Result Report brIHne_JET_SPREADING Version (1.0) - Project 'AQADI_Near dilution study '

CASE 1

Input data

Ambient Conditions	Average depth at discharge point [Ha (m)]	25
	Salinity [Ca (psu)]	40.8
	Density [rho_a (Kg/m3)]	1026.55
Brine effluent characteristics	Saline concentration [Co (psu)]	70.345
	Density [rho_o (Kg/m3)]	1048.73
	Jet discharge velocity [Uo (m/s)]	6.4
Brine discharge configuration	Port diameter [do (m)]	0.3
	Discharge angle [thettag_o (sexaseg)]	60
	Altura de la boquilla respecto al fondo [ho (m)]	1

Initial fluxes and length scales

Qo, brine flow rate (discharge volume flux)	0.45 m3/s
Mo, discharge momentum flux	2.90 m4/s2
Jo, discharge buoyancy flux	0.10 m4/s3
Qco, discharge flux of contaminant mass	13.37 psu*m3/s
LQ, Flux - Momentum length scale	0.27 m
LM, Momentum - Buoyancy length scale	7.18 m
Densimetric Froude Number, Fo	25.4

Jet flow behavior

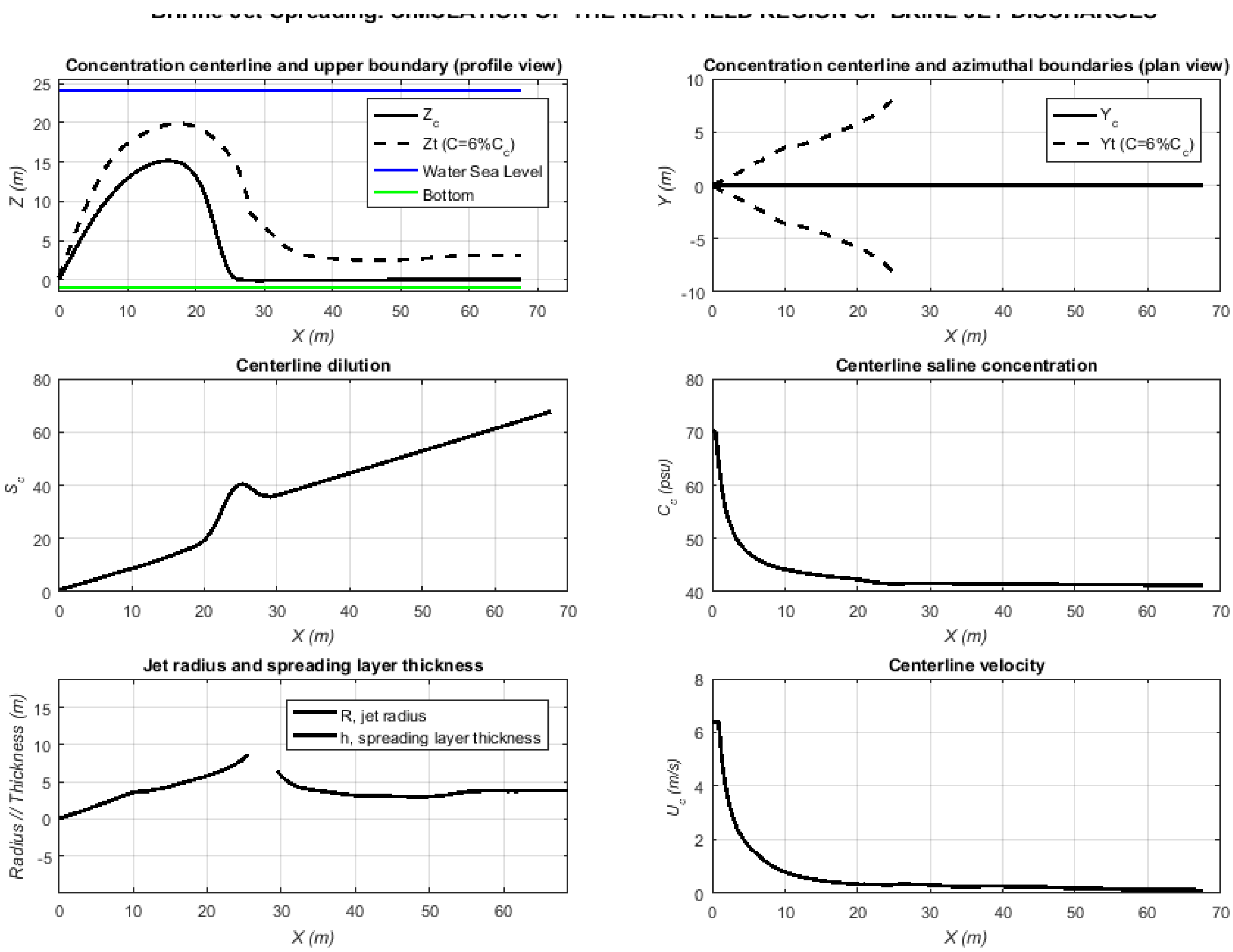
Zm, centerline peak of the jet trajectory (relative to the port nozzle)	15.16 m
Xm, horizontal location of the centerline peak point	15.96 m
Zt, maximum rise height relative to the port nozzle	19.90 m
Zt_bottom, maximum rise height relative to the bottom	20.90 m
Sm, centerline dilution at the jet maximum height (peak)	14.1
Cm, centerline saline concentration at the jet maximum height (peak)	42.9 psu
bm_50%, radius at the jet maximum height (radial distance from the centerline to where concentration is 50% of that at the centerline, C=50%Cc)	2.3 m
rm_25%, radius at the jet maximum height (radial distance from the centerline to where concentration is 25% of that at the centerline, C=25%Cc)	3.3 m
Rm_6%, radius at the jet maximum height (radial distance from the centerline to where concentration is 6% of that at the centerline, C=6%Cc)	4.7 m
Xr, centerline horizontal location of the return point (where the jet axis reaches the port height level)	25.17 m
Sr, centerline dilution at the return point	40.4
Cr, centerline saline concentration at the return point	41.5 psu
br_50%, jet radius at the return point (radial distance from the centerline to where concentration is 50% of that at the centerlinee, C=50%Cc)	4.2 m
rr_25%, jet radius at the return point (radial distance from the centerline to where concentration is 25% of that at the centerline, C=25%Cc)	5.9 m
Rr_6%, jet radius at the return point (radial distance from the centerline to where concentration is 6% of that at the centerline, C=6%Cc)	8.3 m
Xi, centerline horizontal location of the impact with bottom point	28.22 m

Si, centerline dilution at the impact point	35.8
Ci, centerline saline concentration at the impact point	41.6 psu

Spreading layer flow behavior (at the end of the near field region)

Xn, horizontal location of the spreading layer at the end of the near field region	68.63 m
hn, thickness of the spreading layer at the end of the near field region	3.83 m
Sn, centerline dilution of the spreading layer at the end of the near field region	68.6
Cn, centerline saline concentration of the spreading layer at the end of the near field region	41.2 psu
Un, centerline velocity of the spreading layer at the end of the near field region	0.10 m/s

Variables evolution graphs



Jet flow

X	Zc	Lc	Sc	Cc	rho_c	theta	R	Uc	Fc
0.00	0.00	0.00	1.00	70.35	1048.66	60.00	0.15	6.40	25.42
0.41	0.71	0.82	1.02	69.85	1048.29	59.54	0.15	6.40	25.42
0.83	1.40	1.63	1.25	64.35	1044.17	58.89	0.35	6.40	24.86
1.24	2.08	2.43	1.57	59.66	1040.66	58.74	0.48	5.06	23.59
1.65	2.75	3.22	1.90	56.36	1038.19	58.26	0.61	4.18	22.61
2.06	3.41	3.99	2.22	54.09	1036.49	57.77	0.73	3.57	21.49
2.48	4.05	4.76	2.54	52.45	1035.27	57.25	0.86	3.11	20.26
2.89	4.69	5.52	2.88	51.06	1034.23	56.71	0.99	2.75	18.97
3.30	5.31	6.26	3.22	49.97	1033.41	56.15	1.12	2.47	17.91
3.71	5.91	7.00	3.56	49.09	1032.76	55.57	1.25	2.24	17.02
4.13	6.51	7.72	3.90	48.38	1032.22	54.93	1.43	2.05	16.27
4.54	7.08	8.43	4.24	47.77	1031.77	54.23	1.60	1.89	15.61
4.95	7.65	9.13	4.57	47.26	1031.38	53.43	1.77	1.75	15.03
5.36	8.19	9.81	4.91	46.81	1031.05	52.45	1.92	1.64	14.47
5.78	8.71	10.48	5.26	46.42	1030.75	51.30	2.06	1.53	13.94
6.19	9.21	11.13	5.61	46.07	1030.49	50.01	2.19	1.44	13.42
6.60	9.69	11.76	5.96	45.76	1030.26	48.64	2.32	1.33	12.90
7.01	10.14	12.37	6.31	45.48	1030.05	47.27	2.47	1.24	12.39
7.43	10.57	12.97	6.66	45.24	1029.87	45.96	2.64	1.15	11.88
7.84	10.99	13.55	7.01	45.02	1029.71	44.71	2.81	1.07	11.39
8.25	11.39	14.12	7.35	44.82	1029.56	43.52	2.98	1.01	10.92
8.67	11.77	14.69	7.68	44.65	1029.43	42.31	3.14	0.95	10.47
9.08	12.13	15.24	8.00	44.49	1029.31	40.99	3.28	0.90	10.05
9.49	12.48	15.78	8.32	44.35	1029.21	39.48	3.42	0.84	9.67
9.90	12.80	16.31	8.63	44.22	1029.11	37.74	3.55	0.79	9.32
10.32	13.11	16.82	8.94	44.11	1029.02	35.76	3.65	0.75	8.98
10.73	13.39	17.32	9.26	43.99	1028.94	33.58	3.71	0.71	8.67
11.14	13.65	17.80	9.59	43.88	1028.86	31.28	3.75	0.68	8.38
11.55	13.88	18.28	9.93	43.78	1028.78	28.95	3.77	0.65	8.13
11.97	14.10	18.74	10.28	43.67	1028.70	26.65	3.81	0.62	7.91
12.38	14.29	19.20	10.64	43.58	1028.63	24.41	3.87	0.59	7.71
12.79	14.47	19.65	11.00	43.49	1028.56	22.22	3.95	0.57	7.52
13.20	14.62	20.09	11.37	43.40	1028.50	20.05	4.03	0.55	7.34
13.62	14.76	20.52	11.74	43.32	1028.43	17.82	4.10	0.53	7.17
14.03	14.88	20.95	12.12	43.24	1028.37	15.44	4.17	0.51	7.01
14.44	14.98	21.38	12.52	43.16	1028.32	12.82	4.25	0.49	6.85
14.85	15.06	21.80	12.93	43.09	1028.26	9.91	4.35	0.47	6.70
15.27	15.12	22.22	13.35	43.01	1028.21	6.73	4.48	0.45	6.56
15.68	15.15	22.63	13.79	42.94	1028.15	3.31	4.60	0.43	6.44
16.09	15.16	23.04	14.25	42.87	1028.10	-0.31	4.73	0.42	6.32
16.51	15.14	23.46	14.70	42.81	1028.05	-4.14	4.84	0.41	6.22
16.92	15.09	23.87	15.13	42.75	1028.01	-8.28	4.96	0.40	6.13
17.33	15.01	24.29	15.56	42.70	1027.97	-12.88	5.07	0.39	6.03
17.74	14.88	24.72	15.97	42.65	1027.93	-18.13	5.18	0.38	5.93
18.16	14.72	25.16	16.39	42.60	1027.90	-24.00	5.30	0.37	5.84
18.57	14.49	25.62	16.85	42.55	1027.86	-30.47	5.41	0.35	5.77
18.98	14.21	26.12	17.40	42.50	1027.82	-37.31	5.52	0.34	5.72
19.39	13.84	26.66	18.09	42.43	1027.77	-43.45	5.63	0.33	5.71
19.81	13.40	27.27	18.96	42.36	1027.72	-48.57	5.76	0.32	5.75
20.22	12.87	27.95	20.06	42.27	1027.65	-53.42	5.89	0.32	5.84
20.63	12.24	28.68	21.45	42.18	1027.58	-58.37	6.03	0.32	5.99
21.04	11.48	29.47	23.17	42.08	1027.50	-62.89	6.17	0.32	6.17
21.46	10.58	30.45	25.18	41.97	1027.43	-66.71	6.32	0.32	6.39

X	Zc	Lc	Sc	Cc	rho_c	theta	R	Uc	Fc
21.87	9.51	31.62	27.42	41.88	1027.36	-69.69	6.47	0.32	6.60
22.28	8.31	32.96	29.82	41.79	1027.29	-71.67	6.65	0.32	6.78
22.69	7.01	34.40	32.23	41.72	1027.24	-72.61	6.86	0.32	6.94
23.11	5.69	35.87	34.56	41.65	1027.19	-72.60	7.08	0.31	7.07
23.52	4.41	37.27	36.60	41.61	1027.15	-71.72	7.27	0.30	7.21
23.93	3.24	38.56	38.28	41.57	1027.13	-69.93	7.50	0.29	7.36
24.35	2.21	39.68	39.49	41.55	1027.11	-67.16	7.75	0.29	7.50
24.76	1.37	40.63	40.21	41.53	1027.10	-61.41	8.03	0.30	7.65
25.17	0.76	41.44	40.41	41.53	1027.10	-52.05	8.41	0.31	7.80

Spreading layer

X	h	Sc	Cc	rho_c	Uc	Fc
30.53	5.32	36.65	41.61	1027.15	0.28	6.74
31.91	4.47	37.81	41.58	1027.13	0.26	6.53
33.29	4.08	38.96	41.56	1027.12	0.24	6.41
34.66	3.87	40.11	41.54	1027.10	0.22	6.32
36.04	3.70	41.27	41.52	1027.09	0.24	6.29
37.41	3.51	42.42	41.50	1027.07	0.25	6.33
38.79	3.32	43.57	41.48	1027.06	0.26	6.40
40.16	3.20	44.72	41.46	1027.04	0.25	6.49
41.54	3.14	45.88	41.44	1027.03	0.25	6.48
42.91	3.12	47.03	41.43	1027.02	0.24	6.37
44.29	3.11	48.18	41.41	1027.01	0.23	6.18
45.66	3.07	49.33	41.40	1027.00	0.22	6.01
47.04	3.02	50.49	41.39	1026.99	0.20	5.80
48.42	2.99	51.64	41.37	1026.98	0.19	5.57
49.79	3.02	52.79	41.36	1026.97	0.18	5.34
51.17	3.13	53.95	41.35	1026.96	0.18	5.11
52.54	3.31	55.10	41.34	1026.95	0.17	4.88
53.92	3.53	56.25	41.33	1026.94	0.16	4.66
55.29	3.71	57.40	41.31	1026.94	0.15	4.45
56.67	3.80	58.56	41.30	1026.93	0.14	4.26
58.04	3.84	59.71	41.29	1026.92	0.13	4.09
59.42	3.84	60.86	41.29	1026.91	0.13	3.93
60.79	3.82	62.01	41.28	1026.91	0.12	3.78
62.17	3.82	63.17	41.27	1026.90	0.12	3.66
63.55	3.82	64.32	41.26	1026.89	0.11	3.56
64.92	3.82	65.47	41.25	1026.89	0.11	3.44
66.30	3.83	66.62	41.24	1026.88	0.10	3.33
67.67	3.83	67.78	41.24	1026.88	0.10	3.29

Model authors:

BrIHne-Jet-Spreading model has been developed by the Environmental Hydraulics Institute (IH Cantabria).

For questions or more information, please contact to brIHnesupport@ihcantabria.com

Modeling approach and calibration:

The model simulates the near field region (including the jet path and the spreading layer) of a submerged and inclined brine jet discharges. Dimensional analysis formulas proposed by Pincince et al. (1973) and Roberts et al. (1987) are applied to predict the variables value along the jet path. For variables of the spreading layer, dimensional analysis formulae proposed by Roberts et al. (1997) are applied.

These formulas have been calibrated in brIHne-Jet-Spreading with experimental database obtained by non-intrusive optical techniques tests carried out in the Environmental Hydraulics Institute. PIV (Particle Image Velocimetry) and PLIF (Planar Laser Induced Fluorescence) techniques have been applied to characterize the velocity and concentration flow-fields with a high quality and resolution. The characterization includes the jet path (Palomar et al, 2015b) and the spreading layer (Palomar et al, 2015c). Thanks to the experimental data obtained, the near field region flow behavior has been studied in depth (Palomar, 2014) and the model brIHne-Jet-Spreading has been calibrated.

A more detail description of the model can be found in the technical specifications file and in (Palomar et al, 2015a).

Cross-section assumption:

The model considers the asymmetry and non-gaussian cross-section found for this type of inclined negatively buoyant jets, according to the experimental studies carries out by Kikkert et al. (2007), Shao et al. (2010) and Palomar et al. (2015b). This asymmetry is due to the inner edge extra-spreading of the jet lower edge caused by buoyancy instabilities.

Variables glossary:

Cartesian coordinates are considered.

The origin of the coordinate system is set up at the jet nozzle.

Jet flow variables:

X: Horizontal coordinate location from the nozzle.

Zc: Vertical coordinate of the concentration centerline.

Lc: Centerline length from the nozzle.

Sc: Centerline dilution.

Cc: Centerline saline concentration.

Rhoc: Centerline density.

Theta: Vertical angle of the centerline relative to the bottom.

R: Jet radius (considered here as the radial distance from the centerline to where concentration is 6% of that at the centerline).

Uc: Centerline velocity.

Fc: Centerline densimetric Froude Number.

Spreading layer flow variables:

X: Horizontal coordinate location from the nozzle.

h: Spreading layer thickness (corresponding to the vertical distance from the bottom to where concentration is 25% of that at the centerline)

Sc: Centerline dilution.

Cc: Centerline saline concentration.

rhoc: Centerline density.

Uc: Centerline velocity.

Feje: Densimetric Froude Number.

Maximum rise height of the jet trajectory (Zt)

The maximum rise height or upper edge of the jet (Zt) is calculated by the model by adding to the maximum centerline height (Zm), the jet radius, “R”, which stands for the radial distance radial distance from the centerline to where concentration is 6% of that at the centerline (considering a Gaussian profile at the jet upper edge).

Impact of the jet with the sea surface:

To predict if the jet impacts the sea surface, brIHne-Jet-Spreading compares the maximum height reached by the jet with the sea water depth at the discharge point (HA). However, the maximum rise height (Zt) is given by the model relative to the jet nozzle (coordinate system origin). Therefore, to calculate if the jet reaches the sea surface, the port height (ho) has to be added to the maximum rise height (Zt).

The model considers that the jet impacts the sea surface if: Zt + ho > HA. In that case, an error message is given by the model, because a confined environment cannot be simulated by brIHne-Jet-Spreading.

Return and impact point:

The return point is the location where the jet centerline reached the port (nozzle) height, whereas the impact point is the location where the jet centerline impacts the bottom

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