed to be a waiver of a Party's right to later require strict observance and performance of the same. If any provision of these Conditions is held to be invalid or unenforceable, such invalidity shall not invalidate the remainder of the Conditions. (c) For a period of two years after the commencement of this Agreement, Client shall not directly or indirectly try to solicit for employment any of Company's employees.

7. INDEMNITY. CLIENT SHALL HOLD HARMLESS AND INDEMNIFY COMPANY, ITS AFFILIATES AND THEIR RESPECTIVE DIRECTORS, OFFICERS, EMPLOYEES, AGENTS AND SUBCONTRACTORS AGAINST ALL THIRD-PARTY CLAIMS FOR LOSS, DAMAGE, INJURY, DEATH, OR EXPENSE OF WHATEVER NATURE, INCLUDING BUT NOT LIMITED TO CLAIMS ARISING FROM OR RELATING TO (I) THE PERFORMANCE OF ANY SERVICES BY COMPANY, (II) THE SALE, RESALE, MANUFACTURE, DISTRIBUTION OR USE OF ANY OF CLIENT'S GOODS OR (III) BREACH OF CLIENT'S OBLIGATIONS OR WARRANTIES HEREIN.

8. LIMITATIONS OF LIABILITY. (A) COMPANY SHALL NOT BE LIABLE FOR ANY INDIRECT, CONSEQUENTIAL OR SPECIAL LOSS IN CONNECTION WITH THE REPORT, THE PRODUCT FOR WHICH SERVICES WERE PERFORMED, OR THE SERVICES PROVIDED BY COMPANY HEREUNDER. COMPANY SHALL NOT BE LIABLE FOR ANY LOSS OR DAMAGE WHATSOEVER RESULTING FROM ANY DELAY IN THE PERFORMANCE OF ITS OBLIGATIONS HEREUNDER OR FROM THE FAILURE OF COMPANY TO PROVIDE ITS SERVICES WITHIN ANY TIME PERIOD FOR COMPLETION ESTIMATED BY COMPANY, REGARDLESS OF THE CAUSE OF THE DELAY OR FAILURE. (B) THE ENTIRE FINANCIAL AND LEGAL LIABILITY OF COMPANY IN RESPECT OF ANY CLAIM FOR LOSS, INDEMNITY, CONTRIBUTION OR DAMAGE OF WHATEVER NATURE OR HOWSOEVER ARISING, SHALL NOT EXCEED AN AMOUNT EQUAL TO FIVE (5) TIMES THE AMOUNT OF FEES PAID TO COMPANY FOR THE SPECIFIC SERVICES WHICH GAVE RISE TO SUCH CLAIM.

9. Force Majeure. If any event of force majeure or any event outside the control of Company occurs, Company may immediately cancel or suspend its performance hereunder without incurring any liability whatsoever to Client.

10. Governing Law. These Conditions shall be governed by the laws of the country as follows: for Services performed in (i) the Americas: the laws of New York, (ii) Asia Pacific, South Asia, Middle East and Africa: the laws of Hong Kong (except for China where PRC laws govern), and (iii) Europe: the laws of England.

11. Dispute Resolution. (a) If Client desires to assert a claim relating to the Services, it must submit the same to Company in writing setting forth with particularity the basis for such claim within 90 days from discovery of the claim and not more than six months after the date of issuance of the Report. Client waives any and all claims without limitation that it does not submit within such time periods. (b) If a dispute arises under this Agreement, the Parties shall first attempt good faith negotiations, failing which, the Parties (i) agree that the courts of the country of governing law shall have exclusive jurisdiction to settle any such dispute related to this Agreement and (ii) irrevocably waive their right to trial by jury in any such action or proceeding.

12. These Conditions, the applicable order form and/or quotation and the Report represent the entire understanding of the Parties on the subject matter hereof, and no modification is binding unless in writing. Any of Client's terms and conditions attached to, enclosed with or referred to in any order form, purchase order or other document shall not apply.

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END OF THE REPORT.



TEST REPORT



Report No:

(7419)080-0561D(S)

May 16, 2019

Page 1 of 4

Attn: Mr. Nashfa Nashidh

Customer:

Water Solutions (Pvt) Ltd

Address :

MA. Faseri, 1st Floor, Ameenee Magu, Male, Maldives

Date of Sample Received:

Apr 03, 2019

Date of Testing Started:

Apr 03, 2019

Date of Report Modified:

May 16, 2019

Date of Testing Completed:

May 16, 2019

Sample Description:

Sample Received as:

Approximately 500ml x 3 Nos. of Water sample contained in two sealed plastic bottles & one glass bottle respectively

Sample Identified by the Client as:

Ground Water

Thilafushi GW 4

Sample Drawn By BVCPS

NO

Photo of the Samples Submitted



**Bureau Veritas Consumer
Products Services Lanka (Pvt)
Ltd.**

No. 570, Galle Road, Katubedda, Moratuwa, Sri Lanka
Tel: (9411) 2350111-115 (dedicated lines), Fax: (9411)
112622198 & 199
Email: bvcps.lanka@lk.bureauveritas.com

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TEST REPORT



Report No:

(7419)080-0561D(S)

May 16, 2019

Page 2 of 4

TEST RESULTS

No.	Parameters	Results	LOQ	Unit	Test Method
1	Turbidity*	0.4	-	NTU	APHA 23rd ed: 2017: 2130 B
2	pH at 25°C*	8.0	-	-	APHA 23rd ed: 2017 :4500H ⁺
3	Iron (as Fe)*	ND	0.001	mg/l	APHA 23rd ed: 2017: 3125 B
4	Manganese (as Mn)	ND	0.001	mg/l	APHA 23rd ed: 2017: 3125 B
5	Arsenic (as As)	ND	0.001	mg/l	APHA 23rd ed: 2017: 3125 B
6	Total Dissolved Solids*	1003	-	mg/l	APHA 23rd ed: 2017: 2540 C
7	Electrical Conductivity at 25°C*	1.87	-	mS/cm	APHA 23rd ed: 2017; 2510 B
8	Cadmium (as Cd)*	ND	0.0001	mg/l	APHA 23rd ed: 2017: 3125 B
9	Lead (as Pb)*	ND	0.001	mg/l	
10	Mercury (as Hg)	ND	0.00005	mg/l	
11	Polynuclear Aromatic Hydrocarbons*				
a	Naphthalene	ND	1.0	µg/l	CPSD –AN-00576
b	Acenaphthylene	ND	1.0	µg/l	CPSD –AN-00576
c	Acenaphthene	ND	1.0	µg/l	CPSD –AN-00576
d	Fluorene	ND	1.0	µg/l	CPSD –AN-00576
e	Phenanthrene	ND	1.0	µg/l	CPSD –AN-00576
f	Anthracene	ND	1.0	µg/l	CPSD –AN-00576
g	Fluoranthene	ND	1.0	µg/l	CPSD –AN-00576
h	Pyrene	ND	1.0	µg/l	CPSD –AN-00576
i	Benzo[a]anthracene	ND	1.0	µg/l	CPSD –AN-00576
j	Chrysene	ND	1.0	µg/l	CPSD –AN-00576
k	Benzo[a]pyrene	ND	1.0	µg/l	CPSD –AN-00576
l	Benzo[e]pyrene	ND	1.0	µg/l	CPSD –AN-00576
m	Indeno[1,2,3-cd]pyrene	ND	1.0	µg/l	CPSD –AN-00576
n	Dibenzo[a,h]anthracene	ND	1.0	µg/l	CPSD –AN-00576
o	Benzo[g,h,i]perylene	ND	1.0	µg/l	CPSD –AN-00576
p	Benzo[b]fluoranthene	ND	1.0	µg/l	CPSD –AN-00576
q	Benzo[j]fluoranthene	ND	1.0	µg/l	CPSD –AN-00576
r	Benzo[k]fluoranthene	ND	1.0	µg/l	CPSD –AN-00576

TEST REPORT



Report No:

(7419)080-0561D(S)

May 16, 2019

Page 3 of 4

(*)Indicates- ISO 17025 :2005 accredited test.

Remark:

The test report (7419)080-0561D has been replaced with the test report (7419)080-0561D(S) in order to add test results of Heavy metals.

NOTE:

APHA: American Public Health Association,
SLS: Sri Lanka Standard, ND: Not Detected,
LOQ: Limit of Quantification, mg/l: milligrams per liter,
°C :Celcius, NTU: Nephelometric Turbidity Units,
mS/cm : milliSiemens per centimeter.

Contact Information for this report (Technical and General Inquiries and Feedback)

GENERAL INQUIRIES:		
IROSHA UDUGAMPALA	TEL: +94 768 229 528	E-MAIL: Irosha.Udugampala@lk.bureauveritas.com
TECHNICAL INQUIRIES:		
ROHITHA GUNARATHNA	TEL: +94 774 151 768	E-MAIL: rohitha.gunarathna@lk.bureauveritas.com
FEED BACK:		
KUMUDINI RATHNAYAKE	TEL: +94 768 229 455	E-MAIL: kumudinie.rathnayake@lk.bureauveritas.com

REVIEWED BY: SHYAMIKA WICKRAMASINGHE

BUREAU VERITAS CONSUMER PRODUCTS SERVICES LANKA (PVT) LTD.

AUTHORIZED SIGNATORY

ROHITHA GUNARATHNA

MANAGER-
ANALYTICAL LABORATORY

TEST REPORT



Report No:

(7419)080-0561D(S)

May 16, 2019

Page 4 of 4

CPS CONDITIONS OF SERVICE

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3. Representations and Warranties. (a) Company undertakes due care and ordinary skill in the performance of its Services. (b) Client agrees that Company is neither an insurer nor a guarantor and does not take the place of Client or the third parties that it retains, including designers, manufacturers, agents, buyers, distributors, and transportation or shipping companies; Company disclaims all liability in such capacities. Client understands that, if it seeks to protect itself from claims of loss, damage or injury, it should obtain appropriate insurance. (c) Company does not warrant or guarantee Client's products, and Company's Report does not represent a warranty of merchantability, a warranty of fitness for a particular purpose, or any other warranty or guarantee.

4. Payment. Payment in full shall be due 30 days after the date of invoice, failing which Company may revoke any credit extended to Client. Client shall reimburse Company for (i) collection on overdue amounts from the due date until paid at an interest rate of 1.5% per month and (ii) any other costs Company incurs in collecting past due amounts, including court, attorneys and collection agencies' fees.

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6. Relationship. (a) Nothing herein creates a partnership, agency or joint venture between the Parties. (b) The failure to require strict observance or performance of any provision of these Conditions shall not be construed to be a waiver of a Party's right to later require strict observance and performance of the same. If any provision of these Conditions is held to be invalid or unenforceable, such invalidity shall not invalidate the remainder of the Conditions. (c) For a period of two years after the commencement of this Agreement, Client shall not directly or indirectly try to solicit for employment any of Company's employees.

7. INDEMNITY. CLIENT SHALL HOLD HARMLESS AND INDEMNIFY COMPANY, ITS AFFILIATES AND THEIR RESPECTIVE DIRECTORS, OFFICERS, EMPLOYEES, AGENTS AND SUBCONTRACTORS AGAINST ALL THIRD-PARTY CLAIMS FOR LOSS, DAMAGE, INJURY, DEATH, OR EXPENSE OF WHATEVER NATURE, INCLUDING BUT NOT LIMITED TO CLAIMS ARISING FROM OR RELATING TO (I) THE PERFORMANCE OF ANY SERVICES BY COMPANY, (II) THE SALE, RESALE, MANUFACTURE, DISTRIBUTION OR USE OF ANY OF CLIENT'S GOODS OR (III) BREACH OF CLIENT'S OBLIGATIONS OR WARRANTIES HEREIN.

8. LIMITATIONS OF LIABILITY. (A) COMPANY SHALL NOT BE LIABLE FOR ANY INDIRECT, CONSEQUENTIAL OR SPECIAL LOSS IN CONNECTION WITH THE REPORT, THE PRODUCT FOR WHICH SERVICES WERE PERFORMED, OR THE SERVICES PROVIDED BY COMPANY HEREUNDER. COMPANY SHALL NOT BE LIABLE FOR ANY LOSS OR DAMAGE WHATSOEVER RESULTING FROM ANY DELAY IN THE PERFORMANCE OF ITS OBLIGATIONS HEREUNDER OR FROM THE FAILURE OF COMPANY TO PROVIDE ITS SERVICES WITHIN ANY TIME PERIOD FOR COMPLETION ESTIMATED BY COMPANY, REGARDLESS OF THE CAUSE OF THE DELAY OR FAILURE. (B) THE ENTIRE FINANCIAL AND LEGAL LIABILITY OF COMPANY IN RESPECT OF ANY CLAIM FOR LOSS, INDEMNITY, CONTRIBUTION OR DAMAGE OF WHATEVER NATURE OR HOWSOEVER ARISING, SHALL NOT EXCEED AN AMOUNT EQUAL TO FIVE (5) TIMES THE AMOUNT OF FEES PAID TO COMPANY FOR THE SPECIFIC SERVICES WHICH GAVE RISE TO SUCH CLAIM.

9. Force Majeure. If any event of force majeure or any event outside the control of Company occurs, Company may immediately cancel or suspend its performance hereunder without incurring any liability whatsoever to Client.

10. Governing Law. These Conditions shall be governed by the laws of the country as follows: for Services performed in (i) the Americas: the laws of New York, (ii) Asia Pacific, South Asia, Middle East and Africa: the laws of Hong Kong (except for China where PRC laws govern), and (iii) Europe: the laws of England.

11. Dispute Resolution. (a) If Client desires to assert a claim relating to the Services, it must submit the same to Company in writing setting forth with particularity the basis for such claim within 90 days from discovery of the claim and not more than six months after the date of issuance of the Report. Client waives any and all claims without limitation that it does not submit within such time periods. (b) If a dispute arises under this Agreement, the Parties shall first attempt good faith negotiations, failing which, the Parties (i) agree that the courts of the country of governing law shall have exclusive jurisdiction to settle any such dispute related to this Agreement and (ii) irrevocably waive their right to trial by jury in any such action or proceeding.

12. These Conditions, the applicable order form and/or quotation and the Report represent the entire understanding of the Parties on the subject matter hereof, and no modification is binding unless in writing. Any of Client's terms and conditions attached to, enclosed with or referred to in any order form, purchase order or other document shall not apply.

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END OF THE REPORT.